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ORIGINAL ARTICLE

ARTS & HUMANITIES

DEVELOPING INTERCULTURAL COMMUNICATIVE COMPETENCE IN EFL CLASSROOM THROUGH INTERCULTURAL MATERIALS: NECESSITY AND INCORPORATION

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Abstract

This article conceptualizes Intercultural Communicative Competence (ICC) and intercultural materials and shows how they are developed in the English language pedagogy. It attempts to outline how the concept of ICC can build a new dimension of language learning minimizing the communication gap between the speakers of English from different parts of the world by incorporating intercultural materials into EFL curriculum. It brings together the existing literature that prioritize the inclusion of culture in ELT materials. This review paper examines some important principles and theories to focus on the recent changes in the assumptions and exercises of designing culture-sensitive ELT materials. The study finds out that in EFL classes intercultural materials introduce the learners with the multiplicity of cultures across the world. Intercultural materials, in its extended realm, covers a far wider range that opens up immense scope for developing the knowledge and tolerance of other cultures and of the people who practice those cultures. An objective and unbiased mindset can be developed if the intercultural materials are incorporated to the pedagogy that reflect and represent cultures in a positive and balanced way as the principles indicate.

Keywords: Culture, ICC, intercultural awareness, intercultural materials, cultural diversity, tolerance

Introduction

Teaching culture in EFL/ESL is a very popular issue but when there comes the question of practicing it in classroom, it becomes complicated. The foreign language teachers get puzzled how it should be addressed and when they face the uncertainty about which cultural aspects to teach and how to use and adapt authentic materials to integrate course books, it leads to unexpected difficulties (Baccin & Pavan, 2014). Learning and teaching a second or foreign language itself obtains a difficult pedagogical system and the aforementioned uncertainty compels both the teachers and learners to avoid the culture learning intentionally.

The paper attempts to extend discussion addressing the questions as to, i) What role does culture play in teaching and learning language? ii) What is Intercultural communicative Competence or ICC? iii) How can ICC be practiced in EFL classroom? and iv) How to develop intercultural EFL materials for practicing in classroom? To address the questions an extensive literature survey has been done and some materials have been developed to provide an idea of ICC imbued language learning materials that can be practiced in EFL/ESL classrooms.

The aim of this paper is not to configure any specific format or method for developing intercultural materials to use in an EFL classroom; rather it attempts to raise an awareness among the teachers, the learners as well as the materials designers to understand the goals of intercultural materials. The paper tries to outline the principles for developing and designing materials to help them upgrade from communicative competence to a wider range of intercultural communicative competence (ICC). Though this study targets at the secondary to higher secondary level, i.e. the learners from class 6 to class 12 considering their natural inquisitiveness to know unknown people, places and their cultures, intercultural materials are applicable to other levels of students also. Nieto (2002) thinks that comprehending a culture paves the way for "an understanding of how students from diverse segments of society - due to differential access, and cultural and linguistic differences- experience schooling and a commitment to social justice". The general objective of the study is to focus on the importance of ICC and the procedure of

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incorporating that in EFL materials which is detailed by some specific objectives as to explain ICC, its aspects and its practice in EFL/ESL classroom, to explore the methods and principles of developing IC materials and to provide ideas about the ways of developing IC materials and practicing them in the classroom.

Discussion

Language and Culture

Language is a set of signs with some cultural values embedded in it. In our social life communication is mandatory. Depending on various communication contexts, language incorporates culture in 'multiple' and 'complex' ways (Kramsch, 1998). Language not only conveys the communicable issues among its users but the varied attitudes and beliefs of the individuals also and for that it can be summed up in the way that *language embodies, expresses and symbolizes cultural reality* (Kramsch & Widdowson,1998; Jiang,2000; Risager, 2006; Mazari & Derraz, 2016; Swiderski, 1993).

Brown (1994:164) declares that 'language and culture are intricately interwoven and they cannot be separated without losing the significance of either language or culture' (in Cakir 2006). Skopinskaja (2003) finds teaching foreign language a difficult one for the inseparability of these two. If language is studied solely 'as an abstract system' without referring to its cultural context, as Cunningsworth (1995) thinks, it would not prepare the learners to use it in the real life situations. (quoted in Skopinskaja 2003: 41). Learning a language usually refers to learning the culture of that specific region as well as that of the community that uses the language in their everyday life. To communicate perfectly in a language, one should try to think in that because "thought is extremely powerful" (Tang 1999). A language gets completely understandable when its cultural context is realized because language is deeply inherent in it and comprehending a language is hardly possible without connecting it constantly to the culture where it operates (Byram 1994; Malinowski 1923).

People who are the related to language teaching and learning have been debating since the 1970s if the fundamental cultural facts are not included in the curriculum, both acquisition and learning of language may remain only a 'fool's competence'. Highlighting the unavoidability of culture awareness in terms of language teaching, Kramsch (1993) suggests,

> "If...language is seen as social practice, culture becomes the very core of language teaching. Cultural awareness must then be viewed as enabling language proficiency ... Culture in language teaching is not an expendable fifth skill, tacked on, so to speak, to the teaching of speaking, listening, reading and writing".

Being knowledgeable of the grammatical, phonological and lexical patterns is not enough for comprehending a language thoroughly; it requires the awareness of the cultural norms and aspects that the language represents. Communication in an international level recommends intercultural communication for which situations will be created where learners will have to face issues of cultural differences. These types of cultural differences are available as the individual aspects of any language such as the points of "silence, tone of voice, appropriate topic of conversation, and expressions as speech act functions (e.g. apologies, suggestions, complains, refusals, etc.)". For that reason, the presentation of a statement which sounds normal and pleasant in one culture may seem "as clumsy and circular by members of another culture". (Smith 1985, ibid). Effective intercultural communication is possible when language learners can interact effectively in a new language with members of different cultures (Byram, 1997a). Speakers must be aware of their own and others' cultures, and they must have the linguistic and pragmatic skills necessary to navigate another culture (Guilherme, 2000; O'Dowd, 2003, cited in Kim, 2020).

Foreign language instruction may remain inaccurate and incomplete without the study of culture. (Peck 1998). However, accomplishing the competence of using a language in a culturally perfect way is a prolonged process; Sellami (2000) thinks it is 'a lifeless endeavor' and that is why, to accomplish it, culture teaching should be incorporated in language teaching. According to Lessard-Clouston (1997) language teaching is culture teaching (cited in Merilyn Fleet 2006). The famous hypothesis by Sapir (1962) - Whorf (1956) of "Linguistic Relativity" postulates that, "a) we perceive the world in terms of categories and distinctions found in our native language and b) what is found in one language may not be found in another language due to cultural differences" (in Genc & Bada 2005). The objective of this hypothesis is to connect language and culture and also to discover that it is culture that in fact

outlines and defines language. A language essentially presents those features that the group of people that uses the language believes in and practices as the culture of that community.

Culture in Language Curriculum

Culture is obvious in ESL/EFL curriculum and while teaching a language "one is inevitably already teaching culture implicitly"(McLeod 1976). Teaching culture has been overtly necessitated by Byram (1989) in the whole method of language teaching (Figure 1). He develops a model giving emphasis on combining the awareness of language and culture along with the cultural experiences for foreign language pedagogy.

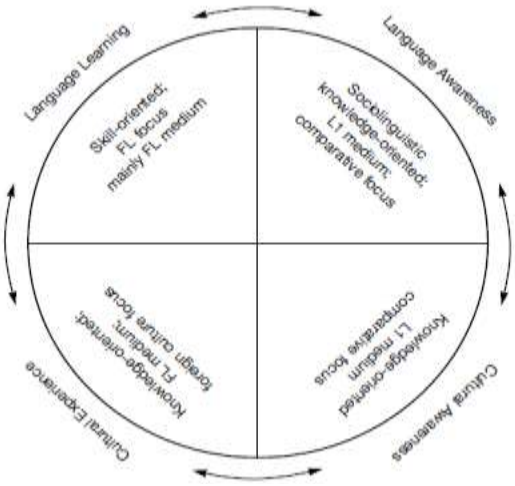


Figure 1. Foreign language teaching model: Byram (1989)

Culture and cultural constituents are intrinsically related to the ESL/EFL programs. ELT proponents agree that it is unlikely that a learner will be able to learn or acquire a language subsiding the intrinsic cultural information of it. Lessard-Clouston (1997) differs from the statement that the introduction of culture is a very recent addition to language teaching. Even in the Grammar-Translation method, the oldest ELT method, second language is taught in such a way that the learners will know about the language and the civilization through the translations of the classic literary texts of that language. They truly represent the culture of that civilization. Byram (1994, quoted in Cortazzi and Jin 1999: 197) sets three goals for foreign language teaching, which are--

- the development of communicative competence for use in situations the learners might expect to encounter;
- the development of an awareness of the target language;
- the development of insight into the foreign culture and positive attitudes toward foreign people.

According to Pulverness (1996), during the 1970s and first half 1980s, core activities of ELT like syllabus designing and materials developing were based on needs analysis, and "culture was subordinated to performance objectives." Culture had been taken as an integral part of language teaching from then on. Since the middle of the 1980s 'intercultural competence' has been a very popular term in the field of second and foreign language acquisition and from then the main focus of teaching English language has been changed considerably. As English is the most popular medium of international communication, the notion of 'intercultural communicative competence' occurs as a vital factor of learning the language in the background of 'global English'.

Language practice is driven by the social and cultural norms and values of the people who use the language where it is evaluated as a social and cultural phenomenon. Each culture has some distinct customs and values that vary from those of other cultures. Most of the time these are revealed in the standards of expression and conversation used by the community. So, strife are natural when people face other cultural contexts that are different. Perhaps they are communicating in a common language, mostly in English; nevertheless, there might be discord if the politeness norms and communication standards in both the cultures are unknown to the speakers.

To answer this problem, the learners should inevitably know the norms as well as the culture-specific behaviors to communicate with the people who practice the culture of the target language. Integrating knowledge and facts of the culture and developing awareness of the language learners about these would be immensely helpful and vital for them.

Following the previous methods, the objectives of English pedagogy had been to develop competencies that help the learners to be successful in the target language setting, or while communicating only with the native-speakers. Those methods mostly had monolingual and monocultural orientation for learning the English language which was achieved by acculturating into the practices, values, behavioral norms and beliefs of the native-speakers of the Anglo-American societies. The available materials for teaching communication situations also used to replicate the contexts and situations where NS-NS (NS= Native Speaker) communications had been presented conforming to the norms and practices of their own culture. There had been barely any NNS-NNS (NNS= Nonnative Speaker) dimension of communication in the materials or in the objectives of the materials e.g. in lessons, activities or tasks though the communicators are from different non-English speaking contexts. However, it is a more realistic demand of most foreign and second language situations because NNS-NNS dimension outnumbers NS-NS situations of communication in the present global world. From this perspective, this study wants to emphasize on the importance of incorporating multicultural norms and practices in the English language learning materials.

The Idea of Intercultural Communicative Competence (ICC)

The term 'intercultural' usually refers to communication in a cross-cultural situation, where speakers from two or more cultures, who may differ in language, religion, nationality, region, sex, social and economic status, etc. are involved. Byram (1997a) distinguishes ICC from Intercultural Competence (IC) as IC "is a competence acquired by the knowledge about different cultures which may be helpful in interacting with people from other cultures while ICC is a competence to communicate with people from other cultures" in a culture-perfect way. This is a complex and specific competence that asks for more comprehensive knowledge of different 'cultures' from a transnational perspective. ICC demands a " more dynamic understanding of how linguistic and cultural flows characterize the world today and foreign- language teaching has the potential to support a transnational approach" (Risager 2007). This is a way to shape a new generation of global citizen characterized by intercultural competence and awareness who can "foster empathy and understanding across social and political divides" (Kim 2020).

Cultural Diversity and ICC

Culture varies in communities and in regions; even in the same country different cultures may co-exist and culture changes with time. Any ethnic group may get used to a set of behaviors that can change with time. There are issues that define the cultural identity of any community that include their 'politico-historical identity, geographical positioning, gender, religion, language, ethnic identity etc'. Along with their variation in both literary and non-literary practices, they vary in 'their daily activities, gestures, non-verbal communications, expressions, salutations etc'. Variation remains in their social and conversational activities, introduction, personal relationships, ways of greetings, family values, work place behaviors, educational attitudes, norms of social gatherings etc' (Little 2016). For an instance, eye contact during conversation is not that accepted in Asia, specifically while conversing with elders and teachers, though in many western countries like in America eye contact is a must while conversing because people in America believe that "Never trust a person who can't look in the eyes." (Levine & Adelman 1982). Proverbial beliefs depict the cultural features and values of a community. Awareness of these aspects are crucial not only for learning a language but for evaluating it and also that language community as, 'a central element of critical cultural awareness is an awareness of banal nationalism' (Risager 2007).

Developing Intercultural Competence in Classroom

Before the advent of ICC, objective of mainstream ELT had been to promote Anglo-American culture and acculturation into that culture was an influential aspect of that. With this view, ELT at that time had reflected the native speaker version of manners, morals, values, and the communication and behavior norms. However, ICC

identifies the 'otherness' of cultures and puts stress on practice to understand and know how to communicate with people of various cultures without being offensive or impolite.

Practicing culture is equally complicated and debated like the attempt to define the concept of 'intercultural'. It is decisive for the language learners as well as the teachers to have effective and applicable teaching materials that give a notion of cultural diversity through communicative tasks. A task-based syllabus is suitable in this case. Sincere attention is required in designing the tasks as well as materials .Considering the vastness of culture Stern (1992) asks about the scale of the designer's task and wants to bring it into light how to address culture knowledge in classroom (in Corbett 2003). Obviously, it is not easy, nor yet feasible for the teachers or the learners to reach at the complete knowledge about every culture or even of any culture specifically. The task gets more difficult in the class. The goal of presenting culture is to develop an intercultural awareness, not as a skill but as a collection of skills and approaches. It can be termed more perfectly as a capability that is known as ICC or Intercultural communicative competence. This capability endeavors to develop the learners' awareness of their own culture, and by doing that, prepare them to deduce and appreciate the cultures of others. "It is not only a body of knowledge, but a set of practices that involve knowledge, skills and attitudes" (Rose 2004). This attempt, Corbett (2003) thinks, means "going beyond the information gap and making peoples' use of language a topic of classroom exploration."

Objectives of Cultural Instruction

As Seeley (1988) points out, cultural instruction will help students develop an understanding that "all people exhibit culturally conditioned behaviors" and they should become "more aware of conventional behavior in common situations in the target culture". They should be more aware of the cultural connotations of words and phrases in the target language. The students will learn to "evaluate and refine generalizations about the target culture" with the help of cultural instructions. It will help them develop their "skills to locate and organize information about the target culture" and will kindle their "intellectual curiosity about the target culture, and to encourage empathy towards its people".

Tomalin & Stempleski (1993) substantiated the goals with some practical teaching principles for designing lesson plans to be practiced in an intercultural English Language learning class. They are—

- The culture should be accessed through the language which is being taught
- It should be ensured that the study of the cultural behaviors is added as an integral part of each lesson
- The socio economic competence that the students prioritize and wants to achieve should be aimed at
- An understanding in cross-cultural level that is, the learners are not only aware of their home culture but that of the target culture should be an objective
- Awareness and tolerance of the influence of the cultures affecting one's own and others' behaviors considering that all teachings cannot change behavior

Practicing Interculturality in Classroom

The content and elements of culture are enormous and it includes almost every aspect of life like subcultures, art, music, education, economy, politics, technology etc. For that it is difficult to cover all of them under the common sphere of 'intercultural'.

Mckay (2002) postulates that cultural materials should be used in class so that they inspire the learners to contemplate on their own culture as well as create a 'sphere of interculturality' (Kramsch: 1993). In this sense, IC prioritizes skills rather than knowledge. Rose (2004) tries to mark it as not only a skill, "but a collection of skills and attitudes better thought of as a competence" (p. 4). These attitudes and skills turn into 'competence' when the learners can—

- Observe, identify and recognize
- Compare and contrast
- Negotiate meaning
- Deal with or tolerate ambiguity
- Effectively interpret messages
- Limit the possibility of misinterpretation

- Defend one's own point of view while acknowledge the legitimacy of others
- Accept difference (Rose 2004)

Clandenfield (2008) has added some skills that are required to develop to increase intercultural competence. She thinks that interculturally competent learners will —

- "Ask questions in culturally acceptable ways
- Listen and seek for clarification
- Negotiate and identify common ground
- Avoid prejudging or stereotyping"

How to Accomplish ICC

Before attempting for the 'competence', it is the duty to develop 'intercultural awareness' in both the teachers' and the learners' ends. Rose (2004) marks four perspectives in communicating with different cultures. It means that the learners can—

- "look at their own culture from the point of view of their own culture (i.e. have a good understanding and awareness of their own culture)
- be aware of how their culture is seen from outside, by other countries or cultures
- understand or see the target culture from its own perspective (i.e. understand and be aware of what other people think of their own culture)
- be aware of how they see the target culture"

According to Rose (2004) students need to be inspired to develop their own learning materials for practicing in the class to develop ICC. They can enjoy the freedom to choose the sources of their materials. For example, as she suggests, learners can produce guidebook, poster, and webpage for those who will visit their place in which they will inform the visitors and advise them about things they might find strange or different about their own culture along with the most important spots to visit or foods to taste. The learners can also be asked to read the books, news reports, features, published online or off line that are written by people who have visited their country or locality. This will help them know about others' opinion or reaction about their place or practices. The learners can also follow the travelogues through some social media. Rose (2004) puts emphasis on media and entertaining sources as important materials as she says,

> "Students will be familiarized with sources of information about the target culture. Again, newspapers and websites can be an invaluable source of reading materials here. Films and literary texts often depict and interrogate their own cultures. (For the UK, for example, popular films such as The Full Monty, Bend it like Beckham, East is East, Billy Elliott or Calendar Girls are vital and engaging depictions of contemporary British culture)." Teachers of second and foreign language who are non-native have "a valuable role to play here, being a person from one culture who has a certain amount of knowledge and/or experience of the target culture." (Rose 2004)

If students have visited the target culture, they can recount their experiences-perhaps by giving a written or oral presentation with advice for other students. If such sources are not available students can imagine a visionary journey into the target culture and predict the 'problems and misunderstandings' they possibly may encounter and the ways to resolve them.

How to Use ICC based Materials

The developed sample materials are meant to be used from secondary to higher secondary level (Class 6-class 12). I have developed a set of materials incorporating the aspects mostly talked of and used in cross-cultural and intercultural communication. Two sample lessons have been added in this paper. The most prominent aspects of intercultural communication have been selected as the titles of the lessons. The whole pack of materials have been divided into some units and the units are segmented into several lessons. Each of the lessons comprises three distinct steps i.e. 'pre', 'while' and 'post' reading steps. The lessons start with the learning objectives that foreshadows the learning outputs also. In the pre reading steps, there are some activities that are not directly about

the text but it creates or prepares a situation that would try to attract the learners to think of or discuss the topic of the lesson. This would work as a warm-up or ice - breaking step. In the second step, the students will go through the while reading stage. They will read the text and get ready to answer the comprehensive questions set on the text. In the last or third step, they will complete some tasks in the post reading stage. Pair work, group work, oral or written presentations, role play or simulations etc. can be assigned. The tasks might not be directly related to the text they have read but they will create a scope to act on or study further on the specific topic.

Conclusion

Materials used for teaching and learning language that encompass the learner's as well as other cultures of the world into consideration are important for language learning . Different varieties of English have emerged as a result of the attempts for integrating local culture in the curricula and teaching-learning materials. As a global citizen, a person of the present world should have idea about the variations for culturally appropriate communication. To meet the demand of international communication in the present context EFL/ESL learners need to be introduced with materials embedded with 'small c' culture or everyday cultures of different communities from different parts of the world as well as the 'big c' culture that refers to the acquired culture, i.e. art, music, history, literature etc. The materials need to be designed in such a way that the learners can be benefitted to act successfully as 'bilingual and intercultural individuals' in both 'local and international settings' (Alptekin 2008:63). Incorporating communication norms in various cultures is essential for developing the ability of tolerance and reverence to cultural variety and small 'c' culture need to be integrated in the linguistic code that are reflected through the 'daily customs and ways of life, and mainstream ways of thinking and behaving.' (Alptekin 2008:59). ICC creates the opportunity to raise the awareness invalidating the myth of 'standard English'. The materials designed in this study are meant to give a glimpse of various cultures of the world from a 'small c' culture perspective.

Communication is a buzz-word in the present world of globalization and ICC is a systematic solution to avail that. ICC is mandatory to qualify as the global citizens. Being connected in all aspects will not meet up the demand completely; the global citizens should also know how to understand others and be understandable; they should know to respect the people and practices of different cultures and at the same time negotiate for their own cultures; and to communicate with others it is essential to know about others' culture. To follow the present international trend of growth and undercurrents in economy, science and technology of the world and to understand the current meanings of personal, cultural and national identities it is necessary to be connected and to develop communication with others that need to be culturally perfect .ICC can be an effective solution to avail that. Therefore, it is essential that ELT curricula of the present time address the demand of modification to provide the learners with active and constant motivation to learn and acquire the language and it will be a vital contribution to ELT in the contexts of EFL/ESL.

References

Alptekin, C. (1993). 'Target language culture in EFL materials'. *ELT Journal.* 47(2).

Alptekin, C. (2008). Multicompetence revisited: From EFL to ELF. Plenary speech presented at the 5th ELT Research Conference—Bridging the gap between theory and practice in ELT. ÇanakkaleOnsekiz Mart University, Turkey.

Brown, H.D. (1994). *Principles of Language Learning and Teaching.* The USA: Prentice Hall Regents.

Byram, M. (1989). *Cultural Studies in Foreign Language Education.* Clevedon, UK:Multilingual Matters.

Byram, M., Morgan, C. and colleagues. (1994). *Teaching-and-Learning Language-and-Culture.* Clevedon: Multilingual Matters.

Byram, M. (1997a). *Teaching and Assessing Intercultural Communicative Competence.* Clevedon: Multilingual Matters.

Byram, M. (1997b). 'Cultural awareness' as vocabulary learning. *Language learning journal*, *16*(1), 51-57.

Cakir, I. (2006). 'Developing cultural awareness in foreign language teaching'. *Turkish Online Journal of Distance Education-TOJDE*. Volume: 7 Number: 3 Article: 12

Clandfield, L. (2008). 'Culture in ELT: Which C? Whose C?' *Contact : Teachers of English as a second Language of Ontario,* 34(3).

Carter, R. & Nunan, D. (eds.) (2001). *The Cambridge Guide to Teaching English to Speakers of Other Languages*. Cambridge: Cambridge University Press.

Corbett, J. (2003). *An Intercultural Approach to English Language Acquisition*. Clevedon: Multilingual Matters Limited.

Cortazzi, M., & Jin, L. X. (1999). Cultural mirrors: Materials and methods in the EFL classroom. In E. Hinkel (Ed.), Culture in second language teaching and learning (pp. 196-219). Cambridge: Cam bridge University Press.

Cunningsworth, A. (1995). *Choosing Your Coursebook*. Oxford, England : Macmillan Heinemann ELT.

Duranti, A. (1997). 'Facts and meanings in British cultural studies'. In S. Bassnett (ed.) *Studying British Cultures*. London: Routledge.

Fleet, M. (2006). 'The role of culture in second or foreign language teaching: Moving beyond the classroom experience'. Retrieved form http://www.eric.ed.gov/ERICDocs/data/ericdocs2/content_storage_01/0000000b/80/23/53/f8.pdf.

Genc, B. & Bada, E. (2005). 'Culture in language learning and teaching.' *The reading matrix 5(1).*

Isik, A. (2008). Linguistic imperialism and foreign language teaching. *Journal of Asia TEFL*, *5*(1).

Jiang, W. (2000). The relationship between culture and language. *ELT journal*, *54*(4), 328-334. https://doi.org/10.1093/elt/54.4.328.

Kim, D. (2020). Learning language, learning culture: Teaching language to the whole student. https://www.researchgate.net/journal/ECNU-Review-of-Education-2096-5311

Kramsch, C. (1993). *Context and Culture in Language Teaching*. Oxford: Oxford University Press.

Kramsch, C., & Widdowson, H. G. (1998). *Language and culture*. Oxford university press.

Lessard-Clouston, M. (1997). 'Towards an understanding of culture in L2/ FL education'. *The internet TESL journal 3(5).*

Levine, D .R. & Adelman, M.B. (1982). *Beyond Language: Intercultural Communication for English as a Second Language*. New Jersey: Prentice Hall Regents, Englewood Cliffs.

Little, W. (2016). *Introduction to Sociology – 2nd Canadian Editino*. BCcampus. https://opentextbc.ca/introductiontosociology2ndedition

Malinowski, B. (1923). 'The problem of meaning in primitive languages'. In C.K. Ogden & I.A.Richards. *The Meaning of Meaning*. London: Routledge and Kegan Paul.

Mazari, A., & Derraz, N. (2016). Language and culture. *International Journal of Humanities and Cultural Studies (IJHCS) ISSN 2356-5926*, *2*(2), 350-359. file:///C:/Users/PAVALI~1/AppData/Local/Temp/492-1407-1-PB.pdf

Mckay, S. L. (2002). *Teaching English as an International Language: Rethinking Goals and Approaches*. Oxford: Oxford University Press.

McLeod, B. (1976). 'The relevance of anthropology to language teaching'. *TESOL Quarterly 10(2).*

Nieto, S. (2002). *Language, culture, and teaching: Critical perspectives for a new century*. New Jersey: Lawrence Erlbaum Associates.

Nunan, D. (1989). *Designing tasks for the communicative classroom*. Cambridge university press.

Pavan, E. & Baccin, P. (2014). *Studi@ Naukowe 27*, 8.

Peck, D. (1998). *Teaching culture: Beyond language.* Yale: New Haven Teachers Institute.

Pennycook, A. (2001). 'Beyond homogeny and heterogeny: English as a global and worldly language I. Plenary address to the MAVEN/GNEL Conference, "The cultural politics of English as a world language". Freiburg, Germany.

Pulverness, A. (1996). 'Worlds within words: Literature and British cultural studies'. In David A. Hill (ed.) Papers on Teaching Literature from the British Council's conferences in Bologna 1994 and Milan 1995. The British Council, Italy.

Risager, K. (2006). *Language and culture*. Multilingual Matters. https://doi.org/10.21832/9781853598609.

Risager, K. (2007). *Language and Culture Pedagogy: From a National to a Transnational Paradigm*. Clevedon: Multilingual Matters Limited.

Rose, C. (2004). 'Intercultural Learning.' Italy. British Council. Retrieved from http:// www.techingenglish.org.

Sapir, E. (1958). *Culture, Language and Personality*. Berkeley: University of California Press.

Seelye, H. N. (1988), Teaching culture, Lincolnwood, IL: National Textbook.

Seelye, H. N. (1993). *Teaching Culture: Strategies for Intercultural Communication (3rd ed.).* Linkolnwood, IL: National Textbook Company.
Sellami, A.B. (2000). 'Teaching towards cultural awareness and intercultural competence: From What through How to why culture is?' Paper presented at the Annual Teachers of English to Speakers of Other Languages. Retrieved form http://www.eric.ed.gov/ERICDocs/data/ericdocs2/content_storage_01/0000000b/80/23/53/f8.pdf.
Skopinskaja, L. (2003). The role of culture in foreign language teaching materials: An evaluation from an intercultural perspective. *Incorporating intercultural communicative competence in language teacher education*, 39-68.
Smith, E. L. (1985). 'What is the difference and what difference does the difference make.' *In Forum.* vol.22.
Swiderski, R. M. (1993). Teaching Language, Learning Culture. https://eric.ed.gov/?id=ED364093
Tang, R. (1999). 'The Place of "Culture" in the Foreign Language Classroom: A reflection. *The Internet TESL Journal, Vol. V, No. 8*. Retrieved form, URL:http://iteslj.org/Articles/ Tang-Culture.html.
Tomalin, B. & Stempleski, S. (1993). *Cultural Awareness.* Oxford: Oxford University Press.
Whorf, B.L. (1956). 'Language, thought and reality'. Cambridge, Mass: MIT Press.
Willis, J. (1996). *A framework for task-based learning.* Harlow: Longman.

Appendix:
Selected and Developed ICC Based Materials

Unit One: Communication in Global Settings
Lesson1: Beginning a Conversation

Beginning a conversation

Objectives: In this lesson students will

- discuss how people start a conversation
- read a dialogue with starter
- know some other conversation starters
- write dialogues and role play

Activities:
A. In pairs discuss the following
1. How do you begin a conversation in your country?
2. Which topics do you usually talk on?
3. Do males and females begin with the same topic?
4. How do the young and elderly people do that? Is that different in rural and urban culture?

B. Initiating and maintaining a conversation is a way of communication and the skill of it is needed when one is learning a new language. To initiate a conversation one of the speakers must ask the other questions.

Now read some dialogues between two strangers. After reading, discuss the following questions:

Text 1

: "It's really cold today, isn't it?"
: "Yeah, what crazy weather we've been having!"
: "I am Peter. What's your name?"
: "My name is Paul"
: "Where are you from Paul?"
: "I am from Buenos Aires"
: "I am from Buenos Aires, too!"
: "Really! Where did you live in?"
: "In San Telmo"
: "What a coincidence! I also lived in San Telmo!"
: "That's very interesting! Did you enjoy Tango?"
: "Yes, of course. I used to go to a Tango bar on each weekend. But now it has lost much of its charm, you know."
: "you are right. But this should not happen…"

Answer the following questions:

1. What do you think is the relationship between the two persons in the dialogue—formal or informal? Can you guess where they are meeting?
2. How did they start the conversation?
3. What is the subject of their talking?
4. Do you know what Tango is?
5. Do you know where Buenos Aires is? If you have any world map in your class, try to locate the place.

The best way of continuing a conversation and for making the communication successful is to add some extra information to a one-word response; otherwise it may become monotonous and any of the speakers might feel frustrated that ends in an ineffective communication.

Now read another dialogue between Rick and Debbie in a party:

Text 2

Rick: Hello where are you from?
Debbie: From New York. Where are you from?
Rick: I am from Texas. Why did you come to California?
Debbie: To study. Are you also studying?
Rick: No, I am working here. I am a Laboratory Assistant in a high school. What are you studying?
Debbie: Solar energy. That's my favorite subject.
Rick: That's great! I also like the subject. How long do you plan to stay here?
Debbie: Two years. Then I'll try to switch to Cambridge.
Rick: That'll be wise. When did you come?
Debbie: Three weeks ago.

Discussion Questions:

i. How did Rick and Debbie start the conversation?
ii. What is the subject of their talking?
iii. What is Rick in California for?
iv. What is Debbie's plan about study?
v. Do you consider the conversation meaningful?

C. Notice the following conversation starters .In pairs discuss how the starters have been used. Then write short dialogue using each of the starters. Then role play in pairs using those dialogues.

1. Hi, what have you been up to since I last saw you?
2. Good to finally meet you, how have you been?
3. What line of work are you in?
4. Do you have kids?
5. Where did you grow up?
6. Hi, good to see you again. Hey, I like your jacket/bag/shoes etc.
7. Hi Jim, Long time no see!

Unit One: Communication in Global Settings
Lesson 2: Introduction: Use of Titles

Objectives: In this lesson students will

- discuss different manners of introduction and addressing
- read a text on styles of addressing in different cultures
- write dialogues and role play dialogues

A. What do you say and do when you introduce someone and are introduced to someone? How do people address you in different settings? Do you like the addressing? If, yes/no, why? What, according to you, should be the proper manner of addressing others?

B. Have you noticed how people in Western world address each other? Can you see any difference?

Introducing and greeting

B. Look at the picture. Notice how they are introducing themselves? Now read the following excerpt about addressing people and answering questions.

Often when there is a difference in status or age between two individuals, formal titles and last names are used unless the person of lower status is told to use the first name.

For example:

ACCOUNTANT (age 50).Hello, my name is Bob Thomas.
STUDENT (age 20).It's nice to meet you, Mr. Thomas.
ACCOUNTANT. Please just call me Bob.

In informal introductions there is a tendency to reduce status differences by using first names. In more formal situations, the title along with the last name is appropriate.

For example, when a student introduces herself/himself to a university professor, she might speak as Susan does in the utterance below:

SUSAN (student). Hello, Dr. McCarrick. My name is Susan Hall and I would like to ask you about your course.

C. Now read the text (within the box) on how people address each other in Bangladesh.

In Bangladesh, it is considered impolite to address a person with the first name if he/she is senior by age. It is usual to address them as brother or uncle even if they are just introduced. In official environment, people who are in higher position should be called 'Sir'. People in Bangladesh can not think of addressing teachers with their names or titles as it is taken as a serious offence. They should only be addressed as 'Sir'. People who are in the same rank or of the same age use each other's first name, surname or title. Typically colleagues do that to communicate among themselves though high officials and senior colleagues address the lower officers and juniors with their first names and titles.

Calling women with their titles is very rare in Bangladesh. In an informal setting they are called 'sister' or 'aunty' if senior by age. In a formal setting they are called 'Madam'. Female teachers are also called madam.

Discussion Questions:

i. What do people say in the West when they are introduced to others?
ii. Why do they use first names in informal introductions?
iii. How do people in Bangladesh address a just introduced person? Can you explain why they do so?
iv. Can you mark two distinct qualities of these two nations from their style of addressing others?

D. Suppose you are in a party in the UK and have just been introduced with Mr. Joe Philipson , who is a University professor. Draft a conversation between you two and role play that with a partner.

Unit One: Communication in Global Settings
Lesson 3: Greetings in Europe

Objectives: In this lesson students will

- discuss rude and polite manners of greetings
- know about the manners of greetings across cultures/contexts
- write a passage

A. What do you do and say when you meet somebody for the first time? Discuss what language and manners are considered rude and polite for greetings in Bangladesh.

B. Look at the picture below, and discuss how the two persons seem to greet each other. How is it like or unlike the greetings in Bangladesh? What do you think is the relationship—(formal or informal) between the two?

C. Now read the following text about greetings in different countries and discuss the questions below it:

Eye Contact and Handshaking in Introductions

Italy

Italians greet friends with two light kisses on the cheek, first the right and then the left. Even if you are merely acquaintances, this form of greeting is usual, both on arrival and on departure. When groups are splitting up, expect big delays as everyone kisses everyone else. When being introduced, a handshake is usual; although not necessarily the firm businesslike shakes other nationalities may be used to.

Hugging in cordial introduction

Britain

On meeting someone for the first time, British people only shake hands in a formal situation, especially at workplaces or even just smile at each other. They rarely come to physical contact. But if it's a friend or casual acquaintance, they would hug or (between two women or a man and woman) make one kiss on the cheek. Different areas of UK sometimes have their regional greetings. For example in Yorkshire it's common to say Alright! instead of "hello, how are you?".

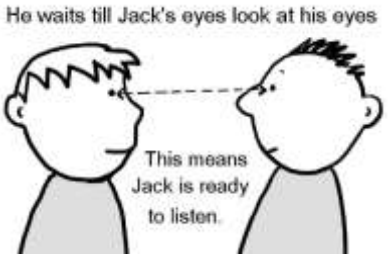
Finland

When greeting, the parties shake hands and make eye contact. A full bow denotes special respect — in normal circumstances, a nod of the head is enough. A Finnish handshake is brief and firm, and involves no supporting gestures such as touching the shoulder or upper arm. Embracing people when greeting them is rare in Finland. A man greeting someone in the street should raise his hat; in the cold of winter, a touch of the hand to the brim of the hat is enough.

Germany

German culture can be quite formal and hierarchical, so titles, honorifics, and last names are commonly used in introductions. Germans offer a firm, but brief, handshake as a greeting. Handshakes between a man and a woman or

between two women will likely be less robust. It is customary for people to also shake hands upon departing from one another. Eye contact is generally expected during the course of the introduction and conversation.



France

The French culture is a formal culture. This applies to the language spoken and greeting styles. The usual French greeting is a quick, lightly gripped handshake. An overly firm handshake may be considered impolite. When leaving, a handshake is repeated to say goodbye. Proper etiquette dictates that visitors should greet and shake hands upon arrival and departure with everyone, including children. Friends and family will often exchange a quick kiss on both cheeks.

Kissing on cheeks in introduction

Discussion Questions:

i) When do Italian people kiss each other?
ii) How do British people greet a friend?
iii) What is the sign of special respect in Finland?
iv) What is the usual trend of German people for handshaking?
v) How do the French people take leave?
vi) Say **whether the following are true or false:**

a. Italians prefer firm handshakes when being introduced.
b. Finnish people touch the brim of hat while greeting others in winter.
c. An overly firm handshake is not considered very warm and friendly in France.
d. People embrace while greeting in Finland.
e. French culture is a formal culture.

C. Write a short passage to be published in any English daily on "Eye contact and handshaking in Bangladesh and their impact in different situations".

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ORIGINAL ARTICLE

FINE ARTS

NAKSHI KANTHA OF KHULNA: EMERGING REALITY AND SOCIO ECONOMIC OBSERVATIONS

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Abstract

Nakshi Kantha is the most traditional needle-craft and important domestic art of women in Bangladesh that displays the multiracial and multi-religious expressions of motifs which indicate the aspiration for fluency as well as display the objectives of craftswomen. It is not only an ornate coverlet but also the work of art for beliefs, values and clarity of rural women of Bangladesh. Women fabricate the art in reusing depleted resources like sharees, dhutis and lungis, which are sewing to form needlework coverlets for their essential function in a fastidious exploit. Though it is a very old traditional artistic element of material art but for its unique design and elegance, it is a fascination to the people of Bangladesh and West Bengal of India till contemporary period. Various type of Nakshi Kantha in style, form, fabric or technique has been found in different places of Bangladesh. It is also been seen own style of art work in different regions. Nakshi Kantha of Khulna developed glory in the scale of its motifs, using magnum size floral and foliate borders, the Kalka, and alien mythological symbols as well as unique for the colored threads of vibrant and contrasting. This article is an attempt to study and understanding of the emerging reality and socio economic observations of Nakshi Kantha featuring new challenges and scope in greater Khulna of Bangladesh.

Keywords: Nakshi Kantha, motifs, socio economic, impact, challenge, scope

Introduction

Almost half of the people of Bangladesh are women. They are working in various kinds of socio economic and cultural activities in both public and private sectors. Nakshi Kantha is one of the most traditional indigenous products that highlighted the folk art of rural women. Nakshi Kantha snatched the tradition of rural Bengal. The story is explained by the story of miseries. Nakshi Kantha is an eyewitness to the story. The rural women used to stitch Kantha at leisure time, but now women are also the means of earning. Nakshi Kantha has the biggest demand in both home and abroad. It has a demand for ages. The most famous Nakshi stitch folk art have found in greater Mymensingh, Rajshahi, Faridpur, Jessore and Khulna of Bangladesh.

In the rural Bangladesh it is a common ritual in woman, from generation to generation, they have gained knowledge of art of Nakshi Kantha and mainly ordinary are coverlets. Thickness of Nakshi Kantha is depended on whether a winter or summer wrap is essential. Old useless sharees, dhutis and lungis are encrusted consequently. Various forms of a successively stitch to decorate the borders and to enrichment the coverlet with special designs. Women recycle the yarn hauled from the sharees and are capable to generate colorful and vivacious coverlets.

Nakshi Kantha of Khulna in style, form, fabric or technique is more unique than that of other regions of Bangladesh. The women of Khulna developed glory in the scale of its motifs, using magnum size floral and foliate borders, the Kalka, and the alien mythological symbols. They are unique for their colored threads of vibrant and distinct. A large portion of rural women in Bangladesh are occupied in the Nakshi Kantha stitching work.

Nakshi Kantha can play a vital role in providing employment opportunity to rural women. But women who worked on Nakshi Kantha have been facing numerous difficulties since the partition of India. Even income of the Kantha stitching women has dropped down significantly since the recent Corona pandemic began. Most of them could not get contract for producing Nakshi Kantha during the Corona pandemic period. More than half of them

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could not pay back the loan they have taken from NGOs or other sectors. They even did not get any government support or fair prices for their Nakshi products. They affirmed that the shortage of buyers; lack of exhibition system, they are suffering more but earn less. Due to this they changed their profession from Nakshi stitching to agriculture, fishing or switching jobs to other sectors. All these problems made their life and livelihood difficult to survive.

Although Bengal is politically divided into maps but the style and design of Kantha sewing are mostly similar in both Bengalis, because this art was introduced long before the partition of Bengal. That is why Nakshi Kantha has become immortal in Bengali proverbs, stories, songs or poems.

For praising such amazing artifact and the dedication of the artisans, a dramatized Bengali narrative named 'Nakshi Kanthar Math' (The Field of Embroidered Quilt) was written by Jasimuddin[1] in 1929. After the publication of this narrative the word Nakshi Kantha became famous among the country people. It is with this narrative that the story of love and pain can come to the fore in Bengali literature. This poem is an immortal tale of love between the couple Rupai and Saju.

After the marriage, the love story of Rupai and Saju could not go far. Rupai become disguised. While waiting for day after day, month after month for her husband, Saju started weaving Nakshi Kantha for the rest of her life. How many stories are written on the Kantha by the needle of Saju but Rupai does not come back. On the day Saju finished weaving the Nakshi Kantha, she requested her mother to spread it on her grave after her death. After a long time, the body of a foreign flutist was found near Saju's grave lying under the Nakshi Kantha. In this way, the women of Bengal have woven Nakshi Kantha even in the absence of their husband or lovers. Someone may have been able to give a new Kantha to their relative, but not like the Saju-Rupai of Jasimuddin.

Nakshi Kantha is one of the most eminent and highly privileged folk arts of Bengal. These embroidered quilts have become an identity maker of the rural women, as they can find an opportunity to express desires, aspirations and sentiments through creative embroidered platform with the help of needles and threads.

According to Prof. Abdul Hafiz at the foreword of 'The Aesthetics & Vocabulary of Nakshi Kantha' by Perveen Ahmed[2], "The story of Kantha is rooted in the history, culture and civilization of Bangladesh. Three great religions of Indian Subcontinent i.e. Hinduism which came earliest, Buddhism second and Islam which follows last, each influenced Kanthas so greatly that it changed designs, and motifs into a unique decorative art form which are highlighted in this study. There is no denying the fact, the oldest inhabitants of Bangladesh knows as Australoid, then the Dravidians, Aryans and the Muslims made a chequered history of this region and the Kanthas found a unique character as a multi-religious product and also a multiracial expression.

Kantha is a product of a non-literate society with the psychological and cultural traditions of Bangladesh. The difference between folk art and folk craft in many instances is not always clear and transparent. A simple Kantha used as wrapper or bedspread a Kantha became folk art when it absorbs old age symbols, designs, motifs, decorations and therefore bears a deeper content. A simple chair without folk motif is not folk art but as soon as a traditional motif or design is placed on its surface people call it a folk art object.

The sense of beauty displayed in folk art lies in its decorations and the interpretive mind of the artisan. One Kantha is different from the other only when an individual does something especially with its form. The love of traditional knowledge finds a lovelier expression in the Kantha." Nakshi Kantha of Khulna that has a uniqueness of undivided Bengal belongs to the fore as the specialty of Nakshi Kantha. Thus, the objectives of this study were to (i) observe the emerging reality and the socio-economic impact on Nakshi Kantha in greater Khulna region and (ii) analyze the issues relevant to the challenges of Nakshi Kantha as well as to provide suitable recommendations for elevator of socio-economic condition

Methodology

Here qualitative method is used to gather data from several sources. Data has been collected from both the primary and secondary sources. The primary data from the needle-art women conducting in-depth interview and 6 case studies and the secondary data from different departments of Government, books, journals, museums and private preservers concerned with this study. The questionnaire is formulated to collect the information regarding their family size, business engagement of family members, economic status, problems of their business, income from their occupations, social impact of Nakshi Kantha stitch in their livelihood, financial support from the government

[1] Jasimuddin, Nakshi Kanthar Math, 1929

[2] Perveen Ahmad, Aesthetics and Vocabulary of Nakshi Kantha

and non-government levels. The questionnaire consists of 10 questions. Questions were asked sequentially to the respondents to seek their views.

Background

Bangladesh is a land of old heritage. Nakshi Kantha is one of the old heritages of Indian subcontinent. The village women talent of indication in existence, desire, and traditions explain their substantial visibility of imaginative shape in needle-craft art work like Nakshi Kantha which is basically a kind of folk art. Colorful prototypes and drawings are overstated into a coverlet with a consecutively stitch up called 'Kantha Stitch'. The custom of making a new Kantha for a child at home has been around for a long time. The traditional custom of welcoming guests with new Kantha at social functions like weddings or festivals at home is found in more or less every village of Bangladesh. Nakshi Kantha is one of the best traditions as gift list when the girl is sent to the in-laws after marriage.

In the rainy season in Bangladesh, it is a traditional practice of Bengali women to sew Kantha with needle and thread in their leisure time. With the rapid change in rural society, such kind of socialization is also changing. But still the rural women are most fascinated to go from noon to evening to work on Nakshi Kantha. They decorate motifs of trees, birds or herbs emerge on the ground of Kantha with their unparalleled skills. Sometimes the story of sorrows and happiness has come up in the Kantha as well as the story of the book heard in the dim light of the lantern has been told by the women with the needle.

Alpana patterns combined with figures from folk tales and ancient legends, gods and deities has found in Jessore and Faridpur. In Mymensingh and Jamalpur it is developed a lyrical style using motifs of spatial art, rather than relating a theme. Floral roam, foliate patterns and the traditional rose has found in Bougra. Rajshahi is famous for a diverse texture, heavy and stiff, and set format of design. But in Khulna we found the unique style of Nakshi Kantha because of the majority of Hindu people of Bangladesh is living there. They followed the religious form and motifs as well as using magnum size floral and foliate borders, the Kalka, and extraordinary mythological symbols. They are unique for their colored threads of vibrant and contrasting.

According to "Aesthetics and Vocabulary of Nakshi Kantha" by Perveen Ahmad[3], There are 994 objects which is the largest in the country at Bangladesh National Museum Collection. It has been attained from the regions of Rajshahi, Bogura, Rangpur, Pabna, Jamalpur, Mymensingh, Kishoreganj, Tangail, Faridpur, Jessore, Kushtia, Dhaka, and Khulna including 83 of them from Khulna region. The artistic value of Nakshi Kanthas is of high talent, and reflects enormous value both in the skill of needle art as well as in the socio-cultural content of design.

The oldest Kantha is a Hindu ceremonial Nakshi Kantha No. 84.2009 belonging to approximately 1850 A.D. from Gopalganj of greater Faridpur. The largest piece is a beautiful Muslim household Kantha No. 68.17 from Khulna approximately 80 years old shown in the Islamic Motif vocabulary chapter. Both these objects are of remarkable artistic, historical and socio-cultural value.

We found there the following information of the Museum objects: year-wise accession numbers, name of object, measurement, material, color, stitches, description of motifs and design and cultural specialty as well as 994 forms along with colored photographs of each Kantha and placed in 23 albums that are the biggest resource material for a better understanding of the folk treatment of traditional images and forms whereas in eight categories like Linear patterns, Kalka, Elephants, Horses, Birds, Symbols, Figural objects and Tree of Life are mentioned by Perveen Ahmad.

The border of the Kanthas form is possibly the only constraint to the needle-women; everything is her liberty, to use the idiom and metaphors from the store house of reminiscence and believe.

According to Zaman and Stevulak, Nakshi Kantha symbolizes the lifestyle of Bangladeshi people through the various colorful sewing which sustains the cultural diversity, geological features, climatic conditions as well as the socio-economic features of the people who interlace them. (Zaman and Stevulak, 2014)[4]. The learning on customary darns and its completion on contemporary textile will notably supply to the enlargement of socio-economic standard of millions of people in Bangladesh.

'The Kantha represents the love of the needle women for the addressee and, being complete of rags, is also supposed to grant shield from the sin eye. It is also the form part of the dowry of brides in certain parts of Bangladesh. But due to commercialization of this creation, now days the touching additions is gone and eye

[3] Perveen Ahmad, Aesthetics and Vocabulary of Nakshi Kantha
[4] Perveen Ahmad, Aesthetics and Vocabulary of Nakshi Kantha

transmittable colorful design are being introduced (Afroj, 2012). The design of Nakshi Kantha also being shifted to regular clothing in commercial clothing industries like pant, panjabi, dhuti, sharee and shal etc. (Zaman and Stevulak, 2014).

In the Nakshi Kantha, two crafts- quilting and embroidering-are involved. Even then both Gurusaday Dutt and Stella Kramrisch, the two pioneers, were content with the term Kantha in their study of the Nakshi Kantha. "The art of the Kantha furnishes an illustration of the wonderful patience, craftsmanship and resourcefulness of the village women," says Dutt. Kramrisch wrote on the Nakshi Kantha under the title of "Kantha" in the Journal of the Indian Society of Oriental Art in1939, and she adhered to this term in 'Unknown India: Ritual Art in the Tribe and Village', which was published in 1968.

Niaz Zaman also used the term Kantha when she produced her excellent work titled 'The Art of Kantha Embroidery[5]' in 1981 and revised it in 1993. Because of the popularity of Jasimuddin's famous poem Nakshi Kanthar Math[6] (The Field of Embroidered Quilt) the term Nakshi Kantha has come into use increasingly in Bangladesh and has now become synonymous with the embroidered quilt.

Etymology of Nakshi Kantha

The Kanthas collected by ICS Gurusaday Dutt from Bangladesh in the 19th century and the names of the Nakshi Kantha artists that have been recovered are mostly from the Hindu community. Churamani Hati[7], Nakshi Kantha in Various Forms: Paschim Bango, Kolkata, August-September, 2018, p. 128.

The word Kantha is thought to have originated from the Sanskrit word Kontha, the Prakrit word Kattha. According to Quilt (Kantha) Art of Bengal[8] by Manjary Mohanty, the first mentioned of Bengali Nakshi Kantha is found in Sri Sri Chaitanya Charitamrita by Krishnadas Kabiraj, which is written about 500 years ago, where it is mentioned that Sri Chaitanya's mother sent him a Kantha. Exactly when the commonly used Nakshi Kantha passes the Kantha level is not recorded. Due to the nature of the materials used and the climate of Bengal, the Kantha is quickly destroyed under normal conditions. The earliest examples of Bengali Nakshi Kantha are therefore not local, that were from sixteenth century's Bangala Kantha or Satganj Kanthas which were made at the order of the Portuguese. The earliest mention of Bengali Nakshi Kantha is found in English commercial documents in the court proceedings of the East India Company dated 25th February, 1818. (Niaz Zaman[9], Arts and Crafts, Bangladesh Asiatic Society, 2007, p.547)

According to the article of Tanvir Ahamed Fahad[10], titled 'A Traditional Embroidery Art of Bengal-Nakshi Kantha' we found the following etymology of Nakshi Kantha.

Kantha is originated from the Sanskrit word 'Kontha' meaning teases. It makes sense, as Kantha is generally prepared out of teases. The definition of Kantha is that it is a piece of cloth that is worn out for warmness during winter. Different variations of the word Kantha are used in different regional dialects in Bangladesh. And when the Kantha, or quilt or coverlet, has sewing woven onto it, then it becomes the Nakshi Kantha, or overstated coverlet in English.

According to Vedic literature, the needle has been used in India since the ancient times and it is evident in many Vedic hymns. A part from the literary references, archeological findings have also given sufficient evidences of needles and their uses. Needles have been found in the excavation sites of Harappa & Mohenjo-daro in the 3rd millennium B.C.

In India and Bangladesh there is a tradition of sixty four 'Kalas (arts) in which Suchi-karma i.e. needle work is an essential part of the Kala for the women folk. Therefore, we can say that the needle work must have been existed in the Indian subcontinent from a very early historic period.

The prevalence of Kantha art in ancient India is supported by several old texts viz. Rig-Veda, Upanishads, Budhha-Jatakas, Jain-text-Kalpa-Sutra, Panini-text, Ashtadhyaee, Maharshi Harit's Samhita Sansatak, Kasika-Vritti etc.

[5] Niaz Zaman, The Art of Kantha Embroidery
[6] Jasimuddin, Nakshi Kanthar Math, 1929
[7] Churamani Hati, Nakshi Kantha in various forms: Paschim Bango, Kolkata, August-September, 2018, p. 128.
[8] Manjary Mohanty, Quilt (Kantha) Art of Bengal
[9] Niaz Zaman[9], Arts and Crafts, Bangladesh Asiatic Society, 2007, p.547
[10] Tanvir Ahamed Fahad, A Traditional Embroidery Art of Bengal-Nakshi Kantha

Different types of Nakshi Kantha in Bangladesh

It is found that the interest in Kantha dates back to the early decades of the 20th century when Stella Kramrish, Gurusaday Dutt, Dinesh Chandra Sen and Jasimuddin revived this Nakshi art. Stella Kramrish wrote about Nakshi Kantha and collected many of them which are currently housed in the Philadelphia Museum of Art. Gurusaday Dutt also wrote on Nakshi Kantha and his collection is preserved in the Gurusaday Museum at Thakurpukur, Kolkata. Bengali poet Jasimuddin also collects Kantha for researcher Dinesh Chandra Sen, who has not only stopped writing on the Kantha but has also been able to create designs in multiple Kantha combinations. Jasimuddin was already inspired to write poetry on Nakshi Kantha. At the same time poet Rabindranath Tagore at Santiniketan, encouraged the search for indigenous roots of Bengali culture. In this environment local folk art including Kantha was observed. (Niaz Zaman[11], Arts and Crafts, Bangladesh Asiatic Society, 2007, p.554).

Although the Kantha of Jessore is the best, the Kantha of Rajshahi is also exceptional. The thickest Kantha comes from Chapainawabganj in Rajshahi, in which the ripple Kantha is entirely designed with plain yarn instead of sharee fringe. Besides, Sujani Kantha made with Lalsalu is also notable. Jessore's Kantha is very dull in color. Although the Kantha of Faridpur is similar to that of Jessore, the phore is not so sharp, the color is also a little more. The Kantha of Khulna is as colorful as Faridpur. Although the Kantha of Dhaka, Mymensingh and Tangail is like Jessore, it does not have any thorns. Although the Kantha of Kushtia is similar to that of Jessore, some influence of Rajshahi can be noticed. Rangpur, Jamalpur and Pabna have less motivation. And the Kantha of Chittagong is not soothed, but the geometric table is depicted in flower herbs.

Patterns

Various types of Nakshi Kantha patterns can be seen in Bangladesh. Such as Sujani- Kantha, Lep-Kantha, Chadar-Kantha, Ashan (Ason)- Kantha, Dastarkhan, Palki-Kantha, Baby-Kantha, Handkerchief-Kantha, Arshilata, Gilaf, Boska etc. There are two main streams of Nakshi Kantha stitching in Bangladesh, one is from Jessore and the other is from Rajshahi. Jessore style Kantha can be divided into three categories according to the variation of decoration i.e. Painted Kantha, Motif Kantha and Pier Kantha. Pictures of weddings, dances and songs are decorated by needle stitch. Motif Kantha depicts motifs or coins of life tree, lotus, moon, star, fish, elephant, mirror, comb etc. The Pier Kantha is made of needle thread and the pier is made as long as the Sharees pier. … There are so many pier-Kantha is found in Bangladesh like paddy sheaf, bats-chara (bats nails), pair of crabs, manure of ants, scissors edge, tabich-par, nine-chire, shyamalata, moipar, kajal-lata, mohanmala, madarkanta, tersilada, haritaki, khenjurchhari, karalabichi etc. (Tofael Ahmad, Folk Art[12], Bangla Academy, Dhaka, 1985, p. 59-60).

Motifs

There are so many motifs is found in Bangladesh. The number of motifs is less in small size Kanthas like Batua, Arshilata, Bastani etc. but there is excess and diversity in motifs are found at Lep-Kantha and Ashan (Ason) Kantha. Notable among the Kantha motifs are lotus, sun, chakra, Kalka, flowers, herbs, life of trees, animals, and geometric lines as well as various objects used in worldly life. Some motifs have a fixed location, such as the lotus and the sun are usually in the middle of the Kantha, the Kalka and green-trees are at the four corners, and the wavy flowering vine is at the border and the rest of motifs are scattered. (Wakil Ahmed[13], Folklore, Bangladesh Asiatic Society, 2007. p.179-180). Kantha is usually woven with pictures of fish, leaves, rice sticks, moon, stars, horses, elephants, gods and goddesses or any rural event. (Jasimuddin, Monthly Mohammadi, Baisakh 1358, 'The East Bengal Nakshi Kantha & Sharees[14]p.380).

Dinesh Chandra Sen mentioned his book that Nakshi stitch arts are the familiar objects like lotus, Padma, rice husk, leaves, flowers etc. in addition to the image of Kantha are the king, tenant, chariots, elephants, horses, mythological legends etc. (Dinesh Chandra Sen[15], Greater Bengal, p. 43).

Most of the writers on Kantha point out the link between Kantha and Alpana for motifs and spiritual similarity. For example, in Senjuti Brata, Alpana is drawn with a lotus in the middle of a circle or mall. The sun,

[11] Niaz Zaman, Arts and Crafts, Bangladesh Asiatic Society, 2007, p.554
[12] Tofael Ahmad, Folk Art, Bangla Academy, Dhaka, 1985, p. 59-60.
[13] Wakil Ahmed, Folklore, Bangladesh Asiatic Society, 2007. p.179-180
[14] Jasimuddin, Monthly Mohammadi, Baisakh 1358, 'The East Bengal Nakshi Kantha & Sharees'p.380
[15] Dinesh Chandra Sen, Greater Bengal, 1935.p. 43

moon, ornaments, a boat, a palanquin are added as motifs. Other Alpana depicts animals, trees, footprints and objects of the devotee's own or the aspirations of the person for whom the vows are being observed. (Niaz Zaman, Arts and Crafts[16], Bangladesh Asiatic Society, 2007, p.500).

Other widely used motifs represent the heart of a woman. Although the peacock is not a native bird of Bengal, it is a popular motif in the Kantha industry. The peacock is usually a symbol of the god Kartika. (Jasimuddin[17], Nakshi Kanthar Math). But Indian peacocks are often associated with the missing lover. Therefore, it can be said that the popularity of peacock may be related to the desire of women. In a nineteenth-century, a Nakshi Kantha of Faridpur is found where there are two female statues, both of which are hugging peacocks.The most ever-present motif is used in the middle at the traditional Nakshi Kantha is always the lotus. The lotus is eight-petals or hundred petals and is surrounded by a wavy vine or a Sharees fringe design. Occasionally the outermost border of the lotus is not round but square, with flower or Kalka designs at the corners. Perveen Ahmed, The Aesthetics and Vocabulary of Nakshi Kantha[18]: Bangladesh National Museum Collection (Dhaka 1997).

The motif Kantha depicts lotus, tree of life, chakra, swastika, betel leaf, household items, elephant, fish etc. Some identical motifs of world-class folk art can be seen. To unravel the mystery of these motifs, folklorists, archaeologists and artisans need to work together. (Tofael Ahmad, Folk Art[19], Bangla Academy, Dhaka, 1985, p. 61).

Kalka is thought to have come to India via Persia where it is usually a leaf symbol. It is variously associated with a flame, a mango, a tree, half of the symbol of In Young. The lower part of Kalka symbolizes a woman's body. Some of the motifs show the other Kalka is very similar to a fertility symbol of Alpana. If the Kalka is the symbol of the tree, then it refers to the tree of life which is closely associated with women. (Niaz Zaman, Arts and Crafts[20], Bangladesh Asiatic Society, 2007, p.550).

In the center of the Muslim artist's Kantha, it is found the round flower picture and the sun. Both Hindu and Muslim artists emphasize a circular idea at the center. Chakra (Wheel) is a symbol of worldly order, the sun is a symbol of strength and the lotus is the symbol of sanctity, peace and good luck. (Churamani Hati[21], Nakshi Kantha in Various Forms, Paschim Bango, Kolkata, India, August-September, 2017, p.130).

In Bangladesh, different types of Nakshi Kantha having trees, plants, fruits, flowers, and geometric shapes. Most of them have an inner design including bordered by minor designs. And most of these designs have been woven for thousands of years which taking influences from the multiple religions including Hinduism, Islam, and Buddhism.

In the track of my study I find various types of Kantha based on size, shape and utility of the object as well as relevant ritualistic or iconoclastic symbols. I also discover different types of motifs, designs and forms such as the tree of life, the Kalka, birds, horses, elephants, abstract and tantric symbols, linear patterns and figural objects.

The lotus motif symbolizes the power of life – the union of earth, water, and sky; its open and closed petals indicate the ups and downs of life and the multiplicity of the universe. It is one of the most common designs found in Nakshi Kanthas, and is associated with Hinduism. It symbolizes a heavenly throne, while also being a symbol for harmony and womanhood. It also signifies the unity of earth, water, and sky. The designs feature many variations of the lotus, from the eight-petaled satadal to the hundred-petaled satadal. Solar is a lotus motif that is often found together as the central design of a Kantha. It is a symbol of the power of life within the sun.

The moon is associated with Islam. And in most designs like this, the crescent and the star, symbols of Islam, can be seen in many Kanthas. The wheel is a common sight in India and Bangladesh, with influences from both Hinduism and Buddhism. It is also a representation of the world. This design is popular in rural Bengal.

The varying treatment of the Kalka in four corners expresses the designer's whim, shortening, broadening, enlarging and reducing each one to convey a changing harmony. This design gained popularity during the Mughal period. Originally from Persia and Kashmir, it has become an integral part of Nakshi Kantha embroidery in the Indian subcontinent.

Swastika is a symbol of good fortune, and dates back to the Indus Valley civilization. With time the design became more curvilinear. It is a popular symbol in Hinduism, Buddhism, and Jainism.

[16] Niaz Zaman, Arts and Crafts, Bangladesh Asiatic Society, 2007, p.500
[17] Jasimuddin, Nakshi Kanthar Math,1929.
[18] Perveen Ahmed, The Aesthetics and Vocabulary of Nakshi Kantha, Dhaka 1997
[19] Tofael Ahmad, Folk Art, Bangla Academy, Dhaka, 1985, p61
[20] Niaz Zaman, Arts and Crafts, Bangladesh Asiatic Society, 2007, p.550
[21] Churamani Hati, Nakshi Kantha in Various Forms, Paschim Bango, India, August-September, 2017, p.130

The Tree of Life design is another design that originates from the Indus Valley civilization. The Bangladeshi interpretation of this design features leaves and vines. Rath is a significant Hindu symbol which is the multitiered chariot or car of Jagannath (Lord of the universe).

The Ashon (Asan) being a cloth spread for sitting at the place of worship, or family altar within the home, often indicates the God most honored in the household. Since the Hindu calendar, especially in Bengali tradition, worships different Gods during different seasons, one may come upon Ashons bearing symbols representative of the family's various Gods.

The Nakshi Kantha is very versatile, with different types of Kantha serving different purposes. And even while being extremely practical, the design of the Kantha always stands out, along with the stories behind every weave and thread.

According to the article of Tanvir Ahamed Fahad[22], titled 'A Traditional Embroidery Art of Bengal-Nakshi Kantha' we found the following Nakshi Kantha:

Lep-Kanth is a thick winter coverlet used as a replacement for the coverlets during the winter, Dastarkhan is used as a place to sit and eat for visitors and is laid on the floor, Sujni-Kantha is used for bed sheet and it is also laid down for visitors to sit on. Bochka-Kantha is used for bundle wrapper cloths and treasure, Balish-Kantha is used for the cover of pillow, Arshilota is used for wrapping mirrors and combs, Borton-Dhakna is used for covering up food during events and the Ashan (Ason) Kantha is laid down in religious ceremonies in places where visitors will sit.

Some case studies

Case Study 1

Respondent: Chandana Rani Bairagi, Husband: Swapan Bairagi, Village, PO & PS: Ashasuni, District: Satkhira. (Photo 1).

From a young age, she interested and has learned needle stitching art by watching her mother, relatives and other women of the family used to do it. Although it used to be made more but now it is less, because of readymade things are more available like carpet which were not before there. Kantha was the main element for winter.

As because it takes a long time to stitch and prices are not profitable, so she doesn't sell. Most of it is used as lep-Kantha in winter as well as souvenir and welcome ceremonies.

Using the bright color yarn on the white texture like red, green and blue are used in old dhutis in the ground whereas old white thaan are used in inside. She collects the yarn from petty yarn shop. She stitched the motif of eight petals inside the rectangle and repetition. This type of motif is commonly used for taking advantage of stitching.

Case Study 2

Respondent: Priya Bairagi, Village: Kachari Bari, Thana: Batiaghata, District: Khulna.

From a young age, she interested and has learned needle stitching by watching her mother, relatives and other women of the family used to do it. Although it used to be made more but now it is less, because of readymade things are more available like blanket and quilt which were not before there. This Kantha is the main element for winter. (Photo 2). As because it takes a long time to stitch and prices are not profitable, so she doesn't sell. Most of it is used to sit on the ground during religious worship and ceremonies.

Using the bright color yarn on the white texture like red, green and blue are used in old dhutis in the ground whereas old white thaan are used in inside. She collects the yarn from petty yarn shop. She stitched the motif of four leaf flower, eight leaf flower and vine-leaf. This type of motif is commonly used for taking advantage of stitching.

[22] Tanvir Ahamed Fahad, A Traditional Embroidery Art of Bengal-Nakshi Kantha

Photo 1. Chandana Rani Bairagi was sewing Pair-Kantha

Photo 2. Priya Bairagi was sewing Ful-kata (Local Name) Kantha

Case Study 3

Respondent: Shyamali Sana, Village: West Patibunia, Thana: Dumuria, District: Khulna.

From a young age, she interested and has learned needle stitching by watching her mother, relatives and other women of the family used to do it. However, her children are not interested in this work. Although it used to be made more but now it is less, because of readymade things are more available like blanket which were not before there. This Kantha is used in winter as the main element.

Bright red, green, yellow, blue type yarns have been used on the white texture on old dhutis fabric and old white thaan used in the inside She collects the yarn from petty yarn shop. She stitched the motif of four leaf flower, Jaba flower, Kalka, lotus curry, six leaf flowers. This type of motif is usually familiar (Photo 3).

Photo 3. A Part of Nakshi Kantha Motif of Shyamali Sana

Case Study 4

Respondent: Namita Bairagi, Husband: Monimohan Bairagi, Village: North Shailmari, Thana: Harintana, District: Khulna (Photo No. 4). From a young age, she interested and has learned needle stitching by watching housewives, her mother, aunt, relatives and other women of the family used to do it. However, her children are not interested in this work. Although it used to be made more but now it is less, because of readymade things are more available like plastic mats & small rugs.

As because it takes a long time to stitch and prices are not profitable, so she doesn't sell. Most of it is used to sit on the ground during religious worship and ceremonies.

Using bright color on white texture like red and blue on old dhutis fabric in the ground and old white thaan in the inside and she collects the yarn from petty yarn shop. This Kantha is made in 2000. The design is made with filled phores and in border it has been given a simple Kantha phore for avoiding stress. She stitched the motif of four leaf flowers, eight leaf flowers and vine-leaf.

This type of motif is commonly used for taking advantage of stitching. The red cloth on the side is called 'kuchi jhuri' which was made with old thin georgette sharis. This Ashan Kanthas are mainly made by old cloths.

Case Study 5

MRDI (Management and Resources Development Initiative) and Green World jointly conducted a six month training program on Nakshi Kantha titled 'Bon Laudob Project' in three spots in two unions of Dacope Thana of Khulna i.e. Bon Laudob and Kailashgonj of Kailashgonj union and Dhangmari of Banishanta union. More than two hundred women of Sundarbans region (mostly married) joined these training programs (Photo 5). Training was conducted several times from 2010 to 2012. Mr. Md. Shamim Reza (Assistant Professor of Fine Arts at Jahangirnagar University) from Dhaka was the trainer of this project.

Photo 4. Ashan (Ason) Kantha of Namita Bairagi

Photo 5. Halima Begum, Bon Laudob Project

In the training session women used the local motifs as well as followed motifs of Jessore and other regions. Before stitching, many of them used to stitch with their freehand even though it was painted in stencil method. Sometimes Tiger and Golpata of Sundarbans were used as motifs.

There is a registered women's association there and it conducted fairs in several times and earned money by selling Nakshi Kantha. They also sold it to Dhaka Mini-marts and enchanting foreign buyers occasionally. Even

after the completion of this 'Bon Laudob Project', there is still stitching, but it is for one's own needs and of course, some women still have sell.

Research Findings

Specialty of Nakshi Kantha of Khulna

In the ancient kingdom of Vanga and Samatata, Khulna was part of it and became a part of the Sena dynasty during the 12th century under Ballala Sena, and formed part of the Bagri division of Bengal. Khulna was the very first sub-division of United Bengal Province which was established in 1842 under Jessore district. On 1 June 1882 by notification of the official gazette published from Kolkata, Khulna and Bagerhat sub-division of Jessore district and and Satkhira sub-division of 24 Pargana district formed the new district 'Khulna'. In 1984 Satkhira become a district.

In this study, greater Khulna means not only Khulna division but also it's old area with Satkhira which is very relevant to our study topics like Nakshi Kantha. Therefore there is no confusion to study the chronological history of Nakshi Kantha in this greater Khulna or to specify the research area.

Limitations of this study is the biggest problems which I have explained in the limitation of study section. These obstacles also impacted in to my field works. But the socio economic impact of Nakshi Kantha is very important for this study and I am attempting to understand the emerging reality and socio economic observations of Nakshi Kantha featuring new challenges and scope in greater Khulna of Bangladesh.

A look at the Kanthas preserved in several Aristocratic Family in Calcutta and museums in West Bengal of India gives me an idea of the form of Nakshi Kantha which was once published. Kantha crowds can also been seen in several museums of Bangladesh. Several notable Kanthas are being preserved in both Bangladesh and West Bengal of India.

This study discovered Manadasundori Dasya Kantha of Khulna at Gurusaday Museum, Thakurpukur in Kolkata, Sonamoni Dasya Kantha collected by Abanindranath Tagore at the residence of Amitendranath Tagore, Bamasundari Dasya Kantha of Magura at Victoria Memorial Hall of Calcutta, Gift of Shilaidah Kantha to Rabindranath Tagore at Rabindra Bhaban of Visva-Bharati. Nakshi Kantha of Bangladesh also preserved in the Museum of North Bengal University of Siliguri including Ashutosh Museum of Calcutta University.

None of the Nakshi Kanthas preserved in the archives date back to before 1600 AD. In the 19th century, Stella Kramrish identified a Nakshi Kantha as dated 1875 AD. Some specimens of handicrafts, including Nakshi Kantha, collected by Gurusaday Dutt, were displayed on 20 March 1932 at The Indian Society of Oriental Art[23], Calcutta. (Churamani Hati, Naksha Gatha Kantha Pith, Shiladitya, Kolkata, February, 2019, p. 13).

A total of 210 Nakshi Kanthas of 19th and 20th centuries are preserved in Gurusaday Museum. Of these, 201 were collected by Gurusaday Dutt. Nakshi Kantha, popularly known as Manadasundori Kantha in folk culture, researcher and artist community, is preserved in Gurusaday Archive and collected by Gurusaday Dutt. This 19th century Nakshi Kantha was collected from Mulghar, Fakirhat of Khulna, then undivided Bengal and present day Bangladesh. It is hard to understand and realize how consonantal the colored threads of some previously used sharis, dhotis and cloth spread from the fringe of this Nakshi Kantha.

Manadasundori Dasya Kantha

Firstly, the Kantha of Manadasundori which is clearly mentioned in the dedication script of the Zamindarbari, and secondly, it is the embroidered Sujni Kantha.

[23] The Indian Society of Oriental Art, Calcutta. Churamani Hati, Naksha Gatha Kantha Pith, Shiladitya, Kolkata, February, 2019, p. 13

Photo 7. Nakshi Kantha of Manadasundori Dasya

In the classification of Nakshi Kantha by Gurusaday Dutt, Sujni Kantha is mainly used as a bed sheet to welcome guests or loved ones or at festive occasions. This Kantha, which is made with difficulty as well as skilled hands, is one of the two characteristics; hence the word 'dorokha' has been used.

The dedicational script has only been reversed there inversely. In the dedication part written in Bengali as 'I Manadasundori Dasya, the daughter of Mr. Bardakanta Basu resident of Bandhal prepared with wax dedicated this Sajni to my beloved father with great respect. Dear gentlemen, please pardon me as much as you can' (Photo 7). Child widow Manadasundori has been decorating this Kantha for a long time.

The printed picture of company as well as the Kalighat pot suggested that she might have been influenced by the fragmentary nature of the social scene of the time. Or as the daughter of a Zamindar, she had the opportunity to meet the other Zamindars of Calcutta.

This Kantha is a combination of social imagery and the spiritual world. The lotus blossoms used in the middle of this Kantha which is 5 feet 9 inches long and 4 feet 5 inches in size. The dazzling chained Kalka around the lotus and the geometric design-hyacinth chakti. Either the Gora-platoon lined up in the two opposite sides of

the Kantha or the Portuguese army on the opposite side of the British Indian army. Foreigners in camouflage hats and oil coats also have swords in their hands and Indian soldiers in pokri hats also carry guns.

This gun reminds me of Bengal Sepahi rebellion. The Indian Army is not only distinguished by the quality of its clothing, but also by its appearance. Andaramahal is one side and just opposite the Barmahal. It shows the impressions of a close-knit family in the inner courtyard of a Zamindar's house. Middle-aged women are engaged in good deeds by touching each other. And young women are busy dressing up.

It is seen that a girl is busy with the veil. External men are not allowed in the inner courtyard. It is clear in their costumes those only clansmen, saints, monks, astrologers could enter, so they are seen as men in the inner court.

On the other hand, there are oarsmen in the Barmahal, dancers dancing, dancers' dressing room, intoxicated Zamindars are sitting in chairs, women traveling with wine, there are seen dressing as colored Hanuman.

The rectangular Kantha is surrounded by lotus and bunches of kadam flowers with stalks. There is also the desire to be freed from captivity by staring at the doors and windows of the Zamindar's house and the windows of the girls. As well as being allowed to go out with the male character with any one woman. Earlier, the scene of gentleman (Babu) walking around with a chain around the dog's neck or gentlewoman (Begum) inside the chariot and Nawab is outside; A kind of touring scene, an Indian mahout riding on an elephant and two gentlemen.

The bed sheet on the back of the elephant is also patterned. There is the yoga power of the saint and the ability to carry the mass of incense and smoke and Elephant (Irabat) can be called divine power. There are chariots with flags at the top. Scattered are insects and birds, butterflies, bees, wasps, lizards, gossips, crocodiles, several fishes and birds, animals, chicken, duck, fox, pig, , woodpecker, spider, earthworm, snake etc.

There are two-dimensional coins with the front and back facing aside. Needless to say, except for the pictorial parts, there are small phore in all over the Kantha. There is no way to make the characters look better than to wonder about the sewing skills.

The body of the Kantha is flat, there is no difference in the pull of the line on the opposite side but the difference in the filling is noticeable. The filling on the reverse side is relatively light but when viewed from a distance, small dots accumulate and solidify. There was the use of black, yellow, green, blue yarn. There was also the use of red thread.

In Hindu reform Manadasundori painted the sign of victory on the foreheads of the Indian men, but not a single woman she painted the vermilion on their sinthi. Maybe she didn't want to push a character of her love towards evil by calling herself a widow. The artist seems to have caught everything herself. It is possible to create such Kantha from the love of the devotee's mind.

Other Specialty of Nakshi Kantha of Khulna

Accession No: 90.1321[24]; Object: Nakshi Kantha (lep); Provenance: Khulna: Measurement :190 cm x 130 cm; Material: white cotton handloom sharee, three layers, threads from old woven sharee borders, and an original red woven border sewn on as outer edge; Colors : Pinkish red, orange, jade green, dark blue, purple, black, light orange, pink, white ; Approximate date: 1920 A.D. Plate No. 45

The Jeevan vriksha (Jibon brikho) trees as flowering shrubs appearing in the four corners of this charmingly decorated Kantha spread, is recent enough in time to overrule ancient totemism into its-every motif. Indeed one does not have to draw conclusive or even indicative meanings out of the composition. The centre circle contains the sun's rays, also the rice stalks and the petal-like projections of a lotus flower on its parameter, but by no code of ritualistic design is it either a cultist sun or a ritualistic lotus. The drooping branches with exotic flowers are gracefully held on the erect inner leaf-trees as seen in traditional forms. The four mid-points of the centre field have building shapes which are mausoleums, temples, or mosque images. The bottle-like forms could be ceremonial water vessels or incense holders, the curved handled bowl also looks like a ritual or domestic object and the combs and sleek stylized fish seem to be patterns of visual pleasure. This may be an example of beauty for beauty's sake, but with undeniable expressions of traditional folk art-craft (Photo 8).

[24] Perveen Ahmad, Aesthetics and Vocabulary of Nakshi Kantha

Accession No: 77.1899[25]; Object: Bostani; Provenance: Khulna, Material: White cotton handloom sharees two layers, threads from old sharees borders; Color red, black, ochre, pink, dark blue, grey-green, white; Approximate date; 1890 A.D. (Plate Nos: 63 & 63A) (Photo 9).The two striking features of this bostani Kantha are its brilliance of color and the extraordinary textural quality which stand out in luminous shades.

The ground is worked in the artful stitch called pipre-sharee (Antline stitch) which has a magical effect of creating visual movement. Thus the entire piece gives a sensation of liquidity, as if all the images are floating on moving waters, the closely worked stitches forming triangles, rectangles, pentagons, hexagons, and shapeless forms, circumscribe the motifs in light or dark colors giving density or lightness to the field. This style is similar, yet different from the 'modeling' stitch seen in other Kanthas.

Photo 8. Nakshi Kantha (Lep)

[25] Perveen Ahmad, Aesthetics and Vocabulary of Nakshi Kantha

Photo 9. Bostani

Once again the satadal padma, hundred petal lotus containing an eleven petalled flower with bindu centre, is surrounded by outward pointing petals. Then come the corner point, the four directions of the earth, with meanings understood by mankind in all civilizations, from Mesopotamia to the Indo-Gangetic civilizations and beyond. It is noteworthy that the tree of life motifs seen in the previous two Kanthas are all put together in this piece in its three manifestations: geometric, linier and floral. In the forth corner a Rath (chariot) completes the visual symphony. Whether this happened by actually seeing the two older Kanthas, or merely that the artist, familiar with a wide repertoire of design, used all image to suit her layout, is speculative. It certainly goes to the credit of the embroiderer that she arranged the two figurative and two abstract motifs at diagonal points, with tremendous pictorial grace.

A very rare Nakshi Kantha of Khulna

Lady Amir Un-Nagar of Alipur, Sathkhira produced this Nakshi Kantha on 1379 (Bengali Year) just after the Liberation war of Bangladesh. This Kantha is archived in the Bangladesh Folk Art & Crafts Foundation, Sonargaon, Narayangonj (Photo No. 10).

This Kantha represent the Bangladesh map in the foreground mixing with different color threads, expressing the Sonar Bangla filled up the wealth and resources of Bangladesh mentioning place name and artist name. In this Kantha we found the Bay of Bengal under the map stitching the water wave. This Kantha represent the patriotic love of a needle craft artist of Bangladesh.

Photo 10. Nakshi Kantha of Amir Un-Nagar

Bayton Khantha

This Kantha is made in the nineteenth centuries. In this Kantha we found the motifs as Round Padma in the center surrounded by jiban brikkha (life of tree) and the border is sew the edges stitched. Kalka, fish elephant, horse, peacock and Rath motifs also stitched that represent the religious beliefs as well as Khulna region. Writer and researcher Shila Basak[26] of India mentioned her book titled 'Banglar Nakshi Kantha' published by Ananda Publishers, Kolkata, First published in 2002, page 255, Photo No. 244 (Photo 11).

Socio economic impacts of Nakshi Kantha

Nakshi Kantha is a medium to promote the local communities through commercial opportunities, employment opportunities, income generation, conservation and development of rural arts, crafts and cultures. The majority of the rural people in Bangladesh live in below poverty level but there have a unique traditional way of life, heritage culture, handicrafts, art etc. that has a great vista for crane the socio-economic conditions. It acts as enhance in employment opportunities in rural areas and the products of rural needlewomen get a ready market. Bangladesh government has been organizing various types of exhibitions, fairs, festivals etc. for encouragement the rural arts, cultures and handicrafts and Nakshi Kantha is one of prominent.

[26] Shila Basak, Banglar Nakshi Kantha, 2002. p.255

There are so many constructive crashes of Nakshi Kantha stitch on socio-economical perception are stated below:

- Create employment opportunity for rural women.
- Rise income level of the Kantha artisans.
- Generate foreign exchange.
- Improve culture, health and education of the rural communities.
- Cultural understanding through fairs and festivals of Kantha artisans.
- Reduce migration of rural people to urban areas.
- Development of market of the agro products and handicrafts.
- Rural artisans get direct contact with the customers.

Photo 11. Bayton Kantha

New challenges of Nakhsi Kantha

There are some many new challenges and struggles concerned in Nakshi Kantha of Bangladesh. The women who engaged in Nakshi stitching work are facing numerous difficulties which are mentioned below:

- Lack of managing time for Naksha stitching work.
- Due to natural disaster like the cyclone Amphan, Aila, Sidor and devastating floods, women of these areas couldn't give time to Nakshi stitching work than that of other income generating works.
- Due to Covid Pandemic women switching their profession from needle craft to agriculture, fishing, wood collector etc.

- Poverty is the main reason to involve women in other income generating works like agriculture, fishing, private business as well as private job.
- Lack of labors in agricultural sectors, women are bound to involve in agro-farm in spite of needle craft work.
- Lack of leisure time and involvement in social media like Facebook, Instagram, Twitter, and watching television serial and drama, women couldn't feel interest in needle work.
- Nakshi Kantha of other areas in Bangladesh and commercially produced Nakshi Kantha by NGOs fulfilled the demands and supply chain of Khulna region, so that the women who worked in needle craft just quit themselves for lack of demands.
- Migration is one of the major reasons to decrease Nakshi Kantha production in Khulna region. Two types of migration are found in Khulna. Migration to Dhaka or other districts for works and migration to India for living.
- NGOs provided jute-cotton and other raw-materials for making carpet and other handicrafts, for that reason woman is switching their profession from needle craft to jute-craft.

The scope of Nakshi Kantha

Government initiative

Bangladesh government has taken steps to create a vast indicator to represent the traditional sources on artistic work to enlarge the embroidery textile market of our country. Recently Bangladesh Handloom Board finalized Tk. 21.13 billion projects in this connection. The construction of the hub is expected to be finished by 2023 and will be located across two upazilas of Jamalpur. Once completed, the 300-acre hub to be known as 'Sheikh Hasina Nakshi Palli[27],' would accommodate almost 1,200 entrepreneurs while tripling the production of embroidery items in the country. This would be one of the biggest government projects for the whole textile sector in the country and it will help create a bigger market for embroidered textiles while generating more than three hundred thousand additional jobs. Government can play an important role to create similar kind of project for sustaining needle craft women in Khulna.

There are alternative scopes for Nakshi stitching women of Khulna are the following:

- Developing tourism system for foreign and local tourists based on Sundarbans to attracting Nakshi Kantha. Nakshi Kantha can play significant role in familiarizing the country's tourism resources, attracting tourists, stated the inhabitant of a country engaged in needle-craft work. It's a tendency of the tourist that they like to collect a small piece of memory with them while they return from a place and the best thing to be collect from Bangladesh is Nakshi Kantha. Nakshi Kantha thus plays a pivotal role in the field of tourism sector and it helps not only attracts the tourist groups but also it helps the country's economy to increase its GDP by earning foreign currencies.
- Ministry of Cultural Affairs can open a window in Khulna for exhibit and sale of Nakshi Kantha. At the same time they can create a government website where Nakshi Kantha and other handicrafts information are available.
- Local government can open a Nakshi Kantha Hat like Shanibarer Hat of Santiniketan, Bolpur, West Bengal, India in regular basis for sale so that local needle crafts women can sale their Nakshi products there.

Suggestions and recommendations

A set of broad recommendations are proposed that will allow the state to attain the preferred growth and development in infrastructures and in the rural tourist numbers to attract Nakshi Kantha.

- For creating awareness government should give training to the technical and non-technical persons associated with rural tourism.
- By providing attractive financial scheme government should generate attractive schemes for entrepreneurship development related with Kantha stitch among the rural community.

[27] Sheikh Hasina Nakshi Palli, Jamalpur

- Implementation- Rural Tourism covering the Kantha stitching areas to facilitate direct experience of these products by tourists
- For entrepreneurship development and existing business development, loans and others financial support like subsidy, tax concession and others incentives should be given to the local needlecraft-women.

Limitations of study

Before the partition of India greater Khulna is well-known for the biggest community of Hindu people. The biggest number of Nakshi stitching women was from the Hindu community. Bangladesh is a Muslim majority country in where the Hindus are the minority people. After the partition of India in 1947, Hindu-Muslim riot in 1947 and 1964-65, India-Pakistan conflicts of 1947, 1965, 1971, and 1999, Liberation war of Bangladesh in 1971, Babri Mosque incident of 1990s and geopolitical conflicts of India-Bangladesh and subcontinent made a significant impact to migrate the minority Hindu community of Bangladesh to India.

In greater Khulna was once the majority of Hindu community than that of the Muslims, but the results of several incidents of communal conflicts that it has been turns to minority due to the largest people of Hindu community migration to India. Even this tendency of migration of Hindu community to India is still going on. That's why it has been created a biggest negative impact on Nakshi Kantha production in greater Khulna region.

At the same time women have been switched their professions from needle stitch work to agriculture, fishing, readymade garments, and other jobs. On the other hands, television talk-show, drama, drama serial and attractive programs of satellite television, social media like Facebook and the rapid changes of villages to urban made an incredible impact to reduce leisure time of women's life style which made a negative impact on Nakshi Kantha.

In addition, with poor sales during the Corona pandemic period, about 50-60% of workers in needle-craft have lost their jobs in Bangladesh and it made a negative impact to the women of needle stitch for switching their jobs to another sector in greater Khulna region. Even there are so many alternative hubs of Nakshi Kantha that existing needle crafts women switch their jobs to other handicrafts works for better earning.

Moreover, the rapid development of infrastructure and communications of rural Bangladesh as well as the development of women education that has been creating more job hubs in urban markets, which made a negative impact in Nakshi stitching sector due to lack of needle crafts workers. Generation gap has also made a break in Nakshi stitching sector. Where the grandmothers or mothers were Nakshi crafts women of a family, their granddaughters or daughters have no interest in needle crafts stitch.

Therefore there are so many limitations and obstacles have taken place in the area of Nakshi Kantha stitching. Limitations of women empowerment, lack of interest in needle crafts, limitations of leisure periods, and lack of opportunities in Nakshi Kantha, needle crafts women switching them to agro farm, fishing, and other job sectors.

There are also some limitations to this study paper effectively due to the availability of authentic data of this traditional folk stitch.

- The insufficiency of previous records about the traditional stitches in Bangladesh.
- Different districts have different patterns of Nakshi Kantha motifs.
- Discontinued chain of skilled artisans in the current century.
- Modern fashion designers sometimes also tried to replica the Nakshi Kantha design in other dress. Although this attitude of the fashion designers have enlarged their business but on the other hand it is downfallen the traditional value of the product itself.
- Nakshi Kantha once existed among the basic household items that have now become a piece of art, exhibited during special occasions. Many use the handicrafts as decorative element than that of understanding the cultural and traditional value.

That's why this article is an attempt to study the emerging reality and the socio economic impact of Nakshi Kantha as well as to seek the new challenges and scope in greater Khulna region of Bangladesh.

Conclusion

This art has given an economic freedom to the female folk and they have gladly accepted this work as a parallel economy to earn money, without hampering their family responsibilities. Women are also aware of their self-respect and their position in the society and community. Apart from their traditional role of a homemaker, many of them have taken this art as a profession and the Nakshi Kantha craft acts as a tool for women empowerment.

Now a day the concept and trend of tourism are changing gradually. Tourism means not only to visit prominent destinations and stay overnight in star categories hotel but also to visit remote lesser known places and enjoy the real flavor of rural areas in close proximity of local community. They prefer to purchase handmade indigenous products like Nakshi Kantha stitch from local shops rather than branded products from showroom. This type of tourism suggests real experience of unique culture of Bangladesh. Hence the development should guarantee the social and cultural sustainable tourism development compatible with the culture and values of the local people. The plan for action should focus around community participation in tourism development and planning, training of the personnel associated with art and craft work so that they can provide quality services without devaluing the same.

In conclusion, we may say that the Nakshi Kantha market in Khulna requires a judicious mix of creativity and institutionalization. On one hand the creativity of the craftswomen need to be encouraged and on the other hand the linkages in the production processes need to be formerly structured so that there is productive efficiency and rewarding returns to labor. Craftswomen of Khulna have the traditional skill and a latent entrepreneurial spirit to their advantage for their socio-economic development.

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Conflict of interest

None declared.

References

Ahmed, P. (1997), The Aesthetics & Vocabulary of Nakshi Kantha, Bangladesh National Museum, Dhaka
Ahmed, P. (2009), Nakshi Kantha Art in the Indo-Gangetic Matrix, Bangladesh National Museum, Dhaka
Ahmed, W. (2007), Loko Sanskriti, Bangladesh Asiatic Society, Dhaka
Basak, S. (2002), Banglar Nakshi Kantha, Ananda Publishers, Kolkata
Bosu, K. (1336 Bangabda), Maheshwarpasha Porichoy
Fahad, T. A. A Traditional Embroidery Art of Bengal-Nakshi Kantha
Hati, C. (August-September, 2017), Nakshi Kantha Nanarupe: Pashchim Banga, Kolkata
Manjary Mohanty, `Quilt (Kantha) Art of Bengal
Nakshi Kanthar Bishesh Prodarshoni (2008), Bangladesh National Museum, Dhaka
Pride of Bangladesh: Our Nakshi Kantha (2016), Bangladesh Folk Art & Crafts Foundation, Sonargaon, Narayangonj, Ministry of Cultural Affairs
Sen, D. C. (1935), Brihat Banga
Talukder, S. (2001), Folk Art of Bangladesh through Ethno-Archaeological Perspective, Bangla Academy, Dhaka
Textile Traditions of Bangladesh (2006), National Crafts Council of Bangladesh
Uddin, J. (Baishakh 1358), Purbabanger Nakshi Kantha O Sharee, Masik Mohammadi
Zaman, N. (2007), Nakshi Kantha: Charu O Karukala, Bangladesh Asiatic Society, Dhaka

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ORIGINAL ARTICLE **LIFE SCIENCE**

TOXICITY STUDY OF *URENA LOBATA* USING *ALLIUM SATIVUM*: A NEW EUKARYOTIC BIOMONITORING TEST SYSTEM

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Abstract

Urena lobata (L.) has diverse biological activities. A recent study suggests that its leaf extract exerts acute toxicity on three different phases of Zebra fish, where the authors calculated the median lethal concentration (LC_{50}) value ranges between 2,548 and 8,748 g/L. This study aims to re-check its toxic effects on a new eukaryotic test model named the *Allium sativum* toxicity test model. For this, the ethanolic leaf extract of *Urena lobata* (ELEUL) was tested at 2, 4, 8, 16, and 32 mg/mL on the cloves of *A. sativum* at 24, 48, and 72 h exposure times (ET) using copper sulphate ($CuSO_4$) as a reference standard. Manual observation of root number and length profiles was considered in this study. The results suggest that ELEUL significantly ($p< 0.05$) and concentration-dependently reduced the number and length of roots of the test system in comparison to the control group. However, the ELEUL exerted more toxic effects at 72 h ET on the test system, and it showed an adaptive capacity at 48 h inspect of 24 h ET. The LC_{50} value was obtained between 4 and 8 mg/mL. Taken together, the ELEUL exerted toxic effects on the root meristems of *A. sativum* cloves, and this new model was sensitive like other popularly used toxicogenetic biomonitoring systems, like the *A. cepa* test model. Therefore, *A. sativum* might be another hopeful plant-based toxicogenetic test model.

Keywords: *Allium sativum*; eukaryotic system, biomonitoring model, toxicity study

Introduction

It is evident that *Urena lobata* (L.) (Family: Malvaceae) is used to treat many diseases empirically (Islam and Uddin, 2017; Roespandi et al., 2018). To date, a number of pre-clinical studies have proven its efficacy (Babu et al., 2016). However, the safety profile of this hopeful medicinal plant has yet to be evaluated. One study reports that the plant at 100, 200, and 300 mg/kg (p.o.) caused alteration of biochemical and morphological organization of the rat liver significantly with repeated and increased use of the aqueous root extract (Mshelia et al., 2013). A seminar presentation suggests that an acute toxicity study of the leaf extract (decoction method) of the plant exerted a significant toxic effect on the embryo, juvenile, and adult phases of zebra fish (*Danio rerio*) (Roespandi et al., 2018).

Many species of the Allium genus are quite important due to their economic and health benefits (Fredotović et al., 2020). For example, *Allium cepa* and *A. sativum* have many health benefits. It is to be noted that *A. cepa* is popularly used as a test model for toxicogenetic studies (e.g., toxicity, cytotoxicity, genotoxicity, mutagenicity) of varieties of test substances (e.g., crude extracts or their fractions, isolated compounds, laboratory synthetic derivatives, drugs and chemicals, environmental pollutants, etc.) in the laboratory due to its availability, economy, sensitivity, etc. (Levan, 1938; Fiskesjö, 1985; Cresencio et al., 2017). Its results can be related to animal-based higher eukaryotic test systems as a eukaryotic test model. Therefore, it is also used as an environmental toxicogenetic biomonitoring system (Fiskesjö, 1985). However, the *A. cepa* model has some limitations, such as onions not being preserved for a long time. It requires a whole bulb, whereas *A. sativum* only requires cloves, so the *A. sativum* model may be less expensive than the *A. cepa* model. Each garlic bulb produces enough cloves and even more roots than an onion bulb. Therefore, a single *A. sativum* clove can provide an adequate number of meristems rather than a

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whole onion bulb. This study re-evaluates the toxicity of ethanolic leaf extract of *U. lobata* by using a new eukaryotic plant-based test model called the *A. sativum* toxicity test system.

Materials and Methods

Collection and identification of Urena lobata

Fresh *U. lobata* leaves were collected from the hilly areas of Foy's Lake, Chittagong, Bangladesh in October, 2010 and the plant was identified by a taxonomist at the Forest Research Institute, Chattagram, Bangladesh (Voucher specimen: BFRIH-7011).

Extraction

Collected plant materials (leaves) were washed with running tap water and air-dried thoroughly. Then, it is followed by shade-drying at a temperature not exceeding 45° C and grinding into coarse powder with a suitable mechanical grinder. Approximately 125 g of leaf powder was soaked in 500 mL of absolute ethanol at room temperature for seven days with occasional shaking and stirring. The extract was filtered off first by using a surgical cotton plug and then filtered by using Whatman filter paper no. 1. A rotary evaporator was used to concentrate the filtrate at a lower temperature and pressure. This yielded 7.06 g (5.65%) of extractive *U. lobata*. The extract was preserved in an amber-colored glass vial until the test commenced.

Collection of test systems

For this study, fresh large-size garlic (*A. sativum*) was purchased from the local market in Gopalganj district (Bangladesh).

Standard

The standard, copper sulphate ($CuSO_4$), was purchased from Merck India Ltd.

Preparation of test samples and controls

The ELEUL at 2, 4, 8, 16, and 32 mg/mL was tested to determine the toxic effects on the above-mentioned test system. For this, the required amount of extract was soaked in distilled water for 12 hours prior to adding the samples to the test marked tubes. The highest concentration (32 mg/mL) was diluted to get 16 to 2 mg/mL concentrations. Distilled water and $CuSO_4$ (0.6 μg/mL) were used as control (vehicle) and positive control (PC), respectively.

Toxicity test (A. sativum test)

General steps involved in this study

Step-I: Dried outer layers were removed carefully, and only large cloves were collected.
Step-II: The outer peels of each clove were removed carefully.
Step-III: The old region in the budding parenchyma was removed by using a sharp incisor and a small spheroid laceration was made. This facilitated root growth (RG) in the cloves.
Step-IV: The cloves were washed with running tap water for 5 minutes and their root portions were then soaked in the test/controls by using toothpicks.
For this study, plastic containers (capacity: 15-20 mL) were used, and the study was conducted for up to 72 hours at room temperature in a dark place. The number and root length were measured every 24 h. The root length was measured in cm. Five cloves were used for each concentration/sample.

Calculation

%Inhibition of RG = [(RL Control - RL Test sample) ÷ RL Control] × 100
%RG = 100 - %Inhibition of RG
%Adaptive capacity = [(RG Highest ET - RG Lowest ET) ÷ RGHighest ET] × 100
N.B. – RG was determined inspect of respective exposure time (ET). RG and RL are mean root growth and root length, respectively.

Statistical analysis

Values are mean ± standard error mean (SEM) and were analyzed by using Graph Pad Prism software (version: 6.0); analysis of variance (ANOVA) followed by Tukey post test considering $p< 0.05$ with a 95% confidence level.

Results

ELEUL concentration-dependently reduced the RL/RG at all ETs. The highest percentage of RG inhibition was seen at 72 h by 32 mg/mL and the lowest at 48 h by 2 mg/mL. The LC_{50} value was between 4 and 8 mg/mL (Table 1).

Table 1. Effects of ethanolic leaf extract of *Urena lobata* and controls on *Allium sativum* root meristems at 24, 48 and 72 h

Treatments		Root length (cm)			%Inhibition of root growth		
		24 h	*48 h*	*72 h*	*24 h*	*48 h*	*72 h*
Control		14.08 ± 2.11	28.19 ± 3.11	53.08 ± 2.12	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$CuSO_4$ (0.6 µg/mL)		3.18 ± 0.34*	7.08 ± 1.57*	20.13 ± 2.58*	77.41 ± 0.34*	74.88 ± 1.57*	62.08 ± 2.58*
ELEUL (mg/mL)	2	11.08 ± 2.08*	27.13 ± 1.24*	39.08 ± 2.08*	27.08 ± 2.08*	03.76 ± 1.24*	26.28 ± 2.08*
	4	9.12 ± 1.28*	22.21 ± 2.91*	31.12 ± 1.28*	35.23 ± 1.28*	21.21 ± 2.91*	41.37 ± 1.28*
	8	6.86 ± 1.91*	12.08 ± 1.04*	20.86 ± 1.91*	51.28 ± 1.91*	57.15 ± 1.04*	60.70 ± 1.91*
	16	4.60 ± 0.68*	10.11 ± 1.05*	12.60 ± 0.68*	67.33 ± 0.68*	64.14 ± 1.05*	72.49 ± 0.68*
	32	3.48 ± 1.07*	7.58 ± 1.68*	10.08 ± 1.07*	75.28 ± 1.07*	73.11 ± 1.68*	81.13 ± 1.07*

*Values are mean ± standard error mean (SEM) (n = 5); *p< 0.05 when compared to the vehicle group; ANOVA followed by Tukey post test, considering p< 0.05 at 95% confidence level; Control: Distilled water; $CuSO_4$: Positive control; ELEUL: Ethanolic leaf extract of Urena lobata.*

Figure 1 suggests that the PC ($CuSO_4$) increased the adaptation capacity (DNA damage repair capacity or resistance towards toxic response of the toxic agents) at 72 h inspect of 24 h ET. Its adaptive capacity at 72 h inspect of 48 h was better than that seen at 48 h inspect of 24 h ET. On the other hand, ELEUL showed a concentration-dependent adaptation capacity at 48 h inspect of 24 h ET, where the adaptation power was gradually decreased with decreasing the test concentration. ELEUL only at 2 mg/mL showed a negligible adaptation capacity (1.09%) at 72 h inspect of 24 h ET, while it remained non-responsive at 8-32 mg/mL at the same ET inspect of 24 h ET. ELEUL did not show adaptive capacity at 72 h inspect of 48 h ET.

Discussion

A. cepa is widely used in toxicogenetic studies (Fiskesjö, 1985). However, some general facts, such as storage facilities and cost, can be reduced in the case of the *A. sativum* test. It may be due to garlic (*A. sativum*) remaining fresh for a longer time than the onion (*A. cepa*). On the other hand, only one clove of garlic is necessary to replace a whole onion bulb. Furthermore, each garlic bulb produces enough cloves, and each clove produces more roots than a whole onion bulb.

Toxic substances clearly disrupt cellular events (Bhattacharya et al., 2012; Adeyemo and Farinmade, 2013). It is due to these substances accumulating in the roots that can cause chromosomal aberrations (e.g., C-mitosis, chromosomal bridges, chromosomal tack, and micronuclei formation). The ultimate result is RG inhibition (Qin et al., 2015). Accumulated toxicants in the meristems impair the microtubule organizations by inhibiting RG in a plant-based eukaryotic test model. Therefore, a substance having toxic and cytotoxic effects can elongate the cell cycle differentiation phase (Fusconi et al., 2006), increase apical meristematic activity (Webster and Macleod, 1996), and inhibit protein synthesis in root tips (Seth et al., 2007). Copper (Cu), a toxic agent, and works in this manner (Achary and Panda, 2010). In this study, both $CuSO_4$ and ELEUL significantly reduced the RG profile in *A. sativum* in comparison to the vehicle. The ELEUL concentration-dependently decreased in the RG profile in *A. sativum* suggests that this test model is a sensitive model like the *A. cepa* test model. Moreover, the number of roots was also reduced at a higher concentration of ELEUL. Additionally, ELEUL also showed an RG reducing effect at 48 h inspect of 24 h of ET, suggesting the system's adaptation capacity on the 2nd day of test concentrations of ELEUL.

It seems this test system reduced the toxic effects due to the damage preventive capacity of it on day 2 (48 h), probably by distressing the adaptive response pathways and/or cellular damage repairing capacity in this test system (Achary and Panda, 2010; Panda and Achary, 2014). However, low concentrations of ELEUL showed more adaptive capacity than the higher concentrations. It may be due to its genomic protection capacity at low concentration regardless of exposure time (Panda and Achary, 2014). Roespandi et al. (2018) suggested that *U. lobata* leaf extract might have teratogenic effects as it had more toxic effects on the embryo than in the juvenile and adult phases of *D. rerio*. Thus, the meristematic regions of the test system in this current study might be attracted by the toxic effects of the ELEUL. Moreover, the LC_{50} value obtained in this study is also consistent with the previous studies (Mshelia et al., 2013; Roespandi et al., 2018).

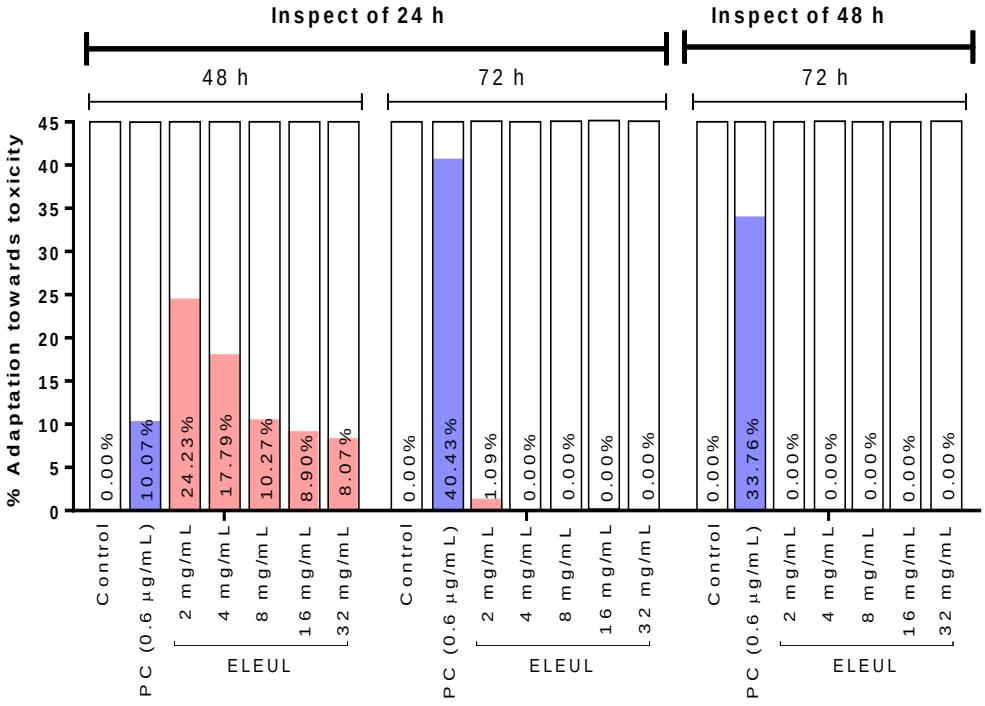

Figure 1. Percentage adaptive capacity of ethanolic leaf extract of *Urena lobata* and controls on *Allium sativum* root meristems [Values are percentage (%) (n = 5); Negative values are considered to have no adaptive capacity and have been omitted from the table; Control: Distilled water; $CuSO_4$: Positive control; ELEUL: Ethanolic leaf extract of *Urena lobata*; ET: Exposure time]

Aerial parts of *U. lobata* contain alkaloids, flavonoids, phytosterols (e.g., stigmasterol, β-sitosterol, daucosterol, 7α-methoxysitosterol, 7β-hydroxysitosterol, 7α-hydroxysitosterol, ergosterol peroxide), flavonoid and cardiac glycosides, tannins, terpenoids, saponins, triglycerides, and phenolic and phenolic glycosides (Fagbohun et al., 2012; Shrestha et al., 2016; Aimé et al., 2020). To date, a number of important phytoconstituents have been isolated from this medicinal plant. These include imperatorin, kaempferol-3-O-β-D-glucopyranoside, tiliroside, benzoic acid, protocatechuic acid, monordicophenoide A, glycerol, β-adenosine, and L-tryptophan (Shrestha et al., 2016). Many compounds of *U. lobata* have cytotoxic effects on eukaryotic systems. For example, stigmasterol is evident to a decrease in RNA content in G1 and G2 phases of human intestinal (Caco-2) cells (Alemany et al., 2012), while β-sitosterol induces apoptosis through activating caspase-3 and -9 in hepatocellular (Huh7 and HepG2)

cells (Vo et al., 2020). Therefore, the toxic effects of ELEUL in this study might be in agreement with the cytotoxic effects of its other compounds present in the plant.

Conclusion

The ELEUL concentration-dependently decreased the RG profile of *A. sativum*. An adaptive power of 48 h was seen in a comparison of 24 h of ET in this test system. The root number and length of *A. sativum* were also effectively inhibited by the ELEUL. It seems this test system also showed an almost similar response to the widely used test model *A. cepa*. The toxic effects were significant ($p < 0.05$) at 95% confidence intervals when compared to the vehicle group. Therefore, *A. sativum* can be incorporated into the toxicogenetic analysis of various substances in different areas of toxicological research. This study will be able to provide supportive information to the future pre-clinical and clinical settings on this hopeful medicinal plant's toxicogenetic effects on higher eukaryotic models, and *A. sativum* might be a hopeful toxicogenetic test system.

The study was conducted in a home-setting environment; therefore, it suffers from a well-defined laboratory setup. Physical observation of the RG profile was the basis of this study in comparison to the vehicle RG as a basement. No microscopic observation was done. Other suitable methods, such as alkaline comet assay, micronucleus test, and so on, should be investigated to determine their feasibility in comparison to the commonly used *A. cepa* test.

Conflict of interest

None declared.

References

Achary, V. M. M., & Panda, B. B. (2010). Aluminium-induced DNA damage and adaptive response to genotoxic stress in plant cells are mediated through reactive oxygen intermediates. *Mutagenesis*, *25*, 201-209.

Adeyemo, O. A., & Farinmade, A. E. (2013). Genotoxic and cytotoxic effects of food flavor enhancer, monosodium glutamate (MSG) using *Allium cepa* assay. *African Journal of Biotechnology*, *12*, 1459-1466.

Aimé, A. O. V., Carinne, K. F., Hortense, G. K., Anatole, P. C., Véronique, P. B. (2020). Phytochemical screening and in vitro antimicrobial and antioxidant activity of *Urena lobata* and *Emilia coccinea* methanolic stems extracts. Global Scientific Journals, 8, 1423-1442.

Alemany, L., Laparra, J. M., Barberá, R., & Alegría. A. (2012). Evaluation of the cytotoxic effect of 7keto-stigmasterol and 7keto-cholesterol in human intestinal (Caco-2) cells. *Food and Chemical Toxicology*, *50*, 3106-3113.

Babu, S. S., Madhuri, D. B., & Ali, S. L. (2016). A pharmacological review of *Urena lobata* plant. Asian Journal of Pharmacy and Clinical Research, *9*(2), 20-22.

Bhattacharya, S., De Sarkar, N., Banerjee, P., Banerjee, S., Mukherjee, S., Chattopadhyay, D., *et al.* (2012). Effects of Arsenic toxicity on germination, Seedling growth and Peroxidase activity in *Cicer arietinum. International Journal of Agriculture and Food Science*, 2, 131-137.

Cresencio, C. Jr., Abelada, J. J. Z., Apostado, R. R. Q., Hernando, B. J. H., Lador, J. E. C., Obenza, O. L. P., et al. (2017). *Allium cepa* test: An evaluation of genotoxicity. *Proceedings of the International Academy of Ecology and Environmental Sciences*, *7*, 12-19.

Fagbohun, E.D., Asare, R. R., & Egbebi, A. O. (2012). Chemical composition and antimicrobial activities of *Urena lobata* L. (Malvaceae). *Journal of Medicinal Plants*, 6, 2256-2260.

Fiskesjö, G. (1985). The *Allium* test as a standard in environmental monitoring. *Hereditas*, *102*(1), 99-112.

Fredotović, Ž., Soldo, B., Šprung, M., Marijanović, Z., Jerković, I., & Puizina, J. (2020). Comparison of Organosulfur and Amino Acid Composition between Triploid Onion *Allium cornutum* Clementi ex Visiani,

1842, and Common Onion *Allium cepa* L., and Evidences for Antiproliferative Activity of Their Extracts. *Plants (Basel)*, *9*(1), 98.

Fusconi, A., Repetto, O., Bona, E., Massa, N., Gallo, C., Dumas-Gaudot, E., & Berta, G. (2006). Effect of cadmium on meristem activity and nucleus ploidy in roots of *Pisum sativum* L. cv, Frisson seedlings. *Environmental and Experimental Botany*, 58, 253-260.

Islam, M. T., & Uddin, M. A. (2017). A revision on *Urena lobata* L. International Journal of Medicine, *5*(1), 126-131.

Levan, A. (1938). The effect of colchicine on root mitoses in *Allium*. *Hereditas*, *24*(4), 471-486.

Mshelia, I. Y., Dalori, B. M., Hamman, L. L., & Garba, S. H. (2013). Effect of the aqueous root extract of *Urena lobata* (Linn) on the liver of albino rat. *Research Journal of Applied Sciences*, *Engineering and Technology*, *5*(1), 1-6.

Panda, B. B., & Achary, M. M. (2014). Mitogen-activated protein kinase signal transduction and DNA repair network are involved in aluminum-induced DNA damage and adaptive response in root cells of *Allium cepa* L. Frontiers in Plant Science, *5*, 1-10.

Qin, R., Wang, C., Chen, D., Björn, L. O., & Li, S. (2015). Copper-induced root growth inhibition of *Allium cepa* var. *agrogarum* L. involves disturbances in cell division and DNA damage. *Environmental Toxicology and Chemistry*, *34*, 1045-1055.

Roespandi, Y. P., Aini, N., & Widodo, M. A. (2018). Acute toxicity of *Urena lobata* leaf extract on embryo, juvenile and adult of zebra fish (*Danio rerio*). Poster session, PO3-13-35, WCP2018.

Seth, C. S., Chaturvedi, P. K., & Misra, V. (2007). Toxic effect of arsenate and cadmium alone and in combination on Giant Duckweed (*Spirodela polyrrhiza* L.) in response to its accumulation. *Environmental Toxicology*, 22, 539-549. Shrestha, S., Park, JH., Cho, JG. Lee, D.-Y., Jeong, R.-H., Han, J.-T., Cho, S. K., Lee, D.-S., & Nam-In Baek, N.-I. (2016). Phytochemical Constituents of the *Urena lobata* Fruit. *Chemistry of Natural Compounds*, *52*, 178-180.

Vo, T. K., Ta, Q. T. H., Chu, Q. T., Nguyen, T. T., & Vo, V. G. (2020). Anti-Hepatocellular-Cancer Activity Exerted by β-Sitosterol and β-Sitosterol-Glucoside from *Indigofera zollingeriana* Miq. *Molecules*, *25*, p. 3021.

Webster, P. L., & Macleod, R. D. (1996). The root apical meristem and its margin. In: Waishel Y, Eshel A, Kafkafi U (eds) Plant roots. The hidden half, 2nd edn. Marcel Dekker, New York, pp. 51-76.

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ORIGINAL ARTICLE

LIFE SCIENCE

GENETIC VARIABILITY ASSESSMENT OF *Sonneratia apetala* (BUCH. -HAM.) IN THE SUNDARBANS OF BANGLADESH

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Abstract

Sundarbans is the single largest tract of natural mangrove forest in the world, which is situated in the south western coast of Bangladesh. This forest defends the south-western coastal region of the country from natural calamities, like cyclones, flood, tidal surges, tsunami etc. Sundarbans is the natural habitat for many mangrove plants. *Sonneratia apetala* exists in the low saline zone (LS), medium saline zone (MS) and in the high saline zone (HS) as a pioneer tree species of the Sundarbans. Genetic variability of *S. apetala* in these three saline zones were examined through the adoption of RAPD-PCR molecular marker. The expected heterozygosity of *S. apetala* in MS and HS (0.75±0.05 and 0.76±0.06, respectively) was greater than that of LS (0.60±0.13). Again, the average gene diversity over loci of this species in the MS and HS (0.59±0.37 and 0.62±0.38, respectively) was greater than that of LS (0.51±0.32). The greater heterozygosity and genetic diversity of *S. apetala* establishing in the MS and HS are the causes of its higher salt adaptability than that of growing in the LS in the Sundarbans. Due to higher genetic diversity and salt adaptability, *S. apetala* could persist in the increasing salinities in the Sundarbans. Moreover, *S. apetala* seedlings derived from the MS and HS zones of the Sundarbans can be planted in the high saline substrates in the coastal regions of Bangladesh, hence got added advantages for the coastal afforestation programs of Bangladesh.

Keywords: Adaptive variability, environmental variability, genetic diversity, saline zone

Introduction

The coastal region of Bangladesh expands as long as 711 km (Minar et al., 2013), which is located at the mouth of funnel shaped Bay of Bengal (Rahman & Biswas, 2011). Because of the geographical location, this coastal region is extremely prone to natural calamities such as tidal surges, intrusion of salt water, tropical cyclones, tsunami, etc. which are repeatedly originating from the Bay of Bengal (Alam et al., 2017). The Sundarbans, the world's largest natural mangrove vegetation (Mahmood, 2015), as well as the coastal mangrove plantations provide protection to the coastal regions of Bangladesh against those natural calamities (Alam et al., 2018a). Since mangrove forests fringe into the coastal areas (Sereneski-Lima et al., 2021), it experiences various stressful conditions such as salinity, high rate of sedimentation, anaerobic conditions, etc. (Saenger, 2002).

The mangroves are capable to adapt to the repeatedly occurring biotic and abiotic stresses. This adaptability is imperative for the survival, establishment as well as reproduction of mangroves (Tomlinson, 1986; Hutchings & Saenger, 1987). Siddiqi (2001) and Hogarth (1999) stated that mangrove plants are well adapted to the ecosystems in which they grow naturally. However, the variations in mangrove environments in terms of salinity, nutrient, sedimentation, frequency and duration of tidal inundation (Saenger, 2002) result in the environmental gradients that cause eco-physiological, morphological, physiological, anatomical and genetic differences in mangrove plants, even within the same species, growing in different environmental conditions (Alam et al., 2020). Plants exhibit variability in adaptive responses with respect to their morphological and physiological characteristics to cope with different physical environments (West-Eberhard, 1989; Alam et al., 2018a; Nasrin et al., 2019; Alam et al., 2020).

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The physical environments in the Sundarbans mangrove forest are variable owing to the variation in salinity, like, low saline zone (LS) (0.5-5 psu), medium saline zone (MS) (5-18 psu) and high saline zone (HS) (18-30 psu) (Hossain, 2015; Mahmood, 2015; Alam et al., 2018a; Nasrin et al., 2019). Though mangrove species compositions in these three saline zones are different, *S. apetala* is distributed along the salinity gradient and performs as a pioneer species in the phyto-successional processes in the Sundarbans (Siddiqi, 2001). This species grows well along the salinity gradient (from 0.5 to 30 psu) in the Sundarbans and possesses a wider salt adaptability along the salinity cline in the Sundarbans. Specifically, this species grown in MS and HS is more salt adaptive with respect to nutrient re-translocation than that grown in LS (Nasrin et al, 2019). Again, the seeds of *S. apetala* produced in the MS and HS germinate faster and farther vigorously at higher salinities than such of LS (Nasrin et al., 2020). Moreover, the seedlings of the species produced in the MS and HS grow satisfactorily at high salinities compared with such of LS (Nasrin et al., 2021). Therefore, there exists adaptive variability in *S. apetala* that is thriving in the different saline zones of Sundarbans (Nasrin et al., 2021).

Alam et al. (2018a, b) and Alam et al. (2019) in their several studies found that *A. officinalis* thriving in MS and HS is physiologically, morphologically and anatomically better salt adaptive that such of LS in the Sundarbans. *Avicennia officinalis* growing in MS and HS is genetically more diverse than such of LS, and that was proved to be the reason of higher salt adaptability of the species in the MS and HS (Alam et al., 2020). Having this information and considering the adaptive variability of *S. apetala,* we attempted to find out the cause(s) of this variability in salt adaptability of *S. apetala* in the different saline zones of Sundarbans by studying the genetic variability of this species.

The heterozygosity and quantitative genetic diversity of mangroves enables them be able to survive in the adverse mangrove environments (Reed & Frankham, 2002). Genetic diversity is crucial to overcome the stressful environmental conditions, like, mangrove ecosystems (Alam et al., 2020). Genetic diversity in a species also helps develop acclimatization mechanisms that allow mangroves to cope up with the changing environmental stresses (Munne-Bosch & Alegre, 2013). Alam et al. (2020) proved that the genetic diversity within *A. officinalis* generates adaptive plasticity in the species that makes this species be able to withstand variable habitat conditions caused by variations in salinity in the Sundarbans. Considering the ecological significance of *S. apetala* in mangrove succession, present study was carried out on genetic variability of *S. apetala* flourishing in different saline conditions in the Sundarbans by adopting RAPD marker with PCR.

Materials and Methods

Leaf sample collection

With a view to collecting leaf samples of *S. apetala* from the three salinity zones of Sundarbans, the pre-selected maternal trees of the species (Figure 1) were chosen. The tender leaf samples of *S. apetala* from the pre-selected six maternal trees of each saline zone of Sundarbans were collected separately, viz., LS (N 22° 37'13.37″ and E 89° 64'53.3″), MS (N 22° 37'13.37″ and E 89° 64'53.3″) and HS (N 22° 17' 19.7 ″ and E 89° 19'50.8″) in January, 2018. The leaf samples of each of the maternal trees were preserved separately and were labeled from LS1 to LS6 for the LS; MS1 to MS6 for the MS; and from HS1 to HS6 for the HS of Sundarbans.

Isolation of genomic deoxyribonucleic acid (gDNA) of S. apetala

The genomic DNA of each leaf sample of *S. apetala* was extracted separately by using Gene-jet plant genomic DNA purification mini kit # K0791 (Thermo Scientific) in plant genetics laboratory of Bio-technology and Genetic Engineering Discipline of Khulna University, Bangladesh during January, 2018. All of the leaf samples were kept in a refrigerator for lyophilization at -80 °C for 24 hours. Then, 20 mg of each leaf sample was kept into liquid nitrogen and then ground into powder by using pestle and mortar in the laboratory. Subsequently, each powdered sample was transferred in a 1.5 ml centrifuge tube. Then, 350 µL lysis buffer A was added in each sample in the micro centrifuge tube. It was vortexed thoroughly for 15 seconds. After that, 50 µL lysis buffer B and 20 µL RNase A were added to each sample, and they were mixed thoroughly by vortexing for 1.5 minutes. The samples were thereafter incubated for 15 minutes at 55 °C. 130 µL precipitation buffer was poured in each sample and kept in ice for 5 minutes. All the samples were then centrifuged by using NF800R, NUve at 14000 rpm for 5 minutes according to Alam et al. (2020)

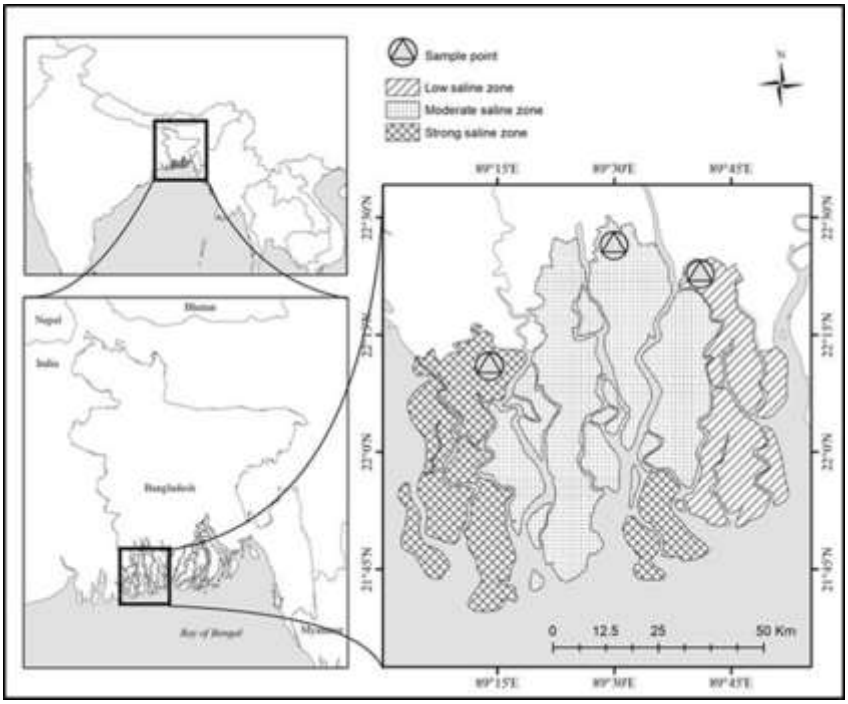

Figure 1. Map showing the study sites in the Sundarbans (Nasrin et al., 2020).

Some 500 µL supernatant form each sample was collected and poured into another micro centrifuge tube. 400 µL plant gDNA binding solution and 400 µL 96% ethanol were added to each supernatant sample and mixed up thoroughly. Half of the mixture (650 µL) was transferred in a spin column and then centrifuged for 1 minute at 8000 rpm. The flow-through was removed. Subsequently, the remaining half of that mixture was poured in the spin column and then centrifuged again for 1 minute at 6000 rpm. 500 µL washing buffer 1 was pour in the spin column and then centrifuged for 1 minute at 8000 rpm. The flow-through was removed. After that, 500 µL washing buffer 11 was instilled in the spin column and then centrifuged for 3 minutes at 14000 rpm. Collection tube was removed. Then, the spin column was shifted in a new sterile 1.5 mL centrifuge tube.100 µL elution buffer was instilled in the spin column and kept for 5 minutes at room temperature. Spin column was then centrifuged for 1 minute at 10000 rpm. Similarly, the second step elution was carried out. Purified DNA samples were kept in a refrigerator at -20 °C for further use.

RAPD-PCR analysis

Six random primers were used for each sample for amplifications of the DNA nucleotide sequences for examining the genetic variability of a species (Alam et al., 2020). For RAPD-PCR, each sample was made by admixing Taq DNA polymerase (5 U/µl), dNTPs (10 mM each), $MgCl_2$, 10 X reaction buffer, random primer, milli Q water and template DNA. The samples were instilled in the slots of Biometra professional thermos-cycler. Temperature sequences in the PCR were fixed as lead temperature at 105 °C, DNA denaturing temperature at 94 °C, annealing temperature at 26 °C, and expansion temperature at 72 °C with 42 cycles. Finally, the thermos-cycler was held for 7 minutes at 72 °C. the process was followed for each random primer.

Gel electrophoresis

Agarose gel was made up with 1% TAE (Tris HCl, EDTA, Glacial Acetic Acid) buffer. Gel was instilled in the Biometra gel electrophoresis containing 1% TAE buffer solution. PCR product was instilled in the slots of the gel. 75 ampere electric field was applied for gel electrophoresis and run for 50 minutes.

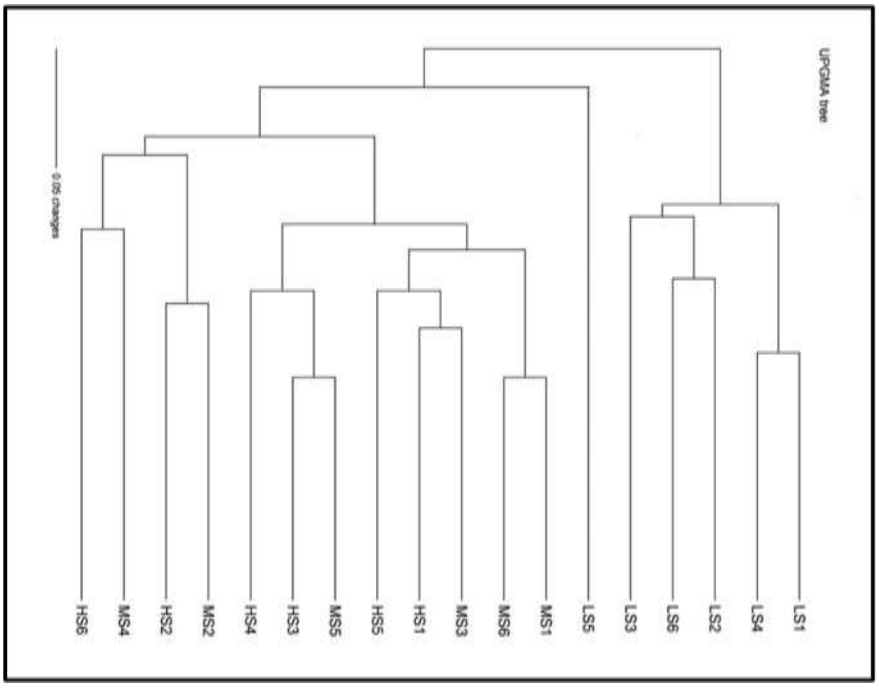

Figure 2. UPGMA tree of *S. apetala* of LS, MS and HS of Sundarbans.

Gel documentation

Image of every gel was taken up by applying gel documentation system (UV star BDA compact, Biometra).

Molecular data analysis

Molecular data were produced from each image. Data were analyzed with the help of PAUP, version 4.0 software to generate UPGMA tree in order to assay the phylogeny of *S. apetala* in different saline zones of Sundarbans. Secondly, the data were analyzed through using Arlequin ver. 3.5.1.2 to examine the expected heterozygosity (H_{EXP}) of different populations, gene diversity over loci and analysis of molecular variance (AMOVA) and to calculate genetic distance matrix for comparison of genetic distance among the populations of *S. apetala* in the Sundarbans.

Results

DNA molecules of LS1, LS2, LS3 LS4 and LS6 of the LS created a monophyletic taxon (Figure 2). While those of LS5 of LS; MS1, MS2, MS3 MS4, MS5 and MS6 of the MS and those of HS1, HS2, HS3 HS4, HS5 and HS6 of the HS formed larger paraphyletic taxon of *S. apetala* (Figure 2).

RAPD-PCR analysis

RAPD-PCR analysis exhibited that the DNA molecules of *S. apetala* of different saline zones produced RAPD-bands at different base-pairs levels (Fig. 3). Each of the DNA samples of LS, MS and HS produced polymorphic band when run with random primers OPE-20 (5´AACGGTGACC3´), OPA-04 (5´AATCGGGCTG3´), OPB-05 (5´TGCGCCCTTC3´), OPC-06 (5´GAACGGACTC3´), OPB-08 (5´GTCCACACGG3´), OPC-17

(5´TTCCCCCCAG3´) while only one DNA sample of the LS produced monomorphic band when run with OPB-08 (5´GTCCACACGG3´) (Table 1).

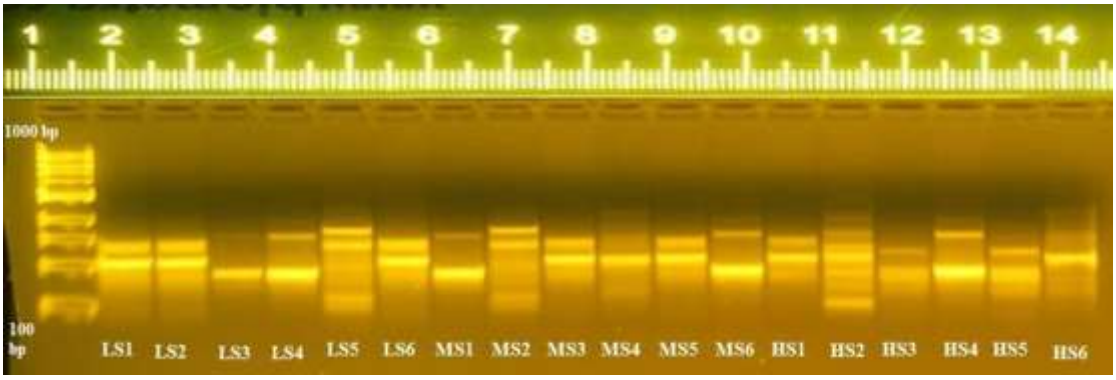

Figure 3. RAPD bands of *S. apetala* of LS, MS and HS of Sundarbans.

Expected heterozygosity (H_{EXP}) of different populations

Expected heterozygosity (H_{EXP}) of *S. apetala* in the LS, MS and and HS were 0.60±0.13, 0.75±0.05, 0.76±0.06, respectively (Table 2).

Average gene diversity over loci

Average gene diversity *S. apetala* in the LS, MS and HS were 0.51±0.32, 0.59±0.37 and 0.62±0.38, respectively (Table 3).

Table 1. RAPD bands of *S. apetala* in different saline zones of Sundarbans.

Primers	LS						MS						HS					
	LS1	LS2	LS3	LS4	LS5	LS6	MS1	MS2	MS3	MS4	MS5	MS6	HS1	HS2	HS3	HS4	HS5	HS6
5´AACGGTGACC3´	2	2	2	3	4	3	2	5	3	5	3	3	3	8	4	3	4	6
5´AATCGGGCTG3´	3	3	3	3	3	3	5	4	5	5	5	4	5	5	5	5	5	5
5´TGCGCCCTTC3´	4	2	3	5	3	4	5	4	4	4	4	5	4	3	6	2	3	2
5´GAACGGACTC3´	3	3	3	3	3	3	7	5	5	6	5	6	7	5	6	6	4	5
5´GTCCACACGG3´	5	1	2	5	3	3	6	5	6	5	5	5	3	6	3	5	3	4
5´TTCCCCCCAG3´	2	4	4	2	3	5	5	4	2	5	3	4	2	4	4	2	3	5

Table 2. Expected heterozygosity (H_{EXP}) of *S. apetala* in different saline zones of Sundarbans.

Saline zone	H_{EXP} (mean±sd)
LS	0.60±0.13
MS	0.75±0.05
HS	0.76±0.06

Table 3. Average gene diversity of *S. apetala* in different saline zones of Sundarbans.

Saline zone	Average gene diversity (mean ± sd)
LS	0.51±0.32
MS	0.60±0.37
HS	0.63±0.38

Table 4. Analysis of molecular variance (AMOVA).

Source of Variation	d.f	Sum of squares	Variance components	Percentage (%) of variation
Among populations	2	20.000	0.51667 va	21.38
Among individuals within Populations	15	57.000	1.90000 vb	78.62
Total	17	77.000	2.41667	
Fixation Index	F_{ST} :	0.21379		

Analysis of molecular variance (AMOVA)

Analysis of molecular variance was performed in order to calculate the genetic variation (Patrick & Shenglin, 2018) within different populations of *A. officinalis* in the Sundarbans. Genetic variation in different populations and within the population of *S. apetala* were 22.38% and 78.62%, respectively (Table 4). The fixation index (F_{ST}) for the species in LS, MS and HS was 0.21 (Table 4).

Genetic distance matrix

Genetics distance matrix is important to examine the strength of genetic structure and to assay the genetic variations within the individual, within the population and among the populations of a species ((Patrick & Shenglin, 2018) Pair-wise genetic distance of S. apetala between LS and MS (0.34) and between LS and HS (0.36) were higher than that of between MS and HS (0.13) (Table 5).

Table 5. Pairwise genetic distance (F_{ST}) matrix of *S. apetala.*

Saline zone	LS	MS	HS
LS	0.00		
MS	0.34	0.00	
HS	0.36	0.13	0.00

Discussion

Genetic diversity provides a species with necessary adaptive mechanisms to the prevailing environmental conditions (Kimmins, 1987). Again, the genetic variability of mangroves generates adaptive plasticity in the species and consequently allows it to cope up with a wider range of physical environments (Alam et al., 2020). Since the saline conditions in Sundarbans fluctuate, the physical environmental conditions in LS, MS and HS of the Sundarbans are different (Nasrin et al., 2019). But, *S. apetala* grows everywhere in the Sundarbans and exhibits wide spectrum of salt adaptive variability (Nasrin et al., 2021). To determine the reason, the genetic diversity of the species flourishing in LS, MS and HS of Sundarbans was studied.

Most RAPD bands of the species of LS, MS and HS are polymorphic (Table 1) and a higher percentage (78.62%) of genetic variation was found among the individuals within each of the populations of *S. apetala*. Alam et al. (2020) also detected the polymorphism and higher genetic variation within the population of *A. officinalis* spreading in the LS, MS and HS of Sundarbans. Therefore, the polymorphism and higher genetic variation were the clear reflections of higher genetic diversity of *S. apetala* across the Sundarbans.

Genetic diversity of *S. apetala* of MS and HS was higher than that of LS (Table 3), and expected heterozygosity of this species of MS and HS was also higher than that of LS (Table 2). As a result, the genetic distance between the populations of the species of MS and HS was narrower than that between LS and MS and between LS and HS. Alam et al. (2020) in their study found higher genetic diversity and expected heterozygosity of *A. officinalis* in MS and HS compared with that in LS. Genetic structure of *A. schaueriana* populations of South America are diversified (Mori et al., 2015). Genetic diversity of different populations of *A. marina* favors the species to cope up with the changing environmental conditions in east coast of India (Hazarika et al., 2013). Sereneski-Lima et al. (2021) also found genetic diversity in *L. racemosa* in the equatorial, tropical and subtropical population in the Pacific region. They argued that the ecological conditions are ascribable to the genetic structure of mangroves.

So, the results demonstrated that the higher genetic diversity and expected heterozygosity of *S. apetala* in MS and HS resulted in larger salt adaptability of the species surviving in MS and HS compared with that of LS. Finally, it

can be inferred that the higher genetic diversity of *S. apetala* is the reason of the species' salt adaptive variability in LS, MS and HS of Sundarbans. Hence, salt adaptability is the outcome of the genetic diversity of *S. apetala.* Moreover, the higher heterozygosity in the populations *S. apetala* of MS and HS allows them to take part in cross pollination. This might result in further increase in genetic diversity within the species.

High genetic diversity favors a plant species in the heterogeneous environments (Alam et al., 2020). Dashzeveg et al. (2017) also demonstrated that intra-species genetic diversity is necessary for its survival in various habitats. Again, Alam et al. (2020) validated that *A. officinalis* can cope up with different saline environments due to its genetic diversity in the LS, MS and HS of Sundarbans. Therefore, it is concluded that the greater genetic diversity among populations and among individuals within populations of *S. apetala* may make this species be capable to survive and grow in the increasing saline conditions in the Sundarbans of Bangladesh.

Bangladesh started coastal afforestation program in 1966, and since then, *S. apetala* has been the principal mangrove planting species in those coastal plantations (Siddiqi, 2001; Nasrin et al., 2021). In the coastal areas of Bangladesh, salinity is increasing owing to sea level rise (Alam et al., 2018a, b). *Sonneratia apetala*, particularly, of MS and HS possesses salt adaptive variability and genetic diversity so that the species will continue to be a major mangrove planting species in the higher saline conditions in the coastal areas of Bangladesh.

Conclusion

Sonneratia apetala of MS and HS is more heterozygous and genetically more diverse than that of LS. The genetic distance of *S. apetala* between MS and HS is less, thereby constituting a larger population of it while the species of LS is genetically more distant from such of MS and HS. Owing to greater heterozygosity and genetic diversity, *S. apetala* of MS and HS is much more adaptive to salinity than that of LS of the Sundarbans of Bangladesh. Considering this, it can be inferred that *S. apetala* maternal trees can give precise evidence of the genetic variability in the three distinct salinity zones. Though the salinity in the Sundarbans is increasing day by day, *S, apetala* of MS and HS zones can persist in its habitats and thereby playing a significant role in the sustainability of the Sundarbans. Again, owing to higher salt adaptability and genetic diversity, *S. apetala* of MS and HS zones can be a reliable source of planting material for restoration of Chokaria Sundarbans and also for the coastal afforestation in the high saline coastal regions of Bangladesh. Hence, the coastal dwellers get protection against frequently arising natural calamities in future.

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Conflict of Interests

The author declares no conflict of interest.

References

Alam, M.R., Mahmood, H., Rahman, M.M., Biswas, T., Nasrin, S. & Khushi, M.S.T.L.R. (2017). Ecological status and environmental protective role of *Avicennia officinalis* in the vulnerable coastal regions of Bangladesh: An overview. *The Indian Forester,* 143 (9), 817-822.

Alam, M.R., Mahmood, H., Khushi, M.S.T.L.R. & Rahman, M.M. (2018a). Adaptive phenotypic plasticity of *Avicennia officinalis* L. across the salinity gradient in the Sundarbans of Bangladesh. *Hydrobiologia,* 808(1), 163-174.

Alam, M.R., Mahmood, H. & Rahman, M.M. (2018b). Maternal origins induced plasticity in salt adaptability of *Avicennia officinalis* L. seedlings in the Sundarbans of Bangladesh. *Hydrobiologia,* 820, 227-244.

Alam, M.R., Mahmood, H., Biswas, T. & Rahman, M.M. (2019). Physiologically adaptive plasticity in nutrient resorption efficiency of *Avicennia officinalis* L. under fluctuating saline environments in the Sundarbans of Bangladesh. *Hydrobiologia,* 828, 41-56.

Alam, M.R., Mahmood, H. & Rahman, M.M. (2020). Deciphering the genetic diversity of *Avicennia officinalis* L. across the salinity gradient in the Sundarbans mangrove forest of Bangladesh. *Wetlands Ecology and Management*, 28, 449-460.

Hazarika, D.M., Thangaraj, S., Sahu, K. & Kathiresan, K. (2013). Genetic diversity in three populations of *Avicennia marina* along the east coast of India by RAPD markers. *Journal of Environmental Biology,* 34, 663-666.

Hogarth, P.J. (1999). The Biology of Mangroves. *Oxford University Press*, New York.

Hossain, M.K. (2015). Silviculture of plantation trees of Bangladesh. *Arannayk Foundation*, Dhaka, Bangladesh.

Hutchings, P. & Saenger, P. (1987). Ecology of mangroves. *University of Queensland Press*, St Lucia, London, New York.

Mahmood, H. (2015). Handbook of selected plant and species of the Sundarbans and the embankment ecosystem. Sustainable Development and Biobdiversity Conservation in coastal Pritection Forests, Bangladesh (SDBC-Sundarbans) Project implemented by the DEeutsche Gesellschaft fur Internationale zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), Dhaka.

Minar, M.H., Hossain M.B. & Shamsuddin, M.D. (2013). Climate Change and Coastal Zone of Bangladesh: Vulnerability, Resilience and Adaptability. *Middle- East Journal of Scientific Research*, 13, 114-120.

Mori, G.M., Zucchi, M.I. & Souza, A.P. (2015). Multiple-Geographic-Scale Genetic Structure of Two Mangrove Tree Species: The Roles of Mating System, Hybridization, Limited Dispersal and Extrinsic Factors. *PLoS ONE* 10(2), e0118710. https://doi.org/10.1371/journal.pone.0118710.

Munné-Bosch, S. & Alegre, L. (2013). Cross-stress tolerance and stress "memory" in plants: An integrated view. *Environmental and Experimental Botany*, 94, 1-2.

Nasrin, S., Mahmood, H. & Rahman, M.M. (2019). Adaptive responses to salinity: nutrient resorption efficiency of *Sonneratia apetala* (Buch.-Ham.) along the salinity gradient in the Sundarbans of Bangladesh. *Wetlands Ecology and Management,* 27(2-3), 343-351.

Nasrin, S., Mahmood, H., Siddique, M.R.H. & Rahman, M.M. (2020). Adaptive responses to salinity: seed germination traits of *Sonneratia apetala* (Buch.-Ham.) along salinity gradient in Sundarbans, Bangladesh. *Journal of Tropical Forest Science,* 32(2), 179-186.

Nasrin, S., Mahmood, H. & Rahman, M.M. (2021). Parental influences on salt adaptive divergence of *Sonneratia apetala* (Buch.-Ham.) along the salinity gradient in the Sundarbans of Bangladesh. *Environmental Challenges*, 4, https://doi.org/10.1016/j.envc.2021.100121.

Patrick, G.M. & Shenglin, L. (2018). Analysis of molecular variance (AMOVA) for auto polyploids. *Front. Ecol. Evol.,* https//doi.org/10.3389/fevo 21800066.

Rahman, M.M. Biswas, S.K. (2011). Feasible Solution of Protection and Adaptation Strategy for Coastal Zone of Bangladesh, *Pakistan Journal of Meteorology,* 8 (15), 9- 19.

Reed, D.H. and Frankham, R. (2002). Correlation between Fitness and Genetic Diversity. Conservation Biology*,* 17, 230-237.

Saenger, P. (2002). Mangrove Ecology, Silviculture and Conservation. *Kluwer Academic Publishers*, P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Sereneski-Lima, C., Baggio, R.A., WilhelminaPil, M., Boeger, M.R.T. & Walter AntonioBoeger, W. (2021). Historical and contemporary factors affect the genetic diversity and structure of *Laguncularia racemosa* (L.) Gaertn, along the western Atlantic coast *Estuarine, Coastal and Shelf Science,* https://doi.org/10.1016/j.ecss.2020.107055.

Siddiqi, N.A. (2001). Mangrove Forestry in Bangladesh. *Institute of Forestry and Environmental Sciences*, University of Chittagong, Bangladseh.

Tomlinson, P.B. (1986). The botany of mangrove. *Press Syndicate of the University of Cambridge*, New York.

West-Eberhard, M. J., 1989. Phenotypic Plasticity and the origins of diversity. *Annual Review of Ecology and Systematics*, 20, 249-78.

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ORIGINAL ARTICLE

LIFE SCIENCE

STUDY ON GENETIC PARAMETERS IN SELECTED PARENTS AND THEIR HYBRIDS OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

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Abstract

A total of 12 diverse tomato genotypes as parents and their 32 hybrids, obtained through Line × tester mating fashion, were evaluated to observe the consequence of different genetic parameters on yield contributing traits. The experiment was conducted during two consecutive years of the 2016-2017 and 2017-2018 winter seasons in a Randomized Complete Block Design (RCBD) with three replications. The analysis of variance (ANOVA) revealed highly significant differences for all the characters, suggesting the presence of genetic variation among the parents. In parents, the highest GCV and PCV were observed 48.94 and 49.10 for fruits plant^{-1}, 39.40 and 39.77 for yield plant^{-1}, and 29.32 and 29.49 for fruits cluster^{-1}, respectively. In hybrids, the higher level of GCV was observed for yield plant^{-1} (35.62), fruits plant^{-1} (25.83), individual fruit weight (24.73), cluster plant^{-1} (21.79), and of PCV for yield plant^{-1} (35.86), fruits plant^{-1} (25.83), individual fruit weight (24.93), and cluster plant^{-1} (21.79). The heritability ranged between 83.92-100% in parents and 99.38-100% in hybrids for most of the traits which denotes a higher level of heritability. The GA as % of mean was higher (>10%) for most of the characters except for days to maturity in parents (9.91) and in hybrids (10.19). According to the per se performance, the promising parents were G_{10}, G_4, G_9, G_8, G_7, G_6, G_{14}, G_1, and hybrids were $G_7 \times G_{14}$, $G_8 \times G_{14}$, $G_{10} \times G_6$, $G_{10} \times G_{12}$, and $G_9 \times G_1$ based on their yield plant^{-1} which could be used as elite varieties of tomato.

Keywords: Tomato, parents, hybrids, genetic parameters, selection

Introduction

Tomato (*Solanum lycopersicum* L.) belongs to the family *Solanaceae* is a commonly grown vegetable crop cultivated worldwide for its fleshy fruits. It has an amusing source of therapeutic nature against cancer and heart diseases due to its higher content of different vitamins, minerals, and strong antioxidants (Dhaliwal *et al.,* 2003). It is also a rich source of polyphenolic compounds, such as flavonoids and hydroxyl cinnamic acids (Bugianesi *et al.,* 2004). Tomato is one of the most economically important vegetable crops for diversified uses like salads, pickles, canned food, paste, ketchup, sauce, puree, and fruit. Considering the nutritional value and various uses of tomato, creation of variation for developing new traits is always a key component in a breeding program. Wild relatives are more genetically diverse compared to cultivate ones (Ghosh *et al.,* 2010). Attention has been paid to combining novel genes in cultivated species from wild ones for extended shelf life and different biotic and abiotic stresses of tomato (Tigchelaar, 1986). Heritability is the measure of the correspondence between breeding values and phenotypic values, (Falconer and Mackay 1996). Thus, heritability plays an important role in breeding and expresses the reliability of phenotype as a guide to its breeding value. The breeding value determines how much of the phenotype would be passed onto the next generation (Tazeen *et al.,* 2009). Genetic advance is the term used to describe the link between heredity and response to selection. High heritability with high genetic advance estimates offers the utmost operative form for selection (Larik *et al.,* 2000). In order to quantify the quantity of genetic gain in a character obtained under certain selection pressure, genetic progress is estimated. Genetic advancement is a further crucial selection factor that supports the breeder in a selection procedure in this way.

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Breeders might choose a trait to be used in breeding programs by considering its heritability, genetic gain, and degree and pattern of variability (Prajapati *et al.,* 2015 and Titus *et al.,* 2020). Therefore, the goal of the current study was to select promising parents and hybrids in order to create commercial cultivars by estimating the level of genetic variability on yield and yield contributing features of parents and their various hybrids.

Materials and Methods

The research was carried out in the Department of Genetics and Plant Breeding experimental field of Sher-E-Bangla Agricultural University, Dhaka during two consecutive winter seasons of 2016-2017 and 2017-2018. Twelve distinct water stress-tolerant tomato genotypes (G_2, G_3, G_4, G_7, G_8, G_9, G_{10}, G_{13}, G_1, G_6, G_{12}, G_{14}) identified by SAU (Begum, 2016) were used in the first year for crossing purposes following the Line × tester design. The genotypes G_2, G_3, G_4, G_7, G_8, G_9, G_{10}, and G_{13} were used as lines, and G_1, G_6, G_{12}, and G_{14} were used as testers. In *Rabi* season of the succeeding year, thirty two F_1 hybrids and their twelve parents were assessed. Thirty days old seedlings were transplanted into the main plot on 20th November of each year. The soil of the experimental field was clay loam with pH 7.3. The experiment was set up following RCBD design with three replications, each with a plot size of 4.0 m^2 and a spacing of 60 by 40 cm on a 1 m wide bed. The recommended fertilizer dose was applied for better crop growth and all necessary agronomic practices were taken on when necessary. Days to initial blooming, duration of maturity, plant height (cm), number of fruits cluster^{-1}, number of cluster plant^{-1}, fruits plant^{-1}, single fruit weight (g), fruit length (mm), and diameter and yield plant^{-1} (kg), (mm) were collected. According to the procedures outlined by Panse and Sukhatme (1985), the analysis of variance (ANOVA) was conducted. Genotypic variance (σ^2g), phenotypic variance (σ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (H^2bs), genetic advance (GA) and genetic advance as % mean were analyzed following the formula illustrated by Singh *et al.* (1985) using statistical software program R (version 2.14.0).

Results

Analysis of variance for different characters of tomato parent

At the 1% and 5% probability levels, the analysis of variance showed that the genotypes used for the hybridization program had significantly higher levels of variability for all 10 characters (Table 1). Therefore, genotypes could be selected for the breeding programs for developing hybrids. Bhandari *et al.*, (2017), Patel *et al.,* (2013), and Shashikanth *et al.,* (2010) also predicted similar findings.

Table 1. Analysis of variance for different characters of tomato genotypes used as parents in hybridization

Characters	RMS	GMS	EMS	SEm±	CD@ 5%	CD @ 1%
Days to first flowering	0.18	59.93**	0.09	0.18	0.51	0.70
Days to maturity	0.05	51.77**	0.05	0.13	0.39	0.53
Plant height (cm)	0.05	2359.35**	0.03	0.10	0.29	0.40
Cluster plant^{-1}	0.06	17.16**	0.03	0.09	0.27	0.37
Fruits cluster^{-1}	0.07	5.30**	0.02	0.08	0.24	0.33
Fruits plant^{-1}	9.11	1039.80**	2.25	0.87	2.54	3.45
Fruit length (mm)	2.86	45.42**	2.73	0.95	2.80	3.80
Fruit diameter (mm)	0.01	53.73**	0.01	0.03	0.08	0.11
Individual fruit weight (g)	0.04	172.93**	0.02	0.08	0.24	0.33
Yield plant^{-1} (kg)	0.01	0.55**	0.01	0.02	0.06	0.09

RMS= Replication mean square, GMS= Genotype mean square, EMS= Error mean square, SEm= Standard error of mean, CD= Critical difference.

Performance of parents

The mean performance of 12 parents (8 lines and 4 testers) for their ten yield contributing traits is presented in Table 2. The mean yield performance was (1.07 kg fruit yield plant^{-1}) which was lower than the arithmetic mean of the yield of genotypes G_7 (1.72 kg fruit yield plant^{-1}), G_8 (1.66 kg fruit yield plant^{-1}), G_{10} (1.66 kg fruit yield plant^{-1}), and G_4 (1.21 kg fruit yield plant^{-1}). The genotypes having high mean values for other traits compared to the mean would be used as a promising material for the selection with increased yield potential as well as for other yield contributing traits.

Table 2. Mean performance of tomato genotypes used as parents for yield and yield contributing traits

Parent	Days to first blooming	Duration of maturity	Plant height (cm)	Cluster plant^{-1}	Fruits cluster^{-1}	Fruits plant^{-1}	Fruit length (mm)	Fruit dia. (mm)	Fruit weight (g)	Yield plant^{-1} (kg)
G2	31.00	85.33	59.5	4.50	4.16	18.72	30.36	32.67	34.80	0.65
G3	25.83	87.66	73.83	5.16	5.50	28.38	26.82	30.48	30.70	0.87
G4	30.66	81.66	132.33	9.16	4.66	42.68	34.46	35.22	28.33	1.21
G7	29.66	83.66	88.50	10.33	6.50	67.14	30.22	29.60	25.65	1.72
G8	24.16	84.33	120.50	12.66	6.33	80.13	26.66	27.38	20.76	1.66
G9	33.50	90.16	75.50	8.33	3.66	30.48	34.04	30.70	30.65	0.93
G10	35.50	95.16	122.33	8.66	4.16	36.02	36.25	40.53	45.90	1.65
G13	39.33	90.16	82.83	7.66	4.66	35.69	28.46	27.72	25.25	0.90
G1	31.40	86.16	120.66	9.16	2.83	25.92	30.86	32.44	40.33	1.04
G6	28.00	85.33	131.66	10.33	2.33	24.06	30.16	28.10	20.50	0.49
G12	32.16	82.66	100.50	7.33	5.50	40.31	27.22	28.22	24.68	0.99
G14	25.16	81.66	55.33	5.33	3.16	16.84	22.24	24.32	31.60	0.53
Mean	30.57	86.14	96.89	8.28	4.52	38.00	30.11	30.61	29.89	1.07
SE	0.17	0.13	0.99	0.09	0.08	0.87	0.95	0.03	0.08	0.02
CD@5%	0.51	0.39	0.29	0.27	0.24	2.54	2.80	0.08	0.24	0.06
CD@1%	0.70	0.53	0.40	0.37	0.33	3.45	3.80	0.11	0.33	0.09
Min.	23.66	81.16	55.00	4.33	2.33	16.84	22.24	24.32	20.50	0.49
Max.	39.83	95.50	132.35	12.83	6.83	80.13	38.42	40.54	45.90	1.78

SE= Standard error, CD= Critical difference.

Genetic variability in parents

The performance of different genotypic parameters like the range of mean performance, genotypic and phenotypic variance heritability are presented in Table 3. The highest range of variability was observed for height of plant (55.0-132.35) then the number of fruits plant^{-1} (16.84-80.13), individual fruit weight (20.50-45.90), fruit length (22.24-38.42), fruit diameter (24.32-40.54), days to initial blooming (23.66-39.83), and duration of maturity (81.16-85.50). In the case of variance, the highest genotypic variance was observed for plant height (786.44) followed by fruits plant^{-1} (345.85), individual fruit weight (57.64), and for yield plant^{-1} the lowest genotypic variance (0.18) was observed followed by fruit cluster^{-1} (1.76) and cluster plant^{-1} (5.71). Similarly, the phenotypic variance was also the highest for height of the plant height (786.47) followed by fruits plant^{-1} (348.10), individual fruit weight (57.66), and the least genotypic variance was observed for yield plant^{-1} (0.18) followed by fruit cluster^{-1} (1.78) and cluster plant^{-1} (5.74).

The characters with significant genotypic variance suggest that more genetic factors contributed to the overall variation. Therefore, these characters could be taken into account and used as selection criteria. These outcomes matched those that had been revealed by Mohanty *et al.,* (2002), Lecome *et al.,* (2004), Hyder *et al.,* (2007), Ghosh *et al.,* (2010), Bernousi *et al.,* (2011), Manna *et al.,* (2012), Naik *et al.,* (2012), Patel *et al.,* (2013), Agrawal *et al.,* (2014) and Khapte *et al.,* (2014).

The phenotypic coefficient of variation (PCV) ranged from 4.83 to 49.10, while the genotypic coefficient of variation (GCV) of all the characteristics ranged from 4.82 to 48.94 (Table 2). The highest phenotypic coefficient of variation was observed for fruits plant^{-1} (49.10), yield plant^{-1} (39.77), fruits cluster^{-1} (29.49), plant height (28.95), and cluster plant^{-1} (28.90). Similarly, the highest genotypic coefficient of variation (GCV) was observed for fruits plant^{-1} (48.94), yield plant^{-1} (39.40), fruits cluster^{-1} (29.32), plant height (28.94), and cluster plant^{-1} (28.84). Mohamed *et al.* (2012), Patel *et al.* (2013), Santader *et al.* (2013), Lecome *et al.* (2004), Shashikant *et al.* (2010), Bernousi *et al.* (2011), and Agrawal *et al.* (2014) also reported similar results. For all the traits, the genotypic coefficient of variation (GCV), the accurate measure of the degree of genetic variability in a population, was high with the exception of days to maturity (4.82). Generally, PCV values were higher than GCV values for all traits indicating the higher magnitude of variability for these characters. The findings are in conformity with Khapte *et al.* (2014), Ghosh *et al.* (2010), Hyder *et al.* (2007), Shashikant *et al.* (2010), Bernousi *et al.* (2011), Manna *et al.* (2012), and Agrawal *et al.* (2014).

Table 3. Different genetic parameters for ten quantitative traits in tomato genotypes used as parents in hybridization

Characters	Range		Mean	Variance		GCV (%)	PCV (%)	H^2 (bs)	GA (%)	GA as % of mean
	Min	Max		σ^2 g	σ^2 p					
Days to initial blooming	23.66	39.83	30.57	19.95	20.04	14.61	14.64	99.54	9.18	30.02
Duration of maturity	81.16	95.50	86.14	17.24	17.29	4.82	4.83	99.69	8.54	9.91
Plant height (cm)	55.00	132.35	96.89	786.44	786.47	28.94	28.95	100	57.77	59.63
Cluster plant^{-1}	4.33	12.83	8.29	5.71	5.74	28.84	28.90	99.56	4.91	59.28
Fruits cluster^{-1}	2.33	6.83	4.52	1.76	1.78	29.32	29.49	98.85	2.72	60.05
Fruits plant^{-1}	16.84	80.13	38.00	345.85	348.10	48.94	49.10	99.35	38.19	100.48
Fruit length (mm)	22.24	38.42	30.11	14.23	16.96	12.53	13.68	83.92	7.12	23.64
Fruit diameter (mm)	24.32	40.54	30.61	17.90	17.91	13.82	13.83	99.99	8.72	28.48
Single fruit weight (g)	20.50	45.90	29.89	57.64	57.66	25.39	25.40	99.96	15.64	52.31
Yield plant^{-1} (kg)	0.49	1.78	1.08	0.18	0.18	39.40	39.77	99.12	0.87	81.21

σ^2g= Genotypic variance, σ^2p= Phenotypic variance, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, H^2bs= Heritability in broad sense, GA= Genetic advance.

Three types of heritability are suggested by Johnson *et al. (*1955) high (above 60%), medium (30%-60%), and low (below 30%). The highest heritability was recorded in all the characters studied and ranged between 83.92 and 100 (table 2). Though high heritability estimates have been found to be helpful in making a selection of superior genotypes on the basis of phenotypic performance, Johnson *et al.* (1955) also suggested heritability estimates coupled with the high genetic advance in the percentage of mean would be more useful in predicting selection of the best individual. It is classified as low less than 10%, moderate 10-20%, and high more than 20% by Johnson *et al.* (1955). Here most of the characters showed high genetic advance as % of mean except days to maturity performed low (9.91%). High genetic progress as a percentage of mean and high heritability suggests that choosing such features should be quite simple. Because the environment contributes less to the phenotype than the genotype. As a result, it would be feasible to apply a straightforward selection approach based on phenotype, which would ultimately enhance the genetic basis of these traits. Sharmin *et al.* (2019), Meena *et al.* (2015), Nwosu *et al.* (2015), and Dutta *et al.* (2018) also cited similar findings.

Per se performance of hybrids

The performance of the hybrids is based on each of the traits assessed, on the basis of average data, the means and their standard errors are calculated, and they are summarized in Table 4. For all the attributes examined, tomato hybrids generally displayed a large range of variability, with all ranges between the maximum and minimum mean values. Days to maturity, for instance, ranged from 78.33 to 95.28 with a mean of 86.57, and days to first flowering ranged from 25.52 to 40.55 with a mean of 32.77. In a similar manner, the height of plant and cluster plant^{-1} ranged from 60.14 to 135.48 and 4.32 to 9.48 respectively. The maximum fruit yield plant^{-1} obtained was $G_7 \times G_{14}$ (2.17) followed by $G_8 \times G_{14}$ (2.01), $G_{10} \times G_6$ (1.72), $G_{10} \times G_{12}$ (1.45), and $G_9 \times G_1$ (1.32)) and range varied between 0.40 and 2.19 via means of 1.06. So, it is feasible to increase fruit yield through direct selection as suggested by Saleem, *et al.* (2013), and Meena *et al.* (2015).

Table 4. Performance of 32 distinct crosses (hybrids) for qualities that contribute to tomato yield on their own

Hybrids	Days to first blooming	Duration of maturity	Plant height (cm)	Cluster plant^{-1}	Fruits cluster^{-1}	Fruits plant^{-1}	Fruit length (mm)	Fruit dia. (mm)	Fruit weight (g)	Yield plant^{-1} (kg)
$G_2 \times G_1$	30.33	82.46	90.63	4.33	4.22	26.71	32.65	34.80	36.56	0.66
$G_3 \times G_1$	29.65	85.44	92.44	5.54	4.64	25.70	35.20	32.65	35.66	0.92
$G_4 \times G_1$	32.40	88.45	110.55	6.54	4.30	28.12	32.45	34.44	36.45	1.02
$G_7 \times G_1$	36.29	90.44	100.34	6.55	5.60	36.73	30.37	32.65	35.55	1.30
$G_8 \times G_1$	25.54	82.44	95.64	5.46	4.44	24.24	36.26	40.51	48.64	1.17
$G_9 \times G_1$	32.40	85.65	96.44	8.45	4.32	36.50	32.65	34.80	36.66	1.32
$G_{10} \times G_1$	40.24	90.24	100.36	6.44	3.56	22.92	40.24	42.32	45.56	1.04
$G_{13} \times G_1$	38.45	90.44	95.65	7.45	3.62	49.31	30.34	32.44	40.44	1.08
$G_2 \times G_6$	32.43	82.46	110.55	7.65	4.32	33.08	32.22	35.43	28.65	0.95
$G_3 \times G_6$	30.54	85.36	100.34	4.45	4.64	20.64	30.32	32.44	35.32	0.73
$G_4 \times G_6$	28.63	84.55	130.56	8.84	4.56	40.31	22.22	25.32	32.44	1.44
$G_7 \times G_6$	32.46	87.45	120.64	7.46	4.45	33.19	26.43	30.72	30.32	1.04
$G_8 \times G_6$	26.44	80.64	135.45	7.54	4.54	34.23	28.43	27.34	30.22	1.03
$G_9 \times G_6$	31.34	82.45	105.75	6.44	4.32	27.82	27.54	24.44	25.27	0.70
$G_{10} \times G_6$	36.26	90.46	130.34	7.88	4.54	35.77	36.63	40.55	48.32	1.72
$G_{13} \times G_6$	36.34	92.46	109.45	6.64	4.56	30.27	30.24	28.32	20.18	0.61
$G_2 \times G_{12}$	34.24	90.45	80.64	4.45	5.54	24.65	34.34	30.45	30.32	0.74
$G_3 \times G_{12}$	28.34	80.44	90.45	6.65	4.64	30.85	33.44	34.33	28.24	0.87
$G_4 \times G_{12}$	30.46	85.64	120.34	8.32	4.40	36.60	28.35	30.34	25.63	0.94
$G_7 \times G_{12}$	35.26	88.56	95.35	9.45	4.64	43.84	24.45	23.44	22.32	0.97
$G_8 \times G_{12}$	28.44	78.35	95.64	7.66	5.56	42.58	22.42	24.32	24.42	1.03
$G_9 \times G_{12}$	38.34	87.65	80.44	8.44	4.36	36.79	24.65	24.56	25.64	0.94
$G_{10} \times G_{12}$	40.44	95.25	92.34	6.66	4.32	28.77	40.46	42.44	50.54	1.45
$G_{13} \times G_{12}$	40.53	92.35	85.46	4.54	5.54	25.15	32.44	33.34	34.32	0.86
$G_2 \times G_{14}$	28.34	82.36	60.15	4.40	5.34	23.49	27.32	30.45	32.22	0.75
$G_3 \times G_{14}$	30.64	84.54	70.44	4.42	3.22	14.23	33.45	34.44	28.54	0.41
$G_4 \times G_{14}$	28.25	83.35	100.46	7.45	4.54	33.82	28.32	28.34	30.32	1.02
$G_7 \times G_{14}$	30.43	82.34	80.65	8.45	5.55	46.89	40.32	42.44	46.55	2.17
$G_8 \times G_{14}$	30.45	85.54	90.45	8.64	5.48	47.34	38.55	40.56	42.32	2.01
$G_9 \times G_{14}$	32.26	87.24	72.55	7.42	4.44	32.94	22.32	22.44	28.34	0.93
$G_{10} \times G_{14}$	36.16	94.24	100.34	6.45	3.56	22.96	32.54	36.56	50.44	1.15
$G_{13} \times G_{14}$	36.26	90.36	75.64	6.22	5.45	33.89	26.34	25.22	27.32	0.92
Mean	32.77	86.57	97.39	6.79	4.60	31.24	31.06	32.28	34.31	1.06
SE	0.01	0.01	0.01	0.01	0.01	0.10	0.02	0.02	0.63	0.03
CD@%	0.03	0.03	0.03	0.02	0.03	0.27	0.04	0.05	1.78	0.07
CD@%	0.04	0.04	0.04	0.03	0.04	0.36	0.06	0.07	2.36	0.10
Min.	25.52	78.33	60.14	4.32	3.20	14.21	22.21	22.42	20.17	0.40
Max.	40.55	95.28	135.48	9.48	5.62	47.46	40.48	42.46	50.56	2.19

SE= Standard error, CD= Critical difference.

Variability in hybrids

Different genotypic parameters were estimated for all the studied traits in hybrids have been shown in (Table 5). High heritability was observed for all the traits. For traits like cluster plant^{-1}, fruits plant^{-1}, individual fruit weight, and yield plant^{-1} that showed substantial GCV, PCV, and genetic advancement as % of mean, indicates direct selection may be applied.

Table 5. Ten quantitative features in tomato hybrids have various genetic factors

Characters	Range		Mean	Variance		GCV	PCV	H^2	GA	GA as%
	Min.	Max.		σ^2 g	σ^2 p	(%)	(%)	(bs)	(%)	of mean
Days to first flowering	25.52	40.55	32.77	17.42	17.42	12.74	12.74	100	8.60	26.24
Days to maturity	78.33	95.28	86.57	18.32	18.32	4.94	4.94	100	8.82	10.19
Plant height (cm)	60.14	135.48	97.39	313.17	313.17	18.18	18.17	100	36.46	37.43
Cluster plant^{-1}	4.32	9.48	6.79	2.19	2.19	21.79	21.79	99.99	3.05	44.88
Fruits cluster^{-1}	3.20	5.62	4.60	0.40	0.40	13.75	13.75	99.90	1.30	28.30
Fruits plant^{-1}	14.21	47.46	31.24	65.10	65.13	25.83	25.83	99.96	16.62	53.20
Fruit length (mm)	22.21	40.48	31.06	28.85	26.85	16.68	16.68	100	10.67	34.36
Fruit diameter (mm)	22.42	42.46	32.28	35.29	35.29	18.40	18.40	100	12.24	37.91
Single fruit weight (g)	20.17	50.56	34.31	71.98	73.17	24.73	24.93	98.38	17.34	50.52
Yield plant^{-1} (kg)	0.40	2.19	1.06	0.14	0.14	35.62	35.86	98.68	0.77	72.89

σ^2g= Genotypic variance, σ^2p= Phenotypic variance, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, H^2bs= Heritability in broad sense, GA= Genetic advance.

Conclusion

Analysis of variance (ANOVA) revealed significant genetic variability for yield and its constituent parts among the research parents. High genotypic parameters for fruits plant^{-1}, yield plant^{-1}, cluster plant^{-1}, fruits cluster^{-1}, and individual fruit weight were expressed by both the parental genotypes and hybrids, indicating that these traits should be taken into consideration for direct selection. Based on yield plant^{-1} performance alone, the potential hybrids were $G_4 \times G_6$, $G_7 \times G_{14}$, $G_8 \times G_{14}$, $G_{10} \times G_6$ and $G_{10} \times G_{12}$. Among the hybrids, $G_7 \times G_{14}$ and $G_8 \times G_{14}$ had better performance compared to their parents.

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Conflict of Interests

The author declares no conflict of interest.

References

Agrawal, A., Arya, N. and Ahmed, Z. (2014). Genetic variability studies in tomato (Solanum Lycopersicum Mill.). *Progressive Horticulture,* 46(2): 50-52.

Bernousi, I. E., Tajbakhsh, A., Darvishzadeh, M. and Henareh, M. (2011). Studies on genetic variability and correlation among the different traits in tomato (*Solanum Lycopersicum* Mill.). *Notulae Botanicae Horti Agrobotanici Cluz- Napoca,* 39(1): 152-158.

Begum, B. (2016). Genotype-stress Interaction and Transcriptional Profile Analysis of Water Stress Responsive Genes in Tomato (*Solanum lycopersicum* L.). *Ph.D. Thesis, Department of Genetics and Plant Breeding, Sher-E-Bangla Agricultural University.*

Bhandari, H. R., Srivastava, K. and Reddy, G. E. (2017). Genetic Variability, Heritability and Genetic Advance for Yield Traits in Tomato (*Solanum lycopersicum*L.). *International Journal of Current Microbiology and Applied Science*, 6(7): 4131-4138.

Bugianesi, R., Salucci, M., Leonardi, C., Ferracane, R., Catasta, G., Azzini, E. and Madani, G. (2004). Effect of domestic cooking on human bioavailability of naringenin, chlorogenic acid, lyopene and β-carotene in cherry tomatoes. *European Journal of Nutrition,* 43: 360–366.

Dutta, P., Hazari, S., Karak, C. and Talukdar, S. (2018). Study on genetic variability of different tomato (*Solanum lycopersicum.* L.) cultivars grown under open field condition. *International Journal of Chemical Studies,* 6(5): 1706-1709.

Falconer, D.S. and Mackay, T.F.C. (1996). Introduction to Quantitative Genetics. 4th Edition, Addison Wesley Longman, Harlow.

Ghosh, K. P., Islam, A. K. A., Mian, M. A. K. and Hossain, M. M. (2010). Variability and character association in F_2 segregating population of different commercial hybrids of tomato (*Solanum lycopersicum* Mill). *Journal of Applied Sciences and Environmental Management*, 14(2): 91- 95.

Haydar, A., Manda, M. A., Ahmed, M. M., Hannan, M. A., Karim, U. K., Razvy, U. K., and Solahin, M. (2007). Studies on genetic variability and interrelationship among the different traits in tomato (Lycopessicon esculentium Mill.). *Middle East Journal of Scientific Research,* 2(3-4): 139-142.

Khapte, P. S. and Jansirani, P. (2014). Genetic variability and performance studies of tomato (*Solanum lycopersicum* Mill.) genotypes for fruit quality and yield. *Trends in Bioscience*, 7(12):1246.

Larik, A. S., Malik, S. I., Kakar, A. A., and Naz, M. A. (2000). Assessment of heritability and genetic advance for yield and yield components in Gossypium hirsutum L. Scientific Khyber, 13: 39-44.

Lecomte, L., Colmbani, S., Gautier, V., Jilmnez, G., Dufee, M.C., Buret, P. and Causse, M. (2004). Fine mapping of QTLs of chromosome 2 affecting the fruit architecture and composition of tomato. *Molecular Breeding,* 13(1):1-14.

Manna, M. and Paul, A. (2012). Studies on genetic variability and character association of fruit quality parameter in tomato (*Solanum Lycopersicum* Mill.). *HortFlora Research Spectrum*, 1(2): 110-116.

Meena, O. P., Bahadur, V., Jagtap, A. B., Saini, P. and Meena, Y. K. (2015). Genetic variability studies of fruit yield and its traits among indeterminate tomato genotypes under open field condition. *African Journal of Agricultural Research*,10(32): 3170-3177.

Mohamed, S. M., Ali, E. E. and Mohamed, T. Y. (2012). Study of heritability and genetic variability among different plant and fruit characters of tomato (*Solanum lycopersicon* Mill.). *International Journal of Scientific and Technological Research* 1(2).

Mohanty, B.K. (2002). Studies on variability, heritability, interrelationship and path analysis in tomato. *Annals of Agricultural Research*, 33: 65-69.

Naik, A. (2012). Characterization of fenugreek (Trigonella foenumgraecum L.) genotypes through morphological characters. *International Journal of Agriculture, Environment & Biotechnology*, 5(4): 445-449.

Nwosu, D. J., Onakoya, O.A., Okere A.U., Babatunde, A.O. and Popoola, A.F. (2014). Genetic variability and correlations inrainfed tomato (*Solanum spps*.) accessions in Ibadan, Nigeria. *Greener Journal of Agricultural Sciences,*4 (5):211-219.

Panse, V.G., Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers, Indian Council of Agricultural Research, New Delhi.

Patel, S. A., Kshirsagar, D. B., Attar, A.V., and Bhalekar, M.N. (2013). Study on genetic variability, heritability and genetic advance in tomato. *International Journal of Plant Sciences,* 8(1): 45-47.

Prajapati, S., Tiwari, A., and Kadwey, S., and Jamkar, T. (2015). Genetic Variability, Heritability and Genetic Advance In Tomato (*Solanum Lycopersicon* Mill.). *International Journal of Agriculture, Environment & Biotechnology,* 8(2): 245-25

Saleem, M. Y., Iqbal, Q. and Asghar, M. (2013). Genetic variability, heritability, character association and path analysis in F_1 hybrids of tomato. *Pakistan Journal of Agricultural Science,* 50(4): 649-653:

Santader, L. K. L., Vallejo, F. A., Bubano, T. C. L. and Esteban, D. (2013). Genotypic correlations, phenotypic, environmental and path analysis in tree tomato (*Cyphomandra betacea* Cav. Sendt.). *Acta Agrophysica,* 62(3): 217-224

Sharmin, S., Hannan, A., Tahjib, M., Arif, U. and Sagor, G. H. M. (2019). Genetic association and path coefficient analysis among yield and nutritional traits of tomato (*Lycopersicon esculentum* L.). *Journal of the Bangladesh Agricultural University.* 17(2): 187–193.

Shashikanth, N., Basavaraj, R.M., Hosamani, and Patil, B.C. 2010. Genetic variability in tomato (*Solanum lycopersicon* [Mill]. Wettsd.). *Karnataka Journal of Agricultural Sciences*, 23(3): 536-537.

Singh, R. K., Choudhury, B. D. (1985). Biometrical methods in quantitative genetic analysis. Revised Edn. Kalyni Publisheds, Ludhiana, India, pp: 39-80.

Tazeen, M., Nadia, K. and Farzana, N.N. (2009). Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in synthetic elite lines of wheat. *Journal of Food, Agriculture & Environment* Vol.7 (3&4): 278-282.

Tigchelaar, E.C. (1986). Tomato Breeding. In: M.J. Basset (ed.), Breeding Vegetable Crops. AVI Publishing Co., INC. *Westport, Connecticut*. pp. 135-171.

Titus, S.R., Kerketta, A., and Bahadur, V. (2020). Genetic Variability, Heritability and Genetic Advance Studies for Different Characters of Tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbial and Applied Science,* 9(12): 1647-1653.

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ORIGINAL ARTICLE

LIFE SCIENCE

EFFECTS OF PROBIOTIC SUPPLEMENTED YOGURT ON NEONATAL STREPTOZOTOCIN-INDUCED TYPE-2 DIABETIC RATS

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Abstract

Probiotics can be considered as biological agents that modify the intestinal microbiota as well as show several health benefits. The purpose of this study was to explore the effects of probiotics in neonatal STZ-induced type-2 diabetic rats. Following the biochemical analysis of probiotic bacteria, yogurt was prepared using cow milk and used to feed the experimental rats. Probiotic yogurt was supplemented to three rat groups, each with six rats, and the doses were 2 g in PYT1, 4 g in PYT2 and 6 g in PYT3 for 21 days. Fasting serum glucose, serum insulin, lipid profiles and liver glycogen levels were measured to investigate the probiotic effects on type 2 diabetic rats. It was observed that fasting serum glucose levels were significantly lower in case of PYT3 group ($p<0.05$) whereas a significant ($p<0.05$) upsurge of serum insulin levels was detected in PYT2 rat group. A significant ($p<0.05$) decrease in LDL level in PYT2 group and significantly ($p<0.05$) increased level of HDL was detected in PYT1 and PYT2 rat groups. However, there were no significant differences regarding triglyceride as well as total cholesterol levels among three probiotic yogurt supplemented rat groups. Hepatic glycogen content was 34.5%, 30.9% and 39.1% among the probiotic yogurt feed groups viz. PYT1, PYT2 and PYT3, respectively. Findings of this research suggest that application of probiotic yogurt can help to manage type-2 diabetes. Further study on clinical trial would be worthy to investigate for probiotic-based product improvement for treatment of type-2 diabetic patients.

Keywords: Diabetes, rats, probiotics, yogurt, metabolites

Introduction

Diabetes is a life-threatening chronic carbohydrate metabolism disorder in which blood glucose levels abnormally increase in the bloodstream due to a lack of insulin production (Sunday et al., 2022). International Diabetes Federation (IDF) stated that diabetes was anticipated to impact 463 million people in 2019 and the number is presumed to climb up to 578 million by 2030 and 700 million by 2045 (IDF, 2019). Type-2 diabetes mellitus (T2DM) is the most typical kind of diabetes, reckoning for 90% of all cases (Ortiz-Martínez et al., 2022; Cho et al., 2018). Retinopathy, nephropathy, and neuropathy are just a few of the issues associated with diabetes. Obesity, cataracts, erectile dysfunction, nonalcoholic fatty liver disease (NAFLD) are all risks associated with diabetes (Stenvers et al., 2019).

Probiotics are live microbial food additives that ensure health benefits surpassing rudimentary aliments when partaken in adequate proportions (Morelli et al., 2012). Probiotics have been studied for their potential to improve immunological function, reduce blood pressure, and improve lipids (Markowiak et al., 2017). Lactic acid bacteria (LAB) strains including *Lactobacillus* along with *Bifidobacterium* are known to be vital probiotic dosages. Fermented dairy products, namely yogurt with enough probiotic LAB, have been shown to have a number of benefits to health (Reid et al., 2005). Nowadays consumption of functional foods has been increased and functional food is one of the best strategies to overcome diabetes (Riezzo et al., 2005). Dairy foods have established health benefits. Dahi is a Bangladeshi homemade variant of yogurt as well as a potential source of probiotic bacteria and

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because of its numerous health benefits, it is regarded as a functional food i.e., antidiabetic (Yadav et al., 2007), antidiarrheal (Barai et al., 2018), anticarcinogenic (Brady et al., 2000), cholesterol-lowering (Ataie-Jafari et al., 2009), anti-allergic (Al Azad et al., 2020), antiatherogenic properties (Chawla et al.,1984; Abbas et al.,1992).

At present a significant number of people have type 2 diabetes as well as most of these individuals are living below the poverty line. They could not meet up their dietary requirements per day and a significant population remained malnourished. Because probiotic bacteria may have medicinal or preventive benefits, several probiotic products have been developed, including fermented milk drinks, yogurt, cheese, ice creams, sausages, probiotic juice and drinking water etc. with defined culture. This study aimed to analyze the effects of yogurt augmented with natural probiotic bacteria on neonatal Streptozotocin (STZ) induced diabetic rats.

Materials and methods

Probiotic bacterial identification

Ten probiotic bacteria were isolated from regional yogurt samples of Bangladesh and biochemical assay was performed based on the morphological (size, shape, and motility) and biochemical (Gram staining and catalase test) as well as physiological (pH tolerance, bile salt tolerance, NaCl tolerance, phenol tolerance, antibiotic activities) characteristics according to Hoque et al., 2010 and Barai et al., 2018.

Yogurt preparation

Milk was obtained from a residential cow farm then boiled above 100°C for 15 minutes before cooling to 40°C. A liquid culture of isolated probiotic bacteria was used to inoculate the bacteria at a concentration of 5% (v/v). The inoculated milk was then transferred into containers and incubated at 40°C for 12 hours in anaerobic condition. Raw coagulated yogurt was stored at 4°C in order to carry out onward applications (Barai et al., 2018).

Experimental Rats

In the present experiment, 36 mature Long Evans rats were used. The experimental rats were reared in the animal shed of the Bangladesh University of Health Sciences (BUHS), Dhaka, Bangladesh. Rats were kept at a constant room temperature of 22±50°C with a humidity of 40–70% at a natural 12-hour day-night cycle. Standard laboratory rat pellets were provided to the rats (as per formula and specifications of icddr,b) purchased from Jamuna Traders, Dhaka and ad libitum drinking water was provided. Rats were separated into six groups, each with six rats. The groups were normal water control (NWC), diabetic water control (DWC), Gliclazide treated diabetic rat (GT), 2 gm probiotic yogurt supplemented diabetic rats (PYT1), 4 gm probiotic yogurt supplemented diabetic rats (PYT2) and 6 gm probiotic yogurt supplemented diabetic rats (PYT3). Gliclazide was delivered orally to type-2 diabetic rats and the dosage was 20 mg/kg body weight. This study obtained informed consent from the ethical committee of Bangladesh University of Health Sciences (BUHS).

Preparation of type-2 diabetic model rats

A single intraperitoneal injection of Streptozotocin (STZ) in citrate buffer (10 ml) at a concentration of 90 mg/kg body weight was used for producing type-2 diabetes in rat pups (48 h old, average weight 7 g) according to Hassan et al., 2018; Hasan et al.,2019. The rat pups were administered an intraperitoneal injection of STZ solution with a dosage of 10 µl /g body weight. The three-month-old rats were first tested using a routine oral glucose tolerance test according to Barik et al., 2008. The experimental rats were considered as type-2 diabetic based due to their fasting blood glucose level > 7.0 mmol/l.

Biochemical analysis

To collect blood samples from rats that had been fasting, tail tip amputation was performed under diethyl ether anesthesia on "day 0". The tail was soaked using mild water (40°C) for 20 to 30 seconds for vasodilation shortly before amputation. To evade hemolysis, 0.2 ml of blood was accumulated with caution from the tail tip and placed in eppendorf tubes. Rat blood was obtained via heart puncture on the 21st day, after they had been decapitated. Obtained serum were divided into new eppendorf tubes for biochemical analysis. After centrifuging the blood samples at 3500 rpm for 15 minutes, 100 µl serum was frozen at -20°C until fasting serum insulin analysis. The glucose oxidase (GOD-PAP) technique was applied for determining serum glucose levels according to Trinder et al., 1969, which produces gluconic acid and hydrogen peroxide by oxidizing glucose. When peroxidase (POD) is

present, H_2O_2 produces a red violet hue when combined with a chromogenic oxygen acceptor, phenol aminophenazone. The glucose concentration was proportional to the sample's color intensity. The level of serum insulin was calculated via enzyme-linked immunosorbent assay (ELISA) following the protocol of the manufacturer (Crystal Chem. Inc. Downers Grove, IL, USA). The rats' serum cholesterol levels were estimated after enzymatic hydrolysis and oxidation. In the presence of phenol and peroxidase, the indicator quinoneimine was synthesized from hydrogen peroxide and 4 aminoantipyrine (Kendall et al., 1952). Calculation of low-density lipoprotein (LDL) was performed as stated by Friedewald et al., 1972. Serum HDL was assessed using the procedure stated by Kendall et al., 1952. By employing glycerol-3-phosphate oxidase, the serum triglyceride level was calculated using the GPO-PAP technique according to Fossati et al., 1982. The anthrone-sulfuric acid procedure was used to calculate liver glycogen levels, as per Vries et al., 1954.

Statistical Analysis

Statistical program SPSS was used to analyze the data (Windows Version 16, SPSS Inc., Chicago, Illinois, USA). The mean ± standard deviation was applied to represent the data. The paired t-test and one-way ANOVA were employed for the purpose of comparing the groups. The significance threshold was adjusted at $p<0.05$.

Results

Isolation of probiotic bacteria

Table 1 demonstrates that isolated bacteria were rod-shaped, gram-positive, catalase-negative, non-motile, and coagulase-positive. They exhibited resistance to low pH (3.0), NaCl (2-8%), phenol (0.1-0.4%), and bile salt (0.1-0.4%) concentrations (0.3%). The bacteria were identified as Lactobacillus spp. by all the tests performed.

Table 1. Physiological and biochemical features of the isolated bacteria

Isolate no.	Shape	Gram staining & Coagulase	Catalase & Motility	pH tolerance	Bile tolerance	NaCl tolerance				Phenol tolerance			
				pH 3.0	0.3%	2%	4%	6%	8%	0.1%	0.2%	0.3%	0.4%
1	rod	+	−	++	++	++	++	+	−	++	++	++	++
2	rod	+	−	++	++	++	++	+	−	++	++	++	++
3	rod	+	−	++	++	++	++	+	−	++	++	++	++
4	rod	+	−	++	++	++	++	+	−	++	++	++	++
5	rod	+	−	++	++	++	++	+	−	++	++	++	++
6	rod	+	−	++	++	++	++	+	−	++	++	++	++
7	rod	+	−	++	++	++	++	+	−	++	++	++	++
8	rod	+	−	++	++	++	++	+	−	++	++	++	++
9	rod	+	−	++	++	++	++	+	−	++	++	++	++
10	rod	+	−	++	++	++	++	+	−	++	++	++	++

++, the most excellent tolerant against the condition; +, the excellent tolerant against the condition; −, no tolerance against the condition.

Fasting serum glucose level in different groups of type-2 diabetic model rats

Measurement of fasting serum glucose levels is necessary to observe the glucose metabolism status**.** The effects of probiotic yogurt on glucose metabolism were evaluated by measuring the fasting serum glucose levels of different experimental groups. Probiotic yogurt treated group 3 (PYT3) indicated a significant ($p<0.05$) decrease in fasting glucose levels in contrast to the other probiotic treated groups (PYT1 and PYT2; Table 2**)**. On the contrary, the standard drug Gliclazide, which served as positive control (PC), showed 4.6% hypoglycemic effect. The results showed that PYT1, PYT2 and PYT3 decreased fasting blood glucose level by 14.6%, 24.8% and 23.1%, respectively at day 21 when compared with 'day 0' in type 2 diabetic rats. The results of serum glucose level also compared between probiotic supplemented yogurt treated groups with type 2 diabetic positive rat groups. However, no significant effects were obtained.

Effect of Probiotic Yogurt on serum insulin level

The serum insulin levels of experimental groups were examined to analyze the effect of probiotic yogurt on insulin levels. During the 21-day study period, PYT2 group showed a significant (p<0.05) increase in serum insulin levels in type 2 diabetic rats compared to PYT1 and PYT3 groups (Table 2). In Gliclazide treated group (positive control group), serum insulin level was amplified by 22.97% compared to 7.07% in the probiotic yogurt group, PYT2. However, interestingly, in PYT1 and PYT3 groups, serum insulin level was decreased by 7.72% and 28.07%, respectively at day 21 when compared with 'day 0'. The results of serum insulin levels were also compared between probiotic supplemented yogurt treated groups with type 2 diabetic positive rat groups. However, no significant effects were obtained.

Effects of Probiotic Yogurt on the Liver Glycogen

Controlling glucose metabolism primarily depends on the liver as it absorbs excess blood glucose as glycogen and/or regulates new glucose production via gluconeogenesis (Yoon et al., 2001). The present experiment investigated the impact of probiotic yogurt on hepatic glycogen level of type 2 diabetes model rats. All rats from separate test groups were executed after 21 days and their hepatic glycogen content was assessed. Table 2 depicts that there was 34.5%, 30.9% and 39.1% hepatic glycogen content in probiotic yogurt fed groups (PYT1, PYT2 and PYT3), respectively after 21 days of oral yogurt administration. The results of liver glycogen were also compared between probiotic supplemented yogurt treated groups with type 2 diabetic positive rat groups. However, no significant effects were obtained.

Table 2. Serum glucose, serum insulin and glycogen level of different experimental rat groups

Rat Groups	Serum glucose level (mmol/L)		Serum Insulin level (µg/L)		Glycogen level (mg/g)
	0 Day	21th Day	0 Day	21th Day	21th Day
NWC	6.12 ± 0.61 (100%)	6.26± 0.47 (102.2%)	-------	------	14.2±1.8
DWC	7.17 ± 1.13 (100%)	7.73 ± 1.14 (107.8%)	0.22±0.026 (100%)	0.213±0.023 (96.8%)	17.1±4.7 (100%)
GT	7.71 ± 0.75 (100%)	7.36 ± 1.34 (95.4%)	0.209±0.000 (100%)	0.257±0.062 (122.97%)	17.3±3.7 (101.1%)
PYT1	7.31 ± 0.17 (100%)	6.24 ±1.66 (85.4%)	0.259±0.008 (100%)	0.239±0.039 (92.28%)	23.0±1.0 (134.5%)
PYT2	7.64 ± 1.18 (100%)	5.75 ± 1.44 (75.2%)	0.198±0.003 (100%)	0.212±0.003* (107.07%)	22.4±1.1 (130.9%)
PYT3	8.93 ± 0.18 (100%)	6.87 ±1.19* (76.9%)	0.310±0.151 (100%)	0.223±0.03 (71.93%)	23.8±2.3 (139.1%)

*The outcomes are stated as Mean ± SD. Statistical analysis within groups was done using paired t-test. SD, Standard Deviation; NWC: Normal Water Control; DWC: Diabetic Water Control; GT: Gliclazide Treated Diabetic Rat; PYT1:2 gm probiotic yogurt supplemented diabetic rat group; PYT2:4 gm probiotic yogurt supplemented diabetic rat; PYT3:6 gm probiotic yogurt supplemented diabetic rat group. * indicates statistically significant ($p < 0.05$).*

Plasma lipid profiles of type-2 diabetic model rats

The level of LDL cholesterol was reduced (p<0.05) in PYT2 group and significant (p<0.05) upsurge in HDL cholesterol level in PYT1 as well as PYT2 groups were observed following a 21-day period of constant feeding (Table 3). However, there were no noteworthy differences in triglyceride and total cholesterol levels among the three probiotic yogurt supplemented groups. The results of lipid profiles were also compared between probiotic supplemented yogurt treated groups with type 2 diabetic positive rat groups. However, no significant effects were observed.

Table 3. Plasma lipid profiles of different experimental rat groups

Rat Groups	TG (mg/dL)		Cholesterol (mg/dL)		HDL (mg/dL)		LDL (mg/dL)	
	0 Day	21th Day	0 Day	21th Day	0 Day	21th Day	0 Day	21th Day
NWC	87.2±16.9 (100%)	56.6±12.8 (64.9%)	51.0±2.5 (100%)	38.4±4.9 (75.2%)	16.4±4.6 (100%)	17.9±5.4 (109.1%)	17.1±6.2 (100%)	16.2±3.2 (94.7%)
DWC	51.1±12.6 (100%)	82.9±15.9 (162.2%)	50.7±10.1 (100%)	52.7±10.1 (103.9%)	21.4±6.1 (100%)	21.3±4.1 (99.5%)	21.0±12.0 (100%)	17.9±6.1 (85.2%)
GT	68.3±29.4 (100%)	93.6±18.6 (137.0%)	50.9±5.5 (100%)	58.3±10.5 (114.5%)	20.1±4.5 (100%)	20.9±3.1 (103.9%)	20.1±6.9 (100%)	20.2±7.6 (100.4%)
PYT1	99.8±45.3 (100%)	74.2±21.5 (74.3%)	51.1±4.9 (100%)	62.8±6.2 (122.8%)	20.0±4.0 (100%)	25.7±3.2* (128.5%)	17.5±5.1 (100%)	24.6±7.5 (140.5%)
PYT2	94.2±33.6 (100%)	79.6±11.2 (84.5%)	54.4±3.0 (100%)	57.9±7.3 (106.4%)	23.0±4.2 (100%)	28.0±5.6* (121.7%)	18.7±3.2 (100%)	15.6±3.1* (83.4%)
PYT3	105.4±29.9 (100%)	89.3±22.3 (84.7%)	50.2±6.0 (100%)	60.1±7.6 (119.7%)	24.5±4.7 (100%)	22.5±5.9 (91.8%)	10.1±4.3 (100%)	17.5±2.6 (173.2%)

*The outcomes are stated as Mean ± SD. Statistical analysis within groups was done using paired t-test. SD, Standard Deviation; NWC: Normal Water Control; DWC: Diabetic Water Control; GT: Gliclazide Treated Diabetic Rat; PYT1: 2 gm probiotic yogurt supplemented diabetic rat group; PYT2: 4 gm probiotic yogurt supplemented diabetic rat; PYT3: 6 gm probiotic yogurt supplemented diabetic rat group. * indicates statistically significant ($p < 0.05$).*

Body weights of different rat groups

The findings of this study reveal that after 21 days of feeding, body weight of the rats did not differ significantly. All the rat groups had a proclivity status for gaining body weight. The variations in the body weight of rats have shown in Table 4. The results of body weights were also compared between probiotic supplemented yogurt treated groups with type 2 diabetic positive rat groups. However, no significant effects were recorded.

Table 4. Body weight of different experimental rat groups

Rat groups	Body weight (gm)			
	Day 0'	Day 7'	'Day 14'	"Day 21'
NWC	238 ± 10 100%	270 ± 8	283±10	304±13 127%
DWC	259±42 100%	252±46	257±42	264±42 101%
GT	254±30 100%	251±32	255±29	257±27 101%
PYT1	208±19 100%	207±20	214±20	206±20 99%
PYT2	205±35 100%	203±32	211±34	206±27 100.4%
PYT3	208±16 100%	215±14	218±13	210±14 100.9%

*The outcomes are stated as Mean ± SD. Statistical analysis within groups was done using paired t-test. SD, Standard Deviation; NWC: Normal Water Control; DWC: Diabetic Water Control; GT: Gliclazide Treated Diabetic Rat; PYT1: 2 gm probiotic yogurt supplemented diabetic rat group; PYT2: 4 gm probiotic yogurt supplemented diabetic rat; PYT3: 6 gm probiotic yogurt supplemented diabetic rat group. * indicates statistically significant ($p < 0.05$).*

Discussion

Insulin insufficiency are the consequences of pancreatic β-cell failure characterized Type 2 diabetes (IDF, 2019). Several researches revealed that, between diabetic and non-diabetic individuals, gut microbiota was altered in diabetic patients and gut which did contribute to the onset of diabetes as well as metabolic disorders (Larsen et al., 2010, He et al., 2015). Antimicrobial agents or metabolic chemicals produced by probiotics prevent the development of additional microbes (Spinler et al., 2008; O'Shea et al., 2012). On the intestinal mucosa, they compete with other gut microbes for receptors and binding sites, as well as change the gut environment (Collado et al., 2007).

Probiotic bacteria were isolated and characterized by biochemical screening process in the present study. They were cultured on the de Man, Rogosa and Sharpe (MRS) agar media. These isolates were sub-cultured after growing on MRS agar medium, and colonies were chosen for physiological and biochemical analysis. After that for the purpose of determining probiotic characteristics, ten isolates were chosen. The most crucial characteristic of probiotic bacteria is the ability to resist low pH like gastric juice (pH 1.5-3) as they move through the stomach (Chou et al., 1999). All of the isolates showed resistant to low pH in the present study. Bile tolerance is among the most essential characteristics of probiotic bacteria (Walker et al., 2000). Bile salt tolerance activity of probiotic isolates showed more or less nearly equal resistance against 0.05%, 0.1%, 0.15% and 0.3% artificial bile acid concentration after 0, 2, 4 and 24 hours of incubation, respectively (Prasad et al., 1998; Hossain et al., 2018). Findings of current study shows that all of the isolates were able to withstand at 0.3% bile salt concentration. According to Hoque et al., 2010 and Barai et al., 2018, yogurt was used to isolate *Lactobacillus* spp. and was analyzed at various NaCl concentrations (1-10%) and were tolerant to 1-9% NaCl. The present study showed that all the isolated bacteria were able to survive at 2% and 4% NaCl, but less survival ability was observed at 6% and 8% NaCl concentrations. It is reported that, bacteriostatic action in some microorganisms occurred at 0.4% concentration of phenol (Xanthopoulos et al., 2000). In findings of present study, all the isolated bacteria were able to survive at 0.1%, 0.2%, 0.3% and 0.4% phenol concentrations, respectively. It has been reported that, probiotic bacteria ferment sugars (glucose, sucrose, maltose, lactose) except sorbitol and mannitol which corresponds to the findings of present study (Ghanbari et al., 2009).

Appropriate experimental models are necessary to test the effect of various bio-therapeutic agents. Type-2 diabetes animal models were obtained either spontaneously, surgically or using chemicals or a combination of these techniques. It has been reported that neonatal streptozotocin-induced Long Evans rats showed the mimic effects on human diabetes with fair parallelism. However, these effects are manifestations of insulin secretory dysfunction rather than insulin resistance (Asrafuzzamanet al., 2018; Mudi et al., 2017) and for this reasons neonatal STZ-induced diabetic rats were chosen in the present study.

Determination of treatment doses of probiotic yogurt is so much important. In the present study, the treatment doses of probiotic yogurt were determined as reported by the previous studies (Delia et al., 2012). Yadav et al., 2008 reported that, in STZ-induced type 2 diabetic rats, oral feeding of probiotic dahi (15 g/day/rat) delayed insulin secretion, reduced total cholesterol, triglycerides, LDL and VLDL cholesterol, however, enhanced HDL cholesterol levels. An equivalent pattern was demonstrated in the present research where probiotic high doses yogurt fed treatment group (PYT3) decreased fasting serum glucose level significantly ($p<0.05$). Administration of *L. plantarum* for 20 weeks at 25×10^8 CFU/day lowered blood glucose level in a high fat diet female C57BL/6 J mouse (Andersson et al., 2010). Lu et al. (2010) reported that administration of *L. reuteri* for 4 weeks at 1×10^9 CFU/day lowered blood glucose level and glycated hemoglobin in a male Sprague–Dawley diabetic rats. In this study, a significant ($p<0.05$) decrease in the LDL cholesterol level along with an increased ($p<0.05$) HDL cholesterol level was observed. It was found that, treating with diet supplemented with 15% of dahi for 8 weeks, lowered blood glucose level in male Wistar rats fed a high fructose diet (Yadav et al., 2007). Administration of *Bifidobacterium adolescentis* for 12 weeks increased insulin sensitivity and decreased body weight in male Wistar rats when provided a high fat diet (Chen et al., 2012). The present study revealed a significant ($p<0.05$) upsurge in serum insulin levels in case of probiotic supplemented treatment groups. Body weight gain was slowed or ceased 8 weeks later in case of *Lactobacillus gasseri* BNR17 administration on a type 2 diabetes mouse model (Yun et al., 2009). In the findings of the present study, all the probiotic yogurt supplemented rat groups showed similar trend of body weight after 2 weeks compared to other experimental rat groups. Human clinical trials of probiotic capsules or yogurt were conducted and yielded mixed outcomes. Six weeks of probiotic yogurt consumption up surged blood glucose levels dramatically (Ruan et al., 2015).

In the present research, antidiabetic impact of probiotics was determined on streptozotocin induced type-2 rats. It was a laboratory animal study and the duration of the experiment was 3 weeks. From this experiment, a significant ($p<0.05$) decrease in fasting serum glucose levels was observed in case of PYT3 group and a significant ($p<0.05$) increase in serum insulin levels in PYT2 group. Due to some unknown factors it was observed that, blood glucose levels decreased in PYT3 group, however, the corresponding insulin level was also decreased. GT used in the present experiment might not have had the desired effects for which the GT group did not show the expected result. It may me mentioned that, the experimental groups were treated with high doses of yogurt, which might be resulted increased levels of liver glycogen. It was observed that probiotic enriched yogurt lowered the blood glucose

level and increased the insulin, HDL and glycogen level. Changes in HDL and LDL levels are not consistent between the experimental groups. However, unknown factors might be responsible for this particular results. In addition, no significant results were obtained regarding increased body weight among the experimental groups which is corroborated by the findings of other authors.

Further study regarding molecular characterization and proper gene identification would be worthy to investigate. Moreover, probiotic-based food may be developed as a bio-therapeutic agent for type 2 diabetic patients.

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Conflict of Interests

The author declares no conflict of interest.

References

Abbas, Z., & Jafri, W. (1992). Yogurt (dahi): a probiotic and therapeutic view. *Journal of Pakistan Medical Association*, 42(9), 221.

Al Azad, S., Moazzem Hossain, K., Rahman, S. M. M., Al Mazid, M. F., Barai, P., & Gazi, M. S. (2020). In ovo inoculation of duck embryos with different strains of Bacillus cereus to analyse their synergistic post-hatch anti-allergic potentialities. *Veterinary medicine and science*, 6(4), 992-999.

Andersson, U., Bränning, C., Ahrné, S., Molin, G., Alenfall, J., Önning, G., & Holm, C. J. B. M. (2010). Probiotics lower plasma glucose in the high-fat fed C57BL/6J mouse. *Beneficial microbes*, 1(2), 189-196.

Asrafuzzaman, M., Rahman, M. M., Mandal, M., Marjuque, M., Bhowmik, A., Rokeya, B., & Faruque, M. O. (2018). Oyster mushroom functions as an anti-hyperglycaemic through phosphorylation of AMPK and increased expression of GLUT4 in type 2 diabetic model rats. *Journal of Taibah University medical sciences*, 13(5), 465-471.

Ataie-Jafari, A., Larijani, B., Majd, H. A., &Tahbaz, F. (2009). Cholesterol-lowering effect of probiotic yogurt in comparison with ordinary yogurt in mildly to moderately hypercholesterolemic subjects. *Annals of Nutrition and Metabolism*, 54(1), 22-27.

Barai, P., Hossain, K. M., Rahman, S. M. M., Al Mazid, M. F., & Gazi, M. S. (2018). Antidiarrheal efficacy of probiotic bacteria in castor oil induced diarrheal mice. *Preventive Nutrition and Food Science*, 23(4), 294.

Barik, R., Jain, S., Qwatra, D., Joshi, A., Tripathi, G. S., & Goyal, R. (2008). Antidiabetic activity of aqueous root extract of Ichnocarpus frutescens in streptozotocin-nicotinamide induced type-II diabetes in rats. *Indian Journal of Pharmacology*, 40(1), 19.

Brady, L. J., Gallaher, D. D., &Busta, F. F. (2000). The role of probiotic cultures in the prevention of colon cancer. *The Journal of nutrition*, 130(2), 410S-414S.

Chawla, K., &Kansal, V. K. (1984). Effect of milk & its culture products on the plasma & organ lipids in rats. *The Indian Journal of Medical Research*, 79, 418-425.

Chen, J., Wang, R., Li, X. F., & Wang, R. L. (2012). Bifidobacterium adolescentis supplementation ameliorates visceral fat accumulation and insulin sensitivity in an experimental model of the metabolic syndrome. *British Journal of Nutrition*, 107(10), 1429-1434.

Cho, N., Shaw, J. E., Karuranga, S., Huang, Y., da Rocha Fernandes, J. D., Ohlrogge, A. W., & Malanda, B. (2018). IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. *Diabetes research and clinical practice*, 138, 271-281.

Chou, L. S., & Weimer, B. (1999). Isolation and characterization of acid-and bile-tolerant isolates from strains of Lactobacillus acidophilus. *Journal of Dairy Science*, 82(1), 23-31.

Collado, M. C., Meriluoto, J., &Salminen, S. (2007). Role of commercial probiotic strains against human pathogen adhesion to intestinal mucus. *Letters in applied microbiology*, 45(4), 454-460.

Delia, E., Tafaj, M., &Männer, K. (2012). Efficiency of probiotics in farm animals. *Probiotic in animals*, 247-272.

Fossati, P., &Prencipe, L. (1982). Serum triglycerides determined colorimetrically with an enzyme that produces hydrogen peroxide. *Clinical chemistry*, 28(10), 2077-2080.

Fridewald, W. T. (1972). Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*, 18, 499-502.

Ghanbari, M., Rezaei, M., Jami, M., & Nazari, R. M. (2009). Isolation and characterization of Lactobacillus species from intestinal contents of beluga (Huso huso) and Persian sturgeon (Acipenser persicus).

Hasan, M. N., Sabrin, F., Rokeya, B., Khan, M. S. H., Ahmed, M. U., Matondo, A., &Akter, S. (2019). Glucose and lipid lowering effects of Enhydra fluctuans extract in cadmium treated normal and type- 2 diabetic model rats. *BMC complementary and alternative medicine*, 19(1), 1-10.

Hassan, M., Islam, M., Uddin, S., Bhowmik, A., &Rokeya, B. (2018). Antihyperglycemic Potential of Ethanolic Extract of Couroupitaguianensis on Streptozocin Induced Experimental Diabetic Rat Model. *Asian Journal of Research in Medical and Pharmaceutical Sciences*, 5(3), 1-10.

He, C., Shan, Y., & Song, W. (2015). Targeting gut microbiota as a possible therapy for diabetes. *Nutrition Research*, 35(5),361-367.

Hoque, M. Z., Akter, F., Hossain, K. M., Rahman, M. S. M., Billah, M. M., & Islam, K. M. D. (2010). Isolation, identification and analysis of probiotic properties of Lactobacillus spp. from selective regional yogurts. *World J Dairy Food Sci*, 5(1), 39-46.

Hossain, K. M., Barai, P., Rahman, S. M. M., Al Mazid, M. F., Gazi, M. S., & Jalil, M. A. (2018). Isolation and biochemical characterization of probiotic bacteria obtained from yogurt samples of Rajshahi and Chittagong divisions of Bangladesh and their antimicrobial activity against enteric pathogens. *Bangladesh Journal of Livestock Research*, 142-152.

Federation, I. D. (2019). IDF Diabetes Atlas, 9th edn. Brussels, Belgium; 2019.

Kendall, F. E. (1952). A simplified method for the estimation of total cholesterol in serum and demonstration of its specificity. *J biol Chem*, 195, 357-366.

Larsen, N., Vogensen, F. K., Van Den Berg, F. W., Nielsen, D. S., Andreasen, A. S., Pedersen, B. K., & Jakobsen, M. (2010). Gut microbiota in human adults with type 2 diabetes differs from non-diabetic adults. *PloS one*, 5(2), e9085.

Lu, Y. C., Yin, L. T., Chang, W. T., & Huang, J. S. (2010). Effect of Lactobacillus reuteri GMNL-263 treatment on renal fibrosis in diabetic rats. *Journal of bioscience and bioengineering*, *110*(6), 709-715.

Markowiak, P., &Śliżewska, K. (2017). Effects of probiotics, prebiotics, and synbiotics on human health. *Nutrients*, 9(9),1021.

Morelli, L., &Capurso, L. (2012). FAO/WHO guidelines on probiotics: 10 years later. *Journal of clinical gastroenterology*, 46,S1-S2.

Mudi, S. R., Akhter, M., Biswas, S. K., Muttalib, M. A., Choudhury, S., Rokeya, B., & Ali, L. (2017). Effect of aqueous extract of Aegle marmelos fruit and leaf on glycemic, insulinemic and lipidemic status of type 2 diabetic model rats. *Journal of Complementary and Integrative Medicine*, 14(2).

O'Shea, E. F., Cotter, P. D., Stanton, C., Ross, R. P., & Hill, C. (2012). Production of bioactive substances by intestinal bacteria as a basis for explaining probiotic mechanisms: bacteriocins and conjugated linoleic acid. *International journal of food microbiology*, 152(3), 189-205.

Ortiz-Martínez, M., González-González, M., Martagón, A. J., Hlavinka, V., Willson, R. C., & Rito-Palomares, M. (2022). Recent Developments in Biomarkers for Diagnosis and Screening of Type 2 Diabetes Mellitus. *Current Diabetes Reports*, 1-21.

Prasad, J., Gill, H., Smart, J., & Gopal, P. K. (1998). Selection and characterisation of Lactobacillus and Bifidobacterium strains for use as probiotics. *International Dairy Journal*, 8(12), 993-1002.

Reid, G., Anand, S., Bingham, M. O., Mbugua, G., Wadstrom, T., Fuller, R., Anukam, K., & Katsivo, M. (2005). Probiotics for the developing world. *Journal of clinical gastroenterology*, 39(6), 485–488.

Riezzo, G., Chiloiro, M., & Russo, F. (2005). Functional foods: salient features and clinical applications. *Current Drug Targets-Immune, Endocrine & Metabolic Disorders*, 5(3), 331-337.

Ruan, Y., Sun, J., He, J., Chen, F., Chen, R., & Chen, H. (2015). Effect of probiotics on glycemic control: a systematic review and meta-analysis of randomized, controlled trials. *PloS one*, 10(7), e0132121.

Spinler, J. K., Taweechotipatr, M., Rognerud, C. L., Ou, C. N., Tumwasorn, S., &Versalovic, J. (2008). Human-derived probiotic Lactobacillus reuteri demonstrate antimicrobial activities targeting diverse enteric bacterial pathogens. *Anaerobe*, 14(3), 166-171.

Stenvers, D. J., Scheer, F. A., Schrauwen, P., la Fleur, S. E., &Kalsbeek, A. (2019). Circadian clocks and insulinresistance. *Nature Reviews Endocrinology*, 15(2), 75-89.

Sunday, H. G., Sadia, A. H., & Ojo, O. G. (2022). Mechanisms of Diabetes Mellitus Progression: A Review. *Journal of Diabetic Nephropathy and Diabetes Management*, 1(1), 1-5.

Trinder, P. (1969). Determination of blood glucose using an oxidase-peroxidase system with a non- carcinogenic chromogen. *Journal of clinical pathology*, 22(2), 158-161.

Vries JV., 1954. Two methods for the determination of glycogen in liver. Biochem. J., 57: 410-416.

Walker, W. A. (2000). Role of nutrients and bacterial colonization in the development of intestinal host defense. *Journal of pediatric gastroenterology and nutrition*, 30, S2-S7.

Xanthopoulos, V., Litopoulou-Tzanetaki, E., &Tzanetakis, N. (2000). Characterization of Lactobacillus isolates from infant faeces as dietary adjuncts. *Food Microbiology*, 17(2), 205-215.

Yadav, H., Jain, S., & Sinha, P. R. (2007). Antidiabetic effect of probiotic dahi containing Lactobacillus acidophilus and Lactobacillus casei in high fructose fed rats. *Nutrition*, 23(1), 62-68.

Yadav, H., Jain, S., & Sinha, P. R. (2008). The effect of probiotic dahi containing Lactobacillus acidophilus andLactobacillus casei on gastropathic consequences in diabetic rats. *Journal of medicinal food*, 11(1), 62-68.

Yun, S. I., Park, H. O., & Kang, J. H. (2009). Effect of Lactobacillus gasseri BNR17 on blood glucose levels and body weight in a mouse model of type 2 diabetes. *Journal of applied microbiology*, 107(5), 1681-1686.

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ORIGINAL ARTICLE

LIFE SCIENCE

CAUSES AND CONSEQUENCES OF LIVESTOCK REARING DURING THE FALLOW PERIOD OF CROP PRODUCTION

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Abstract

There are a few compelling issues that make the coastal dwellers to accept livestock rearing as an alternative means of livelihood. The study examined the causes and consequences of livestock farming during the fallow period of crop production as perceived by the farmers. Data were collected from 111 villagers of Assasuni upazila of Satkhira district from May 08 to December 23, 2021. Respondents' perceptions regarding the causes and consequences of livestock rearing were the focus variable and the thirteen selected characteristics of the respondents were the independent issues. All the respondents (100%) had clear perception about the causes. 'Paddy was cultivated once a year and the land remains fallow during rest of the times' was the leading cause (1st ranked, 98.37%) of livestock rearing. Almost all of the respondents (98.2%) had high score on perception of consequences. 'It has been possible to earn some money from the fallow land' was the 1st ranked consequence (96.26%). Most of the respondents (92.8%) had faced highly severe problems. 'Shortage of food for cattle during the cropping season', 'lack of nutritious fodder' and 'lack of good medical treatment' were the main problems. Knowledge, number of trainings received, cosmopolitanism and extension media contact showed significant positive relationship with the farmers' perceptions on related causes, consequences and faced problem of livestock rearing. Based on the findings, it is recommended that respective authorities i.e., the Department of Livestock Services, the Department of Agricultural Extension and NGOs might foster livestock rearing to enhance this alternate livelihood in the study area.

Keywords: Causes, consequences, grazing land, livestock rearing, paddy field

Introduction

Bangladesh is predominantly an agricultural country and agriculture is the backbone of Bangladesh's economy. Livestock animals, are kept especially on a farm, for economic benefits. In Bangladesh, these are generally poultry, cattle, goats and sheep etc. Livestock constitutes an integral part of the wealth of a country, since in addition to draft power and leather; it provides manure, meat and milk to the vast majority of the people. About 61.82% of the people live in rural areas (Statista, 2021), and 48.4% of the total workforce is involved in agriculture (FAO, 2021), and agriculture contributes 17.5% of the gross domestic product (GDP) of the country (FAO, 2021). Majority of the rural people are dependent mainly on cropping and livestock farming for their livelihood. Livestock sub-sector is playing a crucial role in the traditional subsistence farming, contributing about 2.5% of the GDP (BIDS, 2019), and providing employment to 20% of the population as full-time and 50% of the population as part-time (Rahman et al., 2014). The majority of the rural households in Bangladesh have an average of 1.52 bovine animals (Banglapedia, 2021). The livestock sub-sector plays a vital role for the economic development of agro-based Bangladesh. About 48% of the meat comes from cattle (cow and buffalo), 40% from poultry and 12% from sheep and goats (Daily Star, 2018).

Almost every household (83.9%) in Bangladesh possesses livestock (Banglapedia, 2021). Members of the household have an affinity for rearing livestock and also expertise for caring their owned livestock. In the southwestern part of Bangladesh, a large area remains under monocropping. Only in monsoon, T. Aman rice is grown from September to December. In the other time of the year, large areas remained fallow due to a lack of fresh irrigation water; salinity problem and the underground water also contain soluble salt. On the other hand, the

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stored fresh water in the pond or small canals is not sufficient for crop cultivation. All the rivers and large canals remain full of saline water (Hoque, 2019). Now some government organizations and NGOs try to cultivate a second crop after short duration T. Aman rice variety, such as sunflower, mungbean, wheat, etc. However, during the cultivation of short-duration rice variety, the rice production is reduced and very often the second crop's cost of production is also very high. Thus, the farmers are not enough interested in that cropping system. In that area, very often people keep the land fallow and use it for grazing of different livestock such as cows, goats, sheep etc. But it is not well planned, the naturally born grass is directly eaten by the livestock in that area.

Livestock rearing is an important income generating activities that was initiated by the farmers, and eventually nurtured and aided by different government, non- government organizations for livelihood security of the rural villagers as they have scanty opportunity to earn livelihood during the fallow period. It is quite pertinent and necessary to know the other salient causes of participation of the rural farmers towards livestock rearing. But a very limited research work has been done on this aspect. Therefore, the researcher felt necessity to conduct a research entitled "Causes and consequences of livestock rearing during fallow period of crop production as perceived by the farmers".

In view of above-cited facts, the present study was conducted with the following specific objectives:

i. To point out the causes of livestock rearing;
ii. To explore the consequences of livestock rearing;
iii. To describe the socioeconomic characteristics of the respondents;
iv. To ascertain the relationship between the selected characteristics of causes and consequences; and
To find out the problems associated with livestock rearing.

Materials and Methods

The study was designed to investigate the causes and consequences of livestock rearing during fallow period of crop production. It was conducted at six different villages of Assasuni upazila under Satkhira district. The of collection of data was conducted by interviewing the villagers, both male and female. Data were collected from the randomly selected 111 respondents during May 08 to December 23, 2021. An ex-post facto explanatory cross sectional research design was used for the study (Hasan et al., 2018). The study was quasi-experimental and tried to predict the relationship of the selected characteristics of the respondents with the causes and consequences of livestock rearing. Data were collected through a face-to-face interview.

The selected 13 characteristics of the respondents, i.e., the independent issues, were (i) age, (ii) gender, (iii) family size, (iv) educational qualification, (v) livestock rearing experience, (vi) crop production experience, (vii) aquaculture experience, (viii) knowledge on agriculture, (ix) farm size, (x) monthly family income, (xi) training received, (xii) cosmopolitanism and (xiii) extension media contact. The focus variable of the study were the causes of rearing livestock, consequences produced as a result of livestock rearing and the problems faced while rearing the ruminant animals. All the selected characteristics were measured following standard procedure and then categorized and arranged in simple table for interpretation and discussion (Islam et al., 2019 and Mondol et al., 2019). Data analysis was done by using a micro-computer with SPSS and MS Excel. The researcher converted all qualitative data to quantitative form by means of applying some appropriate scoring technique. A coding plan was developed and code numbers were given to each category of measurements. Number, frequency, percentage, mean, standard deviation and range were used for statistical description. Pearson's Product Moment Correlation Coefficient 'r' was used to ascertain the relationship between selected characteristics of the respondents and the causes and consequences of livestock rearing. Throughout the study, five percent (0.05%) level of probability was used.

In this study, each respondent was asked to indicate the causes of different livestock rearing in the study locale. Ultimately 20 causes of livestock rearing were incorporated in the interview schedule. Each respondent was asked to indicate the score (rating scale) of the causes of livestock rearing against each of the statements. The causes of livestock rearing was rated as strongly agree, agree, undecided, disagree and strongly disagree and the rating scale was assigned as 5, 4, 3, 2, 1 respectively. The score of the causes of livestock rearing for a respondent was determined by summing up the scores of all the causes mentioned in the interview schedule. The possible range of causes' score was 20 to100 for the respondents.

To compare the perception of the respondents regarding the selected statements on causes of livestock rearing a Farmers' Perception on Causes Score (FPCS) was calculated by using the following formula (concept adopted and modified from Hamid et al., 2019):

$$FPCS = N_{sa}\times5+N_a\times4+N_u\times3+N_{da}\times2+N_{sda}\times1$$

Where, FPCS= Farmers' Perception on Causes Score; Nsa= Number of respondents rated the statement as strongly agree; Na= Number of respondents rated the statement as agree; Nu = Number of respondents rated the statement as undecided; Nda= Number of respondents rated the statement as disagree; Nsda= Number of respondents rated the statement as strongly disagree.

Farmers' Perception on Causes Index (FPCI) is the ratio of observed cause perception score to possible highest cause perception score and multiplied by 100. It was calculated the following formula:

$$FPCI\ (\%) = \frac{\text{Observed perception score on causes}}{\text{Possible highest perception score on causes}}\times100$$

On the basis of the obtained FPCI value ranking was done among the individual statements.

Similarly the Farmers' Perception on Consequences Score (FPCqS) and Farmers' Perception on Consequences Index (FPCqI) were calculated, and then the 20 consequence statements were ranked based on the obtained index value.

In this study, each respondent was asked to indicate his/her problems faced for rearing different livestock animals. Ultimately 10 problems of livestock rearing were incorporated in the interview schedule. Each respondent was asked to identify intensity of the problems of livestock rearing against each of the statements. The problem of livestock rearing was rated as highly severe, severe, moderately severe, less severe and not at all and the rating score was assigned as 4, 3, 2, 1, and 0, respectively. The problem of livestock rearing score of a respondent was determined by summing up the scores of all the problems mentioned in the interview schedule. The possible range of score was 0 to 40 for the respondents.

The severity of a problem of livestock rearing was determined based on Problem Severity Score (PSS). The PSS was determined by using the following formula (Islam et al., 2020):

$$PSS = N_1\times4+N_2\times3+N_3\times2+N_4\times1+N_5\times0$$

Where, N_1= Number of respondents faced the problems and rated as highly severe; N_2= Number of respondents faced the problems and rated as severe; N_3= Number of respondents faced the problems and rated as moderately severe; N_4= Number of respondents faced the problems and rated as less severe; and N_5= Number of respondents did not face the problems at all and rated as not faced at all.

After determination of PSS, the Problem Severity Index (PSI) for each of the problem was determined by following formula:

$$PSI\ (\%) = \frac{\text{Observed problem score in livestock rearing}}{\text{Possible highest problem score in livestock rearing}}\times100$$

Then the 10 problem statements were ranked based on the obtained index value.

Results and Discussion

A. Causes of livestock rearing

Every activity has its own happening reason. In the southwestern coastal area of Bangladesh a large part remains under monocropping, i.e., in monsoon *T. Aman* rice is grown and after harvesting that crop the arable land remains fallow, due to the effect of salinity. During this period most of the farmers rear livestock in that fallow arable land as there is some fodder available for grazing. However, this is not the sole reason for livestock rearing to be considered as the cause of livestock rearing. This study tried to find out the other salient causes of livestock rearing in the study area.

(i) Rank order of the causes of livestock rearing

The data presented in **Table 1** showed different causes of livestock rearing and their relative rank order position perceived by the respondents. The score of ranged from 324 to 546 whereas the possible range was 111 to 555.

Table 1. Rank order of the causes of livestock rearing as perceived by the respondents

Sl. No.	Causes of Livestock Rearing	Score	FPCI (%)	Rank
1.	Paddy is cultivated once a year and the land remains fallow	546	98.37	1st
2.	There is comparatively more time for grazing cattle	536	96.57	4th
3.	Naturally grown grass can be fed	526	94.7	5th
4.	A source of additional family income	543	97.8	2nd
5.	Anyone in the family can nurture it easily	538	96.9	3rd
6.	Milk and fuel are available from cows	515	92.7	6th
7.	It is the tradition of many aristocratic families	324	58.3	19th
8.	2nd or 3rd crop production is costly	415	74.7	17th
9.	The yield of 2nd or 3rd crop is also much less	410	73.8	18th
10.	Raising cattle is an easy way to save money	480	86.4	11th
11.	Livestock acts as a source of emergency money	497	89.5	9th
12.	Many people use cattle in religious festivals	471	84.8	12th
13.	Raising cattle is a dependent business	456	82.1	14th
14.	In need of social festivities. As; Marriage, Akika etc.	509	91.7	7th
15.	Due to the high price of cattle	465	83.7	13th
16.	With a little investment one can make a profit in less time	454	81.8	15th
17.	Cattle care is relatively easy	482	86.8	10th
18.	In addition to the main work, cattle can be easily reared	498	89.7	8th
19.	Some people kept cattle as a hobby	444	80.0	16th
20.	Algae are being used as cattle feed in the southern region	410	73.8	18th

(ii) Respondents' categorization on the basis of perception on the causes of livestock rearing

Results presented in Table 2 indicate that, all of the respondents (100%) had highly clear perception score (FPCS) for the causes of livestock rearing. The minimum and maximum score was 68 and 95 with the mean of 85.18 and standard deviation of 4.94.

Table 2. Distribution of the respondents according to their FPCS for livestock rearing

Causes	Categories of perception clarity	Score	N=111		Mean±SD	Range (observed)	
			Number	%		Min.	Max.
Livestock Rearing (Score)	Low	≤33	0	0	85.18 ±4.94	68	95
	Medium	34-66	0	0		Range (possible): 20-100	
	High	>66	111	100			

'Paddy is cultivated once a year and the land remains fallow at other times' is the main cause (1st) of livestock rearing in that area. Beside this, the other causes are 'a source of additional family income' (2nd), 'anyone in the family can nurture it easily' (3rd), 'there is comparatively more time for grazing cattle' (4th), 'naturally grown grass can be fed' (5th), and so on, as mentioned in Table 1. 'Algae are being used as cattle feed in the southern region' (18th), 'the yield of 2nd or 3rd crop is also much less' (18th) and 'it is the tradition of many local aristocratic families' (19th) are the least important reasons.

Livestock is the basis of survival for many of the poverty stricken people and the landless (<0.02 ha) households in Bangladesh. The poorest peoples often collect dung from fields for making dried dung cakes to sell to other people as fuel material during the winter.

The local office of the Department of Livestock (DLS) and the Department of Agricultural Extension (DAE) have also ratified the ranked reasons which have been mentioned by the respondents.

Sometimes, very poor people (very often the females) rear animals on shared ownership, whereby poor people care for richer people's animals in return for 50% of its production including offspring (Islam, 2008). Dairy provides a sustainable subsidiary occupation for the unemployed rural poor (Shamsuddoha, 2009).

B. Consequences of livestock rearing

Every cause has a result and consequence. Consequence means 'the effect, result, or outcome of something occurring earlier'. There might have many consequences of livestock rearing in the study area. However, by rigorous exploration, the researchers have found 20 vivid and visible consequences in the present study.

(i) Rank order of the consequences of livestock rearing

The data presented in Table 3 showed different consequences of livestock rearing and their relative rank order position as perceived by the respondents. The score of ranged from 213 to 534, where possible range was 111 to 555.

Table 3. Rank order of the consequences of livestock rearing as perceived by the respondents

Sl. No.	Consequences of Livestock Rearing	Score	FPCqI (%)	Rank
1.	Economic prosperity is coming	485	87.38	4th
2.	Livestock production has increased	468	84.32	7th
3.	The food security and nutrition needs of the villagers were largely met	386	69.54	17th
4.	These areas have become self-sufficient in meat	332	59.81	18th
5.	Milk production has increased	451	81.26	11th
6.	Extreme poverty has been somewhat eradicated	430	77.47	15th
7.	Many women have become self-reliant	467	84.14	8th
8.	Economic security has been ensured	449	80.90	12th
9.	Social conditions have improved	435	78.37	14th
10.	Appropriate use of natural resources has been ensured	481	86.66	5th
11.	It has been possible to earn some money from the fallow land	534	96.26	1st
12.	Cattle manure is being used in agriculture as organic manure	474	85.40	6th
13.	The use of chemical fertilizers is relatively low in these areas	243	43.78	19th
14.	Using dung in fish farming land is giving good results	510	91.89	2nd
15.	Peoples are getting a large amount of money from cattle	448	80.72	13th
16.	Money is being made available in times of crisis	461	83.06	9th
17.	Unemployment problems of many have been solved	425	76.57	16th
18.	It has created employment for the elderly and women	452	81.44	10th
19.	Proper use of uncultivated land has been ensured	489	88.10	3rd
20.	Social solidarity and brotherhood have been strengthened	213	38.37	20th

Through livestock rearing, 'it has been possible to earn some money from the fallow land' was the 1st ranked consequence. 'Using dung in fish farming land is giving good results' placed in 2nd rank. 'Proper use of uncultivated land has been ensured' (3rd), 'economic prosperity is coming' (4th) and 'appropriate use of natural resources has been ensured' (5th) obtained the immediate next positions respectively. The least ranked consequence was 'social solidarity and brotherhood have been strengthened' (20th).

All the consequences were good enough to bring some wellbeing for the local inhabitants of the study area. Department of Livestock (DLS) and the Department of Agricultural Extension (DAE) have also agreed the ranked consequences mentioned by the respondents.

(ii) Respondents' categorization on the basis of perception on the consequences of livestock rearing

The data presented in Table 4 indicate that almost all of the respondents (98.2%) had highly score of consequences and rest (1.8%) had medium score on perception of consequences of livestock rearing. The minimum and maximum score were 63 and 86 with the mean 77.20 and standard deviation of 4.21.

Table 4. Distribution of the respondents according to their FPCqS of livestock rearing

Consequences	Categories of perception clarity	Score	N=111		Mean±SD	Range (observed)	
			Number	%		Min.	Max.
Livestock Rearing	Low	≤33	0	0	77.20 ±4.21	63	86
	Medium	34-66	2	1.8		Range (possible): 20-100	
	High	>66	109	98.2			

Livestock rearing has enabled the local residents to earn some money from the fallow land. Besides, the dung is being used in fish farming land and is giving good results, milk production has increased tremendously, money is being made available in times of crisis, employment opportunity have been created for the elderly and women, etc. were some of the good consequences of livestock rearing.

Parveen (2008) opined that care of all livestock animals is an important domain for peoples. Cattle, sheep and goats are led to graze by older peoples and children, while housewives prepare feed, feed and clean animals, and very often milk cows. Jahan and Rahman (2003) also confirm this finding. Eggs and milk tend to be sold by peoples, primarily within the premise of the villages. Livestock rearing was found difficult for small families due to the small number of working members. Goat and cow rearing (even on a shared-basis) requires collection of fodder or taking the animals regularly for grazing. The farmers should be trained from grass production. Peoples often face difficulties to get support from government veterinary hospitals. This service should be made easily available for the farmers.

C. Socioeconomic characteristics of the respondents

Table 5 represents the socioeconomic characteristics of the respondents. Highest proportion (43.2%) of the respondents was middle aged. The minimum and maximum age was 19 and 85 years respectively with a mean of 43.72 years and standard deviation 14.47. Among the respondents 57.6% were male and 42.4% were female. The majority of the families (42.3%) were medium sized (4-6 members). The minimum and maximum family members of the respondents were 3 and 15 respectively with a mean of 5.09 and standard deviation of 1.86. The highest portion (57.7%) of respondents had secondary level of education. The minimum and maximum schooling years were 0 and 17 classes respectively with a mean of 6.88 and standard deviation of 4.61. Highest proportion (34.2%) of the respondents had low (≤10 years) and medium (11-20 years) level of livestock rearing experience with a mean of 20.12 and standard deviation 10.95. The maximum and minimum experiences range from 50 years to 5 years respectively.

The highest proportion (32.5%) of the respondents had high level (>20 years) of crop production experience with a mean of 23.81 and standard deviation 14. The maximum and minimum experiences range from 65 years to 5 years respectively. Also, the highest proportion (67.6%) of the respondents had no aquaculture experience with a mean of 15.58 and standard deviation of 8.21. The maximum and minimum experiences ranged from 40 years to 5 years respectively. Majority of the respondents (78.4%) had low knowledge regarding scientific method of livestock rearing, with minimum and maximum score of 0 and 8 respectively. The mean of this variable was 2.57 with a standard deviation of 1.39. The farm size of the maximum respondents (69.4%) was small (0.21-1.0 ha). The minimum and maximum land sizes of the respondents were 0.00 ha and 6.57 ha respectively with a mean of 0.6572 and standard deviation of 0.75. The highest portion of the respondents (65.8%) had medium income (10,000-20,000 BDT month-1) with a mean and standard deviation of 15,293.69 and 8,870.38 respectively. The minimum and maximum income was 5,000 BDT and 85,000 BDT.

Among the total respondents, 77.5% had no training in different agricultural sectors, and the maximum number of trainings was 2 to minimum 0 numbers of training. The majority of respondents (83.8%) had low cosmopolitanism. The minimum and maximum score of the respondents were 1 and 9 with a mean of 2.53 and a standard deviation 1.14. Most of respondents (97.3%) had rare extension media contact, and the minimum and a maximum score of the respondents were 6 and 25.

Table 5. Distribution of the respondents according to their socioeconomic characteristics

Respondents	Categories	Score	N=111		Mean±SD
			Number	%	
Age (Years)	Young	≤35	36	32.4	43.72 ± 14.47
	Middle	36-55	48	43.2	
	Old	>55	27	24.4	
Gender (Type)	Male		64	57.6	
	Female		47	42.4	
Family size (Numbers)	Small	≤4	46	41.4	5.09±1.86
	Medium	5-6	47	42.3	
	Large	>6	18	16.3	
Educational qualification (Schooling years)	Illiterate	0	17	15.3	6.88±4.61
	Can sign only	0.5	12	10.8	
	Primary	1-5	7	6.3	
	Secondary	6-10	64	57.7	
	Higher Secondary	11-12	6	5.4	
	Undergraduate	13-16	3	2.7	
	Postgraduate	>16	2	1.8	
Livestock rearing experience (Years)	No	0	1	0.9	20.12±10.95
	Low	≤10	38	34.2	
	Medium	11-20	38	34.2	
	High	>20	34	30.7	
Crop production experience (Years)	No	0	23	20.7	23.81±14.00
	Low	≤10	24	21.6	
	Medium	11-20	28	25.2	
	High	>20	36	32.5	
Aquaculture experience (Years)	No	0	75	67.6	15.58±8.21
	Low	≤10	20	18	
	Medium	11-20	11	9.9	
	High	>20	5	4.5	
Knowledge (Score)	Low	≤3	87	78.4	2.57±1.39
	Medium	4-6	21	18.9	
	High	>6	3	2.7	
Farm size (ha)	Landless	≤0.02	2	1.8	0.6572±0.75
	Marginal	0.02-0.2	15	13.5	
	Small	0.21-1.0	77	69.4	
	Medium	1.01-3	16	14.4	
	Large	>3	1	0.9	
Family income (BDT month^{-1})	Low	<10000	25	22.5	15293.69±8870.38
	Medium	10000-20000	73	65.8	
	High	>20000	13	11.7	
Training received (Numbers)	No	0	86	77.5	0.279±0.558
	Low	1	19	17.1	
	Medium	2	6	5.4	
	High	>2	0	0	
Cosmopolitanism (Score)	Low	≤3	93	83.8	2.53±1.14
	Medium	4-8	17	15.3	
	High	>8	1	0.9	
Extension media contact (Score)	No	0	0	0	14.16±4.35
	Rare	1-24	108	97.3	
	Occasional	25-48	3	2.7	
	Often	49-72	0	0	
	Regularly	>72	0	0	

D. Relationship between the selected characteristics of the respondents with the causes, consequences and problems of livestock rearing perceived by the respondents

Among the selected twelve characteristics (except 'gender', because gender is a nominal type of data and not suitable for correlation test) knowledge, cosmopolitanism and extension media contact had a significant and positive relationship with causes of livestock rearing at a 1% level of significance. It means that the higher the knowledge, cosmopolitanism and extension media contact the higher the perception of the causes of livestock rearing. Training received had a significant and positive relationship with causes of livestock rearing at a 5% level of significance. Educational qualification and family income had a positive but non-significant relationship. Age, family size, livestock experience, crop production experience, aquaculture experience and farm size had a non-significant and negative relationship.

Knowledge, training received, cosmopolitanism and extension media contact had a significant and positive relationship with consequences of livestock rearing at a 1% level of significance. It means that the higher the knowledge, training received, cosmopolitanism and extension media contact the higher the consequences of livestock rearing. Educational qualification, farm size and family income had a positive but non-significant relationship. Age, family size, livestock experience, crop production experience, and aquaculture experience had a non-significant and negative relationship.

Table 6. Relationship between the selected characteristics with causes, consequences and problems of livestock rearing [Pearson's Product Moment Correlation Coefficient 'r']

Characteristics (Independent issues)	Focus variable	
	Causes	Consequences
1. Age	-0.101	-0.168
2. Family size	-0.022	-0.028
3. Educational qualification	0.127	0.181
4. Livestock experience	-0.111	-0.154
5. Crop production experience	-0.034	-0.188
6. Aquaculture experience	-0.172	-0.163
7. Knowledge	0.290**	0.351**
8. Farm size	-0.030	0.047
9. Family income	0.013	0.124
10. Training received	0.215*	0.320**
11. Cosmopolitanism	0.313**	0.316**
12. Extension media contact	0.336**	0.250**

In fact, the causes and consequences regarding livestock rearing largely depend on contacts of the farmers with the service providers, and extension media. Frequent-communications with the service providers (e.g., extensionists, input dealers, livestock experts, etc.) and extension media (e.g., individual, group, and mass media) positively influenced the attitude of the farmers (both beneficiaries and non-beneficiaries) towards livestock rearing (Zahan, 2008; Sadat, 2002). Moreover, opinion, knowledge, and adoption of selected livestock programs were determined through extension media contact and attitude of the farmers (Kaur, 1988).

E. Problems related to livestock rearing

There is no venture which doesn't have any problems. Livestock rearing is also not an exception. The respondents faced various types of problems during the operationalization of livestock rearing. By consulting with the study area dwellers 10 problems were identified which have been mentioned in Table 7.

(i) Relative position (rank order) of the problems of livestock rearing as perceived by the respondents

The data showed in Table 7 are representing different problems of livestock rearing and their severity as perceived by the respondents. The score of severity ranged from 215 to 434, where possible range was 0 to 444.

Table 7. Relative position (rank order) of the problems of livestock rearing faced by the respondents

Sl. No.	Problems in Livestock Rearing	Score	PSI (%)	Rank
1.	There is a shortage of food for cattle during the cropping season	434	97.74	1st
2.	Lack of nutritious fodder	387	87.16	6th
3.	Sometimes grass cannot grow due to salinity and lack of water	426	95.94	2nd
4.	During the summer there is a shortage of potable water in the lake (beel)	434	97.74	1st
5.	Lack of good medical treatment for cattle	395	88.96	3rd
6.	There is no fair market system for buying and selling cattle	288	64.86	8th
7.	Social recognition and economic problems in raising cattle	215	48.42	9th
8.	Lack of government support.	370	83.33	7th
9.	Farmers lack training in cattle	389	87.61	5th
10.	Cattle theft occurs	390	87.83	4th

'Shortage of food or feed for cattle during the cropping season' and 'during the summer there is a shortage of potable water in the lake (i.e., beel)' were the jointly 1st ranked problems. 'Sometimes grass cannot grow due to salinity' and 'lack of water' placed in 2nd rank. 'Lack of good medical treatment for cattle', 'cattle theft occurs' and 'farmers lack training in cattle' obtained 3rd, 4th and 5th rank, respectively. If these faced problems have been controlled by the incumbent authority, and if the farmers get some aid and assistance to overcome the problems the production of the livestock might have increased tremendously.

(ii) Respondents categorization based on faced problems in livestock rearing

The data presented in Table 8 represent that the lion's share of the respondents (92.8%) had faced highly severe problems and the rest (7.2%) had faced severe problems. The minimum and maximum score was 22 and 38 with the mean 33.45 and standard deviation 2.44.

The respondents were rearing livestock as they didn't have a suitable alternative to earn livelihood in the fallow period when the arable land remain uncultivated. In a sense, the respondents were compelled to do so. However, the majority of them are facing a highly severe extent of problems that must be addressed and eradicated at the earliest possible time to sustain the productivity of the reared livestock.

Table 8. Distribution of respondents according to their perception on problems of livestock rearing

Problems	Categories	Score	N=111		Mean±SD	Range (observed)	
			Number	%		Min.	Max.
Livestock Rearing	Less severe	<11	0	0	33.45±2.44	22	38
	Moderately severe	11-20	0	0			
	Severe	21-30	8	7.2			
	Highly severe	>30	103	92.8			
						Range (possible): 0-40	

Conclusion

The most important cause was monoculture of paddy compels to keep land fallow which provoked them to rear livestock, and livestock rearing in fallow land contributes to earn livelihood. Though the prospects of livestock rearing regarding the causes and consequences are clear, the farmers faced highly severe problems such as shortages of food in cropping season and potable water in summer. The prospects of the farms regarding causes and consequences of livestock rearing were affected by farmers' knowledge, training received, cosmopolitanism and extension media contact. Thus, to boost up the existing practice of livestock rearing, the farmers should be provided with sufficient number of trainings and extension support so that they could overcome the existing problems and sustain the livelihood earning.

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References

Banglapedia.(2021).*Livestock*.https://en.banglapedia.org/index.php/Livestock#:~:text=On%20average%2C%20each%20household%20owns,of%20livestock%20over%20the%20households

BIDS (Bangladesh Institute of Development Studies). (2019). *Barriers to Development of Livestock Sub-sector in Bangladesh*. https://bids.org.bd/page/researches/?rid=36#:~:text=The%20livestock%20sub%2Dsector%20is,GDP%20is%20about%202.5%20percent

Daily Star. (2018). *Self-sufficient in fish, meat* (Feb 11, 2018). https://www.thedailystar.net/frontpage/self-sufficient-fish-meat-1532953

FAO (Food and Agriculture Organization of the United Nations). (2021). *Implementation of the Global Strategy in Bangladesh*. https://www.fao.org/asiapacific/perspectives/agricultural-statistics/global-strategy/results-in-the-region/bangladesh/en/

Hamid, M.I., Datta, S. and Islam, M.M. (2020). *Problems faced by the sub-assistant agriculture officers (SAAOs) working in department of agricultural extension*. Research in Agriculture, Livestock and Fisheries, 7(1): 61-73. DOI: *https://doi.org/10.3329/ralf.v7i1.46832*

Hasan, M.F., Begum, H. and Khatun, F. (2018). *Research Methodology in Social Sciences*. Borna Prokashoni, Dhaka, Bangladesh.

Hoque, M.E., Haque, S.S., Hossain, M.M., Sen, M. and Karmakar, S. (2019). *Water quality parameter as a predictor of small watershed land cover*. Ecological Indicators, 106, p.105462.

Islam, M.S., Islam, S., Islam, M., and Billah, M.M. (2019). *Exploring Women Participation in Small-scale Dairy Farming: A Case of Paikgachha Upazila, Khulna, Bangladesh*. Asian Journal of Research in Animal and Veterinary Sciences, 3(4), 1-13. https://journalajravs.com/index.php/AJRAVS/article/view/30051

Islam, M.Z.A. (2008). *Survival Strategies of the Female Displaces in Rural Bangladesh: A Study of Two Riparian Villages on the Right Bank of Jamuna*. XII World Congress of Rural Sociology, Goyang, Korea. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=Hd-1HMUAAAAJ&citation_for_view=Hd-1HMUAAAAJ:UeHWp8X0CEIC

Islam, S.S., Hasan, M.S., Ghosh, N., Islam, M.S. and Islam, M.M. (2020). *Prospects and Problems of Indigenous Sheep Production in South-Western Coastal Regions of Bangladesh*. The Journal of Agricultural Sciences - Sri Lanka, 16(1): 54-66. DOI: http://doi.org/10.4038/jas.v16i1.9183

Jahan, N. and Rahman, H. (2003). *Livestock Services and the Poor in Bangladesh: A Case Study*. Danish Agricultural Advisory Centre, Udkaersvej 15, Skejby, DK- 8200 Aarhus N, Denmark. An Initiative by Danida, IFAD and World Bank.

Kaur, M.R. (1988). *An Evaluative Study of Women Development Program Under Indo German Dhauladhar Project Palampur, District Kumgra, H. P.* Thesis Abstract, XVI (4): 258. 75. https://indcat.inflibnet.ac.in/index.php/thesesrequest?id=105104

Mondol, S., Mollick, A., Ahmed, M. B., and Islam, M. M. (2019). *Farmers' awareness regarding deforestation at Jalma union of Batiaghata upazila under Khulna district of Bangladesh*. Research in Agriculture Livestock and Fisheries, 6(2), 193–202. https://doi.org/10.3329/ralf.v6i2.42965

Parveen, S. (2008). *Access of Rural Women to Productive Resources in Bangladesh: A Pillar for Promoting their Empowerment*. International Journal of Rural Studies, 15(1): 1-8.

Rahman, S., Begum, I.A. and Alam, M.J. (2014). *Livestock in Bangladesh: distribution, growth, performance and potential*. Livestock Research for Rural Development, 26 (10). http://www.lrrd.org/lrrd26/10/rahm26173.html

Sadat, M.U. (2002). *Farmer"s Attitude towards Proshika: A Comparative Study between Proshika Beneficiaries and Non Beneficiaries*. M.S. (Ag. Ext. Ed.) Thesis. Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh.

Shamsuddoha, M. (2009). *Development of Livestock Sector through Leading NGO in Bangladesh*. The Annals of the "Ştefancel Mare" University Suceava. Fascicle of the Faculty of Economics and Public Administration, 9(1):1-9. 79

Statista. (2021). *Share of rural population in Bangladesh from 2011 to 2020*. https://www.statista.com/statistics/760934/bangladesh-share-of-rural-population/

Zahan, A. (2008). *Attitude of Rural Women towards Livestock Rearing*. M.S. (AEIS.) Thesis, Development of Agricultural Extension and Information System, Sher-E-Bangla Agricultural University, Dhaka

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ORIGINAL ARTICLE **LIFE SCIENCE**

PROFILING OF ANTIBIOTIC RESISTANT BACTERIA ISOLATED FROM POULTRY LITTER OF COMMERCIAL FARMS IN KHULNA DISTRICT, BANGLADESH

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Abstract

Microbial resistance to antibiotics has become a global threat that interferes with the interaction among humans, the environment, and microbes. Our study sought to detect antibiotic-resistant bacteria in light of the growing interest in using antibiotics in the poultry sector. We collected 24 poultry liter samples from 04 different upazilas of Khulna district (Batiaghata, Dumuria, Paikgachha and Koyra). Initially, 09 bacterial isolates were selected and among them, 77.78% bacteria were found gram positive. Subsequently, to characterize these bacteria, a toal of 10 biochemical tests (methyl red test, MacConkey agar test, indole test, catalase test, triple sugar iron test, mannitol salt agar test, oxidase test, Voges-Proskauer test, citrate test and nitrate test) were carried out in this experiment. Moreover, our study also isolated and amplified bacterial DNA for Sanger sequencing and finally disclosed 09 different antibiotic resistant bacterial species, namely *Priestia aryabhattai, Bacillus cereus, Priestia megaterium, Lysinibacillus macrolides, Rossellomorea aquimaris, Mammaliicoccus sciuri, Bacillus wiedmannii, Escherichia coli* and *Citrobacter freundii.* Further, disk diffusion assays were performed following CLSI guidelines and it unveiled the susceptibility and resistant properties of isolates against commonly used 08 antibiotics (penicillin 10U, tetracycline 20 µg, nitrofuran 300 µg, clindamycin 2 µg, azithromycin 15 µg, quinolones 5 µg, tetracycline 30 µg and penicillin 30 µg) in poultry farms. All of the bacterial isolates were found resistant to at least one of the antibiotics except *C. freundii* (isolate 9). Most of the isolates (66.67%) were resistant to nitrofuran, whereas all of them were susceptible to penicillin. Lastly, this study also made an effort to understand the evolutionary relationships of the identified species through a phylogenetic tree. Thus, the findings of this study will help farmers and common people to better understand the risk of developing antibiotic-resistant bacteria as a result of excessive antibiotic usage.

Keywords: Antibiotic resistance, CLSI, PCR, sanger sequencing

Introduction

Antibiotics transformed our society by allowing previously incurable illnesses to be treated and medical treatments such as surgery and chemotherapy to be conducted safely (Barriere, 2015). The discovery of antibiotics was a defining moment in the history of humankind. Hundreds of millions of lives have been saved, and our level of living has increased significantly. However, the time we have with these medications is going out. Antibiotics have been used so widely in humans and animals that many of them are losing their effectiveness to kill germs (Ventola, 2015).

Antibiotics are used by humans in an estimated 34.8 billion doses per year, with worldwide consumption growing by 65 percent between 2000 and 2015 (Klein et al., 2018). Antibiotics are provided unnecessarily 1 in every 5 times in the United Kingdom and this figure climbs to one in three in the United States (Pouwels et al., 2019).

Animal farming in low-resource settings is critical, since many nations migrate to more intensive animal farming techniques, resulting in increased antibiotic usage and, as a result, a larger risk of antibiotic resistance exposure in animals and humans throughout the world (Landers et al., 2012). As low to middle-income nations progress toward high-income status, there will be an ever-increasing demand for high-quality animal protein sources (Henchion et al., 2017).

Poultry is one of the most widely consumed foods on the planet. With nearly 90 billion tons of chicken meat produced each year, chicken is the most widely farmed animal (Machuve et al., 2022). As the need for protein rises,

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this business will continue to expand. Antibiotics must be used frequently during this process. Farmers and stakeholders rely heavily on intensive poultry farming to satisfy current demand, which necessitates the use of vaccinations, vitamins and minerals, and, most importantly, antibiotics (Pouwels et al., 2019). Antibiotics have aided in the efficient production of chicken, allowing consumers to acquire high-quality meat and eggs at an affordable price (Mehdi et al., 2018).

Currently, approximately 80% of all food-producing animals and birds receive medication for part or most of their lives (Truong et al., 2019). Even though the European Union has outlawed the use of antibiotics for growth promotion, there is little regulation of growth promotion drugs globally (Casewell et al., 2003). Because of the extensive use of antibiotics for growth promotion, illness prevention, and infection treatment in industrial animal food production, resistance may develop.

Antibiotic resistance develops naturally, although it has been exacerbated by overuse and abuse of antibiotics when bacteria's sensitivity to antibiotics changes and they gain the capacity to overcome the medications (Reygaert, 2018). The uprising of antibiotic-resistant bacteria results in severe health risks and economic collapse due to longer hospital stays, more medical expenses, and more fatalities that could have been avoided (Dadgostar, 2019). According to the World Health Organization (WHO), antibiotic resistance is one of the most serious health dangers to the world is facing (WHO, 2021). There is an estimated 4·95 million deaths associated with bacterial antibiotic resistance in 2019, including 1·27 million deaths attributable to resistant bacteria (Murray et al., 2022). Without immediate action, this number is expected to skyrocket. While new medications have been developed, they have not kept up with the rate of resistance (Podolsky, 2018).

The most resounding message that comes through from every new resistance study is that the pool of resistance genes and the mechanisms of resisting antibiotics, available to bacteria are effectively limitless (Hayes, 2022). However, the battle against antibiotic resistance is far from over. We must continue the struggle, which necessitates a greater understanding of the mechanisms of action of antimicrobial drugs as well as their mechanisms of resistance. But, most importantly, we must first identify the resistant bacteria.

Due to the growing use of PCR and DNA sequencing, 16S rRNA gene sequencing has become more important in clinical microbiology laboratories for the precise identification of bacterial isolates and the discovery of novel bacteria. 16S rRNA gene sequencing not only sheds light on the causes of infectious diseases, but also aids clinicians in selecting medications, estimating the length of treatment, and planning infection control measures (Woo et al., 2008). These predictions are more accurate and reasonable for bacterial identification because the intergenic spacer region of bacterial DNA encodes for 16s rRNA and this spacer region is unique for every strain of bacteria. Hence, our study shed light on profiling antibiotic resistant bacteria isolated from litter of poultry farms following both biochemical and molecular approaches. In addition, the evolutionary distances were computed among the isolated bacteria.

Materials and Methods

The sequential workflow of our research is presented in Figure 1.

Sample collection and isolation of bacterial isolates

A total of 24 poultry litter samples were collected from 04 different upazilas of Khulna district (Batiaghata, Dumuria, Paikgachha and Koyra). Dry, clean, and sterile polythene bags were used to collect samples. Later, 1g of sample was weighed out and diluted in 100 ml of distilled water followed by precipitation with blotting paper. The processed sample suspension was diluted in 10 ml test tubes until 1:100000 dilution was achieved. Samples from the 4^{th} and 5^{th} dilution tubes were selected for further processing. Subsequently, 1 ml from each dilution was aseptically spread on appropriately labeled nutrient agar plates that were previously sterilized by autoclaving at 121^{o}C for 15 mins. Finally, these nutrient agar plates were incubated at 37˚C for 24 hours. At the end of the incubation period, colonies with a specific shape, surface texture, and edge were picked and streaked on a new plate. In this process, a small amount of inoculum from each morphologically different single colony was streaked onto the nutrient agar plate and incubated at 37^{o}C for 24 h. Additionally, 40% glycerol was used to store each bacterial culture for long-term storage.

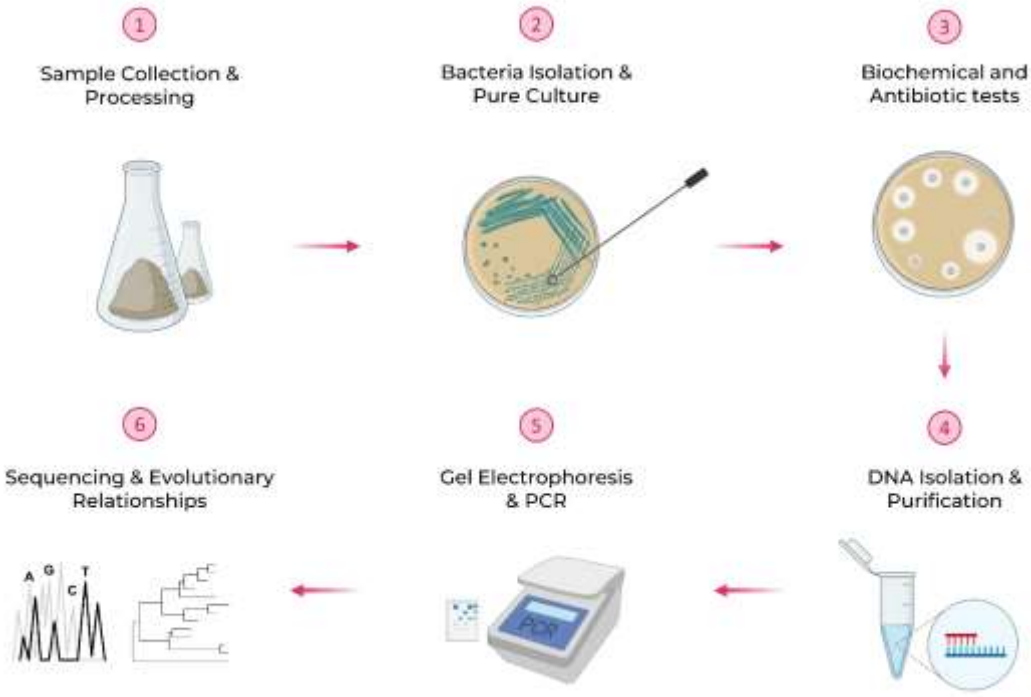

Figure 1. Schematic illustration of the overall general workflow of this study

Biochemical characterization of presumptive bacterial isolates

A standard gram staining procedure was followed to identify the gram-positive and gram-negative bacteria (Claus, 1992). However, the following biochemical tests were used to further identify and classify the isolates: methyl red test, MacConcy agar test, indole test, catalase test, triple sugar iron test, mannitol salt agar test, oxidase test, Voges-Proskauer test, citrate test and nitrate test. The outcomes from all biochemical tests were analyzed according to Bergey's manual of systematic bacteriology (Bergey, 1994).

Table 1. Class, generic and commercial names of the antibiotics with their concentrations.

Serial number	Class of antibiotics	Generic name of antibiotics	Commercial name of antibiotics	Concentration
1	Penicillin	Amoxicillin	Penvik	10U
2	Tetracycline	Oxytetracycline	Oxyvet	20 µg
3	Nitrofuran	Nitrofurantoin	Nintoin	300 µg
4	Clindamycin	Clindamycin	Clindacin	2 µg
5	Azithromycin	Azithromycin	Azith	15 µg
6	Quinolones	Ciprofloxacin	Ciprocin	5 µg
7	Tetracycline	Doxycycline	Vibramycin	30 µg
8	Penicillin	Amoxicillin	Amoxicillin	30 µg

Antibiotic sensitivity test

Eight different types of commercial antibiotic discs (6mm diameter) were used to screen out the resistant pattern among the isolated bacteria (Table 1). On the other hand, sterile blank discs impregnated with distilled water (200µl) was used as positive control. Kirby Bauer's disc diffusion, an antibiotic sensitivity test, was performed on Muller – Hinton agar (MHA) media following The Clinical & Laboratory Standards Institute (2006) guidelines. Hinton agar plates were prepared and sterilized by autoclaving at 121°C for 15 min. Standard suspensions of the isolates were adjusted to 0.5 McFarland Standard (McFarland, 1907). Immediately after standardization, 1 ml suspension was

spread on a petri dish by using a spreader, and a lawn culture was performed on the surface of the MHA plate. Then, discs were arranged on the surface of inoculated plates. The plates were incubated at 37°C for 24 hours.

Molecular characterization of bacterial isolates

The most reliable bacterial identification is the integration of morphological methods with molecular applications (Franco-Duarte et al., 2019). Thus in this experiment, total DNA was isolated by an automated DNA extractor (Maxwell 16, Promega, USA). Broad range universal primers (27F: AGAGTTTGATCMTGGCTC AG and 1492R: GGTTACCTTGTTACGACTT) were used to recognize conserved sequences within the 16S rRNA gene and amplified the intervening variable regions (Weisburg et al., 1991). Polymerase chain reactions (PCR) were carried out in a total volume of 20 uL containing 25 ng genomic DNA, 15 pMol of forward and reverse primers, and 10uL master mix. Reactions were run on a Gene Amp PCR system 2700 thermocycler (PE Applied Biosystems) programmed with the cycling conditions of: one cycle for 3 min at 95 °C, 35 cycles of 30 sec at 95 °C, 1 min at the appropriate annealing temperature at 48°C and 90sec at 72 °C, with a final extension of 5 min at 72 °C. The PCR products were then separated on a 1.0% agarose gel containing 1 mM ethidium bromide for visualization on a UV light box. The amplified gene fragments were purified with QIAquick Gel Extraction Kit and sequenced from Invent Technologies Ltd., Dhaka, Bangladesh.

Analysis of sequence and construction of a phylogenetic relationship

The raw sequence data from Sanger sequencing in ABI chromatogram file format was observed in finch TV software version 1.4.0. We converted them into FASTA format by ABI to FASTA Converter version 1.1.2. The FASTA format files were used to find out the strains from NCBI. Then we opened the FASTA files in MEGA 7.0 and aligned them using the muscle tool (Kumar et al., 2016). The extra parts were trimmed out. The tree was constructed following the neighbor-joining statistical method where the number of bootstrap replications was 1000. The evolutionary distances were computed using the Kimura 2-parameter method and are in the units of the number of base substitutions per site (Kimura, 1980; Saitou & Nei, 1987). The rate variation among sites was modeled with a gamma distribution (shape parameter = 1). All positions containing gaps and missing data were eliminated. There were a total of 1133 positions in the final dataset.

Results and discussion

Isolation and cultivation of unknown bacterial isolates

A total of 9 bacterial isolates (Isolate 1 to Isolate 9) were selected according to their distinct physical appearance (Figure 2). Later, they were subjected to biochemical and antibiotic susceptibility tests. The results of gram staining test revealed that the majority (77.78%) of the isolated bacteria were gram-positive whereas the rest of the isolates were found gram-negative (22.22%). Later, they were subjected to biochemical and molecular characterization.

Biochemical and molecular characterization of bacterial isolates

Results of all biochemical tests are summarized (Table 2) and illustrated (Figure 2) below. Additionally, comparative analysis of the sequences obtained from isolated bacterial DNAs with an already available database (NCBI BLAST) finally revealed all the bacterial species (Table 3). Among them, *Bacillus cereus*, *Lysinibacillus macrolides*, *Mammaliicoccus sciuri*, *Escherichia coli* and *Citrobacter freundii* were highly pathogenic for animal. *B. cereus* causes non-gastrointestinal infections, respiratory tract infections, and nosocomial infections ((Bottone, 2010). *M. sciuri* has been discovered as an opportunistic pathogen linked with mastitis, dermatitis, and exudative epidermitis on rare occasions (D et al., 2022). At least six separate pathotypes of *E. coli* are responsible for causing enteric illnesses like diarrhea or dysentery, while other pathotypes are responsible for extra-intestinal diseases like meningitis and urinary tract infections (Kaper et al., 2004).

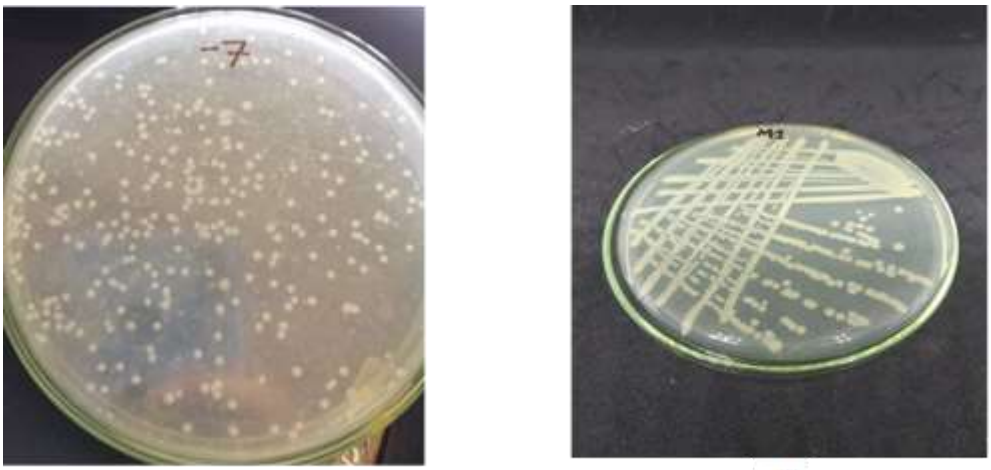

Figure 2. Bacteria was initially isolated on crowed plates (A) and then pure culture were prepared from those isolates (B).

Table 2. Results of biochemical tests for bacterial isolate identification including gram staining.

Strain	MR	MAC	VP	IND	TSI	CAT	NIT	OXI	CIT	MAN	GS
Isolate 1	-	-	-	-	K/K	+	-	-	-	-	+
Isolate 2	-	-	-	-	K/K	+	-	-	-	-	+
Isolate 3	+	-	-	-	K/A	+	+	+	+	-	+
Isolate 4	-	-	-	-	K/K	+	-	+	+	-	+
Isolate 5	-	-	-	-	K/K	+	+	-	-	-	+
Isolate 6	+	-	-	-	K/K	+	+	+	+	+	+
Isolate 7	+	-	-	-	K/A	+	+	-	-	-	+
Isolate 8	+	+	-	+	A/A	+	+	-	-	-	-
Isolate 9	+	+	-	-	K/A	+	+	-	+	-	-

Here, MR: Methyl Red; VP: Voges-Proskauer; TSI: Triple Sugar Iron; CAT: Catalase; IND: Indole; OXI: Oxidase; NIT: Nitrate; MAC: MacConkey; CIT: Citrate; MAN: Mannitol; GS: Gram Staining.

Table 3. Bacterial species identified by 16S rRNA gene sequencing of isolates obtained from poultry liter (mostly 98% identity).

Isolate No.	Scientific Name	Strain	Accession	% of similarity
Isolate 1	*Priestia aryabhattai*	WTB77	MK241860.1	98.73
Isolate 2	*Bacillus cereus*	NA-28	MN882654.1	99.51
Isolate 3	*Priestia megaterium*	Ni2_2	MH762123.1	98.88
Isolate 4	*Lysinibacillus macrolides*	KPB6	MH542661.1	99.35
Isolate 5	*Rossellomorea aquimaris*	AP BFT2	MK934550.1	96.31
Isolate 6	*Mammaliicoccus sciuri*	AA1	MT275460.1	98.88
Isolate 7	*Bacillus wiedmannii*	B16-2	MT256061.1	99.26
Isolate 8	*Escherichia coli*	JCD1	MH517447.1	98.66
Isolate 9	*Citrobacter freundii*	DSR1	MH181794.1	98.29

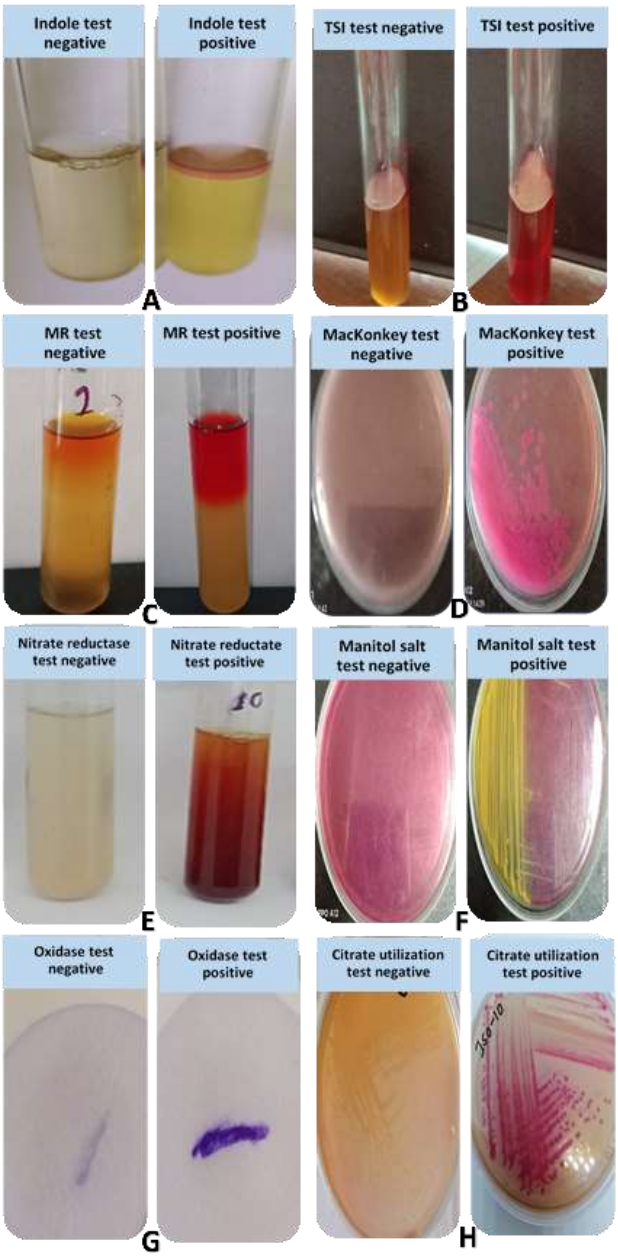

Figure 3: Figure showing the positive and negative outcomes of biochemical tests: Indole test (A), Triple sugar iron test (B), Methyl red test (C), MacConkey agar test (D), Nitrate reductase test (E), Mannitol salt test (F), Oxidase test (G) and Citrate utilization test (H).

Antibiotics susceptibility profiling of isolated bacteria

All the isolates were subjected to antibiotic susceptibility test against 9 commercially available antibiotics following CLSI guidelines (Figure 4). The obtained result revealed high level of multi-drug resistance among the isolates. It was observed that majority of the bacterial isolates were resistant to nitrofurantoin (66.66%), followed by doxycycline (55.55%), azithromycin (33.33%), oxytetracycline (22.22%) and amoxicillin (22.22%) (Table 4; Figure 5).

The resistance of gram-negative bacteria to nitrofurantoin is 100% followed by amoxicillin 50%. *E.coli*, a gram-negative bacteria showed multiple antibiotic resistance, namely nitrofurantoin, doxycycline, and amoxicillin. In the present study, none of the gram-negative isolates showed resistance against ciprofloxacin. This was different from other studies that have been performed in Bangladesh (Hasan et al., 2020). Among Gram-positive bacterial isolates, the most striking multiple drug-resistant isolates, which were resistant to 4 antibiotics, was *B. cereus* (isolate-2*)* followed by *L. macroides (*isolate-4*)*. On contrary, the only multi-resistant gram-negative bacterial isolate was *E.coli* (isolate-8).

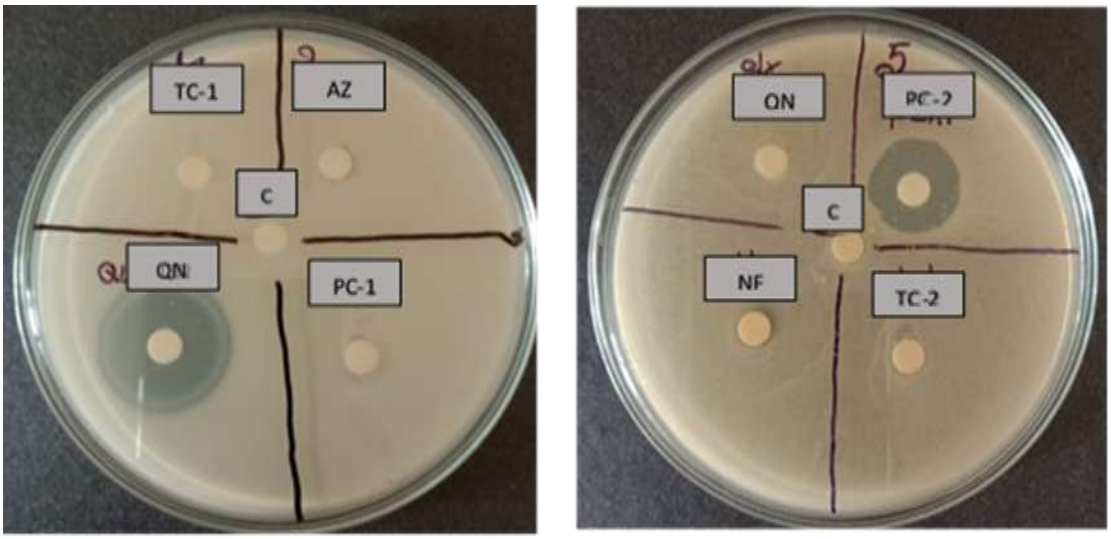

Figure 4. Antibiotic treatments against *B. cereus* (A) and *L. macrolides* (B). Here, TC: Tetracyclin; AZ: Azithro-mycin; QN: Quinolones; PC: Penicillin; NF: Nitrofuran and C: Control.

Table 4. Sensitivity of different bacterial isolates to different antibiotics.

Isolates	Antibiotics							
	Penicillin	Tetracycline	Nitrofuran	Clindamycin	Azithromycin	Quinolones	Tetracycline	Penicillin
P. aryabhattai	S	S	R	S	R	S	R	S
B. cereus	R	R	S	S	R	S	R	R
P. megaterium	S	S	R	S	R	S	S	S
L. macrolides	S	R	R	S	S	R	R	S
R. aquimaris	S	S	R	S	S	S	S	S
M. sciuri	R	S	S	S	S	S	S	S
B. wiedmannii	R	S	R	S	S	S	R	S
E. coli	S	S	R	S	S	S	R	R
C. freundii	S	S	S	S	S	S	S	S

Here, S= Susceptible and R= Resistant

Construction of evolutionary relationship among the isolates

The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree (Figure 6). There are 3 main clades in the tree. They are two *Bacillus* bacteria (clade1), two *Priestia* bacteria (clade 2), and *Citrobacter* and *Escherichia* (clade 3). *Rossellomorea*, *lycinibacillus,* and *mammalicoccus* are three outgroups. From the tree, we can see that *R. aquimaris* and *C. freundii* have gone through the most genetic change.

One of the main two branches of the tree is gram-negative (*C. freundii* and *E. coli*) and the other one is gram-positive which also supports our gram staining results.

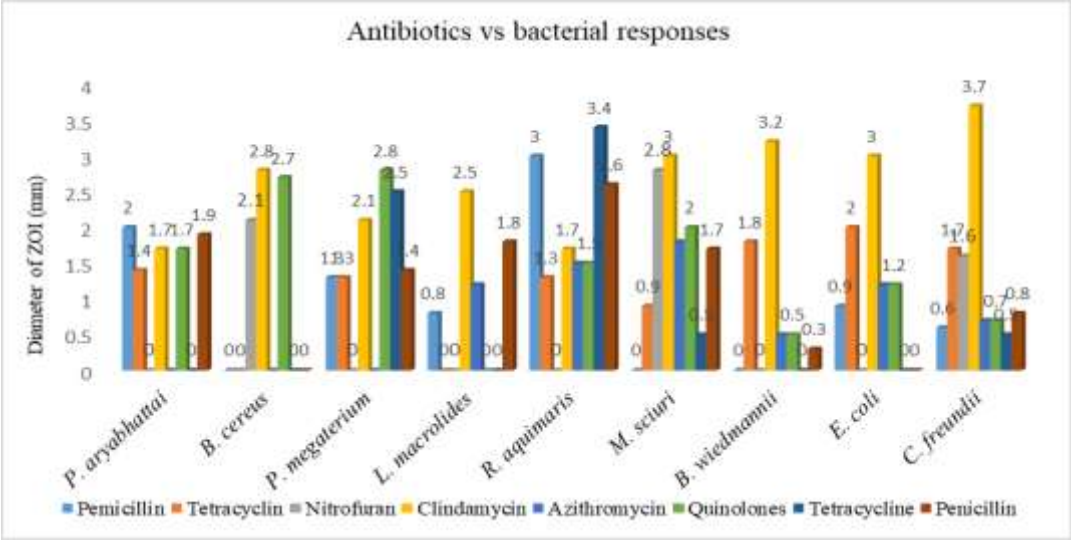

Figure 5. Bar diagram showing the responses of bacterial isolates against different antibiotics. Zone of inhibition (ZOI) was measured (mm) for antibiotic sensitive bacteria.

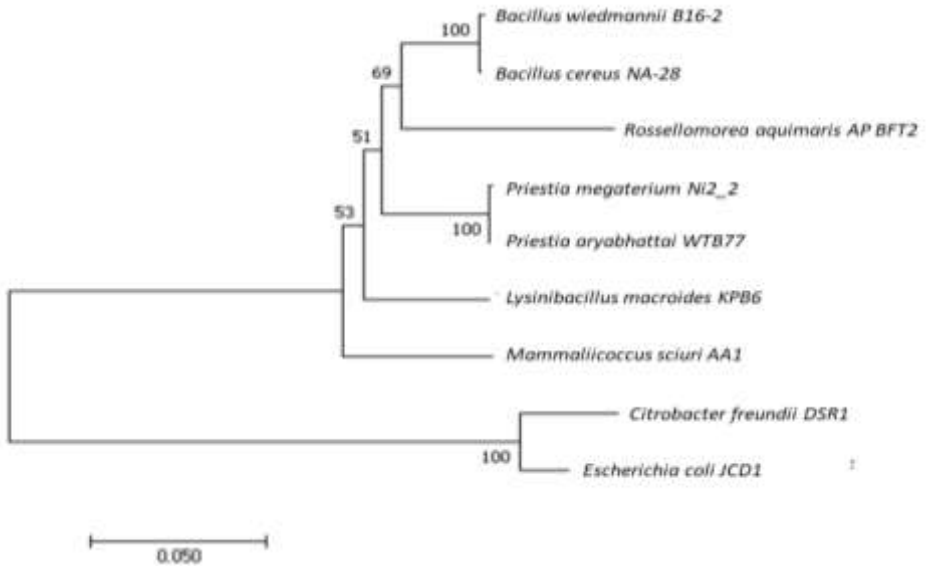

Figure 6. Evolutionary relationships of taxa. The optimal tree with the sum of branch length = 0.49176152 is shown. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown next to the branches.

Conclusion

We can infer from our experiment and the aforementioned data that the bacteria in the various poultry farms in the Khulna district have alarmingly evolved antibiotic resistance. Given that the majority of the chicken farms in our nation use excessive antibiotics, there is a great likelihood that the same situation will occur there as well. The majority of the bacteria we've discovered in our experiments are pathogenic, meaning they can result in serious

illnesses in people like meningitis, brain abscesses, endophthalmitis, pneumonia, gas gangrene, tropical ulcer formations, dermal and/or respiratory infections, mastitis, dermatitis, and exudative epidermitis, infections of the skin, soft tissues, CNS, and urinary tract, among other conditions. We found that the majority of the bacteria and their evolution are similarly based on sequencing analysis and phylogenetic relationships. This study's results are scientific evidence and could justify that excessive antibiotic usage can lead to produce several antibiotic-resistant bacteria. However, there is a need for further study on the antibiotic resistance genes and genetic relatedness of these isolates.

Authors' contributions

AH designed and prepared the proposal, analyzed data, wrote and revised the manuscript. SR conducted the field and laboratory work, analyzed data and revised the manuscript. MHP analyzed data, reviewed the manuscript and edited the language. AH and MH reviewed the manuscript, analyzed data and edited the language. All authors read and approved the final manuscript.

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Conflict of Interests

The author declares no conflict of interest.

References

Barriere, S. L. (2015). Clinical, economic and societal impact of antibiotic resistance. *Expert Opinion on Pharmacotherapy*, *16*(2), 151–153. https://doi.org/10.1517/14656566.2015.983077

Bergey, D. H. (1994). Bergey's manual of determinative bacteriology. Lippincott Williams & Wilkins.

Bottone, E. J. (2010). *Bacillus cereus*, a Volatile Human Pathogen. *Clinical Microbiology Reviews*, *23*(2), 382. https://doi.org/10.1128/CMR.00073-09

Casewell, M., Friis, C., Marco, E., McMullin, P., & Phillips, I. (2003). The European ban on growth-promoting antibiotics and emerging consequences for human and animal health. *Journal of Antimicrobial Chemotherapy*, *52*(2), 159–161. https://doi.org/10.1093/jac/dkg313

Claus, D. (1992). A standardized Gram staining procedure. *World Journal of Microbiology and Biotechnology*, *8*(4), 451–452. https://doi.org/10.1007/BF01198764

Clinical and Laboratory Standards Institute (2006). Performance standards for antimicrobial disk susceptibility tests; Approved standard— 9th ed. CLSI document M2-A9. 26:1. Clinical Laboratory Standards Institute, Wayne, PA.

D, V. der V., C, H., M, V., C, M., S, B., S, W., & F, L. (2022). Genome-Based Characterization of a Plasmid-Associated Micrococcin P1 Biosynthetic Gene Cluster and Virulence Factors in Mammaliicoccus sciuri IMDO-S72. *Applied and Environmental Microbiology*, *88*(4). https://doi.org/10.1128/AEM.02088-21

Dadgostar, P. (2019). Antimicrobial Resistance: Implications and Costs. *Infection and Drug Resistance*, *12*, 3903–3910. https://doi.org/10.2147/IDR.S234610

Franco-Duarte R., Černáková L., Kadam S., Kaushik K.S., Salehi B., Bevilacqua A., Corbo M.R., Antolak H., Dybka-Stępién K., Leszczewicz M., et al (2019). Advances in chemical and biological methods to identify microorganisms—from past to present. Microorganisms. doi: 10.3390/microorganisms7050130

Hasan, M., Hossain, M. K., Rumi, N. A., Rahman, M. S., & Hosen, M. A. (2020). Isolation and characterization of multiple drug-resistant bacteria from the waste of hospital and non-hospital environment. *Asian Journal of Medical and Biological Research*, *6*(3), 460–468. https://doi.org/10.3329/ajmbr.v6i3.49794

Hayes, J. F. (2022). Fighting Back against Antimicrobial Resistance with Comprehensive Policy and Education: A Narrative Review. *Antibiotics (Basel, Switzerland)*, *11*(5). https://doi.org/10.3390/antibiotics11050644

Henchion, M., Hayes, M., Mullen, A. M., Fenelon, M., & Tiwari, B. (2017). Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods (Basel, Switzerland)*, *6*(7). https://doi.org/10.3390/foods6070053

Kaper, J. B., Nataro, J. P., & Mobley, H. L. T. (2004). Pathogenic *Escherichia coli*. *Nature Reviews Microbiology*, *2*(2), 123–140. https://doi.org/10.1038/nrmicro818

Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution*, *16*(2), 111–120. https://doi.org/10.1007/BF01731581

Klein, E. Y., Van Boeckel, T. P., Martinez, E. M., Pant, S., Gandra, S., Levin, S. A., Goossens, H., & Laxminarayan, R. (2018). Global increase and geographic convergence in antibiotic consumption between 2000 and 2015. *Proceedings of the National Academy of Sciences*, *115*(15), E3463–E3470. https://doi.org/10.1073/pnas.1717295115

Kumar, S., Stecher, G., & Tamura, K. (2016). MEGA7: Molecular Evolutionary Genetics Analysis Version 7.0 for Bigger Datasets. *Molecular Biology and Evolution*, *33*(7), 1870–1874. https://doi.org/10.1093/molbev/msw054

Landers, T. F., Cohen, B., Wittum, T. E., & Larson, E. L. (2012). A review of antibiotic use in food animals: Perspective, policy, and potential. *Public Health Reports (Washington, D.C.: 1974)*, *127*(1), 4–22. https://doi.org/10.1177/003335491212700103

Machuve, D., Nwankwo, E., Mduma, N., & Mbelwa, J. (2022). Poultry diseases diagnostics models using deep learning. *Frontiers in Artificial Intelligence* (Vol. 5).

McFarland, J. (1907). Nephelometer: an instrument for media used for estimating the number of bacteria in suspensions used for calculating the opsonic index and for vaccines. J *Am Med Assoc* 14:1176-1178.

Mehdi, Y., Létourneau-Montminy, M.-P., Gaucher, M.-L., Chorfi, Y., Suresh, G., Rouissi, T., Brar, S. K., Côté, C., Ramirez, A. A., & Godbout, S. (2018). Use of antibiotics in broiler production: Global impacts and alternatives. *Animal Nutrition*, *4*(2), 170–178. https://doi.org/10.1016/j.aninu.2018.03.002

Murray, C. J. L., Ikuta, K. S., Sharara, F., Swetschinski, L., Robles Aguilar, G., Gray, A., Han, C., Bisignano, C., Rao, P., Wool, E., Johnson, S. C., Browne, A. J., Chipeta, M. G., Fell, F., Hackett, S., Haines-Woodhouse, G., Kashef Hamadani, B. H., Kumaran, E. A. P., McManigal, B., … Naghavi, M. (2022). Global burden of bacterial antimicrobial resistance in 2019: A systematic analysis. *The Lancet*, *399*(10325), 629–655. https://doi.org/10.1016/S0140-6736(21)02724-0

Podolsky, S. H. (2018). The evolving response to antibiotic resistance (1945–2018). *Palgrave Communications*, *4*(1), 124. https://doi.org/10.1057/s41599-018-0181-x

Pouwels, K. B., Hopkins, S., Llewelyn, M. J., Walker, A. S., McNulty, C. A., & Robotham, J. V. (2019). Duration of antibiotic treatment for common infections in English primary care: Cross sectional analysis and comparison with guidelines. *BMJ (Clinical Research Ed.)*, *364*, l440. https://doi.org/10.1136/bmj.l440

Ranjan, K. P., & Ranjan, N. (2013). Citrobacter: An emerging health care associated urinary pathogen. *Urology Annals*, *5*(4), 313.

Reygaert, W. C. (2018). An overview of the antimicrobial resistance mechanisms of bacteria. *AIMS Microbiology*, *4*(3), 482–501. https://doi.org/10.3934/microbiol.2018.3.482

Saitou, N., & Nei, M. (1987). The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution*, *4*(4), 406–425. https://doi.org/10.1093/oxfordjournals.molbev.a040454

Schuller, M., Sloots, T. P., James, G. S., Halliday, C. L., Carter, I. W. J. (2010). PCR for Clinical Microbiology *Volume 876* || Universal Bacterial Identification by PCR and DNA Sequencing of 16S rRNA Gene. , 10.1007/978-90-481-9039-3(Chapter 28), 209–214. doi:10.1007/978-90-481-9039-3_28

Truong, L., Morash, D., Liu, Y., & King, A. (2019). Food waste in animal feed with a focus on use for broilers. *International Journal of Recycling of Organic Waste in Agriculture*, *8*(4), 417–429. https://doi.org/10.1007/s40093-019-0276-4

Ventola, C. L. (2015). The antibiotic resistance crisis: Part 1: Causes and threats. *P & T: A Peer-Reviewed Journal for Formulary Management*, *40*(4), 277–283.

Weisburg, W. G., Barns, S. M, Pelletier, D. A., Lane, D. J. (1991). "16S ribosomal DNA amplification for phylogenetic study". *Journal of Bacteriology*. 173 (2): 697–703. doi:10.1128/jb.173.2.697-703.1991

Woo, P. C. Y., Lau, S. K. P., Teng, J. L. L., Tse, H., & Yuen, K. (2008). Then and now: use of 16S rDNA gene sequencing for bacterial identification and discovery of novel bacteria in clinical microbiology laboratories. *Clinical Microbiology and Infection*, *10*(14), 908–934.

World Health Organization. (2021). A report on "Antimicrobial resistant". Retrieved from https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance.

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ORIGINAL ARTICLE

LIFE SCIENCE

DRY MATTER ALLOCATION AND GRAIN YIELD OF WHEAT AS INFLUENCED BY SOLAR RADIATION LEVEL AND PLANT DENSITY

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Abstract

An experiment was conducted from November 2018 to March 2019 to identify the effect of radiation levels and plant population on dry matter allocation and yield of wheat with the variety 'BARI Gom 25'. The study was set out in the Randomized Complete Block Design with four radiation levels (full sunlight, 75% light, 55% light and 25% light) and three plant densities (160 plants m^{-2}, 200 plants m^{-2}, 230 plants m^{-2}) that replicated thrice. Full sunlight or 75% light in combination with optimal plant density (200 plants m^{-2}) resulted maximum culm dry weight, leaf dry weight, spike dry weight and total dry matter weight $plant^{-1}$. The numbers of filled grain and unfilled grain $plant^{-1}$ and yields of grain and straw m^{-2} were the highest from the above-mentioned combination. The lowest dry weights for culm, leaf, spike, and total dry matter and minimum grain yield and straw yield were obtained from 25% light either alone or in combination with any plant densities indicating the profound influence of light on dry matter production and grain yield of wheat. Therefore, reduced light (up to 25%) and optimal plant density can ensure wheat production without significant yield loss. This finding suggests possibility of wheat cultivation in agroforestry system and light limiting areas in Bangladesh and other parts of the world.

Keywords: Wheat, radiation level, plant density, dry matter partitioning, grain yield

Introduction

Wheat, the top cereal crop in the world, ranks second just after rice in Bangladesh. For developing countries, wheat serves as the main source of protein and second most important source of calories (Braun et al., 2010). Production of wheat in Bangladesh is highly variable due to different agro-climatic conditions and average yield is much lower compared to rest of the world. Wheat production needs to increase in the country as the area under wheat is decreasing day by day. Moreover, demand of wheat is increasing due to population pressure. It is expected that yield of wheat may reduce by 15% - 30% just for increase of global temperature by 2 °C within 2040 (Moore and Lobell, 2014; Zhao et al., 2017). Thus, shortage of food is a likely phenomenon in Bangladesh. Therefore, Bangladesh including other developing countries of the world need to make an attempt to grow grain crops on land that remain fallow due to environmental issues.

Wheat is a cool-season crop; requires cool weather for vegetative growth and warm weather for maturity. Solar radiation is an important climatic factor directly influenced the growth and yield of crops including wheat. Solar radiation i.e. light determines photomorphogenesis of plant along with rate of photosynthesis (Albayrak et al., 2011). In fact, light intensity and quality controls plant growth and development through triggering plant physiological reactions (Bozorgi et al., 2011). Received light increases plant biomass that contributes to the crop growth, dry matter production and yield (Poorter and Nagel, 2000; Asseng et al., 2004). Low light reduces plant growth, development, dry matter production and yield (Strain and Cure, 1986) and excess light reduces crop yield through photoinhibition and burning crop canopy (Hasanuzzaman et al., 2012). At optimal light, plant growth is maximum through maximal photosynthesis (Lichtenthaler, 1996). However, low light intensity due to presence of aerosols and air pollutants in the atmosphere appears as a challenge for producing crop in various parts of the world (Mu et al., 2010). Low cloud reduced the light by 25% - 60% in the southern Appalachian Mountains of USA (Reinhardt et al., 2010) and the reduction was 30% - 44% in an apricot-based agroforestry system (Zhang et al.,

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DOI: https://doi.org/10.53808/KUS.2022.19.02.2239-ls

2018). Steady cloudy days or rainfall at critical crop growth stages (e.g. panicle differentiation, grain-filling) make poor quality grains along with loss of grain yield (Janardhan et al., 1980).

Plant density expresses the number of plant population in a unit area, a determinant of allowable space for a single plant. Plant density can affect growth, development and yield of a crop through modulating crop's microenvironment. Increase of plant density beyond optimal limit decreases crop growth and yield (Cakmak et al., 1994). Plant can intercept majority of the photosynthetically active radiation (≥95%) at optimal density resulting highest yield (Dong et al., 2014) and beyond this yield decreases due to decrease of radiation use efficiency (Pommel and Bonhomme, 1998). However, dense planting of wheat can increases the leaf area index, rate of photosynthesis, filled spikelets (%), 1000-grain weight, and grain yield (Nakano et al., 2012). Though there are some studies that evaluated the response of plant population density on growth and yield of wheat; limited information is available on effects of light intensity alone or in combination with plant population density on dry matter partitioning and yield of wheat. Therefore, the objective of this study is to elucidate the effect of light intensity and plant density on the dry matter allocation and grain yield of wheat.

Materials and Methods

Experimental site, treatment and design

The experiment was conducted at the Field Laboratory of Agrotechnology Discipline of Khulna University, Khulna with the wheat variety 'BARI Gom 25' during the *Rabi* season (November 2018 to March 2019) having low temperature, low rainfall, low relative humidity and plenty of sunshine. The experimental area is under the Agro-ecological Zone (AEZ) 13 (Ganges Tidal Floodplain) having sub-tropical climate and the soil was clay loam having a pH of 7.6. The variety 'BARI Gom 25' is a semi-dwarf, early maturing, low to medium salt tolerant (8-10 dsm^{-1}), high yielding wheat variety released by Bangladesh Agricultural Research Institute (BARI) of Gazipur (BARI, 2012) particularly for southern region (e.g. Khulna) of the country. The field was prepared to good tilt through ploughing, cross ploughing and laddering and divided into 36 experimental unit each accounting an area of 6 m^2 (3.0 m x 2.0 m) and maintaining 1 m distance between plots and 1.5 m distance between replications and then fertilized with 220, 160, 45 and 115 $kgha^{-1}$, respectively for urea, TSP, MoP and gypsum along with 7 t ha^{-1} cow dung. During final land preparation, one-third of urea and full dose of other fertilizers were applied, and remaining urea was applied in two equal halves at 20 and 40 days after sowing (DAS). The experiment was set out in randomized complete block design with four levels of radiation (full sunlight, 75% light, 55% light, 25% light) and three plant densities [160 plants m^{-2}, 200 plants m^{-2} (optimal), 230 plants m^{-2}] that has been replicated thrice. The seed rate was calculated following plant density treatments and sown directly in line maintaining 20 cm between lines on 16 November 2018. The screens [one layer white net, two layer white net, and two layer markin cloth] were placed over the plot at 35 DAS. Intercultural operations (gap filling, irrigation, weed and insect-pest control) were done as per requirement.

Light measurement

Two-type screens (white net and white markin cloth) were bought from the market and light level under one layer and two layers of white net and two layers of markin cloth were measured several times using Digital Lux Meter (LX1010BS, Taiwan) and compared with that of open field. It revealed that light levels under one layer and two layer of white net were 75% and 55% of full sunlight, respectively and light under two layers of markin cloth was 25% of full sunlight; therefore, the light levels (75%, 55%, 25%) under nets along with full sun (open field) were considered as the treatments. Light intensity at upper canopy and lower canopy from the open field and under the screens (at different levels of solar radiation) was measured at 45, 60, 75, and 90 DAS using the lux meter.

Growth and yield parameters

Five plants from each plot were selected randomly to collect data on culm dry weight (g), leaf dry weight (g), spike dry weight (g), and total dry weight (g) for individual plant starting at 45 DAS and continue up to 90 DAS. The collected plant parts were placed in a labelled brown paper bag and dried in an oven (60 °C temperature for 48 hours. Just before final harvest, five plants were randomly harvested for collecting yield-contributing data. During final harvest, an area of one m^2 was harvested with sickles and sun dried for 2-3 days; threshed, winnowed, separated the clean grains and was weighed to calculate grain yield and straw yield.

Statistical analysis

The collected data on various dry matter and yield parameters were analyzed following ANOVA and F-test using Statistix 10 statistical program. Data means were separated by Duncan's Multiple Range Test at $P \leq 0.05$.

Results and Discussion

Radiation levels at upper and lower canopy of wheat

Radiation levels at upper canopy of wheat plant varied among the radiation levels under cloths at all DAS (45, 60, 75, 90). The highest radiation was measured at full sun, which decreased as the layer of shade net and markin cloth increased, and the lowest radiation from markin cloth (two-layer). Shade net decreased light level under net proportionately to shade level (Kittas et al., 2008; Kabir et al., 2019). At the lower canopy of wheat plant, the highest radiation was measured from the open field at all DAS and the lowest from 25% light (Table 1). Radiation levels varied at the lower canopy but not at the upper canopy of wheat due to plant population density (Table 2) as high density (230 plant m^{-2}) hinders the penetration of light at the lower canopy of wheat but not at the higher canopy. The highest radiation was measured at the lower canopy of wheat plant at the lowest plant population (160 plant m^{-2}) which was statistically similar with optimum plant population (200 plant m^{-2}) and lowest at highest plant density (230 plant m^{-2}) at all DAS (Table 2).

Table 1. Radiation at upper and lower canopy of wheat plants as affected by solar radiation level at different days after sowing (DAS) [z].

Solar radiation level	Radiation (× 100 Lux) at upper and lower canopy of wheat							
	45 DAS		60 DAS		75 DAS		90 DAS	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Full sunlight	589 a	196 a	599 a	157 a	598 a	177 a	609 a	172 a
75% sunlight	464 b	151 ab	379 b	135 ab	381 b	132 ab	397 b	138 ab
55% sunlight	360 c	113 ab	298 c	94 b	309 c	98 b	311 c	103 b
25% sunlight	175 d	95 b	163 d	88 b	124 d	87 b	139 d	88 b
Level of significance	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01

[z] *Means in a column having the same letters are not statistically different according to Duncan's Multiple Range Test ($P \leq 0.05$).*

Effect of radiation levels and plant density on culm and leaf dry weight of wheat

Culm dry weight $plant^{-1}$ varied among the radiation levels at all DAS except 60 (Table 3). The highest culm dry weight (1.93 g) was resulted from full sunlight, which was statistically similar with 75% light and the lowest dry weight (1.49 g) from 25% light at 90 DAS (Table 3). The culm weight $plant^{-1}$ also varied among the plant population density at 75 DAS only (Table 4). The culm dry weight varied at 45 DAS and 75 DAS due to combined effect of radiation level and plant population (Table 5). The highest culm weight (2.27 g) was recorded from interaction of full sun with optimum (200 plant m^{-2}) plant density. The highest culm dry weight was also obtained from optimal plant density (200 plant m^{-2}) through minimizing internal and external plant competition (Ferreira and Abreu, 2001). Culm dry weight was the lowest at lower (160 plant m^{-2}) and higher (230 plant m^{-2}) plant density because of suboptimal and overcrowded plant population, respectively. Low light decreased tiller number, number of functional chloroplast, activity of photosystem II, net photosynthesis and thus dry matter production (Demotes-Mainard and Jeuffroy, 2004; Mu et al., 2010).

The leaf dry weight $plant^{-1}$ varied due to solar radiation level (Table 3), plant population (Table 4) and interactions between radiation and plant population (Table 5) at all DAS except 90. The highest leaf dry weight was recorded usually from full sunlight (Table 3), 160 and 200 plant m^{-2} plant densities (Table 4) and interactions between them (Table 5). The highest leaf area index (LAI) and consequently a maximum light absorption resulted higher leaf dry weight at optimal plant density (Agele et al., 2007). Sometimes, the leaf dry weight at 90 DAS was lower than 75 DAS, which might due to increased competition among the plants at 90 DAS.

Table 2. Radiation at upper and lower canopy of wheat plants as affected by plant population at different days after sowing (DAS) [z].

Plant Population	Radiation (× 100 Lux) at upper and lower canopy of wheat							
	45 DAS		60 DAS		75 DAS		90 DAS	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
160 plant m^{-2}	329	179 a	350	146 a	360	155 a	327	152 a
200 plant m^{-2}	399	137 ab	328	117 ab	346	123 ab	304	131 ab
230 plant m^{-2}	373	101 b	309	89 b	353	91 b	332	93 b
Level of significance	NS	0.05	NS	0.05	NS	0.05	NS	0.05

[z] *Means in a column with the same letter do not differ following Duncan's Multiple Range Test (P ≤ 0.05). NS = Non-significant.*

Table 3. Effect of radiation levels on dry weights of wheat culm and leaf at different days after sowing (DAS) [z].

Solar radiation level	Culm dry weight (g) $plant^{-1}$				Leaf dry weight (g) $plant^{-1}$			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Full sunlight	0.62 a	1.53	2.00 a	1.93 a	0.75 a	0.96 b	1.20 a	1.34
75% sunlight	0.42 b	1.19	1.43 b	1.66 ab	0.61 b	0.99 b	1.06 b	1.22
55% sunlight	0.47 b	1.32	1.30 b	1.61 b	0.43 c	1.18 a	1.07 ab	1.15
25% sunlight	0.47 b	1.31	1.30 b	1.49 b	0.43 c	0.97 b	1.14 ab	0.94
Level of significance	0.05	NS	0.05	0.05	0.05	0.05	0.05	NS
CV (%)	19.44	26.05	5.16	13.85	14.26	6.92	9.50	19.00

[z] *Means in a column with the same letter do not differ following Duncan's Multiple Range Test at P ≤ 0.05.*
NS = Non-significant; CV = Coefficient of variation.

Table 4. Effect of plant population on wheat culm and leaf dry weights at different days after sowing (DAS) [z].

Plant Population	Culm dry weight (g) $plant^{-1}$				Leaf dry weight (g) $plant^{-1}$			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
160 plant m^{-2}	0.53	1.29	1.43 b	1.65	0.56 ab	0.98 b	1.29 a	1.13
200 plant m^{-2}	0.52	1.30	1.58 a	1.71	0.50 b	1.00 b	1.12 b	1.19
230 plant m^{-2}	0.44	1.43	1.44 b	1.65	0.59 a	1.10 a	0.95 c	1.17
Level of	NS	NS	0.05	NS	0.05	0.05	0.05	NS
CV (%)	19.44	26.05	5.16	13.85	14.26	6.92	9.50	19.00

[z] *Means in a column with the same letter do not differ following Duncan's Multiple Range Test at P ≤ 0.05. NS = Non-significant; CV = Coefficient of variation.*

Effect of radiation levels and plant population on spike and total dry weight of wheat

The spike dry weight $plant^{-1}$ varied with the radiation levels at 75 DAS and 90 DAS (Table 6). At 75 DAS, the highest spike dry weight (1.2 g) was recorded at full sunlight and the lowest from 25% light (0.68 g). Similar trend was observed at 90 DAS. Spike dry weight did not vary due to plant population density (Table 7). However, the spike dry weight varied at 75 DAS due to combined effect of radiation level and plant population. The highest spike dry weight (1.37 g) was resulted from full sunlight with optimum plant population (200 plant m^{-2}) and lowest from 25% light with highest plant population (230 plant m^{-2}) (Table 8). Low radiation under shade decreased spike dry weight through reduction of grain number in spring wheat (Willey and Holliday, 1971; Fischer, 1975).

Table 5. Interaction effect of solar radiation level and plant population on culm and leaf dry weight of wheat at different days after sowing (DAS) [z].

Solar radiation level × Plant population [y]	Culm dry weight (g) plant^{-1}				Leaf dry weight (g) plant^{-1}			
	45 DAS	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1S_1	0.65 a	1.47	1.87 b	1.90	0.92 a	0.84 de	1.47 a	1.39
P_2S_1	0.64 a	1.63	2.27 a	1.97	0.63 bcd	1.23 b	1.16 a-e	1.31
P_3S_1	0.58 abc	1.5	1.87 b	1.93	0.67 abc	0.81 df	0.97 def	1.33
P_1S_2	0.29 d	1.23	1.27 c	1.57	0.55 cde	0.69 e	0.99 def	1.07
P_2S_2	0.47 a-d	1.10	1.47 c	1.77	0.44 def	1.12 bc	1.04 c-f	1.49
P_3S_2	0.51 a-d	1.23	1.30 c	1.63	0.83 ab	1.17 bc	1.15 b-e	1.09
P_1S_3	0.59 ab	1.56	1.30 c	1.67	0.52 cde	1.70 a	1.43 ab	1.20
P_2S_3	0.49 a-d	1.3	1.30 c	1.47	0.44 def	0.70 e	0.96 def	0.88
P_3S_3	0.30 cd	1.10	1.30 c	1.70	0.34 ef	1.15 bc	0.82 f	1.39
P_1S_4	0.57 a-d	0.90	1.30 c	1.47	0.27 f	0.68 e	1.26 a-d	0.86
P_2S_4	0.48 a-d	1.18	1.30 c	1.63	0.50 c-f	0.97 cd	1.31 abc	1.08
P_3S_4	0.35 bcd	1.87	1.30 c	1.37	0.52 cde	1.27 b	0.85 ef	0.87
Level of significance	0.05	NS	0.05	NS	0.05	0.05	0.05	NS
CV (%)	19.44	26.05	5.16	13.85	14.26	6.92	9.50	19.00

[y] P_1 = 160 plant m^{-2}, P_2 = 200 plant m^{-2}, P_3 = 230 plant m^{-2}; S_1 = Full sunlight, S_2 = 75% sunlight, S_3 = 55% sunlight, S_4 = 25% sunlight. [z] Means in a column followed by the dissimilar letters differ significantly according to Duncan's Multiple Range Test (P ≤ 0.05); NS = Non-significant, CV = Coefficient of variation.

Table 6. Effect of radiation levels on spike dry weight and total dry weight of wheat at different days after sowing (DAS) [z].

Radiation level	Spike dry weight (g) plant^{-1}			Total dry weight (g) plant^{-1}			
	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Full sunlight	0.62	1.2 a	2.30 a	0.82	2.62	3.46 a	4.47 a
75% sunlight	0.66	0.80 b	1.65 ab	0.61	2.13	2.41 b	3.52 b
55% sunlight	0.61	0.93 ab	1.73 ab	0.87	2.24	2.49 b	3.57 b
25% sunlight	0.43	0.68 b	1.33 b	0.72	2.37	2.42 b	3.03 b
Level of significance	NS	0.05	0.05	NS	NS	0.05	0.05
CV (%)	15.75	24.33	28.51	18.75	26.30	9.49	17.56

[z] Means in a column having similar letters are not statistically different at P ≤ 0.05 (Duncan's Multiple Range Test); NS = Non-significant; CV = Coefficient of variation.

The total dry matter of wheat plant did not vary at early stages (45 DAS and 60 DAS) of growth but at later stages (75 DAS and 90 DAS) (Table 6). The highest dry matter was recorded from full sun and lowest one from 25% light at 75 DAS and 90 DAS. The maximum total dry matter (2.82 g) was obtained from optimal plant population and minimum from highest plant population (230 plant m^{-2}) at 75 DAS (Table 7). The highest total dry matter was recorded from full sunlight with optimum plant population (200 plant m^{-2}) and the lowest from 25% light with highest plant population (230 plant m^{-2}) (Table 8). A little accumulation of dry matter at low light resulted lowest dry matter at 25% light either separately or in combination with plant densities (Staver et al., 2001).

Table 7. Effect of plant population on spike dry weight and total dry weight of wheat at different days after sowing (DAS) [z]

Plant Population	Spike dry weight (g) plant^{-1}			Total dry weight (g) plant^{-1}			
	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
160 plant m^{-2}	0.52	0.87	1.70	0.86	2.28	2.70 ab	3.58
200 plant m^{-2}	0.56	0.98	1.90	0.76	2.16	2.82 a	3.83
230 plant m^{-2}	0.65	0.86	1.66	0.65	2.57	2.56 b	3.54
Level of significance	NS	NS	NS	NS	NS	0.05	NS
CV (%)	15.75	24.33	28.51	18.75	26.30	9.49	17.56

[z] Means in a column having similar letters are not statistically different at P ≤ 0.05 (Duncan's Multiple Range Test); NS = Non-significant; CV = Coefficient of variation.

Table 8. Interaction effect of radiation and plant population on spike dry weight and total dry weight of wheat at different days after sowing [z].

Solar radiation level × Plant population [y]	Spike dry weight (g) plant^{-1}			Total dry weight (g) plant^{-1}			
	60 DAS	75 DAS	90 DAS	45 DAS	60 DAS	75 DAS	90 DAS
P_1S_1	0.60	1.10 ab	2.33	0.82 ab	2.76	3.25 ab	4.48 ab
P_2S_1	0.67	1.37 a	2.50	0.85 ab	2.55	3.89 a	4.68 a
P_3S_1	0.59	1.33 ab	2.07	0.80 ab	2.54	3.24 ab	4.25 ab
P_1S_2	0.59	0.59 b	1.42	0.44 b	2.06	2.13 c	3.04 ab
P_2S_2	0.47	0.93 ab	1.77	0.65 ab	1.87	2.64 bc	3.79 ab
P_3S_2	0.92	0.93 ab	1.93	0.74 ab	2.45	2.47 c	3.75 ab
P_1S_3	0.60	1.03 ab	1.83	1.38 a	2.53	2.62 bc	3.73 ab
P_2S_3	0.70	0.94 ab	1.87	0.72 ab	2.24	2.46 c	3.51 ab
P_3S_3	0.53	0.80 ab	1.50	0.51 b	1.95	2.41 c	3.47 ab
P_1S_4	0.30	0.76 ab	1.42	0.81 ab	1.77	2.80 bc	3.07 ab
P_2S_4	0.41	0.68 b	1.46	0.79 ab	1.98	2.33 c	3.32 ab
P_3S_4	0.57	0.60 b	1.12	0.55 ab	3.35	2.12 c	2.70 b
Level of significance	NS	0.05	NS	0.05	NS	0.05	0.05
CV (%)	15.75	24.33	28.51	18.75	26.30	9.49	17.56

[y] P_1 = 160 plant m^{-2}, P_2 = 200 plant m^{-2}, P_3 = 230 plant m^{-2}; S_1 = Full sunlight, S_2 = 75% sunlight, S_3 = 55% sunlight, S_4 = 25% sunlight. [z] Treatment means in a column followed by the dissimilar letters differ significantly according to Duncan's Multiple Range Test (P ≤ 0.05); NS = Non-significant, CV = Coefficient of variation.

Table 9. Grain yield and straw yield of wheat as affected by solar radiation [z].

Radiation level	Filled grain (no.) spike^{-1}	Unfilled grain (no.) spike^{-1}	Grain yield (g m^{-2})	Straw yield (g m^{-2})
Full sunlight	43.17 a	2.89 a	382 a	481 a
75% sunlight	43.68 a	3.22 a	317 b	398 b
55% sunlight	35.03 b	2.63 a	294 b	369 b
25% sunlight	29.48 b	1.63 b	188 c	285 c
Level of significance	0.05	0.05	0.05	0.05
CV (%)	11.26	22.34	12.96	12.96

[z] Means in a column having similar letters are not statistically different at P ≤ 0.05 (Duncan's Multiple Range Test); CV = Coefficient of variation.

Effect of solar radiation levels and plant population on yield and yield attributes of wheat

The number of filled grain and unfilled grain in a spike varied among the radiation levels, plant population, and interactions between them (Table 9-11). The maximum number of filled grain and unfilled grain were recorded from 75% light and the minimum from 25% light (Table 9). Similarly, both the filled grain and unfilled grain were maximum at lowest plant density and minimum at highest plant density (Table 10). The highest number of filled grain and unfilled grain in a wheat spike were resulted from combination of full sunlight or 75% light with different plant populations particularly (200 plant m^{-2} and 160 plant m^{-2}) and the lowest from 25% light with highest plant population (230 plant m^{-2}) (Table 11). Similar number of filled and unfilled grains were observed at full sunlight and 75% light as a slight shade (e.g. 20%) did not alter the number of filled grains in wheat (Li et al., 2010). However, low light from transplanting to booting in rice reduces number of grains (Liu et al., 2014). Planting density highly influenced the number of grains per panicle in wheat (Valério et al., 2013). However, below optimal density may decrease yield and net profit (Whaley et al., 2000) and above optimal may increase cost of production (Laghari et al., 2011).

Table 10. Wheat grain yield and straw yield as influenced by plant population [z].

Plant Population	Filled grain (no.) spike^{-1}	Unfilled grain (no.) spike^{-1}	Grain yield (g m^{-2})	Straw yield (g m^{-2})
160 plant m^{-2}	40.80 a	2.84 a	274 b	352 b
200 plant m^{-2}	37.26 b	2.76 ab	296 ab	393 a
230 plant m^{-2}	34.46 b	2.109 b	316 a	404 a
Level of significance	0.05	0.05	0.05	0.05
CV (%)	11.26	22.34	12.96	12.96

[z] *Means in a column having similar letters are not statistically different at P ≤ 0.05 (Duncan's Multiple Range Test); CV = Coefficient of variation.*

Table 11. Interaction effect of radiation levels and plant population on grain yield and straw yield of wheat [z].

Solar radiation level × Plant population [y]	Filled grain (no.) spike^{-1}	Unfilled grain (no.) spike^{-1}	Grain yield (g m^{-2})	Straw yield (g m^{-2})
P_1S_1	50.94 a	3.00 ab	366 abc	431 ab
P_2S_1	36.98 bcd	2.98 ab	386 ab	500 a
P_3S_1	41.59 abc	2.70 abc	394 a	513 a
P_1S_2	44.46 ab	2.90 ab	272 b-f	370 cd
P_2S_2	50.99 a	4.35 a	323 a-d	411 a-d
P_3S_2	35.59 bcd	2.40 bc	355 abc	412 a-d
P_1S_3	38.98 abc	2.61 abc	295 a-e	368 cd
P_2S_3	30.12 cd	2.66 abc	256 c-f	354 cde
P_3S_3	36.10 bcd	2.60 bc	329 a-d	385 bcd
P_1S_4	32.84 bcd	2.77 abc	162 f	239 e
P_2S_4	31.05 cd	1.06 c	219 def	308 de
P_3S_4	24.56 d	1.06 c	184 ef	307 de
Level of significance	0.05	0.05	0.05	0.05
CV (%)	11.26	22.34	12.96	12.96

[y] *P_1 = 160 plant m^{-2}, P_2 = 200 plant m^{-2}, P_3 = 230 plant m^{-2}; S_1 = Full sunlight, S_2 = 75% sunlight, S_3 = 55% sunlight, S_4 = 25% sunlight.* [z] *Treatment means in a column followed by the dissimilar letters differ significantly according to Duncan's Multiple Range Test (P ≤ 0.05); CV = Coefficient of variation.*

The highest grain yield (382 g m^{-2}) and straw yield (481 g m^{-2}) were obtained from full sunlight and the lowest grain yield (188 g m^{-2}) and straw yield (285 g m^{-2}) were obtained from 25% light. The highest grain yield (316 g m^{-2}) and straw yield (404 g m^{-2}) were obtained from maximal plant population density which were statistically similar with optimal plant density and the lowest yields from lowest plant population density. The highest grain yield

(394 g m^{-2}) and straw yield (513 g m^{-2}) were estimated from full sunlight with maximal plant population, which was statistically similar with several other combinations and the lowest from the 25% light with 160 plants m^{-2} (Table 11). Yield of crops can be reduced at low light (Islam et al., 1993, Abeledo et al., 2014; Wang et al., 2015; Kabir et al., 2022) and low yield is the result of low carbon-use efficiency at reduced light (Ball et al., 2000). However, grain yield of wheat was lower at 100% irradiance compared to 90% and 50% at Mediterranean environment where annual irradiance is much higher compared to other parts of Europe (Arenas-Corraliza et al., 2019) and a 19% shade resulted highest photosynthesis in bell pepper during summer in Georgia of USA (Kabir et al., 2022). Increase of plant density may result higher yield providing availability of resources along with prevalence of optimal climate for crop production (Bavec and Bavec, 2002). Increase of planting density at a certain threshold level increases the grain yield through increasing total number of grains as reported in the present study. The straw yield increases at full sunlight through higher accumulation dry matter compared to 25% light. The increase of total plant population also increases the total straw yield and vice versa.

Conclusion

Full sunlight or 75% light with optimal plant density (200 plant m^{-2}) resulted maximum dry weights for culm, leaf, spike, and total dry matter for a wheat plant. These combinations also yielded higher number of filled and unfilled grains per plant along with higher grain yield and straw yield in an area of one m^2. Though the high plant density (230 plant m^{-2}) resulted statistically similar grain yield with optimal plant density, it is not recommended due to higher seed requirement. Therefore, 75% light with optimal plant density is sufficient for good yield of wheat. This information could be useful for growing wheat in an agroforestry system and light limiting areas in Bangladesh as well as in other parts of the world.

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Conflict of Interests

The author declares no conflict of interest.

References

Abeledo, L. G., Savin, R., & Slafer, G. A. (2014). Leaf photosynthesis during grain filling under mediterranean environments: are barley or traditional wheat more efficient than modern wheats? *Journal of agronomy and crop science*, *200*(3), 172-182. https://doi.org/10.1111/jac.12054

Agele, S. O., Maraiyesa, I. O., & Adeniji, I. A. (2007). Effects of variety and row spacing on radiation interception, partitioning of dry matter and seed set efficiency in late season sunflower (Helianthus annuus L.) in a humid zone of Nigeria. *African Journal of Crop Science*, *2*(3), 80-88.

Albayrak, S., Mevlüt, T. Ü. R. K., & Yüksel, O. (2011). Effect of row spacing and seeding rate on hungarian vetch yield and quality. *Turkish Journal of Field Crops*, *16*(1), 54-58.

Arenas-Corraliza, M. G., Rolo, V., López-Díaz, M. L., & Moreno, G. (2019). Wheat and barley can increase grain yield in shade through acclimation of physiological and morphological traits in Mediterranean conditions. *Scientific reports*, *9*(1), 1-10.

Asseng, S., Jamieson, P. D., Kimball, B., Pinter, P., Sayre, K., Bowden, J. W., & Howden, S. M. (2004). Simulated wheat growth affected by rising temperature, increased water deficit and elevated atmospheric CO2. *Field Crops Research*, *85*(2-3), 85-102. https://doi.org/10.1016/S0378-4290(03)00154-0

Ball, R. A., Purcell, L. C., & Vories, E. D. (2000). Optimizing soybean plant population for a short-season production system in the southern USA. *Crop Science*, *40*(3), 757-764. https://doi.org/10.2135/cropsci2000.403757x

BARI (Bangladesh Agricultural ResearchInstitute). (2012). Means of profitable wheat cultivation (A booklet in Bangla). Wheat Research Centre. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

Bavec, F., & Bavec, M. (2002). Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars (FAO 100–400). *European Journal of Agronomy*, *16*(2), 151-159. https://doi.org/10.1016/S1161-0301(01)00126-5

Bozorgi, H. R., Faraji, A., Danesh, R. K., Keshavarz, A., Azarpour, E., & Tarighi, F. (2011). Effect of plant density on yield and yield components of rice. *World Applied Sciences Journal*, *12*(11), 2053-2057.

Braun, H. J., Atlin, G., & Payne, T. (2010). Multi-location testing as a tool to identify plant response to global climate change. *Climate change and crop production*, *1*, 115-138.

Cakmak, I., Hengeler, C., & Marschner, H. (1994). Partitioning of shoot and root dry matter and carbohydrates in bean plants suffering from phosphorus, potassium and magnesium deficiency. *Journal of Experimental Botany*, *45*(9), 1245-1250. https://doi.org/10.1093/jxb/45.9.1245

Demotes-Mainard, S., & Jeuffroy, M. H. (2004). Effects of nitrogen and radiation on dry matter and nitrogen accumulation in the spike of winter wheat. *Field Crops Research*, *87*(2-3), 221-233. https://doi.org/10.1016/j.fcr.2003.11.014

Dong, C., Fu, Y., Liu, G., & Liu, H. (2014). Low light intensity effects on the growth, photosynthetic characteristics, antioxidant capacity, yield and quality of wheat (Triticum aestivum L.) at different growth stages in BLSS. *Advances in Space Research*, *53*(11), 1557-1566. https://doi.org/10.1016/j.asr.2014.02.004

Ferreira, A. M., & Abreu, F. G. (2001). Description of development, light interception and growth of sunflower at two sowing dates and two densities. *Mathematics and Computers in simulation*, *56*(4-5), 369-384. https://doi.org/10.1016/S0378-4754(01)00308-1

Fischer, R. A. (1975). Yield potential in a dwarf spring wheat and the effect of shading 1. *Crop Science*, *15*(5), 607-613. https://doi.org/10.2135/cropsci1975.0011183X001500050002x

Hasanuzzaman, M., Hossain, M. A., Silva, J. A., & Fujita, M. (2012). Plant response and tolerance to abiotic oxidative stress: antioxidant defense is a key factor. In *Crop stress and its management: perspectives and strategies* (pp. 261-315). Springer, Dordrecht. DOI: 10.1007/978-94-007-2220-0_8

Islam, M. T., Kubota, F., Mollah, F. H., & Agata, W. (1993). Effect of shading on the growth and yield of mungbean (Vigna radiata [L.] Wilczek). *Journal of Agronomy and Crop Science*, *171*(4), 274-278. https://doi.org/10.1111/j.1439-037X.1993.tb00140.x

Janardhan, K. V., Murty, K. S., & Dash, N. B. (1980). Effect of low light during ripening period on grain yield and translocation of assimilates in rice varieties. *Indian Journal of Plant Physiology*, *23*, 163-168.

Kabir, M. Y., Nambeesan, S. U., & Díaz-Pérez, J. C. (2022). Carbon Dioxide and Light Curves and Leaf Gas Exchange Responses to Shade Levels in Bell Pepper (Capsicum annuum L.). *Plant Science*, 111532. https://doi.org/10.1016/j.plantsci.2022.111532

Kabir, M. Y., Nambeesan, S. U., Bautista, J., & Díaz-Pérez, J. C. (2022). Plant water status, plant growth, and fruit yield in bell pepper (Capsicum annum L.) under shade nets. *Scientia Horticulturae*, *303*, 111241. https://doi.org/10.1016/j.scienta.2022.111241

Kabir, M. Y., Díaz-Pérez, J. C., & Nambeesan, S. U. (2019). Effect of shade levels on plant growth, physiology, and fruit yield in bell pepper (Capsicum annuum L.). In *XI International Symposium on Protected Cultivation in Mild Winter Climates and I International Symposium on Nettings,1268,* 311-318. https://doi.org/10.17660/ActaHortic.2020.1268.42

Kittas, C., Rigakis, N., Katsoulas, N., & Bartzanas, T. (2008). Influence of shading screens on microclimate, growth and productivity of tomato. In *International Symposium on Strategies Towards Sustainability of Protected Cultivation in Mild Winter Climate, 807,* 97-102. https://doi.org/10.17660/ActaHortic.2009.807.10.

Laghari, G. M., Oad, F. C., Tunio, S., Chachar, Q., Ghandahi, A. W., Siddiqui, M. H., ... & Ali, A. (2011). Growth and yield attributes of wheat at different seed rates. *Sarhad Journal of Agriculture*, *27*(2), 177-183.

Li, H., Jiang, D., Wollenweber, B., Dai, T., & Cao, W. (2010). Effects of shading on morphology, physiology and grain yield of winter wheat. *European Journal of Agronomy*, *33*(4), 267-275. https://doi.org/10.1016/j.eja.2010.07.002

Lichtenthaler, H. K. (1996). Vegetation stress: an introduction to the stress concept in plants. *Journal of plant physiology*, *148*(1-2), 4-14. https://doi.org/10.1016/S0176-1617(96)80287-2

Liu, Q. H., Xiu, W. U., Chen, B. C., & Jie, G. A. O. (2014). Effects of low light on agronomic and physiological characteristics of rice including grain yield and quality. *Rice science*, *21*(5), 243-251. https://doi.org/10.1016/S1672-6308(13)60192-4

Moore, F. C., & Lobell, D. B. (2014). Adaptation potential of European agriculture in response to climate change. *Nature Climate Change*, *4*(7), 610-614. https://doi.org/10.1038/nclimate2228

Mu, H., Jiang, D., Wollenweber, B., Dai, T., Jing, Q., & Cao, W. (2010). Long-term low radiation decreases leaf photosynthesis, photochemical efficiency and grain yield in winter wheat. *Journal of Agronomy and Crop Science*, *196*(1), 38-47. https://doi.org/10.1111/j.1439-037X.2009.00394.x

Nakano, H., Morita, S., Kitagawa, H., Wada, H., & Takahashi, M. (2012). Grain yield response to planting density in forage rice with a large number of spikelets. *Crop science*, *52*(1), 345-350. https://doi.org/10.2135/cropsci2011.02.0071

Pommel, B., & Bonhomme, R. (1998). Variations in the vegetative and reproductive systems in individual plants of an heterogeneous maize crop. *European Journal of Agronomy*, *8*(1-2), 39-49. https://doi.org/10.1016/S1161-0301(97)00012-9

Poorter, H., & Nagel, O. (2000). The role of biomass allocation in the growth response of plants to different levels of light, CO2, nutrients and water: a quantitative review. *Functional Plant Biology*, *27*(12), 1191-1191. https://doi.org/10.1071/PP99173_CO

Reinhardt, K., Smith, W. K., & Carter, G. A. (2010). Clouds and cloud immersion alter photosynthetic light quality in a temperate mountain cloud forest. *Botany*, *88*(5), 462-470. https://doi.org/10.1139/B10-008

Staver, C., Guharay, F., Monterroso, D., & Muschler, R. G. (2001). Designing pest-suppressive multistrata perennial crop systems: shade-grown coffee in Central America. *Agroforestry systems*, *53*(2), 151-170. https://doi.org/10.1023/A:1013372403359

Strain, B. R., & Cure, J. D. (Eds.). (1986). *Direct effects of increasing carbon dioxide on vegetation*. US Department of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division.

Valério, I. P., Carvalho, F. I. F. D., Benin, G., Silveira, G. D., Silva, J. A. G. D., Nornberg, R., ... & Oliveira, A. C. D. (2013). Seeding density in wheat: the more, the merrier?. *Scientia Agricola*, *70*, 176-184. https://doi.org/10.1590/S0103-90162013000300006

Wang, L., Deng, F., & Ren, W. J. (2015). Shading tolerance in rice is related to better light harvesting and use efficiency and grain filling rate during grain filling period. *Field Crops Research*, *180*, 54-62. https://doi.org/10.1016/j.fcr.2015.05.010

Whaley, J. M., Sparkes, D. L., Foulkes, M. J., Spink, J. H., Semere, T., & Scott, R. K. (2000). The physiological response of winter wheat to reductions in plant density. *Annals of Applied Biology*, *137*(2), 165-177. https://doi.org/10.1111/j.1744-7348.2000.tb00048.x

Willey, R. W., & Holliday, R. (1971). Plant population, shading and thinning studies in wheat. *The Journal of Agricultural Science*, *77*(3), 453-461. https://doi.org/10.1017/S0021859600064522

Zhang, D., Du, G., Sun, Z., Bai, W., Wang, Q., Feng, L., ... & Zhang, L. (2018). Agroforestry enables high efficiency of light capture, photosynthesis and dry matter production in a semi-arid climate. *European Journal of Agronomy*, *94*, 1-11. https://doi.org/10.1016/j.eja.2018.01.001

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., ... & Asseng, S. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences*, *114*(35), 9326-9331. https://doi.org/10.1073/pnas.1701762114

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REVIEW ARTICLE

MANAGEMENT & BUSINESS

CO-CREATION FRAMEWORK IN PROFESSIONAL SERVICE CONTEXT: TOWARD A PRAXIS MODEL

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Abstract

Co-creation in service is essential through facilitating the coordination between customers and service providers. A holistic understanding of value co-creation in professional services can ensure the improvement of service experience. The objective of this paper is to form a praxis model of value co-creation in professional services. The authors performed a Systematic Review of Literature (SRL) by analyzing 113 research documents and articles on co-creation literature within the year range 1996-2021. The study assimilated the key considerations of co-creation in the professional service context. These led to the formation of a conceptual framework. This study identifies the roles of the actors in value co-creation and outlines the procedures for involving the customers. The paper also provides the inhibitors and enablers of co-creation. The study makes contribution to the existing literature by delineating the criteria and factors for co-creation in the professional service context. The praxis model of co-creation developed here could also be beneficial for the practitioners in improving service design.

Keywords: Co-creation, professional services, praxis model, systematic literature review, value creation

Introduction

Contemporary research has addressed co-creation as a means of inducing organizational competitiveness. Researchers have explored various dimensions of the co-creation process (Keeling et al., 2021; Lusch et al., 2007). Considering the dynamic and competitive business climate in which customer preferences and requirements constantly change, co-creation may precede competitive advantages for a business firm (Pillitteri et al., 2021). As a result, firms have started to embrace the service-dominant philosophy (Vargo & Lusch, 2004; Scarlett et al., 2021), resulting in collaborative, dynamic interactions and engagement with target consumers for value creation (Bhat & Sharma, 2021). This marks the essence of co-creation. The resulting customer satisfaction (McAlexander et al., 2003; Yi & Gong, 2013) and the competitive edge of the business firm, followed by an increase in brand equity and revenue, have motivated the managers to introduce co-creation in service design (Pillitteri et al., 2021; Kennedy & Guzmán, 2016). This also caused increased research interest by academicians (Vargo & Lusch, 2004, 2016).

Extant research has investigated co-creation from various perspectives, including co-creation in social media (Moghadamzadeh et al., 2020); co-creation experience in value creation (Prahalad & Ramaswamy, 2004; Srivastava, 2021); consumer co-creation behavior (Yi & Gong, 2013) and the relationship of co-creation with brand equity (Kennedy & Guzmán, 2016). However, in the domain of the professional service (e.g., legal, architectural, health services, accounting), the practice and discussion of value co-creation are relatively limited (Anderson et al., 2013). The contribution of professional service is considered significant to the service economy. However, studies that encompass co-creation in this field are few. Factors affecting the different stages of the value delivery system have also not yet been explored (Akolk et al., 2016), which are essential in coordinating the value co-creating process. In the work of Chan et al. (2010), it was suggested to explore how the roles of customers facilitate the value creation phases in the professional service design. The development of co-creation can ensure the effective delivery of such services. To manage co-creation in professional services, issues need to be delineated from the contexts of the

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company and consumer. Based on the arguments above, our research is aimed at developing a praxis model for co-creation in professional services along with providing answers to the following questions:

a) Which criteria affect the co-creation procedure in professional service development from the service provider and user perspective?
b) What are the motivations and roles of the actors for getting involved in this process?
c) What are the enablers and barriers to implementing co-creation in a professional service context?
d) Which factors need to be addressed in the proposed framework to develop co-creation in the professional service context?

The current research has been conducted by reviewing the literary work on co-creation-related issues in service development, service logic, and architecture of co-creation logic in service. The paper contributes to service co-creation literature by delineating a praxis model and the related elements of co-creation in a professional service setting.

Materials and Methods

To accomplish the research, a Systematic Review of the Literature (SRL) was applied to identify the most appropriate studies on the co-creation literature (Table 1). The SRL has been used to classify and appraise the available literary data and evidence from a particular research area (Xiao & Watson, 2019). To answer the previously mentioned research questions, systematic searches and literature summarization were done. This was facilitated by detecting keywords, search criteria, and selection of academic databases for search. In particular, the following particulars were of use**:**

i) Academic databases: Google Scholar, Scopus.
ii) Type of document: articles, conference papers, books, and working papers.
iii) keywords: Co-creation, Customer, Service-Dominant Logic, Professional Service, Collaboration.
iv) Language: English.
v) Period of publication: 1996-2021

Literature Distribution by Publication Types: The study is based on four types of documents generated from a search in Scopus and Google Scholar databases, namely books, articles, conference proceedings, and working papers. From these publications, 'Article' category was the most dominantly used type, comprising (94; 84% of the total number of publications), followed by books (7; 6%), working papers (7; 6%), and conference proceedings (5; 4%).

Text Analysis: The word cloud is an interesting tool to summarize all the key buzzwords centered around a theme (McNaught & Lam, 2010). Qualitative researchers prefer the word cloud due to its ability to synthesize a key theme in a well-shaped graphic (Heimerl et al., 2014). The current research identified the commonly used words in the domain of the co-creation of professional services. The text analysis reveals the general topics of interest in this research. We used the R studio for the text analysis by applying a 1-gram model (Haneem et al., 2017). The 1-gram model analysis (Figure 1) helped the researchers to form a word cloud. This model shows the one word that is the most frequently used in the sections of title and abstract of the scholarly articles related to co-creation in professional services. The word cloud generated in this process depicts the visualization of the most frequently used words.

Here, we have formulated a word cloud to introduce the key concepts/most widely used terms for explaining co-creation in professional service context. As we see from the figure, some notable keywords include 'co-creation', 'value', 'services', 'interactions', 'motivation', 'holistic' etc. Co-creation is a value enhancing process where there is embeddedness of the 'context' i.e., the professional service setting where co-creation occurs. There is systematic 'value co-destruction' to remove the backdated 'value' for customers and make new 'value', which the customers may find meaningful. In turn, the customers also 'exchange' value by providing monetary payments to get the firm's new 'value'. Thus, the word cloud provides the researchers cues for a deeper understanding of the co-creation process.

Table 1. Summary of the findings of literature exploration

Timeline	Key Authors	Key thematic concentrations
1996-2000	Bettencourt & Gwinner (1996) Grönroos (1997) Oliver (1999) Grönroos (2000)	• Co-creation as a new source of value • Co-creating processes by professional service providers • Customer role in the service process
2001-2005	Bendapudi & Leone (2003) Harhoff et al. (2003) McAlexander et al. (2003) Prahalad & Ramaswamy (2004) Vargo & Lusch (2004) Ramaswamy (2005)	• DART (Dialogue, Access, Risk Assessment and Transparency) model of interaction in service • The relative importance of service components in value creation • Managing activities in professional service
2006-2010	Holbrook (2006) Vargo & Lusch (2010) Payne et al. (2008) Voss & Hsuan (2009) Ramaswamy & Gouillart (2010) Zwass (2010) Chan et al. (2010)	• Business model development through value co-creation • Motivation to participate in co-creation • Effect of customer participation on value creation • S-D (Service-Dominant) logic in value creation • Managing co-creation process through co-creators • Applying the co-creation attributes in B2B (Business to Business) services
2011-2016	Frow et al. (2011) Grönroos (2011) Gronroos (2012) Aarikka-Stenroos & Jaakkola (2012) Anderson et al. (2013) Grönroos & Voima (2013) Jaakkola & Alexander (2014) Pirinen (2016) Pera et al. (2016) Davis et al. (2016) Kennedy & Guzmán (2016) Vargo & Lusch (2016)	• Benefits and motivation of actors in online service co-creation • Enhancing the S-D logic through co-creation in knowledge-intensive services • Consumers' motivation in co-creation activities • Barriers and enablers in co-designing of values • Key motives and outcomes of the co-creation in the multi-stakeholder ecosystem
2017-2021	Bhat & Sharma (2021) Pillitteri et al. (2021) Scarlett et al. (2021) Keeling et al. (2021) Srivastava (2021) Tóth et al. (2018) Kuula et al. (2018) Bonamigo et al. (2020) Figueiredo et al. (2019)	• The roles of professionals and clients in professional service projects. • Presence of tension and structural imbalance in value co-creation • Integration of knowledge resources between service providers and consumers

Figure 1. 1-gram model word cloud of title and abstract in co-creation of professional service literature

Results and Discussion

***The Domain of Professional Services*:** Professional service providers offer specialized knowledge and niche-interest-based services such as law, marketing, accounting, architecture, legal services, recruitment services, soft skill training, health care, project, and portfolio management services. The customers enter into Service-Level-Agreements (SLAs) for professional services with the providers. The company decides what services to outsource to a professional service provider by considering the strategic benefits of value creation, competitive advantage, operational flexibility, and cost minimization. McLaughlin et al. (1995) argued that the focus of professional service involves realignment of the process and infrastructure properties of the service delivery system to fulfill the needs of the target market segments. The provision of service offerings entails specifying and standardizing the service and methods (Barile et al., 2020). Similarly, productization practice is required for transforming the abstract service into exchangeable components and processes (Friend et al., 2020).

Maister (1982) emphasized the "balancing" of delivery of professional services, which encompasses a tradeoff between the needs of the service developer and customers. The service developer is expected to opt for those clients who have access to the utilization of opportunities, whereas the service provider can build its knowledge base by delivering innovative services.

Concept of Value Co-creation: Based on diverse research, Prahalad and Ramaswamy (2004) familiarized the notion of value co-creation. They expressed it as the experiences accumulating, disseminating and evaluating from the consumers. Rather than targeting only the delivery, firms need to focus on sharing experiences at different phases of interaction as the core of value co-creation. Grönroos (2012) illustrates co-creation as a shared cooperative activity both from service providers and users through direct interactions focused on generating value for service firms and consumers.

Value is the capability of products or services to fulfill a need or offer a utility to a customer (Babu et al., 2020), which actualizes the customer perspective. Grönroos and Voima (2013) further extend this view and explain that the service provider changes its role from a value organizer to a value co-producer by analyzing how customers combine resources, procedures, and outcomes in interaction. As an important participant, the customer can augment the effectiveness of value co-creation (Jiang & Yang, 2017). While interacting with customers, the service provider needs to offer attractive value propositions, resources and capabilities challenging for the competitors to imitate (Vargo & Lusch, 2010).

Co-creation from the User's Perspective: In recent times, consumers have been more informed, associated, and engaged on a larger dimension than at any other time. Because of the advancement of modern technologies, the internet's expansionary features provide tools to generate co-creation (Schulz et al., 2021; Ramaswamy & Gouillart, 2010). According to the customer's perspective, co-creation has been identified in their participation level phases, their motivational aspects for participation, role-playing in co-creation, and their overall mode of contribution (Cluley & Radnor, 2020). Diverse buying settings need a different range of consumer inclusion, selecting the input participated by the consumer and the firm. Consumers can be attached to word-of-mouth generation, client benefit, the conformation of new items, and partly agents (Terblanche, 2014). Additionally, they can be engaged through self-service technological platforms (Payne et al., 2008). The range of client contributions affects the operation outcomes and strengthens the communication between the consumer and the firm (Akhmedova et al., 2020).

Co-creation from the Service Provider's Perspective: Organizations have gradually moved from the firm-centric view toward the customer-led view (Rossi & Tuurnas, 2021). In a competitive business climate, firms are now more concerned with the co-creation concept through leveraging user knowledge. Based on the evaluation of Steen (2013) and Khramova (2014), 'User Knowledge' and 'User Relationship Management' inspire and make a foundation for the management of co-creation. While enabling the co-creation with consumers, the firm also creates favorable experiences for the internal employees (Ramaswamy & Gouilart, 2010). For example, firms might establish a platform for employees to cooperate with clients, such as maintaining well-trained staff and setting up information systems.

Other stakeholders comprising consumers, personnel, and distributors need to be involved in management decision-making such as marketing, R&D, and product design. For instance, the French company LaPoste is an ideal demonstration of how a firm applies a co-creative approach to increase client gratification, employee self-esteem, and substantial advancement in the company's operation system (Ramaswamy & Gouillart, 2010).

Two diverse methods are applied in customizing services in the co-creation process (Bettencourt & Gwinner, 1996). Firstly, adapting the interactive conduct refers to the interaction between employee and customer and comprises language and inflection. Secondly, the customization of services can be done by modifying or pushing service essentials to match consumers' requirements and inclinations. According to Voss and Hsuan (2009), two different methods are available for service customization: combinatorial and menu-driven customization. Combinatorial customization is a procedure in which the service firm delivers a "starting point," and the user can enhance additional service components. On the other hand, in menu-driven customization procedures, the firm offers a range of services, and the customers can pick services according to their suitability.

Criteria Affecting the Co-creation Procedure in Professional Services

The co-creation process is influenced by the consumer and service provider paradigms and the involved tools and components of engaging in it (Knote et al., 2021). In addition, the evolution of technological media, including broadband, digital TV, and fifth-generation mobile services, create a scope where consumers and stakeholders can engage without the physical presence (Payne et al., 2021). As a result, there has been an increasing trend of S-D (Service-Dominant) logic (Font et al., 2021; Vargo & Lusch, 2004) which refers to the architecture of co-creation and is considered a major criterion for the co-design of services. Some of the major criteria of value co-creation are appended below:

The Relationship Experience: The collaborative creation process entails the consumers being engaged in the cognitive function of decision-making where they decide on the importance of getting involved in past, present, or future experiences (Khan & Krishnan, 2021; Oliver, 1999). Customer evaluates the pains and gains of a designed service, and they must be ready to search for information and characteristics whether to buy a particular service (Zeithaml, 1988; Grönroos, 1997). The Three main cognitive points of this relationship experience are cognition, emotion, and behavior.

Customer Learning: Customer learning emerges from the continuous interaction between users and providers (Hsu et al., 2021). Service providers attempt to understand the relationship experience of the users through analyzing customer cognition, emotion, and behavior. Customer satisfaction and the magnitude of customer participation help the service provider gain required customer learning and devise appropriate encounters, which also help consumers in reviewing the service experience (Aakerblom & Ness, 2021). Creating a learning culture is

crucial for adapting the co-creation process over time. The knowledge management system focuses on building an architectural system where the service processes could be reconfigured and stored for further experimentation (Hussain et al., 2020; Frow et al., 2011). Firms can implement co-design process economically by configuring processes and developing a knowledge management system (Nonaka & Takeuchi, 1995).

Inhibitors and Enablers for Professional Services Co-creation

While designing customer collaboration and simultaneous co-creation for professional services, service firms must look for the driving factors that direct the co-creation mechanisms (Barnet et al., 2021). While implementing co-creation, service providers tend to face a set of barriers and facilitators which influence the outcomes (Bonamigo et al., 2020; Kleinsmann et al., 2007). For example, according to Pirinen (2016), language and cultural diversification might influence why some service projects are not on the due track to implementation while dealing with the professional communities. In addition, the lack of commitment of the service provider to co-designing the services and responding to the empathy domains of the clients could have a bearing on the progress of professional services. On the other hand, the service firms' inability to mobilize the appropriate degree of time, resources and, funding might thwart the service co-production. Moreover, the skills and learned experience of the professionals such as architects, designers, and lawyers dictate a lot regarding the success of co-design projects.

Zwass (2010) posited that creating trust in the reputation systems is one of the enablers of building a successful transactional and participatory relationship between service firms and users. The lack of trustworthiness among the counterparties demonstrates an erosion in value co-creation (Sudo & Ito, 2021). Therefore, Zwass (2010) discussed the term 'Adhocracy' in co-creation efforts to distribute the decision rights and coordinate work among the collaborative partners. Paulini et al. (2013) cited the innovative processes of the service co-design with the users' community as the facilitators in service co-creation because innovation processes are inherently rewarding and motivating for the participants.

Davis et al. (2016) opined that the lack of a flexible and defined structure for co-creation is poised to create hindrances in the facilitation of service co-design among professionals and service users. Thereby, some of the enabling factors for the professional service co-creation have been mentioned, such as the lively involvement of the multi-professional members, the generation of design thinking, and convergent thinking through the participatory processes of brainstorming, ideation, and visualization of service mechanisms with the participants (Davis et al., 2016). According to Lawler and Bilson (2009) and Davis and Smith (2012), the collaborative service design by the service users and professionals can be facilitated through the humanistic concept of problem-solving based on the collective sharing of varied personal experiences and tacit knowledge of the participants. In addition, both the users and provider must be engaged in reliable and approachable communication by bearing responsibilities and contributing to the co-design process. Pirinen (2016) described the well-concentrated systems and reporting criteria as the key enablers in monitoring the progression of service co-creation efforts. According to Pirinen, the growing contribution of convenient process toolkits and appropriate training of the implementers are important facilitators.

Motivations of the Actors in the Co-creation Process

The Motivation of the Consumers: Customers' motivation to volunteer in service co-creation can vary in different contexts. The nature of motivation is dependent on which factors trigger consumer behavior and the subsequent course of actions. For example, the factors contributing to the customer's tendency to co-producing the professional service are determined by the consumers' benefits (Tóth et al., 2018). Similarly, the cognitive processes operating in consumers' minds dictate the consumer perceptions of tangible or intangible benefits that might accrue from such value creation activities (Nambisan, 2002; Holbrook, 2006). Consumer motivations to directly collaborate with a firm for co-creating values can be broadly explained under three dimensions (Figure 2).

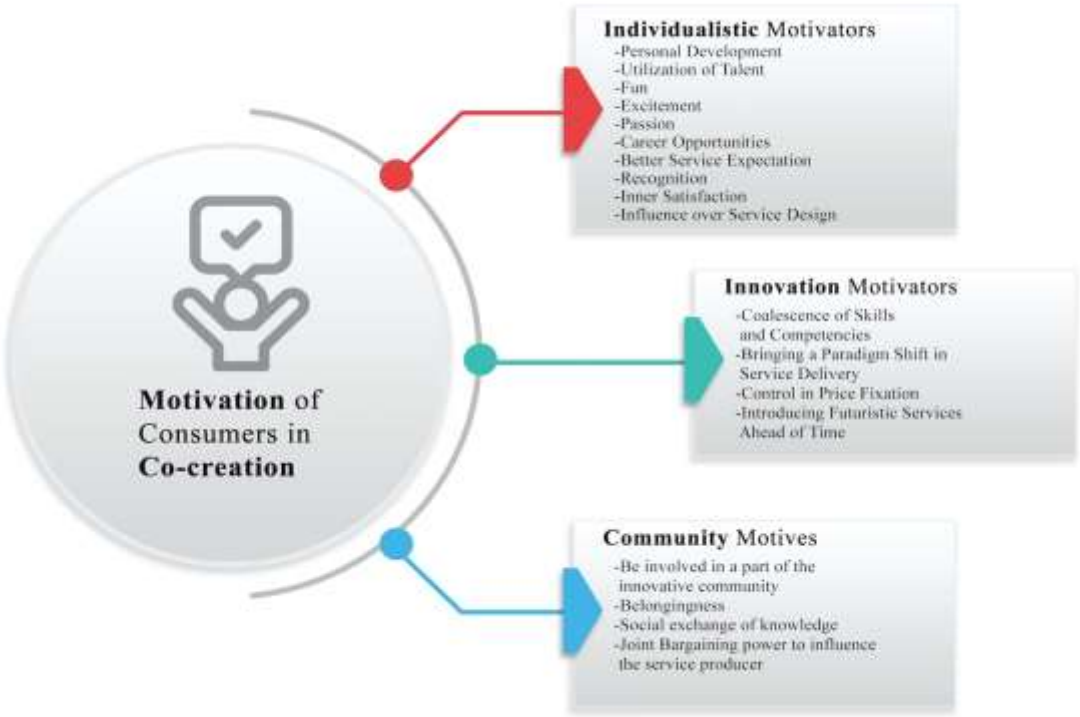

Figure 2. Motivators of consumers for co-creation in professional service

The above model shows that the three main dimensions of motivation are: consumers' individual motives, community-centered motives and innovation-driven motives. First, consumers possess the intrinsic need to acquire an ideally satisfactory service as well as incur fun, excitement, and pride in the adaptation of services (Fuentes et al., 2019). Customers' community motive to act in a group makes a chain of social exchange among multiple consumers to accumulate their collective knowledge for better service process design. In such instances, co-creation is propelled by the motivation for reputational gains, opportunities for recognition, the building of the network, community ties, belongingness, and reciprocal learning (Harhoff et al., 2003). Then come the innovation motivators, which facilitate the users to collaborate with innovative services that can change their lifestyle. Finally, consumers feel empowered to control the mode of delivery and the price fixation of the service.

The Motivation of the Service Providers in Co-creation: The professional service firm tends to have specific intrinsic and extrinsic motivations to co-create. First, there are economic consequences of having collaborative services. Firms recognize that when users provide reviews while using less popular professional services, the marketers tend to have more sales from the market niches (Roberts et al., 2006). Firms focus on three major intrinsic motives which trigger the co-creation process: i) image improvement, ii) relationship building and, iii) new experimentation with innovation. Firms have the intrinsic expectation of forming new partnerships and alliances to create superior quality services. These relationships could build an increased level of bonding and information exchange in the service ecosystem (Payne et al., 2021). Finally, firms inherit an instinct desire for deliberate experimentation to bring innovation to new services development. The experimentation motive empowers firms to adapt solutions from other stakeholders and embed service solutions into their service design (Pera & Viglia, 2015). On the other hand, firms have their extrinsic motives to utilize organizational capabilities, consumers' knowledge, and the relationships with key stakeholders to deliver high-quality shared services (Edvardsson et al., 2011). Organizations that establish the linkages between stakeholder motives and pool resources for co-creation tend to achieve competitive advantages (Gyrd-Jones & Kornum, 2013).

Roles of Actors in the Co-creation Process: The co-creation process is facilitated by the joint contributory roles from both the perspectives of the firm and consumers. Service providers can improve and distinguish their offerings by adding diverse resources that customers and stakeholders can invest in through collaborating and co-producing behavior (Wang et al., 2021). In technology-enabled and medical services, empirical evidence shows firms invite community consumers into their operations (Jaakkola & Alexander, 2014). Service providers play a crucial first-hand role in co-creation by investigating how prospective service users' resources can be enhanced to convert them as potential collaborators. The roles of actors in a co-creating service environment can be summed in the Figure 3.

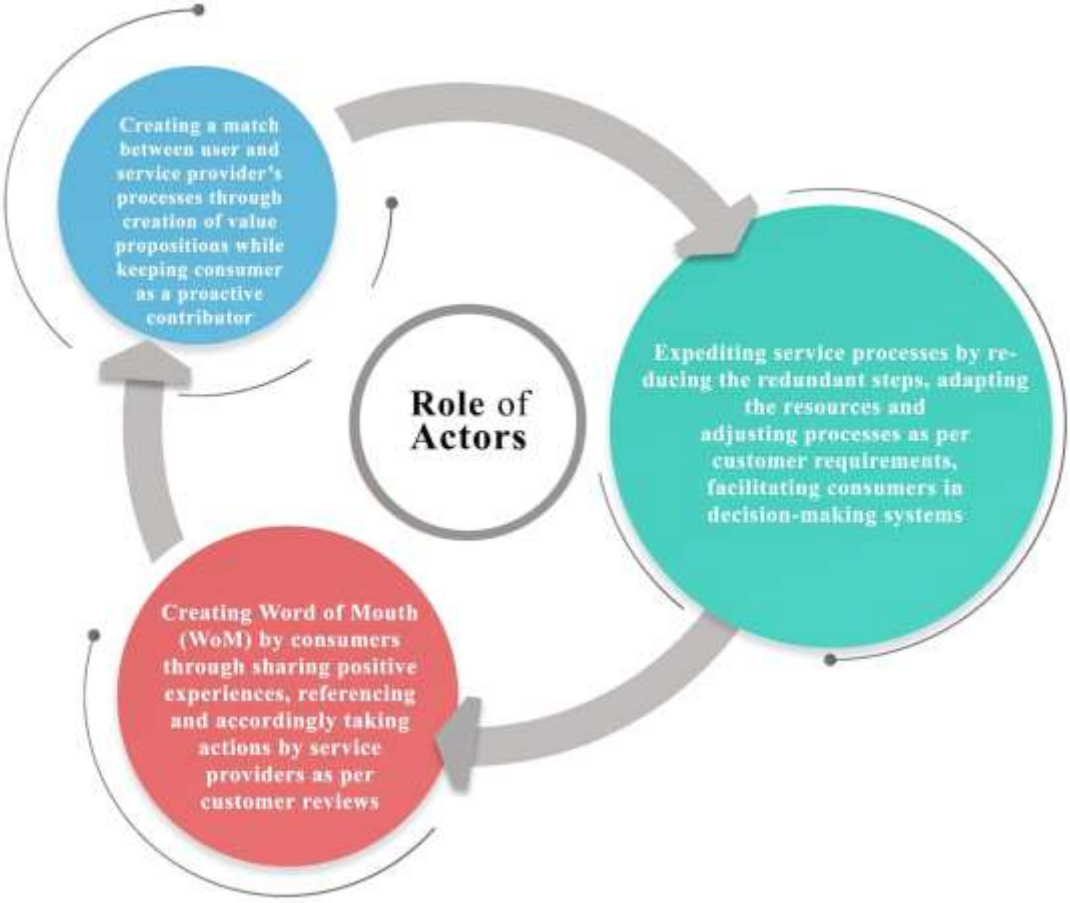

Figure 3. Role of actors in the co-creation process

To sustain the co-creating service attempts, customers furnish diagnostics information on the needs and demands (Aarikka-Stenroos & Jaakkola, 2012; Bagdonienė & Gegužytė, 2018). On the contrary, service providers stimulate customers to define their needs to facilitate co-creation (Chih et al., 2019; Bendapudi & Leone, 2003).

Proposed Model of Co-creation in Professional Services

Developing co-creation by involving multiple stakeholders, including internal and external actors and consumers, is a complex process. Building a conceptual model by deploying the relevant dimensions could range from identifying co-creation opportunities to delineating the roles and motivations of actors for self-sustaining co-creation. The co-creation model is portrayed in the Figure 4.

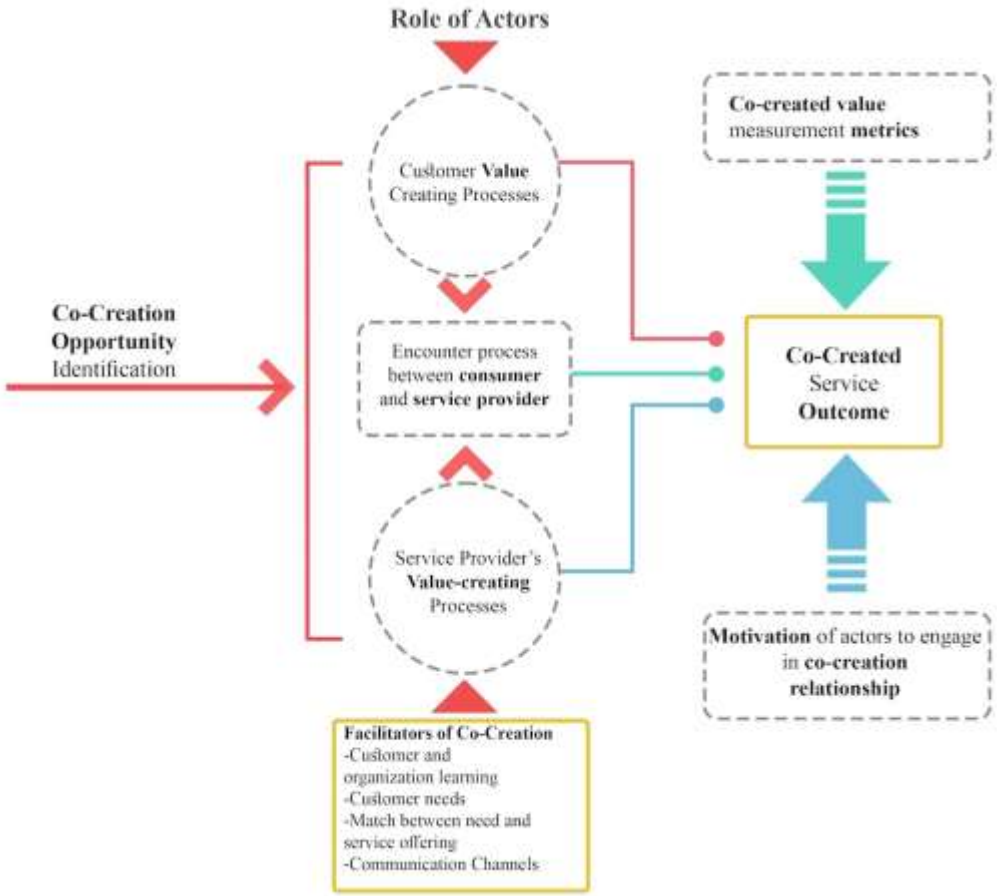

Figure 4. Conceptual model for co-creation development in professional services

The proposed model first introduced the concept of "Opportunity Identification" as the beginning point of co-creating services because the professional service organization determines that a co-created service would lead to better competitive advantage and improve customer satisfaction (Kuula et al., 2018). When the firm finds a congenial atmosphere to bring the stakeholders and customers together for co-creation, such opportunity emerges.

Such co-creation opportunity dictates the respective roles of customers, service providers, and the interaction process between the customer and service providers. For example, the customers come out with their needs, inputs, and experiences so that the service provider can incorporate customers' perspectives into service dimensions. Similarly, the provision of customer reviews and word-of-mouth by the customers promote the service providers' products in a significant way (Figueiredo et al., 2019).

In such a value creation process, the customers' specific needs act as facilitators where the service providers match between the need and offers. In addition, organizational learning is further facilitated as the organization gains experiential learning due to collaboration with the consumers over the years. Next, the motivations of the participating customers and service providers are important determinants of the sustainability of such co-creation efforts. Through the internal communication process within the organizational groups and the external communication elements with the customers, organizations can bring radical and gradual innovative features into the co-creation process (Laud & Karpen, 2017). Finally, the outcomes of these attempts are controlled and quantified through the measurement of metrics which can specify the standards of value creation and how much deviation has passed from the standard. The overall synthesized outcome of these mutually dependent processes is called the "resultant co-created service outcome."

Implications of the Research

Modern service development logic treats the roles of the service providers and consumers as not distinct; instead, the actors can collaborate and co-create the service production process through the amalgamation of mutual interests, resources, and competencies. The current study framed a conceptual model to develop the co-creation in a professional service setting by reflecting on the roles of participants and the criteria and antecedents that could lead to meaningful value co-creation. Our research has implications for the researchers interested in exploring dimensions of co-creation and testing the mechanism in empirical research. The research is also helpful for the service managers and professionals who want to develop a competitive service quality and ensure superior customer satisfaction through introducing a favorable atmosphere for co-creation. The praxis model developed in our paper could help the practitioners better understand the process and implement them in their service context.

Future Research Directions

The proposed co-creation framework has been established by analyzing existing literature. Further research might be conducted on whether the proposed model can be validated through hypotheses testing in empirical research of more specific service sectors, such as accounting or health care, to explore how the model works in diverse sectors. Moreover, the academicians may generate different key thematic concepts from our literature review and formulate relevant co-creation models based on the perceived knowledge gaps. Our research has specified the actors' roles in the process; thereby, further research could specifically examine which traits the actors should have to co-create radical services and whether these traits change at different stages of co-creation processes over time. Our research has attempted to advance how co-creation occurs in the professional service context. Future researchers may develop longitudinal studies to further investigate the different components of our framework.

Conclusion

The objective of the paper was to improve the understanding of co-creation by formulating a conceptual framework for co-creation in professional services. The methodology was to analyze the concerned literature on co-creation within the range of 26 years. The relevant literary sources were reviewed to assimilate the narratives and perspectives in line with the objectives of our research paper. Firstly, the criteria important to consider during the service co-creation procedure were identified and explained from the perspective of the service provider and the consumer. Then, the motivating factors which play a vital role in the interactive co-creating process were evaluated. Thirdly, the concerned actors' precise roles, including user, service provider and the stakeholders were defined to facilitate and successfully implement the co-creation activities. Finally, a model encompassing the required antecedents and processes in a pictorial diagram was proposed. Also, the concerned components and processes of the proposed model were elaborated to explain how a successful co-creation process can be implemented. This paper contributes to the service development literature by presenting co-creation in professional service via the core antecedents and a comprehensive model.

Conflict of Interests

The author declares no conflict of interest.

References

Aakerblom, K. B., & Ness, O. (2021). Peer support workers in co-production and co-creation in public mental health and addiction services: Protocol for a scoping review. *Plos one*, *16*(3), e0248558.

Aarikka-Stenroos, L., & Jaakkola, E. (2012). Value co-creation in knowledge intensive business services: A dyadic perspective on the joint problem solving process. *Industrial marketing management*, *41*(1), 15-26. https://doi.org/10.1016/j.indmarman.2011.11.008

Akhmedova, A., Mas-Machuca, M., & Marimon, F. (2020). Value co-creation in the sharing economy: The role of quality of service provided by peer. *Journal of Cleaner Production*, *266*. https://doi.org/10.1016/j.jclepro.2020.121736

Akolk, N., Huang, Y., & Perrone, V. (2016). *A holistic study of the factors influencing the co-creation process in the B2B market from two perspectives*. http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8876457&fileOId=8876458

Anderson, L., Ostrom, A. L., Corus, C., Fisk, R. P., Gallan, A. S., Giraldo, M., & Williams, J. D. (2013). Transformative service research: An agenda for the future. *Journal of Business Research*, *66*(8), 1203-1210. https://doi.org/10.1016/j.jbusres.2012.08.013

Babu, M. M., Dey, B. L., Rahman, M., Roy, S. K., Syed Alwi, S. F., & Kamal, M. M. (2020). Value co-creation through social innovation: A study of sustainable strategic alliance in telecommunication and financial services sectors in Bangladesh. *Industrial Marketing Management*, *89*, 13–27. https://doi.org/10.1016/j.indmarman.2020.06.003

Bagdonienė, L., & Gegužytė, G. (2018). Working together: understanding value co-creation processes in professional service delivery. *Inžinerinė ekonomika*, *29*(1), 104-114. https://doi.org/10.5755/j01.ee.29.1.18436

Barile, S., Grimaldi, M., Loia, F., & Sirianni, C. A. (2020). Technology, value co-creation and innovation in service ecosystems: Toward sustainable co-innovation. *Sustainability*, *12*(7). https://doi.org/10.3390/su12072759

Barnet, A. F., Ciurana, A. B., Pozo, J. X. O., Russo, A., Coscarelli, R., Antronico, L., & Aguilar, E. (2021). Climate services for tourism: An applied methodology for user engagement and co-creation in European destinations. *Climate Services*, *23*, 100249. https://doi.org/10.1016/j.cliser.2021.100249

Bendapudi, N., & Leone, R. P. (2003). Psychological implications of customer participation in co-production. *Journal of marketing*, *67*(1), 14-28. https://doi.org/10.1509/jmkg.67.1.14.18592

Bettencourt, L. A., & Gwinner, K. (1996). Customization of the service experience: the role of the frontline employee. *International journal of service industry management*. *International journal of service industry management, 7*(2), 3-20. https://doi.org/10.1108/09564239610113442

Bhat, D. A. R., & Sharma, V. (2021). Enabling service innovation and firm performance: the role of co-creation and technological innovation in the hospitality industry. *Technology Analysis and Strategic Management*. https://doi.org/10.1080/09537325.2021.1919614

Bonamigo, A., Dettmann, B., Frech, C. G., & Werner, S. M. (2020). Facilitators and inhibitors of value co-creation in the industrial services environment. *Journal of Service Theory and Practice*. https://doi.org/10.1108/JSTP-03-2020-0061

Chan, K. W., Yim, C. K., & Lam, S. S. (2010). Is customer participation in value creation a double-edged sword? Evidence from professional financial services across cultures. *Journal of marketing*, *74*(3), 48-64. https://doi.org/10.1509%2Fjmkg.74.3.048

Chih, Y. Y., Zwikael, O., & Restubog, S. L. D. (2019). Enhancing value co-creation in professional service projects: The roles of professionals, clients and their effective interactions. *International Journal of Project Management*, *37*(5), 599-615. https://doi.org/10.1016/j.ijproman.2019.04.001

Cluley, V., & Radnor, Z. (2020). Rethinking co-creation: The fluid and relational process of value co-creation in public service organizations. *Public Money and Management*, *41*(7), 563-572. https://doi.org/10.1080/09540962.2020.1719672

Davis, J. M., & Smith, M. (2012). *Working in Multi-professional Contexts: A Practical Guide for Professionals in Children's Services*. Sage.

Davis, J., Docherty, C. A., & Dowling, K. (2016). Design thinking and innovation: Synthesising concepts of knowledge co-creation in spaces of professional development. *The Design Journal*, *19*(1), 117-139. https://doi.org/10.1080/14606925.2016.1109205

Edvardsson, B., Tronvoll, B., & Gruber, T. (2011). Expanding understanding of service exchange and value co-creation: a social construction approach. *Journal of the academy of marketing science*, *39*(2), 327-339. https://doi.org/10.1007/s11747-010-0200-y

Figueiredo, R., Ferreira, J. J., Silveira, R. G., & Villarinho, A. T. (2019). Innovation and co-creation in knowledge intensive business services: the Spinner model. *Business Process Management Journal*, *26*(4), 909-923. https://doi.org/10.1108/BPMJ-10-2019-0424

Font, X., English, R., Gkritzali, A., & Tian, W. S. (2021). Value co-creation in sustainable tourism: A service-dominant logic approach. *Tourism Management*, *82*, 104200. https://doi.org/10.1016/j.tourman.2020.104200

Friend, S. B., Malshe, A., & Fisher, G. J. (2020). What drives customer Re-engagement? The foundational role of the sales-service interplay in episodic value co-creation. *Industrial Marketing Management*, *84*, 271–286. https://doi.org/10.1016/j.indmarman.2019.07.012

Frow, P., Payne, A., & Storbacka, K. (2011). Co-creation: A typology and conceptual framework. Proceedings of *ANZMAC*, 1-6

Fuentes, M., Smyth, H., & Davies, A. (2019). Co-creation of value outcomes: A client perspective on service provision in projects. *International Journal of Project Management*, *37*(5), 696–715. https://doi.org/10.1016/j.ijproman.2019.01.003

Grönroos, C. (1997). Value-driven relational marketing: from products to resources and competencies. *Journal of marketing management*, *13*(5), 407-419. https://doi.org/10.1080/0267257X.1997.9964482

Grönroos, C. (2012). Conceptualising value co-creation: A journey to the 1970s and back to the future. *Journal of Marketing Management*, *28*(13-14), 1520-1534. https://doi.org/10.1080/0267257X.2012.737357

Grönroos, C., & Voima, P. (2013). Critical service logic: making sense of value creation and co-creation. *Journal of the academy of marketing science*, *41*(2), 133-150. https://doi.org/10.1007/s11747-012-0308-3

Gyrd-Jones, R. I., & Kornum, N. (2013). Managing the co-created brand: Value and cultural complementarity in online and offline multi-stakeholder ecosystems. *Journal of business research*, *66*(9), 1484-1493. https://doi.org/10.1016/j.jbusres.2012.02.045

Haneem, F., Ali, R., Kama, N., & Basri, S. (2017). Descriptive analysis and text analysis in Systematic Literature Review: A review of Master Data Management. In *International Conference on Research and Innovation in Information Systems, ICRIIS*. IEEE Computer Society. https://doi.org/10.1109/ICRIIS.2017.8002473

Harhoff, D., Henkel, J., & Von Hippel, E. (2003). Profiting from voluntary information spillovers: how users benefit by freely revealing their innovations. *Research policy*, *32*(10), 1753-1769. https://doi.org/10.1016/S0048-7333(03)00061-1

Heimerl, F., Lohmann, S., Lange, S., & Ertl, T. (2014). Word cloud explorer: Text analytics based on word clouds. In *2014 47th Hawaii international conference on system sciences,*1833-1842. IEEE.

Holbrook, M. B. (2006). Consumption experience, customer value, and subjective personal introspection: An illustrative photographic essay. *Journal of business research*, *59*(6), 714-725. https://doi.org/10.1016/j.jbusres.2006.01.008

Hsu, P. F., Nguyen, T. K., & Huang, J. Y. (2021). Value co-creation and co-destruction in self-service technology: A customer's perspective. *Electronic Commerce Research and Applications*, *46*, 101029. https://doi.org/10.1016/j.elerap.2021.101029

Hussain, K., Jing, F., Junaid, M., Zaman, Q. U., & Shi, H. (2020). The role of co-creation experience in engaging customers with service brands. *Journal of Product and Brand Management*, *30*(1), 12-27. https://doi.org/10.1108/JPBM-08-2019-2537

Jaakkola, E., & Alexander, M. (2014). The role of customer engagement behavior in value co-creation: a service system perspective. *Journal of service research*, *17*(3), 247-261. https://doi.org/10.1177/1094670514529187

Jiang, L., & Yang, L. S. (2017). Research on the Value Co-Creation in College Students' Professional Development Service. In *Proceedings of the 2017 International Conference on Management Engineering, Software Engineering and Service Sciences*, 285-289

Keeling, D. I., Keeling, K., de Ruyter, K., & Laing, A. (2021). How value co-creation and co-destruction unfolds: a longitudinal perspective on dialogic engagement in health services interactions. *Journal of the Academy of Marketing Science*, *49*(2), 236-257. https://doi.org/10.1007/s11747-020-00737-z

Kennedy, E., & Guzmán, F. (2016). Co-creation of brand identities: consumer and industry influence and motivations. *Journal of Consumer Marketing*, *33*(5), 313-323. https://doi.org/10.1108/JCM-07-2015-1500

Khan, A., & Krishnan, S. (2021). Citizen engagement in co-creation of e-government services: a process theory view from a meta-synthesis approach. *Internet Research*, *31*(4), 1318-1375, https://doi.org/10.1108/INTR-03-2020-0116

Khramova, M. (2014). *Co-creating value with customers as a new approach of entering new market*. http://urn.fi/URN:NBN:fi-fe2014112146488

Kleinsmann, M., Valkenburg, R., & Buijs, J. (2007). Why do (n't) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design. *CoDesign*, *3*(1), 59-73. https://doi.org/10.1080/15710880601170875

Knote, R., Janson, A., Söllner, M., & Leimeister, J. M. (2021). Value co-creation in smart services: a functional affordances perspective on smart personal assistants. *Journal of the Association for Information Systems*, *22*(2), 5. http://dx.doi.org/10.2139/ssrn.3923706

Kuula, S., Haapasalo, H., & Tolonen, A. (2018). Cost-efficient co-creation of knowledge intensive business services. *Service Business*, *12*(4), 779-808. https://doi.org/10.1007/s11628-018-0380-y

Laud, G., & Karpen, I. O. (2017). Value co-creation behaviour–role of embeddedness and outcome considerations. *Journal of Service Theory and Practice*, *7*(4), 778-807, https://doi.org/10.1108/JSTP-04-2016-0069

Lawler, J., & Bilson, A. (2009). *Social work management and leadership: Managing complexity with creativity*. Routledge

Lusch, R. F., Vargo, S. L., & O'brien, M. (2007). Competing through service: Insights from service-dominant logic. *Journal of retailing*, *83*(1), 5-18. https://doi.org/10.1016/j.jretai.2006.10.002

Maister, D. H. (1982). Balancing the professional service firm. *Sloan Management Review*, *24*(1), 15-29.

McAlexander, J. H., Kim, S. K., & Roberts, S. D. (2003). Loyalty: The influences of satisfaction and brand community integration. *Journal of marketing Theory and Practice*, *11*(4), 1-11. https://doi.org/10.1080/10696679.2003.11658504

McLaughlin, C.P., Yang, S. & van Dierdonck, R. (1995). Professional service organizations and focus", *Management Science*, *41*(7), 1185-1193.

McNaught, C., & Lam, P. (2010). Using Wordle as a supplementary research tool. *Qualitative Report*, *15*(3), 630-643.

Moghadamzadeh, A., Ebrahimi, P., Radfard, S., Salamzadeh, A., & Khajeheian, D. (2020). Investigating the role of customer co-creation behavior on social media platforms in rendering innovative services. *Sustainability*, *12*(17), 6926. https://doi.org/10.3390/SU12176926

Nambisan, S. (2002). Designing virtual customer environments for new product development: Toward a theory. *Academy of Management review*, *27*(3), 392-413. https://doi.org/10.5465/amr.2002.7389914

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.

Oliver, R. L. (1999). Whence consumer loyalty? *Journal of marketing*, *63*(4_suppl1), 33-44. https://doi.org/10.1177%2F00222429990634s105

Paulini, M., Murty, P., & Maher, M. L. (2013). Design processes in collective innovation communities: a study of communication. *CoDesign*, *9*(2), 90-112. https://doi.org/10.1080/15710882.2012.716850

Payne, E. H. M., Dahl, A. J., & Peltier, J. (2021). Digital servitization value co-creation framework for AI services: a research agenda for digital transformation in financial service ecosystems. *Journal of Research in Interactive Marketing*, *15*(2), 200-222. https://doi.org/10.1108/JRIM-12-2020-0252

Payne, A. F., Storbacka, K., & Frow, P. (2008). Managing the co-creation of value. *Journal of the academy of marketing science*, *36*(1), 83-96. https://doi.org/10.1007/s11747-007-0070-0

Pera, R., & Viglia, G. (2015). Turning ideas into products: subjective well-being in co-creation. *The Service Industries Journal*, *35*(7-8), 388-402. https://doi.org/10.1080/02642069.2015.1015521

Pillitteri, F., Mazzola, E., & Bruccoleri, M. (2021). The four spheres of value co-creation in humanitarian professional services. *Journal of Humanitarian Logistics and Supply Chain Management*, *11*(3), 402–427. https://doi.org/10.1108/JHLSCM-06-2020-0049

Pirinen, A. (2016). The barriers and enablers of co-design for services. *International Journal of Design*, *10*(3), 27-42

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creation experiences: The next practice in value creation. *Journal of interactive marketing*, *18*(3), 5-14. https://doi.org/10.1002/dir.20015

Ramaswamy, V., & Gouillart, F. J. (2010). *The power of co-creation: Build it with them to boost growth, productivity, and profits*. Simon and Schuster.

Roberts, J. A., Hann, I. H., & Slaughter, S. A. (2006). Understanding the motivations, participation, and performance of open source software developers: A longitudinal study of the Apache projects. *Management science*, *52*(7), 984-999. https://doi.org/10.1287/mnsc.1060.0554

Rossi, P., & Tuurnas, S. (2021). Conflicts fostering understanding of value co-creation and service systems transformation in complex public service systems. *Public Management Review*, *23*(2), 254-275. https://doi.org/10.1080/14719037.2019.1679231

Scarlett, G., Reksoprawiro, R., Amelia, N., & Wibowo, A. J. I. (2021). Institutions and technology in the value co-creation process of restaurant consumers: a service-dominant logic perspective. *TQM Journal*, *34*(3), 357-376. https://doi.org/10.1108/TQM-10-2020-0255

Schulz, T., Zimmermann, S., Böhm, M., Gewald, H., & Krcmar, H. (2021). Value co-creation and co-destruction in service ecosystems: The case of the Reach Now app. *Technological Forecasting and Social Change*, *170*, 120926. https://doi.org/10.1016/j.techfore.2021.120926

Srivastava, S. (2021). Exploring Enablers of Value Co-Creation in the Healthcare Service Delivery: An Internal Customer Perspective. *International Journal of Service Science, Management, Engineering, and Technology*, *12*(1), 111-126. https://doi.org/10.4018/IJSSMET.2021010107

Steen, M. (2013). Co-design as a process of joint inquiry and imagination. *Design Issues*, *29*(2), 16-28. https://doi.org/10.1162/DESI_a_00207

Sudo, S., & Ito, Y. (2021). A Possibility of Value Co-creation in the Service Ecosystem of the Paid Media in Japan: Focusing on Viewers' Life Stories. In *International Conference on Applied Human Factors and Ergonomics*, 485-492. Springer, Cham.

Terblanche, N. S. (2014). Some theoretical perspectives of co-creation and co-production of value by customers. *Acta Commercii*, *14*(2), 1-8. https://doi.org/10.4102/ac.v14i2.237

Tóth, Z., Peters, L. D., Pressey, A., & Johnston, W. J. (2018). Tension in a value co-creation context: A network case study. *Industrial Marketing Management*, *70*, 34-45. https://doi.org/10.1016/j.indmarman.2017.08.015

Vargo, S. L., & Lusch, R. F. (2004). Evolving to a new dominant logic for marketing. *Journal of marketing*, *68*(1), 1-17. https://doi.org/10.1509/jmkg.68.1.1.24036

Vargo, S. L., & Lusch, R. F. (2010). From repeat patronage to value co-creation in service ecosystems: a transcending conceptualization of relationship. *Journal of Business Market Management*, *4*(4), 169-179. https://doi.org/10.1007/s12087-010-0046-0

Vargo, S. L., & Lusch, R. F. (2016). Institutions and axioms: an extension and update of service-dominant logic. *Journal of the Academy of marketing Science*, *44*(1), 5-23. https://doi.org/10.1007/s11747-015-0456-3

Voss, C. A., & Hsuan, J. (2009). Service architecture and modularity. *Decision Sciences*, *40*(3), 541-569. https://doi.org/10.1111/j.1540-5915.2009.00241.x

Wang, X., Yuen, K. F., Teo, C. C., & Wong, Y. D. (2021). Online Consumers' Satisfaction in Self-Collection: Value Co-Creation from the Service Fairness Perspective. *International Journal of Electronic Commerce*, *25*(2), 230-260. https://doi.org/10.1080/10864415.2021.1887699

Xiao, Y., & Watson, M. (2019). Guidance on Conducting a Systematic Literature Review. *Journal of Planning Education and Research*, *39*(1), 93-112. https://doi.org/10.1177/0739456X17723971

Yi, Y., & Gong, T. (2013). Customer value co-creation behavior: Scale development and validation. *Journal of Business research*, *66*(9), 1279-1284. https://doi.org/10.1016/j.jbusres.2012.02.026

Zeithaml, V. A. (1988). Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. *Journal of marketing*, *52*(3), 2-22. https://doi.org/10.1177/002224298805200302

Zwass, V. (2010). Co-creation: Toward a taxonomy and an integrated research perspective. *International journal of electronic commerce*, *15*(1), 11-48. https://doi.org/10.2753/JEC1086-4415150101

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ORIGINAL ARTICLE

SCIENCE & ENGINEERING

CHALLENGES OF ACCESSIBILITY FOR MARGINAL PEOPLE IN PRIVATELY OPERATED PUBLIC SPACE: LINEAR PARK, KHULNA AS A CASE

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Abstract

Apart from economic and environmental significance, public spaces have been argued to be one of the most important integrants of urban life for their social role. Nonetheless, a large number of public spaces in different contexts do not promote heterogeneity and lack in publicness. The exclusion of the marginal people from using public space has become a rising issue. However, built environmental design and management play significant roles in contributing to this exclusionary nature in state-owned but privately operated public spaces. To assess the extent and depth of exclusion, this study initially investigates the user condition of the park, who comes to the park, the number of visitors, and above all, the presence of marginal people. Later, with the indicators of accessibility, the study explores the shortcomings of design and management aspects, which are responsible for exclusion. This qualitative research employs a case study approach and uses observation and interview methods in the urban context of Bangladesh. Empirical data is collected from Linear Park in Khulna, a recently developed riverfront park by Khulna City Corporation (KCC) which is leased to a private organization. Findings from this study reveal that different roles of both public and private bodies are responsible for diminishing publicness in both development and use phases. Accordingly, design and management considerations for such urban parks need to be revised to ensure the public space is more comprehensive and inclusive to serve the diverse groups of people.

Keywords: Exclusion, accessibility, publicly owned privately operated park, publicness

Introduction

Public spaces are those that are open to the public and equally accessible to all (Newman, 1973; Carr et al., 1992; Kohn, 2004; Németh & Schmidt, 2007; Maciejko & Czajka, 2019; Micha, 2021). Public spaces enhance social equity through creating and maintaining environments for social interaction (Niemelä, 2014; Wolch et al., 2014). Madanipour (2010) argues that these places are seen as nodes for social cohesion, bringing different people together in public places. Besides, one of the most important characteristics of public places is democracy, which provides participatory, conciliatory, and transparent public spheres (Madanipour, 1996; Yılmaz, 2018). The eleventh goal of the Sustainable Development Goals (SDGs) also sets out to provide universal access to safe, inclusive, accessible, green public spaces, particularly for women and children, older people, and people with physical challenges. Furthermore, a key to achieving the New Urban Agenda is promoting public spaces that are socially inclusive, connected, accessible, and gender-responsive (Andersson, 2021).

But in urban spaces, marginal people have become the forgotten elements (Yatmo, 2008). The public spaces of the contemporary world are being questioned by the equity issue (Lynch, 1972; Carr et al., 1992; Badshah, 1996; Madanipour, 1996; Marcus & Francis, 1997). The presence of constraints and restrictions on access to public space is a common aspect of exclusion, identified in various studies (Madanipour, 1996; Loukaitou-Sideris & Banerjee, 1998; Oc & Tiesdell, 1998; Madanipour, 1999; Carmona et al., 2003). Due to limited access to public space, many marginal groups have been deprived of public spaces to congregate for social interaction (Doherty et al., 2008). With the state's limited fiscal capacity in the provision and management of public space, the number of public spaces managed by private interests are increasing (De Magalhaes & Trigo, 2017; Rahman & Zhang, 2018). "Privatization" in its different forms transforms public spaces, increasing inequalities and limiting access (Miao, 2011; Micha, 2021).

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Furthermore, the limitation of democratic decision-making is that the participation of all voices is merely counted. This fact contributes to shaping public policy, the policy that controls all types of development (Madanipour, 2003).

In our context, marginal people are asserted as a deprived population and providing public space access to them is determined as a future challenge in the Urban Development Directorate (UDD) country paper of Bangladesh. Different accessibility analyses of public space in Dhaka city illustrate that many of these places are losing their inclusive character (Tabassum & Sharmin, 2013; Rahman & Zhang, 2018). Most of the parks cannot accommodate children, the elderly, and the physically challenged as they are not convivial to access and use (Mishu et al., 2014). Realizing the importance of parks for social development, public authorities like Khulna City Corporation (KCC) and Khulna Development Authority (KDA) are establishing new parks and maintaining existing ones (Khaza et al., 2020). Due to low financial capacity and manpower scarcity, KCC is currently contracting out the management rights of a few parks through leasing to private authority. These privately managed parks are seriously prone to marginalized people's exclusion and degrade the character of accessibility. Moreover, assessment of public space accessibility is an important task that is currently inadequately performed in Khulna city (Rahman & Zhang, 2018).

This research is going to search for answers to how exclusionary design and management practices are responsible for diminishing the public character of a publicly owned but privately operated park. With the core vision of exploring the nature, degree, and form of exclusions and limitations of access, this study primarily investigates the user status of a privately leased park. Later, the park is assessed by the indicators of accessibility to understand the influencing factors behind its exclusion. Finally, challenges of accessibility are identified by focusing on the role of public-private partnerships in both the development and use phase.

Literature Review

Those communities who are not accommodated, become marginalized in public space. The term "marginalization," when used broadly, refers to a dynamic between two social analytic categories: the "center" and the "margins." Ordinarily, supremacy, power, and privilege are linked with the center, and apparent powerlessness is associated with the margin. Marginalization is often determined by factors such as gender identity, culture, language proficiency, ethnicity, sexual orientation, religion, political affiliation, financial status, and geographical location (Kurniawati, 2012). In various studies conducted in the European context, the poor, the elderly, children, women, and ethnic minorities have all been identified as marginal communities at risk of social exclusion (Atkinson, 2000; Andersen & Van Kempen, 2003; Kohli & Woodward, 2004).

There are a variety of ways to define marginalization depending on the context and degree of investigation. Badshah (1996) identified marginalized populations very precisely based on their use and accessibility of public space. According to the investigation, women, children, the elderly, physically challenged, street people, and vendors are prone to exclusion in public spaces. This exclusion is determined by their gender, age, economic capacity, and physical ability (Table 1). However, it is also observed that these exclusionary trends are apparent in outdoor public spaces such as squares, streets, and parks. Researchers argue that the tendency has been more prominent in the twenty-first century (Borsdorf & Hidalgo, 2009).

Table 1. Marginal people specification based on public space use

Determinant	Classification
Gender & age	Women, children, elderly
Economic capacity	Vendors and street people
Physical ability	Physically challenged

Privatization occurred with the rise of industrial urbanism when land was co-opted for industrial production and exclusive residential usage. In neoliberal economic restructuring, private sectors have increased in serving urban space, and different modes of public-private partnership initiatives are encouraged by public authorities (Sorkin, 1992). In most developing countries, the government's traditional role and fiscal capacity have diminished, increasingly facilitating "commoditizing" public and urban spaces (Banerjee, 2001; Németh & Schmidt, 2011). Moreover, in need of safety and in search of a better community, restricted spaces are also becoming an inevitable choice for urban decision makers (Doherty et al., 2008).

Because of the global privatization movement, the concept of public-private partnership has been diverse in different contexts. Based on ownership and operation criteria, urban space can be classified into four categories (Zhang, 2017). Typically, ownership is connected to operation, public places are typically operated by the government, whereas private areas are typically managed privately. We can put these two typical spaces at either end of the axis, and spaces with a mix of ownership and operation can be placed somewhere in between (Németh & Schmidt, 2011). Figure 1 represents the four possible ownership and operation combinations. Mixed ownership spaces have become increasingly popular in recent years (Katz, 2006). A large number of public spaces in modern cities are publicly owned but leased to private investors. This 'contracting out of management' is something different from so called 'privatization'. But contracting out the management of public spaces affects accessibility in different ways, depending on what kind of management responsibilities are transferred. The rules for behavior, rights to access and use, opening schedules, etc., are set by the terms and conditions of the lease (De Magalhaes & Trigo, 2017).

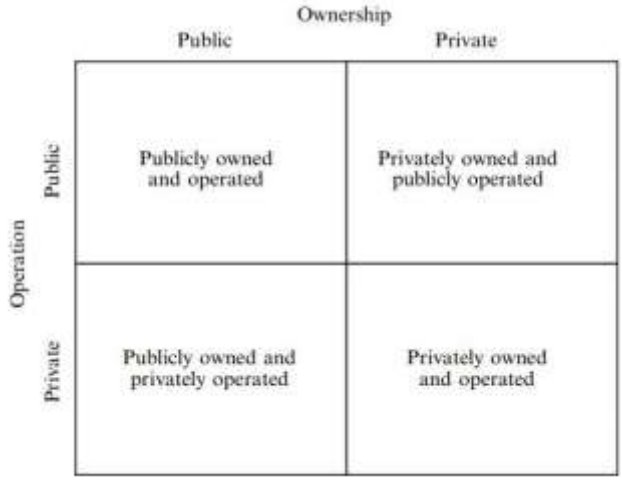

Figure 1. Ownership and operation combinations of public space. Source: (Németh & Schmidt, 2011)

Due to the variety of public–private partnership forms, not all private owners have complete disposal rights, especially with regard to urban public places. If a space is publicly owned, protecting the public interest is the formal requirement for the regulation. Although the management of such spaces might be contracted out, the private management legally should still be accountable to the government and people. Moreover, if the primary purpose of a facility is to serve the general people, the private ownership could not excuse an unjustified refusal of access (Zhang, 2017).

Access is a useful indicator applied in different context for defining and assessing the segregation trend of public space (Schmidt & Németh, 2010; Németh, 2012; La Rosa, 2014; Reyes et al., 2014; Ekdi & Çıracı, 2015). Openness of public space should include physical as well as social accessibility: access to the place and to the activities within it (Madanipour, 2010). Synonymously, physical and social accessibility are the attributes used to measure the accessibility of a space widely used in different studies (Carr et al., 1992; Pasaogullari & Doratli, 2004; Ercan, 2010). Benn and Gaus (1983) divided 'attributes of access' into access to spaces, activities, information, and resources. According to his study, besides physical and social accessibility, a public place should provide activities, resources, information, and discussion to anybody who wants it. Therefore, the exclusion trend of this study is assessed by these four mutually supportive qualities of accessibility. They are physical access, social access, access to activities and access to information. As a functional dimension, the first quality relates to access to the physical environment, as public space is a place where everyone has the right to be physically present (Benn & Gaus, 1983). The second attribute is social access, which indicates who is and is not welcome in the place (Carr et al., 1992). The third and fourth qualities both relate to 'public space' as a place where all are welcome to participate in activities and design discussions about its development and use processes. This research is conceptualized in such a way that the exclusion of marginal people in privately operated parks is directly linked with these four attributes of accessibility.

Materials and Methods

Khulna city covers an area of 45.65 km2 and has a population of about 663,342 (BBS, 2011; KCC, 2021, October 12) . As it was stated earlier, this study is going to assess the accessibility of a publicly owned but privately operated park. There are 3 parks in Khulna city built under KCC supervision but contracted out on a lease basis. These are Khalishpur Wonderland Park, Muzgunni Children's Park, and Linear Park. Khalishpur Wonderland Park started in 1997, Muzgunni Children's Park in 2006, and Linear Park in 2016. Linear Park is new compared to the other parks, and the other two parks are temporarily shut down.

Based on two different continuums of ownership and operation responsible for corresponding development and use phases, Linear Park positions itself as a publicly owned but privately operated entity. As an initiative of KCC, the design and construction of the park started in the year 2009 to increase the city's beautification and to protect the Moyur River from pollution and encroachment. The KCC spent around 24 crore takas to develop the park with the financial help of the Asian Development Bank (ADB) under the City Regional Development Project (CRDP). After completing the construction of the first phase, the park is leased to a private authority named Messrs. Faruq Enterprise in 2015 for 25 years. This study focuses on the existing built area of the park, as highlighted in the Figure 2.

Part of the data that was collected for this research came from documents and archival records, which can be considered secondary data. On the other hand, primary data was collected through face-to-face interviews with a semi-structured questionnaire, direct observation, and key informant interviews.

The population size would be infinite as anybody can visit the park. But since tickets are required to enter the park, only those who entered the park have been interviewed. Data from the park's entry record for the month of September 2021 shows that an average of 113 people came into the park every day. By considering 113 people as a finite population, 88 respondents were interviewed (where the confidence level was 95% and a 5% margin of error was considered) through stratified random sampling. Firstly, the sample population is divided into two broad categories, named marginalized and non-marginalized. Here, all males with an age range between children and elderly are considered non-marginalized respondents. People between the ages of 0 and 12 are regarded as children, 13-18 are adolescents, 19-30 are young adults, 31-55 are adults, and people beyond 55 are considered elderly. Meanwhile, marginal people's categories (women, elderly, children, physically challenged, vendors, and street people) are justified in the literature review section based on determinants such as age, gender, economic capacity, and physical ability. As children and the elderly are treated as separate marginalized groups, women of all ages, other than children and the elderly, are considered marginalized. Other marginal respondents, like vendors, street people, and people with physical disabilities, are chosen based on their economic capacity and physical abilities.

When investigating about physical access, they were asked about their travel distance, mode of transportation, walkability, universal accessibility, and approachability of different park features. During social access, they were asked about the park's attractiveness, safety and security, unpleasant experiences, image and ambience. When collecting data about the third parameter, access to activities, they were asked about why they came to the park, what they liked to do there, and what they really wanted to do more of in the future. In the case of the last parameter, they were asked whether they were aware of the design activities and, if they were involved in the design activities, if they were aware of the various programs or activities that took place at different times after the park was created. Through direct observation, various types of spatial mapping have been made by collecting information about who is coming here on weekdays and weekends, the activities that are taking place both outside and inside the park at any time of the day.

From a holistic point of view, it would not be wise to only listen to the people inside the park but also talk to the people outside. Since this is basically a research of qualitative genre, even though the population size is infinite, 30 people are considered as sample respondents according to the sample size guideline of qualitative research (Creswell, 1998) when conducting unstructured interviews of people outside the park. The only purpose of this unstructured interview was to find out the answer to the question, "Why don't they visit the park?" These 30 respondents are divided equally according to the category of marginalized group.

Figure 2. Understanding the study area

In the case of key informant interviews, semi structured interviews were conducted with the people involved in project design and implementation of the public body KCC and with the person in charge of park management of the Messrs. Faruq Enterprise. Finally, through data triangulation, suitable data was accumulated for this research. A descriptive statistical analysis was done using Microsoft Excel to get a clear picture of the park's user status. Besides, by using the criteria of accessible places and inclusive processes, we analyzed the existing design and managerial practices of the park. The latter part of this research brings together the results of these investigations and presents the challenging scenarios for accessibility.

Results and Discussion

As this research is trying to find different influencing factors that are responsible for marginal people's exclusion in a state-owned but privately operated public space, so the first aspect to look at is the presence ratio of marginal and non-marginal people (Figure 3). Among the total recorded respondents who came to the park, 57% (n = 50) were from the non-marginalized category and 43% (n = 38) were from the marginalized group. Besides, among the non-marginalized group, 32% were adolescents, 50% were young adults, and 18% were adults (fig. 3). Within the marginalized group, 9% were children. 20% were women, 12% were elderly, and 2% were physically challenged. Among 20% of women, 29% of respondents were adolescents, 55% were young adults, and 16% were adults. No street people or street vendors were found inside the park. All these percentage indicates that marginal people have limited access inside the park. However, only 19% of the respondents who came to this park live within 10 minutes' walking distance, but still not all of them came to the park on foot. On the other hand, from the unstructured interview performed with the marginal group outside the park, the reasons for not visiting this park are as follows: (1) Payment to enter the park, (2) Proximity to the entrance, (3) Unsocial activity inside the park, and, (4) Restrictions of street people and street vendors to enter. Further findings are briefly stated below in four key indicators of accessibility, following the methods explained in the previous section.

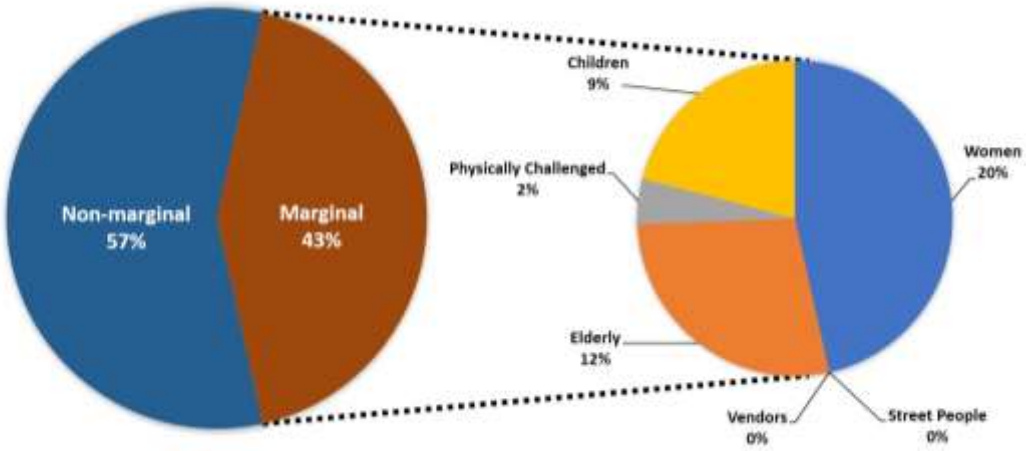

Figure 3. Status of users at Linear Park

Physical Accessibility

A public space is a place that is physically reachable and open to the public (Benn & Gaus, 1983). Under the physical accessibility parameter, vehicular and pedestrian connectivity with the city and surroundings are considered as primary aspects to explore. Though Khulna Linear Park is situated on the outer periphery of the city, it is accessible by different types of vehicular means. It is identified that most people come to visit the park by auto-rickshaw (52%). Other users rely on rickshaws (28%), public transport (6%), personal vehicles (3%) and on foot (11%). In terms of road connectivity, the entrance of the park is connected to the Khulna-Satkhira highway by a secondary road and is situated right next to the park (Figure 4). There is an absence of pedestrian facilities (Figure 5a) on the surrounding roads, including the highway. A park or a public open space is also an important resource for the surrounding community. Therefore, easy and safe access from the surrounding neighborhood ensures spontaneous use of a park (Moran et al., 2020). Moreover, building a safe approach to a park requires separating pedestrian routes from roads so that pedestrians do not compete with automobiles (National Recreation and Park Association, 2015). Despite having a residential neighborhood within a 400-meter radius or 5-minute walking distance of this park, the physically challenged, elderly people, and children are afraid to come to the park on foot due to a lack of pedestrian facilities in the adjoining roads.

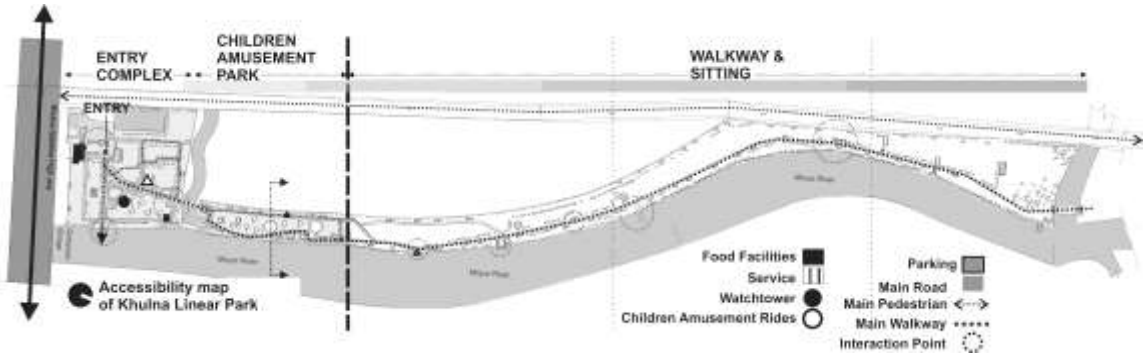

Figure 4. Vehicular and pedestrian access

The entrance to the park is located at the starting corner, and no other gateways are available for the visitor to enter this linear elongated development. Without multiple entrance or exit points, fences and other barriers limit

pedestrian access, resulting in longer walking distances (NRPA, 2015). From activity analysis, it is observed that very few people get access and perform activities in the last portion of the park. According to users, since there is no option to exit or enter from any other point of such a long linear pathway, children, women, the elderly, and physically challenged people have little interest in going inwards as they become tired of walking such a distance. So, it's a clear indication that, the single gateway of the linear park itself is a barrier to access.

Figure 5. (a) Absence of pedestrian facility (b) Less accessible heightened gateway

From the key informant interview with the public body, it is clear that the entrance gate was created with traffic calming and exclusivity in mind. Public authority proposed the elevated gateway (Figure 5b) to welcome the affluent user. Moreover, the entry level is raised so high that children, the elderly, and physically challenged people cannot enter smoothly. Although there is a ramp for physically challenged people, the safe range of slope ratio between 5% -12% (Yılmaz, 2018) is not maintained. As a result, wheelchair users are unable to access the entry on their own. However, if the width of the stair exceeds 6 feet, a handrail should be installed in between for smooth movement of the elderly and children (Yılmaz, 2018), which was not addressed when designing the stair of the entrance gate. Moreover, the elevated gateway symbolically and physically expresses the undesirable people, like street people and vendors, excluded from the environment.

Furthermore, universal accessibility is not properly addressed in different features inside the park. Features like toilets, amusement rides, a watch tower, and the boundary side benches are inaccessible for the elderly and physically challenged people. In addition to this, although the pedestrian walkway within the park is well-designed, there are a number of locations and elements (particularly seating, sculpture, and children's play equipment) where no walkway has been built. Due to the lack of a path, it is impossible to reach there even after establishing all of those features.

The key informant interview with private management revealed that the problems faced by the users related to universal accessibility, walkways, and multiple access points were visible to the private management, but they did not make any modifications or take any initiative to inform the public body about mitigating these issues.

Social Accessibility

A space can be described as socially accessible only if it is accessible to all members of society from all socioeconomic strata (Madanipour, 2013). One of the goals of the Linear Park was to attract visitors from all across the city. However, observation demonstrates that there is a degree of homogeneity (Figure 6a) that prevails rather than variety. The presence of people of varying social classes and orders is rare here. Although, the place has enough area capacity to bind people from different social classes, people of a certain age group, particularly the young, around 40% of the total population, outnumber those of other age groups. Thus, homogeneity creates an unsocial environment which discourages visitors, especially the elderly, women, and children Figure. 6b). Moreover, the absence of heterogeneous users and activity degrades the social image and ambience, making it difficult to welcome the wider social groups of society.

Figure 6. (a) Lack of heterogeneity (b) Activity of homogenous users

When designing the park, a boundary wall was included to ensure the users' safety. In Khulna Linear Park, the boundary wall is perforated adjacent to the parking spot at the park's entry, but it is constructed as a solid wall in other locations. This solid surface (Figure 7a) separates the neighboring community from the park, preventing people from the surrounding neighborhood from seeing inside the park, resulting in a lack of social surveillance. A boundary wall designed with visual transparency ensures natural surveillance as well as safety and security (Saxena & Kamal, 2018). Here, the lack of visual permeability contributes to the creation of unsocial spaces, particularly near the impermeable boundary benches. From the key informant interview, KCC mentioned that though they had planned to build a perforated boundary wall like parking space, due to the limitation of construction budget, they had to build a temporary boundary wall with cheap and unperforated material. Another issue with visual permeability is that the park's front part cannot be seen from the major road. From the street, it is difficult to get a clear view of the area due to some temporary structures of street market. Although both private and state entities attempted to remove them, their efforts were unsuccessful.

Figure 7. (a) Lack of social surveillance due to solid boundary wall (b) Lack of lighting fixtures

Moreover, as a social space, this park should be convivial to use for a longer duration of time, covering both day and night. However, shortage of lighting features in the park discourages people's access at night. Along with a lack of lighting (Figure 7b), the park's limited access and neighborhood exclusion can be attributed to deteriorating the 'safety' image of this place. Illumination, mechanized surveillance (CCTV), and regulated patrolling are some measures for enhancing surveillance of public realms (Banerji & Ekka, 2016). Besides natural surveillance, mechanical surveillance measures and infrastructures are not sufficient compared to the large area that falls under the managerial rights of the private authority. Children, along with women and elderly people, prefer to leave the premise immediately after the sunset.

The authority declares that the insufficient economic benefits push them to a lower maintenance scenario. According to community people who entered the park, they envisioned the park as a location to spend leisure time

after work with their families. They also expected their children would get to play within the park premise during the daytime. This is how they utilized the riverside before the development. However, once the park developed and started to be privately operated, they became the outsiders as users. Thus, the entity has lost its social value.

Access to Activity

It is generally true that people and human activities attract other people (Gehl, 1987; Gehl & Gemzøe, 2001). In a public space, people should have the right to do whatever they want to, except be involved in unsocial and harmful activities. As a privately managed public park, to enter Khulna Linear Park, everyone has to pay an entry fee. After paying entrance through the gate complex, there are rides available for children, a watchtower, a voluntary animal exhibition, a restaurant, and a food stall for all (Figure. 8a).

Among these features, the watchtower is temporarily restricted to entry for safety reasons (Figure 9a). Even though these functions and services are present, they are not uniformly distributed with its long linear development, which is responsible for generating inactive areas on the rear side. The number of inactive areas is around 72% of the total area rendered that contains only walkway and sitting facilities (Figure 8b); whereas, no surveillance measures (natural or mechanical) or even toilets are found nearby in the last portion of the park.

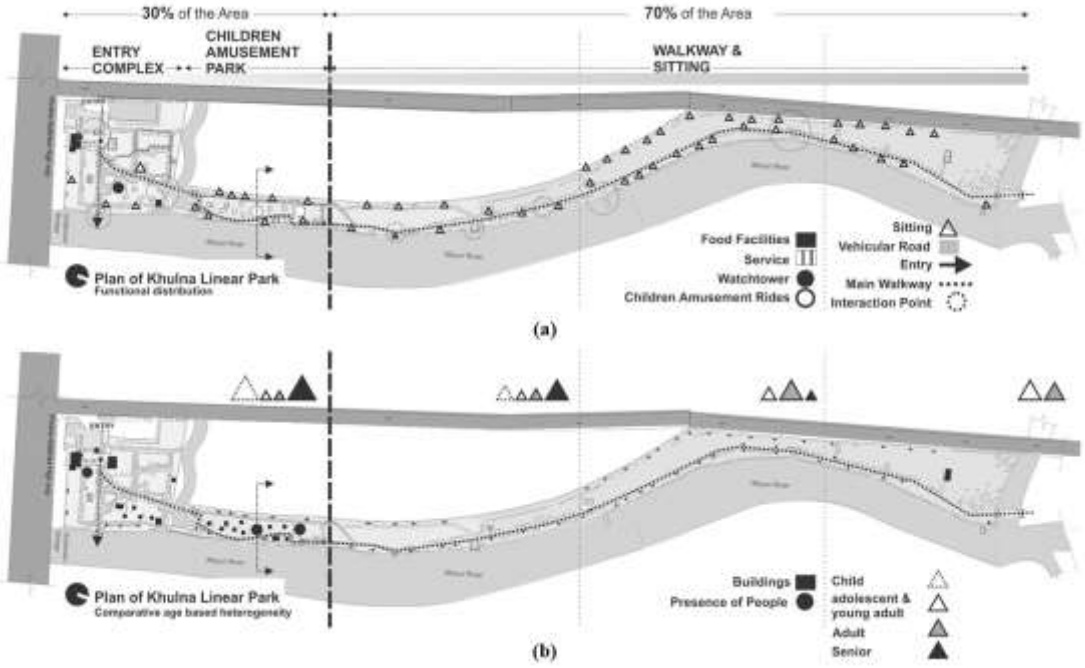

Figure 8. (a) Distribution of features (b) Distribution of user

Besides that, the whole park is accessible by a network of walkways where, after a regular interval, benches are available to sit on. However, these benches were specially designed with a partition rail in the middle to prevent anyone from laying down (Figure 9b). These benches did not meet any special requirements to support elderly people, women, and children sitting there properly. Whereas, seating in public spaces should be age friendly and should avoid the 'one size fits all' model (Barron, 2015).

Figure 9. (a) Inaccessible Park facilities (b) Non-Flexible Park facilities

Although extra fees are required to use children's amusement rides, children are eagerly expecting to try these rides. The mechanical ride, 'Marry-go-round', operated only at the weekend. Besides, other rides remain untouched and vacant on a regular working day, while the number of child visitors appears low. Moreover, there is literally no scope left for street children to enter freely and enjoy these rides. There is also no equipment found for physical exercise, especially for elderly people. For women, those who want to visit the park with their infants have no provision for privacy for breastfeeding and diaper-changing facilities.

There are ample street hawkers and vendors found outside the park gate. These are mostly street foods that remain occupied and crowded with people. But, inside the park, vendors' access is strictly prohibited. Here, as a private entity to enhance their economic benefit, authority is strict to discourage income-generating opportunities for others. However, during the survey, there were very few people found in the restaurant and food stall located inside, whereas this part should be occupied by a good number of visitors.

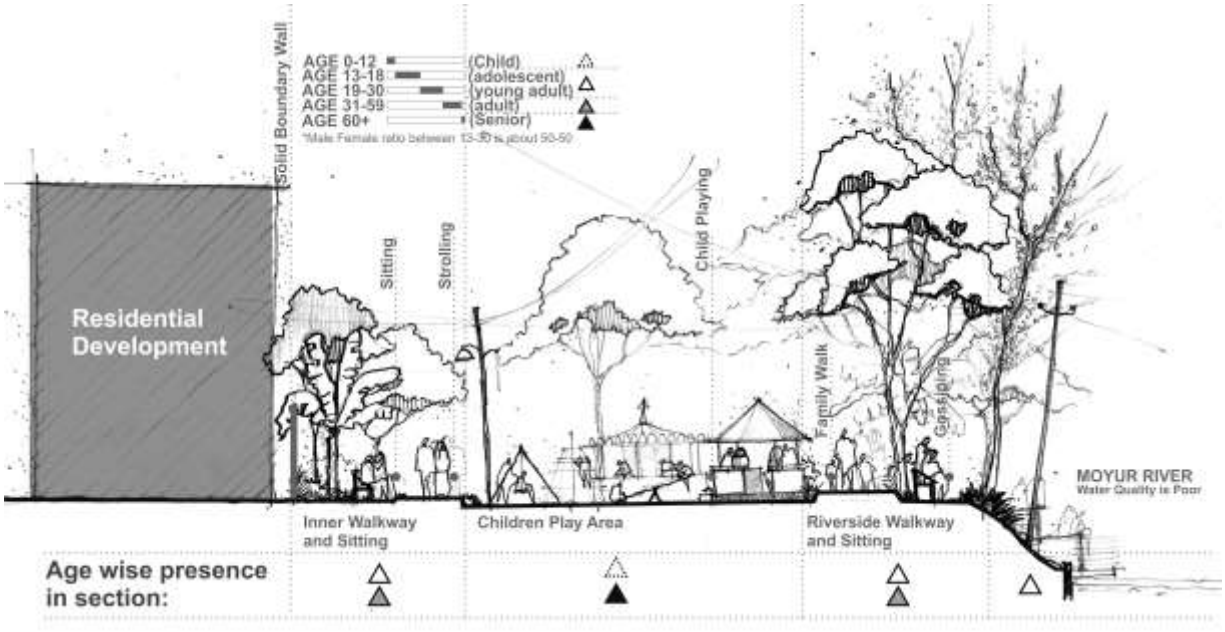

Figure 10. Expected heterogeneous activity

As mentioned earlier, this park is located by the river Moyur and is envisioned as an active waterfront park (Figure 10). But due to its controlled environment, the general public is deprived of the opportunity to enjoy this intended waterfront free of cost. In different examples around the world, riverfront developments and activities are

mostly 'open to all' (Un-Habitat, 2020; Getachew et al., 2022). Creating such a controlled environment excluded marginalized people and even the general population from having access to the Moyur River. In addition, despite being a waterfront park, the safety of children has not been considered while developing roadways and other elements along the water in numerous locations.

In addition, with all these shortcomings, the celebration of Bangla New Year is the most prominent event that is organized by the park authorities every year. But the number of visitors is not that satisfactory. There is no dedicated performing platform designed by the public body to host diversified events or cultural activities. Apart from taking some small initiatives like mini zoo construction, food stall renovation etc., no significant other steps have been taken by the private authority to further enhance the activity inside the park.

Table 2. Challenging factors of accessibility for marginal people in Linear Park, Khulna

Indicators	Design Aspect	Management Aspect	Challenges of Accessibility
Physical Access	No pedestrian connection for neighboring community Single gateway limits to access and disperse Symbolic and physical exclusion by elevated gateway Inapproachable green space and designed areas by walkable pathway Features are not convivial to access	No initiatives are observed to solve the inaccessible features Universal accessibility is not acknowledged and solved Unwillingness to inform the public body for necessary up-gradation	Pedestrian friendliness Walkability Multiple access Universal accessibility Accountability of private body Design sensibility
Social Access	Neighborhood exclusion reduce social surveillance Solid boundary wall develops impermeable visual connectivity Lack of diversified features to promote heterogeneity Budgetary constraint to build the perforated boundary Insufficient lighting fixtures Absence of neighboring community integration	Tolerating homogenous user's unsocial activity Lack of concern to improve lighting condition Insufficient surveillance measures (CCTV, Security guard)	Heterogeneity Permeability Control measure Surveillance Community belongingness
Access to Activity	Inappropriate functional distribution generating inactive areas Universal design considerations are absent Insufficient features compared to large areas Irrespective of approaching riverfront Unsafe water edge for children No formal provision for street vendors	Charging unaffordable entry and rides fees Absence of park-side riverfront maintenance Maintenance deficiency of existing features Lack of upgrading and increasing new features Depriving street vendors from economic activity Profit oriented motives (Facility Commodification) Lack of initiatives to organize cultural and social events	Affordability Universal accessibility Liberal mindset of private body Maintenance Feature commodification Flexibility of features
Access to Information	Absence of participatory approach in design and development Resource limitation of manpower Financial limitation in implementation Lack of wider social vision	Absence of signage to guide Lack of initiatives for raising public awareness	Participatory design Information communication User awareness Capacity buildup

Access to Information

This attribute of 'access' allows us to describe the 'public space' as a place where all members of society can contribute ideas about its development and use processes (Ercan, 2010). Hence, crucial discussions and information, such as the decision-making stage of developing a public space and the design scheme preparation process, must be open to all. However, there was no participatory event during the planning phase of Khulna Linear Park to accommodate the insights of society's underserved people. Even, local people are treated as marginalized by getting deprived from the development process. Only 24% of the interviewed users of the park heard about the initiatives of KCC to develop the area. None of them participated in any phase of design or planning discussion. On the other hand, according to the statement of the authority (KCC), it was quite challenging to accommodate general people's feedback in the development phase. This is one of the vital aspects that lie behind the exclusionary nature of this park. From the key informant interview, the limitations are specified as scarcity of the manpower of the municipal authority, economic insolvency of the governing body, narrow political vision, and stratified mindset of the user are responsible for avoiding public participation in the design process.

In the use phase, the user did not remain up-to-date with political and cultural events through posters and verbal announcements. However, very few cultural events took place in the park. Furthermore, necessary instructions like signage, area map have not been provided by the private authority to inform and guide the users inside the park.

Summary of the findings indicate that design and management aspects addressed by public and private bodies have contributed to promoting exclusion in Linear Park, Khulna. We can categorize these influencing factors, which can be termed as the 'challenges of accessibility' (Table 2).

Conclusion

In light of the data, it's possible to conclude that marginalized people are being excluded from the Linear Park because of design and management challenges. KCC expected to revitalize the Mayur River and created a public park to meet the city's growing demand for recreational space. However, due to their resource limitations, they were forced to lease the park after design implementation. As a result of the profit-driven nature of the private authority management, this park has become increasingly homogeneous.

From the accessibility analysis of the case study, it is revealed that marginal people are excluded from access both physically and socially. Moreover, they are not prominently involved in diversified activities and have no participation in accessing information and design activities. Physical accessibility of the park is challenged by design aspects like pedestrian friendliness, universal accessibility, and means of access. However, private authorities lack the accountability and willingness to minimize those physical barriers. Furthermore, the social ambience of the park is hampered by the absence of heterogeneity. Here, the permeability of the peripheral boundary plays a key role in minimizing social surveillance. Since there is no visual connection, the surrounding community also does not have any belongings with the inner environment. Apart from the KCC initiative, private authority is also quite reluctant to manage these situations and accentuate different control measures like lighting, posting sufficient security guards and CCTVs. Moreover, it is also observed that activities inside the park are not widely performed by different marginal groups. Most of the amenities and functions constructed by the city authority are not designed as flexible and universally accessible. Space and feature commodification by private authority excludes the environment from the urban poor since they are unaffordable to access and use. Besides, the lease holder prioritizes economic beneficiaries without properly operating the maintenance. In terms of design participation, from the early period of the development phase, people were not involved in the design process. Like many other city governing bodies in developing countries, KCC had serious financial and manpower limitations for conducting participatory design approaches. Even though private authority has the right to run the park, they don't give visitors any information to help them figure out how to use the park.

As evidenced by this study, there has been a clear conflict between the social value of the public space and the economic interests of the park's stakeholders. However, the commodification of urban space is unavoidable in developing countries due to the limited resources of the local government. Capacity building of the local authority is required to accelerate the traditional role in the provision and management of public space. Moreover, in terms of contracting out of the management, the rules and responsibilities of the private body need to be specified in the

leasing documents. The public-private partnership should not diminish the 'Publicness' and may appear as a potential strategy to accelerate this prominent characteristic of public space. Collaborative engagement between public and private bodies, active participation by all stakeholders in decision-making at all stages of development and use phase, as well as assuring people's 'Access to Design', may ensure that public space has a socially valuable purpose for everyone. The findings of this study may assist urban planners, architects, and government decision-makers in reforming design and management strategies and providing viable, accessible, and inclusive public space for all.

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Conflict of Interests
The author declares no conflict of interest.

References

Andersen, H. T., & Van Kempen, R. (2003). New trends in urban policies in Europe: evidence from the Netherlands and Denmark. *Cities*, *20*(2), 77-86.

Andersson, C. (2021). Public space and the new urban agenda. In *Public Space Reader* (pp. 420-425). Routledge.

Atkinson, R. (2000). Combating social exclusion in Europe: the new urban policy challenge. *Urban studies*, *37*(5-6), 1037-1055.

Badshah, A. A. (1996). Our urban future: new paradigms for equity and sustainability. *London and New Jersey*, *1*.

Banerjee, T. (2001). The future of public space: beyond invented streets and reinvented places. *Journal of the American planning association*, *67*(1), 9-24.

Banerji, H., & Ekka, A. A. (2016). Designing Safer Cities-Review of Environmental Crime Prevention Strategies. *GSTF Journal of Engineering Technology*, *3*(4), 25-32.

Bangladesh Bureau of Statistics. (2011). *Population and Housing Census, Khulna, Bangladesh*. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, .

Barron, A. (2015). *Age-friendly seating and sense of place*. Manchester City Council.

Benn, S. I., & Gaus, G. F. (1983). The public and the private: concepts and action. *Public and private in social life*, *3*, 297-325.

Carmona, M., Heath, T., Oc, T., & Tiesdell, S. (2003). *Urban spaces-public places: The dimensions of urban design*. Oxford: Architectural Press.

Carr, S., Stephen, C., Francis, M., Rivlin, L. G., & Stone, A. M. (1992). *Public space*. Cambridge University Press.

Creswell, J. (1998). *Qualitative inquiry and research design. Choosing among five traditions*. Sage Publications. Inc.

De Magalhaes, C., & Trigo, S. F. (2017). Contracting out publicness: The private management of the urban public realm and its implications. *Progress in Planning*, *115*, 1-28.

Doherty, J., Busch-Geertsema, V., Karpuskiene, V., Korhonen, J., O'Sullivan, E., Sahlin, I., . . . Wygnanska, J. (2008). Homelessness and exclusion: regulating public space in European cities. *Surveillance & Society*, *5*(3).

Ekdi, F. P., & Çıracı, H. (2015). Really public? Evaluating the publicness of public spaces in Istanbul by means of fuzzy logic modelling. *Journal of Urban Design*, *20*(5), 658-676.

Ercan, M. A. (2010). *Less public than before? Public space improvement in Newcastle city centre*. Routledge.

Gehl, J. (1987). *Life between buildings* (Vol. 23). New York: Van Nostrand Reinhold.

Gehl, J., & Gemzøe, L. (2001). *New city spaces*. Danish Architectural Press.

Getachew, A., Asnake, K., & Desta, H. (2022). Increasing the publicness of riversides as public space development on Kebena River, Addis Ababa, Ethiopia. *Environmental Systems Research*, *11*(1), 1-14.

Katz, C. (2006). Power, space, and terror: Social reproduction and the public environment. *The politics of public space*, *185*, 105-110.

Khaza, M. K. B., Rahman, M. M., Harun, F., & Roy, T. K. (2020). Accessibility and service quality of public parks in Khulna city. *Journal of Urban Planning and Development*, *146*(3), 04020024.

Khulna City Corporation. (2021, October 12). *"Basic Statistics"*. http://www.khulnacity.org/content/index.php?page=about_kcc&zwc&pid=30

Kohli, M., & Woodward, A. (2004). *Inclusions and exclusions in European societies*. Routledge.

Kohn, M. (2004). *Brave new neighborhoods: The privatization of public space*. Routledge.

Kurniawati, W. (2012). Public space for marginal people. *Procedia-Social and Behavioral Sciences*, *36*, 476-484.

La Rosa, D. (2014). Accessibility to greenspaces: GIS based indicators for sustainable planning in a dense urban context. *Ecological Indicators*, *42*, 122-134.

Loukaitou-Sideris, A., & Banerjee, T. (1998). *Urban design downtown: Poetics and politics of form*. University of California Press.

Lynch, K. (1972). *The Openness of Open Space*.

Maciejko, A., & Czajka, R. (2019). Accessibility of the Open Public Space in Cities. International Conference on Applied Human Factors and Ergonomics,

Madanipour, A. (1996). *Design of urban space: An inquiry into a socio-spatial process*. Wiley.

Madanipour, A. (1999). Why are the design and development of public spaces significant for cities? *Environment and Planning B: Planning and Design*, *26*(6), 879-891.

Madanipour, A. (2003). *Public and private spaces of the city*. Routledge.

Madanipour, A. (2010). Marginal public spaces in European cities. In *Whose Public Space?* (pp. 111-130). Routledge.

Madanipour, A. (2013). *Whose public space?: International case studies in urban design and development*. Routledge.

Marcus, C. C., & Francis, C. (1997). *People places: design guidlines for urban open space*. John Wiley & Sons.

Miao, P. (2011). Brave new city: Three problems in Chinese urban public space since the 1980s. *Journal of Urban Design*, *16*(2), 179-207.

Micha, E. (2021). The public space of capitalist society: Acts of inclusion and exclusion. In *School of Architecture* (Vol. 2020-2021, pp. 10): National Technical University of Athens.

Mishu, M. R., Barua, U., & Stoican, I.-A. (2014). The changing nature of urban public places in Dhaka city. *Urbanism. Architecture. Constructions/Urbanism. Arhitectura. Constructii*, *5*(4).

Moran, M. R., Rodríguez, D. A., Cotinez-O'Ryan, A., & Miranda, J. J. (2020). Park use, perceived park proximity, and neighborhood characteristics: Evidence from 11 cities in Latin America. *Cities*, *105*, 102817.

National Recreation and Park Association. (2015). *Safe Routes to Parks: Improving Access to Parks through Walkability*.

Németh, J. (2012). Controlling the commons: how public is public space? *Urban Affairs Review*, *48*(6), 811-835.

Németh, J., & Schmidt, S. (2007). Toward a methodology for measuring the security of publicly accessible spaces. *Journal of the American planning association*, *73*(3), 283-297.

Németh, J., & Schmidt, S. (2011). The privatization of public space: modeling and measuring publicness. *Environment and Planning B: Planning and Design*, *38*(1), 5-23.

Newman, O. (1973). *Defensible space: Crime prevention through urban design*. Collier Books New York.

Niemelä, J. (2014). Ecology of urban green spaces: The way forward in answering major research questions. *Landscape and Urban Planning*, *125*, 298-303.

Oc, T., & Tiesdell, S. (1998). City centre management and safer city centres: approaches in Coventry and Nottingham. *Cities*, *15*(2), 85-103.

Pasaogullari, N., & Doratli, N. (2004). Measuring accessibility and utilization of public spaces in Famagusta. *Cities*, *21*(3), 225-232.

Rahman, K. A., & Zhang, D. (2018). Analyzing the level of accessibility of public urban green spaces to different socially vulnerable groups of people. *Sustainability*, *10*(11), 3917.

Reyes, M., Páez, A., & Morency, C. (2014). Walking accessibility to urban parks by children: A case study of Montreal. *Landscape and Urban Planning*, *125*, 38-47.

Saxena, R., & Kamal, M. A. (2018). The impact of built environment on crime prevention and safety in schools: An environmental-behavior design guidelines approach. *American Journal of Civil Engineering and Architecture*, *6*(6), 260-270.

Schmidt, S., & Németh, J. (2010). Space, place and the city: Emerging research on public space design and planning. *Journal of Urban Design*, *15*(4), 453-457.

Sorkin, M. (1992). *Variations on a theme park: The new American city and the end of public space*. Macmillan.

Tabassum, S., & Sharmin, F. (2013). Accessibility analysis of parks at urban neighborhood: The case of Dhaka. *Asian Journal of Applied Science and Engineering*, *2*(2), 48-61.

United Nations Human Settlements Programme. (2020). *Public space site-specific assessment: Guidelines to achieve quality public spaces at neighbourhood level*. UN-Habitat. https://unhabitat.org/public-space-site-specific-assessment-guidelines-to-achieve-quality-public-spaces-at-neighbourhood

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'. *Landscape and Urban Planning*, *125*, 234-244.

Yatmo, Y. A. (2008). Street vendors as 'out of place'urban elements. *Journal of Urban Design*, *13*(3), 387-402.

Yılmaz, M. (2018). Public space and accessibility. *ICONARP International Journal of Architecture and Planning*.

Zhang, X. (2017). Identifying consumerist privately owned public spaces: The ideal type of mass private property. *Urban studies*, *54*(15), 3464-3479.

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ORIGINAL ARTICLE

SCIENCE & ENGINEERING

EXPLORING IMPACTS OF URBAN DENSITY ON TRAVEL BEHAVIOR IN KHULNA CITY, BANGLADESH USING SPATIAL ANALYSIS

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Abstract

Urban density not only represents the intensity of travel demand, but also serves as a useful tool for quantifying the elements that influence travel behavior and demand. In this study, Khulna City of Bangladesh has been selected as a case study to explore the impacts of urban density on travel behavior in a city of a developing country. The average characteristics of urban density, as well as their impacts on travel behavior and demand, have been studied using geospatial analysis techniques. Urban densities have been categorized into Single Density (Population Density, Employment Density, and Building Density) and Composite Density (Household to Work trip Density, Household to School trip Density and Household to Shop trip Density) based on characteristics of travel behavior and demand. Descriptive statistics have been used to explore the impacts of urban densities on the various trip characteristics such as trip production, trip distance, trip cost, trip time, and trip mode. Diversity of trips and overall trip attraction areas have been identified using the Shannon diversity index and other spatial analyses. Trip production, trip distance, trip time, trip cost, and mode choice all show a positive linear relationship with urban single-density, according to this study. The everyday activities of residents are closely related to urban composite densities, and trip production increase in tandem with composite densities. It has been concluded that different urban densities have significant impacts on travel demand and travel behavior.

Keywords: Urban density, travel behavior, mode choice, spatial analysis, trip variation

Introduction

Transportation is one of the most important sectors among all sectors that the urban planner has to plan because the economic and social condition of a city largely depends on the transportation systems. Urban transportation systems spatially connect various activities occurring in an urban area (Meyer & Miller, 1984; Sun et al., 2017). The urbanization of developing countries is dynamic; large cities in these countries are under constant strain as a result of massive migration from rural regions and the rapid rise of private transportation services in addition to the public transportation (Domencich & McFadden, 1975). Travel behavior depends on dynamic factors of transportation where people's characteristic and the geographic location plays an important role. People use transportation for different purpose but the variation of travel behavior highly depends on the geographic location. Travel behavior in urban area is different from other sub-urban and rural area (Ewers, 1995; Kockelman, 1997). People's activities cannot be performed without traveling; hence transportation plays the most crucial part in their day-to-day activities. The trip of people is closely related to their social demographic characteristics such as gender, age, marital status, occupation, education level, vehicle ownership, and family activities. Working activities, educational activities, shopping, leisure activities, and so on are all included in the activities (Maduwanthi & Marasinghe, 2015). One of the most important factors in determining travel demand and behavior is urban density. It not only reflects the magnitude of travel demand, but also provides a useful technique for quantifying the elements that influence travel demand and behavior (Cervero & Kockelman, 1997). The significant proportion of data collected and analyzed in many disciplines of urban planning and development, such as various statistics and observation data, is regional. As a result, it is a useful tool for identifying, quantifying, and describing urban development and changes based on urban densities (Peng & Lu, 2007).

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Bangladesh is a developing country and its third largest metropolitan city is Khulna. With the passage of time, modern science and technology adhere the changes required for the human civilization. The earth has become the primary concern to prioritize the changes in terms of land use and transportation. In this era urban density is increasing day by day (Bhadra & Sazid, 2015). With the growth of population, the demand will change with socio-economic pattern of the community. The urban transportation system has been aggravated by population growth, which has resulted in it exceeding its capacity (Sharmeen, 2014). Khulna city is also facing increased population growth and rapid growth of urban built up area day by day. Defining the Khulna city's transportation sector, it has peculiarities and has great dependence on non-motorized slow-moving vehicle (Bhadra & Sazid, 2015).

Individual and household socioeconomic variables have been proven to have a significant impact on mode choice decisions in previous study. Income, gender, car ownership, and employment status are the most important variables in determining the mode of transportation, and approximately 50 to 60 percent of trips are completed for work, school, or shopping (Lin & Yang, 2009; Miller et al., 2005). According to a series of researches, sociodemographic factors have a significant impact on travel preferences (Hanaoka et al., 2014; Hsieh et al., 1992). Gender, household income, household composition, car ownership, and age, among other variables, have a larger impact in socio-demographic aspects (Curtis & Perkins, 2006). Many researches have investigated into the connections between work patterns, time management, and travel behavior (Aguilera, 2008). The majority of human trips are done for work, school, and shopping purpose that's why these three purposes of trip is used in this research. This study aims to identify the patterns of travel behavior in Khulna City, investigate the relationship between urban density and travel behavior, and determine the most diversely attractive travel destination in the city.

Materials and Methods

This research has applied spatial analysis to explore the impact of urban density on travel behavior in Khulna, Bangladesh. The impact of urban densities on travel behavior has been studied for various landforms and activities based on this analysis. The main purpose of this research is to observe the spatial relationship between urban density and travel behavior. The selected study area for this research is Khulna City Corporation area. Khulna is one of the largest metropolitan cities in Bangladesh. Geographically, Khulna lies at 22"49'north latitude and 89"34'east longitudes. Khulna is a linear-shaped city. There are mainly two reasons behind the selection of the study- i) Urban density is increasing day by day in this city and the purpose of this research is to explore the impact of urban densities on travel behavior. ii) The census data, Detailed Area Plan and Master Plan of Khulna city is available which can be a great help for data collection.

Necessary Data and Sample Size

For this research both primary and secondary data have been used. Secondary data has been collected from BBS population and housing census 2011, Detail area plan and other related information. Necessary secondary GIS database is collected from KDA and Urban and Rural Planning discipline of Khulna University. BBS statistics were forecasted for 2019 in order to be used in this study. To get travel behavior data systematic random sampling technique have been used to determine the sample size. Each ward has been considered as traffic zone and major road is the main target to collect sample data in this sampling process. Primary data collection has been done through questionnaire survey at household level in 2019. The Household interview survey has been conducted to know the socio-economic status of the trip maker, travel characteristics for different modes, trip purpose, travel distance, travel time, travel cost etc. For estimating the sample size, Yamane's Simplified Formula for Proportions method is used. Total 400 household survey has been done for this research where the acceptable sampling significance was 5%.

Urban Density and Travel Behavior

In this research, Single density and composite-density are two forms of measurable urban density indicators that have been used. Population density, employment density, and building density are all included in a single density. Home to work trip density, home to school trip density, and home to shopping trip density are all included in the composite density. Trip production, mode choice, trip distance, trip cost, and trip time, on the other hand, have all been considered into travel demand. In this work, the single density and composite density are calculated using the spatial analysis approach. GRID has been created for all data in the GIS environment to identify the relationship between urban densities and travel behavior. Basically, (400m*400m) 0.16 sq km GRIDs are prepared to increase

the accuracy of the trip destination data and then using a spatial analysis method, mathematical calculations were made among the GRID data in the context of urban density and travel behavior.

According to method suggested by (Hanaoka et al., 2014), purpose wise trip origin-destination and trip number composite density is generated. Where trip flow from origin to destination and trip number is used to measure composite density in Khulna city. Line density is measured through ArcGIS where each trip flow represents the length of the portion of each line that falls within the circle radius. The corresponding population field values are total number of weekly trips in a household for each trip purpose.

Composite Density = ((L1 * V1) + (L2 * V2)) / (area of circle)

The length of the portion of each line that falls within the circle is represented by lines L1 and L2. V1 and V2 are the corresponding population field values.

It has been hypothesized that people's travel behavior will vary because of the variation of urban density. In order to meet the objectives formulated before the study, various analytical procedures e.g. cross-tabulation, and multiple response analysis have been performed. This analysis was done using SPSS and MS Excel. These procedures have given us information on trip generation, the pattern of trip variation with variation in housing condition, land use, family-size income group modal choices in the study area. The conceptualization of this research is shown in **Figure 1**.

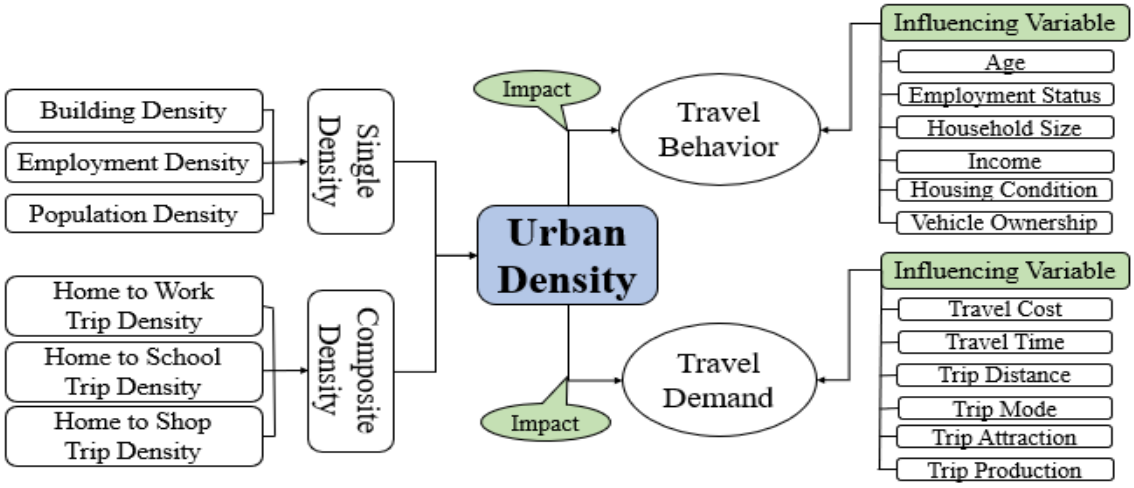

Figure 1. Conceptual flow chart of this study

Result & Discussion

Travel Behavior in Khulna City

The study of what people do in space and how they use transportation is known as travel behavior. It is critical to understand the behavior of a large number of people while examining travel behavior. Individuals' decision to choose one option among the others in the choice set, as well as their assessment and consideration of the various alternatives, must be based on various of factors, including their need, task, socioeconomic, environmental, and the level of service provided by the various alternatives. In the following part analysis has been done for household and individual attributes including housing type and mode choice, mode choice by income group, mode choice and trip purpose, and using travel distance by trip purpose for different modes.

The analysis result (Figure 2a) shows that use of various kind of modes varies significantly with the change of housing type of the trip makers. Lower income group basically lives in Katcha house, and they like to walk prior to use any kind of motorized mode for producing trip. That's why people from Katcha housing likes to walk and produce 48% of total walking trip. Easy Bike has been found as the most dominated mode in Khulna City. The 'private car' mode is used only by the people from 'Pucca' house type, as they earn more. The high-income group people in Khulna city prefer to use mainly motor cycle, rickshaw or private car.

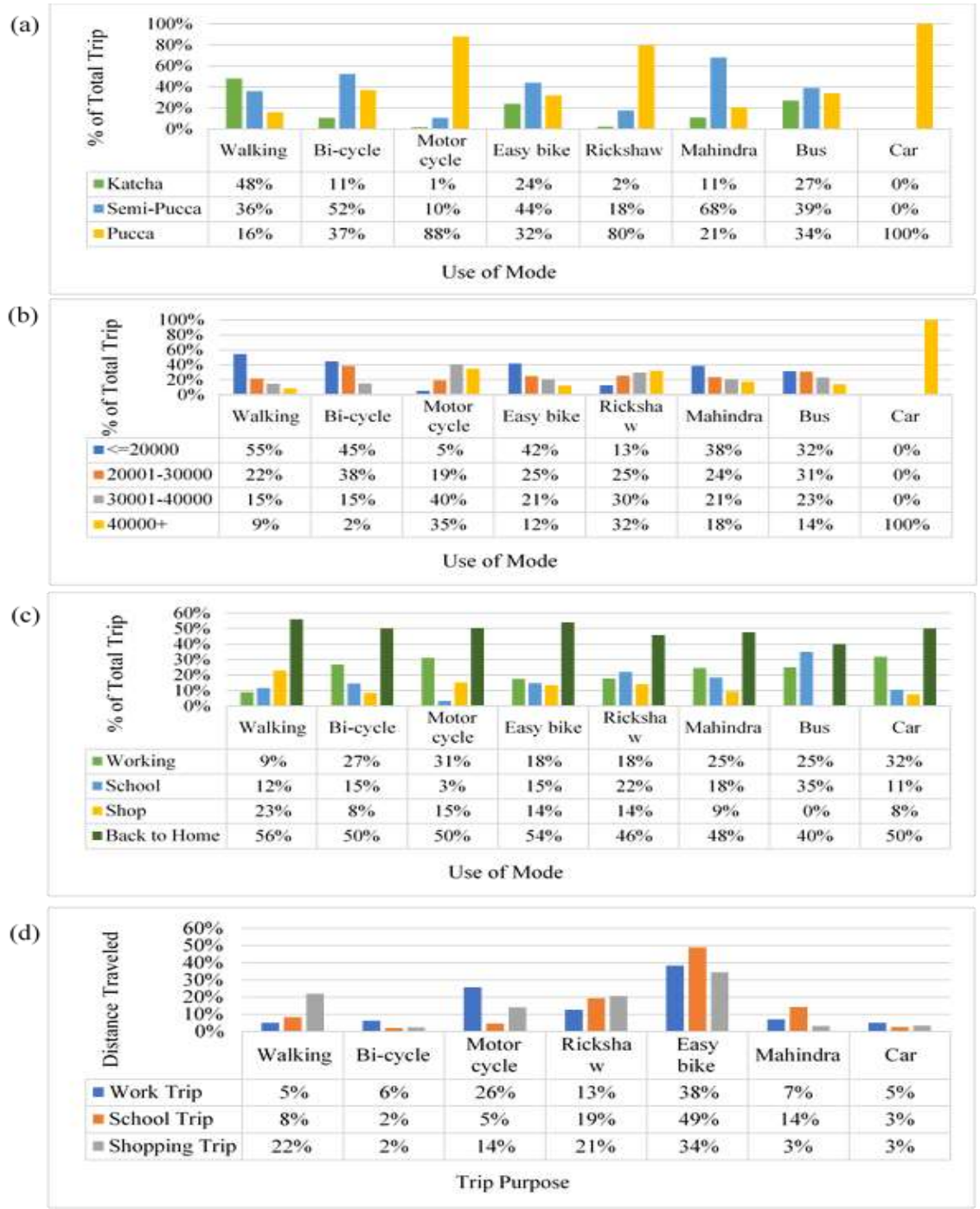

Figure 2. Travel Behavior in Khulna City use of different Mode by a) Housing Type b) Income Group c) Trip Purpose d) Travel Distance

Use of mode changes when the income group changes (Figure 2b). People who have a lower income usually likes to walk where person with a handsome income tends to choose motorized mode e.g. motorcycle, rickshaw, personal

car or others. Figure 2b shows the monthly household income in Khulna city, broadly categorized into four major groups. Use of personal vehicles e.g. motorbike or personal car is pretty low in the study area and so does the use of public transport as there is no effective public transport system in Khulna city. Privately owned vehicle and rickshaw is mainly used by the comparatively high-income group. Use of travel mode changes with the change of purpose of any trips.

The cluster bar chart (Figure 2c) shows that people like to walk for shorter trips no matter what the purpose is. But in case of women or child use of rickshaw and easy bike is common for making any trip regardless of travel distance. It is also seen that people use different modes in different times of the day.

In recent decades, trends in travel behavior have been characterized by increase of trip distances and a modal shift towards the private vehicle. But in the selected area the scenario is different, here most of trips are made by a particular paratransit called 'easy bike'. From the clustered bar chart (Figure 2d) it is clear that for all purposes of trip maximum distance is travelled by easy bike- such as for work trip 38%, school trip 49% and shopping trip 34% distance of the journey is travelled by easy bike. In the case of shopping trip maximum distance is travelled by rickshaw compared to other two trip purposes.

Mode Choice of the Home-Based and Home-End Trip

Mode choice is the most important determinant of the travel behavior of the people. Travel mode choice indicate the social and economic condition of the people in developing countries. The mode also indicates the transportation supply in the city.

Work trip is the most important purpose for all trip makers. For leading human life work trip is mandatory for all. Work trip is the main factor which produces most of the trips. The result (Table 1a) shows that Easy bike is the most dominant mode for work trip. It also shows the differences between Home-Based Trip and Home-End Trip mode choice. Here for the work trip purpose Home-End rickshaw choice is lower than Home-Based trips but Home-End walking & Easy Bike choice is higher than Home-Based trips.

Table 1: Mode Choice of Home-Based & Home-End Trip for a) Work b) School c) Shopping

Purpose	(a) For Work		(b) For School		(c) For Shopping	
Mode	Home-Based Trip	Home-End Trip	Home-Based Trip	Home-End Trip	Home-Based Trip	Home-End Trip
Walking	13%	15%	17%	24%	37%	31%
Bi-cycle	7%	7%	5%	5%	3%	3%
Motor cycle	18%	18%	2%	2%	11%	11%
Rickshaw	17%	10%	27%	18%	16%	24%
Easy bike	34%	40%	42%	44%	31%	29%
Mahindra	3%	3%	3%	2%	2%	2%
Car	4%	4%	2%	2%	1%	1%
Bus	3%	3%	2%	2%	---	---

School trip also another major purpose for all educated family. According to Bangladesh Government, now a day's primary education is mandatory for all level of people. Here for the school trip purpose Home-End rickshaw choice is lower than Home-Based trips but Home-End walking & Easy Bike choice is higher than Home-Based trips (Table 1b). Easy bike is the most dominant mode for school trips as well. Shopping trip is also another major trip purpose; to meet basic need shopping trip is a must for any household. Shopping trip distance and trip number per week is low compared to other two purposes of trip. It also shows the differences between Home-Based Trip and Home-End Trip mode choice (Table 1c). Here, for the shopping trip purpose Home-End walking and Easy Bike choice is lower than Home-Based trips, but Home-End rickshaw choice is higher than Home-Based trips.

Urban Density and Travel Demand in Khulna City

The number of people who live in a given urbanized area is referred to as urban density in urban planning and design. As a result, it differs from other population density measurements. When it comes to understanding how things operate, urban density is a critical factor to consider. The intensity of human activities within the confines of city space, as well as the intensity of urban land use development, are both reflected in urban density. Due to the close relationship between urban density and mixed land use, its analysis can produce a lot of information about urban travel demand. Considering all issue, two types of density have been considered in this research- **A.** single density and **B.** composite density.

A. Single Density:

In this research under the single density category three types of density have been considered-population density, employment density and building density. Population density and Employment density maps have been prepared using BBS 2011 community series data where the density map shows per acre population density and employment density respectively. And building density is prepared using the KDA DAP data, where per acre floor density is measured. Figure 3a shows the population density in KCC area where per acre density is measured. Ward no 19, 20, 27, 26, 25, 10, 11 and 12 shows high population density where per acre population density is 151 or close to 151. Figure 3b shows the employment density in KCC area where per acre density is measured. Here, ward no 7, 11, 19, 20, 21, 22, 26 and 27 shows high employment density where per acre employment density is 9 or close to 9. This result shows high variation of employment density among the wards. Figure 3c shows the building floor density in KCC area where per acre building floor density is measured. Minimum per acre building floor density is 3 and maximum building floor density is 23.65 per acre in KCC area.

B. Composite Density:

In this study three types of composite density are measured through origin to destination trip flow. According to three purposes of trip three types of composite density are measured using spatial analysis- Household to Work trip density, Household to School trip density and Household to Shop trip density. Figure 4a shows the Household to Work trip density. From the spatial analysis it is clear that trip concentration is higher in the ward no 19, 20, 21, 22 and 23. Highest household to work trip density indicates the TAZ where maximum work trips are attracted. Basically, this is the CBD area in Khulna city.

Figure 4b shows the school trip density, and it is clear that trip concentration is higher in the ward number 6, 9, 14, 24 and 27 where maximum school trips are attracted. Most of the bigger educational institutes are situated in these wards. It is also clear that most of the household to school trip density is observed at the middle of the southern and northern part of the KCC area. Figure 4c shows the shopping trip flow from household. Trip density is higher in ward no 5, 6, 10, 14, 16, 17, 19, 20, 21 and 24. Higher household to shopping trip density is visible near the residential areas of KCC area. This indicates the fact that most residential areas are served by a market in proximity. To meet the local demand most of the wards in KCC area have small or medium sized grocery market in proximity to the residential areas.

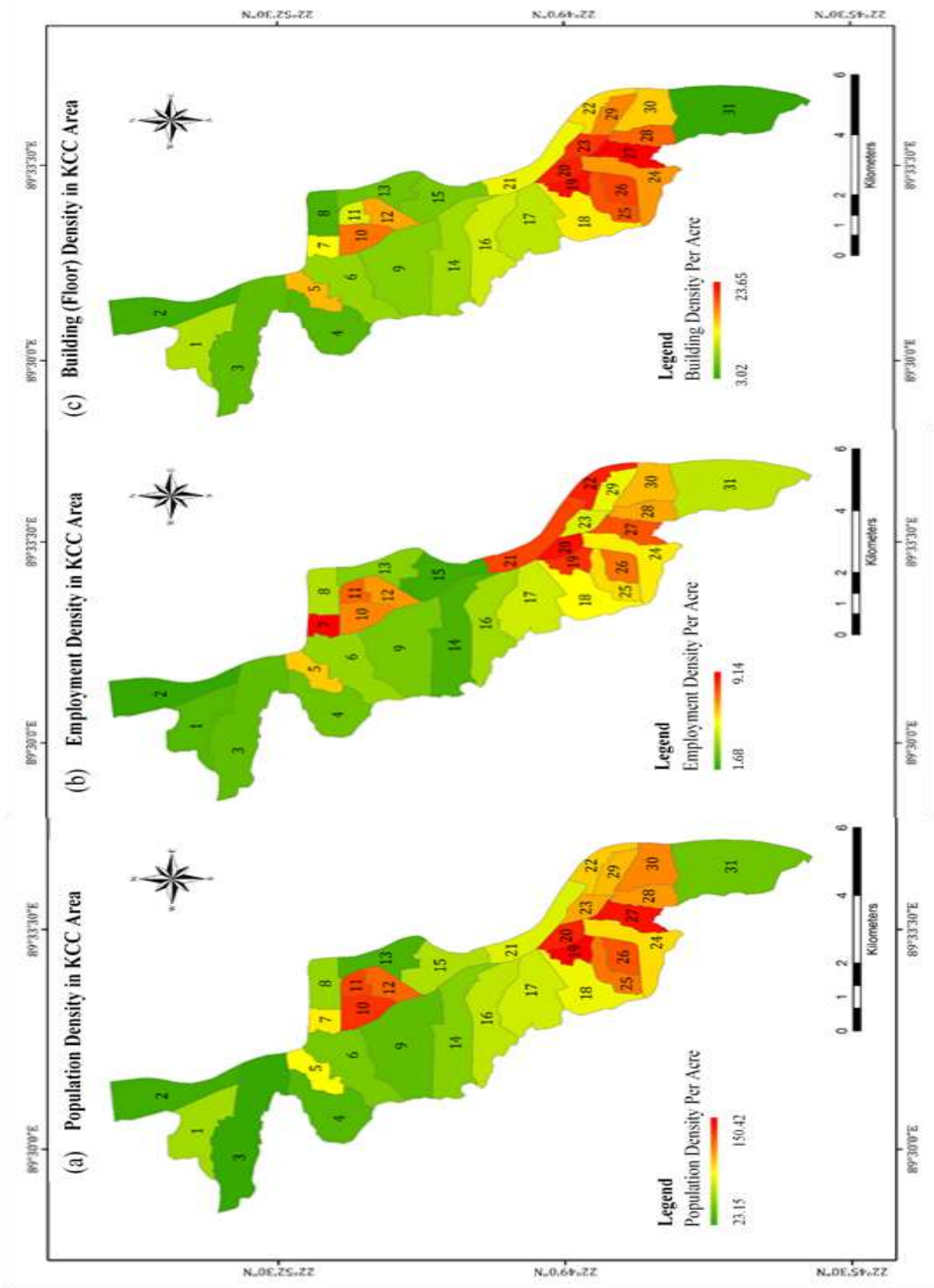

Figure 3. Map of Single Density in KCC a) Population Density b) Employment Density c) Building Density

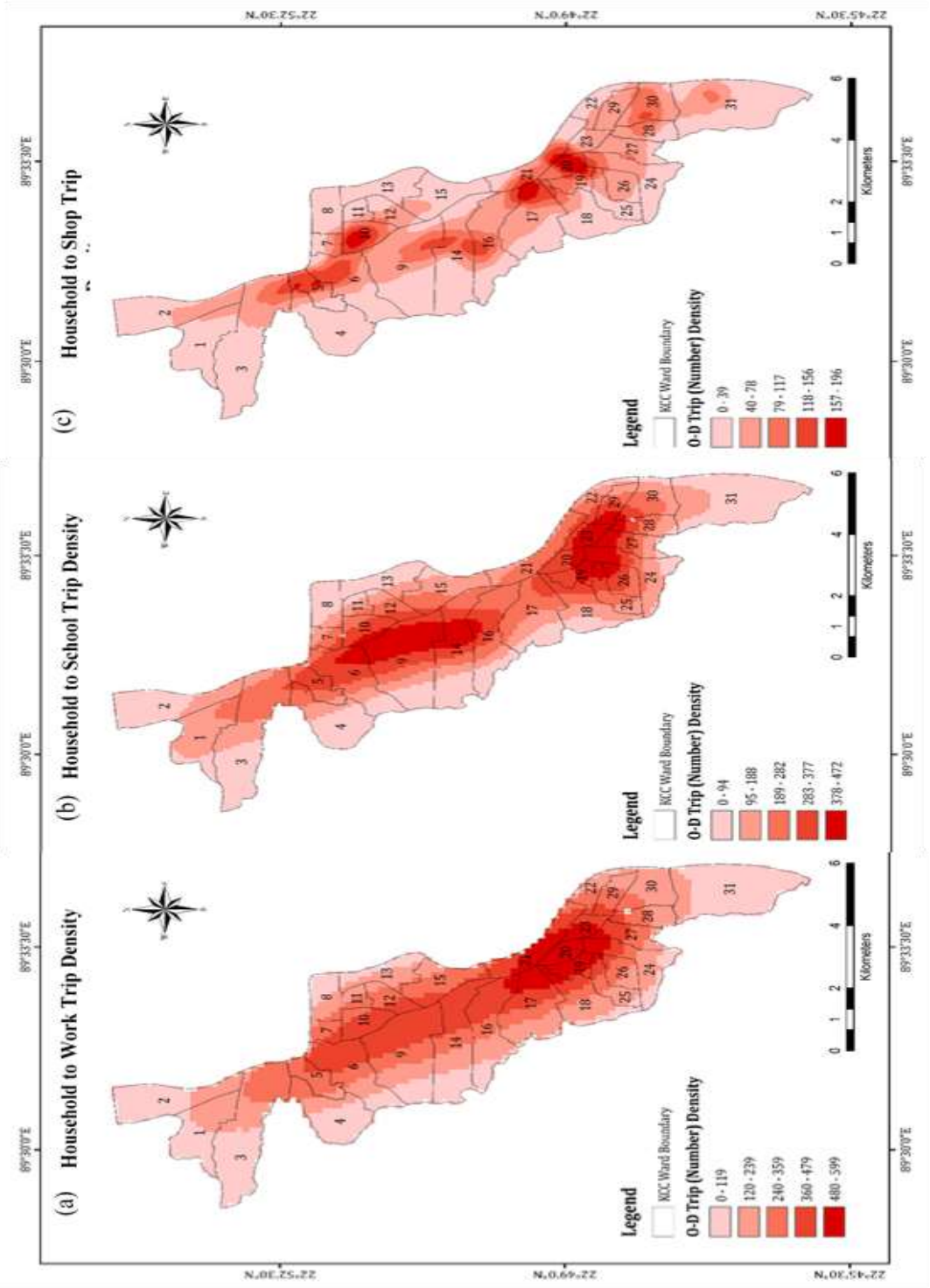

Figure 4. Map of Composite Density in KCC a) HH to Work Trip b) HH to School Trip c) HH to Shop Trip

a) Population Density and Trip Parameters

For the purposes of urban transportation analysis, population density is a critical factor. Spatial analysis has been used to study the relationship between urban densities and travel behavior since the introduction of GIS in transportation research. The relationships among population density, trip production, trip distance, trip time, and trip cost were investigated using spatial analysis in this study. Here, population density is considered as five categories of density (<38=Very Low, 38-57= Low, 57-102= Medium, 102-124= High and 124+= Very High). All the density is provided as per acre population density.

In Khulna City, the box plot (Figure 5a) illustrates a monotonically increasing relationship between population density and trip production. As the population density is higher, the number of trips produced is also higher. Where population density is low or medium, the number of trips produced (weekly) is low compared to higher density area. Ward no 17 and 24 are exceptional considering their density category and high trip production. Trip distance also shows similar relationship with population density. The trip distance (in km) decreased as the population density increased in Khulna City (Figure 5b). Trip distance variability is high for very low and low population density area compare to other density area. Trip distance variability is low for very high-density area. That means travel distances of the people of high-density area is low compared to low density area's people. Population density and trip time box plot (Figure 5c) shows that with the increase of the population density, the trip time (in minute) is decreased in Khulna City. Trip time variability is high for low and medium population density compared to other density area. Population density and trip cost box plot (Figure 5d) indicates that with the increase of population density trip cost (weekly) is decreased in Khulna City. Trip cost variability is high for very low, low and very high density compared to other density area. Low population density area's people spend more money for making trips compared to very high population density area's people.

b) Employment Density and Trip Parameters

The method for determining employment density is similar to that used to determine population density. Employment density, trip production, trip distance, trip time, and trip cost are all related in the same way that population density and trip parameters are. Here, employment density is considered as five categories of density (<2=Very Low, 2-3.4= Low, 3.4-4.8= Medium, 4.8-7.22= High and 7.22+= Very High). All the density is provided as per acre employment density.

In Khulna City, the analysis reveals a monotonously increasing relationship between employment density and trip production (Figure 5e). When employment density is low and very low, the trip production (weekly) variability is low compared to other density category area. That means where employment density is high, the probability of trip production is also high. Figure 5f, Figure 5g and Figure 5h shows a generic trend where if employment density is increased, people's trip distance (in km), trip time and trip cost is decreased. Trip distance variability is high for very low and low employment density area compared to other density areas. That means high density area's people usually make shorter trips compared to low density area's people. Trip time variability is low for high and medium density area. That means people of very high-density area's travel time is low compared to low density area's people. Accordingly, trip cost variability is high for low, very low and very high density compared to other density areas. That means trip cost of high-density area's people is lower compared to low and very low-density area's people.

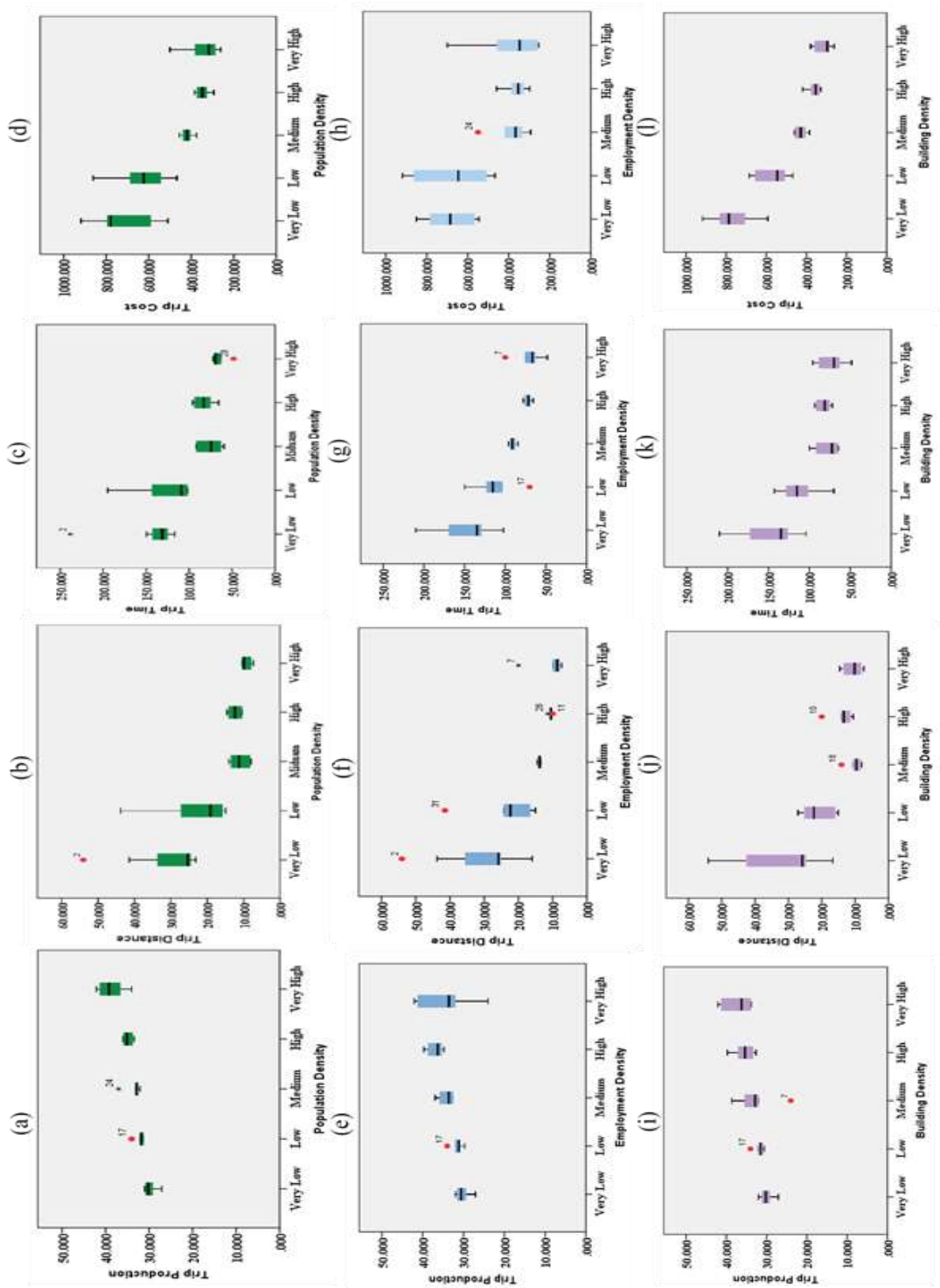

Figure 5. Single Density and Variation of Trip Parameter

c) Building Density and Trip Parameters

The density of buildings is an important factor to consider when analyzing urban transportation. Where building density is high, people's residence and activity will also be high. At the same time those places produce or attract more trips compared to low density area. The relationships among building density, trip production, trip distance, trip time, and trip cost have been analyzed using spatial analysis and spatial statistics. Here, building density is considered as five categories of density (<6=Very Low, 6-9= Low, 9-14= Medium, 14-19= High and 19+= Very High). All the density is provided as per acre building density.

There is (Figure 5i) a positive linear relationship between building density and amount of traffic in Khulna City. When building density is low and very low, the trip production (weekly) is also low compared to other density area. Figure 5j, Figure 5k and Figure 5l also shows the trend similar to employment density. When the area's building density is increased, trip distance, trip time and trip cost are also decreased. Trip distance is higher for very low and low building density compared to other density areas. It is also seen that high building-density area's people make shorter trips compared to low density area's people. Trip time is higher for very low and low building density compared to other density area. Accordingly, trip cost is higher for very low, low density compared to other density area. Low building density area's people spend more money for making trips compared to very high building density area's people.

Trip Attraction

The map (Figure 6a) shows the trip attraction pattern. Total number of destination trip points is analyzed through hot spot analysis where spatial clustering tendency has been found significant. Using the hot spot Z score value, IDW interpolation has been done to get the predicted trip-attraction surface, where high Z value indicates the areas with higher trip attraction. Here, ward no 14, 17, 21, 20 and 23 attracts more trips compared to other wards. In fact, ward no 17, 21, 20 and 23 are the CBD area in KCC.

Spatial Autocorrelation for Destination

From the Global Moran's I analysis (Table 2), the autocorrelation value of Z=5.78 indicates a strong significance that trip points are spatially clustered, not random. The near zero (0) p value rejects the null hypothesis and indicates that total number of trip points distribution are more spatially clustered than random with high confidence level. Positive Moran's index also suggests spatial clustering of the trip points.

Table 2. Global Moran's I statistics

Global Moran's I Summary	
Moran's Index:	0.250894
Expected Index:	-0.003559
Variance:	0.001935
z-score:	5.784607
p-value:	0.000000

From the spatial analysis it is identified that in KCC area trips are spatially clustered. In reality, CBD area attract more trips compared to other area or wards.

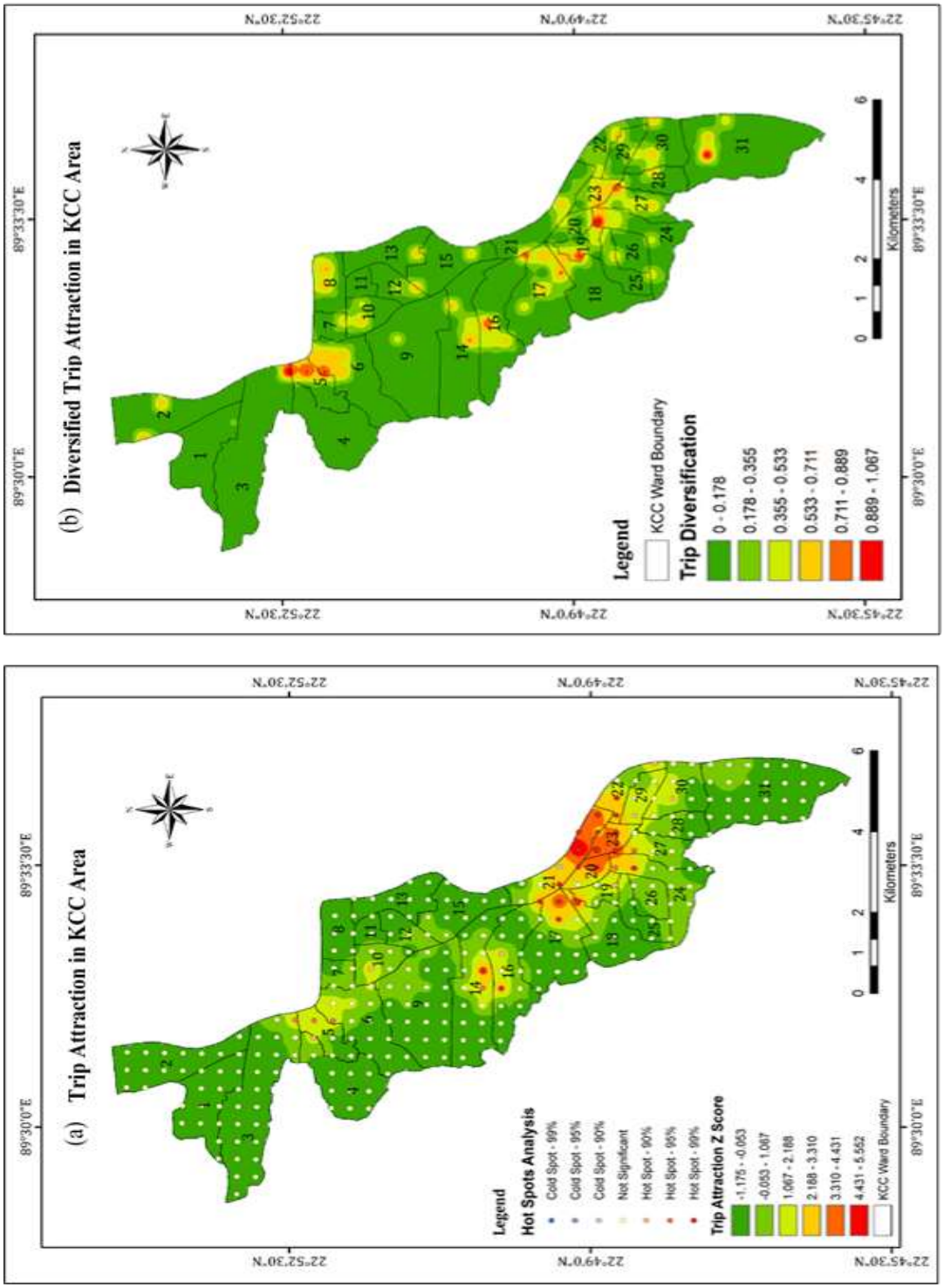

Figure 6. Map of Trip Attraction in KCC Area a) Trip Attraction Hot Spot b) Diversified Trip Attraction

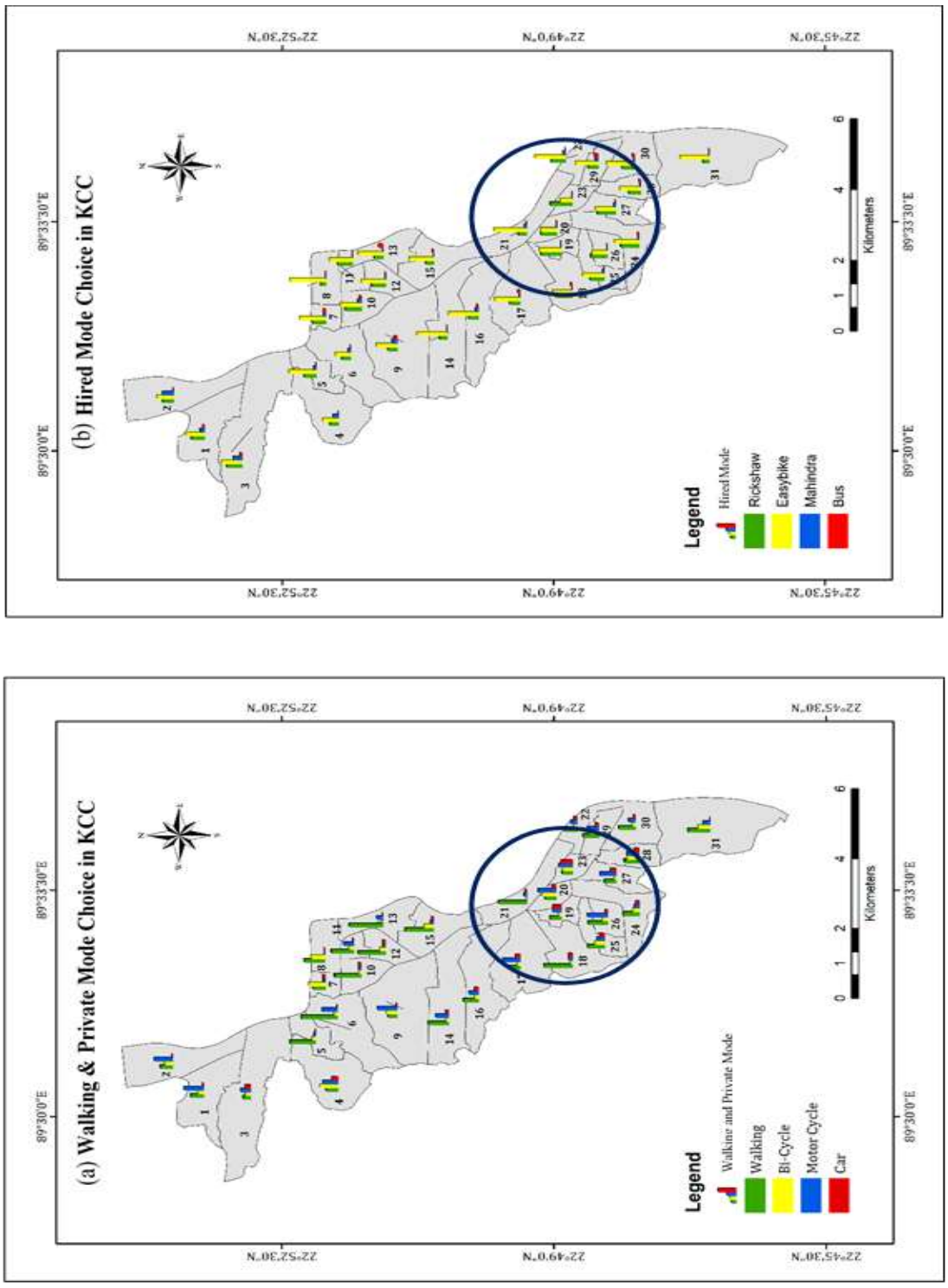

Figure 7. Map of Spatial Variation of Mode Choice a) Walking & Private Mode Choice b) Hired Mode Choice

Diversified Trip Attraction Area in KCC

Figure 6b shows diversification of trip attraction in KCC area. To measure diversity of trip attraction, Shannon diversity index has been used. Here, three purposes of trip have been considered here to measure trip diversity. For Khulna City Corporation area 1.06 is the maximum value for diversified trip attraction which is indicated by red color. These red colored areas indicate that these areas attract all three purposes of trip (work trip, school trip and shopping trip). Highest value of Shannon diversity index indicates existing maximum trip diversity. On the other hand, close to zero or zero value indicate there is no trip diversity. No trip diversity means there is only one type of trip attraction, high value indicates that this area attracts all types of trips. In contrast, the green color indicates that the area attracts only one type of trips from work trip, school trip or shopping trip.

Spatial Variation of Mode Choice

In this part of the study eight modes of travel have been chosen to describe the spatial variation of mode choice. Here, these modes are categorized into two groups. The first one is walking and private mode (Bi-Cycle, Motor Cycle and Car) and second one is hired mode (Rickshaw, Easybike, Mahindra and Bus). Figure 7a and Figure 7b shows the percentages of total mode share for the wards in KCC. From the previous spatial analysis of urban density, areas of high density have been identified. Both single and composite density areas are identified for ward number 18 to 29. Figure 7a shows the percentages of Walking, Bi-Cycle, Motor Cycle and Car choice of total trips in the respective wards. Here, the blue circle area represents highly dense areas and the diversity of chosen mode is also higher in those areas compared to outside areas of the circle. In reality, this area is the CBD area in KCC and people in this area like to use more private mode compared to low density area. Areas outside the circle are mainly low-density areas. Figure 7b shows the percentages of Rickshaw, Easybike, Mahindra and Bus choice of total trips in the respective wards. Here also, the blue circle area shows high density areas and the diversity of chosen mode is also higher in these areas compared to outside areas of the circle. Highly dense area's people like to use more Rickshaw and Easybike. Share of Rickshaw is higher in areas within the blue circle or high-density areas. Overall, in Khulna the most dominating mode is Easybike. Easybike takes the highest share in all wards. People of high-density areas like to use Rickshaw more than low density areas.

Conclusion

One of the most important factors that reflects travel behavior and demand is urban density. Travel behavior and demand are affected differently by different densities. The average density, on the other hand, does not reflect the diversity in the same traffic area. In this study, spatial analysis was used to show that it is possible to overcome the drawbacks of using average density and investigate how urban density influences travel behavior and demand. The scientific and reasonable parameters of the urban space configuration for job or work, school, and shop can be obtained after the analyses on the relationship between urban densities, travel behavior, and travel demand.

In this study, both single density and composite urban density were used. Where the result shows interesting findings for the Khulna City. Interestingly, Home-Based and Home-End Trip mode choice has differences. For work trip and School Trip rickshaw choice is comparatively lower while returning home, but for shopping trip the share is comparatively higher. On the other hand, for Work and school trips share of Walking and Easy Bike is comparatively higher while returning home, but for shopping trips the share is comparatively lower. In Khulna city, urban single-density has a monotonously positive relationship with trip production, distance, time, cost, and mode choice. The daily activities of residents are closely related to urban composite densities (Household to Work trip density, Household to School trip density, Household to shopping trip density). It has been discovered that as composite density rises, trip production rises as well. Diversified Trip and Overall Trip Attraction area have some dissimilarities. CBD area does not attract diversified trip but has attraction of overall trip. Diversified trip attraction is spread out on the geographic space but overall trip attraction is more spatially clustered. The percentage of Rickshaws choice in high-density areas is higher than in low-density areas. In dense areas, the preference for private mode choice is also higher compare to low density area.

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Conflict of Interests

The authors declare no conflict of interest.

References

Aguilera, A. (2008). Business travel and mobile workers. *Transportation Research Part A: Policy and Practice*, *42*(8), 1109–1116. https://doi.org/10.1016/j.tra.2008.03.005

Bhadra, S., & Sazid, A. K. M. T. (2015). *A GIS Based Walkability Measurement within the Built Environment of Khulna City, Bangladesh*. ResearchGate. https://www.researchgate.net/publication/312589637_A_GIS_Based_Walkability_Measurement_within_the_Built_Environment_of_Khulna_City_Bangladesh

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Curtis, C., & Perkins, T. (2006). *Travel behaviour: A review of recent literature (Library resource)*. European Institute for Gender Equality. https://eige.europa.eu/library/resource/AMZ_NET7576

Domencich, T., & McFadden, D. (1975). *Urban Travel Demand: A Behavioral Analysis*. https://eml.berkeley.edu/~mcfadden/travel.html

Ewers, H.-J. (1995). The Locational Impact of Declining Costs of Transportation and Communication. In H. Giersch (Ed.), *Urban Agglomeration and Economic Growth* (pp. 183–195). Springer. https://doi.org/10.1007/978-3-642-79397-4_8

Hanaoka, K., Nakaya, T., Yano, K., & Inoue, S. (2014). Network-based spatial interpolation of commuting trajectories: Application of a university commuting management project in Kyoto, Japan. *Journal of Transport Geography*, *34*, 274–281. https://doi.org/10.1016/j.jtrangeo.2013.09.006

Hsieh, S., O'Leary, J. T., & Morrison, A. M. (1992). Segmenting the international travel market by activity. *Tourism Management*, *13*(2), 209–223. https://doi.org/10.1016/0261-5177(92)90062-C

Kockelman, K. M. (1997). Travel Behavior as Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from San Francisco Bay Area: *Transportation Research Record*. https://doi.org/10.3141/1607-16

Lin, J.-J., & Yang, A.-T. (2009). *Structural Analysis of How Urban Form Impacts Travel Demand: Evidence from Taipei*. https://journals.sagepub.com/doi/10.1177/0042098009106017

Maduwanthi, M., & Marasinghe, A. (2015, December). *Factors Influencing to Travel Behavior on Transport Mode Choice*. ResearchGate. https://doi.org/10.5057/ijae.IJAE-D-15-00044

Meyer, M. D., & Miller, E. J. (1984). *Urban transportation planning: A Decision-Oriented Approach*. https://trid.trb.org/view/207171

Miller, E. J., Roorda, M. J., & Carrasco, J. A. (2005). A tour-based model of travel mode choice. *Transportation*, *32*(4), 399–422. https://doi.org/10.1007/s11116-004-7962-3

Peng, H., & Lu, H. (2007). Study on the Impacts of Urban Density on the Travel Demand Using GIS Spatial Analysis. *Journal of Transportation Systems Engineering and Information Technology*, *7*(4), 90–95. https://doi.org/10.1016/S1570-6672(07)60033-6

Sharmeen, N. (2014). *Development of a GIS-based model for optimum traffic flow distribution a case study on selected major routes of Dhaka City*. http://lib.buet.ac.bd:8080/xmlui/handle/123456789/2935

Sun, B., Ermagun, A., & Dan, B. (2017). Built environmental impacts on commuting mode choice and distance: Evidence from Shanghai. *Transportation Research Part D: Transport and Environment*, *52*, 441–453. https://doi.org/10.1016/j.trd.2016.06.001

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REVIEW ARTICLE SCIENCE & ENGINEERING

MATRIX FACTORIZATION, DECOMPOSITION AND SPLITTING METHODS AND ITS APPLICATIONS IN PHYSICAL PROBLEMS

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Abstract

Matrix factorization is the process that transforms a matrix into the product of some constituent matrices. This is comparable to factoring a number into the product of several numbers. Matrix splitting methods are similar to matrix factorization process which transforms a matrix into the sum of some basis matrices. In this short review article, we address the different types of matrix factorization and matrix splitting methods as well as their applications in the physical problems rather than exhibiting their computational procedure. Some matrix structural facts are shown to exhibit the fundamental pattern of different matrix decompositions.

Keywords: Matrix decomposition, matrix factorization, matrix splitting, LU decomposition, QR decomposition, singular value decomposition

Introduction

There are numerous matrix algorithms in linear algebra which are dependent on a variety of criteria to solve the problem. In computer programming storage capacity is crucial issue to preserving the efficiency of computational purposes. The amount of arithmetic operations required to complete the algorithm is also a key consideration (Faragó 2001 & Gilbert 2016). The algorithm complexity of a matrix can be reduced by converting it into the product or sum of upper triangular matrices, lower triangular matrices, diagonal matrices, permutation matrices, symmetric matrices, or banded matrices. Most of these structured matrices are used for matrix factorization and matrix splitting (Howard 2015; Hsu 2011).

Scientists and engineers have to handle a large system of linear equations when working on their physical ground. For example, in the solution of finite difference method of a partial differential equation there may arise a system of linear equations with large number of zeros and a banded structure matrix with non-zero entries. In a steady-state concentration problem, when a system of reactors, reservoirs or any type of tank with chemical where the concentration vary from each one tank to other may arise to a system of linear equations with large number of entries (Ke 2018; Lei-Hong 2014; Morse 1993). Numerical solution of this large system of linear equations in computational platform requires huge amount of memory. The naive Gaussian elimination method is not suitable to handle this type of problem perfectly as it is prohibitively expensive (Piziak 1999). The matrix iterative solution method is suitable for this large system of equations especially, for sparse system (Pedrag 2001; Varga 1960; Yifken 2021; Yuan 2018; Zbigniew 1998). The key purpose of this review work is to discuss to some matrix factorization and matrix splitting methods in a one shed for better understanding and be able to distinguish among them as well as in which domain of linear algebra they can be applied.

The paper is organized as follows: Introductory discussion is given in section 1. An overview of different matrix decompositions based on the solving the system of linear equations is given section 2. The matrix factorization methods based on eigenvalue and eigenvector are discussed in section 3. In section 4, various matrix splitting strategies for solving matrix iterative systems are presented. In section 5, the discussion part discusses some of the applications of matrix factorization and matrix splitting methods. Section 6 contains the conclusion.

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Decomposition based on solving the system of linear equations:
In this section, we describe the different matrix decomposition methods that are used to solving the system of linear equation and to finding the inverse of the matrix (Gilbert 2017; Howard 2015).

QR *Decomposition*

QR and LU decompositions are the two extensively used factorization methods in linear algebra among many others. The QR algorithm is credited to Francis and Kublanovskaya that was discovered independently in the late 1950s (Hsu 2011). The main idea of QR decomposition is to factoring a matrix $A \in R^{m\times n}$ of order $m\times n$, as a product of an orthogonal matrix and an invertible upper triangular matrix as

$$A = QR \tag{1}$$

Where $Q \in R^{m\times n}$ is an orthogonal matrix and $R \in R^{m\times n}$ is an upper triangular matrix of order $m\times n$. The general form of QR decomposition can be written as

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1n} \\ q_{21} & q_{22} & \cdots & q_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ q_{m1} & q_{m2} & \cdots & q_{mn} \end{bmatrix} \cdot \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ 0 & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & r_{mn} \end{bmatrix} \tag{2}$$

An example of QR decomposition is

$$\begin{bmatrix} 3 & 4 & 1 \\ 2 & 1 & 5 \\ 1 & 7 & 6 \end{bmatrix} = \begin{bmatrix} -0.8018 & -0.0851 & -0.5915 \\ -0.5345 & -0.3405 & 0.7735 \\ -0.2673 & 0.9364 & 0.2275 \end{bmatrix} \begin{bmatrix} -3.7417 & -5.6125 & -5.0780 \\ 0 & 5.8737 & 3.8307 \\ 0 & 0 & 4.6412 \end{bmatrix}$$

LU *Decomposition (Crout's method or triangularization method)*

Alan Turing, an English mathematician, is credited for the *LU* decomposition. This mostly used factorization method is applied to solve the system of linear equation and finding the inverse of a matrix as an alternative to the Gauss-Jordan elimination method. The *LU* decomposition factorizes the coefficient matrix into a product of upper and lower triangular matrices, namely,

$$A = LU \tag{3}$$

where A is a square matrix of order $n\times n$, L is the lower triangular and U is the upper triangular matrix of order $n\times n$. The general form of LU decomposition can be expressed as

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & \cdots & 0 \\ l_{21} & l_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ l_{n1} & l_{n2} & \cdots & l_{nn} \end{bmatrix} \cdot \begin{bmatrix} 1 & u_{12} & \cdots & u_{1n} \\ 0 & 1 & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \tag{4}$$

The key feature of LU decomposition is that all the diagonal entries of the upper triangular matrix of U are 1. Another name of LU decomposition method is Crout's method or triangularization method (Gilbert 2017; Howard 2015; Hsu 2011).

A typical example of LU decomposition is

$$\begin{bmatrix} 3 & 4 & 1 \\ 2 & 1 & 5 \\ 1 & 7 & 6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0.6667 & -0.2941 & 1 \\ 0.3333 & 1 & 0 \end{bmatrix} \begin{bmatrix} 3 & 4 & 1 \\ 0 & 5.6667 & 5.667 \\ 0 & 0 & 6 \end{bmatrix}$$

LDU *Decomposition (Doolittile method)*

In generally, the LU decomposition approach is not unique. For example, the Eq. (4) can be written as

$$A = LU = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ l_{21}/l_{11} & 1 & 0 & \cdots & 0 \\ l_{31}/l_{11} & l_{32}/l_{22} & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & 0 \\ l_{n1}/l_{11} & l_{n2}/l_{22} & l_{n2}/l_{33} & \cdots & 1 \end{bmatrix} \cdot \begin{bmatrix} l_{11} & 0 & \cdots & 0 \\ 0 & l_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & l_{nn} \end{bmatrix} \cdot \begin{bmatrix} 1 & u_{12} & \cdots & u_{1n} \\ 0 & 1 & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix} \tag{5}$$

Here, the diagonal entries are shifted from the left to the right factor, and all the diagonal entries in the lower triangular matrix has been transformed in 1. The factorization (5) is known as LDU decomposition or Doolittle method of the matrix A where L is a lower triangular matrix, in which all the diagonal entries are 1, D is a diagonal matrix, and U is an upper triangular matrix in which also all the entries on the main diagonal are 1. An example of LDU decomposition is

$$\begin{bmatrix} 3 & 4 & 1 \\ 2 & 1 & 5 \\ 1 & 7 & 6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0.3333 & 1 & 0 \\ 0.6667 & 1.1176 & 1 \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 5.6667 & 0 \\ 0 & 0 & -7.4118 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

PLU *Decomposition*

The presence of the LU decomposition of a matrix is not always assured. However, by introducing a permutation matrix Q and conducting the row interchange before performing the LU decomposition, it is possible to factorize the coefficient matrix A into the product of lower and upper triangular matrix. Multiplying the matrix A by a permutation matrix Q, the LU decomposition becomes

$$\begin{aligned} &QA = LU \\ &\text{or } A = Q^{-1}LU = PLU, \text{ where } P = Q^{-1} \end{aligned} \tag{6}$$

The process of factoring a matrix A in this way is called the PLU decomposition and a typical example is given by

$$\begin{bmatrix} 3 & 4 & 1 \\ 2 & 1 & 5 \\ 1 & 7 & 6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0.3333 & 1 & 0 \\ 0.6667 & 1.1176 & 1 \end{bmatrix} \begin{bmatrix} 3 & 0 & 0 \\ 0 & 5.6667 & 0 \\ 0 & 0 & -7.4118 \end{bmatrix}$$

Choleski's Decomposition

The Choleski decomposition was devised for simply real symmetric matrices. This factorization procedures splits the matrix A into

$$A = LL^T \tag{7}$$

where L is the lower triangular matrix and L^T is the transpose of L. The general form of Choleski's decomposition can be written as

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} l_{11} & 0 & \cdots & 0 \\ l_{21} & l_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ l_{n1} & l_{n2} & \cdots & l_{nn} \end{bmatrix} \cdot \begin{bmatrix} l_{11} & l_{21} & \cdots & l_{n1} \\ 0 & l_{22} & \cdots & l_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & l_{nn} \end{bmatrix} \tag{8}$$

A numerical example of Choleski decomposition is

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \\ 1 & 3 & 6 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Decomposition based on eigenvalue and eigenvector

Factorization by Diagonalization or Eigenvalue Decomposition

Before going to the discussion of main topics in this section, we pose the diagonalization problem. Two matrices A and B are said to be similar if

$$B = P^{-1}AP \tag{9}$$

If the matrix B is in simple form, e.g. diagonal matrix D such that $D = P^{-1}AP$, then we can ascertain many properties such as rank, nullity, determinant of A directly from the diagonal matrix D. For instance, if the diagonal entries of D are eigenvalues, then the product of these eigenvalues will be the determinant of A (Gilbert 2016).

Theorem 1: If A is an $n \times n$ square matrix and if A has n linearly independent eigenvectors, then A is diagonalizable i.e. $D = P^{-1}AP$ where P is the invertible matrix whose columns are the eigenvectors of A.
From the theorem 1, it can be concluded that

$$A = PDP^{-1} \tag{10}$$

Thus the matrix A can be factored with the aid of eigenvectors and an example is given below:

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \\ 1 & 3 & 6 \end{bmatrix} = \begin{bmatrix} -0.5438 & -0.8165 & 0.1938 \\ 0.7812 & -0.4082 & 0.4722 \\ -0.3065 & 0.4082 & 0.8599 \end{bmatrix} \begin{bmatrix} 0.1270 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 7.8730 \end{bmatrix} \begin{bmatrix} -0.5438 & -0.8165 & 0.1938 \\ 0.7812 & -0.4082 & 0.4722 \\ -0.3065 & 0.4082 & 0.8599 \end{bmatrix}^{-1}$$

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Factorizing by Orthogonal Diagonalization

In the earlier section, the matrix A was any square matrix and the columns of the matrix P were the eigenvectors. There was no concern about the orthogonality criteria of those eigenvectors. But, if we consider any special class of matrices e.g. the symmetric matrix then the column vectors of the matrix P will be orthogonal. Therefore, the matrix A can be factored as $A = PDP^{-1}$ where the columns of P are orthogonal. Since P is orthogonal, $P^{-1} = P^T$ and consequently

$$A = PDP^T \tag{11}$$

An example of this factorization is

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \\ 1 & 3 & 6 \end{bmatrix} = \begin{bmatrix} -0.5438 & -0.8165 & 0.1938 \\ 0.7812 & -0.4082 & 0.4722 \\ -0.3065 & 0.4082 & 0.8599 \end{bmatrix} \begin{bmatrix} 0.1270 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 7.8730 \end{bmatrix} \begin{bmatrix} -0.5438 & -0.8165 & 0.1938 \\ 0.7812 & -0.4082 & 0.4722 \\ -0.3065 & 0.4082 & 0.8599 \end{bmatrix}^T$$

Spectral Decomposition

The spectral decomposition is an alternative form of orthogonal diagonalization. If A is symmetric matrix, then it can be orthogonally diagonalizable by the column matrix $P = [v_1, v_2, \cdots, v_n]$, where $v_1, v_2, \cdots, v_n$ are orthogonal eigenvectors. The orthogonal diagonalization $A = PDP^T$ can be written in an alternative form as ……

$$A = PDP^T = [v_1, v_2, \cdots, v_n] \begin{bmatrix} \lambda_1 & 0 & \cdots & 0 \\ 0 & \lambda_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_n \end{bmatrix} \begin{bmatrix} v_1^T \\ v_2^T \\ \vdots \\ v_n^T \end{bmatrix} = [\lambda_1 v_1, \lambda_2 v_2, \cdots, \lambda_n v_n] \begin{bmatrix} v_1^T \\ v_2^T \\ \vdots \\ v_n^T \end{bmatrix}$$

Now multiplying, the matrix A reduces to

$$A = \lambda_1 v_1 v_1^T + \lambda_2 v_2 v_2^T + \cdots + \lambda_n v_n v_n^T \tag{12}$$

This linear factorization is called the spectral decomposition of the matrix A and an numerical example is

$$\begin{bmatrix} 2 & 1 \\ 1 & 3 \end{bmatrix} = 1.3820 \begin{bmatrix} -0.8507 \\ 0.5257 \end{bmatrix} \begin{bmatrix} -0.8507 & 0.5257 \end{bmatrix} + 3.6180 \begin{bmatrix} 0.5257 \\ -0.8507 \end{bmatrix} \begin{bmatrix} 0.5257 & -0.8507 \end{bmatrix}$$

Schur's Decomposition

In section 3.2, the orthogonal decomposition was $A = PDP^T$, where D is a diagonal matrix whose diagonal entries are the eigenvalues of the matrix A. Issai Schur, a German mathematician (Howard 2015 & Hsu 2011), proposed a matrix decomposition where the diagonal matrix D is replaced by an upper triangular matrix S like as

$$A = PSP^T \tag{13}$$

where

$$S=\begin{bmatrix} \lambda_1 & * & * & \cdots & * \\ 0 & \lambda_2 & * & \cdots & * \\ 0 & 0 & \lambda_3 & \cdots & * \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & \lambda_n \end{bmatrix}$$

The Schur decomposition of the matrix $\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \\ 1 & 3 & 6 \end{bmatrix}$ is $\begin{bmatrix} 10.6978 & -0.4767 & 2.6436 \\ 0 & 2.7586 & 0.8857 \\ 0 & 0 & -3.4564 \end{bmatrix}$.

Hessenberg Decomposition

The Hessenberg decomposition

$$A=PHP^T \tag{14}$$

is similar to the Schur's decomposition where the upper triangular matrix S is replaced by the Hessenberg matrix H of the following form:

$$H=\begin{bmatrix} * & * & \cdots & * & * & * \\ * & * & \cdots & * & * & * \\ 0 & * & \cdots & * & * & * \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & * & * & * \\ 0 & 0 & \cdots & 0 & * & * \end{bmatrix}$$

The Hessenberg form of the matrix $\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \\ 1 & 3 & 6 \end{bmatrix}$ is $\begin{bmatrix} 3 & -4.0249 & -0.8944 \\ -2.2361 & 6.8 & -4.6 \\ 0 & -6.6 & 0.2 \end{bmatrix}$.

Singular Value Decomposition

It is observed that all the decompositions based on the eigenvalues and eigenvectors discussed in the earlier sections resulted from either square matrix or especial type symmetric matrix; no rectangular matrix was considered for decomposition. Singular value decomposition overcomes the barrier of decomposing a rectangular matrix of order $m\times n$. Herein, before going to the main topics, we first outline the most important definition; singular values of a matrix.

Singular values of an $m\times n$ matrix:

Let A be the matrix of order $m\times n$, then the matrix A^TA is a symmetric matrix. Since A^TA is symmetric matrix, it is orthogonally diagonalizable. Let $\lambda_1,\lambda_2,\ldots,\lambda_n$ be the eigenvalues of the symmetric matrix A^TA, then the square root of eigenvalues

$$\sigma_i=\sqrt{\lambda_i},\ 1\le i\le n$$

are called the singular values of the matrix A.

Suppose A be a square matrix of order $m \times n$ and rank r. Then the factorization

$$A = U \sum V^T \tag{15}$$

where U is an $m \times m$ matrix, V is an $n \times n$ orthogonal matrix and $\sum$ is an $m \times n$ matrix where all the diagonal entries are the singular values of the matrix A. The decomposition (15) is called the singular value decomposition of matrix A. The general form of singular value decomposition can be expressed as

$$A = U \sum V^T = \left[u_1 \quad u_2 \quad \cdots \quad u_k \mid u_{k+1} \quad \cdots \quad u_m \right] \left[\begin{array}{cccc|c} \sigma_1 & 0 & \cdots & 0 & \\ 0 & \sigma_2 & \cdots & 0 & 0_{k\times(n-k)} \\ \vdots & \vdots & \ddots & \vdots & \\ 0 & 0 & \cdots & \sigma_k & \\ \hline \multicolumn{4}{c|}{0_{(m-k)\times k}} & 0_{(m-k)\times(n-k)} \end{array} \right] \left[\begin{array}{c} v_1^T \\ v_2^T \\ \vdots \\ v_k^T \\ \hline \vdots \\ v_n^T \end{array} \right] \tag{16}$$

An example of singular value decomposition is

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix} = \begin{bmatrix} -0.2298 & 0.8835 & 0.4082 \\ -0.5247 & 0.2408 & -0.8165 \\ -0.8196 & -0.4019 & 0.4082 \end{bmatrix} \begin{bmatrix} 9.5255 & 0 \\ 0 & 0.5143 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} -0.6196 & -0.7849 \\ -0.7849 & 0.6196 \end{bmatrix}^T$$

Reduced Singular Value Decomposition

In singular value decomposition, it is notable that the matrix $\sum$ contains a few numbers of zero rows and zero columns which is superfluous and does not carry any information. These extra rows and columns can be removed by block multiplication from the expression and finally zero blocks drop out, just keeping the mathematical expression as

$$A = \begin{bmatrix} u_1 & u_2 & \cdots & u_k \end{bmatrix} \begin{bmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \sigma_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_k \end{bmatrix} \begin{bmatrix} v_1^T \\ v_2^T \\ \vdots \\ v_k^T \end{bmatrix} \tag{17}$$

The reduced singular value decomposition of the above matrix is

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix} \approx \begin{bmatrix} -0.2298 & 0.8835 & 0.4082 \\ -0.5247 & 0.2408 & -0.8165 \end{bmatrix} \begin{bmatrix} 9.5255 & 0 \\ 0 & 0.5143 \end{bmatrix} \begin{bmatrix} -0.6196 & -0.7849 \\ -0.7849 & 0.6196 \end{bmatrix}^T$$

The factorization (17) is called the reduced singular value decomposition which is used for dimension reduction in multivariate data analysis.

Matrix Splitting

In this section, we give a brief idea of matrix splitting procedures. Different matrix iteration solution methods e.g., Jacobi iteration method, Gauss-Seidel iteration method, successive over relaxation method will not discuss herein as all of these methods are available in the most text books (Gilbert 2016; Howard 2015; Hsu 2011). Here, we only discuss the basic principle of matrix splitting methods. Moreover, where and how matrix splitting methods can be applied in the iteration solution of system of equations will be outlined (Gilbert 2016; Howard 2015) & (Zbigniew 1998, 2001).

Suppose, we have given a system of linear equations

$$Ax = k \tag{18}$$

where $A \in R^{n\times n}$ is real non-singular square matrix and $k \in R^n$ is a column vector. The key idea of the matrix splitting methods is to divide the matrix A into two or more parts like as

$$A = M - N \tag{19}$$

where M and N matrices are in simpler formation.

Regular Splitting

The matrix M is a non-singular matrix with a simple structure such as diagonal or upper triangular or lower triangular matrix and so on. If the matrix M is so, then the solution of the system of equations can be written as

$$Ax = Mx - Nx = k \qquad or \qquad Mx = Nx + k \tag{20}$$

Now suppose $x^0 \in R^n$, therefore the iteration algorithm process becomes

$$Mx^{(m+1)} = Nx^{(m)} + k, \;\; m = 0,1,2,\ldots \tag{21}$$

Equivalently,

$$x^{(m+1)} = (M^{-1}N)x^{(m)} + M^{-1}k, \;\; m = 0,1,2,\ldots \tag{22}$$

If the matrix A has a regular splitting, then the matrix $M^{-1}N$ has non-negative entries (Howard 2015). The Eq. (22), shows that at every stage of the iteration, the system of linear equations are being solved with matrix M. We outline the regular splitting method providing a concrete example in below:

Example 1: Suppose the system of equations is given by

$$6x + 2y + z = 8; \;\; 2x + 4y + 2z = 6; \;\; 3x + 2y + 5z = 4$$

The matrix form of this system is

$$\begin{bmatrix} 6 & 2 & 1 \\ 2 & 4 & 2 \\ 3 & 2 & 5 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 8 \\ 6 \\ 4 \end{bmatrix}$$

For the regular splitting case, choose

$$M = \begin{bmatrix} 6 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 5 \end{bmatrix}, \; N = \begin{bmatrix} 0 & -2 & -1 \\ -2 & 0 & -2 \\ -3 & -2 & 0 \end{bmatrix}$$

The iterated solution will be

$$x^{m+1} = \begin{bmatrix} 1/6 & 0 & 0 \\ 0 & 1/4 & 0 \\ 0 & 0 & 1/5 \end{bmatrix} . \begin{bmatrix} 0 & -2 & -1 \\ -2 & 0 & -2 \\ -3 & -2 & 0 \end{bmatrix} x^m + \begin{bmatrix} 1/6 & 0 & 0 \\ 0 & 1/4 & 0 \\ 0 & 0 & 1/5 \end{bmatrix} . \begin{bmatrix} 8 \\ 6 \\ 4 \end{bmatrix}; \;\; m = 0,1,2,\ldots \tag{23}$$

Jacobi Iteration Method

The Jacobi iteration method splits the coefficient matrix A of a linear system of equations into the summation of a lower triangular matrix L, an upper triangular matrix U and a diagonal matrix D in the following way,

$$(L+D+U)x=k \tag{24}$$

This splitting form is expressed in an iteration form $x^{m+1}=Cx^m+d$ by the following way

$$\begin{aligned} &Dx=(-L-U)x+b \\ &\text{or } x=D^{-1}(-L-U)x+D^{-1}b \end{aligned} \tag{25}$$

which implies that

$$x^{m+1}=Cx^m+d;\ m=0,1,2,\ldots \tag{26}$$

Now consider the example 1, the Jacobi iteration method splits the coefficient matrix A as

$$L=\begin{bmatrix}0&0&0\\2&0&0\\3&2&0\end{bmatrix},\ U=\begin{bmatrix}0&2&1\\0&0&2\\0&0&0\end{bmatrix}\ \text{and}\ D=\begin{bmatrix}6&0&0\\0&4&0\\0&0&5\end{bmatrix}$$

and the final iteration form goes to

$$x^{m+1}=\begin{bmatrix}1/6&0&0\\0&1/4&0\\0&0&1/5\end{bmatrix}.\left(\begin{bmatrix}0&0&0\\-2&0&0\\-3&-2&0\end{bmatrix}-\begin{bmatrix}0&2&1\\0&0&2\\0&0&0\end{bmatrix}\right)x^m+\begin{bmatrix}1/6&0&0\\0&1/4&0\\0&0&1/5\end{bmatrix}.\begin{bmatrix}8\\6\\4\end{bmatrix};\ m=0,1,2,\ldots$$

Gauss-Seidel Iteration Method

The Gauss-Seidel iteration method follows the same splitting procedure of Jacobi iteration method but differs only forming the final iteration step $x^{m+1}=Cx^m+d$ as the following way [5]:

$$\begin{aligned} (D+L)x&=-Ux+b \\ x&=(D+L)^{-1}(-U)x+(D+L)^{-1}b \\ x^{m+1}&=Cx^m+d;\ m=0,1,2,\ldots \end{aligned} \tag{27}$$

and the final step of iteration of example 1 goes to

$$x^{m+1}=\begin{bmatrix}1/6&0&0\\-1/12&1/4&0\\-1/15&-1/10&1/5\end{bmatrix}.\begin{bmatrix}0&2&1\\-2&0&2\\-3&-2&0\end{bmatrix}x^m+\begin{bmatrix}1/6&0&0\\-1/12&1/4&0\\-1/15&-1/10&1/5\end{bmatrix}.\begin{bmatrix}8\\6\\4\end{bmatrix};\ m=0,1,2,\ldots$$

Successive Over Relaxation Method

The successive over relaxation method also follows the same splitting principle of Gauss-Seidel method with an extra constant number ω, which is called relaxation parameter and the splitting equation becomes (Hsu, 2011)

$$\omega(D+L)x = -\omega Ux + \omega k \tag{28}$$

Now adding both sides of Eq. (28) by $(1-\omega)Dx$, we get

$$(D-\omega L)x = ((1-\omega)D - \omega U)x + \omega k$$

Solving this for x, we obtain

$$x = (D-\omega L)^{-1}((1-\omega)D + \omega U)x + \omega(D-\omega L)^{-1}k \tag{29}$$

Table1. Efficiency comparison of different decomposition method

Cost efficiency of matrix A of order $n \times n$, when n is very large	
Algorithm	Cost in Flops
Gauss-Jordan elimination method	$\approx (2/3)n^3$
QR decomposition method	$\approx n^2$
LU decomposition method	$\approx (2/3)n^3$
LDU decomposition method	$\approx n^2$

Discussion

Matrix factorization and splitting methods decomposes a complex form matrix into simpler constituent parts. In computer, to implement any matrix algorithm efficiently decomposition or splitting is essential. In this section, we outline some applications of QR, LU, LDU, PLU and Choleski's factorization method (Gilbert 2016; Howard 2015). Particularly all of these methods are applied to solve the system of linear equations. The naive Gaussian elimination method is suitable for small size of matrix but not appropriate if the system of equation is very large i.e. the coefficient matrix is very bulky. In any computational software packages, many simple algorithm arise computation complexities and the number of arithmetic operations and round of error increases in an exponential order. The factorization of a matrix into the lower triangular or upper triangular or diagonal form reduces the number of operations notably. The cost efficiency of the large system of equations by using different algorithms is given in the Table 1. Also in Table 2, the factorizations based on the solving system of linear equations are shown (Gilbert 2016; Howard 2015).

Table 2. Factorization based on the solving of system of linear equations

Factorization	Applicable to	Characteristics
$A = QR$	$m \times n$ matrix A	Q is an orthogonal matrix of order $m \times m$ R is an upper triangular matrix of order $m \times n$
$A = LU$	Square matrix A	L is a lower triangular matrix U is an upper triangular matrix with 1's on the diagonal
$A = LDU$	Square matrix A	L is a lower triangular matrix with 1's on the diagonal D is a diagonal matrix U is an upper triangular matrix with 1's on the diagonal
$A = PLU$	Square matrix A	$P = Q^{-1}$, where Q is an permutation matrix L is a lower triangular matrix U is an upper triangular matrix with 1's on the diagonal
Cholesky's $A = LL^T$	Symmetric matrix A	L is a lower triangular matrix L^T is the transpose of the lower triangular matrix L

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Table 3. Factorization based on eigenvalues and eigenvectors

Decomposition	Applicable to	Characteristics
Eigen decomposition $A = PDP^{-1}$	Square matrix A	P is a matrix whose column vectors are eigenvectors of A D is a diagonal matrix whose diagonal entries are eigenvalues of A
Orthogonal decomposition $A = PDP^{T}$	Symmetric matrix A	P is a matrix whose column vectors are orthogonal eigenvectors of A D is a diagonal matrix whose diagonal entries are eigenvalues of A
Spectral decomposition $A = \lambda_1 v_1 v_1^T + \cdots + \lambda_n v_n v_n^T$	Symmetric matrix A	λ_i are the eigenvalues of A v_i are the eigenvectors of A and v_i^T are the transpose of v_i
Schur decomposition $A = PSP^{T}$	A is not symmetric but square and has real eigenvalues	P is a matrix whose column vectors are eigenvectors of A S is the upper triangular matrix which is in Schur form and eigenvalues of A along the main diagonal
Hessenberg decomposition $A = PHP^{T}$	A is not symmetric but square	P is the matrix same as Schur decomposition H is the triangular matrix of Hessenberg form
Singular value decomposition $A = U \sum V^{T}$	A is of order $m \times n$, need not to be square or symmetric	$U = [u_1, \cdots, u_m]$ is an orthonormal basis of the column space A $\sum$ is a diagonal matrix whose non-zero diagonal entries are singular values of A $V = [v_1, \cdots, v_n]$ orthogonally diagonalizes $A^T A$

Factorization based on eigenvectors also plays an important role in the application of identifying different conics, and optimization by using quadratic forms. Now a day in the technological environment, efficient transmission and data storage of massive amounts of digital information has become a serious issue. For example, a black-and-white image could be scanned and it preserves the data as a rectangular array of pixels (points) which is saved as matrix A by giving a numerical value to each pixel based on its gray level. A lot of extra information may be added to process this. The reduced singular value decompositions can be used to compress this visual data in order to reduce storage space requirements and speed up electron transmission. The decompositions based on eigenvalues and eigenvectors are given in Table 3.

Matrix iteration methods, Jacobi, Gauss-Seidel, and successive over relaxation methods are used when the system of equations is particularly large and sensitive in the coefficient matrix (Gilbert 2016; Howard 2015). All of these methods divide the coefficient matrix into diagonal, lower diagonal, and upper diagonal matrices that are carefully chosen. Table 4 shows the techniques for splitting.

Table 4. Matrix splitting for iteration solution

Regular splitting	$A = M - N$	$x^{(m+1)} = (M^{-1}N)x^{(m)} + M^{-1}k,\ \ m = 0,1,2,\ldots$
Jacobi splitting	$A = L + D + U$	$x^{m+1} = D^{-1}(-L-U)x^m + D^{-1}b;\ m = 0,1,2,\ldots$
Gaus-Seidel	$A = L + D + U$	$x^{m+1} = (D+L)^{-1}(-U)x^m + (D+L)^{-1}b;\ m = 0,1,2,\ldots$
Successive over relaxation	$A = L + D + U$ $\omega(D+L)x = -\omega Ux + \omega k$	$x = (D-\omega L)^{-1}((1-\omega)D + \omega U)x + \omega(D-\omega L)^{-1}k$

Conclusion

The theoretical utility of matrix decomposition has long been recognized, and it has become the backbone of numerical linear algebra. Matrix decompositions, matrix splitting, and the canonical forms are the most important ideas in matrices theory. All of these converted forms of original matrix simplify the computing platform, allowing a wide range of problems to be solved, including systems of linear equations, dimension reduction, and noise removing form digital image among others. This short overview article explains the logic behind matrix decompositions and matrix splitting methods. The applications of these matrix transformations as well as their characterizations are also outlined shortly in tables.

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Conflict of Interests

The author declares no conflict of interest.

References

Faragó I., Tarvainen P. (2001), Qualitative analysis of matrix splitting methods, Computers & Mathematics with Applications, Vol. 42, Issues 8–9, pp. 1055-1067.

Gilbert Strang (2016), Introduction to Linear Algebra, 5th edition, Wellesley-Cambridge Press, New York, ISBN: 978-09802327-7-6.

Howard Anton (2015), Chris Rorres, Elementary Linear Algebra: Applications Version, 10th edition, Wiley & Sons, New York.

Hsu D., Kakade S. M. and Zhang T. (2011), "Robust Matrix Decomposition With Sparse Corruptions," in IEEE Transactions on Information Theory, 57(11), pp. 7221-7234, doi: 10.1109/TIT.2011.2158250.

https://en.wikipedia.org/wiki/Matrix_decomposition.

https://en.wikipedia.org/wiki/Matrix_splitting.

https://machinelearningmastery.com/introduction-to-matrix-decompositions-for-machine-learning/.

Ke, YF., Ma, CF. & Zhang, H. (2018), The Modulus-based Matrix Splitting Iteration Methods for Second-Order Conde Linear Complementarity Problems, Numer. Algorithm 79, pp. 1283-1303.https://doi.org/10.1007/s11075-018-0484-4.

Lei-Hong Z., Wei Hong Y. (2014), An Efficient Matrix Splitting Method for the Second-Order Cone Complementarity Problem, SIAM J. Optim., 24(3), pp. 1178-1205.

Morse, A.S., (1993), A gain matrix decomposition and some of its applications, Systems & Control Letters, 21(1), pp. 1-10.

Piziak, R., Odell, P. L. (1999). Full Rank Factorization of Matrices, Mathematics Magazine. 72 (3): pp. 193-200. doi:10.2307/2690882. JSTOR 2690882.

Predrag S., Dragan D. (2001), A New Type of Matrix Splitting and its Applications, Acta Mathematica Academiae Scientiarum Hungaricae, 92(1), pp. 121-135. Doi: 10.1023/A: 1013712329516.

Stewart G.W. (1993), On the early history of singular value decomposition, SIAM Review, 35(4), pp. 551-566.

Uhlmann, J.K. (2018), A Generalized Matrix Inverse that is Consistent with Respect to Diagonal Transformations, SIAM Journal on Matrix Analysis and Applications, 239 (2), pp.781–800, doi:10.1137/17M113890X

Uhlmann, J.K. (2018), A Rank-Preserving Generalized Matrix Inverse for Consistency with Respect to Similarity, IEEE Control Systems Letters, arXiv:1804.07334, doi:10.1109/LCSYS.2018.2854240, ISSN 2475-1456

Varga, Richard S. (1960), Factorization and Normalized Iterative Methods, In Langer, Rudolph E. (ed.). Boundary Problems in Differential Equations. Madison: University of Wisconsin Press. pp. 121–142.

Varga, Richard S. (1962), Matrix Iterative Analysis, New Jersey: Prentice-Hall, LCCN 62-21277.

Yifen Ke, (2021), The Matrix Splitting Iteration Method for Nonlinear Complementarity Problems Associated with Second-Order Cone. Bulletin of the Iranian Mathematical Society, 47(1), pp. 31-53.

Yuan, G., Zheng, W. S., Shen, L., & Ghanem, B. (2018). A Generalized Matrix Splitting Algorithm. arXiv preprint arXiv:1806.03165.

Zbigniew I.W. (1998), Matrix Splitting Principles, Novi Sad J. Math., 28(3), pp. 197-209.

Zbigniew I.W. (2001), Matrix Splitting Principles, International Journal of Mathematics and Mathematical Sciences, 28(5), pp. 251-284.

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ORIGINAL ARTICLE

SCIENCE & ENGINEERING

IMPLICATIONS OF RESIDENTIAL HOUSING EXPOSURE TO URBAN ENVIRONMENTAL NOISE ON RESIDENT'S WELLBEING IN MINNA, NIGERIA

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Abstract

Environmental noise constitutes a major contributor to environmental pollution, with its unintended consequences posing a serious challenge to public health in the built environment. This study assessed the perception and the implications of urban environmental noise on urban residents' wellbeing. Data was collected using a sound pressure level meter and a self-developed questionnaire. Findings from eight hundred and eighty (880) responses obtained through random sampling were analysed and benchmarked against national (50 dBA) and international (55 dBA) standards by the WHO. The results showed that noise from places of worship and traffic noise were rated high, with about 75 percent of the respondents indicating that environmental noise negatively impacts their wellbeing. The study suggested the need for improved environmental quality in the built environment. It advocated for synergistic interventions from architects, other built environment professionals, and environmental protection agencies to tackle urban environmental pollution in residential environments. The contribution of this research lies in the necessity for further investigation, since it has important ramifications for architects, urban planners, and urban managers.

Keywords: Built Environment, urban environmental noise, residential housing, public health, resident's wellbeing

Introduction

Environmental noise is slowly becoming more common but still not widely recognised as a form of pollution, especially in poorer nations. With its unintended effects challenging public health in the built environment, noise is a major contributor to environmental pollution. One of the main concerns influencing quality of life in urban areas around the world in recent years is noise pollution (Hunashal & Patil, 2012; Akan, 2012; Frei et al., 2014). After air pollution and water pollution, WHO (2005) ranked city noise as the third most dangerous form of pollution. According to Trombetta *et al.* (2011), faster urban growth is correlated with rising levels of noise pollution in economically developing nations. As a result, noise pollution in the environment has become worse due to the rapid development of urban areas.

When compared to other urban environmental issues, noise pollution is currently growing at an unprecedented rate, and those who are exposed to it are more frequently affected. One of the difficulties associated with urban environmental issues is that noise has steadily grown to be a significant environmental contaminant, endangering people's quality of life, particularly in residential areas. Babisch (2002) characterised noise as a powerful stressor whose prolonged or repetitive exposure results in dysregulation or otherwise typical psychoneurohormonal stress responses, raising blood pressure, accumulating visceral fat, and generating deleterious physiologic alterations. According to Babisch *et al.* (2005) and van Kempen *et al.* (2002), this causes hypertension, coronary heart disease, and myocardial infarction. Therefore, the effects of large-scale development brought on by growing urbanization

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and an increase in the number of people exposed to typical noise levels worldwide are viewed as potentially detrimental.

The main causes of noise pollution in Nigeria's cities are industrial machinery, road traffic, and generators (Oyedepo, 2012). Due to the severity of the noise pollution issue, effective and well-thought-out solutions are required. While it is known that excessive noise in the built environment has a number of negative effects on health, researchers haven't focused enough on the issue to properly treat and stop the epidemic of many diseases linked to this noise pollution (Oyedepo, 2012). Mead's (2007) research showed that exposure to environmental noise might cause tinnitus, hearing loss, disturbed sleep, and other harmful consequences to health. Others, including Landrigan *et al.* (2002) and Goines & Hagler (2007), have also noted that employees who work in noisy environments are more likely to experience circulatory issues, heart disorders, hypertension, and neurosensory and motor impairment.

Therefore, given the health risks posed by environmental noise as afore mentioned and the need to improve the quality of life of urban residential housing environments' exposure to noise pollutants in Minna metropolis, this study assessed the perception and the implications of urban environmental noise on urban residents' wellbeing. The objectives are (i) to identify residential environments most prone to noise pollution; (ii) to determine the implications of noise pollution on residents' well-being; and (iii) to propose urban noise management strategies for residential environments with a view to limiting its adverse effect on the urban populace. This study examines the effect of noise pollution and its perception on urban residents' health by putting forward the following two hypotheses:

Hypothesis One

H_0: There is no relationship between the length of stay of the respondent and the effect of noise pollution on their health.

H_1: There is a relationship between the length of stay of the respondent and the effect of noise pollution on their health.

Hypothesis Two

H_0: There is no relationship between educational qualification and the perception of noise pollution

H_1: There is a relationship between their educational level and their perception of noise pollution.

In this study, a quantitative approach was used to collect pertinent data from the respondents and the field. The study's predicted result is that it may give built-environment specialists like architects, planners, urban managers, and geographers some directions and suggestions for addressing environmental noise pollution problems. The value of this research lies in highlighting the need for additional study because it has significant implications for urban managers, planners, and architects.

Globally, the consequences of noise pollution have been studied from a variety of angles, in a variety of cities, and with a variety of methodologies. In Taiwanese hospitals, Juang *et al.* (2010) investigated the impact of noise pollution on patients and medical staff. Their research indicated that the average daily sound levels measured within hospitals during the daytime were between 52.6 and 64.6 dB. They did this using a sound level meter and a self-administered survey questionnaire on noise pollution. These numbers exceeded Taiwan's current 50 decibel environmental noise limit for the daytime. In the meantime, Martins *et al.* (2006) have already expressed concern about how prolonged exposure to noise puts people at risk for health consequences such as headaches compared to those who do not. According to a study by Claeson *et al.* (2013), air pollution raises health risks for people and causes health complaints. According to Wakefield *et al.* (2001), the general public is generally unaware of the difficulties caused by noise pollution.

Oyedepo *et al.* (2013) did a study in Nigeria on the analysis of traffic noise in Akure, Ondo State. They employed digital sound level meters to assess noise reported in decibels during the morning and evening hours. The research objective was to measure and assess the noise pollution caused by traffic along the road. Their findings demonstrate that noise pollution from traffic is typically at or over outdoor limits in most places and can have a negative impact on welfare activities. In research conducted in Gettysburg, Pennsylvania, by Kapp *et al.* (2014), traffic noise pollution was examined. Over the course of three weeks, noise pollution was measured in dB (A) using a sound meter at a total of nine (9) sampling sites, six (6) of which were located in the town and three (3) of which were on the college campus. Their findings show that noise pollution in the town in which the highest recorded

noise level was 99.6 dBA was found to be louder than 70 dB (A) above the noise threshold set by the World Health Organization to indicate possible hearing damage overtime.

Data about noise in Nairobi, Kenya, was gathered through field measurements by Wawa and Mulaku (2015). The authors investigated the mapping of noise pollution using GIS, a sound level meter, and a portable GPS. During site visits for sampling, coordinates were recorded along with readings. According to the study, the central business district's (CBD) average noise levels ranged from 61 dB to 78 dB, rising from the west to the east, and were primarily caused by vehicles. Their research was successful in locating and establishing a number of noise hotspots, mostly to the east of the CBD. Similar research was conducted by Abbaspour *et al.* (2015) on the hierarchal assessment of noise pollution in district 14 of Tehran Metropolitan City. At each of the eighty-eight (88) stations, the equivalent sound pressure level was measured using a sound level meter, and at the same time, GPS was utilized to record the location of the measurement point. Their findings revealed that out of 88 measurement points, 63 stations' average equivalent sound levels were higher than 70 dB. (A).

It was concluded from the results of the studies from the literature reviewed above that, in addition to traffic noise, there were other elements that contributed to noise pollution in urban areas, such as diverse land uses, population distribution, and types of passageways. While they might not have the same level of consequences in cities, it is regrettable that studies on noise pollution have given little consideration to the implications of urban environmental noise in residential settings. Hence, this study identified and addressed the gap within the literature that while many studies have been conducted on the impact of noise in the environment, less attention is given to the implications of urban environmental noise in residential settings particularly in sub–Saharan Africa.

Material and Methods

Geographically, the study area is located in the city of Minna, the capital of Niger state, in the north central geopolitical zone of Nigeria. Minna is located at latitude $9^{0}37'$ North and longitude $6^{0}33'$ East and occupies an area of about 884 hectares. According to the 2006 Nigerian census, the estimated population was 304,113, but the city is currently estimated to have a population of about 479, 000. This study was conducted in two stages: (i) using noise measurement equipment in both exposed and non-exposed areas of the Minna metropolis; and (ii) conducting health investigations in seventeen (17) residential environments. This research work was carried out with the use of the following instrument for data collection:

(i) A sound level meter was used to collect the noise readings over the selected random points, which have been used in a similar noise study by Kapp *et al.* (2014) and Abbaspour *et al.* (2015). For this work, Extech 407730 was useful. The model characteristics include an accuracy of ±2dB accuracy, A and C weighting, and a 40 to 130dB measuring range.

(ii) The hand-held geographic positioning system (GPS) was used for taking the coordinates of points where noise level was recorded. This instrument (handheld geographic positioning system) was also used by Wawa and Mulaku (2015) in research work on noise.

(iii) A well-structured questionnaire was used for data collection. It collected useful data and information from respondents, which helped to understand their opinions about noise pollution in their environment and how they have been affected. A structured questionnaire was also used in a similar noise study carried out by Mishra *et al.* (2010).

Data Collection

The sound level meter was stationed at the different sampling points at specific times of the day, which included 8:00am to 8:15am, 12:00pm to 12:15pm, 4:00pm to 4:15pm, and 6:00pm to 6:15pm. These time periods were considered because they indicate the time in which specific activities are carried out around Minna. 8:00am indicates the time of movement to work in the morning, 12:00pm indicates the time when work activities would have started; 4:00pm shows the time when some workers close from work and also closing time for students; and 6:00pm indicates the time at which activities for the day end. To assess the level of exposure to road traffic noise in each of these locations, noise maps were created. An area to which a certain class of values expressed in decibels (dB [A]) corresponds is limited by noise maps, which describe external ambient noise using indicators that are determined by reference periods and represented by lines that indicate the same rating levels (isophone lines).

To link the noise level with the different land use types in Minna, a land use map of Minna or visual method (field interpretation) was used to relate the noise level to different land uses in the study area. The land use map or

visual method shows the area with the highest or lowest level of noise due to the activities going on in such an area. To identify the causes of noise pollution. Questionnaires were used to collect information from respondents to know what causes noise pollution in their environment. A field survey was also carried out to determine the various causes of noise pollution. To determine the focus area for noise management in Minna, this was achieved using the noise map generated from objective one to show areas with noise levels above NESREA noise standards.

Stratified random sampling was adopted for this study. Thirty (30) sampling points were required to carry out the noise level reading, the map of Minna was divided into strata using fishnet which provided 20 points for noise reading and was later transferred to Google map of Minna to identify those points selected (Figure 1). This method was carried out with the use of ArcGIS10.1. Purposive sampling also referred to as judgment or selective sampling: 20 sampling sites were chosen purposively for noise reading after which 20 points have been selected using the fishnet method in ArcGIS10.1. To determine how residents in urban soundscapes perceive and react to noise, a cross-sectional study was carried out. The study population was made up of adults over the age of 20 who volunteered to participate by filling out a questionnaire. They received instruction booklets outlining the study's purpose and nature. To gather pertinent data regarding noise pollution, the researchers created a well-structured questionnaire that was then distributed by research assistants to the study area's residents. This was administered based on the age of people ranging from 16 years of age and above. The questionnaire was distributed randomly to 900 people.

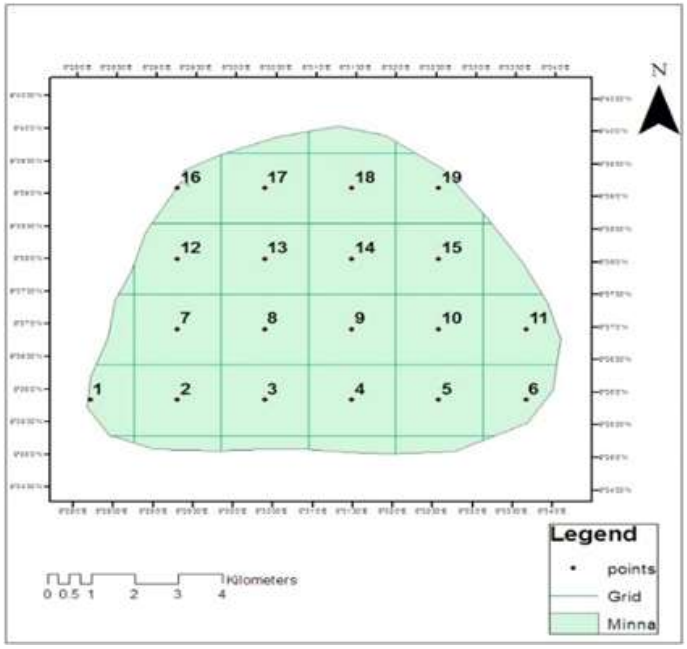

Figure 1. Random points for noise reading using fishnet ArcGIS

Data Analysis and procedure

Based on the descriptive study, a demographic profile of the populace was created that took into account how they perceived noise sources, environmental issues, and the consequences of exposure to the urban soundscape. The Chi-square test was used to find correlations between the respondent's time spent in the environment and how their well-being was affected by noise pollution. Descriptive data analysis was used to analyse the data collected. The noise level collected was used to create a map showing the temporal distribution of noise and the intensity of noise in the study area. The inverse distance weighting interpolation technique is utilized for temporal data processing (IDW). A particular deterministic method for multivariate interpolation using a predetermined distributed collection of points is known as IDW. A weighted average of the values available at the known points was used to generate the values allocated to the unknown points.

The focus area for noise management in Minna was determined using the reclassified noise map, which was compared in accordance to NESREA's (National Environmental Standards and Regulations Enforcement Agency) permissible noise level for various land uses using the reclassifying tool in ArcGIS. The reclassified map was overlaid on the land use map of Minna to determine the land uses and their associated noise. Areas with noise above the NESREA (2009) noise level standard were the areas to focus on for noise management. The causes of noise in the various areas derived from the structured questionnaire were useful in determining the noise management strategy. The demographic profile of the population was examined using descriptive data analysis in relation to how each group perceived noise and its consequences on their well-being. The possible impacts of this noise exposure in the domestic environment were examined using the Chi-square test to determine connections between exposure and perception of sources. For the questionnaire, reliability statistics were conducted for the items in the questionnaire and the Cronbach alpha value obtained was 0.5. This falls within the acceptable value and implies that the finding is reliable.

Results and Discussions

From the results obtained, most of the respondents are male, with 65.1% being male and 34.9% being female. Also, 36.8% are from the age group of 25–34 years old, and 17% are from 35–44 years old, and 35.9% are aged 16–24 years old, and only 7.8% are aged 45–54 years old. From the results of the survey, 32.4% of the respondents have O-level results and 27.8% are graduate or HND holders, 8.3% are postgraduate students, and 19.5% are vocational or ND holders, with only 11.9% having no formal education. 41% of the respondents are students, and 25.5% are traders, and 21.8% are civil servants. To achieve objective 1, which is to "*determine the residential neighbourhood most prone to noise pollution in Minna*". The spatio-temporal distribution of noise map established over Minna metropolis was determined to be able to identify the residential neighbourhood areas most prone to noise pollution across the metropolis. The spatio-temporal distribution of the noise map created across the Minna metropolis is shown in Figures 2–5. Figure 2 depicts the spatiotemporal distribution of noise across Minna and its environs in the morning, with the red colour indicating the greatest noise level at 94 dBA. while the lowest noise level recorded is 52 dBA, indicated by the yellow colour tone.

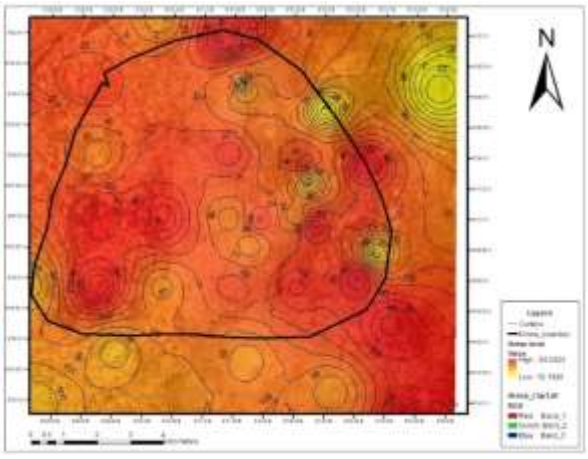

Figure 2. Noise map for morning time (8:00am)

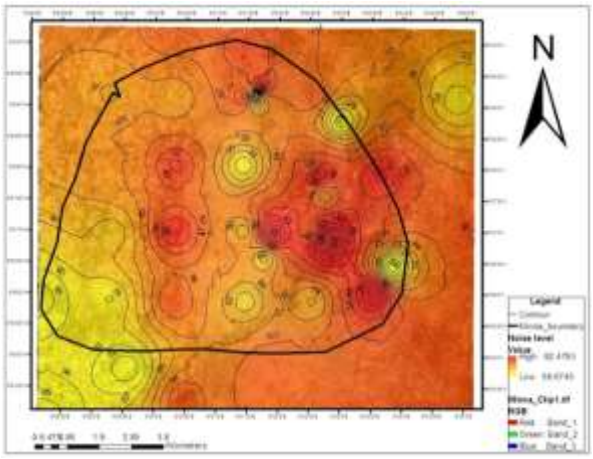

Figure 3. Noise map for midday (12:00 noon)

The highest noise level at this time is prominent in the south-east, some parts of the upper south-west and the lower part of the north-east. Meanwhile, the extreme north-east and the lower part of the south-west have lower noise. Hence, residential neighbourhoods which fall into these areas will experience various noise levels according to the values obtained. This finding corroborates with that of Oyedepo *et al.* (2013), whose work on noise pollution assessment in Nigeria was carried out by measuring noise levels at different hours of the day and found that interpreted noise for residential indicates that the highest noise level was observed at different locations and the

lowest level at another location during the day time. Similarly, the compacted contours also depict areas with high noise, while the scattered contour line shows the noise spreading. Similar contour values indicate places with similar noise. The high level of noise during the morning time in Minna could be explained to be associated with the time where daily activities in Minna are gathering up due to the rush hour.

Areas with low noise values could be attributed to the land use type and the low level of activities in such areas. Some areas that had deep red now have a light or yellow colour, indicating a reduction in noise. This indicates that activities causing noise have moved from noise-concentrated areas to the centre of human activities. Figure 3 reveals the highest noise level recorded at noon to be 92dBA and the lowest noise level, which is 58 dBA. The hot red tone indicates areas with very high noise, and the yellow colour indicates areas with very low noise. The south-east, the lower part of the north-east and some parts of the north-west and south-west of the region experience the highest noise, while the south-west and some parts of the north-west, north-east and south-east experience very low noise. This is also similar to the contour lines; the dense contours are areas with high noise, and the loose contour lines show areas with low noise level. It can be seen from the noise spread over Minna at noon that noise pollution is now concentrated in the central part. This represents areas where most human activities are at their peak. Thus, when the two maps in Figure 2 and 3 (i.e., for morning and noon time) were compared, the result indicates that noise pollution has reduced in some areas with higher noise.

The noise map shown in Figure 4 indicates the result of the noise recorded at that time. The findings show that the selected locations with red colour recorded up to 96 dBA are exposed to a higher level of noise pollution than the areas with yellow colour that recorded up to 56 dBA. The extreme south-west and a few parts of the south-east and north-east experience low noise, while the rest experience very high noise. The 6:00pm map depicts further spread of noise over Minna. This looks fairly similar to the 8:00am noise map, whereby noise has spread over the whole of Minna and its environment. This could be due to the return of human activities to the various spaces.

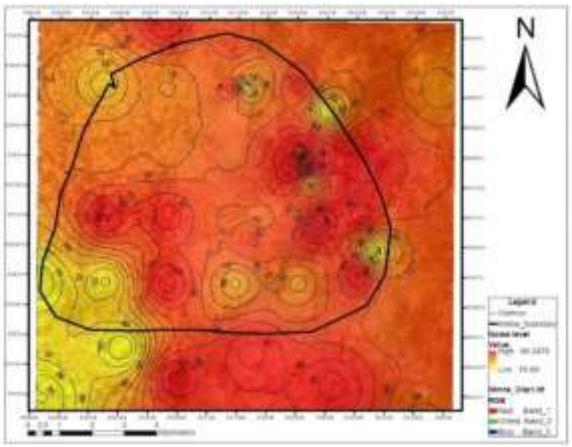

Figure 4. Noise map for evening time (6:00pm)

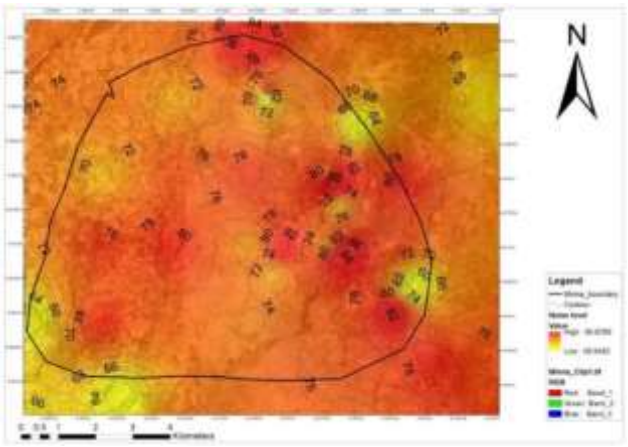

Figure 5. Noise map for overall mean noise level

Figure 5 explains the overall mean noise level experienced in Minna and its environment, with the highest noise of 90 dBA indicated in red and the lowest noise of 58 dBA indicated in yellow. The outcome demonstrates that in Minna, locations with a red tone and packed contour lines are those that are exposed to very high noise levels, while areas with a yellow tint and dispersed contour lines are those that are less noisy. Table 1 shows the maximum permissible noise level for the general environment from daytime to midnight and vice versa, obtained from the National Environmental Standards and Regulations Enforcement Agency (NESREA) permissible noise level for various land uses. The values in the table were used to establish the tolerable noise level for land uses that was observed in the city.

Table 1. Maximum Permissible Noise Level for General Environment

Facility	Noise limits dB (A)	
	Day 6:00a.m to 10: 00p.m	Night 10:00p.m to 6. 00a.m
Institutes for learning, offices etc.	45	35
Residential areas	50	35
Mixed residential (with some commercial and entertainment)	55	45
Residential + industry	60	50
Industrial	70	60

Source: NESREA (2009)

To achieve objective 2, which is to "*determine the implications of noise pollution on residents' well-being*", residential areas within the areas where noise measurements were taken were identified. The values for the noise level recorded were calculated and benchmarked against the standard noise limit as shown in Table 1. The result is presented in Figure 6, showing the residential neighbourhood of Minna and its different noise levels. The values obtained include the minimum, maximum, and mean noise for the entire neighbourhood. According to NESREA (2009), the reference parameters of 50 dB(A) (Table 1) were compared to the World Health Organization's recommendation of 55 dB(A) for residential areas. This comparison showed that the residential neighbourhoods' urban noise levels were intolerable in terms of acoustic comfort. As it can be seen in Figure 6, all of the values exceeded the standard noise limit for residential areas. This shows that these areas, alongside the residential environment in these areas, are exposed to very high levels of noise, which can be harmful to the health. Incidentally, responses from the respondents showed that noises from places of worship and traffic noise were the most pronounced and were consequently rated higher than other sources of noise. This outcome is comparable to that of Abbaspour *et al.* (2015) who evaluated noise pollution in Tehran Metropolitan City's metropolitan regions on a hierarchical basis. They demonstrated that in addition to traffic noise, other elements such as land use, population density, and the type of routes also contributed to noise pollution in urban areas, albeit not to the same extent. Unfortunately, this has received less attention in research that evaluates noise pollution.

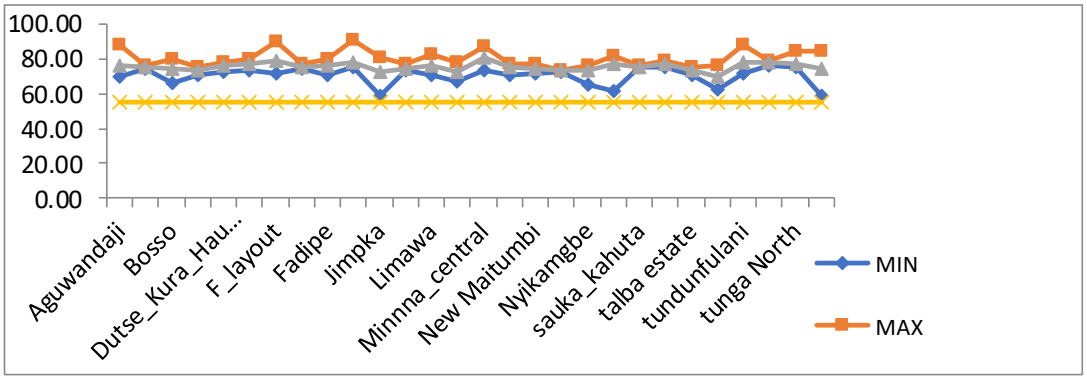

Figure 6. Minna residential neighborhoods and their noise level

In addition to the findings above, to determine the implication of the noise pollution on the residents who live in the high-level noisy area as shown in Figure 6, the residents were asked in the questionnaire to indicate from various options of possible effects of noise pollution on their wellbeing. According to the questionnaire responses shown in Table 3, 79% of the respondents said that noise pollution had an impact on their wellness. About one third (31.1%) indicated that noise pollution causes general disturbance (irritation) for them. This was followed by 24.4 percent indicating that it causes headache for them. To other respondents (10.1%) noise pollution is causes them loss of sleep/insomnia while for others (7.5%) it causes stress. The findings of Mead (2007), Martins *et al.* (2006), and Paneto *et al.* (2017), who focused on the "connection between urban noise and the health of users of public places,"

are comparable to those of these studies. In a study similar to this one, Paneto *et al.* (2017) asked 375 participants to complete a questionnaire. The results revealed that the most common responses to noise exposure were irritation (58%) and headaches (20%). (20 percent). Meanwhile, Martins *et al.* (2006) found that people who experience long-term noise exposure are more susceptible to headaches than those who do not.

Table 3. Implications of noise pollution on the respondents' well-being

	How would you describe the effect of noise pollution on your wellbeing	Frequency	Percent	Rank
Valid	No disturbance (can tolerate)	185	21.0	3
	General Disturbance (irritation)	274	31.1	1
	Headache	215	24.4	2
	Hypertension	24	2.7	6
	Loss of Sleep/Insomnia	89	10.1	4
	Stress	66	7.5	5
	Hearing loss due to continuous noise	10	1.1	8
	Physically and mentally affected	17	1.9	7
	Total	880	100.0	

In order to know the extent of the effect of noise pollution on the residents who indicated that noise pollution impacts their wellbeing, how the length of stay of the respondents in the residential environment affects their wellbeing was investigated. The length of time the respondents had lived in the area was requested of them. A cross tabulation was performed to know if the length of stay of the respondents in the residential environment is associated with the effect of noise pollution on the respondents. Results from Table 4 reveal that the majority of the study's population, or 79 percent, answered questionnaires in a way that showed they were aware of the negative consequences of noise exposure. This level of awareness is considered to be high. Hence, the result from the cross tabulation shows how the length of stay in the residential environment contributes to the effect of noise pollution on respondents' wellbeing.

From Table 4, 363 respondents who had been in the environment between 1–5 years experienced headaches, hypertension, loss of sleep, stress, and hearing loss, while 98 respondents who had spent over 20 years in the environment had also experienced irritation, headache, hypertension, loss of sleep, stress, and hearing loss. Each of the respondents has experienced one effect of noise pollution or the other as the length of stay increases in the environment. To confirm these findings, the relationship between the length of stay of the respondents in the environment and the effect of noise pollution on their wellbeing was further examined through the following hypothesis:

H_0: There is no relationship between the length of stay of the respondent and the effect of nose pollution on their health.

H_1: There is a relationship between the length of stay of the respondent and the effect of nose pollution on their health.

Table 4. Length of stay in the environment and the effect of noise pollution on respondents' health

		How long have you lived in your current neighbourhood (in years)					
		1-5	6-10	11-15	16-20	20+	Total
How would you describe the effect of noise pollution on your wellbeing	No disturbance (can tolerate)	83	51	20	14	17	185
	General Disturbance (irritation)	132	68	26	17	31	274
	Headache	80	51	36	19	29	215
	Hypertension	2	10	6	5	1	24
	Loss of Sleep/Insomnia	46	20	10	10	3	89
	Stress	9	29	9	12	7	66
	Hearing loss due to continuous noise	3	1	0	3	3	10
	Physically and mentally affected	7	3	0	0	7	17
Total		362	233	107	80	98	880

Table 5 shows the result of the Chi-Square tests that were carried out to know if the relationship is significant. There is a significant and positive relationship between the length of stay in the environment and the effect of noise pollution on the respondent's well-being since the significant value is less than 0.05. Therefore, as the length of stay increases, the effect of noise pollution also increases on the health of the respondents.

Table 5. Chi-Square Tests to know if there is significant relationship between the length of stay of the respondent in the environment and the effect of noise pollution on their wellbeing

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	94.916[a]	28	.000
Likelihood Ratio	96.212	28	.000
Linear-by-Linear Association	11.176	1	.001
N of Valid Cases	880		

a.12 cells (30.0%) have expected count less than 5. The minimum expected count is .91.

Table 6. Relationship between educational qualification and the respondents' perception of noise pollution

			Educational Qualification
Kendall's tau_b	How would you describe your knowledge about noise pollution	Correlation Coefficient	.242**
		Sig. (2-tailed)	.000
		N	880
	How important is the issue of noise pollution to you personally?	Correlation Coefficient	.179**
		Sig. (2-tailed)	.000
		N	880
	Do you perceive any problem of noise pollution in your neighbour?	Correlation Coefficient	-.150**
		Sig. (2-tailed)	.000
		N	880
	Does any particular noise annoy you on a daily basis?	Correlation Coefficient	-.020
		Sig. (2-tailed)	.495
		N	880
		N	880

Further investigation was conducted to ascertain the relationship between an occupant's educational level, occupation, and perception of noise pollution. 28.3% of the respondents took the issue of noise to be very important; 25.3% took the issue of noise as moderately important; and 18.9% took it as slightly important; while only 21.8% did not regard noise pollution as an issue. 57.2% of the respondents perceived an issue with noise pollution in the area, while only 32% did not perceive it. To ascertain whether there is a relationship between educational attainment and the respondents' impression of noise pollution as indicated by the following hypothesis, Kendall's tau b analysis was conducted.

H_0: There is no relationship between educational qualification and their perception of noise pollution
H_1: There is a relationship between their educational level and their perception of noise pollution.

Table 6 shows the findings of Kendall's tau b analysis to ascertain the association between respondents' perceptions of noise pollution and their level of education. The findings indicate a substantial correlation between educational background and how residents describe their familiarity with noise pollution. The crucial value is less than 0.05, so the null hypothesis is rejected. The relationship is observed to be moderate and positive, with pho being 0.242. This implies that an educated person will be more knowledgeable about the impact of noise pollution on their well-being than a respondent who is less educated. It was also discovered that educational qualification has a significant relationship with the importance of noise pollution to the respondent personally. The relationship is observed to be weak and positive, with pho being 0.179. This implies that a well-educated person will take the issue of noise pollution more seriously than a less educated individual, which may be due to the fact that they know the implications of its effect on their well-being**.**

To achieve objective 3 of this study, which is to "*propose urban noise management strategies for residential environments with a view to limiting its adverse effect on the urban populace*", The study investigated the residential areas for noise management in Minna and its environment. Figure 7 shows the result of the analysis conducted, which indicates the priority residential environment for noise management in Minna metropolis.

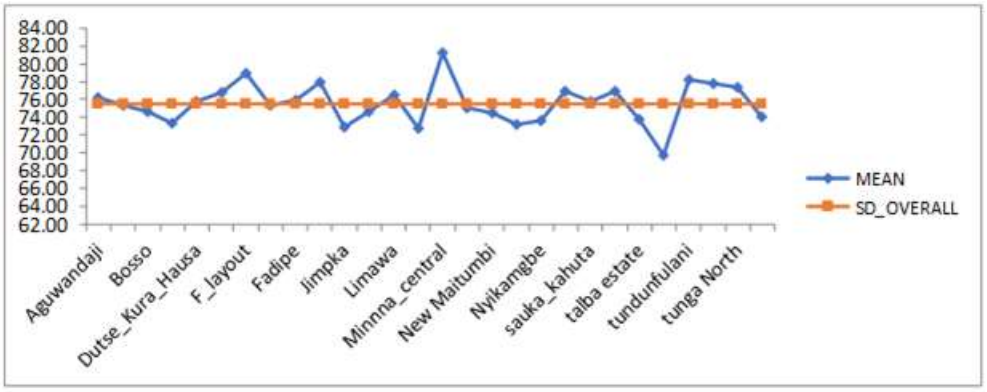

Figure 7. Residential neighborhood most prone noise for noise management

The residential environments as shown in Figure 7 with points which exceed the standard deviation for the noise level calculated include: Anguwandaji, Dutse_Kura_Hausa, Dutsen_Kura_Gwari, F_layout, Gbeganu, Fadipe, GRA Jimpka, Kpakungu, Limawa, Maitumbi, Minnna_central, Nasarawa, New Maitumbi, New GRA, Nyikamgbe, Sabon Gari, Sauka_kahuta, Shango, Talba estate, Tayi_village, Tundunfulani, Tunga low-cost and Tunga North. Thus, it may be said that these home settings can be classified as an area that is acoustically polluted. The areas with points below did not exceed the standard deviation. As a result, residential areas with sound levels below the standard deviation can be considered optimal and acoustically regulated settings. As a result, other evaluations might use their specifics as a point of comparison. Thus, Minna's priority regions for noise management are those places above the standard deviation that can be categorised as acoustically contaminated areas. Table 7 shows the respondents' rate of the degree of annoyance of noise to them.

Table 7. Degree of annoyance of noise to you Cross tabulation

		Rate the degree of annoyance of noise to you							
		Very low	Low	Neither low or high	High	Extremely high	Total for high & extremely high	Rank	Total
Location	Angwandaji Minna	6	11	20	42	0	42	1	79
	Bosso	11	26	6	8	7	15	11	58
	Democratic Garden	2	2	5	6	3	09	14	18
	Dutse Kura	4	27	25	26	8	34	2	90
	F Layout	0	16	20	10	5	15	11	51
	Fadekpe	8	23	13	11	7	18	9	62
	Garima Junction	13	15	19	3	4	07	15	54
	Gudugudu Maitunbi	5	15	7	24	3	27	4	54
	Jikpon	0	19	28	27	6	33	3	80
	Limawa	2	9	22	25	1	26	5	59
	Mobil Central/Old Airport Road	1	6	6	11	1	12	13	25
	Mobile Park	10	9	6	4	0	04	16	29
	Nikangbe	4	8	24	22	2	24	6	60
	Talba Estate	7	21	16	14	2	16	10	60
	Tundun Fulani	1	12	23	20	4	24	6	60
	Tunga North	11	7	4	14	5	19	8	41
Total		85	226	244	267	58			880

Considering different locations in Minna metropolis, the rate of the degree of annoyance of noise in each location varies. For instance, in Angwandaji, 53% (i.e., out of 79 respondents, 42 considered the degree of annoyance of noise to be high). In Bosso, 26% (i.e., 8 considered it as high and 7 considered it as extremely high) In the Dutse Kura area, 29% (i.e., out of 90 respondents, while 26 considered it as high) In the Gudugudu Maitunbi area, 44% (i.e., out of 54 respondents, 24 considered the degree of annoyance of noise as high). In the Jikpon area, 34% (i.e., out of 80 respondents, 27 considered the degree of annoyance of noise as high). In the Limawa area, 42% (i.e., out of 59 respondents, 25 considered the degree of annoyance of noise as high). In the Nikangbe area, 37% out of 60 respondents considered the degree of annoyance of noise as high. In Tundun Fulani, 33% out of 60 respondents, 20 considered it high. The rate of the degree of annoyance that environmental noise causes the respondents was cross-tabulated with the residential location where they live. The sum of those who rated high and extremely high their degree of annoyance was found and ranked. Findings show that Angwandaji ranked 1st, followed by Dutse Kura 2nd, Jikpon 3rd, Gudugudu Maitunbi 4th, and Limawa 5th. This finding was supported by the measured mean sound pressure levels, which indicated that the residential neighbourhood had the highest noise level at 90 dBA and the lowest noise level at 58 dBA. All these residential areas were corroborated with the results earlier discussed above, as they are the same residential areas where the calculated noise level was above the mean standard deviation obtained. This finding implies that these residential areas are the area's most prone to noise pollution in Minna metropolis and are to be targeted for noise management.

Recommendations and Implications of the Study

Based on the findings above, this study suggests the need for improved environmental quality in the built environment. This could be achieved through a synergistic intervention from architects, other built environment professionals, and environmental protection agencies on tackling urban environmental pollution in residential environments. The following recommendations could be considered by relevant stakeholders to control noise pollution and as strategies to mitigate the health impacts of noise in the residential environment.

- Nature-based solutions (e.g., the creation of community gardens, parks, simple green infrastructure, green roofs, and green facades) should be introduced to residential environments to improve the health of the citizens.
- Barriers from vegetation (e.g., tree planting) can be introduced to increase mixing and dilution of pollution levels more quickly. Vegetative barriers will provide modest attenuation up to 0.52 dBA/10 m.
- The use of natural topography as a barrier and/or erecting commercial buildings between roadways and residential areas are valuable strategies to reduce noise pollution.
- Residential buildings should be designed with the integration of suitable absorbing noise materials for walls, doors, windows, and ceilings to reduce the infiltration of noise into the building.
- A noise management policy implementation plan should be developed by the municipal management for noise reduction in residential environments.

The implications of this study are that the methodology and the results obtained and presented could be of interest to experts working in the fields of architecture, urban planning, environmental noise control, and city management. In making decisions to address issues with urban planning and worries about noise pollution in the environment, it could support urban managers.

Conclusion

The study uses monitoring, mapping, and a questionnaire as a tool for effect evaluation to show the geographical temporal distribution of noise and the priority locations for noise management in Nigeria's cities and its residential neighborhoods. According to measured data, Nigerian cities and their surroundings are subjected to noise levels that range from very low to excessively high when compared to national and international standards. The study found that residential environments around the following areas in Minna, namely: Agwandaji, F-Layout, G.R.A, Minna central (Mobil roundabout), Tundun Fulani, Tunga north, and Tunga south, have the highest level of noise. Incidentally, responses from the respondents showed that noise from places of worship and traffic noise were the most pronounced and were consequently rated higher than other sources of noise. The significance of this research lies in the necessity for further investigation, since it has important ramifications for architects, urban planners, and urban managers. It implies that individuals in some urban areas are subjected to noise levels that are excessive for their health and well-being. Therefore, some corrective measures are required to keep the current situation from deteriorating further. Based on the study's findings, it can be said that Nigerian cities urgently require the implementation of noise control and standards in order to reduce the impact of urban environmental noise pollution in residential areas. This study recommends nature-based solutions, barriers from vegetation, use of natural topography as a barrier, integration of suitable absorbing noise materials, and the development of policy for noise reduction.

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Conflict of Interests

The author declares no conflict of interest

References

Abbaspour M, Karimi E., Nassiri P., Monazzam M. R, Taghavi L. (2015), Hierarchal Assessment of Noise Pollution in urban Areas - A case study. Transportation Research, Part D 34, 95-103. DOI:10.1016/j.trd.2014.10.002

Akan, Z. Y. (2012). P-436 – Noise pollution, psychiatric symptoms and quality of life: Noise problem in the east 1–9. region of Turkey. Eur. Psychiatry 27 (1), 1. https://doi.org/10.1016/S0924-9338(12)74603-5

Babisch, W., Beule, B., Schust, M., Kersten, N., and Ising, H. 2005. Traffic noise and risk of myocardial infarction. Epidemiology, 16(1): 3340. DOI: 10.1097/01.ede.0000147104.84424.2

Babisch W. 2002. The noise/stress concept, risk assessment and research needs. Noise Health **4** (16): 1-11 Medline. https://www.noiseandhealth.org/text.asp?2002/4/16/1/31833

Claeson, A. S., Lidén, E., Nordin, M., and Nordin, S. (2013). The Role of Perceived Pollution and Health Risk Perception in Annoyance and Health Symptoms: A Population-Based Study of Odorous Air Pollution. International archives of occupational and environmental health, 86(3), 367-374. DOI: 10.1007/s00420-012-0770-8

Frei, P. M. (2014). Effect of nocturnal road traffic noise exposure and annoyance on objective and subjective sleep quality. Int. J. Hyg. Environ. Health 217 (2–3), 188–195. DOI: 10.1016/j.ijheh.2013.04.003

Goines, L, & Hagler, L. (2007). Noise Pollution: A Modern Plague. *Southern Medical Journal*, 100(3), 287-293. DOI: 10.1097/smj.0b013e3180318be5

Hunashal, R., & Patil, Y. (2012). Assessment of noise pollution indices in the city of Kolhapur, India. Procedia – Social Behav Sci 37, 448–457. DOI:10.1016/j.sbspro.2012.03.310

Juang, D.F., Lee, C.H., Yang, T. *et al.* (2010). Noise pollution and its effects on medical care workers and patients in hospitals. *Int. J. Environ. Sci. Technol.* **7,** 705–716 https://doi.org/10.1007/BF03326180

Kapp, Andrew F.; Passmore, Joseph M.; and Schneider, Anika H., (2014) "Noise Pollution? What's the solution? Understanding Traffic Noise Pollution in Gettysburg, Pennsylvania". Student Publications. 272. https://cupola.gettysburg.edu/student_scholarship/272

Landrigan, P. J., Schechter, C. B., Lipton, J. M., Fahs, M. C. and Schwartz, J. (2002). Environmental Pollutants and disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental disabilities, Environmental Health Perspectives, 110(7): 721-728. doi: 10.1289/ehp.02110721

Martin, M., Tarrero, M., Gonzalez, A., & Machimbarrena, M. (2006). Exposure–effect relationships between road traffic noise annoyance and noise cost valuations in Valladolid, Spain. *J. Appl. Acoust.,* 67 (10), 945-958. DOI 10.1016/j.apacoust.2006.01.004

Mead, M. N. (2007). Noise Pollution: The sound behind Heart Effects. Environmental Health Perspectives, 115(11), 536-537. https://doi.org/10.1289/ehp.115-a536b

Mishra, R.K., Parida, M. & Rangnekar, S. (2010). Evaluation and analysis of traffic noise along bus rapid transit system corridor. *Int. J. Environ. Sci. Technol.* **7,** 737–750. https://doi.org/10.1007/BF03326183

NESREA (2009). Review of NESREA Act 2007 and Regulation: Av New Dawn in Environmental Compliance and Enforcement in Nigeria

Oyedepo, S. O. (2012): Noise Pollution in Urban Areas: The Neglected Dimensions. Environmental Research Journal, 6l (4), 259 – 271. DOI: 10.3923/erj.2012.259.271

Oyedepo, J. O. Ekom, R. I. and Ajala, K. A. (2013) Analysis of Traffic Noise along Oyemekun - Oba - Adesida Road Akure Ondo State Nigeria. *Journal of Engineering Science and Technology Review.* DOI:10.25103/JESTR.061.14

Paneto, G. , de Alvarez, C. and Zannin, P. (2017) Relationship between Urban Noise and the Health of Users of Public Spaces—A Case Study in Vitoria, ES, Brazil. *Journal of Building Construction and Planning Research*, **5**, 45-57. doi: 10.4236/jbcpr.2017.52004.

Trombetta Zannin, P. d. (2011). Noise mapping at different stages of a freeway redevelopment project – A case study in Brazil. Appl. Acoust. 72 (8), 479–486. DOI:10.1016/j.apacoust.2010.09.014

van Kempen, E.E., Kruize, H., Boshuizen, H.C., Ameling, C.B., Staatsen, B.A., and de Hollander, A.E. (2002). The association between noise exposure and blood pressure and ischemic heart disease: a meta-analysis. Environmental Health Perspectives, 110(3): 307317. DOI: 10.1289/ehp.02110307.

Wakefield, S. E., Elliott, S. J., Cole, D. C., & Eyles, J. D. (2001). Environmental risk and (re) action: air quality, health, and civic involvement in an urban industrial neighbourhood. Health and place, 7(3), 163-177. DOI: 10.1016/s1353-8292(01)00006-5

Wawa, E. A. and Mulaku, G. C. (2015) Noise Pollution Mapping Using GIS in Nairobi, Kenya. *Journal of Geographic Information System*,07,486-493. doi: 10.4236/jgis.2015.75039

WHO, 2005. United nations Road Safety Collaboration. A Handbook of Partner Profiles. World Health Organization, Geneva, Switzerland. https://apps.who.int/iris/handle/10665/43159?show=full

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REVIEW ARTICLE

SCIENCE & ENGINEERING

A MODEL TO DEVELOP HOTEL MANAGEMENT SYSTEM TO OPTIMIZE REVENUE

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Abstract
Hotel provides facilities for customers and earns revenue. In this sector of business, many challenges might be faced by the hotel management since there arise price competition between hotels. Hotel management has to follow some strategies to earn maximum revenue. Though it is difficult to estimate actual profit in any epidemic situations, we showed the optimal revenue is possible even within this kind of epidemic situations. And to do this, a revenue management model was developed in terms of pricing and room allocation capacity. Price is the sole factor in this model. Two types of demand models are used, one is deterministic demand model and another is stochastic demand model and both are used for pricing model and capacity model formulation. This work showed how hotels can gain more revenue by using proposed capacity and pricing model, even in the time of global crisis situation like COVID-19 epidemic.

Keywords: Deterministic demand model, stochastic demand model, capacity model, pricing model, revenue management, optimal capacity

Introduction

Revenue Management (RM) predicts customer behavior at minuscule level of market, optimize availability of product and finally show the price which maximum revenue can be gained. The main aim of RM is firstly categorized the products for different customers and at time basis to sell the right product to the right customer. Both customer and producer can be benefited by the help of RM system. From customer sight, RM help to choose the right product among many products of same category at a low price, on the other hand by the help of RM system, a producer can easily find what types of products should be produce and also the pricing level. Talurri and Ryzin (2004) define RM as: *"RM is concerned with such demand-management decisions referred to as either sales decisions and the methodology and systems required to make them."*

RM refers to the collection of strategies and tactics, firms use to scientifically manage demand for their products and services, and it is considered as one of the most successful application areas of operations research (OR). The practice of RM has grown as a relatively obscure practice among a handful of major airlines in the post deregulation era in the United States (circa 1978) to its status today as a mainstream business practice with a growing list of industry users, ranging from Walt Disney Resorts to National Car Rental. Professional practice and research in the area is also expanding.

Civil Aviation Board of U.S. started to lose control of the regulation of airlines fare after the deregulation act of 1978. At that time, former Chairman and CEO of American Airlines invented yield management system, as a result the strictly pricing system diminished. Then there occurs more flexible pricing strategy called American Super Saver Fares. Later on, in 1985 a more flexible capacity-controlled model occurred called DINAMO (Dynamic Inventory Allocation and Maintenance Optimizer), which is called Ultimate Super Saver Fares. So, this yield management system aimed discounts in those situations of surplus of empty seats.

In 1972 when developing the overbooking first RM system research had been exercised by Littlewood (1972). Necessary conditions like- handling capacity, competitors' rate, is included in this system explicitly as variables. The maximum likelihood method is used to determine the unknown parameters. A dynamical model which helps to

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finding booking strategy for hotel yield management is made by Badinelli (2000) and which shows relationship among the marketing segments.

Game theory is also used in pricing strategy like-hotel management, hospitality management. Where the strategies (price and player) moving simultaneously. It is a duopoly game segmentation which works in competitive market like-hotel industry. In this case two hotels compete between them by offering same products in this regards price moves simultaneously; which is called *'Bertrand equilibrium'*. On the other hand, Cournot method describes how much revenue gained by a company through a competition among them. In this regards many companies should be produce same product and there exists no cooperation and also no collusion. Companies should be rational in this model and there is no product differentiation. Bertand and Cournot (2004) competition have been used to model the demand of a company that has influenced from the competitors.

For hotel industry RM system helps both the customer and the hotel company. A customer can be categorized the hotel by price basis against of hotel facilities. Then it is easier for the customer to choose the appropriate one to stay. On the other hand, for a hotel company it is easier for them to find the best room allocation system in against of price also they can aware of the customer choice. The main problem they face is the cancellation of a booking room near the booking date, it generally occurs when a customer book a room over phone. The fixed capacity of room is also a problem for them at the time of vacation. Finally, the price factor; is the main factor when the hotel companies compete among them, because of high price, one may lose some customers and as a result there occurs a situation where the number of unbook rooms increase and the cherished revenue level cannot be gained. To avoid the loss, need proper type of management of pricing system and capacity of room allocation.

A tourist spot like-Saint Martin Island in Bangladesh, people go there to spend their leisure and entertain them, and hotel provides those opportunities for the customers. Our main objective is to construct a revenue management system which will be useful in increasing the revenue of the hotels at Saint Martin Island during Covid-19 epidemic environment. In order to do that first we constructed an optimal capacity allocation model and then with the help of game theory a pricing model was developed based on the competition of two hotels.

Methodology

In this section various methods and topics are discussed that helped us to understand and formulate the capacity and pricing model. We examined quantity-based revenue management for a single resource, especially allocating capacity of a resource to different classes of demand and the controls known as booking limits and protection levels. Next, revenue management (RM) duopoly games between two firms are discussed. Finally, we talked about pricing-based revenue management using game theory model of pricing by Bertrand and Cournot Competition.

Probability Distributions of Demand

In order to understand and formulate capacity model and pricing model, we need to consider the probability distribution of demand. In our case demand is the customers' arrival rate. According to Talurri and Ryzin (2004), demand follows Poisson distribution which is used to model the booking limit. Also, exponential distribution can be used to calculate the time interval between each demand, which is used to model the stochastic demand model.

Poisson Distribution

Poisson distribution is a discrete probability distribution that expresses the probability of a given number of events occurring in a fixed interval of time or space if these events occur with a known constant mean rate and independently of the time since the last event.

When the following assumptions become true, the Poisson distribution becomes an appropriate model:

- k is the number of times an event occurs in an interval and k can take values 0, 1, 2 …
- The occurrence of one event does not affect the probability that a second event will occur. That is, events occur independently.
- The average rate at which events occur is independent of any occurrences. For simplicity, this is usually assumed to be constant, but may in practice vary with time.
- Two events cannot occur at exactly the same instant; instead, at each very small sub-interval exactly one event either occurs or does not occur.

If these conditions are true, then k is a Poisson random variable, and the distribution of k is a Poisson distribution.

Exponential Distribution

This distribution is the probability distribution in which events occur continuously and independently at a constant average rate. It is a particular case of the gamma distribution.

The probability density function (pdf) of an exponential distribution is,

$$f(x;\lambda)=\begin{cases}\lambda e^{-(\lambda x)} & x\geq 0\\ 0 & x<0\end{cases} \tag{2.1}$$

Here $\lambda > 0$ is the parameter of the distribution, often called the rate parameter. The distribution is supported on the interval $[0, \infty)$.

The cumulative distribution function is given by

$$F(x;\lambda)=\begin{cases}1-e^{-(\lambda x)} & x\geq 0\\ 0 & x<0\end{cases} \tag{2.2}$$

Booking Limits

Booking limit means the controls which limit the capacity level for a particular item when the company is eager to sell them to its customer at a given point of time. For example, let a hotel has 15 rooms as a booking limit of which the hotel management can allocate them at a fixed price. When they are able to allocate all the rooms, then the fixed price class would be closed for the customer. Generally, most often the room allocation is less than the room shown by them. If they want to maintain capacity level for the future, they can use another class allocation for fixed price. There are two types of booking limit: one is partitioned and other is nested.

For a partitioned booking limit the whole number of rooms can be classified into different blocks. For example, a hotel has total of 40 rooms for allocation. The hotel management is eager to allocate 24 of the total rooms are at a fixed price and other 16 at a discount price. If 24 rooms are allocating at a fixed price then this class would be closed. So, as same for the discount class, then there occurs partitioned booking limit.

For nested booking limit, let the total number of rooms is divided into two prices. For example, a hotel has total of 40 rooms for allocation. The hotel management is eager to allocate 24 of the total rooms are at a fixed price of 3000 Bangladeshi taka (BDT) per room and other 16 at a discount price of 2000 BDT per room, when there is no refund available for 2000 BDT per room. Then if a third-party business group take all the 40 rooms at a fixed price, then the hotel management can increase their revenue by using nested booing limit. Let us consider the nested booking limit for class j denoted by b_j

Protection Levels

A protection level means the amount of capacity which a company can reserve the items for some particular people or some group of people. There are also two types of protection levels, one is partitioned and other is nested. A partitioned protection level is relative to a partitioned booking level. Suppose that, a hotel has a booking limit of 15 rooms as a fixed price is equivalent to reserve (protect) 15 rooms for fixed price. In nested protection level, protection level can be defined for sets of different classes ordered in a hierarchical manner. For example, let a hotel has fixed price rooms for 3000 BDT each and discount price rooms for 2000 BDT each. Then let the protection level denoted by y_j which is defined as the capacity level for classes $j, j-1,....1$.

Let for nested protection level, let a hotel has set a protection level of 24 rooms as a fixed price class that means the hotel management is eager to allocate 24 out of the whole rooms at a fixed price. On the other hand, a protection level of total 40 rooms in which there is a combination of fixed price class and discount price class. In the last case there is no specified protection level, it is clear that there occurs all the availability of capacity level.

Let the booking limit is j , C be the total capacity, y_{j-1} denotes the protection level for classes $j-1$ and higher.

Then we write, $b_j = C - y_{j-1}, j = 2, \ldots, n$ (2.3)

When, $b_j = C$, then occurs highest class of booking limit which is equal to the capacity and when $yn = C$, then occurs combination of all classes' protection level is equal to capacity.

Littlewood's Two-Class Model

In Littlewood's model it deals with prices. Let us assume for two products with their associated prices p_1 and p_2, where $p_1 > p_2$, the total capacity is C and let there are no overbooking and cancellation. D_j be the j^{th} class demand, where $F_j(.)$ is its distribution. In this model, demand for class 2 come first. The main goal for this problem is to find out how much demand of class 2 can be accepted without seeing the demand of class 1. Suppose that a hotel has x units of remaining capacity and they get a booking for class 2. Then they earn revenue p_2 by collecting the order. If they do not accept the request for class 2, they will sell the remaining x unit at p_1 (higher price) if and only if there occurs a high demand for class 1. That is $D_1 \geq x$. Thus, the hotel's gain from reserving x unit class 2 rooms for class 1 rooms is denoted by $p_1 P(D_1 \geq x)$. Therefore, the hotel will accept class 2 request for class 1 as long as price exceeds the marginal value if and only if $p_2 \geq p_1 P(D_1 \geq x)$.

It shows that right hand side is decreasing in x. Let y_1^* denotes an optimal protection level. So, the company will accept when the remaining capacity y_1^* exceeds and on the other hand they will not accept if the remaining capacity is y_1^* or less, such that y_1^* satisfies

$$p_2 < p_1 P(D_1 \geq y_1^*) \text{ and } p_2 \geq p_1 P(D_1 \geq y_1^* + 1) \quad (2.4)$$

If $F_1(x)$ denotes a continuous distribution to model demand then the optimal protection level y_1^* is given by

$$p_2 = p_1 P(D_1 > y_1^*), \text{ equivalently } y_1^* = F_1^{-1}(1 - \frac{P_2}{P_1}) \quad (2.5)$$

This is known as Littlewood's rule. By Littlewood's rule, if we set a protection level y_1^* for class 1, then it is an optimal policy or a booking limit of $b_2^* = c - y_1^*$, then class 2 demand is optimal. Otherwise, we use $\pi(x) = p_1 P(D_1 > x)$ as a bid price control.

Suppose, D_1 is normal distribution, μ be the mean, σ be the standard deviation. Then by Littlewood's rule, $F_1(y_1^*) = 1 - p_2/p_1$ and the optimal protection level can be denoted by $y_1^* = \mu + z\sigma$, where $z = \Phi^{-1}(1 - p_2/p_1)$ and the inverse of standard normal cumulative distribution function (c.d.f) is $\Phi(.)^{-1}$. Meeting the mean demand for class 1, the hotel should reserve enough capacity. μ is plus or minus, a factor which depends both on revenue ratio and demand variation σ. If $p_2/p_1 > 0.5$, the optimal protection level is less than the mean demand. If $p_2/p_1 < 0.5$, it is greater than the mean demand. If the value of ratio p_2/p_1 is low, then the more capacity for class 1 occurs.

RM Duopoly Games

Let us consider a duopoly case where two firms have their fixed capacity level but both of them want to sell them for different price group, for example, H for high and L for low, where the identical prices be $p_H > p_L$. Customer choice among the firms within the same class and strategic decision refers to the capacity allocation for the low (L)class. Customers demand for class (class H and class L) and firms (firm 1 and firm 2) which is modeled D_{kj} as

random variable. Let $k = H, L$ (high class and low class) and $i = 1,2$ (firm 1 and firm 2), then the reallocation of demand can be happening as follows. If the high class H of firm 1 is closed then the remaining customers cherishing class H for firm 1 goes to firm 2. As the same way if for firm 1, class L is closed, all the customers cherishing L goes to firm 2.

If there is the possibility of no buy-up then a customer of demanding L class is assumed to never buy a H class and a customer demanding H never buy L class. It is assumed that all H demand customers appear after L demand customers. There is also possibility of existence of pure-strategy Nash equilibrium by using Littlewood's rule. Let y_1 be the protection level for firm 1 for high fare class over the integer set between $[0, C]$, on the other hand $C - y_2$ be the strategy space for firm 2 for high fare class over the integer set between $[0, C]$ and y_2 be the protection level for firm 2.

By Littlewood's rule, the optimal protection level for H class is independent for L class customer. As there is possibility of not buying-up L class demand, then this duopoly RM games can be defined for only H class demand protection level.

By Littlewood's rule, it is assumed that two classes demand cannot be correlated. That shows that for firm 1, H class demand is correlated with firm 2, H class demand so as for the L class. In this case by using Littlewood's rule each firm is able to set its best response. For different firm for a fixed protection level both L and H class demand is uncorrelated. By the above assumption it is assumed that there is still a guaranteed equilibrium. In case of correlation between L class and H class demand it needs not always existence of an equilibrium.

A firm's (say firm 1) objective function can be caused by the correlation between the demands of L class and H class. At the same time as firm 2 increases their booking limit for L class then the optimal solution for firm 1can jump from one step of the multimodal function to another step. For correlation matrix the existence of pure-strategy equilibrium is one of the main results in this case.

Static Bertrand Models

Bertrand price competition model is the second fundamental model of oligopoly competition. The main assumption of this model in case of perfect competition is firms produce similar product and customers buy from the firm offering the lowest price. Firms produce enough product to satisfy all its demand. Each firm competes on prices and prices of the product changes non-cooperatively and simultaneously.

We consider the model for duopoly but it can be extended to n firm's case. Let us consider two firms, firm-1 and firm-2. We consider that each firm has same marginal cost. Let the market demand denoted by the function $d(p)$.

Demand for firm1 at price p_1 is given by the function $d_{p_1}(.)$, i.e.,

$$d_1(p_1 p_2) = \begin{cases} d(p_1) & if \quad p_1 < p_2 \\ d(p_1)/2 & if \quad p_1 = p_2 \\ 0 & if \quad p_1 > c_1 < c_2 \end{cases} \tag{2.6}$$

Similarly, demand function for firm-2. Firm 1 will lose its demand if firm 2 prices are slight less than firm 1. Then, firm 1 profit function is given by

$$V_1 = (p_1 - c) d_1(p_1, p_2) \tag{2.7}$$

Let (p_1^*, p_2^*) denote the Nash equilibrium in prices. In the Bertrand model the equilibrium is very straight forward, if both firms price of marginal cost c is same then both will obtain unique equilibrium which is similar to the perfect competition. If we explain this, from firm 1 perspective it will lose all the demand if its price is less than firm 2's price p_2. If firm 2's price p_2 is greater than the marginal cost, i.e., $p_2 > C$ than it helps the firm 1 to gain

demand at price $p_1 = p_2 - \delta$ where $\delta > 0$. Firm 1 gets all the demand and make an increasing profit. Similarly, reverse situation for firm 2 also gets the upper hand and gets all the demand and can make a profit. This price competition continues until both firms reach their marginal cost C, which is the only equilibrium.

So, in Bertrand's model, firms do not make any profit even if they face only one competition. This result tells us that, if price is the only difference between the firms, the outcome of their competition will gain nothing for them. That's why firms try to have some difference between them and often avoid direct price competition as far as they can.

Bertrand and Cournot Competition

In Ultraphone game, which is like as Bertrand competition, two firms compete just on cost without separate their indistinguishable produce items. It very well may be shown that if demand is a linear function of price and assuming the two firms have a similar marginal cost, then the only Nash equilibrium is for the two firms to set a value equivalent to their marginal cost. As in the model above, cost may be down when competition between two firms happens, and in a Bertrand competition, costs are driven down to their most reduced limit.

With no matter charged price, both Bertrand model and UltraPhone example assume that it is always possible for the firms to produce a sufficient quantity to supply the market, no matter what price is charged. Therefore, the Bertrand model does not fit industries with capacity constraints that are expensive to adjust. Another alternative model is Cournot competition, in which the firms' strategies are quantities rather than prices. If the firms choose higher the quantities, then the price should be lower the prices. Under a cournot competition between two firms, the resulting Nash equilibrium price is higher than the marginal cost (the Bertrand solution) but lower than the monopoly price. As the number of firms competing in market increase, however, the Cournot equilibrium price falls, in the theoretical limit (an infinite number of competitors), the price drops down the marginal cost. Products are identical is another important assumption of Bertrand competition, besides the assumption that there are no capacity constraints, so that the firm offering the lowest price attracts all demand.

Competitors have two choices: High and Low prices. In practice, firms may choose from a variety of prices, so now assume that each firm chooses a price over a continuous range. Let firm's price be $p_i; i = A \text{ or } B$. In this game, a player's strategy is the choice of a price, and now we have to define payoffs, given the strategies. First, we describe how each competitor's price affects demand for the product. In the last section, all customers chose the lowest price. Here we assume that the products are differentiated, so that some customers receive different utilities from the products and are therefore loyal; they will purchase from A or B, even if the other firm offers lower price. Specifically, let $d_i(p_i, p_j)$ be the demand for product i, given that the competitors charge p_i and p_j. We define the linear demand function,

$$d_i(p_i, p_j) = a - bp_i + cp_j \tag{2.8}$$

If $C > 0$, we say that the products are substitutes: a lower price charged by firm A leads to more demand for A's products and less demand for B's (although if $p_B < p_A$), B does not steal all demand. If $C < 0$, then the products are complements: a lower price charged by A raises demand for both products. In the UltraPhone example, the products are substitutes; product A and a specialized accessory (e.g., a docking station) would be complements. If $C = 0$, then the two products are independent, there is no interaction between the firms, and both firms choose their optimal monopoly price.

Now let m be the constant marginal cost to produce either product. Firm $i's$ margin is therefore $(p_i - m)d_i(p_i, p_j)$. This function is concave with respect to p_i, and therefore the optimal price for firm i given that firm j charges p_j can be found by taking the derivative the function with respect to p_i, setting that first derivative equal to 0, and solving algebraically for p_i. Let $p_i(p_j)$ be the resulting optimal price, then

$$p_i(p_j) = \frac{1}{2b}(a + bm + cp_j) \tag{2.9}$$

Here $p_i(p_j)$ is the best response function of i to j, which is the optimal price function of the competitor's price.

Model Formulation

Capacity Model

The main goal of this model is to fix up capacity for customers who are willing to stay at high price rooms or low-price rooms. Hotel management fix up some rooms for customers with low price which is called booking limit. When they gain their targeted limit then rest of the rooms (protection limit) will be offered to the next customers who want high price rooms and they are always ready to pay the room's rent for full price. Hotel management could not gain optimal point if they set more rooms for booking limit, because there is possibility that the number of demands for high price rooms are more than prediction, on the other hand, if booking limit is to low then number of unallocated rooms may occur and they could not reach their optimal point. So, it is necessary to develop both booking limit and protection limit model.

Here both booking limit and protection level are influenced by low price (p_L) and full price (p_F) ratio (r). We assume that the arrival of demand follows Poission distribution. The CDF of Poission distribution is given by

$$F = \sum_{k=0}^{y} \frac{\lambda^K e^{-\lambda}}{k!} \tag{3.1}$$

Here,

- k is the number of times an event occurs in an interval and k can take values 0, 1, 2…
- e is Euler's number (e = 2.71828...)
- λ is equal to the expected value of a random variable and also to its variance

According to Littlewood's two class model discussed in chapter 2 the optimal protection level denoted b *y** is given by

$$y^* = F^{-1}(1 - \frac{p_{L_i}}{p_{H_i}}) \tag{3.2}$$

Here,

- p_{L_i} is the low priced room of hotel i
- p_{H_i} is the high priced room of hotel i
- F^{-1} is the inverse poission distribution

The booking limit can be obtained using total capacity C. Subtracting protection level from total capacity we get the booking limit *b*:

$$b = C - y^* \tag{3.3}$$

Using this capacity model optimal booking limit (number of rooms fixed for low price) and protection level (number of rooms fixed for high price) can be obtained.

Monopoly Model

There are two types of prices offered for a room and they are high price p_H and low price p_L and $p_H > p_L$. Customers are categorized by two types such as young customers who come as group and customers who come as families. There exist two different cases: for young customer, they have no fixed schedule and in case of pricing system they are more sensitive than the families.

The highest number of rooms allocated for low price is defined as booking limit b. When the hotel is able to reach its booking limit, then the next demand will be set to high price. The protection level y^* is defined as the number of rooms that is protected and always set to high price.

The revenue R depends on price, booking limit, protection level and the expected demand. Let C_i is the total capacity of hotel i and D_i is the demand of hotel i. If the hotel management does not change their capacity, then we use occupancy rate of rooms to model the demand. Demand is always highly correlated with price, if the price of rooms is higher, there occurs lower demand. So, it can be said that the demand function only depends on the lower price. Then the room occupancy rate can be formulated as:

$$d(p_L) = \alpha - \beta p_L \text{ , where } \alpha, \beta > 0 \tag{3.4}$$

Demand for low priced room (booking limit) comes first and after fulfilling the booking limit next demand will go for high priced room (protection level). In this way demand for high priced room depends on low price. So, our demand function depends only on low price.

$$D(p_L) = Cd(p_L) \tag{3.5}$$

The revenue for Hotel A can be formulated as:

$$\max R_A = \begin{cases} p_{L_A} b_A + p_{H_A}(C_A - b_A) & if \quad D_A \geq C_A \\ p_{L_A} b_A + p_{H_A}(D_A - b_A) & if \quad b_A < D_A < C_A \\ p_{L_A} D_A & if \quad D_A < b_A \end{cases} \tag{3.6}$$

Similarly, the revenue model for Hotel B can be written as:

$$\max R_B = \begin{cases} p_{L_B} b_B + p_{H_B}(C_B - b_B) & if \quad D_B \geq C_B \\ p_{L_B} b_B + p_{H_B}(D_B - b_B) & if \quad b_B < D_B < C_B \\ p_{L_B} D_B & if \quad D_B < b_B \end{cases} \tag{3.7}$$

To gain the maximum revenue limit, the hotel management should set the optimum booking limit and protection level, for estimating demand we have to consider the ratio between the high price and low price. It is assumed that the demand follows Poission process, hence the number of demands is Poission distributed with cumulative distributed function $F(y)$. Optimum protection level is determined based on Littlewood's Rule that is discussed in section 3.1.

Duopoly Model with Deterministic Demand

Deterministic demand means that demand is known. Hotel A has rooms fixed for low price known as booking limit denoted by b_A and rooms fixed for full price known as protection level denoted by y_A^*. This model limits on duopoly competition between two hotels called Hotel A and Hotel B. Which means only the competition between two hotels at a time is considered. As the demand is a function of price, in order to maximize the revenue, each hotel management will set competitive price, where the demand is influenced by price of competitor, we will use game theory to analyze the model.

First, we need to construct an occupancy rate for the duopoly model. Here, we will consider both hotels' prices since one hotel's price may affect the other hotels demand. Since demand is a function of price, the higher the price of Hotel A, the demand of Hotel A will be decreasing and for the higher the price of Hotel B, the demand of Hotel A will be increasing. Thus, the occupancy rate for Hotel A is given by,

$$d_A(p_{L_A L_B}) = \alpha_A - \beta_A p_{L_A} + \gamma_A p_{L_B} \tag{3.8}$$

Where, d_A is the occupancy rate (ratio of demand and capacity) and α_A, β_A, γ_A are the coefficient of occupancy rate model of Hotel A towards Hotel B. The demand function which can be found by multiplying the occupancy rate with the total capacity of Hotel A:

$$D_A = C_A d_A(p_{L_A, L_B}) \tag{3.9}$$

So, the revenue for Hotel A is given by:

$$\max R_A = \begin{cases} p_{L_A} b_A + p_{H_A}(C_A - b_A) & if \quad D_A \geq C_A \\ p_{L_A} b_A + p_{H_A}(D_A - b_A) & if \quad b_A < D_A < C_A \\ p_{L_A} D_A & if \quad D_A < b_A \end{cases} \tag{3.10}$$

Now the revenue when demand for Hotel A is less than the total capacity of Hotel A but greater than the booking limit can be written as:

$$R_A = p_{L_A} b_A + p_{H_A}(D_A - b_A) \tag{3.11}$$

The payoff function is:

$$R_A(p_{L_A}, p_{L_B}) = p_{L_A} b_A + \frac{p_{L_A}}{r_A}(C_A \alpha_A - C_A \beta_A p_{L_A} + C_A \gamma_A p_{L_B} - b_A)$$

$$R_A(p_{L_A}, p_{L_B}) = p_{L_A} b_A + \frac{C_A p_{L_A} \alpha_A}{r_A} - \frac{C_A p^2{}_{L_A} \beta_A}{r_A} + \frac{C_A \gamma_A p_{L_B} p_{L_A}}{r_A} - \frac{b_A}{r_A} p_{L_A}$$

Here, r_A is the ratio between low price and high price of Hotel A.

According to Bertrand and Cournot competition, this payoff function is concave, therefore the optimal price for Hotel A given that Hotel B charges p_{L_B} can be found by taking the derivative of the function with respect to p_{L_A}, setting the first derivative equal to 0 and solving algebraically for p_{L_A}, we have

$$\frac{dR_A}{dp_{L_A}} = b_A + \frac{C_A \alpha_A}{r_A} - \frac{2C_A p_{L_A} \beta_A}{r_A} + \frac{C_A \gamma_A p_{L_B}}{r_A} - \frac{b_A}{r_A}$$

$$\Rightarrow b_A + \frac{C_A \alpha_A}{r_A} - \frac{2C_A p_{L_A} \beta_A}{r_A} + \frac{C_A \gamma_A p_{L_B}}{r_A} - \frac{b_A}{r_A} = 0$$

$$\Rightarrow \frac{2C_A p_{L_A} \beta_A}{r_A} = b_A + \frac{C_A \alpha_A}{r_A} + \frac{C_A \gamma_A p_{L_B}}{r_A} - \frac{b_A}{r_A}$$

$$\Rightarrow 2C_A p_{L_A} \beta_B = b_A r_A + C_A \alpha_A + C_A \gamma_A p_{L_B} - b_A$$

$$\Rightarrow p_{L_A} = \frac{b_A r_A + C_A\alpha_A + C_A\gamma_A p_{L_B} - b_A}{2C_A\beta_A}$$

$$\therefore p_{L_A} = \frac{b_A r_A + C_A\alpha_A - b_A}{2C_A\beta_A} + \frac{\gamma_A}{2\beta_A} p_{L_B} \tag{3.12}$$

This is the pricing model for Hotel A which is influenced by the price of Hotel B.

Similarly, Hotel B has rooms fixed for low price known as booking limit denoted by b_B and rooms fixed for full price known as protection level denoted by y^*_B. The occupancy rate for Hotel B is given by,

$$d_B(p_{L_A,L_B}) = \alpha_B - \beta_B p_{L_B} + \gamma_B p_{L_A} \tag{3.13}$$

Where, d_B is the occupancy rate (ratio of demand and capacity) and α_B, β_B, γ_B are the coefficient of occupancy rate model of Hotel B towards Hotel A.

The higher the price of Hotel B the demand of Hotel B will be decreasing and the higher the price of Hotel A the demand of Hotel B will be increasing. The demand function for Hotel B is,

$$D_B = C_B d_B(p_{L_A,L_B}) \tag{3.14}$$

The revenue for Hotel B is

$$\max R_B = \begin{cases} p_{L_B} b_B + p_{H_B}(C_B - b_B) & if \quad D_B \geq C_B \\ p_{L_B} b_B + p_{H_B}(D_B - b_B) & if \quad b_B < D_B < C_B \\ p_{L_B} D_B & if \quad D_B < b_B \end{cases} \tag{3.15}$$

Now the revenue when demand for Hotel B is less than the total capacity of Hotel B but greater than the booking limit, can be written as

$$R_B = p_{L_B} b_B + p_{H_B}(D_B - b_B) \tag{3.16}$$

The payoff function is

$$R_B(p_{L_A}, p_{L_B}) = p_{L_B} b_B + \frac{p_{L_B}}{r_B}(C_B\alpha_B - C_B\beta_B p_{L_B} + C_B\gamma_B p_{L_A} - b_B)$$

$$R_B(p_{L_A}, p_{L_B}) = p_{L_B} b_B + \frac{C_A p_{L_B}\alpha_B}{r_B} - \frac{C_A p^2{}_{L_B}\beta_B}{r_B} + \frac{C_B\gamma_B p_{L_B} p_{L_A}}{r_B} - \frac{b_B}{r_B} p_{L_B}$$

Here r_B is the ratio between low price and high price of Hotel B.

According to Bertrand and Cournot competition, this payoff function is concave, therefore the optimal price for Hotel B given that Hotel A charges p_{L_A} can be found by taking the derivative of the function with respect to p_{L_B}, setting the first derivative equal to 0 and solving algebraically for p_{L_B}, we have

$$\frac{dR_B}{dp_{L_B}} = b_B + \frac{C_B\alpha_B}{r_B} - \frac{2C_B p_{L_B}\beta_B}{r_B} + \frac{C_B\gamma_B p_{L_A}}{r_B} - \frac{b_B}{r_B}$$

$$\Rightarrow b_B + \frac{C_B\alpha_B}{r_B} - \frac{2C_B p_{L_B}\beta_B}{r_B} + \frac{C_B\gamma_B p_{L_A}}{r_B} - \frac{b_B}{r_B} = 0$$

$$\Rightarrow \frac{2C_B p_{L_B}\beta_B}{r_B} = b_B + \frac{C_B\alpha_B}{r_B} + \frac{C_B\gamma_B p_{L_A}}{r_B} - \frac{b_B}{r_B}$$

$$\Rightarrow 2C_B p_{L_B}\beta_B = b_B r_B + C_B\alpha_B + C_B\gamma_B p_{L_A} - b_B$$

$$\Rightarrow p_{L_B} = \frac{b_B r_B + C_B\alpha_B + C_B\gamma_B p_{L_A} - b_B}{2C_B\beta_B}$$

$$\therefore p_{L_B} = \frac{b_B r_B + C_B\alpha_B - b_B}{2C_B\beta_B} + \frac{\gamma_B}{2\beta_B} p_{L_A} \tag{3.17}$$

This is the pricing model for Hotel B which is influenced by the price of Hotel A.

Duopoly Model with Stochastic Demand

Stochastic demand means that demand is uncertain, i.e., demand is a random variable. This model takes into account the stochastic behavior of the demand. Since demand is affected by price, stochastic demand model becomes a function of price. Thus, CDF of price is used to model occupancy rate or demand. $F(p_L)$ is the probability function of demand which is less than or equal to low price p_L. So, $1-F(p_L)$ represents the probability of demand who are able to pay more than the low price p_L. Talluri and Van Rayzin (2004) developed demand model as a function $d(p_L)$ of price given by

$$d(p_L) = N(1-F(p_L)) \tag{3.18}$$

Where N is market size, F_{p_L} is CDF of lower price. However, this model can only be applied for monopoly case. According to (3.18), the occupancy rate for two hotels namely Hotel A and Hotel B are as follow

$$d_A(p_{L_A}) = N\left(1-F(p_{L_A})\right) \tag{3.19}$$

$$d_B(p_{L_B}) = N\left(1-F(p_{L_B})\right) \tag{3.20}$$

Thus, for duopoly model using (3.19) and (3.20) the occupancy rate for Hotel A is

$$d_A(p_{L_A}, p_{L_B}) = N(1-F(p_{L_A})+1-F(p_{L_B})) \tag{3.21}$$

To determine the value of occupancy rate, let us consider two cases, when $p_{L_A} > p_{L_B}$ and $p_{L_A} < p_{L_B}$.

Let CDF for Hotel A is $F_A^+(p_{L_A})$ when $p_{L_A} < p_{L_B}$ and $F_A^-(p_{L_A})$ when $p_{L_A} < p_{L_B}$. Then, CDF of Hotel A can be formulated as:

$$F_A(p_{L_A}) = \begin{cases} F_A^+(p_{L_A}) & if \quad p_{L_A} < p_{L_B} \\ F_A^-(p_{L_A}) & if \quad p_{L_A} \geq p_{L_B} \end{cases}$$

Substituting these values to the previous occupancy rate the new occupancy rate is

$$d_A(p_{L_A}, p_{L_B}) = \begin{cases} N[1-F_A^+(p_{L_A})+1-F_B^-(p_{L_B})] & if \quad p_{L_A} < p_{L_B} \\ N[1-F_A^-(p_{L_A})+1-F_B^+(p_{L_B})] & if \quad p_{L_A} \geq p_{L_B} \end{cases}$$

We assume that, demand that is a CDF of price follows exponential distribution. Where the rate parameter is denoted by λ_A which is the average rate of time between each demand of Hotel A and each price is the random variable.

Thus, the CDF of Hotel A is

$$F_A(p_{L_A}) = \begin{cases} 1-e^{-\lambda_A^+ p_{L_A}} & if \quad p_{L_A} < p_{L_B} \\ 1-e^{-\lambda_A^- p_{L_A}} & if \quad p_{L_A} \geq p_{L_B} \end{cases}$$

Hence, the occupancy model becomes as

$$d_A(p_{L_A}, p_{L_B}) = N[1-1+e^{-\lambda_A^+ p_{L_A}} +1-1+e^{-\lambda_B^+ p_{L_B}}]$$

$$d_A(p_{L_A}, p_{L_B}) = N[e^{-\lambda_A p_{L_A}} + e^{-\lambda_B p_{L_B}}]$$

We know that for optimal value, $\frac{\partial d_A}{\partial p_{L_A}} = 0$ and $\frac{\partial d_A}{\partial p_{L_B}} = 0$. Thus, we have

$$-N\lambda_A e^{-\lambda_A p_{L_A}} = 0$$
$$\Rightarrow e^{-\lambda_A p_{L_A}} = 0$$
$$\therefore\ p_{L_A} = 0$$

Similarly, $p_{L_B} = 0$

So, the extreme value is

$$d_A(p_{L_A}, p_{L_B}) = 0$$
$$\Rightarrow N(e^{-\lambda_A p_{L_A}} + e^{-\lambda_B p_{L_B}}) = 0$$
$$\Rightarrow -e^{-\lambda_A p_{L_A}} = e^{-\lambda_B p_{L_B}}$$

Since, $p_{L_A} < p_{L_B}$ the left-hand side becomes as $e^{-\lambda_A p_{L_A}} = -\lambda_A p_{L_A}$

$$\Rightarrow -(-\lambda_A p_{L_A}) = e^{-\lambda_B p_{L_B}}$$
$$\Rightarrow \ln(\lambda_A p_{L_A}) = -\lambda_B p_{L_B}$$
$$\therefore \ln(p_{L_A}) = -\ln(\lambda_A) - \lambda_B p_{L_B} \quad (3.22)$$

This is the pricing model for Hotel A with stochastic demand.
Similarly, for duopoly model the occupancy rate for Hotel B is

$$d_B(p_{L_A}, p_{L_B}) = N(1 - F(p_{L_B}) + 1 - F(p_{L_A}))$$

To determine the value of occupancy rate let us consider two cases, when $p_{L_B} \geq p_{L_A}$ and $p_{L_B} < p_{L_A}$.

Let CDF for Hotel-B is $F_B^+(p_{L_B})$ when $p_{L_B} < p_{L_A}$ and $F_B^-(p_{L_B})$ when $p_{L_B} < p_{L_A}$. Then, CDF of Hotel B can be formulated as:

$$F_B(p_{L_B}) = \begin{cases} F_B^+(p_{L_B}) & if \quad p_{L_B} < p_{L_A} \\ F_B^-(p_{L_B}) & if \quad p_{L_B} \geq p_{L_A} \end{cases}$$

Substituting these values to the previous occupancy rate the new occupancy rate is

$$d_B(p_{L_A}, p_{L_B}) = \begin{cases} N[1 - F_B^+(p_{L_B}) + 1 - F_A^-(p_{L_A})] & if \quad p_{L_B} < p_{L_A} \\ N[1 - F_B^-(p_{L_B}) + 1 - F_A^+(p_{L_A})] & if \quad p_{L_B} \geq p_{L_A} \end{cases}$$

We assume that, demand for Hotel B is a CDF of price follows exponential distribution. Where the rate parameter is denoted by λ_B which is the average rate of time between each demand of Hotel B and each price is the random variable. Thus, the CDF of Hotel B is

$$F_B(p_{L_B}) = \begin{cases} 1 - e^{-\lambda_B^+ p_{L_B}} & if \quad p_{L_B} < p_{L_A} \\ 1 - e^{-\lambda_B^- p_{L_B}} & if \quad p_{L_B} \geq p_{L_A} \end{cases}$$

Hence, the occupancy model becomes

$$d_B(p_{L_A}, p_{L_B}) = N[1 - 1 + e^{-\lambda_B^+ p_{L_B}} + 1 - 1 + e^{-\lambda_A^+ p_{L_A}}]$$

$$d_B(p_{L_A}, p_{L_B}) = N[e^{-\lambda_B p_{L_B}} + e^{-\lambda_A p_{L_A}}]$$

We know that for optimum value, $\frac{\partial d_B}{\partial p_{L_A}} = 0$ and $\frac{\partial d_B}{\partial p_{L_B}} = 0$. Thus, we have

$$-N\lambda_B e^{-\lambda_B p_{L_B}} = 0$$
$$\Rightarrow e^{-\lambda_B p_{L_B}} = 0$$
$$\therefore \; p_{L_B} = 0$$

Similarly, $p_{L_A} = 0$

So, the extreme value is

$$d_B(p_{L_B}, p_{L_B}) = 0$$
$$\Rightarrow N(e^{-\lambda_A p_{L_A}} + e^{-\lambda_B p_{L_B}}) = 0$$
$$\Rightarrow -e^{-\lambda_B p_{L_B}} = e^{-\lambda_A p_{L_A}}$$

Since, $p_{L_B} < p_{L_A}$ the left-hand side becomes $e^{-\lambda_B p_{L_B}} = -\lambda_B p_{L_B}$

$$\Rightarrow -(-\lambda_B p_{L_B}) = e^{-\lambda_A p_{L_A}}$$
$$\Rightarrow \ln(\lambda_B p_{L_B}) = -\lambda_A p_{L_B}$$
$$\therefore \ln(p_{L_B}) = -\ln(\lambda_B) - \lambda_A p_{L_A} \quad (3.23)$$

This is the pricing model for Hotel B with stochastic demand.

Model Analysis

According to Wikipedia (2021) the best weather in Saint Martin's Island to visit is usually between November to February, this is the peak season. March to July is off-season for tourists. Due to COVID-19 restrictions, all the ships carrying people to Saint Martin's Island were halted until 11 November, 2020 (Prothom Alo 2021). So fewer people traveled in November 2020 and we were able to collect data of two months (December 2020, January 2021) from two hotels in St. Martin's Island, Ocean Blue Resort and Restaurant (Hotel A) and Rupashi Bangla Resort and Restaurant (Hotel B), within the peak season.

Though here we formulated pricing model for both deterministic and stochastic demand, most of the hotels in this region follows deterministic demand model, i.e., number of rooms are fixed for low and high price. So, data analysis is done for the deterministic demand model. We also calculated the optimal booking limit and protection level for both hotels based on our capacity model. Then, based on our pricing model we found the competitive price for each hotel and evaluated the previous and new revenues for both hotels.

Capacity Model

In this section we considered the monopoly situation. This model provides how to allocate capacity for low price rooms and high price rooms. Based on data collected from Hotel A, it has mean of 6 customers per day, 6 rooms fixed for low price (1500 BDT), 8 rooms fixed for high price (2500 BDT) and total capacity (C) of 14 rooms. The ratio of high price and low price of Hotel A is 0.6. If the demand of Hotel A follows poission distribution then according to capacity model the protection level can be found using the ratio. The inverse CDF poission distribution is calculated by using MATLAB's inverse cumulative distribution function (iCDF) function. So, the protection level for Hotel A is,

$$y^* = F^{-1}(1 - \frac{p_{L_A}}{p_{L_B}})$$

$$\Rightarrow y^* = F^{-1}(1-0.6)$$
$$\Rightarrow y^* = F^{-1}(0.4)$$
$$\therefore y_A^* = 5$$

The booking limit for Hotel A is,

$$b_A = C - y^*$$
$$\Rightarrow b_A = 14 - 5$$
$$\therefore b_A = 9$$

Table 4.1 shows optimal protection level and booking limit for different price ratio of Hotel A. From Fig. 4.1 we can see that when price ratio gets higher, number of rooms allocated for low price (Booking Limit) increases and number of rooms allocated for high price (Protection Level) decreases because the difference between prices is low. Similarly, when price ratio gets lower, number of rooms allocated for low price (Booking Limit) decreases (and number of rooms allocated for high price (Protection Level) increases because the difference between prices is high.

Also, booking limit and protection level, i.e., number of rooms allocated for low price and high price are same for price ratio 0.2 and 0.3. From the capacity allocation chart (Table 4.1) as the number of room allocation at high price (Protection Level) decreases (9 to 5) and number of rooms allocated for low price (Booking Limit) increases (5 to 11), as a result then there must be an intersection of two curves which is shown in fig. 4.1 and the intersection ratio exists between the point 0.2 and 0.3.

Table 4.1. Capacity allocation for different price ratio of Hotel-A

Ratio	Protection Level	Booking Limit
0.1	9	5
0.2	7	7
0.3	7	7
0.4	6	8
0.5	5	9
0.6	5	9
0.7	4	10
0.8	3	11
0.9	3	11

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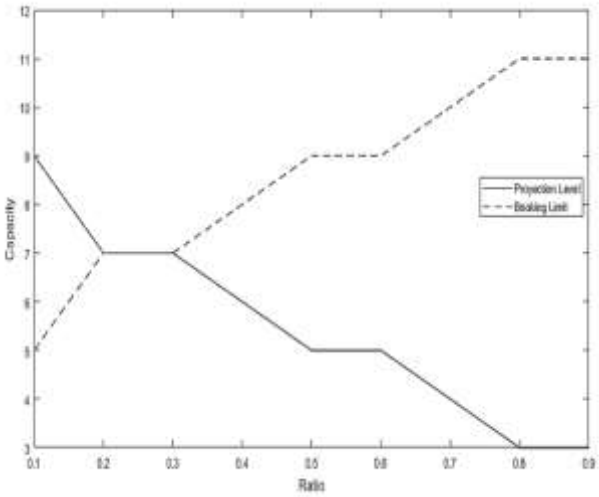

Fig. 4.1. Optimal capacity allocation based on price ratio for Hotel A

Hotel B has mean of 8 customers per day, 8 rooms fixed for low price (2000 BDT), 10 rooms fixed for high price (2500 BDT) and total capacity (C) of 18 rooms. The ratio of high price and low price of Hotel A is 0.7.
If the demand of Hotel B follows poission distribution then according to capacity model the protection level can be found using the ratio. The inverse CDF of poission distribution is calculated using MATLAB's iCDF function. So, the protection level for Hotel B is,

$$y^* = F^{-1}(1-\frac{p_{L_B}}{p_{H_B}})$$

$$\Rightarrow y^* = F^{-1}(1-0.7)$$

$$y^* = F^{-1}(0.3)$$

$$\therefore y^* = 6$$

The booking limit for Hotel A is,

$$b_A = C - y^*$$

$$\Rightarrow b_A = 14-5$$

$$\therefore b_A = 9$$

This is the optimal booking limit for Hotel B.
Table 4.2 shows optimal protection level and booking limit for different price ratio of Hotel B

Table 4.2. Capacity allocation for different price ratio of Hotel-A

Ratio	Protection Level	Booking Limit
0.1	11	7
0.2	10	8
0.3	9	9
0.4	8	10
0.5	7	11
0.6	7	11
0.7	6	12
0.8	5	13
0.9	4	14

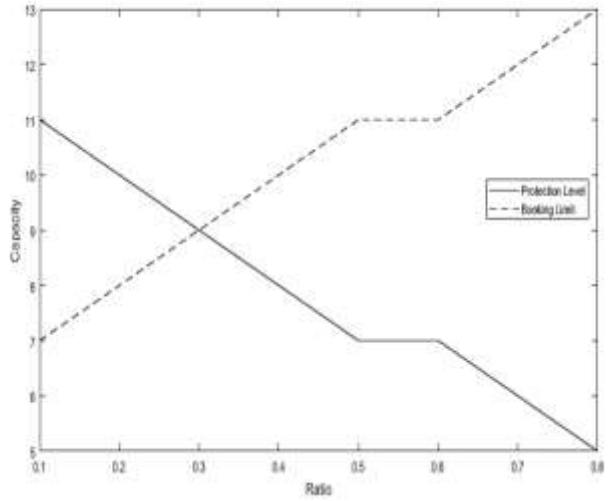

Fig. 4.2. Optimal capacity allocation based on price ratio for Hotel B

From Fig. 4.2 we can see that when price ratio gets higher number of rooms allocated for low price (Booking Limit) increases and number of rooms allocated for high price (Protection Level) decreases because the difference between prices is low. Similarly, when price ratio gets lower number of rooms allocated for low price (Booking Limit) decreases and number of rooms allocated for high price (Protection Level) increases because the difference between prices is high.

Also, booking limit and protection level, i.e., number of rooms allocated for low price and high price are same for price ratio 0.3. From the capacity allocation chart (Table 4.2) as the number of room allocation at high price (Protection Level) decreases (11 to 4) and number of rooms allocated for low price (Booking Limit) increases (7 to 14), as a result then there must be an intersection of two curves which is shown in fig. 4.2 and the intersection ratio exists on the point 0.3.

Pricing Model

Occupancy rate depends on the low price of Hotel A as well as Hotel B. Occupancy rate is calculated by dividing daily demand by total demand of Hotel A. Occupancy rate of Hotel-A is given by,

$$d_A(p_{L_A,L_B}) = \alpha_A - \beta_A p_{L_A} + \gamma_A p_{L_B} \tag{4.1}$$

Fig. 4.3 shows that Hotel-A did not have full occupancy on most of the days. Full occupancy occurred during the starting of January due to New Year and last few days of January because of peak season. Occupancy rate decreased after few days of New Year and increased after that.

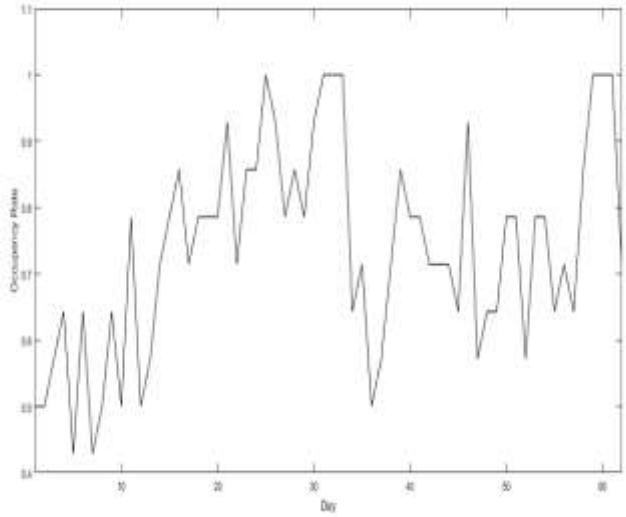

Fig. 4.3. Occupancy rate of Hotel A

Regression analysis was used to find the coefficients for the pricing model (4.2). We used the occupancy rate model (4.3). We considered occupancy rate d_A as dependent variable and low price of Hotel A and Hotel B (p_{L_A}, p_{L_B}) as independent variable in regression analysis and calculated the values of coefficients $\alpha_A = -0.0506$, $\beta_A = 2.9802 \times 10^{-4}$, $\gamma_A = 2.9822 \times 10^{-4}$.

$$\therefore\ p_{L_A} = \frac{b_A r_A + C_A \alpha_A - b_A}{2C_A \beta_A} + \frac{\gamma_A}{2\beta_A} p_{L_B} \tag{4.2}$$

Finally, using the values of booking limit, total capacity, price ratio for Hotel A and daily low price of Hotel B in (4.2) we calculated the low price of Hotel A for each day for two months. Each price we got for Hotel A is based on the price of Hotel B, which is the competitive price for Hotel A in the presence of Hotel B. To understand better, we divided two months of data in 9 weeks.

Table 4.3 shows the weekly revenue of Hotel A in Taka, based on the data collected and the new revenue per week using the new price we got from the pricing model.

Fig. 4.4 compares between the previous and new weekly revenue of Hotel A. It's clearly shown that the revenue increases by 7,995 BDT in first week, 5,195 BDT in second week, 7,195 BDT in third week 1,745 BDT in

fifth week and 2,995 BDT in seventh week. Revenue decreases by 1,605 BDT in fourth week, 105 BDT in sixth week, 2,355 BDT in eighth week and 3,540 BDT in ninth week.

Table 4.3. Weekly previous and new revenue for Hotel A

Week	Previous Revenue	New Revenue
1	26,250	34,245
2	30,850	36,045
3	39,200	46,395
4	45,300	43,695
5	49,600	51,345
6	43,800	43,695
7	38,000	40,995
8	41,100	38,745
9	37,200	33,660

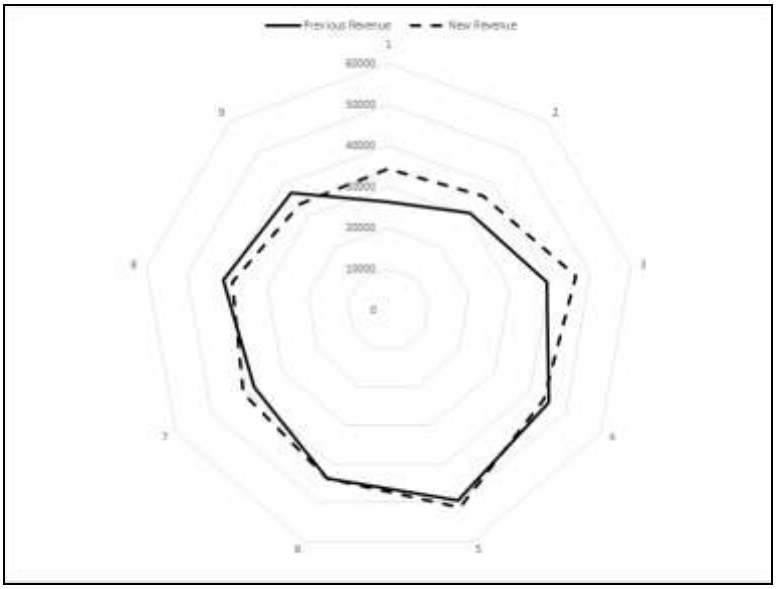

Fig. 4.4. Weekly revenue comparison of Hotel A

Occupancy rate for Hotel B is given by the following equation

$$d_B(p_{L_A,L_B}) = \alpha_B - \beta_B p_{L_B} + \gamma_B p_{L_A} \tag{4.3}$$

Fig.4.5 show that Hotel B had average room occupancy. Full occupancy occurred during the last few of December due to New Year. Occupancy rate decreased after few days of New Year and increased after that.

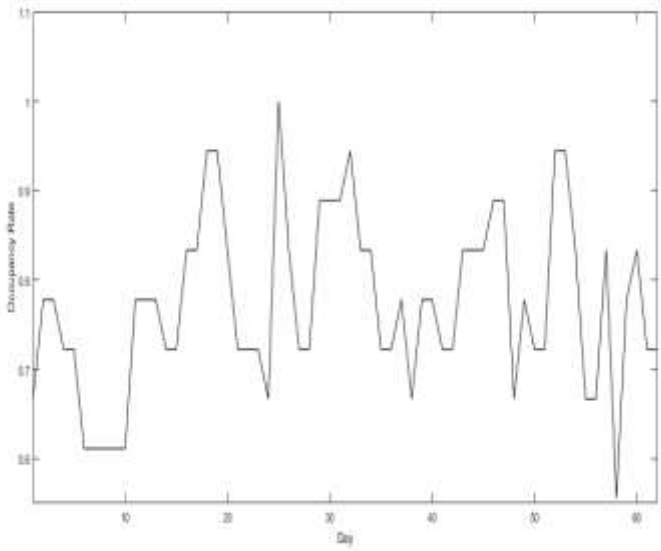

Fig. 4.5. Occupancy rate of Hotel B

Regression analysis was used to find the coefficients for the pricing model (4.4). We used the occupancy rate model (4.5). We considered occupancy rate d_B as dependent variable and low price of Hotel A and Hotel B (p_{L_A}, p_{L_B}) as independent variable in regression analysis and calculated the values of coefficients $\alpha_B = 0.3212$, $\beta_B = 2.436\times10^{-4}$, $\gamma_B = 7.544\times10^{-5}$.

$$\therefore\ p_{L_B} = \frac{b_B r_B + C_B\alpha_B - b_B}{2C_B\beta_B} + \frac{\gamma_B}{2\beta_B}\, p_{L_A} \tag{4.4}$$

Using the values of booking limit, total capacity, price ratio for Hotel B and daily low price of Hotel A in (4.6) we calculated the low price of Hotel B for each day for two months. Each price we got for Hotel B is based on the price of Hotel A, which is the competitive price for Hotel B in the presence of Hotel A.

Table 4.4 and Fig. 4.6 compares between the previous and new weekly revenue of Hotel B. Blue line indicate the previous weekly revenue and red line indicates the new weekly revenue. Revenue increases by 15,848 BDT in first week, 15,752 BDT in second week, 8,460 BDT in seventh week, 16,998 BDT in eighth week and 12,904 BDT in ninth week. Revenue decreases by 9,996 BDT in third week, 1,400 BDT in fourth week, 17,908 BDT in fifth week and 1,380 BDT in sixth week.

Table 4.4. Weekly previous and new revenue for Hotel-B

Week	Previous Revenue	New Revenue
1	53,200	69,048
2	54,400	70,152
3	81,000	71,004
4	72,200	70,800
5	90,400	72,492
6	72,000	70,620
7	60,300	68,760
8	53,250	70,248
9	47,000	59,904

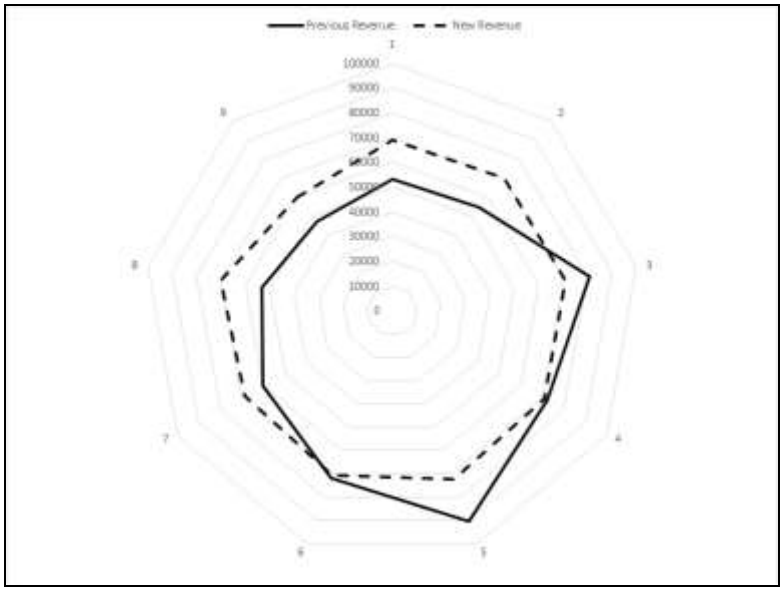

Fig. 4.6. Weekly revenue comparison of Hotel B

Results and Discussion

We formulated capacity model for both hotels which gives the optimal capacity allocation for booking limit and protection level. According to the data that we collected from Hotel A, it had total 14 rooms, 6 rooms for low price (Booking Limit) and 8 rooms for high price (Protection Level). Using the capacity model, we found the optimal capacity allocation for Hotel A be 9 rooms for low price and 5 rooms for high price to earn optimal revenue.

Hotel B had total 18 rooms, 8 rooms for low price (Booking Limit) and 10 rooms for high price (Protection Level). Similarly, optimal capacity allocation for Hotel B by using the capacity model should be as 12 rooms for low price and 6 rooms for high price to achieve its optimal revenue.

By using deterministic demand, we also formulated a pricing model which gives the optimal room price for both hotels considering their duopoly competition. Hotel A had set their low price at 1500 BDT. But from the occupancy rate we saw that most of the times it did not get this price. Hotel A's total revenue for two months was

3,51,300 BDT. Using the daily occupancy, price of rooms and competitors (Hotel B) price as the input, pricing model determined the new optimal price for Hotel A, which increases the total revenue by 17,520 BDT.

Similar way, we saw that Hotel B had set their low price at 2000 BDT and its total revenue for considering two months was 5,83,750 BDT. After using the daily occupancy, price of rooms and competitors (Hotel A) price as the input, pricing model determined the new optimal price for Hotel B, which increases the total revenue by 39,278 BDT.

Table 5.1 shows the previous total revenue for both hotels and their revenue after applying capacity and pricing model. We notice that revenue of Hotel A and Hotel B, increase 4.9% and 6.7% respectively by using our capacity and pricing model.

Table 5.1. Total revenue increase percentage for Hotel-A and Hotel-B

Hotels	Previous Total Revenue	New Total Revenue	Percent Increase
Hotel-A	3,51,300Tk.	3,68,820Tk.	4.9%
Hotel-B	5,83,750Tk.	6,23,028Tk.	6.7%

Based on our capacity model, Hotel A should change their booking limit, i.e., 9 rooms for low price and protection level, i.e., 5 rooms for high price. Hotel B also should change the booking limit to 12 rooms for low price and 6 rooms for high price. This will increase both hotels' occupancy rate and they will be able to profit more.

Pricing model shows, Hotel A and Hotel B both should lower their prices. In order to increase demand, Hotel A should set their low price between 900 BDT to 1000 BDT and Hotel B should set their low price between 800 BDT to 900 BDT. Both hotels revenue will increase eventually by using the optimal capacity allocation for low price and high price and lowering their base price.

Conclusion

In this section, summery of our whole work is discussed. We wanted to construct a revenue management model for hotels in Saint Martin's Island. During this COVID-19 pandemic, hotels could not earn as they used to be. Our main objective was to formulate a model that could increase the revenue of those hotels from what they were earning.

There are certain things we needed to consider, like capacity, price and competition between hotels. Hotels have fixed capacity and they divide their rooms according to prices. Most hotels in tourism sector have two types of prices- high and low. Also, hotels compete with each other based on price. We considered price as the soul factor so demand depends on price of both hotels. We considered two types of demand: stochastic and deterministic. Demand was considered to follow poission distribution in stochastic case and exponential distribution in deterministic case.

After collected required data, we developed a capacity model for both hotels. We used Littlewood's two-class model to find the optimal booking limit (number of rooms for low price) and protection level (number of rooms for high price) for both hotels. We found that to get the optimal capacity allocation both hotels should change their booking limit and protection level. This will result in a higher occupancy rate and help both hotels to gain more demand. We then developed a pricing model based on each hotels demand. With the help of Bertrand and Cournot competition which is a part of game theory, we constructed our pricing model. Pricing model for both hotels is based on stochastic and deterministic demand. Since the nature of the data, we collected was deterministic, data analysis for pricing model was done for deterministic case only. The result we found using our pricing model showed that both hotels should lower their room price for high and low class to increase their revenue which is higher than what they are earning currently.

In summary of our findings, we can say that both hotels should follow the recommendations given below:

- Hotels should increase their booking limit, i.e., number of rooms fixed for low price.
- Protection level, i.e., number of rooms for high price must be decreased.
- According to our pricing model both hotels have to lower the price of low-cost rooms in order to gain more demand as well as earn more revenue.

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Conflict of Interests
The author declares no conflict of interest.

References

Badinelli, R. D. (2000). "An optimal dynamic policy for hotel yield management", European Journal of Operational Research, Elsevier, March, 121(3), pp.476-503.

Bitran, G. and Caldentey, R. (2002). "An Overview of Pricing Models for Revenue Management", Manufacturing & Service Operations Management, l. 5(3), pp.203-229.

Bitran, G. and Gilbert, S. M. (1996). "Managing hotel reservation with uncertain arrivals", Operations Research, 44(1), pp.35-49.

CEIC 2021. "Bangladesh Tourism Revenue", Last modified on December 2019. https://www.ceicdata.com/en/indicator/bangladesh/tourism-revenue

Dai, Y.; Chao, X.; Fang, S.-C. and Nuttle, H.L. (2005). "Pricing in Revenue Management for Multiple Firms Competing for Customers", International Journal of Production Economics, 98, pp.1-16.

El-Gayar, N.; Hendawi, A.T.; Zakhary, A. and El-Shishiny, H. (2008). "A proposed decision support model for hotel room revenue management", ICGST Journal of Artificial Intelligence and Machine Learning, 8(1), pp.23–8.

Kopalle, P. and Shumsky, R.A. (2010). "Game Theory Models of Pricing", Handbook of Pricing Management, Oxford University Press, Oxford.

Littlewood, K. (1972). "Forecasting and control of passenger bookings", in Proceedings of the Twelfth Annual AGIFORS Symposium, Nathanya, Israel.

The Daily Star, 2021. "Covid-19: Movement of tourist ships on Teknaf-St Martin's route halted", 1 April 2021. https://www.thedailystar.net/travel/news/covid-19-movement-tourist-ships-teknaf-st-martins-route-halted-2070361

Talluri, K.T. and Van Ryzin, G.J. (2004). "The Theory and Practice of Revenue Management", Kluwer Academic Publishers, New York

Wikipedia, 2021. "St. Martin's Island" Last modified on 27 May 2021. https://en.wikipedia.org/wiki/St._Martin%27s_Island

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ORIGINAL ARTICLE

SCIENCE & ENGINEERING

INFLUENCE OF URBAN FORM CHARACTERISTICS ON TRAVEL BEHAVIOR: EVIDENCE FROM AUSTIN, TEXAS

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Abstract

Understanding the relationship between the physical form of the built environment and how people travel from origin to destination is vital to formulate policies to reduce the distance traveled and promote public transit. This study has used Austin activity-travel survey data to explore the influence of urban form characteristics on travel behavior. It has been hypothesized that mixed-use high-density development significantly impacts people's travel behavior in this area. Urban form variables like increase in density, better street connectivity, and mixed land use TAZ as origin and destination have been found to be significant in reducing the distance traveled and car dependency. Even after controlling the trip makers' and alternative specific characteristics, urban built form is showing a clear and strong impact on mode choice behavior. Though personal characteristics remain important after including the built form variables, built form variables also show significant influence on mode choice behavior. The results support the hypothesis of this study that mixed-use high-density development has a significant impact on the mode choice behavior of the people of the Austin area. These findings suggest that transportation policy formulation is not only an economic decision but also a land use planning decision. City authorities aiming to reduce automobile trips and distance travelled need to consider these built form characteristics to determine suitable areas to invest to yield the highest return in promoting transit use and active transportation.

Keywords: Built environment, land use, mode choice, discrete choice, mixed land use, transit

Introduction

Although there is a significant amount of literature on investigating the relationship between the physical form of the built environment and the way people travel from origin to destination, the varied nature of empirical findings does not allow to reach consensus. Despite some ambiguous findings, many studies have suggested that the transformation of urban form into a more compact, mixed-use, and transit-friendly pattern will reduce car dependency and increase transit use and active transportation (Ewing & Cervero, 2010; Zahabi et al., 2015; Nasri & Zhang, 2019). While researchers including Ewing & Cervero (2010) claimed that compact urban forms have significant influence on driving less, other researchers including Stevens (2017) concluded that compact development does not have much influence on driving less.

To explain the built form characteristics, researchers have used several variables commonly known as 'D' variables. The original three 'D's were density, diversity, and design to quantify built form (Cervero & Kockelman, 1997). Later, researchers have used 5Ds – adding destination accessibility and distance to transit to the previous list. (Ewing & Cervero, 2001; Ewing et al., 2009). Some recent studies have used 6Ds by adding demand management, including parking supply and cost (Ewing & Cervero, 2010), and 7Ds by adding Demographics to quantify the built environment (Ewing & Cervero, 2010).

'Density' variables have been measured as the density of population, dwelling units, employment, building floor area, or something else. Some studies have used activity density, a combined density of population and employment (Dunphy & Fisher 1996, Cervero & Kockelman 1997; Zegras 2010). Several studies have found that high (residential) density areas promote higher transit usage and less driving (Dunphy & Fisher, 1996; Cervero & Kockelman, 1997). Studies have found that higher walkability and street connectivity result in less auto travel and higher non-motorized trips (Cervero & Kockelman, 1997). Most of these studies have been conducted using census blocks, tracts, and traffic analysis zones (TAZ) as geographical units (Dunphy & Fisher 1996, Cervero & Kockelman

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1997; Ewing et al. 2009). The reason is understandable because data about urban built forms are mostly available for these resolutions. Several studies (Zegras, 2010; Boarnet & Crane, 2001) have found that estimating the relationship between urban form and travel behavior produces different results for different geographic levels. Studies have suggested that active transportation is highly influenced by built forms of local neighborhoods, whereas the choice of the automobile depends more on regional land-use patterns (Ardeshiri & Vij, 2017).

Diversity has been measured as the number of different land uses in a single region. Some studies (Cervero & Kockelman, 1997; Kitamura et al., 1997) have used Entropy to measure diversity: low for single-use environments and higher for multiple land-use areas. Diversity has an impact on accessibility to destination and land-use balance. Several studies have found the relationship is statistically significant that higher diversity reduces the number of trips and trips by automobiles (Cervero, 1996; Cervero & Kockelman, 1997; Kitamura et al., 1997; Kockelman, 1997; Ewing and Cervero, 2010). Kockelman (1997) has used land use-accessibility balance, and household and travelers characteristics to predict travel behavior.

Design is mostly measured by street network characteristics. Dense urban grids of high interconnectivity, straight or curving streets forming loops, and 'cul-de-sacs' in the suburban or less-density areas – are some measures of design characteristics. These also include average block size, the proportion of four-way intersections, and a number of intersections per square mile. Studies have found that high-density grid iron street design, along with fewer parking opportunities lead to less VMT and increase of transit use (Kitamura et al., 1997; Kockelman, 1997; Ewing and Cervero, 2010). Neighborhoods with pedestrian-oriented design, better street connectivity, transit-oriented mixed-use development, and high population density promote switching to active transportation or transit and reduce driving (Cervero, 1996; Kitamura et al., 1997; Frank et al. 2000).

Several studies argued that while any single 'D' variable may not have a significant impact in a particular case, the combined effect of the Ds is substantial on travel behavior (Ardeshiri & Vij, 2017). The majority of the research on this topic has taken the micro approach and considered the land use and built form characteristics only at the local and neighborhood level, such as density, land use mix, street connectivity, transit accessibility etc. (Ewing & Cervero, 2010). This approach suffers from not considering the impact of large-scale land-use patterns and the overall spatial pattern of the city and the region, which also significantly influences travel behavior (Nasri & Zhang, 2012). Improved mobility of modern time has encouraged people to make trips connecting land uses on a large scale. Thus activity space has grown bigger, connecting their home and work along their commuting routes. This makes it important to consider macro-level built environment characteristics to study travel behavior rather than confining it to just immediate neighborhood. Though a limited number of studies have investigated the impact of the built environment at the city and regional level on travel behavior, they have found that macro variables are at least equally influential in determining travel behavior (Boarnet & Sarmiento, 1998). Due to advancements in the transport sector, people are no longer confined to their own neighborhoods or cities. They can travel further distances connecting large geographical spaces for employment, shopping, or entertainment opportunities (Nasri & Zhang, 2019). The physical form of cities, population and employment density, settlement size and pattern, Land use, transportation infrastructures, job-housing balance, degree of decentralization or concentration, etc. have a significant impact on housing and transportation decision (Newman & Kenworthy, 1999; Yang & Ferreira, 2008).

Few studies have introduced the sprawling nature of urban areas to define metropolitan level built form in travel behavior studies (Ewing et al., 2002; McCann & Ewing, 2003). To quantify urban sprawl, most of these studies used density and changes of density over time. In an earlier study, Kain and Fauth (1976) investigated the impact of urban form on travel behavior in 125 metropolitan areas. Their study's metropolitan level variables include employment opportunities at CBD, the density of the central city, percentage of single-family dwelling units, supply of transport infrastructures, and composition of workplaces.

One important consideration in studying the causal relationship between urban form and mode choice behavior is the 'residential self-selection' effect (Nasri, 2016). It has been argued that the choice of transit or active transportation might not be the direct result of characteristics of built environment rather it might be the lifestyle orientation of the individual which leads the individual to choose a high density, transit and pedestrian friendly neighborhood. If this effect of 'self-selection' of neighborhoods is very large and not controlled in a statistical model the output will be biased in favor of urban form characteristics. Researchers have tried to quantify this 'self-selection' effect by using many different approaches. Majority of the studies have included variables explaining personal attitudes in the model to control the 'self-selection' effect (Kitamura et al., 1997; Cao et al., 2007; Ewing & Cervero, 2010). These studies have found this effect significant in determining travel behavior and some studies suggested that 'self-selection' has equal or even stronger impact on travel behavior than true impact of land-uses

(Cao et al., 2007). Researchers have argued that long term decisions like residential location choice and car ownership do not depend on short run mobility decision rather depends on long term lifestyle decisions (Boarnet & Crane, 2001; Walker & Li, 2007).

To address the impact of 'self-selection' some studies have included socio-economic factors which are correlated to travel behavior in the model ((Brownstone &Golob, 2009), some have included factors that determine travel attitudes (Kitamura et al., 1997), some have used structural model to capture the two-way impacts (Vance &Hedel, 2007), and some have used longitudinal analysis to capture the behavioral changes regarding travel behavior (Cao et al., 2009).

Since the varied nature of empirical findings does not allow to reach consensus, this study attempted to investigate the debate by exploring the influence of urban form characteristics on travel behavior in the Austin area. It has been hypothesized that mixed-use high-density development has a significant impact on people's travel behavior in this area. Two kinds of relationships- the relationship between built forms and distance traveled and the relationship between built forms and mode choice behavior- have been investigated using ordinary least squares regression (OLS) and multinomial logit model (MNL), respectively.

Materials and Methods

To explore the influence of urban form characteristics this study has investigated the impact on both distance travelled and mode choice behavior of the people at Austin. Ordinary least squares regression (OLS) has been used to investigate the relationship between built forms and distance travelled. To investigate the mode choice behavior multinomial logit model (MNL) has been developed to capture the discrete choice behavior of the people. All the variables used in these models have been processed using transCAD software. Both the OLS model and MNL model have been developed in 'R' platform.

Data Processing

The variables for both the OLS model for distance travelled the and MNL model for mode choice behavior have been derived from raw Austin activity travel survey 2017-2018 data and Austin TAZ 2015 GIS data using transCAD. Alternative specific variables cost and time for each mode have been processed through network analysis function in transCAD. TransCAD has been used to create network for Car, Bus, Bicycle and Walk modes and skim matrices for all the four modes have been generated. TransCAD has also been used for several data wrangling functionalities such as joining several data files (household information, person information, trip information) of Austin activity travel surveys to get the required variables, making queries (selection by condition etc.) and data transformation (group by etc.). Several tools (tag, overlay etc.) for geographic analysis in transCAD have been used to process GIS data (population density, employment density etc.) to get required variables. For example, 'Intersection density for each TAZ' variable have been processed using the 'from node-to node' information using GIS functionalities of TransCAD.

Discrete Choice Modeling to Study Impact of Urban Form on Mode Choice Behavior

It needs to be noted that most of the studies on this topic have only confirmed the association of urban form with travel behavior; few have tried to investigate the casual relationship between these two. Majority of these studies who looked into causal relationship have used discrete choice modelling to investigate the causal relationship between urban form and mode choice beahvior (Cervero & Kockelman, 1997; Frank et al., 2000; Nasri & Zhang, 2019). These studies have confirmed that impact of urban form on travel behavior is practically and statistically significant (Cervero and Kockelman, 1997; Cao et al., 2007; Ewing & Cervero, 2010). Limited number of studies have attempted to capture the spatial autocorrelation effect of the urban form and socio-economic characteristics to explain the mode choice behavior (Nasri, 2016).

This study used Multinomial Logit model to establish the basis for discrete choice framework and using the random utility model as decision rule will calculate the probability of selecting a particular mode evaluating its utility against the utility of all other available alternatives. In a discrete choice framework, an individual first see the available alternative modes, then evaluate different attributes of those alternatives under some given criteria (led by his socio-economic characteristics) and use a decision rule to select most suitable alternative for him from the available modes (Koppelman & Bhat, 2006). An individual always try to maximize his/her utility when selecting the mode for his trips. Trip maker evaluate the derived the utilities of the modes from attributes like trip cost, trip time,

safety, comfort, etc. and choose the mode with highest utility (Ben-Akiva & Lerman, 1994). This is called utility maximization when making choices.

A utility function of a mode "m" can be expressed mathematically as,

$U_{mi} = \beta_1 X_{mi1} + \beta_2 X_{mi2} + \ldots\ldots\ldots\ldots + \beta_k X_{mik}$ (2.1)

Where,

$U_{mi}$is the net utility function for a mode 'm' for individual i;

X_{mi1} , …, $X_{mik}$are k number of attributes of a mode m for individual i; and

β_1 , ……, $\beta_k$are k number of coefficients (or weights attached to each attribute) which need to be inferred from the survey data.

Thus a utility function of a specific mode is a linear combination of various explanatory variables along with an alternative specific constant term which reflects relative preference for that alternatives. In a three mode hypothetical situation where bus transit, auto and train compete each other, utility functions of the modes can be written as,

Utility bus = ASC bus + (β1* IVTT bus) + (β2 * OVTT bus) + (β3* Cost bus) +……(1)

Utility auto = ASC auto + (β1* IVTT auto) + (β2 * OVTT auto) + (β3* Cost auto) +…….(2)

Utility train = ASC train + (β1* IVTT train) + (β2 * OVTT train) + (β3* Cost train) +…...(3)

Where,

IVTT = In-Vehicle Travel Time

OVTT = Out-of-Vehicle Travel Time

In this situation,the multinomial logit model establishes the basis for the discrete choice framework, and using random utility model as a decision rule calculates the probability of selecting a particular mode by evaluating its utility against the utility of all other available alternatives. This can be expressed mathematically as,

$$P_i = \frac{e^{U_i}}{\sum_{j=1}^{j} e^{U_j}}$$

Where,

*i*and *j* are alternatives in a choice set,

P_i is the probability of choosing Mode *i*,

J is the set of all alternatives available to the individual (including modes *i*and *j*),

U is the utility associated with a given mode

For example, using the three mode example illustrated above the probability of using bus over other modes can be calculated as,

$$P_{bus} = \frac{e^{U_{bus}}}{e^{U_{bus}} + e^{U_{auto}} + e^{U_{train}}}$$

Factors affecting mode choice in a discrete choice framework

McFadden (1978) had studied the factors influencing the choice of mode in a discrete choice framework and they are variables with critical explanatory power - travel cost, on vehicle time, walk time, transfer wait time, transit initial headway, and number of persons in household; variables with important explanatory power - numbers of transfers, respondent's relation to household head, employment density at work location, suburban or urban, family composition; variables with ambiguous explanatory power - household income, residential population density, CBD location with respect to residence, number of workers in household, age of household head, reliability of transportation mode, perception of comfort, safety, convenience; variables with low explanatory power- CBD work location, sex of respondent, age of respondent, work status of household head, general attitudes toward privacy, and delay. Papacostas & Prevedouros (2015) had categorized the variables related to mode choice behavior of trip makers in three categories - the characteristics of the available modes, the socioeconomic status of the trip maker and the characteristics of the trip.Studies investigating impact of urban from on mode choice added several land use related variables to the above list expressing density, diversity, design, accessibility to transit, distance to CBD, supply of transportation infrastructures, settlement size and pattern etc. (Cervero&Kockelman, 1997; Frank et al., 2000;Nasri & Zhang, 2019).

Data

Data for this study have been derived from Capital Area Metropolitan Organization, Austin, Texas. Activity travel survey data 2017-2018 and Street Network of 2015 for Austin area have been used to derive necessary variables for the study (Table 1).

Table1. Types of variables and their source datasets

Type of variables	Derived variables	Source Data Set
Characteristics of trip makers	Vehicle per capita	Activity travel survey 2017-2018
	Gender	
	Income	
Characteristics of Alternatives	Time	Austin Street Network 2015 and Activity travel survey 2017-2018
	Cost/income	
Characteristics of urban form	Population density	Austin TAZ 2015 GIS data
	Employment density	
	Intersection density	Street Network for Austin and Austin TAZ 2015 GIS data
Spatial	Origin and Destination Location	Activity travel survey 2017-2018

Figure 1 is showing the correlation among the variables used for the final models. Instead of taking the cost variable directly, it has been normalized by taking the ratio of cost and income. This also has removed the problem of time and cost being highly correlated. From the correlation plot (Figure 1) it can be seen that the level of correlation between the variables is acceptablefor most variables except for the intersection density-population density pair and intersection density-employment density pair. Since these variables have significant practical significance supported by the literature (Cervero& Kockelman, 1997; Ewing et al., 2014) they have been included altogether to develop the model. Table 2 is showing the descriptive statistics of the variables used in this study.

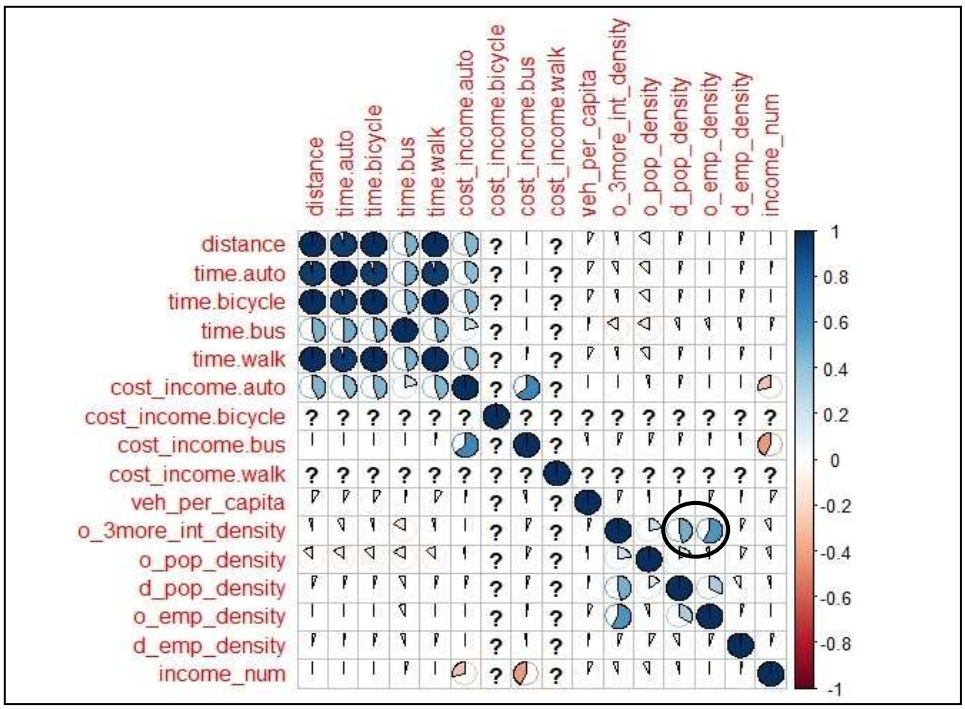

Figure 1. Correlation plot for the list of variables used for final models.

Table 2. Description of the variables

Variable Type	Variable Name	Variable Description	Count	Minimum	Maximum	Mean	Std. Dev.
Trip Characteristics	Distance	Distance travelled in the trip	20691	0.01	65.570	5.383	5.700
	time.auto	Trip time by auto	20691	0.26	70.105	7.934	6.103
	time.bicycle	Trip time by bicycle	20691	0.06	452.727	37.167	39.356
	time.bus	Trip time by bus	20691	0.07	80.166	12.052	6.922
	time.walk	Trip time by walk	20691	0.05	1144.310	103.554	107.263
	cost.auto	Trip cost for auto	20691	0.006	39.342	3.230	3.420
	cost.bicycle	Trip cost for bicycle	20691	0.00	0.000	0.000	0.000
	cost.bus	Trip cost for bus	20691	1.25	3.000	1.382	0.277
	cost.walk	Trip cost for walk	20691	0.00	0.000	0.000	0.000
	cost_income.auto	Trip cost-income ratio for auto	20691	0.00	4.738	0.065	0.161
	cost_income.bicycle	Trip cost-income ratio for bicycle	20691	0.00	0.000	0.000	0.000
	cost_income.bus	Trip cost-income ratio for bus	20691	0.006	1.200	0.029	0.051
	cost_income.walk	Trip cost-income ratio for walk	20691	0.00	0.000	0.000	0.000
Characteristics of Trip maker	gender	Gender of the trip maker: 1 = Male, 2 = Female (Categorical variable), N =20691					
	veh_per_capita	Vechicle per capita in the household	20691	0	5	0.745312	0.403851
	income_num	Income of trip maker as continuous value	20691	2.50	200.000	87.220	54.486
	income	Income of the trip maker (Categorical variable): Low = <25000, Lower-middle = >=25000 but <50000, Upper-middle = >=50000 but <100000, High = >= 100000, N = 20691					
Characteristics of Built Environment	o_3more_int_density	3-way or more intersection density at origin TAZ, per square mile	20691	0.00	401.8001	28.1884	34.2669
	o_pop_density	Populatin density at origin TAZ	20691	3.11	64712.8035	3994.7868	3529.922
	d_pop_density	Populatin density at destination TAZ	20691	0.289	444641.73	6308.080	12893.533
	o_emp_density	Employment density at origin TAZ	20691	0.00	65148.272	3460.756	6712.35
	d_emp_density	Employment density at destination TAZ	20691	0.00	263238.34	4073.822	9976.617
	o_mxd	Dummy variable: '1' if the trip is originated from mixed land use (MXD) parcel and '0' otherwise (MXD at Austin determined by Zhang et. al.,2009), N = 20691					
	d_mxd	Dummy variable: '1' if the trip destination is mixed land use parcel (MXD) and '0' otherwise (MXD at Austin determined by Zhang et. al.,2009), N = 20691					
	internal_mxd	Dummy variable: '1' if the trip is internal to a mixed land use parcel (MXD) and '0' otherwise, N = 20691					

Results

Here results of the study have been discussed in two sections- impact of urban forms on distance travelled and impact of urban forms on mode choice behavior.

Distance Travelled and Urban Forms

Descriptive Analysis

In Figure 2 it can be seen that distance travelled is decreasing significantly with the increase of population density, employment density and intersections density (better street connectivity). Distance travelled by automobile is decreasing more with the increase of density variables.

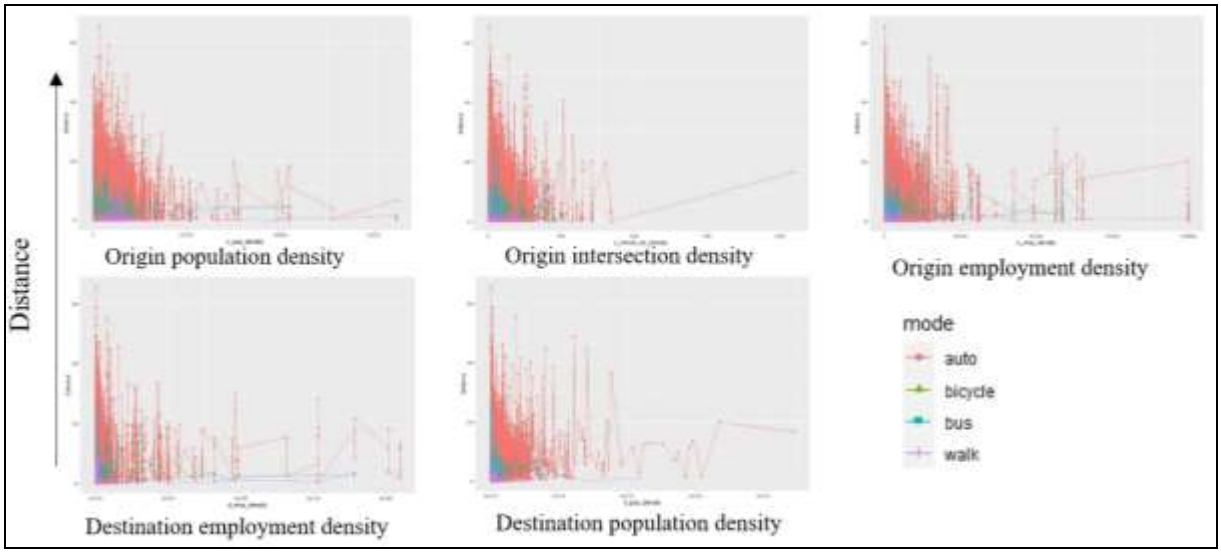

Figure 2. Distance travelled and built environment

Regression analysis

To investigate the relationship between built environment and distance travelled, two separate multiple regression models have been developed- one with only trip makers' characteristics (model 1a in Table 3) and the other including urban form variables along with previous trip makers' characteristics.

Income and vehicle ownership have been found to have positive relationship with distance travelled. Effect of income on distance traveled has been found little ambiguous. Though Distance traveled increases with the increase of income, this increase of distance travelled is more for lower-middle-income group and upper-middle-income group than high-income group compared to low-income group people in Austin.Female trip makers have been found to make shorter trips than male trip makers.

After including urban form characteristics in the model (model 1b), it has been observed that higher population density and intersection density lead to decrease of distance travelled. Model outputs regarding employment density and origin TAZ having mixed land use indicate positive relationship with distance travelled which is confusing since both literature and empirical evidence suggest negative relationship. This issue needs further investigation. Despite this issue model 1b has significantly higher adjusted R^2 value indicating a better fit than model 1a.

Table 3. Regression model for impact of urban form on distance travelled

	Model 1a (without urban form variables)		Model 1b (including urban form variables)	
Variables	Coefficients	P value	Coefficients	P value
Intercept	4.24328	< 2e-16 ***	5.140e+00	< 2e-16 ***
Characteristics of trip maker				
veh_per_capita	1.14857	< 2e-16 ***	1.143e+00	< 2e-16 ***
Income				
Low (ref.)				
Lower-middle	0.87296	2.03e-09 ***	7.704e-01	9.83e-08 ***
Upper-middle	1.00634	2.16e-13 ***	8.375e-01	8.15e-10 ***
High	0.45793	0.000701 ***	2.738e-01	0.041772 *
gender2 (female)	-0.48014	1.21e-09 ***	-4.579e-01	5.11e-09 ***
Urban form characteristics				
o_3more_int_density			-3.629e-03	0.000485 ***
o_pop_density			-1.856e-04	< 2e-16 ***
d_emp_density			1.449e-05	6.66e-12 ***
o_mxd1			1.840e-01	0.200883
Adjusted R^2	0.01133		0.02709	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*'

Mode Choice Behavior and Urban Forms

Descriptive Analysis

From Figure 3 it can be seen that number of trips by automobile is decreasing with the increase of population density, employment density and intersections density (better street connectivity). Figure 4 is also showing that origin TAZ having mixed land use (MXD TAZ) has lower share of trips by automobile and higher share of trips by bus and walk than a Non-MXD TAZ.

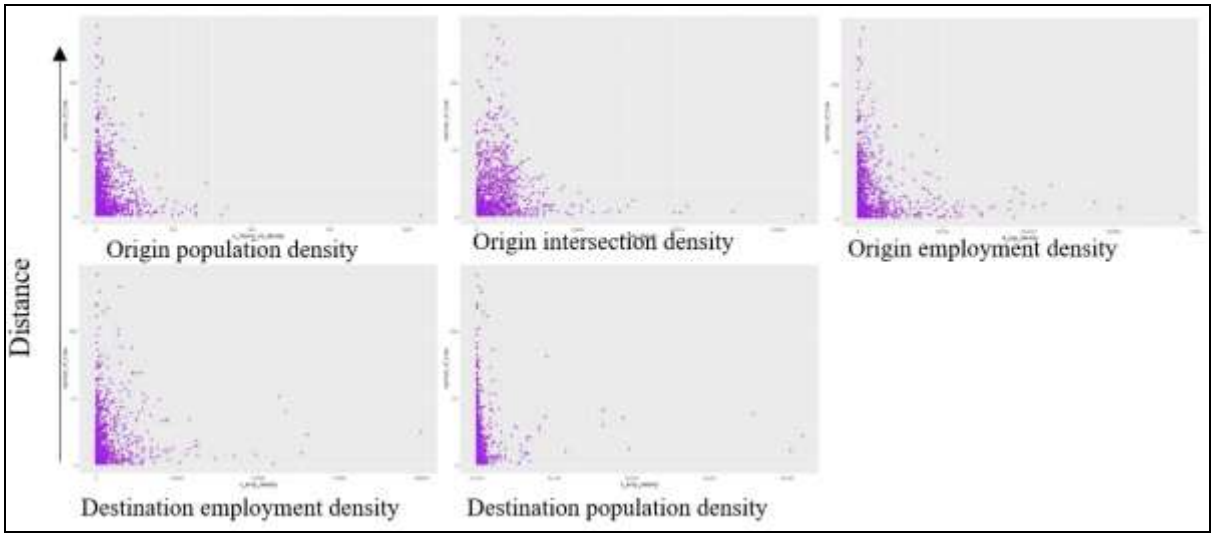

Figure 3. Number of trips by Automobile vs built environment

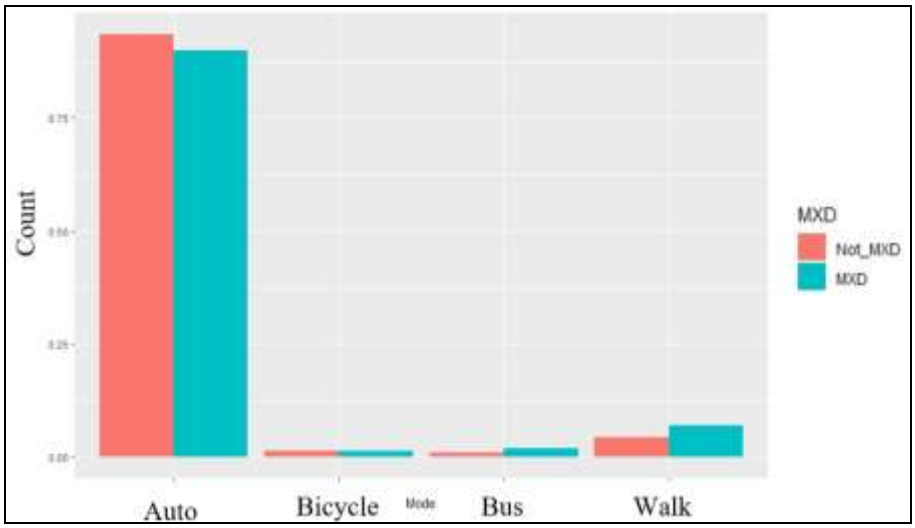

Figure 4. Mode share for MXD (mixed land-use) and Non-MXD trips

Outputs of Multinomial Logit (MNL) model

Multinomial Logit model has been estimated to investigate the impact of urban form characteristics using the variables derived from activity based travel survey 2017-2018 for the Austin area. Estimation results have been presented in Table 4. Various different model specifications have been tried to reach the final model.

The final MNL model (model 2a in Table 4) includes alternative specific variables, characteristics of trip makers, and characteristics of urban forms. There are total four choice alternatives, and 'auto' is the base category for the estimated model. The estimated coefficient for travel time conforms to the fact that modes lose utility with the increase of travel time.

Income, vehicle ownership, and gender (female) negatively correlate to choosing bus or active transportation compared to personal automobile. The probability of riding a bus decreased with increasing the person's income, and the probability of using bus decreased significantly with the increase of per capita vehicles in the household. Female trip makers ride transit or active transportation significantly less than male trip makers. This negative relationship is strong considering riding a bus. Apparently, female trip makers find the bus at Austin less suitable than male trip makers.

Bicycle, bus and walk- all has positive relationships with the density variables which suggests that increase of population density, better street connectivity (intersection density), and Mixed land use TAZ as origin and destination affect mode choice behavior in favor of bus and active transportation. Better street connectivity at origin, represented as an increase of 'three or more way intersection density' in the dataset, has a strong role in increasing the probability of riding a bus compared to personal automobile. This relationship is not statistically significant, but empirical evidence and literature support this finding. Better street connectivity also favors cycling compared to personal automobiles. The probability of using a bus also increases significantly when the origin or destination TAZ has mixed land use. The probability of walking also increases when the origin or destination TAZ has mixed land use.

MNL model 2a, which includes built form variables, is significantly a better model than Model 2b, which does not include them. All the model fitting statistics- the Log-Likelihood, AIC, and McFadden R^2 indicate a better fit for model 2a.

Table 4. Estimation results of Multinomial logit model (reference category = auto)

	Model 2a (including urban form variables)		Model 2b (without urban form variables)	
Variables	Coefficients	P value	Coefficients	P value
bicycle:(intercept)	-2.5600e+00	< 2.2e-16 ***	-2.3957015	< 2.2e-16 ***
bus:(intercept)	-2.1972e+00	< 2.2e-16 ***	-1.5961447	< 2.2e-16 ***
walk:(intercept)	-4.2894e-01	0.0010603 **	-0.0448273	0.7156078
time	-6.9582e-02	< 2.2e-16 ***	-0.0686114	< 2.2e-16 ***
cost_income	1.6293e+00	0.0027642 **	1.7586259	0.0008580 ***
Characteristics of trip maker				
bicycle:incomelower-middle	2.1665e-01	0.3857486	0.1941989	0.4362579
bus:incomelower-middle	-9.8091e-01	3.758e-08 ***	-1.0270693	4.284e-09 ***
walk:incomelower-middle	-2.3061e-01	0.0597453 .	-0.3100884	0.0104266 *
bicycle:incomeupper-middle	8.7952e-01	0.0001212 ***	0.8346226	0.0002527 ***
bus:incomeupper-middle	-1.7015e+00	4.441e-16 ***	-1.6901610	< 2.2e-16 ***
walk:incomeupper-middle	-8.2175e-02	0.4810615	-0.1587546	0.1662839
bicycle:incomehigh	2.0266e-01	0.3925022	0.1699889	0.4714220
bus:incomehigh	-1.9911e+00	< 2.2e-16 ***	-1.8783206	< 2.2e-16 ***
walk:incomehigh	-1.4166e-01	0.2052296	-0.1833685	0.0947958 .
bicycle:veh_per_capita	-1.3128e+00	1.843e-10 ***	-1.2108876	2.744e-09 ***
bus:veh_per_capita	-2.4085e+00	< 2.2e-16 ***	-2.1897951	< 2.2e-16 ***
walk:veh_per_capita	-1.0731e+00	< 2.2e-16 ***	-0.9181364	2.220e-16 ***
bicycle:gender2	-7.0617e-01	3.731e-09 ***	-0.7229512	1.471e-09 ***
bus:gender2	-2.9436e-01	0.0366583 *	-0.3067682	0.0262327 *
walk:gender2	-2.1688e-01	0.0023443 **	-0.2257946	0.0013180 **
Urban form characteristics				
bicycle:o_pop_density	-1.0633e-06	0.9511052		
bus:o_pop_density	4.1946e-05	0.0021042 **		
walk:o_pop_density	5.6298e-05	1.357e-11 ***		
bicycle:o_3more_int_density	3.4886e-03	0.0120939 *		
bus:o_3more_int_density	1.0636e-03	0.4873783		
walk:o_3more_int_density	-6.8776e-04	0.5134107		
bicycle:o_emp_density	1.3216e-05	0.0465433 *		
bus:o_emp_density	4.4575e-05	3.619e-14 ***		
walk:o_emp_density	2.9991e-05	3.953e-12 ***		
bicycle:d_emp_density	8.2595e-06	0.0001072 ***		
bus:d_emp_density	1.1484e-05	< 2.2e-16 ***		
walk:d_emp_density	7.7059e-06	0.0002239 ***		
bicycle:o_mxd1	-1.1797e-01	0.5962796		
bus:o_mxd1	4.2909e-01	0.0310698 *		
walk:o_mxd1	7.6026e-02	0.5427322		
bicycle:d_mxd1	-1.0485e-01	0.6482310		
bus:d_mxd1	6.6802e-01	0.0008539 ***		
walk:d_mxd1	2.3149e-01	0.0615350 .		
Log-Likelihood:	-5163.6		-5332.5	
AIC	10403.24		10704.94	
McFadden R^2	0.25368		0.22927	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*'

Discussion

This study found that the urban built form has a clear and significant impact on travel behavior even after controlling the trip makers' and alternative specific characteristics. Though personal characteristics still remain important after including the built form variables, built form variables also show significant influence on distance traveled and mode choice. Urban form variables like increase in density, better street connectivity, and mixed land use TAZ as origin and destination have been found to be significant in reducing the distance traveled and car dependency. Among the characteristics of the trip makers' vehicle per capita, income and trip maker being a female have been found to increase the distance traveled. The impact of the level of income ondistance traveled helps to understand the residential location choice of the people. Though Distance traveled increases with the increase of income, this increase of distance travelled is more for lower-middle-income group and upper-middle-income group than high-income group compared to low-income group people at Austin. This indicates that the rich people find suitable places to live which is not very close to employment centers but also not very far from the employment centers. This also indicates that the middle-income group people show more tendency to live near the city periphery hence making longer trips. In the urban form model (model 1b), an increase in intersection density and population density led to a reduction of distance traveled indicating that compact city design results in shorter trips.

In the mode choice model (2a), the urban form variables were found to have significant impact on the choice of mode even after controlling other alternative specific variables and characteristics of trip makers. Model outputs suggest that increase of population density, better street connectivity (intersection density), and Mixed land use TAZ as origin and destination favors bus transit and active transportation. Among the characteristics of the trip makers' increase of income, vehicle per capita, and trip maker being a female reduce the likelihood of choosing a bus or active transportation. The influence of income and vehicle ownership on mode choice should be interpreted together. Significantly longer travel time makes the bus an inferior alternative to private automobiles in the city; hence the general tendency is that mostly the people who cannot afford private vehicles use bus transit. If the household has a car, they use it. Also, households with cars often do not consider the availability of transit when choosing their place to live, making the private automobile their only available alternative.

The results support the hypothesis of this study that mixed-use high-density development has a significant impact on the mode choice behavior of the people of the Austin area. These findings conform to the findings of researchers who found density, design, and diversity have a significant influence on mode choice behavior (Cervero&Kockelman, 1997; Ewing &Cervero, 2001; Ewing et al. 2009).

Conclusion

This study has investigated the influence of trip makers' personal characteristics and urban forms' characteristics on mode choice behavior. The findings support the claims of others (Cervero&Kockelman, 1997; Ewing &Cervero, 2001; Naess, 2012) that mixed-use, compact, and pedestrian friendly city designs can reduce the distance traveled and auto-mobile trips while promoting active transport and mass transit.City authorities aiming to reduce automobile trips and distance traveled need to consider these built form characteristics to determine suitable areas to invest in yielding the highest return in promoting transit use and active transportation. The solution for promoting transit in Austin is not only an economic but also a land use planning decision.

Though this study found a strong impact of urban form variables on distance travelled and mode choice behavior of the people in the Austin area, the findings need to be interpreted as an association rather than a causal relationship since the study used cross-sectional statistical analysis. A future longitudinal study investigating the same can confirm whether the relationship is causal or not. Moreover, due to time limitation,this study could not include several important variables to represent urban built forms such as land use diversity, access to transit, average block size, etc. This study also could not capture the fact that travel behavior has a significant spatial dimension, that both distances travelled and choice of a mode may often be influenced by the distance travelled and choice of mode by the neighbors. Developing spatial models may help to capture this spatial dimension of travel behavior.

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Conflict of Interests

The author declares no conflict of interest.

References

Ardeshiri, A., & Vij, A. (2019). A lifestyle-based model of household neighbourhood location and individual travel mode choice behaviours. *arXiv preprint arXiv:1902.01986*.

Ben-Akiva, M. &Ben-Akiva, M. E., Lerman, S. R., & Lerman, S. R. (1985). *Discrete choice analysis: theory and application to travel demand* (Vol. 9). MIT press.

Boarnet, M. G., & Crane, R. (2001). *Travel by design: The influence of urban form on travel*. Oxford University Press on Demand.

Boarnet, M. G., & Sarmiento, S. (1998). Can land-use policy really affect travel behaviour? A study of the link between non-work travel and land-use characteristics. *Urban studies*, *35*(7), 1155-1169.

Brownstone, D., & Golob, T. F. (2009). The impact of residential density on vehicle usage and energy consumption. *Journal of urban Economics*, *65*(1), 91-98.

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2007). Do changes in neighborhood characteristics lead to changes in travel behavior? A structural equations modeling approach. *Transportation*, *34*(5), 535-556.

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009). Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. *Transport reviews*, *29*(3), 359-395.

Cervero, R. (1996). Mixed land-uses and commuting: Evidence from the American Housing Survey. *Transportation Research Part A: Policy and Practice*, *30*(5), 361-377.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation research part D: Transport and environment*, *2*(3), 199-219.

Dunphy, R. T., & Fisher, K. (1996). Transportation, congestion, and density: new insights. *Transportation Research Record*, *1552*(1), 89-96.

Ewing, R., & Cervero, R. (2001). Travel and the built environment: a synthesis. *Transportation research record*, *1780*(1), 87-114.

Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American planning association*, *76*(3), 265-294.

Ewing, R., Greenwald, M. J., Zhang, M., Walters, J., Feldman, M., Cervero, R., & Thomas, J. (2009). Measuring the impact of urban form and transit access on mixed use site trip generation rates—Portland pilot study. *US Environmental Protection Agency, Washington, DC*.

Ewing, R. H., Pendall, R., & Chen, D. D. (2002). *Measuring sprawl and its impact* (Vol. 1, p. 55). Washington, DC: Smart Growth America.

Ewing, R., & McCann, B. (2003). Measuring the health effects of sprawl: A national analysis of physical activity, obesity and chronic disease.

Frank, L., Bradley, M., Kavage, S., Chapman, J., & Lawton, T. K. (2008). Urban form, travel time, and cost relationships with tour complexity and mode choice. *Transportation*, *35*(1), 37-54.

Kain, J. F., Fauth, G. R., & Ingram, G. K. (1976). *The Impacts of Urban Land Use and Transportation Investments on Household Auto Ownership Decisions and Journey to Work Mode Choices*. Department of City and Regional Planning, Harvard University.

Kitamura, R., Mokhtarian, P. L., & Laidet, L. (1997). A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation*, *24*(2), 125-158.

Kockelman, K. M. (1997). Travel behavior as function of accessibility, land use mixing, and land use balance: evidence from San Francisco Bay Area. *Transportation research record*, *1607*(1), 116-125.

Koppelman, F. S., & Bhat, C. (2006). A self instructing course in mode choice modeling: multinomial and nested logit models.

Næss, P. (2012). Urban form and travel behavior: Experience from a Nordic context. *Journal of Transport and Land use*, *5*(2), 21-45.

Nasri, A. A. (2016). *The influence of urban form at different geographical scales on travel behavior; evidence from US cities* (Doctoral dissertation, University of Maryland, College Park).

Nasri, A., & Zhang, L. (2019). How Urban Form Characteristics at Both Trip Ends Influence Mode Choice: Evidence from TOD vs. Non-TOD Zones of the Washington, DC Metropolitan Area. *Sustainability*, *11*(12), 3403.

Newman, P., & Kenworthy, J. (1999). *Sustainability and cities: overcoming automobile dependence*. Island press.

Ortúzar, J., & Willumsen, L. G. (2011). *Modelling transport*. John wiley & sons.

Vance, C., & Hedel, R. (2007). The impact of urban form on automobile travel: disentangling causation from correlation. *Transportation*, *34*(5), 575-588.

Walker, J. L., & Li, J. (2007). Latent lifestyle preferences and household location decisions. *Journal of Geographical Systems*, *9*(1), 77-101.

Yang, J., & Ferreira Jr, J. (2008). Choices versus choice sets: A commuting spectrum method for representing job—housing possibilities. *Environment and Planning B: Planning and Design*, *35*(2), 364-378.

Zahabi, S. A. H., Miranda-Moreno, L., Patterson, Z., & Barla, P. (2015). Spatio-temporal analysis of car distance, greenhouse gases and the effect of built environment: A latent class regression analysis. *Transportation Research Part A: Policy and Practice*, *77*, 1-13.

Zegras, C. (2010). The built environment and motor vehicle ownership and use: Evidence from Santiago de Chile. *Urban Studies*, *47*(8), 1793-1817.

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ORIGINAL ARTICLE **SCIENCE & ENGINEERING**

EXPLORING THE POTENTIALS OF COMMUNITY GARDENS AS GREEN SPACE ON VACANT LAND IN KHULNA CITY

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Abstract

Community garden (CG) is a form of urban green space. It provides social, economic, health and environmental benefits to the urban people in a city. Bangladesh's third largest city is Khulna, which is dominated by agriculture, two of the Wards of this city namely Ward no. 17 and Ward no. 20 are selected as the study area for this study. In many established and developing countries, community gardening is a common feature of urban development, but it is a new concept in Bangladesh. The study aims at exploring the potentials i.e., factors or favorable reasons of introducing community gardens in Khulna City. A wide range of related literature on community gardens are reviewed. A total of 300 households of the study Wards are surveyed through semi-structured questionnaire, key informant interviews of urban planners, civil engineers, architects, agriculturist, environmentalist and sociologist are conducted with review of Khulna City master plans, and other reports and publications. The study finds that approximately 3. 67 acres and 2.43 acres land in Ward no. 17 and Ward no. 20 remain vacant respectively. Also, after knowing the pros and cons of CG, 58.33% people in Ward no. 17 and 60% people of Ward no. 20 become interested to participate in CG. If it is possible to utilize the vacant land for community gardening, community gardens on one acre land having 17 decimal or 10.30 katha land of each community garden will be capable to sequestrate about 3.5 tons of carbon per year and depending on the size and duration of rain event, will be able to hold about 2000-10000 cubic ft. of storm water per year. The study also proposes some sites for the development of community gardens in future.

Keywords: Community gardens, green space, vacant land, Khulna city

Introduction

A community garden is defined as 'any piece of land gardened by a group of people, utilizing either individual or shared plots on private or public land' (Egli et al., 2016). In other words, community gardens are the most valuable space within a neighborhood which provide space for individuals of the community who do not have enough space to participate in agricultural activities and also an opportunity to utilize the underused space of the neighborhood (Grow, 2011). It is one of the most temporary types of land use because it is mostly constructed on those vacant lands which are awaiting for constructions as an interim use. In US, more than 98% of the community gardens were temporary (Colding & Barthel, 2013). Dead space, derelict landscape, and/or wasteland all seem to be the terms used to denote vacant land (Coleman, 1982; Newman et al., 2016). There are also some modern remedies and solutions for such urban vacant land issues. Vacant land can be turned into green infrastructure in the form of open green space or urban agriculture to create a more sustainable environment (Ara, 2018; Schilling & Logan, 2008; Gough & Accordino, 2013; Draus et al., 2014). At the start of the last decade, seventy US cities had upwards of 15% of land that was vacant or abandoned (Pagano & Bowman, 2000). Many vacant plots in Philadelphia, Detroit, and Chicago now have plots of sunflowers, root vegetables, and rows of corns growing in temporary community gardens (Németh & Langhorst, 2014) which demonstrate that if vacant land is effectively handled, it can provide both ecological and social advantages (Kim et al., 2015; Kim et al., 2016).

Depending on the needs of the society and the purpose of construction, the community gardens can be of different types. If the local people construct it only to get fruits and vegetables then allotment garden is the best option. In allotment system, each family take lease of different plots individually and cultivate fruits and vegetables

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according to their own choice. On the other hand, shared community garden is mainly created to strengthen community bonding as here members have access to all plots to work together. Another advantage of this type of community garden is that it requires comparatively less land than allotment garden. If there is enough space, combination of these two types of community garden is also possible. Generally, community garden can be constructed on the land of public open space, vacant plots of residential area, community meeting place, educational institutions, religious institutions etc. (Lilith, 2014).

The environmental benefits of community garden includes environmental sustainability, organic food production, waste minimization and permaculture (Davis et al., 2015; Liau, 2009). It also ensures environmental sustainability through restoration of neglected and low-valued plot of a neighborhood (Krasny & Tidball, 2009). Another important environmental aspect of community garden is preservation of agricultural biodiversity, especially by expanding the range of fruit and vegetable (F&V) varieties available beyond what is commonly available in supermarkets. The role of community garden in providing a relatively cheap food supply through direct interaction with nature (i.e., gardening) has been proposed as a solution to the problem of urban food insecurity (Shisanya & Hendriks, 2011). When traditional fruits and vegetables are inaccessible, community garden helps to make them available (Guitart et al., 2012; McCormack et al., 2010). Greenery also helps to improve the quality of life of the people, focuses mostly on local climate stabilization via air filtration, cooling through shade provision, increase carbon storage and sequestration, and reduction of total energy consumption (Yoong et al., 2017). But at the edge of 21st century, urbanization has accelerated to such a rapid rate that most of the open spaces of the cities are swiftly being converted into built environment. Despite the fact that India is one of the world's least urbanized countries, with only 31.30 percent of the population residing in urban areas, the country is experiencing a significant urban growth dilemma. This urbanization movement is no longer limited to plain areas only. The Himalayan Mountainous areas are all now witnessing the urban revolution. According to a study, there was significant urban sprawl in and around the city of Dehradun from 2004 to 2014, where 6.13 sq. km of agricultural land, fallow land, and vacant land was converted into built-up area (Bhat et al., 2017). In this situation, the concept of community gardening is broadly utilized in modern community to make the environment more livable (Agustina & Beilin, 2012).

In today's world, one of the major challenges of the governing authority is to ensure a proper and inclusive solid waste management system, where a huge portion of the municipal solid waste is organic. In Denmark, about one fifth of municipal waste is green with per capita generation of about 119 kg per year. Most of the green waste in Denmark is used for composting (Ten Hoeve et al., 2019). Community gardens lessen the amount of waste as a major portion of organic waste is used for composting which in return reduce the cost of collection and treatment of household waste (Ayilara et al., 2020; Jaradat & Al-khashman, 2013).

Working in the garden gives the gardeners immense pleasure which in turn have an effect in their health condition. One of the leading motivations for the local people to participate in the gardening activities is enhancement of their health condition, both in terms of mental and physical health (Firth et al., 2011). Gardening involves regular and enjoyable physical activities which helps to control different health related problems like cardiovascular disease, diabetics, blood pressure, orthopedic problems etc. It also offers meditative space and a soothing environment which are very beneficial for mental health (Bonow & Normark, 2018; Khurram et al., 2022; Rindels, 2019; Soga et al., 2017; WHO, 2018).

Bangladesh, as one of the world's fastest urbanizing countries, has seen an unplanned and rapid rate of urbanization in recent years (Angeles, 2022; Hasan & Nazem, 2015; UPPRP, 2011). Its urban sector generated more than 65% of the national gross domestic product (GDP) in 2011, which is now about 75% (Ahmed, 2022; Choe & Roberts, 2011). As a consequence of such socio-economic improvement in recent decades, Bangladesh has experienced unplanned urbanization leading to the territorial extension of each city and growth center as well as to the changes in land use (Hassan, 2017). In this transformation, Bangladesh, like many other countries, faces a tremendous difficulty in proper planning and managing urban expansion, ensuring effective use of urban vacant land and achieving a sustainable urban development (Li et al., 2018; Islam et al., 2018). Table 1 shows the land use land cover change statistics of some major cities of Bangladesh. Only the built-up area has a positive changing trend among the four land use classes, whereas the other three have negative gradients against time. The extraordinary and shocking fact is that the amount of unoccupied land in Dhaka city grows with time, and its value is really high. The concept of community garden is completely new as well as unfamiliar in Bangladesh, though it has huge potentials in respect of neighborhood planning in a developing country like Bangladesh. This study is conducted in Khulna city, the heart of the southwestern part of the country. As a whole the study is conducted to determine the

benefits of installing community gardens on vacant land of the selected area, Ward no. 17 and Ward no. 20 of Khulna City Corporation (KCC).

Table 1. Land use land cover change statistics of some major cities of Bangladesh during 1989-2014

City	Land use type	2013-2014(ha)	%	1999-2000(ha)	%	1989-1990(ha)	%
Dhaka	Vegetation and Cultivated land	2232.63	16.04	3009.6	21.63	5414.67	38.91
	Built-up	7970.67	57.26	7268.4	52.25	4759.92	34.20
	Water bodies and wetland	799.65	5.74	1166	8.38	1715.4	12.33
	Fallow land	2917.44	20.96	2467.9	17.74	2026.71	14.56
Chittagong	Vegetation and Cultivated land	8194.52	48.94	10609	63.36	13228.38	79
	Built-up	7711.83	46.05	5052	30.16	2367.99	14.14
	Water bodies and wetland	746.46	4.46	974.4	5.81	967.23	5.78
	Fallow land	57.51	0.34	84.33	0.50	173.52	1.04
Khulna	Vegetation and Cultivated land	1017	18.61	1836	33.5	3107	56.70
	Built-up	3772	68.83	2798	51.06	1614	29.45
	Water bodies and wetland	635	11.59	767	14	646	11.79
	Fallow land	53	0.97	79	1.44	113	2.06
Rajshahi	Vegetation and Cultivated land	1927	36.74	2619	49.93	3575	68.17
	Built-up	2708	51.63	1864	35.54	966	18.42
	Water bodies and wetland	546	10.41	675	12.87	617	11.76
	Fallow land	64	1.22	87	1.66	87	1.66

Source: Hassan, 2017; Moniruzzaman et al., 2018; Hasan & Nazem, 2015; Mamun et al., 2013

Materials and Methods

Concept Building

As the concept of community gardening is very unfamiliar in context of Bangladesh, several international and national research papers, newspaper article, reports and books are reviewed to enrich the concept. A reconnaissance survey was done to get the overall idea and information about the study area.

Study Area Profile and Sample Size Determination

Ward no. 17 and Ward no. 20 of KCC were chosen as the study area. Ward no.17 has two planned residential areas developed by Khulna Development Authority (KDA). They are Sonadanga Residential Area (1st Phase) and Sonadanga Residential Area (2nd phase).

Ward no. 20 has a large unplanned residential area named Sheikhpara. Table 2 shows a detail description of socio-geographic and land use data of the study wards. Figure 1 shows different land uses, especially of vacant lands and open green spaces as potential sites for community gardens.

Sample size of the household questionnaire survey is determined by using the following equation:

$$N = \left(\frac{Z\sigma}{E}\right)^2$$

Where N is the sample size, Z is the critical value of the normal distribution, σ is the standard deviation and E is the difference between the observed and actual mean. For this study, 95% significance level and 5% error margin are considered. Using the above formula, the sample size was determined 300, where 200 was for Ward no. 17 and 100 was for Ward no. 20). About 30% of the existing vacant plots are surveyed based on their size and locations.

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Table 2. Study area profile

	Ward no. 17		Ward no. 20	
Area (acre)	572.34		120.72	
Name of localities and mohallas	Choto Boyra Dakshin (South), Khulna Textile Mills, Paschim (West) Sonadanga, Purba (East) Sonadanga, Shibbari, Sonadanga Madhaya (Middle) and Sonadanga New Market.		B. K. Roy Road, Deben Babu Road, Farazi Para, Ferryghat (Barada Datta Lane) and Sheikhpara.	
Population	33163		16624	
Density per acre	58		138	
Sex Ratio (M/F)*100	98.676		103.576	
Literacy Rate (%)	70.10		73.20	
Total Household	7710		3689	
Household size	4.2		4.4	
Land use details	Area (Acre)	Percentage	Area (Acre)	Percentage
Agricultural land	70.30	12.28	0	0.00
Park	6.10	1.07	0	0.00
Vacant land/plot	3.67	0.64	2.43	2.01
Urban green space	0.24	0.04	0.04	0.03
Waterbody	48.80	8.52	2.06	1.71
Built-up area	443.23	77.44	116.19	96.25

Source: Author, 2019 & Roy, 2013

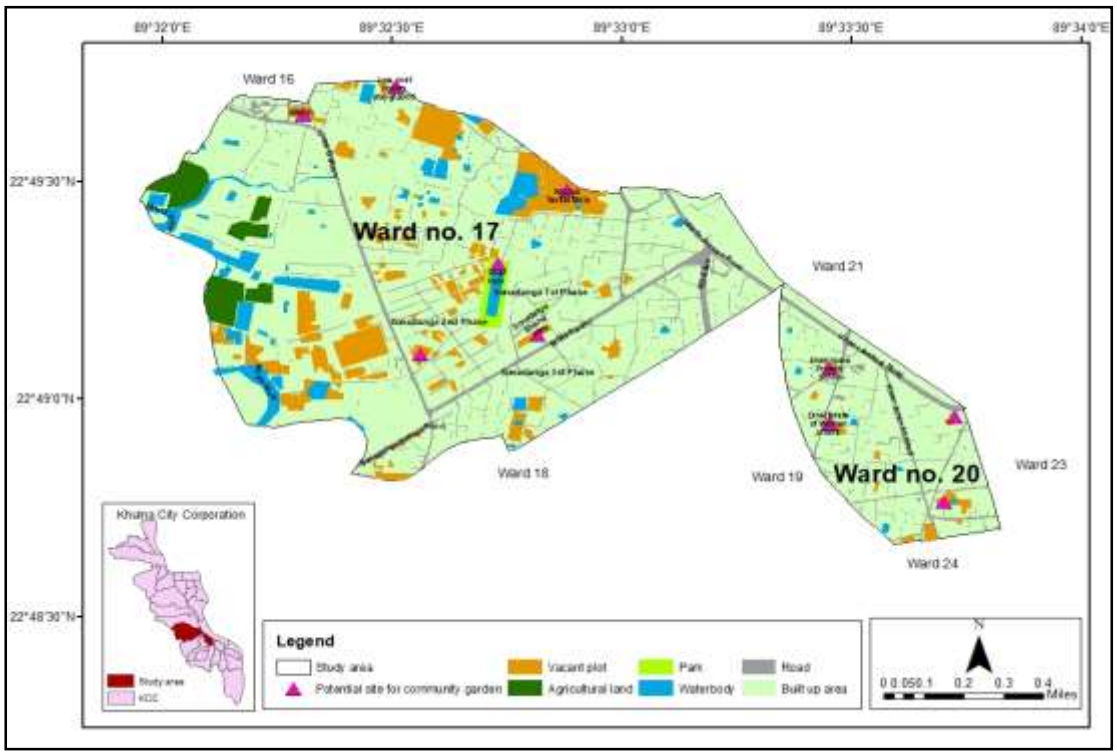

Figure 1. Map of study area with different land uses and potential sites for community gardens

Questionnaire Preparation and Data Collection

Some variables namely availability of vacant land, socio-economic and environmental benefits i.e., impact on solid waste management, and health benefits of community garden are selected for this study to explore the potentials of community gardens in the study area. Both primary and secondary data are collected. After preparation of the questionnaire, primary data are collected from the household survey. Opinions and views regarding the potentials of community gardening in Khulna city are collected from the key informant interview (KII) of urban planners, civil engineers, architects, agriculturist, environmentalist and sociologist. Data on population, infrastructural details and details of existing community services are collected from KCC, KDA and Bangladesh Bureau of Statistics (BBS). Satellite images are used for preparation of the land use map.

Data Analysis

The collected data are analyzed using the statistical software SPSS. Different tables, charts and analytical figures are prepared to show the comparisons and trend analysis of particular sections. Land use land cover (LULC) change of the study area is analyzed applying NDVI method in Arc GIS.

Findings and Recommendations

Based on data analysis and findings, the study provides some recommendations and potential sites for developing community gardens on the vacant and unused lands of Khulna city. The study finally proposes a guideline for introducing community gardening at neighborhood level in Khulna City.

Results and Discussions

Availability and condition of vacant land e*xisting Condition*

Ward no. 20 has very small amount of vacant land, which is approximately 2.43 acres in total. There are only about 40 vacant plots of different sizes ranging from 3 katha to 5 katha (Average 4 katha or 6.6 decimal). On the other hand, approximately 60 plots of total 3. 67 acres land are vacant in Ward no. 17. Figure 2 shows the current condition and use of the vacant plots. In Ward no. 17 most of the vacant plots are remaining unused (about 33.08%) followed by storage of construction materials (about 25.61%). Waste dumping is the most common use of the vacant plots in Ward no. 20. Vegetables gardening is the rarest use of vacant plots in both the wards.

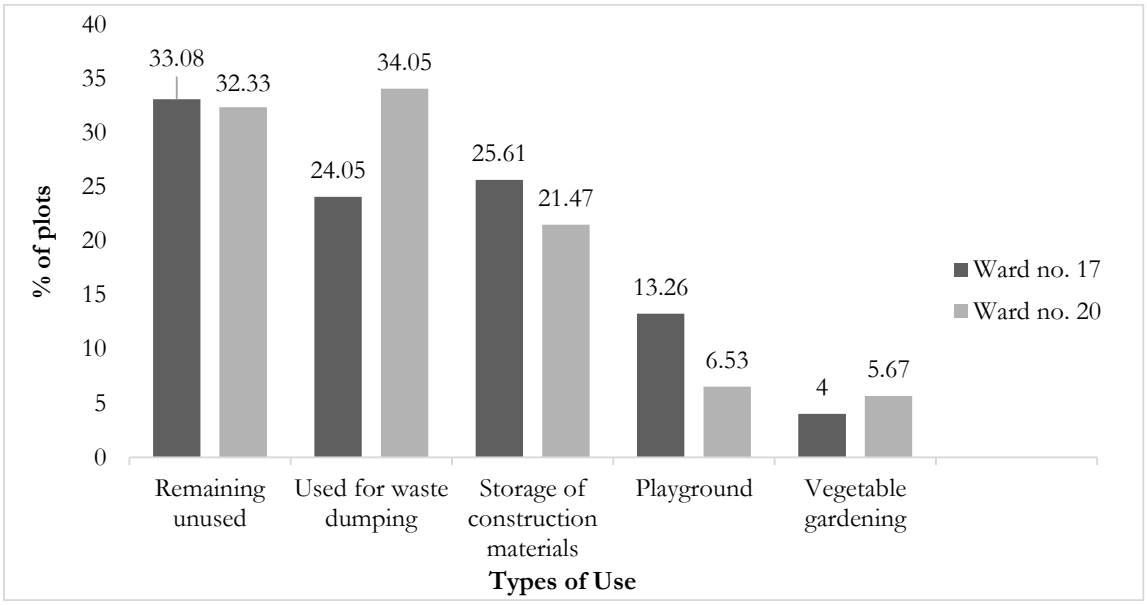

Figure 2. Current use of vacant plots in Ward no. 17 and Ward no. 20 (*Source: Field Survey, 2019)*

Chronological Analysis

Huge amount of land in both the study wards remained vacant for many years before construction of buildings on that. As the land owners gradually construct buildings at their convenience of getting money and wealth in hands, the buildings age varies widely. Figure 3 shows that about 30.46% buildings of Ward no. 17 are constructed 15-20 years ago but most of the buildings of Ward no. 20 are older than 20 years. About 38.21% buildings are constructed more than 20 years ago. Most of the building owners responded that they did not use their vacant plots for any other significant use before construction of buildings. As a result, those vacant plots could not play any role in the socio-economic and environmental development of the city.

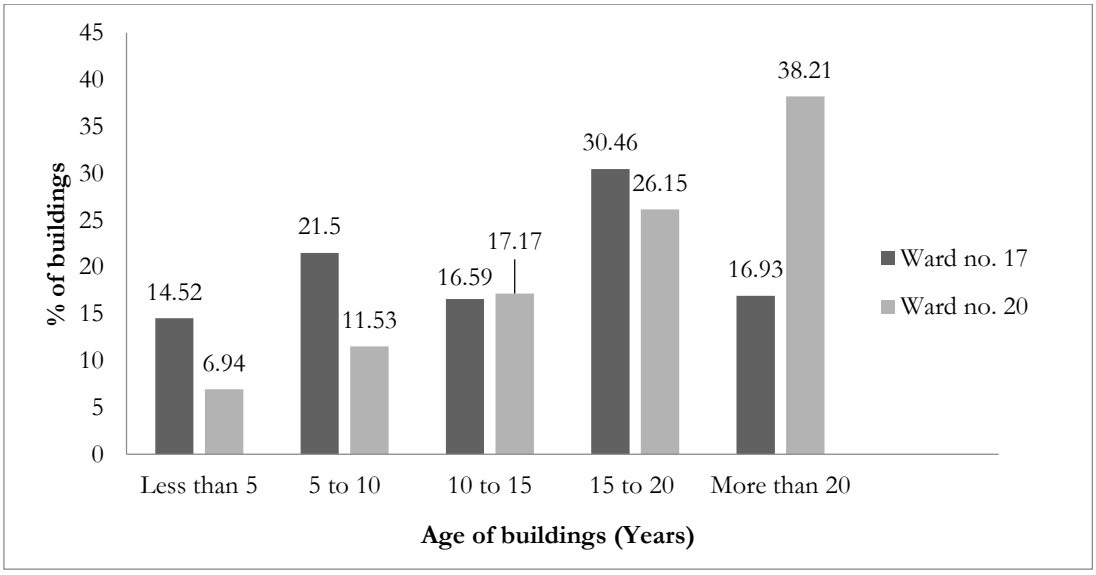

Figure 3. Age of buildings in Ward no. 17 and Ward no. 20 (*Source: Field Survey, 2019)*

The amount of vacant land in both the wards has drastically reduced during the period of 2000-2010. The socio-economic development of the people of Khulna city as well as of the country is one of the main reasons of rapid urbanization, land transformation and land use change in the cities and towns (Hasan, 2017). Table 3 shows that the amount of vacant land in Ward no. 17 has lowered at 7.01 acres in 2010 from 18.93 acres in 2000. In ward no. 20 it has lowered from 30.25 acres in 2000 to 10.42 acres in 2010.

Table 3. Chronological analysis of the amount of vacant land in Ward no. 17 and Ward no. 20

Year	Ward no. 17 (Acres)	Ward no. 20 (Acres)
1990	36.73	55.38
2000	18.93	30.25
2010	7.01	10.42
2019	3.67	2.43

Source: Google Earth Images of Khulna City & KDA, 2018

Environmental Benefit

Existing condition

Greenery is largely shrinking in both the study wards with rapid urbanization over time. Table 4 shows a chronological change of greenery in the wards in different years, from 2013 to 2020. Existence of greenery with practice of gardening is very rare in Ward no. 20, where most of the area is built-up i.e., 96.25%. There is no agricultural land in this Ward. Its sparse vegetation has reduced at only 1.33 acres in 2020 from 8.67 acres in 2013. But the amount of greenery in the form of sparse vegetation, gardening and agriculture in Ward no. 17 is quite

satisfactory. The Ward has agricultural land of about 70.30 acres (12.28%) in 2019 (Table 1). Sparse vegetation in Ward no. 17 has reduced at 38.89 acres in 2020 from 214.39 acres in 2013, which is a massive change.

Table 4. Changes in sparse vegetation coverage in the study area during 2013-2020

Year	Ward no. 17 (in acre)	Ward no. 20 (in acre)
2013	214.39	8.67
2017	83.18	2.22
2020	38.89	1.33

The study has also found that nowadays KCC, Department of Agricultural Extension (DAE), Forest Department (FD), District Administration, some NGOs and nurseries are taking programs to motivate local people in tree plantation, rooftop gardening and urban greening. This is contributing to increase the amount and coverage of greenery in Khulna city. Table 5 represents the relations between the house ownership and gardening practice. In both wards, most of the gardening practitioners are the owners of house (80% in Ward no. 17 and 80.67% in Ward no. 20) and very few tenants of the Wards are involved in gardening (20% in Ward no. 17 and 19.35 % in Ward no. 20).

Table 5. Relation between house ownership types and gardening practice

Area		Ownership Type	
		Owner	Tenant
Ward no. 17	Involved in gardening	80.00%	20.00%
	Not involved in gardening	41.80%	58.20%
Ward no. 20	Involved in gardening	80.67%	19.33%
	Not involved in gardening	44.08%	55.92%

Source: Field Survey, 2019

Among the non-practitioners, most of the respondents are interested about gardening but cannot participate due to lack of available space and time. Figure 4 shows the reasons for not being involved in gardening by the residents.

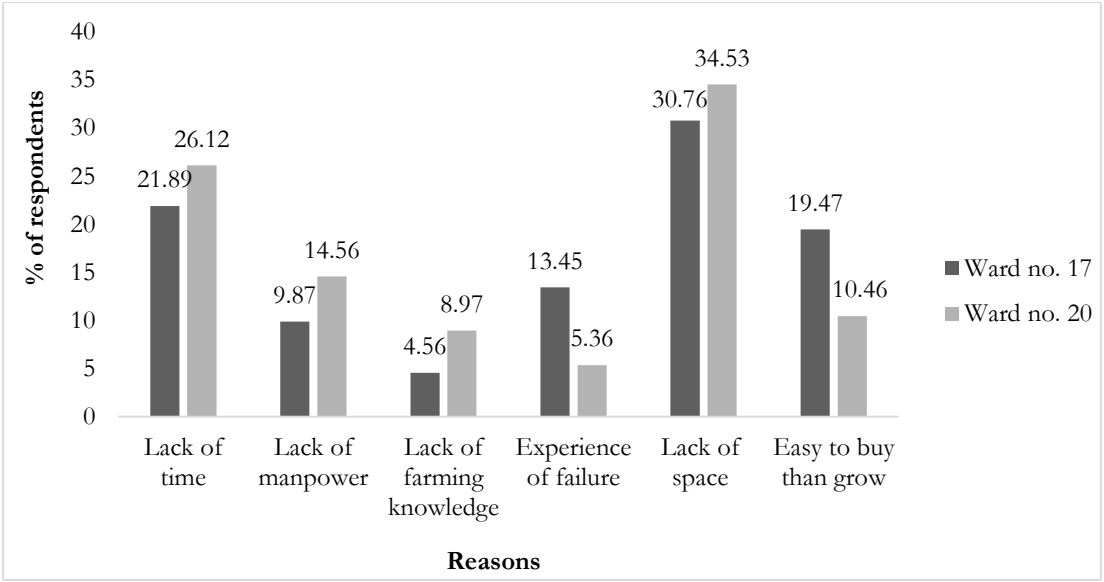

Figure 4. Reasons for not being involved in gardening (*Source: Field Survey, 2019)*

In Khulna City, agriculture comprises only 16.30% land of the total urban land use (Roy et al, 2019). Most of the practitioners in both the Wards are practicing small scale gardening, where the average number of plants in a garden is 12 and 15 in Ward no. 17 and Ward no. 20 respectively. The practitioners cannot expand their gardens due to lack of high value space, less availability of seeds, fertilizer and other logistic supports.

Figure 5 shows the types of gardening and the types of produced vegetables and plants in the gardens. Most of the practitioners are becoming interested in rooftop gardens or pot planting in both areas due to lack of space or lack of permission by owners and family members to use the available vacant space for gardening. Flower plants, fruit plants and vegetable plants are more popular and common in the area. The most common flower plants are Rosa (Rose), Dahlia (Dahlia Pinnata) and Cosmos (Cosmos Bipinnatus) etc. Among fruits and vegetables, Cucumber (Cucumis sativus), Spinach (Spinacia oleracea), Tomato (Solanum lycopersicum), Lemon (Rutaceae) etc. are more common. A very small number of ornamental plants such as Cactus (Cactaceae) and Money Plant (Epipremnum aureum) etc. is also found.

Except homestead gardens at household level, for serving the recreational and environmental need of the local people, there are two parks, named Solar Park and Sonadanga Shishu Park in Ward no. 17. In Solar Park, there is also a waterbody having an area of 3.01 acres. But there is no such parks or open space in Ward no. 20. Table 6 shows a detail description of the two parks of Ward no. 17.

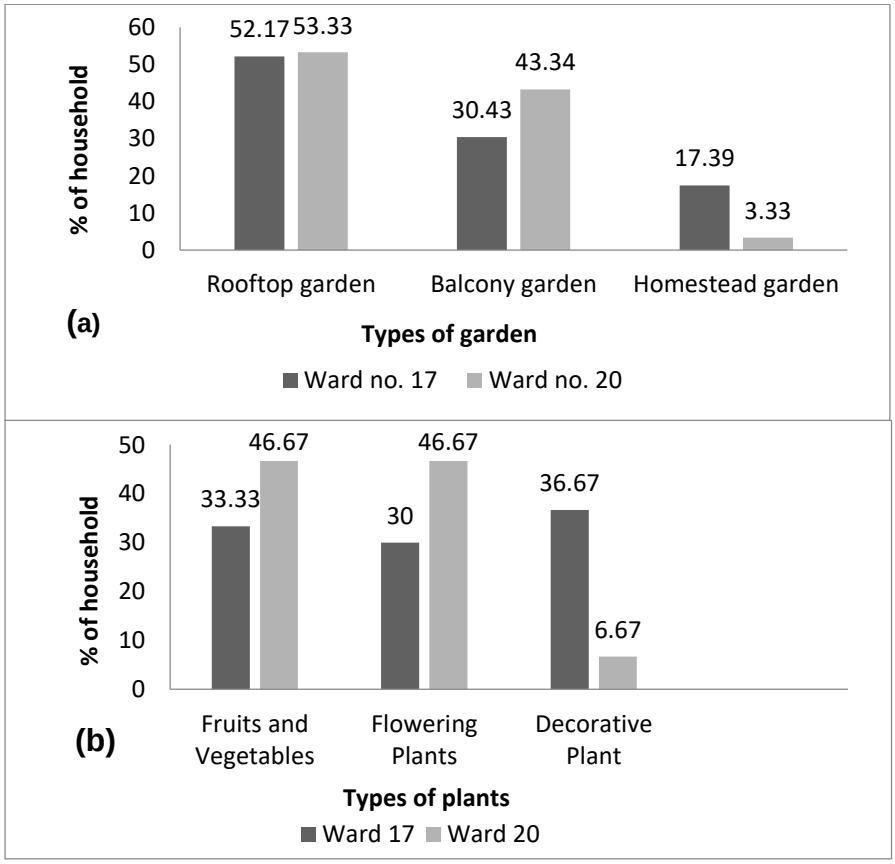

Figure 5. Types of gardening (a) and types of plant in the garden (b) in the study area (*Source: Field Survey, 2019)*

Environmental Benefit Achieved by Community Gardening

Community garden helps to manage and improve the environmental quality in several ways such as sequestrating carbon, management of storm water, maintaining air temperature and air quality and many others. This study aims to quantify two of the most significant environment benefits of community gardening: (i) carbon sequestration and (ii) storm water runoff retention. It is assumed that the area of each of the proposed community garden will be 0.17 acres or 10 Katha or 7200 sq. ft.

Carbon Sequestration

In the tropical region of South East Asia, a typical community garden of 1 hectare sequestrates about 14.46 tons of carbon on an average in a single year (Choudhari et al., 2014). This amount highly depends on growth rate, age, and species of the particular tree. Warm and wet climate of tropical region enhances plant growth and plant with higher growth rate significantly sequestrates carbon at a faster rate than a plant of slower growth rate. The given equation is mainly used in this study to estimate the amount of total carbon that will be sequestrated by the proposed community garden:

C=No. of plant*survival factor*annual sequestration rate $_{(A,T)}$ (US Department of Energy, 1998)
where:

C=Total Carbon sequestrated
A=Age of greenery
T=Type of greenery

From several different literature review, it is found that general number of vegetable plants per hectare or 2.47 acres is 10,000, survival factor is 0.798 and annual sequestration rate is 2.2 lbs Carbon/plant/year on an average. A proposed community garden on 10 katha or 7200 sq. ft. or 0.17 acres land under this study having 688 vegetable plants will sequestrate 0.60 tons of Carbon per year. The calculation is as shown below:

C = 688*0.798*2.2
= 1208 lbs
= 0.60 tons

Table 6. Details of parks in Ward no. 17

Features	Solar Park	Sonadanga Shishu Park
Establishment Year	2007	1981
Location	Sonadanga Residential Area (2nd Phase)	Sonadanga Residential Area (1st Phase)
Area (acres)	4.33	0.46
Presence of Waterbody	Yes (3.01 acres)	No
Managing Body	KCC	KCC
Facilities	Play space, jogging tract, security guard and guard room, lighting facilities, sitting arrangement, CCTV, training center on solar and renewable energy etc.	Play space, rides, sitting benches, paved internal roads etc.

Source: Karim & Roy, 2012; Khaza et al., 2020

Storm water runoff retention

Community gardens contribute to urban environmental development by storm water management. This benefit is quantified by using the TR-55 method (Gittleman et al., 2017), shown below:

$$Q=\frac{(P-Ia)\hat{}2}{(P-Ia)+S}$$

where:
Q= Runoff in inches for a P-inch rain event
S= The potential maximum runoff after runoff begins
I_a= The initial abstraction in inches
= 0.2S

$$Q = \frac{(P-0.2S)^2}{(P-0.2S)+S}$$

$$S = \frac{1000}{CN} - 10$$

where:
CN= curve number which depends on land cover and hydrologic soil group. Table 7 shows the list of CN for different types of soil.

Table 7. Curve number for different land cover

Land Cover	CN of Khulna Region
Open Space (grass cover >75 %)	74
Bare Soil	91
Paved	98

Source: Gittleman et al., 2017

$$CN = (C_o*A_o + C_b*A_b + C_p*A_p)/A$$

where:
CN= Average curve number
C_o= CN for open green space
A_o= Area of the open green space
C_b= CN for bare land
A_b= Area of the bare land
C_p= CN for paved area
A_p= Area of the paved area
A= Total area

$$R = \frac{Q}{12} * A$$

where
R= runoff volume (cubic feet)

From several different literature review, the general composition of a typical community garden is 83 %green space, 16% paved and 1% bare.

$$CN = \{(5976*74) + (1152*91) + (72*98)\} / 7200$$
$$= 76.96$$

Therefore

$$S = \frac{1000}{76.96} - 10$$
$$= 2.9937$$

Therefore, for a rain event of 1.5″, the runoff value will be

$$Q = \frac{(1.5-(0.2*2.9937))^2}{(1.5-(0.2*2.9937))+2.9937}$$
$$= 0.209 \text{ in}$$

and

$$R = \frac{Q}{12} * A$$
$$= 125.4 \text{ cubic feet}$$

Again, for a rain event of 5″, the runoff value will be

$$Q = \frac{(5-(0.2*2.9937))^2}{(5-(0.2*2.9937))+2.9937}$$
$$= 1.47 \text{ in}$$

and

$$R = \frac{Q}{12} * A$$
$$= 882 \text{ cubic feet}$$

Table 8 shows the impact of community garden on the quantity of surface runoff and also the amount of rain water absorbed or retained by each garden during different rain event.

Table 8. Summary of the effect of community garden on surface runoff retention

Rain Event (in)	Runoff Value (With Community Garden) (ft^3)	Runoff Value (Without Community Garden) (ft^3)	Retention Value by Community Garden (ft^3)
1.5	125	445	320
5	882	2520	1640

Source: Author, 2019

Willingness of the local people

The concept of community garden is very new and unfamiliar to the local people. After informing them all the pros and cons of community gardening, 60% people of Ward no. 20 and 58.33% people in Ward no. 17 become interested to participate in community gardening.

Age-based opinion

The total population is divided into 5 age-groups and their corresponding opinions are shown in Table 12.

Table 12. Age based willingness for community garden

Age	Opinion		Total Respondent
	Yes	No	
20-30	100%	0%	4
30-40	54.55%	45.45%	22
40-50	68.75%	31.25%	128
50-60	51.06%	48.94%	94
60-70	46.15%	53.85%	52
Total			300

Source: Field Survey, 2019

People of all age group are interested in participating in gardening but young people have more interest on it, generally the aged group need some time to become familiar with this new concept.

Gender-Based Analysis

To make the community gardening inclusive and gender sensitive, the willingness of male and female to participate in community gardening is analyzed. The result shows that male participants are more interested than female. The only reason is that women do not feel fully socio-culturally secured in the outside environment than their own families and homesteads. So, the socio-cultural security and related issues for the women must be considered while developing the urban community gardens.

Table 13. Gender based willingness for community garden

	Opinion		Total
	No	Yes	
Female	45.45%	54.55%	110
Male	36.17%	63.83%	190
Total			300

Source: Field Survey, 2019

Education Level and Interest

Literacy is an important factor of initiating any noble work and good deed like community gardening, which contributes to urban environmental development. Literacy rate in KCC area is 73.56%, of which male literacy rate is 76.46% and female literacy rate is 70.29%. Literacy rate in Ward no. 17 is 70.10% and in Ward no. 20 is 73.20% (BBS, 2011). Table 14 shows the relation between people's interest and their education level and the analysis shows

that as people become more educated, they are becoming more concern about environmental and health condition and therefore are more interested about participating in community gardening.

Table 14. Education based willingness for community garden

	Opinion		Total
	No	Yes	
Primary	53.87%	46.13%	14
Secondary	53.13%	46.87%	54
Higher Secondary	51.28%	48.72%	78
Graduation	35.35%	64.65%	132
More than graduation	36.36%	63.64%	22
Total			150

Source: Field Survey, 2019

Potential sites of community gardens in the study area

Table 15: Potential sites of community gardens in study area with explanations

KCC Wards	Favorable reasons for community gardens
17	Medium dense area (58 persons/acre) having two parks-KCC Solar Park in Sonadanga Residential Area (2nd Phase) and Sonadanga Shishu (Children) Park in Sonadanga Residential Area (1st Phase). One or two community gardens can be established in the Northern and Southern end of the Solar Park. Solar Park is mainly suitable and used for walking, jogging and physical exercise; and passing leisure time in the morning and afternoon. The potential sites where there exist significant amount of vacant/unused/underused land for future community gardens in this Ward are: • Residential Areas and Staff Quarters/Colonies -Sonadanga Residential Area (2nd Phase) having many KDA allotted vacant and underused plots for many years (33 years from 1987 to 2020). -Sonadanga Residential Area (1st phase) has still few vacant plots, where community gardens can be established • Major Establishments -Khulna Medical College (KMC) and Khulna Medical College Hospital (KMCH)-KMC is a 500 bedded government hospital which has beautiful flower garden with good landscaping in its front or main entrance. It still has unorganized and unused land which can be used for community gardens. Research and demonstration type community gardens are preferable for this site as the patients and their family members, students, academics and researchers involved or interested to health and development sectors can be made aware and motivated on community gardens. The attached KMCH also has land for establishing community garden. -Divisional Women Sports Complex (Bibhagio Mohila Crira Complex) -Boyra Secondary Schools -Khulna Art College (Abandoned)
20	High density area (138 persons/acre) with no parks and playground for recreation, leisure, play, sports and physical exercise; significant number of 7+ age unemployed persons (21.82%) might be directly and indirectly involved in community gardening. Modern Khulna District Shilpakala Academy Complex at Shere-E-Bangla Road is situated in this Ward and the pond of this complex has been an attractive place of water-based recreation (bathing, swimming and jumping from building tops) for the children and youths of this locality. The Government, mainly the Directorate of Youth and Sports, Department of Social Welfare, and KCC can take steps to develop a few community gardens on vacant and unused land under government offices (i.e., Social Welfare Office) and educational institutes (i.e., Ahsanullah College, Sheikh Abu Naser Secondary School) in this Ward.

Guidelines for Community Gardening

At least 7200 sq. ft. area is needed for the construction of a standard community garden. There are some other factors which also should be considered such as topographical details, drainage network, and accessibility from all parts of the residential area. After informing the land owners about the pros and cons of community garden, it is important to take some legal permission from the land owners for a specific time period. After site selection, the next step is site preparation and this phase include building boundary walls to properly designate the area, improving the soil quality by removing the existing debris, implementation of organic matter, raising the soil bed level for better aeration, construction of internal roads and other infrastructural facilities like sitting arrangement, some play equipment for children, separate toilets and washrooms for male and female, small vending opportunity, meeting place etc. It is also important to first decide the plant species and ensure the quality of the seeds or plants brought. It is also important to decide whether to plant seeds or transplants and this decision depends on the cost of seed, the plant population needed, the earliness of desired crop maturity, and convenience. Buying required gardening tools, insecticides and fertilizers are also important. To make the community garden projects successful and to ensure the active participation of the people, some decisions at policy level may be introduced like, special discount on land tax for the land owners of vacant plots who will allow community gardening on their plots; to ensure the practice of composting, the provision of charging the house owners and tenants for household waste collection according to the weight of the wastes may be introduced; and conducting some workshops, seminars, dialogues etc. about the merits and demerits of community gardening.

Key Challenges for Introducing Community Gardening

- The concept of community gardening is very unfamiliar and new to the local people so they might need some time to become familiar with it.
- Currently, in most of the cities of the country as well as in Khulna city, the practice of community gardening is almost absent or if present then in very small scale. That is why the common people cannot understand the potential benefits of community gardening.
- There is no existing direct policies and regulatory frameworks for community gardening. Also, there is no clear instructions about community gardening in the master plans of the cities of the country.
- The stakeholders do not have enough knowledge about the benefits of community gardening.
- There is scarcity of pre-requisite inputs for community gardening such as adequate water supply, quality seeds and fertilizers.
- The roles of the Department of Agriculture and other organizations (KCC, KDA, NGOs, CBOs etc.) for community gardening in the cities are not distinct.

Conclusion

Community gardening is a popular component of urban planning in many of the developed and developing countries. Though it is completely a new as well as unfamiliar concept, it has huge potentials in respect of neighborhood planning in a developing country like Bangladesh. As community garden is a good form of urban green space and the cities of Bangladesh have inadequate number of parks, playgrounds etc. as green space for recreation, jogging and physical exercise and for mental relaxation, community gardens can be developed as better alternative options of green space. Community garden is an important component of urban agriculture and every urban area master plan must consider the provision of adequate land for urban agriculture. In Khulna City, like other cities of Bangladesh, there is no formal community garden. But there are some informal gardens for fruits and vegetables in many of the public housing estates or government employee housing areas in different cities of Bangladesh. There exists huge amount of vacant or unused land in the form of public planned residential area plots, private planned residential area plots, land parcel in unplanned or naturally built-up area, and land under different public and private organizations. Community gardens can be developed in such vacant land. Agricultural land is gradually being converted into residential use and horizontal expansion of city is experienced. Extensive practice of community agriculture and community gardening can also counterbalance between reduction of agricultural land and increase of residential land.

Conflict of Interests
The author declares no conflict of interest.

References

Agustina, I., & Beilin, R. (2012). Community Gardens: Space for Interactions and Adaptations. *Procedia - Social and Behavioral Sciences, 36,* 439–448. doi:10.1016/j.sbspro.2012.03.048

Ahmed, N. (2022). The costs and risks associated with rapid, unplanned urbanization. The Daily Star. https://www.thedailystar.net/recovering-covid-reinventing-our-future/developing-inclusive-and-democratic-bangladesh/news/the-costs-and-risks-associated-rapid-unplanned

Angeles, G., Ahsan, K.Z., Curtis, S.L., Spencer, J., Streatfield, P.K., Chakraborty, N. & Brodish, P. (2022). Measurement Challenges in Designing and Conducting Surveys on Urban Population: Experience from Bangladesh Urban Health Surveys. *Survey Methods: Insights from the Field*. doi:10.13094/SMIF-2022-00001

Ara, M. R. (2018). Urban agriculture for sustainable livelihood of low-income people in Khulna City Corporation, southwest Bangladesh. *Khulna University Studies, 15*(1&2), 117-132. doi:https://doi.org/10.53808/KUS.2018.15.1and2.1909-S

Ayilara, M., Olanrewaju, O., Babalola, O., & Odeyemi, O. (2020). Waste Management through Composting: Challenges and Potentials. *Sustainability, 12*(11), 4456. doi:10.3390/su12114456

BBS (Bangladesh Bureau of Statistics). 2011. Population & housing census 2011. Khulna, Bangladesh: BBS.

Bhat, P. A., Shafiq, M. U., Mir, A. A., & Ahmed, P. (2017). Urban sprawl and its impact on landuse/land cover dynamics of Dehrahun City, India. *International Journal of Sustainable Built Environment, 6*(2), 513-521. doi:https://doi.org/10.1016/j.ijsbe.2017.10.003

Bonow, M., & Normark, M. (2018). Community gardening in Stockholm: participation, driving forces and the role of the municipality. *Renewable Agriculture and Food Systems, 33*(6), 503-517. doi:10.1017/s1742170517000734

Choe, K., & Roberts, B. (2011). Competitive cities in the 21st century: Cluster-based local economic development. Manila: Asian Development Bank.

Choudhari, Nisha R., Mahajan, D.M., Gunale, V.R. & Chaskar, M.G. (2014). Assessment of carbon sequestration potential of an urban managed garden in the Pimpri-Chinchwad City. *Environment Observer, 20,* 63-67.

Colding, J., & Barthel, S. (2013). The potential of "Urban Green Commons" in the resilience building of cities. *Ecological Economics,* 86, 156–166. doi:10.1016/j.ecolecon.2012.10.016

Coleman, A. (1982). Dead Space in the Dying inner City. *International Journal of Environmental Studies, 19*(2), 103-107. doi:http://dx.doi.org/10.1080/00207238208709976

Davis, J. N., Spaniol, M. R., & Somerset, S. (2015). Sustenance and sustainability: maximizing the impact of school gardens on health outcomes. *Public Health Nutrition, 18*(13), 2358–2367. doi:10.1017/s1368980015000221

Draus, P. J., Juliette, R., & McDuffie, A. (2014). We Don't Have No Neighbourhood': Advanced Marginality and Urban Agriculture in Detroit. *Urban Studies, 51*(12), 2523–2538. doi:10.1177/0042098013506044

Egli, V., Oliver, M., & Tautolo, E.-S. (2016). The development of a model of community garden benefits to wellbeing. *Preventive Medicine Reports, 3,* 348–352. doi:10.1016/j.pmedr.2016.04.005

Firth, C., Maye, D., & Pearson, D. (2011). Developing "community" in community gardens. *Local Environment, 16*(6), 555–568. doi:10.1080/13549839.2011.586025

Gittleman, M., Farmer, C. J., Kremer, P., & McPhearson, T. (2017). Estimating stormwater runoff for community gardens in New York City. *Urban Ecosyst 20,* 129–139. https://doi.org/10.1007/s11252-016-0575-8

Gough, M. Z., & Accordino, J. (2013). Public Gardens as Sustainable Community Development Partners: Motivations, Perceived Benefits, and Challenges. *Urban Affairs Review, 49*(6), 851–887. doi: http://dx.doi.org/10.1177/1078087413477634

Grow. (2011). *What is a Community Garden?* http://www.grow-ni.org/get-involved/what-is-a-community-garden/

Guitart, D., Pickering, C., & Byrne, J. (2012). Past results and future directions in urban community gardens research. *Urban Forestry & Urban Greening, 11*(4), 364–373. doi:10.1016/j.ufug.2012.06.007

Hasan, M. M., & Nazem, M. N. (2015). Examination of land use/land cover changes, urban growth dynamics, and environmental sustainability in Chittagong city, Bangladesh. *Environment, Development and Sustainability, 18*, 697–716. doi:10.1007/s10668-015-9672-8

Hassan, M. M. (2017). Monitoring land use/land cover change, urban growth dynamics and landscape pattern analysis in five fastest urbanized cities in Bangladesh. *Remote Sensing Applications: Society and Environment, 7,* 69–83. doi:10.1016/j.rsase.2017.07.001

Ten Hoeve, M., Bruun, S., Jensen, L. S., Christensen, T. H., & Scheutz, C. (2019). Life cycle assessment of garden waste management options including long-term emissions after land application. *Waste Management, 86,* 54–66. doi:10.1016/j.wasman.2019.01.005

Islam, K., Rahman, M. F., & Jashimuddin, M. (2018). Modeling land use change using Cellular Automata and Artificial Neural Network: The case of Chunati Wildlife Sanctuary, Bangladesh. *Ecological Indicators, 88,* 439–453. doi:10.1016/j.ecolind.2018.01.047

Jaradat, A., & Al-khashman, O. (2013). Evaluation of the Potential Use of Municipal Solid Waste for Recovery Options: A Case of Ma'an City, Jordan. *Jordan Journal of Earth and Environmental Sciences, 5*(1), 9-16.

Karim, K. R., & T. K. Roy. 2012. Environment of the parks in metropolitan area: A case of Khulna City. *Journal of Social Studies, 135,* 54–71.

Khaza, M. K. B, Rahman, M. M., Harun, F., & Roy T. K. (2020). Accessibility and Service Quality of Public Parks in Khulna City. *J. Urban Plann. Dev., American Society of Civil Engineers. 146*(3): 04020024. doi: 10.1061/(ASCE)UP.1943-5444.0000589

Khurram, F. B., Johora, F. T., Meem, T. M., & Khan, M. S. (2022). Association between nutritional status and mental health among adults during covid-19 pandemic in Khulna City Corporation. *Khulna University Studies, Special Issue ((ICSTEM4IR)* 352-367. doi:https://doi.org/10.53808/KUS.2022.ICSTEM4IR.0055-se

KDA (Khulna Development Authority). (2018). Detailed Area Development Plan (DAP) for Khulna City. Khulna, Bangladesh: KDA.

Kim, G., Miller, P. A., & Nowak, D. J. (2015). Assessing urban vacant land ecosystem services: Urban vacant land as green infrastructure in the City of Roanoke, Virginia. *Urban Forestry & Urban Greening, 14*(3), 519–526. doi:10.1016/j.ufug.2015.05.003

Kim, G., Miller, P., & Nowak, D. (2016). The Value of Green Infrastructure on Vacant and Residential Land in Roanoke, Virginia. *Sustainability, 8*(4), 296. doi:10.3390/su8040296

Krasny, M. & Tidball, K. (2009). Community gardens as context for science, stewardship and advocacy learning. *Cities and the Environment. 2*(1): article 8, 18 pp. doi:10.15365/cate.2182009

Li, W., Zhou, W., Bai, Y., Pickett, S. T., & Han, L. (2018). The smart growth of Chinese cities: opportunities offered by vacant land. *Land Degradation & Development, 29*, 3512-3520. doi:https://doi.org/10.1002/ldr.3125

Lilith, M. (2014). *The Future of Our Food: Community Gardens and Sustainability.* An unpublished dissertation of Research Masters with Training, Murdoch University, Western Australia. https://www.researchgate.net/publication/305865260_The_future_of_our_food_Community_gardens_and_sustainability

Liau, C., 2009. Bangladesh: Urban Public and Environmental Health Sector Development Program (Program Loan). https://policycommons.net/artifacts/400820/bangladesh/1369809/

McCormack, L. A., Laska, M. N., Larson, N. I., & Story, M. (2010). Review of the Nutritional Implications of Farmers' Markets and Community Gardens: A Call for Evaluation and Research Efforts. *Journal of the American Dietetic Association, 110*(3), 399–408. doi:10.1016/j.jada.2009.11.023

Moniruzzaman, M., Roy, A., Bhatt, C., Gupta, A., An, N., & Hasan, M. R. (2018). Impact Analysis of Urbanization on Land Use Land Cover Change for Khulna City, Bangladesh using Temporal Landsat Imagery. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* Dehradun. doi:https://doi.org/10.5194/isprs-archives-XLII-5-757-2018

Németh, J., & Langhorst, J. (2014). Rethinking urban transformation: Temporary uses for vacant land. *Cities, 40,* 143–150. doi:10.1016/j.cities.2013.04.007

Newman, G. D., Bowman, A. O., Lee, R. J., & Kim, B. (2016). A current inventory of vacant urban land in America. *Journal of Urban Design, 21*(3), 302-319. doi:10.1080/13574809.2016.1167589

Pagano, M. A., & Bowman, A. O. (2000). Vacant Land in Cities: An Urban Resource. *Center on Urban & Metropolitan Policy*. https://www.brookings.edu/wp-content/uploads/2016/06/paganofinal.pdf

Rindels, S. (2019). *Gardening for Exercise*. Retrieved from IOWA State University: https://hortnews.extension.iastate.edu/1993/11-10-1993/exer.html

Roy, T. K. (2013). *Report on Collection and Review of Secondary Information for Formulation Phase of the Fecal Sludge Management (FSM) Project in Bangladesh.* SNV-Netherlands Development Organization.

Roy, T. K., Saroar, M. M., Haque, S. M. (2019). Use of Co-compost from Faecal Sludge and Municipal Organic Waste in Urban Green Space Plantation of Khulna City: Prospects and Problems. In: Ghosh, S. (eds) Waste Valorisation and Recycling. Springer, Singapore. https://doi.org/10.1007/978-981-13-2784-1_17

Schilling, J., & Logan, J. (2008). Greening the Rust Belt: A Green Infrastructure Model for Right Sizing America's Shrinking Cities. *Journal of the American Planning Association, 74*(4), 451–466. doi:10.1080/01944360802354956

Shisanya, S. O., & Hendriks, S. L. (2011). The contribution of community gardens to food security in the Maphephetheni uplands. *Development Southern Africa, 28*(4), 509–526. doi:10.1080/0376835x.2011.605568

Soga, M., Gaston, K. J., & Yamaura, Y. (2017). Gardening is beneficial for health: A meta-analysis. *Preventive Medicine Reports, 5,* 92–99. doi:10.1016/j.pmedr.2016.11.007

Urban Partnerships for Poverty Reduction Project (UPPRP). (2011). *Poor settlement in Bangladesh*. Urban Partnership for Poverty Reduction Project. Dhaka: Local Government Engineering Department.

US Department of Energy. (1998). *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings.* Washington, DC (US): Energy Information Administration.

World Health Organization (WHO). (2018). Noncommunicable diseases country profiles 2018. World Health Organization. https://apps.who.int/iris/handle/10665/274512

Yoong, H. Q., Lim, K. Y., Lee, L. K., Zakaria, N. A., & Foo, K. Y. (2017). Sustainable Urban Green Space Management Practice. International Malaysia-Indonesia-Thailand Symposium on Innovation and Creativity (iMIT-SIC), Vol 2, pp. 362- 371.

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REVIEW ARTICLE

SCIENCE &ENGINEERING

SPATIAL DISTRIBUTION OF PARKS AS URBAN GREEN SPACE IN KHULNA CITY: AN ANALYSIS IN CONTEXT OF EQUITY PLANNING

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Abstract

Equitable distribution of parks as urban green space over a city can provide recreational, health and environmental services to city people. This research aims to assess the spatial distribution of parks as urban green space of Khulna City in equity planning. Primary data on existing condition of parks with facilities, user satisfaction level, improvement of existing parks, and proposals for new parks etc. are collected from questionnaire survey of 384 park users and key informants of urban planners, civil engineers and architects from Khulna Development Authority (KDA) and Khulna City Corporation (KCC), the city planning and urban service delivery government organizations. Implementation status of park proposals in 1961 and 2001 City Master Plans, and proposals in the 2018 Detailed Area Development Plan (DAP) along with relevant published research articles, reports etc. are reviewed as secondary data sources. Demand for parks is assessed through Buffer and Network analysis using GIS and also from Threshold Population analysis. Khulna, the 3rd largest industrial city of Bangladesh has about 0.7 million people in its 45.65 sq. km area. There are only 8 parks in Khulna City, most of which are small and cover only 0.15% of total KCC area. Among the 31 KCC Wards, only 7 (23%) Wards, where 27% city people live have parks. The remaining 24 (77%) Wards having 73% city people are deprived of parks. Increased urban population due to rapid urbanization is causing tremendous pressure on the existing limited number of parks. KCC and KDA have not followed equity principles while planning and implementation of park proposals. The parks are mostly found in the Wards having planned and old built-up areas. The existing parks are unable to fulfill the demand of city people. Considering the served, over served and underserved area of existing parks in a more conservative manner, a total of 14 new parks are proposed to ensure equity in planning and development of parks in Khulna City.

Keywords: Parks, urban green space, equity planning, Khulna city, GIS, master plan

Introduction

Parks as open green space are one of the vital elements of any city and its environment, which have a great importance in the daily life of urban people. Parks fulfill the recreational and environmental needs of a city; and promote both the physical and mental health (Roy et al., 2019). Parks help to generate local employment, reduce poverty, foster economic growth and human development (Calderon & Chong, 2004; Cockburn et al., 2013; Gibson & Rioja, 2014; Hooper et al., 2018; Leipziger et al., 2003; Mendoza, 2017; Lee et al., 2015). Bangladesh is one of the most densely populated countries in the world. Due to continuous socio-economic development of the country, it is facing a rapid spreadof urbanization in recent time. People from rural areas nowadays are migrating to urban areas for searching of jobs and better living. This migration is making the urban area overcrowded putting tremendous pressure on the existing service facilities like schools, hospitals, parks and open space, and many more. As the life of urban people has been more mechanized, there is a pressing need for relaxation. Though urban areas have some parks, they are not sufficient because of over population. Sometimes the city people have low access to the parks for the prevailed poor environment and facilities due to lack of proper maintenance or for security issues (Karim & Roy, 2012; Roy, 2013). Improper road network or connection services sometimes may cause the accessibility problem. Parks and open green spaces are very necessary for urban people as without proper relaxation, people are losing their working efficiency day by day. So, planning and development of urban parks is very much essential and

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for that, urban planners of Bangladesh need to be more focused on equity and accessibility-based planning of parks (Ferdous et al., 2016; Istiaque et al., 2018). Khulna city is located in the southwest coastal region of Bangladesh, which is expanding day by day (Haque et al., 2019). The urban population of Khulna city is also growing due to rural-urban migration and natural growth. Its population now in 2022 is 718,735, which was 663,342 in 2011(BBS, 2015a; BBS, 2022).Total area under the existing 8 parks of Khulna city is only 24.54 acres.

Inequal distribution of infrastructure and services delays and retards the socio-economic and environmental development of an area. The implications of unequal distribution of facilities include deprivation of citizens from government services, failing to attract investment for grasping the fruits of development, and continuing the cycle of provision of inadequate services and facilities etc. (Calderón & Chong, 2004; Howlader et al., 2018). Extreme inequality is detrimental not only to poverty alleviation but also to the attainment of sustained socio-economic growth (Bebbington et al., 2008). Political favors and decisions led by local politicians influence development of infrastructure and economic activities in the cities or regions and thereby creates spatial inequality (Shefer & Antonio, 2013; Sridharan, 2011). Targeted investment and public spending decrease infrastructure inequality (Simon & Natarajan, 2017).Parks as public green spaces provide many social benefits. Park social services help to refrain the children, youths, and even adults from anti-social activities. An urban society having adequate number of parks as social public open space becomes socially sound and sustainable resisting social unrest situation and bringing social peace.

As parks are the main source of recreation and greatly contribute to better health of urban people, the demand for parks is increasing with the increase of population and urban functions (Tabassum & Sharmin, 2013). So, it should be ensured that parks and open spaces are equitably distributed over the city and adequately accessible to all categories of people. There are 520 slums in Khulna city, where 188,442 (about 25%) poor and landless people live. Population density per sq. km in the slum areas is 132,988 (CUS, 2006). But there exists acute shortage of urban open green spaces of parks and playgrounds in Khulna city (Rahman & Salauddin, 2009). There are no parks in the nearby areas of most of the slums. There are only four freely accessible small children parks in Khulna City, among them Golokmoni Shishu Park has only 0.06 acres and Nirala Park has only 0.40 acres land. Recreational use of parks largely depends on different attributes like land use patterns, travel time and travel cost to reach the parks (Litman, 2022). Dhaka Metropolitan Development Plan (DMDP) 1995 recommended only 0.16 acres for every 1000 population. They had to fix such a low standard because of high scarcity of vacant land in and around the city. Urban Development Directorate (UDD) in 1985 by its zila and upazila planning project fixed a reasonable standard of 1 acre per 1000 population for the district and upazila level towns. Though several plans were prepared under the project, none was executed. The 1961 Master Plan of Khulna city recommended 4 acres of open space for every 1000 population, where 2 acres for parks and 2 acres for playgrounds. But this target could not be achieved because of non-execution of open space proposals. The 1961 situation of Khulna city has undergone substantial changes. Now it is extremely difficult to find a sizable chunk of vacant land in the city for use as a Central Park. At the same time, the need for open space for future population cannot be ignored. Considering the foregoing discussion of standard provisions, availability of resources and usable space, the 2001 Master Plan of Khulna city recommended 2.71 acres open space per 1000 population.

Khulna Development Authority (KDA) and Khulna City Corporation (KCC) are mainly responsible in planning, development and management of parks in Khulna City. KDA prepares land use-based city master plan where lands are demarcated in different locations for parks and open green spaces. In spite of having significance and potentials of Khulna City, over the last 60 years, all the concerned government organizations mainly KCC and KDA took very little initiative to establish more parks in Khulna city. Existing environment and facilities of the parks need to be improved with utmost care so that maximum number of children and city people can optimally use the parks for their mental refreshment and sound health. There exists no formal sizable park in Khulna city that a metropolitan city should have. There is no metropolitan or regional level park within the Master Plan area too. The existing open spaces in the city are scattered in small pieces and mostly used as play lots, neighborhood parks and playgrounds. The Park-Cum-Zoo at Gilatala is quite large, but it is outside of the KCC area. Its area is about 40 acres. But its distance from the main city and non-availability of easy transport mode makes its accessibility difficult for a large segment of city dwellers living in the far-off areas of the city southern part.

As per the planning standard of KDA 2001 Master Plan of 2.71 acres land for 1000 population, a total of 1327 acres land area is required for Khulna city. Likewise, according to the planning standard of WHO, 2012 (2.2 acres park area for 1000 population), a total of 1459 acres land area is required. According to the planning standard of the Private Housing Project Land Development Rule 2004 (3 acres park area for 25000 population), a total of 80

acres land area is required for the parks of Khulna city. The number, category, size and equitable distribution of the parks are considered and adjusted calculating the land area obtained from different planning standards.

Materials and Methods

Data Collection and Analysis

The data for this study was collected both from field survey of existing parks and from KDA and KCC. Data on existing facilities and conditions of the parks, satisfaction level of the users in terms of locational suitability and service-facilities, problems of the parks and recommendations to solve the problems etc. were collected from the field as well as from relevant studies conducted by Khulna University (KU), Khulna University of Engineering and Technology (KUET), KDA and KCC, where the researchers of this study are also the key contributors. A total of 384 park users were surveyed using a semi-structured questionnaire. Geographic Information System (GIS) was also used for analysis and preparation of maps, where the shape files of Khulna city land use were collected from KDA. Different methods like Multiple Ring Buffer, Network and Threshold population analysis were also followed. Under the study, Key Informant Interview (KII) was conducted with the Civil Engineers, Urban Planners and Architects of KCC and KDA; and Civil Society representatives to get their opinions and views on the planning aspects and existing condition of the parks as open green space. Their suggestions for creation of more parks and open green space for Khulna city were documented. Parks and open green space proposals and related issues highlighted in 1961 and 2001 Khulna City Master Plans and 2018DAP were also reviewed. Field visits of some proposed sites for parks and open space were conducted. Books, journals, reports etc. on parks and open green space collected from internet and other sources were reviewed. Data was processed through Statistical Package for Social Sciences (SPSS) and Microsoft Excel.

Results and Discussion

Khulna City as Study Area and its Parks

Khulna, the third largest city of Bangladesh is basically a linear city. The city is located on the bank of two rivers- the Rupsha and the Bhairab (Istiaque et al., 2018). It lies between $22^0$47´16´´ to $22^0$52´ north latitude and $89^0$31´36´´ to $89^0$34´35´´ east longitude (Karim & Roy, 2012). The city covers an area of 45.65 sq. km with a population of 718735(BBS, 2022; KCC, 2018). It is divided into 31 Wards. In Khulna, there are some facilities like parks, Rupsha Bridge, cinema, New Market and open green spaces for recreation of the city dwellers. But for this research, public parks are chosen as urban green spaces. There are 8 public parks in KCC area, which are highly unequally distributed (Roy 2012; Howlader et al., 2018).

The parks are Hadis Park, Jatisangha Shishu Park, Wonderland Amusement Park, Sonadanga Residential Park, Nirala Park, Golokmoni Shishu Park, Solar Park and Mujgunni S S World Shishu Park. Figure1 and Table 1 show that out of the 31 KCC Wards, only 7 (23%) Wards have parks. Shahid Hadis Park and Golokmoni Shishu Park are located in the old built-up areas. Whereas Sonadanga Residential Park, Nirala Park, Solar Park, Mujgunni S S World Shishu Park and Wonderland Amusement Park are located within and near the planned residential areas developed by KDA and National Housing Authority (NHA).

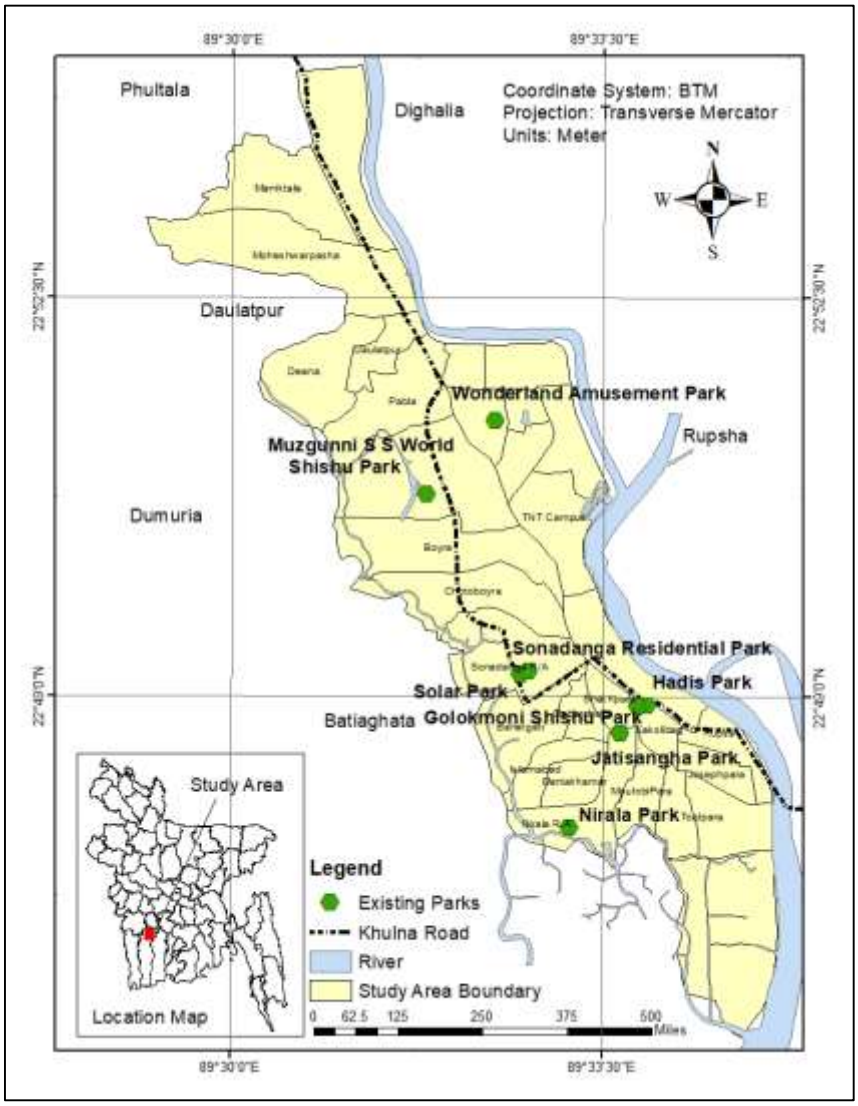

Figure 1. Khulna city and its existing parks

KCC established Solar Park on 4.33 acres land at the eastern side of Sonadanga Second Phase Residential Area and western side of Sonadanga First Phase Residential Area-two planned residential areas developed by KDA in 2007 and 1981 respectively. The park is developed on the land reserved for development of a lake in the design layout. The park has different types of facilities such as slippers, sitting benches, gates and public toilet etc. (Karim & Roy 2012). There is a lake in the middle, one pump house of KWASA (Khulna Water Supply and Sewerage Authority) and one Khulna Renewable Energy Production Workshop cum Training Centre in the park. Internal road and drainage condition of the park is good. Nearby city people use the park for jogging and passing leisure time in morning and evening.

In 2016, KCC has developed a linear park on 14acres land along the western bank of Mayur River just from the north of Gallamary Bridge and eastern side of Khulna University. It is outside of KCC area but adjacent to Ward no. 18 and very close to Ward no. 24 and 25.Leasing out the park to private operator and entry fees amounting BDT 40 per person exclude a large section of marginalized people from using the park (Das et al., 2022). In 1999, KCC has developed another park like amusement spot centering the Bastuhara Lake at the northern side of Bastuhara colony in Muzgunni area. It is located in Ward no. 9. KCC has placed sixround shaped sitting benches

with umbrellas at the eastern bank of the lake. Local people have named the amusement spots Choy Chati Park (Six Umbrella Park) and Sampan Lake as once few Sampan boats were available for visitors.

Table 1. Parks of Khulna city with basic information

Name	*Area (acre)*	*Year of establishment*	*KCC Wards*	*Type*	*Main users*	*Surrounding land use*	*Entry fees*
Hadis Park	5.38	1884	21	Metropolitan park	All people	Commercial	No
Jatisangha ShishuPark	1.13	1994	27	City park	Children	Commercial & Residential	No
Wonderland Amusement Park	3.78	1994	11	Amusement park	Children	Residential	Yes
Sonadanga Residential Park	0.46	1981	17	Neighborhood park	All people	Residential	No
Solar Park	4.33	1999	17	Neighborhood park	All people	Residential	No
Nirala Park	0.40	1980	24	Neighborhood park	All people	Residential	No
Golokmoni Shishu Park	0.06	1960	23	City park	Children	Commercial & Residential	No
Mujgunni S S World Shishu Park	9.0	2006	9	Amusement park	Children	Residential	Yes
Total	24.54						

Source:Karim & Roy, 2012; KDA, 2018;Khaza et al., 2020

Situation regarding availability of parks and green spaces in and around the slum areas of Khulna city is naturally worse. Most of the slum and squatter settlements are found to develop on lands which are normally not suitable for development of shelters or human habitation. Such lands are low lying marshy land, vacant and barren lands next to railway tracks, roadsides and drainage lines etc. (Mowla, 1999). Ward no. 24, 21, 22, and 9 have a higher slum population than other Wards of 7747, 6780, 5927 and 5448 respectively (BBS, 2015b). Only Ward no. 24, 21 & 9 have parks and open spaces. However, these parks are mostly utilized by the higher-income people and have limited applicability to the lower-income people. Lack of education and awareness about the benefits of visiting green spaces of slum people contributes to the low level of use of the parks. Ward no. 24 with a slum population of 7747 has only a small park (Nirala Park on 0.40 acres land), which is primarily used by the residents of Nirala planned residential area. Ward No. 21 having well facilitated, beautifully landscaped, and mostly used Shahid Hadis Park is the most privileged Ward in Khulna city with a slum population of 6780. Considering Hadis Park as one of the significant factors of convenience, Ward no. 21 contributes about 33% contribution to urban convenience, which is about 10 times higher than the expected uniform contribution value of 3.23%.The businessmen and service holders mostly living in Ward no. 21 and its surrounding Wards use Hadis Park for their physical exercise, jogging, and recreation (Howlader et al., 2018). Ward no. 22 having a slum population of 5927 has no open space facility for its residents. Similarly, Ward no. 9 having a slum population of 5884 has Mujgunni S S World Shishu Park. But the entry ticket system costing BDT 70 makes it difficult and inaccessible for the slum dwellers. Concisely, higher transport costs, inadequate transportation infrastructure and entry ticket system at several parks costing between BDT 50-100 make the parks inaccessible to slum and low-income community people (Khaza et al., 2020). Many of the slum clusters are too crowded and densified that there is hardly any open space for further growth and expansion. The lanes or alleys are very narrow and zigzag (Mowla, 1999). Even the slum children cannot use the alleys for their play and recreation. So, parks and open spaces are very much essentials in and around the slum and low-income settlement areas. Consequently, safety and security considerations are a major concern for parks located near slums (Türtseven Doğrusoy & Zeynel, 2017). Authorities should take some security measures (such as 24-hour surveillance) to strengthen the park safety and security for the visitors. Only equity planning based

equitable distribution of parks over Khulna city can ensure socio-environmental justice and accessibility of slum and low-income people to the parks and green spaces.

Equity and Equity in Planning of Parks as Urban Green Space

The concept of equity is a prescriptive approach for the fair, equal and social justice; moral equal treatment; fairness in distributions; equal opportunities or burdens for comparable individuals; and equal respect and equal treatment for individuals (World Bank, 2006; Jones, 2009; Rawls, 1921; and Dworkin, 1983). The government provides essential services and facilities to all its citizens. But in many cases the services and facilities are found unevenly distributed. The more powerful groups capture all the benefits and thus inequity occurs. According to Green & Allen (2008), many of the markets are focused on freely-selected and voluntarily interactions in which individuals achieve or lose in accordance with their attempts and capacities. Inequality occurs when the institutions and their measures are not beneficial; social welfare organizations are inefficient; and political organizations that represent current constructions of political and economic authority within a community are involved in the affairs of unfair, unjust, biased and corruptions (World Bank, 2006).The state of inequality is multidimensional and hard to quantify. Widespread of inequality in developing nations throughout the world is found beyond the normal range (Jones, 2009; Ferreira & Gignoux, 2011).

In equity planning, urban planners use their expertise to impact opinions, mobilize under-represented constituencies and develop strategies and programs that redistribute public and private funds among the impoverished and working groups (Metzger, 1996). According to Davidoff (1965), planning process is a tool for the resolution of the debate on "justice for current social assignment of wealth, knowledge, ability and other social products" where "the right course of action is always an issue of choice, never of fact". The equitability of urban green resources among different social groups is a serious issue of both government and scholar for social and environmental equity (Xiao et al., 2017). The relationship between physical and socio-economic aspects and the significance of equity in access and difficulties is actually the socio-economic consequences. In particular, equity research or 'who should get what' include a number of measures: 1) equality-all residents should have equal opportunity; (2) need-some groups such as low income, minorities, elderly, and children have greater need for services; (3) demand-some groups tend to use parks and trails more than others; and (4) gentrification-instability of local strategies when demographic changes in the neighborhood (Nicholls, 2001; Slater,2004; Talen, 2002). The beneficial impact of parks on property values can, however, lead to competition between financial gain and the equity consequences of affordability of housing and displacement of people.

Social justice of parks is a justice of availing social benefits of parks by all the social groups mainly poor and disadvantaged slum and low-income settlement people. If the parks are not well planned and distributed considering the aspects of social equity, a large share of urban people are excluded and deprived of the social benefits of the parks. Parks as green landscapes provide the city people with various social benefits to improve the quality of life (Chiesura, 2004; Larson et al., 2016). Urban parks promote leisure activities, encourage physical activities, enhance social interactions among different communities, reduce stress and improve both physical and mental health (Barbosa et al., 2007; Akpinar et al., 2016; Richardson et al., 2013; Pazhouhanfar, 2018). The National Recreation and Park Association of USA in a comprehensive review done in 2011 found inequity in park provision (Godbey & Mowen, 2010; Feng et al., 2019; Lee et al., 2015).

According to the Millennium Ecosystem Assessment urban parks can augment social equity as the parks create and maintain public spaces with natural environment for social interactions (Carpenter et al., 2006; Zhao & Zhang, 2006). Social equity and environmental justice can only be ensured if all category city people must have easy and equal access to the public parks. Though in reality it is quite difficult, it can be done in a reasonable spatial distribution manner if the concerned city planning and development organizations namely KDA and KCC consider the social equity and environmental justice issues through their urban planning and policy development instruments. Physical closeness can also not be an indication of a park's usefulness, since the views of prospective customers about the safety or exclusionary atmosphere of a park can actually restrict their access. A study conducted by Carr & Williams (1993) reveals that individuals feel more comfortable and secure to use such parks, in which they see most of the individuals like themselves. Feng et al. (2019) in a study in Beijing, China has shown that accessibility to urban parks varies at district and sub-district levels. Areas with more parks have higher use and accessibility. The study also found that there exists a mismatch between spatial distribution of parks and population, specifically for the elderly residents. The valuable insights of the study are that many developing countries including China currently use only

the public green space ratio to urban construction land and per capita public green space in planning of parks and other public green spaces.

Open Green Space Standards for the Cities of Bangladesh and Other Countries

In determining standards for open green space consideration must be given to two major issues –first, future requirement of open green space and second, availability of vacant land. However, before fixing up standard a review of open green space standards of urban plans of various towns and cities in Bangladesh and abroad is done. The ratio of open space for Khulna city per 1000 population was only 0.40 acres in 1961 and 0.10 acres in 2001, both of which are miserably low compared with urban open green space standard in any country. Khulna City Master Plan of 1961 and 2001 prepared by KDA recommended a standard of 4 acres and 2.71 acres open green space respectively per 1000 population with a good number of open space and green proposals. An emerging megacity, Dhaka should have at least 25 percent of its total land as open green space; but as of now, less than 10 percent of its land, is allocated as open green space.

Table 2. Open space and green standard in cities of Bangladesh and abroad (acre per 1000 population)

Abroad	Bangladesh								
	Dhaka			Zila/ Upazila towns			Khulna		
Hong Kong	DMDP 1995	DAP 2009	DAP 2021	UDD 1985	Master 1961	Plan	Master 2001	Plan	DAP 2018
0.71	0.16	0.13		1.00	4.00		2.71		0.45

Source: KDA, 1961; Khan, 2019; *KDA, 2002; and Preetha, 2011*

The Detailed Area Plan (DAP) of RAJUK (Rajdhani Unnayan Kartripakkho) for Dhaka city approved in 2010 proposed only 0.13 acres of parks and open space for 1000 population, which is significantly lower than the WHO recommendation of 4.23 acres per 1000 population. A reasonable standard (1 acre per 1000 population) was fixed by Zila and Upazila Planning project of Urban Development Directorate (UDD), 1985 for district and upazila level towns of Bangladesh. Whereas Hongkong, the most crowded city in the world provides on average 0.71 acres per 1000 population, which is five times more than the amount proposed by DAP for Dhaka (Preetha, 2011).

Development of public park was one of the policy recommendations of the Master Plan and Structure Plan for the improvement of open green spaces in Khulna City. The Detailed Area Development Plan (DAP) has also set some planning principles and standards for the existing and new urban areas. The 2001 Khulna Master Plan proposed in total 1970.70 acres (797.85 ha) of land for parks and open green spaces for the Master Plan area, where 284.70 acres land was proposed for metropolitan and community level parks within KCC area (Table 3). Considering 2.71 acres of open space for every 1000 population as too ambitious, the DAP has brought down the standard to 0.45 acres land for 1000 population. According to this standard, 798 acres of land would be required to preserve as open space and recreation by the year 2023 for 1662294 population of the Master Plan area. Currently, there has only 179 (72.47 ha) acres of recreational open space. Therefore, additional 619 acres of open space of different categories will be needed to serve the projected population (KDA, 2018).

Proposals of Open Green Space in Khulna City Master Plans and Their Implementation

Open Green Space Proposals of 1961 Master Plan

As indicated by the 1961 Khulna City Master Plan prepared for an area of 181 sq. km. for the period of 1961-1980, the available open space per 1000 population in 1961 in Khulna city was only 0.40 acre. The population in 1961 of Khulna city was140000 and there was only 56 acres of public open space in the city at that time. The plan recommended 1566 acres of open space in the form of park, stadium and playfield based on a standard of 4 acres per 1000 population. On review of 1961 Master Plan implementation, it is revealed that only about 97 acres of open space proposals have so far been implemented which is only 6 percent of the total land earmarked as open space. The only major open space proposal implemented is the divisional stadium at Boyra. Lack of awareness for the need of open space and scarcity of fund are found to be the major reasons for failure to implement open space proposals (KDA, 1961; KDA, 2001; Roy, 2012).

Open Green Space Proposals of 2001 Master Plan

The Khulna City Master Plan 2001 encompasses those areas of Structure Plan coverage that are apprehended to be the most potential for urban growth and agglomeration during the period of ten years (2001-2010). The plan serves as a basis for overall development and land-use based development control of the city. The Master Plan covers an area of 231.67 sq. km. including45.65 sq. km. of KCC area. Structure Plan is the second basic document of the plan package, which sets forth the spatially translated policy, framework for the future Metro-Khulna for a period of 20 years (2001-2020). Open green spaceis a new but a major land use in city Master Plan. Major open space land use provision includes parks, playground, botanical garden and natural greens. A total of 1970.70acres land was proposed for open space use.

Small parks and playgrounds were proposed spread all over the Master Plan area. Metropolitan Park, natural green and botanical garden were put in locations where sufficient vacant land was available for such uses. Open space in the current Master Plan, combining current and proposed, has been categorized as, Metropolitan and Community Level Park; Natural Green and Waterbody/Riverfront Green; Roadside green/Urban Forest/Garden; and Botanical Garden and Zoo/Amusement Park.

Metropolitan and Community Level Parks

The main purpose of Metropolitan Park is to serve as a place of passive recreation at city level, with centrality of its location. It is extremely difficult to find such a large vacant place within the core area of the city that can be used as a Central Park.

After thorough investigation the Master Plan sited the main metropolitan park on 88.42 acres land within the city corporation area at the railway station yard by the side of the Bhairab River. Plenty of land at this place is lying unused. There exist about 15 acres of khas land at the southeast side of Central Storage Depot (CSD) area by the railway line. The land is still found unused. The Plan also suggested converting the land into a metropolitan park with an access road. In absence of large enough land in the central area, there is no option but to go for decentralization of parks at community level. Another advantage of decentralization is to provide easy access of the local people to park facilities. The size of community park varies from 8 acres to over 37 acres.

Open Green Space Proposals of 2018 Detailed Area Development Plan (DAP)

Like the Master Plan and Structure Plan, DAP also has proposed parks at two levels: local level and metropolitan level. One local level park has been proposed for each planning zone. But in a few zones, adequate vacant land is not available to develop parks. Each local level park comprises minimum of 5.12 acres land. In seven planning zones no parks have been proposed due to non-availability of vacant or free space.

DAP has proposed three metropolitan level parks, one water world park and 20 local level new parks for the entire planning zones. Out of the total 20 local level parks on 113.86 acres land, 4 parks on 22.08 acres land have been proposed for KCC area. Among the 4 parks, one park is for Ward no. 1, 2 and 3; one for Ward no. 4; one for Ward no. 5 and 6; and one for Ward no. 9. The 3 metropolitan level larger parks have been proposed on 394.67 acres land and the water world park has been proposed on 24.15 acres land. As the south and southwestern peripheral areas of DAP are the most potential for future urbanization, emphasis has been given to propose parks in those areas (KDA, 2018). Other parts of the Master Plan area are either not suitable for park or adequate space is not available there. If KCC and KDA implement the park proposals of 2018 DAP, Khulna city will have more parks and green space.

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Table 3. Proposals and implementation of metropolitan and community level parks

Sl. No.	Park Type with Proposed Location	Area (Acre)	Recommended Implementation Phase		Implementation Status
			Phase-I (2001-2005)	Phase-II (2006-2010)	
Metropolitan Level Park					
1.	Railway Yard, Central area of Khulna city (Ward no. 21)	88.42	√	-	Not Implemented
2.	Southeast of Central Storage Depot (CSD),Boyra (Ward no. 14)	15.00	√	-	Not Implemented
Sub-Total		103.42		-	
Community Level Park					
1.	Boyra, Northwest of Medical College Hospital, Boyra ((Ward no. 16))	8.00	√	-	Not Implemented
2.	In front of Lion's School, Gallamariin Dubi and Baniakhamar mouza (Ward no. 24)	37.00	√	-	Not Implemented
3.	Maheshwarpasha in Maheshwarpasha mouza (Ward no. 01)	17.20	-	√	Not Implemented
Sub-Total		181.28			
Grand Total		284.70			

Source: KDA, 2002.

Parks as Green Space of Khulna City in Terms of Equity Planning

Many researchers have investigated into the accessibility and quality of park services in a number of different ways. Scholars in a few studies used ArcGIS's buffer analysis feature to determine park service areas (Nicholls 2001; Smoyer-Tomic et al., 2004; Oh and Jeong 2007; Kun et al., 2012; Saleem and Ijaz 2014). Nonetheless, this approach has severe drawbacks (e.g., assume that all parks are of equal size, linear service distance, no interruption into service area). When conducting a buffer analysis, the service area is determined solely by the locations of the parks. Thus, an approximate service area for the parks is estimated. In contrast, Network analysis has been utilized in several studies to determine park service areas (Nicholls 2001; Oh and Jeong 2007; Unal et al., 2016). When calculating the parks' service area, network analysis is more reliable than buffer analysis since it considers both park accessibility and park location. Alternatively, several studies estimated the total number of parks necessary to serve all residents based on a threshold population (Haggett and Gulzawardena, 1964). Some studies also included appropriateness analysis to determine whether the location of parks is optimal for serving the greatest number of individuals (Nejati et al., 2015).

Multiple Ring Buffer Analysis

According to the Information Report by Moeller (1965) of the American Society of Planning Officials, the service radius of a neighborhood park should be 0.5 mile or about 800meters.Performing Multiple Ring Buffer Analysis with 1000m radius, it is seen that 12.55 sq.km area is served by the existing 8 parks and the rest 33.10sq.km area remains unserved. If it is expressed in percentage, only 27.49% area is served by the existing parks and 72.51%area remains unserved. In the Sonadanga, Sheikhpara and Kakolibag, there exists some over-served area. According to 1000m buffer, total 29 parks are needed for the KCC area and here the service gap is 21. Parks are more needed in Maniktala, Moheshwarpasha, Deana, Daulatpur, Boyra, Moulovipara, Tutpara, Josephpara, Rupsha and Labonchara

as there exists no park in these areas. So, it is clear from the analysis that the amount of served area by the existing parks is quite unsatisfactory.

Network Analysis

From the Network Analysis with 1000m service distance, it is seen that about 8.29 sq.km area is served by the existing 8 parks. Rest 37.36 sq.km area is not served by the parks. If it is expressed in percentage, 18% area is served and 82% area remains unserved. In Sonadanga, Sheikhpara and Kakolibag, there exists some over-served area. According to 1000m service distance, total 44 parks are needed and the service gap is about 36 parks. This analysis indicates that the road networks of the existing parks are not so good. More parks should be developed with good road networks for increasing the accessibility of the people of all classes.

Threshold Population Analysis

According to threshold population analysis, total 27 parks are needed for the 663342 population of KCC. But there are only 8 parks which indicates the service gap of 19 parks. According to the Private Housing Project Land Development Rule 2004, 3 acres park area is needed for 25000 population. As 25000 is the threshold population, the required parks should be of around 3 acres land area for fulfilling the demand of existing population.

The Multiple Ring Buffer Analysis with 1000m radius, Network Analysis with 1000m service distance and Threshold Population Analysis with 3 acres area for parks for 25000 population mentioned above determine the number and area of new parks for Khulna city. Considering the served, over served and underserved area a total of 14 new parks are proposed for Khulna city.

The 24 (77%) Wards where about 73% city people live have no parks and the people of these Wards are deprived of the park facilities. The existing parks cover only 0.15% land area of KCC, which should be at least 10%. This situation clearly shows the inadequacy of parks in Khulna city to cater the park services to the maximum number of city people. Besides, slum and low-income settlement area people are very much deprived of park facilities, as there are no parks in and near of the most of the slums and low-income settlements.

Level of Satisfaction and Dissatisfaction for the Parks

Satisfaction level of the park users was assessed through a questionnaire survey. It is seen by the Figure 2 that only Solar Park, Wonderland Amusement Park, Hadis Park and Sonadanga Park have slightly greater percentage of positive response. Lack of proper sanitation or toilet facilities are the main cause of dissatisfaction to these parks. Also, the parks have no or a very few number of rides. About 94% users of Mujgunni S S World Shishu Park are found dissatisfied due to a lack of authority control over the park environment. Majority of neighborhood residents avoid this park. Therefore, authorities should focus on maintaining the environment and transforming it back into a children's park.

There exists inadequate solely designed play space in the neighborhoods and so, children are to play on roads (Miah and Sultana, 2022).In case of Golokmoni Shishu Park, there is nothing except a vacant land with a boundary. About 90% users are dissatisfied to this park.Figure 2 shows that Jatisangha Parkand Solar Park have very high positive response by the 86% and 77.8% users respectively, because Jatisangha Park and Solar Park have facilities and rides. The parks have only lack of sanitation facilities and the park spaces are relatively small. About 80% respondents of Nirala Park have said that they are facing lack of facilities in the park.So, overall satisfaction level of the parks of KCC area is average except the Mujgunni S S World Shishu Park and Golokmoni Shishu Park. Authorities should take proper steps to satisfy the park users.

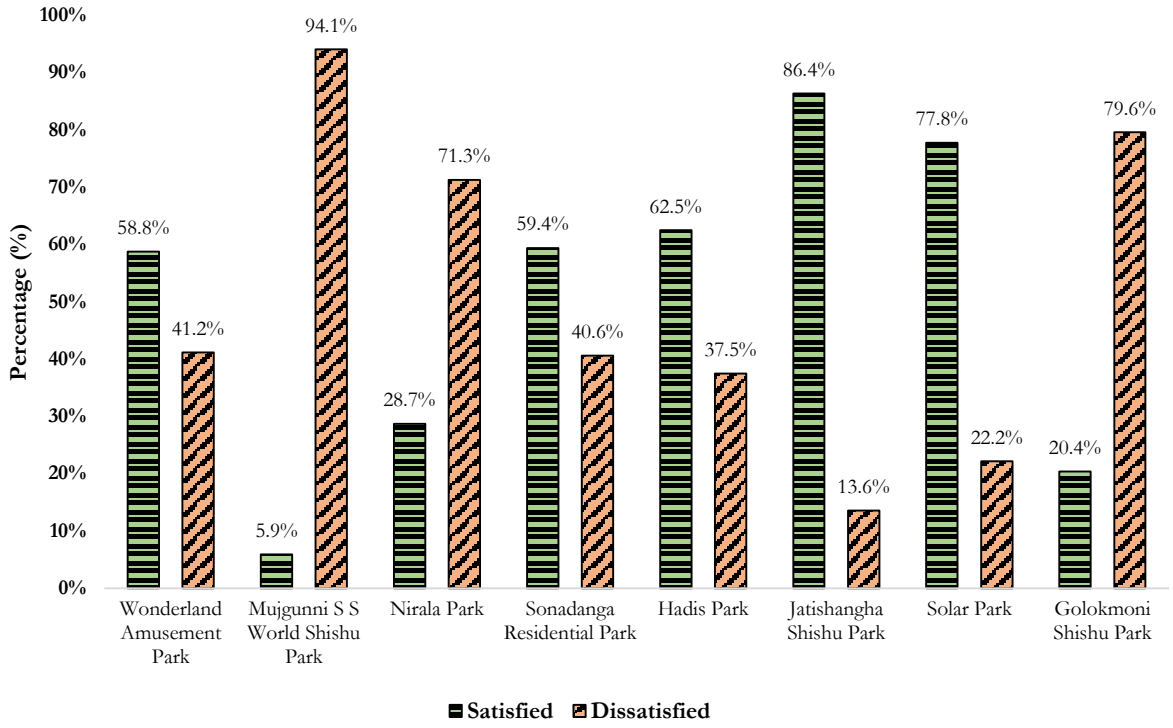

Figure 2. Satisfaction level of the park user

Figure 3 shows that new parks have been proposed in Ward no. 1, 2, 3, 4, 5, 7, 15, 16, 25, 27, 29, 30 and 31. At Ward no. 10, there is Wonderland Amusement Park, which serves the surrounding area (Ward no. 10, 11 & 12 and some parts of Ward no. 7, 8 & 13).At ward no. 9, there is Mujgunni Park, which provide services to Ward no. 9 and some parts of Ward no. 6, & 14. At Ward no. 17, there are two parks named Solar Park and Sonadanga Residential Park, which serve Ward no. 17 & 18. Hadis Park and Golokmoni Shishu Park are located almost at the same place, which serve Ward no. 20, 21 & 23. Jatisangha Park serves some parts of Ward no. 19, 20, 23, 24, 25 & 27.Again, Nirala Park serves some parts of Ward no. 24, 25 & 26. From the analysis, it is seen that there are some overserved areas by the existing parks.For over served areas, the calculations of service gaps have been affected. So, it can be said that the total number of proposed parks and existing parks can serve the whole area of Khulna. That is why the proposed number of parks is 14, which is quite justified.

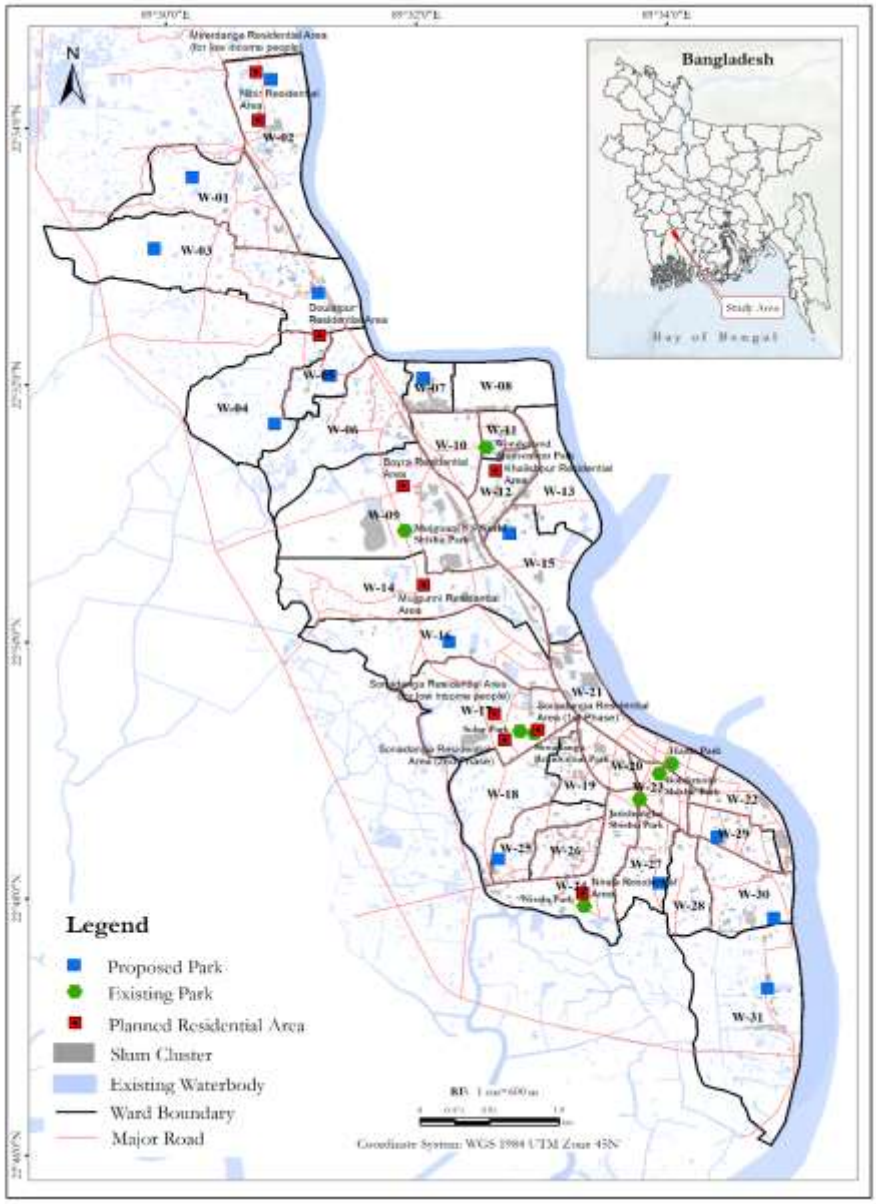

Figure 3.Proposed parks for Khulna city in context of planned residential area and slum clusters

Conclusion

Parks are one of the important components of neighborhood landscape which provide the residents with relief from chaos of the built environment. There were a number of parks and green open space proposals in 1961 and 2001 Khulna City Master Plans. But, their level of implementation is quite unsatisfactory. The main reasons for inadequate and inequal distribution of parks in Khulna city are: lack of coordination and initiatives of KDA, KCC, Forest Department (FD) and other organizations for review of the green space proposals of Khulna City Master Plan and design project proposals for their implementation; lack of awareness of city people and concerned organizations on the needs of parks and open green space in city life and the clear roles of the organizations regarding creation of parks and open green space; lack of commitment of local political leaders and policy makers

for granting allocations for parks; scarcity of funds of concerned organizations i.e. KDA, KCC, FD, DoE and others for developing parks and open green space; and inadequate institutional set up of KDA and KCC mainly with urban planners, architects and civil engineers who are technically and academically motivated towards the needs and provision of parks and open green space for city people. The organizations mainly KCC and KDA should acquire the vacant and non-built-up areas which are generally proposed for parks and open green space to gradually develop parks over the years. It will lessen the acquisition cost and make the land available for parks and open green space. It will also resist the uncontrolled development by the private land owners. Parks can be created in all the KCC Wards to provide park services to all categories of city people. Strict regulatory enforcement should be exercised not to allow any development on the designated sites of river and water bodies till the lands are taken over for the development of open green space projects. Only agriculture or forest related activities may be allowed for the interim period. KDA and KCC can control and monitor such developments using the regulatory instruments namely City Master Plans, EBBC Act 1952, Town Improvement Act 1953, KDA Act 2018, Local Government (City Corporation) Act 2009 and other executive orders. The study through the buffer, network and threshold population analysis finds that the amount of service area of the existing parks is quite unsatisfactory which indicates the need for development of more parks in Khulna city. As KDA and KCC are solely responsible for the planning and development of Khulna city, they should take necessary steps to influence the policy and administrative decisions for investing more on park projects in the deprived Wards for the recreational, health and environmental development of Khulna city in an equitable manner.

Conflict of Interests

The author declares no conflict of interest.

References

Akpinar, A., Barbosa-Leiker, C., & Brooks, K. R. (2016). Does green space matter? Exploring relationships between green space type and health indicators. *Urban Forestry & Urban Greening*, *20*, 407-418. doi:https://doi.org/10.1016/j.ufug.2016.10.013

Barbosa, O., Tratalos, J. A., Armsworth, P. R., Davies, R. G., Fuller, R. A., Johnson, P., & Gaston, K. J. (2007). Who benefits from access to green space? A case study from Sheffield, UK. *Landscape and Urban planning*, *83*(2-3), 187-195.doi:https://doi.org/10.1016/j.landurbplan.2007.04.004

BBS (Bangladesh Bureau of Statistics). (2015a). *Population & housing census-2011 (Community Series, Zila: Khulna)*. Dhaka, Bangladesh: BBS. http://www.bbs.gov.bd/site/page/47856ad0-7e1c-4aab-bd78-892733bc06eb/Population-and-Housing-Census

BBS (2015b). *Census of Slum Areas and Floating Population 2014*. Dhaka, Bangladesh: BBS. http://www.bbs.gov.bd/site/page/cc276201-9150-4e9a-a4a8-7cda87287e13/Slum-Census-2014

BBS (2022). *Population & housing census 2022 (Preliminary Report)*. Dhaka, Bangladesh: BBS. http://www.bbs.gov.bd/site/page/47856ad0-7e1c-4aab-bd78-892733bc06eb/Population-and-Housing-Census

Bebbington, A. J., Dani, A. A., De Haan, A., & Walton, M. (Eds.). (2008). *Institutional pathways to equity: Addressing inequality traps*. World Bank Publications.

Calderón, C., & Chong, A. (2004). Volume and quality of infrastructure and the distribution of income: an empirical investigation. *Review of Income and Wealth*, *50*(1), 87-106. doi:https://doi.org/10.1111/j.0034-6586.2004.00113.x

Carpenter, S. R., DeFries, R., Dietz, T., Mooney, H. A., Polasky, S., Reid, W. V., & Scholes, R. J. (2006). Millennium ecosystem assessment: research needs. *Science*, *314*(5797), 257-258.doi: 10.1126/science.1131946

Carr, D. S., & Williams, D. R. (1993). Understanding the role of ethnicity in outdoor recreation experiences. *Journal of Leisure Research*, *25*(1), 22-38. doi:tps://doi.org/10.1080/00222216.1993.11969907

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and urban planning*, *68*(1), 129-138.doi:https://doi.org/10.1016/j.landurbplan.2003.08.003

Cockburn, J., Dissou, Y., Duclos, J. Y., & Tiberti, L. (Eds.) (2013). Infrastructure and economic growth in Asia. Cham, Switzerland: Springer. doi:10.1007/978-3-319-03137-8

CUS (2006). Slums of Urban Bangladesh-Mapping and Census, 2005. Dhaka, Bangladesh: Center for Urban Studies (CUS)

Das, A., Sen, A. K., & Khan, N. M. (2022). Challenges of accessibility for marginal people in privately operated public space: linear park, Khulna as a case. *Khulna University Studies*, 19(2), 16 pages. https://doi.org/10.53808/KUS.2022.19.02.2143-se

Davidoff, P. (1965). Advocacy and Pluralism in Planning. *Journal of the American Institute of Planners, 31*(4), 331–338. doi:10.1080/01944366508978187

Dworkin, R. (1983). Comment on Narveson: in Defense of Equality. *Social Philosophy and Policy, 1*(1), 24-40. doi:https://doi.org/10.1017/S0265052500003307

Feng, S., Chen, L., Sun, R., Feng, Z., Li, J., Khan, M. S., & Jing, Y. (2019). The distribution and accessibility of urban parks in Beijing, China: Implications of social equity. *International journal of environmental research and public health*, *16*(24), 4894.

Ferdous, M. S., Suphiyan, M. A., &Rabby, S. F. (2016). A Comparative Analysis on Available Service Facilities and Their Deficiencies Using Threshold and Location Quotient Method: A Case Study on Different Wards of Khulna City. Proceedings of 3rd International Conference on Advances in Civil Engineering (pp. 638-642). Chittagong, Bangladesh: CUET.

Ferreira, F. H., &Gignoux, J. (2011). The measurement of inequality of opportunity: Theory and an application to Latin America. *Review of income and wealth*, *57(4), 622–657*. doi:10.1111/j.1475-4991.2011.00467.x

Gibson, J., & Rioja, F. (2014). A bridge to equality: How investing in infrastructure affects the distribution of wealth. *Georgia state university*.

Green, D., & Allen, I. (2008). *The Urgency of Now*. Oxfam. https://oxfamilibrary.openrepository.com/bitstream/handle/10546/115508/bk-the-urgency-of-now-230608-en.pdf;jsessionid=D6A7D2E220A9073DD7759EE8369253FB?sequence=1

Haggett, P., and K. A. Gulzawardena. (1964). Determination of population thresholds for settlement functions by the Reed-Muench method. *Prof. Geogr. 16* (4), 6–9. doi:https://doi.org/10.1111/j.00330124.1964.006_q.x.

Haque, M. N., Mamun, M. A., Saroar, M. M., & T. K. (2019). Application of DPSIR Framework to Assess the Status and Role of Blue Ecosystem Services (BES) in Khulna City. *Journal of Engineering Science, 10*(2), 49-60. https://www.kuet.ac.bd/webportal/ppmv2/uploads/160960605806_JES_234_28-10-2019.pdf

Hooper, E., Peters, S., &Pintus, P. (2018). To what extent can long-term investment in infrastructure reduce inequality?*Journal of Infrastructure Policy and Development 2*(2). doi:10.24294/jipd.v2i2.858

Howlader M. H., Ashikuzzaman M., Hossain M. Z. & Khan M.A. (2018). Urban inequality: An assessment on the distribution of infrastructure and services in Khulna City Corporation, Bangladesh. *Khulna University Studies, 15* (1 & 2), 133-148.**doi:** https://doi.org/10.53808/KUS.2018.15.1&2.1801-S

Istiaque, S., Ahsan, M., Roy, T. K., & Rahman, M. M. (2018). Waterfront development for sustainable urban planning: A case study on Bhairab River, Khulna. *Plan Plus, 8*(1), 25-40. https://planplusjournal.com/index.php/planplus/article/view/24/7

Jones, H. (2009). *Equity in development, Why it is important and how to achieve it*. Working Paper 311. London: Overseas Development Institute.https://odi.org/en/publications/equity-in-development-why-it-is-important-and-how-to-achieve-it/

Karim, K. R., & Roy, T. K. (2012). Environment of the Parks in Metropolitan Area: A Case of Khulna City. *The Journal of Social Studies, 135*, 54-71.

KCC (Khulna City Corporation). (2018). Basic statistics.http://www.khulnacity.org/Content/index.php?page=About_KCC&aGo&pid=30.

KDA (Khulna Development Authority). (1961). Report on the Draft Master Plan for Khulna. Khulna, Bangladesh: KDA.

KDA (Khulna Development Authority). (2002). Structure Plan, Vol. 2 of Structure plan, master plan and detailed area plan for Khulna City. Khulna, Bangladesh: KDA

KDA. (2002). Master Plan, Vol. 3 of Structure plan, master plan and detailed area plan for Khulna City. Khulna, Bangladesh: KDA.

KDA. (2018). Detailed Area Development Plan (DAP) for Khulna City. Khulna, Bangladesh: KDA.

Khan, A. M. (2019). Revisiting Planning Standards for Open Spaces in Urban Areas from Global and National Perspectives. *Journal of Bangladesh Institute of Planners, 12*, 1-20. https://www.bip.org.bd/admin/uploads/bip-publication/publication-24/paper/20201002102922.pdf

Khaza, M. K. B., Rahman, M. M., Harun, F., & Roy, T. K. (2020). Accessibility and Service Quality of Public Parks in Khulna City. *Journal of Urban Planning and Development*, *146*(3): 04020024. doi: 10.1061/(ASCE)UP.1943-5444.0000589

Kun, W., Hao, S., Yannan, X., Mingrui, X., & Quan, Z. (2012). Accessibility Analysis of Urban Parks Based on GIS. 2012 Fifth International Conference on Information and Computing Science, 56-59. Liverpool: IEEE. doi:10.1109/icic.2012.6

Larson, L. R., Jennings, V., & Cloutier, S. A. (2016). Public Parks and Wellbeing in Urban Areas of the United States. *PLOS ONE, 11*(4), e0153211. doi:10.1371/journal.pone.0153211

Lee, A. C., H. C. Jordan, and J. Horsley. (2015). Value of urban green spaces in promoting healthy living and wellbeing: prospects for planning. *Risk Management and Healthcare Policy 8*, 131–137. https://doi.org/10.2147/RMHP.S61654

Leipziger, D., Fay, M., Wodon, Q. T., & Yepes, T. (2003). Achieving the millennium development goals: the role of infrastructure. Policy Research Working Paper; No. 3163. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/17901

Litman, T. (2022). Evaluating Accessibility for Transport Planning-Measuring People's Ability to Reach Desired Services and Activities. Victoria, BC, Canada: Victoria Transport Policy Institute. https://www.vtpi.org/access.pdf

Mendoza, O. M. V. (2017). Infrastructure Development, Income Inequality and Urban Sustainability in the People's Republic of China. ADBI Working Paper 713. Tokyo: Asian Development Bank Institute.https://www.adb.org/publications/infrastructuredevelopment-income-inequality-and-urban-sustainability-prc

Metzger, J. T. (1996). The Theory and Practice of Equity Planning: An Annotated Bibliography. *Journal of Planning Literature, 11*(1), 112–126. doi:https://doi.org/10.1177/088541229601100106

Miah, M. T., & Sultana, M. (2022). Sustainable management of urban facilities in neighbourhood of Khulna city: a case study of Khulna, Bangladesh. *Khulna University Studies,*Special Issue ICSTEM4IR: 189-202, 2022. doi: https://doi.org/10.53808/KUS.2022.ICSTEM4IR.0005-se

Moeller, J. (1965). Standards for outdoor recreational areas. Information Report No. 194. Chicago, Illinois: American Society of Planning Officials. https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/pas/at60/pdf/report194.pdf

Mowla, Q. A. (1999). Khulna's Urban Poor and Their Living Environment-A point to ponder at the beginning of third millennium. *Khulna University Studies, 1*(2), 205-212. https://ku.ac.bd/uploads/kustudies/Vol-1/N%202/205-212.pdf

Nejati, H., Teimouri, R., & Ahmadi., T. (2015). Suitability analysis of urban neighborhood parks using GIS techniques. Academics World 5th International Conference, 34–38. Paris, France. https://www.worldresearchlibrary.org/up_proc/pdf/81-144507341134-38.pdf

Nicholls, S. (2001). Measuring the accessibility and equity of public parks: a case study using GIS. *Managing Leisure, 6*(4), 201–219. doi:https://doi.org/10.1080/13606710110084651

Godbey, G., & Mowen, A. (2010). The benefits of physical activity provided by park and recreation services: The scientific evidence. Ashburn, VA: National Recreation and Park Association. https://www.deltastate.edu/PDFFiles/hper%20outdoor%20program/benefits%20of%20PA%20provided%20by%20P&R%20services.pdf

Oh, K., & Jeong, S. (2007). Assessing the spatial distribution of urban parks using GIS. *Landscape and Urban Planning, 82*(1), 25–32. doi:https://doi.org/https://doi.org/10.1016/j.landurbplan.2007.01.014

Pazhouhanfar, M. (2018). Role of Space Qualities of Urban Parks on Mood Change. *Psychol Stud 63,* 25–31. doi:https://doi.org/10.1007/s12646-017-0434-6

Preetha, S. S. (2011). Rethinking, Remapping and Reclaiming Space. The Daily Star Weekend Magazine. https://www.thedailystar.net/magazine/2011/12/02/index.htm

Rahman, K. R., & Salauddin, M. (2009). A spatial analysis on the provision of urban public services and their deficiencies: A study of some selected blocks in Khulna city, Bangladesh. *Theoretical and Empirical Researches in Urban Management, 4*(1S), 120–132. http://www.jstor.org/stable/24872413

Rawls, J. (1921). A Theory of Justice. (Rev. ed). Cambridge, MA: Belknap Press of Harvard University Press.https://giuseppecapograssi.files.wordpress.com/2014/08/rawls99.pdf

Richardson, J., Goss, Z., Pratt, A., Sharman, J., & Tighe, M. (2013). Building HIA approaches into strategies for green space use: an example from Plymouth's (UK) Stepping Stones to Nature project. *Health Promotion International, 28*(4), 502–511. doi:https://doi.org/10.1093/heapro/das033

Roy, T. K. (2012). Urban open space and green proposals of Khulna City master plan and their implementation. The 2nd international conference in environmental technology and construction engineering for sustainable development (ICETCESD2012). Sylhet, Bangladesh: SUST.

Roy, T. K. (2013). Management of Park Solid Wastes in Khulna City. WasteSafe 2013-3rd International Conference on Solid Waste Management in Developing Countries. Khulna, Bangladesh, KUET.

Roy, T. K., Saroar, M. M., Haque, S. M. (2019). Use of Co-compost from Faecal Sludge and Municipal Organic Waste in Urban Green Space Plantation of Khulna City: Prospects and Problems. In: Ghosh, S. (eds) Waste Valorisation and Recycling. Springer, Singapore. https://doi.org/10.1007/978-981-13-2784-1_17

Saleem, A., & Ijaz, S. (2014). A GIS Based Measurement of Accessibility of Urban Parks in Faisalabad City, Pakistan. *Academic Research International, 5*(3), 94–99. www.savap.org.pk94www.journals.savap.org.pk

Shefer, D., & Antonio, M. (2013). Spatial Inequality Between and Within Urban Areas: The Case of Israeli Cities. *European Planning Studies, 21*(3), 373–387. doi:10.1080/09654313.2012.718198

Simon, N. S., & Natarajan, P. (2017). Nonlinearity between Infrastructure Inequality and Growth: Evidence from India. *Review of Market Integration, 9*(1–2), 66–82. doi:10.1177/0974929217721764

Slater, T. (2004). Municipally managed gentrification in South Parkdale, Toronto. *The Canadian Geographer, 48*(3), 303-325. doi:https://doi.org/10.1111/j.0008-3658.2004.00062.x

Sridharan, N. (2011). Spatial Inequality and the Politics of Urban Expansion. *Environment and Urbanization ASIA, 2*(2), 187–204. doi:https://doi.org/10.1177/097542531100200204

Tabassum, S., & Sharmin, F. (2013). Accessibility analysis of parks at urban neighborhood: The case of Dhaka. *Asian Journal of Applied Science and Engineering, 2*(2), 48-61.https://www.academia.edu/11159451/Accessibility_Analysis_of_Parks_at_Urban_Neighborhood_The_Case_of_Dhaka

Talen, E. (2002). Pedestrian Access as a Measure of Urban Quality. *Planning Practice and Research, 17*(3), 257-278. doi:10.1080/026974502200005634

Türtseven Doğrusoy, İ., & Zeynel, R. (2017). Analysis of perceived safety in urban parks: A field study in büyükpark and hasanağa park.*Journal of the Faculty of Architecture, 34*(1), 63-84. doi: http://dx.doi.org/10.4305/metu.jfa.2017.1.7

Unal, M., Uslu, C., & Cilek, A. (2016). GIS-based accessibility analysis for neighbourhood parks: The case of Cukurova district. *Journal of Digital Landscape Architecture, 1,* 46-56. doi:10.14627/537612006

World Bank. (2006). Equity and Development. World Development Report 2006. Washington Dc: World Bank. doi:https://elibrary.worldbank.org/doi/abs/10.1596/978-0-8213-6249-5

Xiao, Y., Wang, Z., Li, Z., & Tang, Z. (2017). An assessment of urban park access in Shanghai-Implications for the social equity in urban China. *Landscape and Urban Planning, 157,* 383–393. doi:https://doi.org/https://doi.org/10.1016/j.landurbplan.2016.08.007

Zhao, S.D., & Zhang, Y.M. (2006). Ecosystems and human well-being: The achievements, contributions and prospects of the Millennium Ecosystem Assessment. *Advances in Earth Science, 21,* 895–902, doi: 10.3321/j.issn:1001-8166.2006.09.002

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ORIGINAL ARTICLE

SOCIAL SCIENCE

LIFESTYLE FACTORS AND RISK OF OBESITY AMONG THE SCHOOL CHILDREN IN KHULNA CITY

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Abstract

As childhood obesity is increasing in urban areas, this study was designed to explain the association of lifestyle-related factors with obesity among primary school children in the Khulna City of Bangladesh. Data were collected from 257 purposively selected mothers of primary school children. A semi-structured interview schedule was used for data collection during February and March 2019. Findings indicated that a significant proportion of the teenagers were obese (44%). Results from regression analysis revealed that children having health problems, frequency of meals taken per day, and time spent in outdoor games have a significant association ($p < 0.05$) with childhood obesity. Moreover, children having health problems (AOR = 4.941; 95% CI: 2.273-10.745; $p < 0.001$), taking meals more than three times in a day (AOR = 24.534; 95% CI: 10.024-60.046; $p < 0.001$), and spending less time in outdoor games (AOR = 2.736; 95% CI: 1.242-6.028; $p < 0.05$)) were more likely to be obese. The study suggests that parents should motivate their children to adopt a healthy lifestyle. In addition, adequate playgrounds for children can help to prevent obesity and should be prioritized in the management of childhood obesity.

Keywords: Obesity, lifestyle, children, dietary habit, physical activity

Introduction

Childhood overweight and obesity have become serious public health problems in both developed and developing countries, including Bangladesh, because of their robust association with adulthood obesity (Rachmi et al., 2017; Raychaudhuri & Sanyal, 2012). Adverse health consequences such as the high prevalence of blood pressure, diabetes, respiratory disease, and orthopedic and psychosocial disorders are related to obesity (Koirala et al., 2015; Mirelman et al., 2012). It is also related to an increased risk of morbidity and mortality as well as reduced life expectancy (Hasanat et al., 2019). However, the worldwide prevalence of overweight and obesity amongst children and adolescents within the age group of 5 to 19 years was over 340 million in 2016 (World Health Organization, 2020).

However, childhood obesity has been attributed to many factors. Lifestyle-related factors are the significant ones that lead to obesity amongst children. Due to rapid urbanization and modernization, changes in childhood lifestyle, characterized by an increase in the consumption of energy-dense foods and physical inactivity, lead to a global obesity epidemic that poses significant public health challenges (Hasanat et al., 2019). Several studies identified a variety of lifestyle-related risk factors for obesity including dietary habits (Mahfouz et al., 2011), physical activity (Ahmed et al., 2016; Al-Nuaim et al., 2012), sedentary behaviours, screen time (Al-Ghamdi, 2013), and duration of sleep (Al-Hazzaa et al., 2012).

Several factors related to eating habits and food choices have contributed to the incidence of obesity among children, particularly the regularity of skipping breakfast, sugar-sweetened drinks, fruit and vegetable consumption, sweet and candy consumption (Hammad & Berry, 2017), consumption of fast food and soft drinks (Abduelkarem et al., 2020; Rahman et al., 2014; Saha et al., 2011; Xu et al., 2018).

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Physical activity is an important factor contributing to obesity, particularly in children (Al-Nuaim et al., 2012). Physical inactivity increases the risk of child obesity (Alazzeh et al., 2018; Hasanat et al., 2019; Hills et al., 2011). Television viewing and playing computer games could contribute to the increasing rate of obesity by replacing time for physical activity as well as increasing food consumption (Al-Agha et al., 2016; Alghadir et al., 2016; Desalew et al., 2017; Hossain et al., 2020). Sleep duration is another important lifestyle-related factor that has been studied in association with obesity (Ahmed et al., 2016; Piryani et al., 2016). As modern lifestyles give access to smartphones, television, and video games round the clock for teenagers, that ultimately affects their sleep health (Al-Hazzaa & Albawardi, 2019).

Due to rapid urbanization and modernization, the lifestyles of all age groups are changing day by day. The availability of fast food and limited or no space for physical activities triggers the risk of obesity among teenagers in urban areas. However, childhood obesity is a serious concern in developing countries like Bangladesh, especially in urban areas that remain unexplored. Thus, the present study aims to explain the association of lifestyle-related factors with child obesity in the Khulna City of Bangladesh. Moreover, this study will help to further policy interventions as well as add a new dimension to the research area.

Materials and Methods

Due to the blessings of modern technology and urbanization, the lifestyles of children are changing, which ultimately stimulates the propensity for obesity among children. The study was explanatory as it tried to explain the lifestyle-related factors and their relation to obesity amongst primary school children in the Khulna City of Bangladesh. As childhood obesity is increasing in urban settings, six pre-primary and primary schools from the Khalispur region of Khulna City were purposively selected to conduct the study for two months (February-March 2019).

Data were collected from the mothers of school-going children aged 5 to 10 years in the aforesaid study area. Mothers were chosen because they are the primary caregivers and, at present, they usually come to the school with their children and stay at the school to pick them up. Due to children's safety, the principals of the selected schools in the study area did not provide the list of the children. As the size of the population was unknown, a total of 257 mothers were selected purposively for data collection.

A semi-structured interview schedule was followed for data collection. A pre-test on 18 mothers (3 mothers from each school) was conducted in February 2019 before the final data collection to minimize the inconsistency of the data collection tool, which was excluded from the results. Final data were collected by taking verbal consent from the respondents in March 2019.

Children's obesity was measured by their Body Mass Index (BMI). A digital weighing machine and a vertical scale were used to measure these parameters. Children's weight was measured in kilograms and height in meters. The BMI was determined from the ratio of weight (kg) to height (m) square. After that, their BMI was classified into four categories according to the Official Centre for Disease Control (CDC) growth chart for boys and girls aged 2 to 20 years (Kuczmarski et al., 2002) such as, underweight (<5th percentile), healthy weight (5th percentile to<85th percentile), overweight (85th percentile to <95th percentile) as well as obesity (≥95thpercentile) based on age and sex-specific BMI percentiles.

The outcome variable in this study was the child's BMI which was categorized into obese (≥95th) and non-obese (<95th percentile) in line with a prior study (Ganle et al., 2019). Among the predictors, we included several lifestyle-related factors such as preferred food (food away from home and homemade food), frequency of meals taken in a day (regular and irregular), consumption of fast food (regular and irregular), sweetened food (regular and irregular), and soft drinks (regular and irregular), time spent in outdoor games (physically active [<1 hour] and physically inactive [≥1 hour]), time spent on screen watching (≤2 hours and >2 hours), and sleep duration (<9 hours and ≥9 hours). These variables were considered in the present study as some prior studies found those variables to be significant determinants of child obesity, e.g., dietary habits (Abduelkarem et al., 2020; Hammad & Berry, 2017; Mahfouz et al., 2011), physical activity (Ahmed et al., 2016; Al-Nuaim et al., 2012), sedentary behaviours, screen time (Al-Ghamdi, 2013) and sleep duration (Ahmed et al., 2016; Al-Hazzaa & Albawardi, 2019; Al-Hazzaa et al., 2012).

On the contrary, the age of the children (5-6 years, 7-8 years, and ≥9 years), sex of the children (girl and boy), and having health problems (no and yes) were considered under demographic and health-related variables in this study. These variables were also found as significant predictors of childhood obesity in previous studies (Hajian-Tilaki & Heidari, 2013; Hassan et al., 2016; Júlíusson et al., 2010).

We analyzed the data using the Statistical Package for the Social Sciences (SPSS) version 20.0. The personal characteristics of the mothers and children were analyzed by percentage distribution. Pearson's chi-square ($\chi 2$) test was conducted to assess the significant association between outcome and predictor variables considering a $p < 0.05$ significance level. Later, binary logistic regression analysis was executed by considering the variables that were found statistically significant in the Chi-square test. Results of binary logistic regression were presented as adjusted odds ratios (AOR) with 95% confidence intervals (CI).

Results

Personal profile of the mother

The personal characteristics of the mother are presented in Table 1. The highest percent of the mother (56%) were aged between 28 to 34 years and 79 percent of them were Muslim. About 37 percent of the mother had a tertiary level of education. Most of the mothers were housewives (76.7%) and the rest of them (23.3%) were working mothers. Around three-fourths of the mother (76.7%) had been living in a nuclear family, and the majority of the family consisted of 3 to 4 members. Nearly 40 percent of the respondents' monthly household income was more than BDT 40,000.

Table 1. Personal characteristics of mothers

Variables	Number of the mother(n=257)	Percent (%)
Age of mother (in years)		
21-27	60	23.4
28-34	144	56.0
≥35	53	20.6
Religion		
Muslim	203	79.0
Non-Muslim	54	21.0
Education of mother		
Primary (1-5)	4	1.6
Secondary (6-10)	75	29.2
Higher secondary (11-12)	81	31.5
Tertiary (≥13)	97	37.7
Occupation of mother		
Housewife	197	76.7
Working mother	60	23.3
Nature of the family		
Extended	60	23.3
Nuclear	197	76.7
Size of the family		
3-4	180	70.0
≥5	77	30.0
Monthly household income (in BDT)		
≤30000	82	31.9
30001-40000	73	28.4
>40000	102	39.7

Personal profile of the children

Data presented in table 2 reveals that the majority of the children (35.8%) were aged between 5 and 6 years, and more than half (52.1%) of them were boys. About 64 of the children were studied at the primary level, and the remaining children were studied at the pre-primary level of education. Nearly three-fifths of the children did not have any health problems, and the rest of them were suffering from health problems. Regarding the BMI of the children, a significant portion of the children was obese (44%) and 56 percent were non-obese.

Table 2. Personal characteristics of the children

Variables	Number of the children	Percent (%)
Age of the children (in years)		
5-6	92	35.8
7-8	90	35.0
≥9	75	29.2
Sex of the children		
Girl	123	47.9
Boy	134	52.1
Area of study		
Pre-primary (Nursery and KG)	93	36.2
Primary (One to Five)	164	63.8
Having health problems		
No	155	60.3
Yes	102	39.7
BMI of the children		
Obese	113	44.0
Non-obese	144	56.0

Association of lifestyle factors with child obesity (Bivariate analysis)

Table 3 depicts the association of lifestyle-related factors with obesity among primary school children. Overall, findings indicate that childhood obesity was significantly associated with having health problems, preferred food, frequency of meals taken per day, consumption of fast food, sweetened food, and soft drinks, time spent in outdoor games, as well as time spent on screen viewing. On the contrary, age and sex of the children, and sleep duration per day have no significant association with childhood obesity in the study area.

Association of lifestyle factors with child obesity (Binary logistic regression)

Binary logistic regression was executed considering the eight significant variables out of eleven variables used in bivariate statistical analysis, namely children having health problems, child preferred food, frequency of meals taken per day, consumption of fast food, sweetened food, and soft drinks, as well as time spent on outdoor games, and screen viewing. The results indicate that children having health problems, the frequency of meals taken per day, as well as time spent in outdoor games, have significant association with childhood obesity. Moreover, findings predict that children having health problems were 4.941 times more possibly to be obese compared to their counterparts (AOR = 4.41; 95% CI: 2.273-10.745; $p < 0.001$). Similarly, the risk of obesity among children having more than three times meals in a day was 24.534 times higher than that of those who had meals less than or equal to three times a day (AOR = 24.534; 95% CI: 10.024-60.046; $p < 0.001$). Finally, children who spent less time in outdoor games have 2.736 times higher risk of being obese (AOR = 2.736; 95% CI: 1.242-6.028; $p < 0.05$) than those who remain active physically by spending more time in outdoor games.

Table 3. Association of lifestyle-related factors with obesity among school children using bivariate analysis

Independent variables	Children's BMI		Chi-square value	*p*-value
	Non-obese	Obese		
Age of the children (in years)				
≤6	50 (54.3)	42 (45.7)	1.228	0.541
7-8	48 (53.3)	42 (46.7)		
≥9	46 (61.3)	29 [(38.7)		
Sex of the children				
Girl	65 (52.8)	58 (47.2)	0.972	0.324
Boy	79 (59.0)	55 (41.0)		
Having health problems of the children				
No	104 (67.1)	51 (32.9)	19.411	<0.001*
Yes	40 (39.2)	62 (60.8)		
Preferred food of the children				
Food away from home	72 (47.4)	80 (52.6)	11.332	<0.001*
Homemade food	72 (68.6)	33 (31.4)		
Frequency of meals taken per day				
≤ 3 times	102 (91.9)	9 (8.1)	1.020E2a	<0.001*
>3 times	42 (28.8)	104 (71.2)		
Consumption of fast food				
Irregular	123 (66.1)	63 (33.9)	27.866	<0.001*
Regular	21 (29.6)	50 (70.4)		
Consumption of sweetened food				
Irregular	110 (64.3)	61 (35.7)	14.277	<0.001*
Regular	34 (39.5)	52 (60.5)		
Consumption of soft drinks				
Irregular	121 (65.1)	65 (34.9)	22.247	<0.001*
Regular	23 (32.4)	48 (67.6)		
Time spent in outdoor games per day				
Physically active (<1 hour)	84 (68.3)	39 (31.7)	14.396	<0.001*
Physically inactive (≥1 hour)	60 (44.8)	74 (55.2)		
Time spent in screen viewing per day				
≤2 hour	103 (66.0)	53 (34.0)	16.095	<0.001*
>2 hours	41 (40.6)	60 (59.4)		
Sleep duration per day				
<9 hours	61 (61.6)	38 (38.4)	2.039	0.153
≥9 hours	83 (52.5)	75 (47.5)		

** Significant at 5%*

Discussion

Childhood obesity has recently been an important concern worldwide and seems to play a significant role in the development of many childhood diseases (Rauniyar et al., 2018). The present study aimed to explain the association of lifestyle-related factors with obesity among primary school children in the Khulna City of Bangladesh. Findings reveal that in the study area, 44 percent of the children were obese as the study was conducted in the urban areas. The higher rate of childhood obesity and overweight was also noted in prior studies (Akter et al., 2020; Zabeen et al., 2018) conducted in Bangladesh among children between the age group of five to eighteen years. Results of this study also reveal that having health problems, frequency of meals taken per day, and time spent playing outdoor games are the significant lifestyle-related factors correlated with child obesity.

We found that children with health problems were at a higher risk of being obese than their counterparts which corresponds with the findings of earlier studies (Bertapelli et al., 2016; Lee & Ham, 2015). This fact might be explained by the findings of a prior study (Hering et al., 2009) that found obesity among children is associated with increased healthcare use.

We also found that the prevalence rate of obesity was higher among the children who preferred food away from home compared to those children who preferred homemade food though it failed to exhibit any significant association. Inconsistent with this finding, prior studies conducted in China (Ma et al., 2021) and Portugal (Machado-Rodrigues et al., 2018) found that a higher frequency of eating outside per week was significantly associated with a higher prevalence of obesity amongst children. The possible reason for this discrepant finding might be that we only considered the type of food children preferred rather than emphasizing the nature and calorie content of the given meals.

Table 4. Child obesity and its predictors (Binary logistic regression)

Factors	Coefficient (B)	*p*-value	AOR	95% CI
Children suffering from chronic diseases				
No(ref)				
Yes	1.598	<0.001*	4.941	2.273-10.745
Children's preferred food				
Food away from home(ref)				
Homemade food	-0.121	0.762	0.886	0.405-1.938
Frequency of meals taken per day				
≤ 3 times(ref)				
>3 times	3.200	<0.001*	24.534	10.024-60.046
Fast food consumption				
Irregular(ref)				
Regular	-0.807	0.079	0.446	0.182-1.098
Sweetened foods consumption				
Irregular(ref)				
Regular	0.279	0.531	1.322	0.552-3.162
Soft drinks consumption				
Irregular(ref)				
Regular	-0.688	0.129	0.503	0.207-1.221
Time spent in outdoor games				
Physically active (<1 hour) (ref)				
Physically inactive (≥1 hour)	1.006	0.013*	2.736	1.242-6.028
Time spent in screen viewing per day				
≤2 hour(ref)				
>2 hours	0.337	0.404	1.401	0.635-3.093

*Significant at 5%

We noted that children who have more than three meals in a day have a higher chance of being obese than others. It is also found in another study (Lee & Ham, 2015) that the significant effect of overeating among children increased the risk of obesity development. Frequent taking of meals might be influenced by neural and hormonal regulatory control which plays a significant role in hunger and satiety as well as sensory stimulation, gastrointestinal signals, and circulating hormones further contribute to food intake (Scaglioni et al., 2018).

Frequent consumption of fast food was recognized as a significant predictor of obesity among school children in previous studies conducted in Saudi Arabia, America, Bangladesh, and China (Almuhanna et al., 2014; Emond et al., 2020; Habib et al., 2020; Zhao et al., 2017). However, the present study found no significant association between the consumption of fast food and childhood obesity. Inconsistent with the findings of prior studies (Katzmarzyk et al., 2016; Keller & Bucher, 2015) the present study did not find any significant association between childhood obesity with sweetened food and soft drinks consumption. The possible reason for this finding of the present study might be that we included whether children consume fast foods, sweetened foods, and soft drinks on a regular or irregular basis without considering the quantity.

We also observed that children who spent a longer period playing outdoor games have a lower risk of being obese and this is aligned with previous studies (Amidu et al., 2013; Hammad & Berry, 2017; Neto et al., 2014). Reduction of open space for playgrounds due to unplanned and rapid urbanization in Khulna City can be a factor in

reducing the physical activity of the children, which ultimately increases the risk of obesity amongst children (Bhuiyan et al., 2013).

Time spent on TV or screen viewing has a significant relationship with childhood obesity which corresponds with some existing literature (Hossain et al., 2020; Zhang et al., 2020) that found watching TV for more than 2 to 3 hours per day tended to increase the chances of obesity among children. However, the current study did not find any significant association between TV/screen viewing and the prevalence of child obesity.

The strength of the current study is that it covers lifestyle-related factors to assess their relationship with obesity among the younger age group, as childhood obesity is becoming a growing public health concern throughout the world. However, the potential limitation of the present study is that it was conducted in a particular area. That is, it could not be generalized to the entire young population of Bangladesh. In addition, respondents were selected following the purposive sampling technique which might raise the question of biasness.

Conclusion

The study aimed to explain the association of lifestyle-related factors with obesity amongst primary school children in the Khulna City of Bangladesh. Findings indicated that children having health problems, higher frequency of meals taken per day, and less time spent playing outdoor games were the significant predictors of childhood obesity. The study recommends that parents should motivate their children to adopt and habituate a healthy lifestyle, e.g., reducing sedentary activities and motivating them to be active physically. Moreover, adequate playgrounds for children that can help to prevent obesity and should be considered on a priority basis in dealing with the management of childhood obesity. Further research can be carried out in a broader aspect at national level on young children to generalize the effect of lifestyle-related factors on childhood obesity.

Conflict of Interests

The author declares no conflict of interest.

References

Abduelkarem, A. R., Sharif, S. I., Bankessli, F. G., Kamal, S. A., Kulhasan, N. M., & Hamrouni, A. M. (2020). Obesity and its associated risk factors among school-aged children in Sharjah, UAE. *PLoS ONE*, *15*(6), e0234244. doi: https://doi.org/10.1371/journal.pone.0234244

Ahmed, H. S., Khalid, M. E., Osman, O. M., Ballal, M. A., & Al-Hashem, F. H. (2016). The association between physical activity and overweight and obesity in a population of children at high and low altitudes in Southwestern Saudi Arabia. *Journal of Family & Community Medicine*, *23*(2), 82. doi: 10.4103/2230-8229.181011

Akter, S. Rahman, M. H. & Razu, S. R. (2020). Socio-demographic factors associated with obesity among primary school children: A cross-sectional survey from Khulna district of Bangladesh. *Journal of Population and Development*, *2*, 84-96.

Al-Agha, A. E., Nizar, F. S., & Nahhas, A. M. (2016). The association between body mass index and duration spent on electronic devices in children and adolescents in Western Saudi Arabia. *Saudi Medical Journal*, *37*(4), 436. doi: 10.15537/smj.2016.4.15018

Al-Ghamdi, S. H. (2013). The association between watching television and obesity in children of school-age in Saudi Arabia. *Journal of Family & Community Medicine*, *20*(2), 83. doi: 10.4103/2230-8229.114767

Al-Hazzaa, H. M., & Albawardi, N. M. (2019). Activity energy expenditure, screen time and dietary habits relative to gender among Saudi youth: Interactions of gender with obesity status and selected lifestyle behaviours. *Asia Pacific Journal of Clinical Nutrition*, *28*(2), 389-400. doi: 10.6133/apjcn.201906_28(2).0022.

Al-Hazzaa, H. M., Musaiger, A. O., Abahussain, N. A., Al-Sobayel, H. I., & Qahwaji, D. M. (2012). Prevalence of short sleep duration and its association with obesity among adolescents 15-to 19-year olds: A cross-sectional study from three major cities in Saudi Arabia. *Annals of Thoracic Medicine*, *7*(3), 133. doi: 10.4103/1817-1737.98845

Al-Nuaim, A. A., Al-Nakeeb, Y., Lyons, M., Al-Hazzaa, H. M., Nevill, A., Collins, P., & Duncan, M. J. (2012). The prevalence of physical activity and sedentary behaviours relative to obesity among adolescents from Al-Ahsa, Saudi Arabia: Rural versus urban variations. *Journal of Nutrition & Metabolism*, 2012:417589. doi: 10.1155/2012/417589.

Alazzeh, A. Y., AlShammari, E. M., Smadi, M. M., Azzeh, F. S., AlShammari, B. T., Epuru, S., Banu, S., Bano, R., Sulaiman, S., Alcantara, J. C., Syed, A. A., & Qiblawi, S. (2018). Some socioeconomic factors and lifestyle habits influencing the prevalence of obesity among adolescent male students in the hail region of Saudi Arabia. *Children*, *5*(3), 39. doi: 10.3390/children5030039

Alghadir, A. H., Gabr, S. A., & Iqbal, Z. A. (2016). Television watching, diet and body mass index of school children in Saudi Arabia. *Pediatrics International*, *58*(4), 290-294. doi: 10.1111/ped.12834

Almuhanna, M. A., Alsaif, M., Alsaadi, M., & Almajwal, A. (2014). Fast food intake and prevalence of obesity in school children in Riyadh City. *Sudanese Journal of Paediatrics*, *14*(1), 71. PMC4949920

Amidu, N., Owiredu, W., Saaka, M., Quaye, L., Wanwan, M., Kumibea, P., Zingina, F., & Mogre, V. (2013). Determinants of childhood obesity among basic school children aged 6–12 years in Tamale Metropolis. *Journal of Medical and Biomedical Sciences*, *2*(3), 26-34. doi: 10.4314/jmbs.v2i3.5

Bertapelli, F., Pitetti, K., Agiovlasitis, S., & Guerra-Junior, G. (2016). Overweight and obesity in children and adolescents with Down syndrome-prevalence, determinants, consequences, and interventions: A literature review. *Research in Developmental Disabilities*, *57*, 181-192. doi: 10.1016/j.ridd.2016.06.018

Bhuiyan, M. U., Zaman, S., & Ahmed, T. (2013). Risk factors associated with overweight and obesity among urban school children and adolescents in Bangladesh: A case-control study. *BMC Pediatrics*, *13*(1), 1-6. doi: https://doi.org/10.1186/1471-2431-13-72

Desalew, A., Mandesh, A., & Semahegn, A. (2017). Childhood overweight, obesity and associated factors among primary school children in dire dawa, eastern Ethiopia; A cross-sectional study. *BMC Obesity*, *4*(1), 1-10. doi: 10.1186/s40608-017-0156-2

Emond, J. A., Longacre, M. R., Titus, L. J., Hendricks, K., Drake, K. M., Carroll, J. E., Cleveland, L. P., & Dalton, M. A. (2020). Fast food intake and excess weight gain over a 1-year period among preschool-age children. *Pediatric Obesity*, *15*(4), e12602. doi: 10.1111/ijpo.12602

Ganle, J. K., Boakye, P. P., & Baatiema, L. (2019). Childhood obesity in urban Ghana: Evidence from a cross-sectional survey of in-school children aged 5–16 years. *BMC Public Health*, *19*(1), 1-12. doi: https://doi.org/10.1186/s12889-019-7898-3

Habib, M. A., Chowdhury, A. I., Hossen, K., Kibria, T., & Hossain, M. (2020). Fast food intake and prevalence of overweight/obesity in students: Do eating habits have a differential impact on gender? *Journal of Contemporary Medical Research*, *7*(6), F4-F9. doi: http://dx.doi.org/10.21276/ijcmr.2020.7.6.30

Hajian-Tilaki, K., & Heidari, B. (2013). Childhood obesity, overweight, socio-demographic and life style determinants among preschool children in Babol, northern Iran. *Iranian Journal of Public Health*, *42*(11), 1283. PMC4499070

Hammad, S. S., & Berry, D. C. (2017). The child obesity epidemic in Saudi Arabia: A review of the literature. *Journal of Transcultural Nursing*, *28*(5), 505-515. doi: https://doi.org/10.1177/1043659616668398

Hasanat, M. A., Rauniyar, B. K., Jahan, S., Sultana, N., Hasan, M., Rahman, M. A., Aktar, Y., & Fariduddin, M. (2019). Lifestyle has significant influence over obesity among school children in Bangladesh. *Current Research in Diabetes & Obesity Journal*, *10*(1), 555-776. doi: https://doi.org/10.19080/CRDOJ.2019.10.555776

Hassan, N. E., El-Masry, S. A., Farid, T., & Khalil, A. (2016). Influence of parental and some demographic characteristics on overweight/obesity status among a sample of Egyptian children. *Open Access Macedonian Journal of Medical Sciences*, *4*(3), 342. doi: 10.3889/oamjms.2016.088

Hering, E., Pritsker, I., Gonchar, L., & Pillar, G. (2009). Obesity in children is associated with increased health care use. *Clinical Pediatrics*, *48*(8), 812-818. doi: https://doi.org/10.1177/0009922809336072

Hills, A. P., Andersen, L. B., & Byrne, N. M. (2011). Physical activity and obesity in children. *British Journal of Sports Medicine*, *45*(11), 866-870. doi: 10.1136/bjsports-2011-090199

Hossain, M. T., Luies, S. K., & Biswas, T. (2020). Prevalence and factors associated with overweight and obesity among primary school children (9–14 years) in a selected area of Dhaka, Bangladesh: A cross-sectional study. *Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive & Social Medicine*, *45*(4), 429. doi: 10.4103/ijcm.IJCM_466_19

Júlíusson, P. B., Eide, G. E., Roelants, M., Waaler, P. E., Hauspie, R., & Bjerknes, R. (2010). Overweight and obesity in Norwegian children: Prevalence and socio-demographic risk factors. *Acta Paediatrica*, *99*(6), 900-905. doi: 10.1111/j.1651-2227.2010.01730.x

Katzmarzyk, P. T., Broyles, S. T., Champagne, C. M., Chaput, J. P., Fogelholm, M., Hu, G., Kuriyan, R., Kurpad, A., Lambert, E. V., Maia, J., Matsudo, V., Olds, T., Onywera, V., Sarmiento, O. L., Standage, M., Tremblay, M. S., TudorLocke, C., & Zhao, P. (2016). Relationship between soft drink consumption and obesity in 9–11 years old children in a multi-national study. *Nutrients*, *8*(12), 770. doi: 10.3390/nu8120770

Keller, A., & Bucher, D. T. S. (2015). Sugar-sweetened beverages and obesity among children and adolescents: A review of systematic literature reviews. *Childhood Obesity*, *11*(4), 338-346. doi: 10.1089/chi.2014.0117

Koirala, M., Khatri, R., Khanal, V., & Amatya, A. (2015). Prevalence and factors associated with childhood overweight/obesity of private children in Nepal. *Obesity Research & Clinical Practice*, *9*(3), 220-227. doi: https:// dx.doi.org/10.1016/j.orcp.2014.10.219

Kuczmarski, R. J., Ogden, C. L., Guo, S. S., Grummer-Strawn, L. M., Flegal, K. M., Mei, Z., Wei, R., Curtin, L. R., Roche, A. F., & Johnson, C. L. (2002). 2000 CDC Growth Charts for the United States: Methods and development. *Vital and Health Statistics 11*, 1-190. PMID: 12043359

Lee, G., & Ham, O. K. (2015). Factors affecting underweight and obesity among elementary school children in South Korea. *Asian Nursing Research*, *9*(4), 298-304. doi: https://doi.org/10.1016/j.anr.2015.07.004

Ma, Y., Gong, W., Ding, C., Song, C., Yuan, F., Fan, J., Feng, G., Chen, Z., & Liu, A. (2021). The association between frequency of eating out with overweight and obesity among children aged 6–17 in China: A national cross-sectional study. *BMC Public Health*, *21*(1), 1-8. doi: 10.1186/s12889-021-11104-0

Machado-Rodrigues, A. M., Gama, A., Mourão, I., Nogueira, H., Rosado-Marques, V., & Padez, C. (2018). Eating away from home: A risk factor for overweight in children. *European Journal of Clinical Nutrition*, *72*(12), 1724-1727. doi: 10.1038/s41430-018-0165-3

Mahfouz, A. A., Shatoor, A. S., Khan, M. Y., Daffalla, A. A., Mostafa, O. A., & Hassanein, M. A. (2011). Nutrition, physical activity, and gender risks for adolescent obesity in Southwestern Saudi Arabia. *Saudi Journal of Gastroenterology: Official Journal of the Saudi Gastroenterology Association*, *17*(5), 318. doi: 10.4103/1319-3767.84486

Mirelman, A., Koehlmoos, T. P., & Niessen, L. (2012). Risk-attributable burden of chronic diseases and cost of prevention in Bangladesh. *Global Heart*, *7*(1). doi: 10.1016/j.gheart.2012.01.006

Neto, F. A., Eto, F. N., Pereira, T. S. S., Carletti, L., & Molina, M. d. C. B. (2014). Active and sedentary behaviours in children aged 7 to 10 years old: The urban and rural contexts, Brazil. *BMC Public Health*, *14*(1), 1-10. doi: https://doi.org/10.1186/1471-2458-14-1174

Piryani, S., Baral, K. P., Pradhan, B., Poudyal, A. K., & Piryani, R. M. (2016). Overweight and its associated risk factors among urban school adolescents in Nepal: A cross-sectional study. *BMJ Open*, *6*(5), e010335. doi: 10.1136/bmjopen-2015-010335

Rachmi, C., Li, M., & Baur, L. A. (2017). Overweight and obesity in Indonesia: Prevalence and risk factors-a literature review. *Public Health*, *147*, 20-29. doi: 10.1016/j.puhe.2017.02.002

Rahman, M., Reza, S., Islam, M., Rahman, A., & Nath, A. (2014). Prevalence of obesity and overweight among English medium school children of Dhaka City in Bangladesh. *Journal of Environmental Science and Natural Resources*, *7*(1), 63-67. doi: https://doi.org/10.3329/jesnr.v7i1.22146

Rauniyar, B., Jahan, S., Sultana, N., Hasan, M., Rahman, M. A., Aktar, Y., Fariduddin, M., & Hasanat, M. A. (2018). Prevalence of obesity is rising among primary school children in Dhaka city of Bangladesh. *Diabetes & Obesity International Journal,* 3(3), 000182.

Raychaudhuri, M., & Sanyal, D. (2012). Childhood obesity: Determinants, evaluation, and prevention. *Indian Journal of Endocrinology and Metabolism*, *16*(Suppl 2), S192. doi: 10.4103/2230-8210.104037

Saha, S., Zahid, M. K., & Rasheed, S. (2011). The study of the level of knowledge, attitude, practices (KAP) as well as the effects of school environment on the nutritional status of children (7-12) coming from affluent families in the Dhaka City in Bangladesh. *Bangladesh Journal of Nutrition*, 31-48. doi: https://doi.org/10.3329/bjnut.v24i0.14035

Scaglioni, S., De Cosmi, V., Ciappolino, V., Parazzini, F., Brambilla, P., & Agostoni, C. (2018). Factors influencing children's eating behaviours. *Nutrients*, *10*(6), 706. doi: 10.3390/nu10060706

World Health Organization. (2020). *Obesity and overweight*. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

Xu, J., Hardy, L. L., Guo, C. Z., & Garnett, S. P. (2018). The trends and prevalence of obesity and morbid obesity among Australian school-aged children, 1985–2014. *Journal of Paediatrics & Child Health*, *54*(8), 907-912. doi: 10.1111/jpc.13922

Zabeen, B., Sharmin, E., Shamayeen, Z., Khaled, N., Nahar, J., & Azad, K. (2018). Prevalence of overweight & obesity among school students from high and low-income families in Bangladesh: A cross-sectional study. *American Academy of Pediatrics*, 142 (1), 502. doi: 10.1542/peds.142.1_MeetingAbstract.502

Zhang, Y., Zhang, X., Li, J., Zhong, H., & Pan, C. W. (2020). Associations of outdoor activity and screen time with adiposity: Findings from rural Chinese adolescents with relatively low adiposity risks. *BMC Public Health*, *20*(1), 1-9. doi: https://doi.org/10.1186/s12889-020-09897-7

Zhao, Y., Wang, L., Xue, H., Wang, H., & Wang, Y. (2017). Fast food consumption and its associations with obesity and hypertension among children: Results from the baseline data of the childhood obesity study in China Mega-cities. *BMC Public Health*, *17*(1), 1-10. doi: https://doi.org/10.1186/s12889-017-4952-x

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ORIGINAL ARTICLE

SOCIAL SCIENCE

THE ROLE OF NEWSPAPER IN DISSEMINATING INFORMATION IN AMPHAN AFFECTED AREAS: A STUDY ON PIROJPUR DISTRICT

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Abstract

In general, Bangladesh's coastal region has been hit by a lot of disasters, but the frequency of these disasters has grown in recent years. Providing adequate information can help lessen the damage caused by these events. Newspapers are vital medium for disseminating information to the public about impending disasters specially in the coastal areas of Bangladesh. This study is all about analyzing the role of newspapers in disseminating information about the Cyclone Amphan to common people's consciousness. Qualitative and quantitative approaches were used in this study. The information was gathered through content analysis of four national dailies and interviews with two groups: victims of the Amphan affected area in the Pirojpur district and journalists from national dailies working in the same district. The study finds that there was insufficient coverage of Cyclone Amphan concerns in The Daily Star (5%), The Daily Prothom Alo (9%), The Daily Ittefaq (7%), and Bangladesh Pratidin (6%) of the total news. From the analysis, newspapers carried disaster-related news to warn the public in disaster-prone areas about the disaster's damage and measures, as well as to alert affected individuals about the disaster's position and signal. Despite the low coverage of disaster news, newspapers attracted people's attention because they provided accurate and credible news and allowed them to learn more about a diverse range of topics.

Keywords: Disaster, national newspaper, information dissemination, cyclone amphan, Bangladesh

Introduction

Bangladesh is one of the world's most disaster-prone countries in South Asia (Islam, 2014). Bangladesh's coastal areas, which include 19 coastal districts, have been devastated by disaster (Kamal & Kaudstaal, 2003). Every year, a number of disasters happen. The consequences of disasters and post-disaster operations are always front and center in Bangladesh's national publications. One of the most important roles played by newspapers in establishing agendas has been through the adoption of advocacy strategies or the coverage of disasters. Natural disasters, such as hurricanes, earthquakes, tornadoes, and tsunamis, occur as a result of weather or other natural factors.

Disasters have always struck with varying degrees of frequency, depending on local circumstances. Natural disasters can be categorized into two categories: medical issues and environmental issues. Famine and epidemics are the most serious medical issues. Floods, earthquakes, and storms (such as hurricanes, tornadoes, and cyclones) are all serious environmental issues at the same time (Chen, 1973). With the Himalayas to the north and the Bay of Bengal to the south, Bangladesh is located between the two divergent geophysical conditions. Bangladesh is situated in close proximity to frequent natural hazards, which, when combined with socioeconomic and demographic factors, frequently result in tragedy (Neverla, Luthje, & Mahmud, 2012). In May 2020, Bangladesh was devastated by Super Cyclonic Storm Amphan. On May 16, 2020, it developed over the Indian Ocean and began heading north over the Bay of Bengal, towards the coasts of north-east India and south of Bangladesh. The Bangladesh Meteorological Department (BMD) announced the 'great danger' warning number 10 for coastal areas, remote islands, and coral reefs on May 20, 2020. More than 2.4 million people were relocated to 14,636 permanent and temporary shelters after the government of Bangladesh (GoB) issued a great danger signal and emergency order.

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With wind speeds of 150 km/h, cyclone Amphan blasted into the coastal areas of West Bengal, India, and then entered Bangladesh on May 20 evening, wreaking havoc in 26 districts of the country (https://reliefweb.int). When cyclone Amphan made landfall in Bangladesh on May 20, 2020, the "very violent cyclonic storm" killed at least 31 people (Cyclone Amphan, 2020).

Miah et al. (2011) focused on newspaper coverage of natural disasters. This is reinforced by the close proximity of news sources, which is an important component of news value for the general audience. Concerns about climate change's effects on Bangladesh are predicted to significantly increase climate change coverage in the newspaper. According to the web popularity ranking of Bangladeshi newspapers in 2009, The Daily Prothom Alo, The Daily Ittefaq, and The Daily Star were identified as the top three national newspapers covering climate change issues. Content analysis from May 2006 to June 2009 is used in this method. This research revealed that natural disasters receive 47% of press coverage. Three newspapers cover global warming, human health, and agriculture on a regular basis, with the trend of climate-change coverage gradually increasing over the research period. Newspaper presentations on disaster news and the role of newspapers during crisis periods were the focus of the study.

Rashid (2011) identified newspaper stories about natural disasters that covered the scientific and social context in which such disasters occur in addition to the disaster events and their effects on the affected population. Applying content analysis to the coverage of three important cyclone disasters in Bangladesh and Myanmar; Gorky (1991), Sidr (2007), and Nargis (2009) from worldwide online newspapers over the last two decades. The role of the media in informing the public about natural catastrophes and their consequences has grown in prominence. The three disaster characters were all of the same types, and the news reports were quite realistic and effective. The following factors were interconnected: (a) the storms' geophysical characteristics (high wind speeds and rising seas); (b) the high number of deaths; and (c) the significant property destruction. One of the most common starting frames in the newspaper reports reviewed included both qualitative and quantitative information on these three elements.

Islam (2014) found the impact of climate change was one of the most critical issues for Bangladesh is affected by climate conditions due to its geological location. Tropical cyclones, tornadoes, flooding, sea level rise, saltwater intrusion, and a variety of other factors make Bangladesh vulnerable. The media serves as a watchdog since its three primary functions are to inform, educate, and amuse. As a result, print media is playing a critical role during the tragedy. This study is based on an observation of disaster coverage in the print media. Content analysis of four national newspapers in Bangladesh was used as the research approach. Because of the lack of good and effective presentations in newspapers, the newspaper reporter was not properly qualified and skilled in covering environmental and climate change topics.

Rahman (2010) provided essential information that the government of Bangladesh has built frequent disaster warning systems and is strengthening community-based disaster preparedness. The media can play a critical role in raising public awareness about climate change issues. Media coverage has influenced public perception and, as a result, how science is turned into policy, particularly in the area of the environment. The research is essential to determine how the media is covering the climate change issue. It is not to investigate policymakers' perspectives on climate change-related journalism. Content analysis of chosen newspapers and television stations (Prothom Allo and Btv) was used as the research approach. Interview with a media policymaker about the problem of climate change. Its general conclusion is that the media has discovered that the climate change subject may attract a larger audience, making environmental journalism more effective.

Newspapers are helpful during disasters because they provide information on when a crisis is occurring and what actions we can take to keep safe (Islam, 2014). Some scholars in Bangladesh have concentrated on disaster news coverage and presentations. However, there has been relatively little research into the reactions of individuals in affected areas and the contributions of newspaper reporters. Besides, how individuals get information and react to disaster news in the newspaper is critical. In addition, the reporter is the most essential individual in the newspaper since they confront problems and must maintain tactics to cover the news before publishing useful information. Because readers read the news and receive crucial information and knowledge, newspapers have always raised public consciousness. As a result, this study aids in the analysis of news impact, reporter contributions, and reader reactions. To meet the targets, several of the study work's questions have been introduced, such as how to spread information about the calamity during Cyclone Amphan? What kind of news did they pay attention to the most? What was the reaction of the general population to the newspaper that sparked their interest? What was the level of activity among journalists in their local region during the disaster reporting period?

Materials and Methods

This research employs both qualitative and quantitative methods. For this study, content analysis of national newspapers and in-depth interviews with a chosen group of people were employed as data collection methods. In this work, coding sheets for content analysis and semi-structured questionnaires for in-depth interviews were used to collect data. The population of this study was the total number of national newspapers published in Bangladesh, all reporters who work in the Pirojpur district as well as all people. The purposive sampling method was applied in this research work. A total of four national newspapers were selected as a sample in the study, based on circulation. This study sample consisted of three Bengali national dailies and one English national daily to maintain balance. Four daily newspapers were chosen as examples for the study based on their availability during the disaster (The Daily Star, The Daily Prothom Alo, Bangladesh Pratidin, and The Daily Ittefaq). On May 20, 2020, Super Cyclonic Storm Amphan made landfall in Bangladesh and lasted until May 21, 2020 (https://reliefweb.int). All of these selected daily newspapers were analyzed from May 19-23, 29-30, 2020. A total of 7 days and 28 issues of the chosen dailies were considered. The selected four newspapers were not published from May 24 to 28, 2020, due to the Eid-ul-Fitr holiday and the aftermath of the Cyclone. As a result, May's issues 29 and 30 were included. Two in-depth interviews were conducted with two categories first one is four reporters of selected dailies and the second one was conducted with 20 respondents from Chandipur village of Indurkani upazila in Pirojpur district. Southern districts are highly vulnerable during any natural disaster. In fact, Cyclone Amphan wreaked havoc on Chandipur village.

Theoretical Framework

The current study's theoretical framework is based on several well-established media and communication viewpoints, which should ideally include: The Media's Agenda Setting Function and Normative Media Theory. The role of the media has been described as the media's 'social responsibility' through its 'watchdog' functions, according to the normative theory of the mass media. Public interest is a tough concept to understand, despite the fact that public welfare issues should be the focus of media output. McQuail (2000), on the other hand, stressed four goals of the media's role in a democratic society:

- Surveillance in circumstances of societal violations of social and moral discipline, as well as unrestricted access to information.
- A timely critique of society's roles and organs.
- Encourage participation of people through making information available.
- Values and culture of specific communities are passed down via generations.

The technique of presenting some issues prominently and regularly with the conclusion that huge parts of the public consider those issues as more important than others is known as agenda setting in the media (Coleman et al. 2009). According to Gladys Engel Lang and Kurt Lang, media agenda setting is giving priority to subjects and events that they believe are essential and useful to people, while ignoring issues that they believe are less significant. As a result, the media helped to order people's thoughts (Lowery, Shearon & Defleur, 1988). This research focuses on how the public agenda and the media agenda form agendas and have an impact on society.

People pay more attention to newspapers because they provide accurate and reliable news and allow them to learn more about various topics (Tompson, 2016). Other media outlets were more important than newspapers in publishing disaster news with all aspects thoroughly.

Furthermore, the media should urge the public to take a more assertive part in awareness raising through information dissemination with national and international agencies in order to reduce the damage of disaster. There was a lot of news in the newspapers before Cyclone Amphan arrived, and it's evident from the news that a lot of things were done to guide them and raise public awareness. The agenda for whether disaster stories are considered important is set by the media and the public.

Results

Table 1 shows the specific dates of newspaper disaster-related news in The Daily Star. There was several Amphan-related news on May 22, 2020. The news about Amphan is substantially less than the seven-day newspaper's entire news. The most crucial pages in every newspaper are the front and the back page where Amphan news didn't get insufficient attention. It appears that there is news about Amphan on the front pages rather than the back pages.

Table 1. Number of news (The Daily Star)

Date of newspaper	Total news	Amphan news	Amphan news on front page	Amphan news on back page	Other pages
19 May, 2020	85	3	1	0	2
20 May, 2020	71	3	2	0	1
21 May, 2020	75	6	3	0	3
22 May, 2020	69	9	4	0	5
23 May, 2020	67	5	2	0	3
29 May, 2020	87	2	1	0	1
30 May, 2020	75	0	0	0	0
	529	28			

Table 2 shows the percentage of total and Amphan-related news in The Daily Star. The Daily Star published 529 news stories in seven days, but Amphan news made up only 28 of them, accounting for only 5% of the total.

Table 2. Percentage of News (The Daily Star)

Variables	Number	Percentage
Total news	529	95%
Amphan news	28	5%

Table 3 indicates the information about the number of individual dates of newspaper disaster related news in The Daily Prothom Alo. Amphan-related news was the most here on 21 May, 2020. Here, the news of Amphan issues was less than the total news of the seven-day newspaper. The inside pages, in fact, receive more attention than the front and back pages.

Table 3. Number of news (The Daily Prothom Alo)

Date of newspaper	Total news	Amphan news	Amphan news on front page	Amphan news on back page	Other pages
19 May, 2020	95	6	2	1	3
20 May, 2020	85	6	2	0	4
21 May, 2020	86	17	5	0	12
22 May, 2020	86	16	4	0	12
23 May, 2020	93	8	1	2	5
29 May, 2020	93	3	0	2	1
30 May, 2020	99	3	0	1	2
Total	637	59			

The percentage of Amphan news is depicted in Table 4. Only 59 Amphan news items were found in the seven daily issues, out of 637 total news items, making Amphan news only 9%.

Table 4. Percentage of News (The Daily Prothom Alo)

Variables	Number	Percentage
Total news	637	91%
Amphan news	59	9%

Table 5 shows the information regarding the number of specific dates of newspaper disaster related news in The Daily Bangladesh Pratidin. On May 22, 2020, the Amphan-related news can be found more. In terms of the entire news of the seven-day newspaper, the number of new regarding Amphan is comparatively little. The first page and the back page of any newspaper are the most important but both pages relatively receive less attention.

Table 5. Number of news (Bangladesh Pratidin)

Date of newspaper	Total news	Amphan news	Amphan news on front page	Amphan news on back page	Other pages
19 May, 2020	116	2	2	0	0
20 May, 2020	156	2	2	0	0
21 May, 2020	135	9	2	0	7
22 May, 2020	161	22	4	0	18
23 May, 2020	181	14	1	2	11
29 May, 2020	139	4	0	2	2
30 May, 2020	160	5	0	1	3
	1048	58			

From Table 6, it is seen that the total number of hard and soft news articles sans adverts and other items in the Bangladesh Pratidin newspaper was 1048. Only 58 Amphan news stories accounted for 6% of the total news. In the event of a calamity, it appears that having published news is insufficient.

Table 6. Percentage of News (Bangladesh Pratidin)

Variables	Number	Percentage
Total news	1048	94%
Amphan news	58	6%

Table 7 represents the number of specific dates in which newspaper disaster-related news appeared in the Daily Ittefaq. Stories of Amphan published the most news in a seven-day period on May 23, 2020, emphasizing the importance of the inner pages. As a result, it is clear that news of Cyclone was not widely disseminated as it should have been.

Table 7. Number of news (The Daily Ittefaq)

Date of newspaper	Total news	Amphan news	Amphan news on front page	Amphan news on back page	Other pages
19 May, 2020	84	3	1	0	2
20 May, 2020	91	4	1	0	3
21 May, 2020	112	8	2	0	6
22 May, 2020	77	11	4	2	5
23 May, 2020	108	13	2	0	11
29 May, 2020	101	1	0	1	0
30 May, 2020	113	4	1	0	3
	686	44			

Table 8 shows the total seven days of The Daily Ittefaq newspaper carried a number of hard and soft news without advertisement were 686 , out of them 44 Amphan news were about only 7% of the total news, can be considered to be insufficient in the context of disaster.

Table 8. Percentage of News (The Daily Ittefaq)

Variables	Number	Percentage
Total news	686	93%
Amphan news	44	7%

Table 9 displays the comparative percentage of total news and Amphan related news in the four national dailies where The Daily Prothom Alo found to have the highest volume of Amphan news (9%), while The Daily Star the lowest (5%). Only 6% and 7% of news are covered by Bangladesh Pratidin and The Daily Ittefaq, respectively.

Table 9. Comparison of the percentage of Amphan news in four daily newspapers

Variables	Others news	Amphan news
The Daily Star	95%	5%
The Daily Prothom Alo	91%	9%
Bangladesh Pratidin	94%	6%
The Daily Ittefaq	93%	7%

Structural and Characteristic Analysis

The patterns of news presentation on Amphan issues of the selected newspapers are analyzed in this section. The focus of this research was to determine the role of national newspapers in disseminating information about disasters, with a special focus on pre, during and post-disaster coverage.

Pre-disaster period

Super cyclone Amphan has ramped up, as anticipated by four publications, and they were also warning people about the significance of signals and encouraging them to seek shelter. Providing people with information on how big the tidal wave will be and when it will strike. Cyclone Amphan was anticipated to be more powerful than cyclones Sidr and Aila with greater speed. They had to take additional precautions because they needed to do something at the shelter, and though it was not an epidemic, they disseminated information by emphasizing these issues in the media. Due to the Covid 19 outbreak, people spent their days in a bind. The newspapers also stated that Cyclone Amphan had made more appearances in it. All selected newspapers extensively covered the disaster-prone area, the speed and intensity of cyclones, the evacuation procedure, and the cyclone location through photographs.

During the disaster period:

Other than television and radio, online media were the first providers of news. Newspapers, on the other hand, typically print the day before the news is highlighted today. This newspaper did not receive the news of Cyclone Amphan hitting the final that day. Their portal was up and running. Four national newspapers were chosen by the researcher, all of which possessed print copies but were never published. During the pre- and post-disaster periods, newspapers predominantly covered disaster-related news.

Post-disaster period

Relief and rehabilitation arrangements:

After the disaster, the most essential factor was that the topics of relief and rehabilitation were covered extensively in four newspapers. In the aftermath of a disaster, people suffer a variety of losses. Following the tragedy, relief and restoration efforts were carried out in partnership with both government and non-government organizations. Readers discovered what kind of harm had occurred as a result of the disasters reported in the media. Its damages include efforts done both formally and locally to mitigate disaster damage.

The quantity of damage

Bangladesh has evaded the effects of Amphan in the Sundarbans. Cyclone Amphan did not make landfall in Bangladesh as expected. It made landfall in India from Bangladesh. Bangladesh suffered fewer losses than India. However, at least 31 persons were killed (https://reliefweb.int). A large number of people were without electricity. Many people were left without access to mobile phones. Cyclone Amphan wreaked havoc on Koira, Shamnagor, and Shatkhira. After the storm Amphan, people have been living in flooded areas for a long period. In Rajshahi, there was considerable damage, especially to the mango crops. Cropland tracts were severely damaged. By publishing a variety of news, newspapers attracted the attention of both government and non-government organizations to the rehabilitation program.

The respondent numbers and identities for the selected national dailies in Pirojpur district are shown in Table 10. The key points of their conversation are summarized below-

Receiving primary information of disaster

Before publishing any news, journalists gathered material from a variety of sources, double-checked it, and finished the story. Four journalists from the four publications chosen were interviewed by the researcher. The Department of Meteorology, its website, the Red Crescent, and the Deputy Commissioner's office are the first sources of information for reporters. In order to foresee any natural calamity, the District Press Association has been notified.

Table 10. Respondents and newspaper (Reporter)

Respondent number	Sex	Age	Newspaper	Designation
1	Male	35	The Daily Prothom Alo	District correspondent
2	Male	28	The Daily Star	District correspondent
3	Male	31	Bangladesh Pratidin	District correspondent
4	Male	48	The Daily Ittefaq	Senior reporter

News Coverage of disaster

Journalists were given the disaster's precedent at first, and they attempted to update it and acquire information on their local area. The preparation of news was prevalent before the cyclone and the dissemination of news to alert people to seek shelter. Another issue is that they occasionally republish soft news as hard news. Follow-up news was involved on special news. Maintaining the disaster area source, verifying the information, and developing relevant crisis news are all requirements for disaster news coverage. It is critical to monitor the news both before and after the accident. In most cases disaster news begins with a feature story. Media organizations frequently call journalists for disaster coverage.

Training on disaster Journalism

Different sorts of training are provided by the news house or by different training schools in order to boost the speed of work so that journalists can work conveniently and beautifully. Every newspaper deals with disasters on a regular basis. A journalist must have a lot of information and knowledge to undertake disaster journalism.

Disaster news is presented differently at different periods, and in order to comprehend that pattern, a journalist must be offered and receive separate disaster journalism training. Except for one, all four journalists have received disaster journalism training. According to a Daily Star reporter...

"So far, I've taken training in three areas of environmental journalism, two of which were on disaster management, and I've learnt what I need to keep information and report on newspapers as a result of this training. What is the nature of the disaster management training I received? It was given to me by the Press Institute of Bangladesh (PIB)."... (R2)

To raise public awareness of disseminating information

Increasing public awareness of the crisis through disseminating news in several sorts of newspapers. Before Cyclone Amphan hit, a lot of news was published in newspapers, and it is evident from the news that a lot of things were done to guide and develop public awareness. There are several types of news that are mentioned in newspapers, all of which are vital to informing people and safeguarding them from harm. Another issue was that people were constantly urged to seek refuge in shelters. The newspaper goes into great depth about disaster-prone places during Cyclone Amphan, as well as the threat alerts in those areas. The public can take precautions as a result of this. The public cares significantly more about the harm and prospects that are reported before, during, and after a disaster. The public is made aware of matters relating to the many directions of government via releasing news.

A reporter of the Daily Ittefaq said, *"Natural disasters such as Sidr and Aila have struck our country at various times in the past, and the harm caused during this time was more likely than during Cyclone Amphan. With the knowledge of the past, that period was chronicled in detail in the newspapers. It is critical to encourage people in disaster-prone areas to seek refuge in shelters and to*

raise awareness among them." ... (R4)

Since Cyclone Amphan occurred during the COVID-19 epidemic, it needs to have special guidelines and play an important role in disaster message dissemination in newspaper houses. A reporter of the Daily Star said, *"It's become increasingly more critical to raise public awareness about catastrophes like the Cyclone Amphan. The COVID-19 disease was spreading over the world, and another disastrous Cyclone Amphan was on its approach, so it's very crucial to promote public awareness so that people don't get infected in any way during this Amphan. Newspapers have reported on the use of masks at shelters, as well as the frequent use of soap and hand sanitizers to preserve social distance"...(R2).* According to journalists from four newspapers, the news had a critical role in disseminating knowledge about the Corona virus outbreak and the Amphan period.

Challenge of disaster news

People nowadays receive their news first through online news portals and electronic media, then from newspapers. But people pay more attention to newspapers because they contain accurate and reliable news, and they may learn more about things from them. Other media outlets are more significant than newspapers in terms of releasing disaster news since they can post minute-by-minute on a regular basis, which is not possible with a newspaper.

"In many cases, the news of disasters goes online before it reaches the newspapers and takes people from there. During Cyclone Amphan, it has been observed that its speed is constantly changing and keeping pace with this change is much more difficult for the newspaper due to the online portal's constant updating."... (R1)

Table 11. Demographic Data of the Respondents (People of affected areas)

Respondent number	Sex	Age	Educational Background	Occupation
1	Male	33	Post Graduate	Banker
2	Male	35	SSC	Business
3	Male	38	Class nine	Labor
4	Male	49	Post Graduate	Teacher
5	Female	38	HSC	Teacher
6	Female	22	HSC	Student
7	Male	28	Graduate	NGO worker
8	Female	52	HSC	Business
9	Male	59	B.A	Politician
10	Male	31	HSC	NGO worker
11	Male	48	Graduate	NGO worker
12	Female	43	HSC	Health worker
13	Male	55	HSC	Politician
14	Male	52	Post Graduate	Teacher
15	Male	26	HSC	NGO worker
16	Male	21	HSC	Student
17	Female	34	HSC	NGO worker
18	Male	30	Post Graduate	Banker
19	Male	37	Post Graduate	Teacher
20	Male	45	Graduate	Teacher

Table 11 shows the respondent numbers and identities of Amphan affected areas. In-depth interviews were conducted with 20 respondents from Chandipur village in Indurkani Upazila of Pirojpur district. The following are the main elements of their discussion:

Receiving information about Cyclone Amphan

People no longer wait for the print newspaper for the previous day's news. People are getting information about the calamity from television and online media, thanks to a variety of modern media. When it comes to a community, the first thing that is mentioned about the calamity is in the news; everyone claims that it was discovered on television, but some people prefer to read the newspaper for further details.

"It frustrates me if I don't read the daily Ittefaq newspaper one day. That is why I sit with the newspaper day and night, wrapping up its news. When it comes to calamities, I pay greater attention to the specifics in the news"....(R-4)

A respondent was a teacher who keeps a regular newspaper in his home and selects essential news from the newspaper he gave at the time of the disaster and reads it in depth.

"Every day I keep a newspaper in Bangladesh Pratidin and try to read the newspaper sitting in the shop. Those who come here sometimes read from the newspaper I took with me and read various issues also during Cyclone Amphan. Reading newspaper during Amphan and found out that it would be worse than Aila and Sidr. I discussed the matter with those who were sitting in my shop. It also said that the situation could get worse this time."....(R-2)

In this case, another respondent is a regular reader of the Bangladesh Protidin. He reads very carefully the disaster news and discusses it with others for awareness.

"I hear the news from people that disaster is coming but I can know the details of this news through the daily Ittefaq kept in my house. There is no television in the house. I keep a newspaper every day and read it finish the work of the day. "...(R-3)

Trustworthy and diversity of information on disaster

People learned about disasters from the internet and electronic media, yet newspapers were seen as a trustworthy source of information. The newspaper provided information on any subject. In other media, this style of describing disaster news is not conceivable. Normally, disaster news is described in great detail. As a result, people take newspaper selection quite seriously.

"I watched the catastrophe news on TV, but I was skeptical. The information in the newspaper was accurate and trustworthy. The newspaper was disseminating disaster information and offering useful data. The disaster was covered in a special newspaper story that featured newspaper commentary. ".... (R-6)

Another responder watched television and other forms of media to keep up with the news. He is meant to rely on the newspaper from the standpoint of diversity and reliability.

"There was a time when the day would not begin without a newspaper reading. Other mediums are now available. Because there are so many distinctions between newspaper and television news, I always advise my students to read the newspapers. During Cyclone Amphan, I read articles that numerous reports had published about past Cyclones, which provided me with a lot of information. "… (R-14)

Discussion

The study focused on the role of national newspapers in disseminating information and found by analyzing 19 May 2020 to 30 May 2020 total seven-day newspaper Cyclone Amphan issues selected four national newspapers.

Miah et al. (2011) investigated how natural disasters were covered in newspapers. Concerns about the effects of climate change on Bangladesh are expected to lead to a considerable increase in climate change coverage in the media. The Daily Prothom Alo, The Daily Ittefaq, and The Daily Star were named the top three national newspapers covering climate change problems in 2009, according to an online popularity ranking of Bangladeshi media. Natural disasters receive 47% of journalistic attention, according to this study, which looked at content from May 2006 to June 2009. The Daily Prothom Alo, The Daily Ittefaq, The Daily Star, and Bangladesh Pratidin, on the other hand, covered 5-9 per cent of the disaster news during Cyclone Amphan, according to the current study. The Daily Prothom Alo, on the other hand, published the most news, while The Daily Star published the least. Bangladesh's national newspapers are more interested in event-based coverage of the relevant issues than in-depth investigation, analysis and follow-up. Despite the minimal coverage of catastrophe-related topics in national dailies, The Daily Star and Prothom Alo set some new patterns in reporting the subject, using features and images from the disaster to publish features and creating a chart of disaster damage. The conclusions of Bangladesh Protidin and The Daily Ittefaq, which were debated in the tragedy Amphan, are not serious. The following categories of disaster-related news and information are explained by the daily.

Climate change, according to Islam (2014), is one of the most pressing challenges for Bangladesh, which is affected by climate conditions due to its geographical location. Because its three basic functions are to inform, educate, and entertain, the media serves as a watchdog. As a result, print media is playing an important part in the catastrophe. The newspaper reporter was not appropriately qualified and skilled in reporting environmental and climate change subjects due to the lack of strong and effective presentation in newspapers. That claim is debunked by current studies. Because disaster news is presented differently at different times, a journalist must be offered and

receive separate disaster journalism training in order to comprehend this pattern. According to the findings of this study, newspaper executives have organized extensive training for reporters in order to provide them with the skills and information required for disaster reporting.

The theoretical framework of the current study is based on numerous well-established media and communication viewpoints, which should ideally include: the media's agenda-setting function and normative media theory. According to the normative theory of the mass media, the role of the media has been described as the media's "social responsibility" through its "watchdog" functions. Despite the fact that public welfare issues should be the center of media production, public interest is a difficult idea to grasp. According to the findings of this study, the media covered Amphan news out of a sense of social obligation and as a "watchdog" function. According to the Agenda Setting Theory, the technique of presenting some issues prominently and on a regular basis with the conclusion that a large portion of the public considers those issues to be more important than others is the technique of presenting some issues prominently and on a regular basis with the conclusion that large parts of the public consider those issues to be more important (Coleman, et al., 2009). Media agenda setting, according to Gladys Engel Lang and Kurt Lang, entails prioritizing subjects and events that they believe are important and valuable to people while neglecting concerns that they consider are less important. As a result, the media aided in the organization of people's thoughts (Lowery, Shearon & Defleur, 1988). The findings of the current investigation are very similar to the idea. Given the global importance of 'disaster' issues in general and in Bangladesh in particular, the newspaper's strategy and agenda is to "inform, educate, and persuade disaster-affected individuals by following up on diversifying news on the Amphan issue." On the other hand, the public agenda, by consistently covering news, turned the issue into a media agenda.

On the eve of the COVID-19 epidemic, Super Cyclone Amphan struck. Cyclone Amphan frightened new people, while Corona frightened old ones. During Amphan, newspapers focused on ways to protect people from COVID-19 and took comparable precautions to prevent it. Government directives on social distance and different sanitary issues, including how cyclone centers will be set up and what kind of facilities would be available, have been published in newspapers. Any natural disaster has various follow-up news in newspapers, which is utilized to inform people in greater depth. People will never lose interest in the newspaper, no matter how soon it is available on the web and electronic media because the topics related to any tragedy in the newspaper are presented in a more and more informative manner.

Conclusion

According to this study, Bangladesh's national newspaper covers disaster news, but not adequately. Newspapers are usually important in catastrophe situations. According to the findings, Bangladeshi national newspapers are more interested in event-based coverage of significant issues than in-depth investigation and analysis. Given the gravity of the disaster issues in Bangladesh, the newspaper should devise and implement a strategy to inform, educate, and persuade the public. Findings exhibit that the majority of these four publications addressed disaster issues and reported on the aftermath of the disasters. Regardless of its low coverage, the daily consistently draws attention to its reliable and trustworthy information. Newspapers publish a greater variety of news and follow-up stories than other forms of media. This study also shows that news organization or different training schools provide various types of training in order to increase the speed of work so that journalists may work efficiently and attractively, which has not been seen in previous studies. Therefore, since people have a higher level of trust in printed newspapers than in online ones or other media, the amount of coverage of the disaster period in the news should be enhanced. The researchers had to work around some constraints in order to complete this study, such as determining the sample size. The finding would have been more accurate if a large number of samples had been taken. Another issue was time and budget, as the researchers could not reach a significant number of respondents if they funded the study themself.

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Conflict of Interests

The author declares no conflict of interest.

References

Akter, T. (2009). *Climate Change and Flow of Environmental Displacement in Bangladesh.Unnayan* Onneshan-The Innovators.

Boykoff, M. T., & Yulsman, T. (2013). *Political economy, media, and climate change: sinews of modern life*. Wiley Interdisciplinary Reviews: Climate Change, 4(5), 359-371.

Chen, L. C. (1973). *Disaster in Bangladesh*. Oxford University Press.

Coleman, R., McCombs, M., Shaw, D., & Weaver, D. (2009). *Agenda setting.* In *The handbook of journalism studies,* Routledge (pp. 167-180).

DOMINICK, R. J & WIMMER, D. R. (2011). *Mass Media Research, An Introduction.* 9th Edition, Wadsworth, Cengage Learning.

Haque, M A. Yamamoto, S. and Sauerborn, R. (2010). *Print Media and Climate Change in Bangladesh: The Missing Health Issue*, Institute of Public Health, Heidelberg University,

Germany; Proc. of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, Sept. 2010; http://benjapan.org/iceab10/40.pdf, retrieved on 26.03.2014

Islam, S. M. (2014, July 2). *Print media coverage on climate change issues in Bangladesh*. DIU Journal of Humanities and Social Science.

Kamal, U. A. M., & Kaudstaal, R. (2003). *Delineation of the coastal zone working paper. WP005*. Dhaka, Bangladesh.

Lasswell, H. D. (1948). Bryson, L. (ed.) *The Structure and Function of Communication in Society. The Communication of Ideas*. New York: Institute for Religious and Social Studies. p. 117.

Lowery, Shearon A. & Defleur,M.L. (1988), *Milestones in mass communication research,* Longman Inc, New york.

Miah, D. M., Kabir, h. M., Koike, M., & Akter, S. (2011). *Major climate-change issues covered by the daily newspapers of Bangladesh*. Springer Science.

Mallick, B., Ahmed, B., & Vogt, J. (2017). *Living with the risks of cyclone disasters in the south-western coastal region of Bangladesh.* Environments, 4(1), 13.

Neverla, I., Luthje, C., & Mahmud, S. (2012). *Challenges to climate change communication through mass media in Bangladesh: A developing country perspective. Rethinking Climate Change Research: Clean Technology, Culture and Communication*; Almlund, P., Jespersen, PH, Riis, S., Eds, 223-241.

Osanloo, A., & Grant, C. (2016). *Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your "house".* Administrative issues journal: connecting education, practice, and research, 4(2), 7.

Reza, Shameem, S. M. and Haque, A. (2011), *'Agenda Setting on Environment and Climate Change Issues in Bangladesh Newspapers: the case of UN Climate Change Conference, Cancun'. Social Science Review* (The Dhaka University Studies, Part-D), 28(2)

Rashid, H. (2011). *Interpreting cyclone disasters in Bangladesh and Myanmar from web-based newspaper discourse: media framing of cyclone vulnerability on the Bay of Bengal coast.* The Arab World Geographer, 14(1), 1-32.

Rahman, M. (2010). *Climate change coverage on the mass media of Bangladesh*. Global Media Journal Paistan .

Rice, R. E., & Atkin, C. K. (2009). *Public communication campaigns: Theoretical principles and practical applications.* In Media effects (pp. 452-484). Routledge.

Roy, C., Sarkar, S. K., Åberg, J., & Kovordanyi, R. (2015). *The current cyclone early warning system in Bangladesh: providers' and receivers' views.* International journal of disaster risk reduction, 12, 285-299.

Shahid, S. (2009). *Probable Impacts of Climate Change on Public Health in Bangladesh*, Asia Pacific Journal of Public Health

Tompson, T. (2016). *A New Understanding: What Makes People Trust and Rely on News*. American press institute.

Walizer, M. H. & Wienir, P. L. (1978). *Research methods and analysis: Searching for relationships.* New York: Harper & Row.

https://reliefweb.int. Cyclone Amphan: Death toll rises to 31. (2020, May 22). Dhaka Tribune. https://archive.dhakatribune.com/bangladesh/nation/2020/05/22/cyclone-amphan-death-toll-rises-to-34

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ORIGINAL ARTICLE

SOCIAL SCIENCE

PRACTICES OF AND CHALLENGES FOR CITIZEN JOURNALISM IN THE MAINSTREAM MEDIA OF BANGLADESH

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Abstract

In the past few years, it is observed that social media was the first to respond to some issues that become the talk of the town. Broad and easy access to mobile devices and social media has created immense opportunities for the public to share and publish their works on open forums. The audience as the prosumer (producers and active consumers) generates 'user-generated content' that undoubtedly influences the mainstream media's content production procedure and manner through distributing them to many news or social platforms. This process leads to citizen journalism as a parallel mode of journalism where collection, collaboration and dissemination of the information go through a single channel. This study is based on both primary and secondary data sources to understand the impacts, challenges, and opportunities of citizen journalism needed beside the journalism. The qualitative data are collected from seven in-depth interviews with senior journalists, editors, academics and news managers. And two semi-structured interviews were conducted with citizen journalism project coordinators. Their analysis regarding this citizen journalism practices in mainstream media creates access to information by opening a new door to more significant resources. However, the concern remains whether incorporating citizen journalism into mainstream journalism poses any threat or not. It is observed that the absence of practicing journalistic rules and regulations in social media makes their credibility questionable and generates confusion. Online news sites use mobile technologies to create and disseminate their media products, gradually attracting the audience and readers. As a result, people are often used to accessing news from online sites rather than print media. With this current demand, mainstream news media is focusing on more interactivity on their online platforms and encouraging their audiences to join in the news production process.

Keywords: Citizen journalism, user-generated content, social media, mainstream journalism, digital

Introduction

Bangladesh is one of the developing countries in South Asia, with a population of more than 166.50 million (BBS, 2020). Over the last couple of decades, Bangladesh has seen rapid growth in internet access and mobile phone usability. According to the Bangladesh Telecommunication Regulatory Commission (BTRC), at the end of January 2022, Bangladesh's Internet subscribers reached 121.87 million (BTRC, 2022). The total number of mobile phone subscribers has reached 180.78 million, and over 95 percent of them are using their mobile phones to go online as of March 2022, according to BTRC data. With the development of the ICT industry, a massive shift has happened in the journalism sector as well. The Internet opened an entirely new opportunity for them.

According to Data eportal survey, 52.58 million people have access to the internet, which shows the internet penetration in Bangladesh is 31.5%. Interestingly, there were 49.55 million social media users in Bangladesh in 2022, and between 2021 to 2022, the number of social media users in Bangladesh increased by 4.6 million (+10.1%), which means 29.7% of its population uses social media (DataReportal, 2022). Since social media is a big platform in the age of information and technology, it has created an opportunity for borderless communication.

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For visual content creation and consumption, people from many countries are choosing mobile devices as their tools. Marching with the trend, in Bangladesh, youth are creating visual content on mobile devices and sharing directly on social media more frequently. YouTube, the video-sharing website, has already created a generation of young stars in Bangladesh to influence teenagers. Since the rollout of 4G services in 2018, YouTube and Facebook viewership has skyrocketed in Bangladesh, opening a new window for content makers to produce Bengali content for Facebook and YouTube. According to bdnews24, during the ongoing COVID-19 crisis, Bangladeshis are reportedly using internet data at more than 50 percent of their usual average, watching YouTube and Facebook videos in the local language (Bdnews24.com, 2020). The younger generations in Bangladesh are using mobile devices for communication purposes and as an interactive content creation tool as mobile and web-based technologies that enable them to create highly interactive multimedia content.

The use of mobile technology is not limited to creating content but also how audiences receive the news. It has been said that the telegraph transformed the way that newspapers could report the news more than 100 years ago. Now, smartphones are doing the same for TV news organizations (Lita, 2022). With the rapid growth in internet consumption, people from different statuses of life gather their day-to-day information from social media pages. Here the 'online and mobile technologies play an increasingly prominent role in television newsrooms, particularly on the local level' (Chadwick, 2014, p. 2) when it comes to reporting, gathering information and delivering those to the audiences. Citizen journalists bring that information to them instantly, sometimes without even any censorship. To meet that demand, 'mobile devices have reformed the newsroom environments by introducing new means to connect with the audience and to communicate with other journalists within the same place' (Jamil & Appiah-Adjei, 2019, p. 42). As a result, both traditional news agencies and broadcast channels find it important to use mobile technology to gather information and disseminate those from the location. From the early 2000s, we have observed the development of information and communication technologies in many South Asian countries, including Bangladesh. These emerging new technologies and platforms have affected where citizens can get their daily news and how mainstream journalists do their job. As noted by Anthony Adornato, 'social media and mobile devices are the latest technologies shaping the field' (Adornato, 2017, p. 3).

Technology can affect news values in both positive and negative ways. Like mainstream journalists, with the help of limited resources and cheap equipment, citizens can broadcast live anytime from anywhere. Nevertheless, it is often said that just because something is of interest to the public and gets lots of clicks does not make it public interest journalism (Ergas et al., 2019, p.1). Similarly, the rise of user-generated content has gone hand-in-hand with poor-quality click bait and fake news (Hill & Bradshaw, 2018, p. 52). Traditional journalism has now slowly moved to digital format. The visibility of 'declining public trust in news, loss of advertising revenue, and an increasingly participatory, self-expressive and digital media culture', leading news organizations are trying to find new ways to reach their audiences (Deuze et al., 2007, p. 322). Many print newspapers today have online versions; television channels are streaming user-generated content on their websites. The content of news media is actively integrated with social networks. Today Bangladeshi news organizations are very much open in terms of using the content that citizen journalists produce; even in some cases, the news outlets offer audiences to share their stories as photos, texts, or videos.

Ordinary citizens can craft and distribute user-generated contents due to the wide access to social media and mobile devices. Bangladeshi ordinary citizens now use their smartphones and social media channels to instantly deliver newsworthy multimedia content from the field, which directly impacts the news production process in the mainstream media in Bangladesh. In the article (Uncertain) Future of Journalism in Bangladesh, Kaberi Gayen talks about the changes in the media ecosystem. Media organizations that used to control content and channels now only produce content; companies like Google and Facebook are the gatekeepers to audiences. Online versions of almost all newspapers use social media accounts to gather, distribute and publish content (Gayen, 2020).

In 2011, we observed mass protests and civil unrest in different Islamic countries of the Middle East and North Africa, which later turned into national revolutions (Kinfu & Khan, 2013). Also affecting the Asian region there were also a series of demonstrations in Bangladesh where Facebook was used to generate buzz about those events (Khan, 2020). Citizen Journalists captured photos, recorded videos, and instantly shared original stories with millions of people worldwide. Thus, these untrained non-professional journalists play an active role in their community and cover untold stories to satisfy public curiosity. Social media is a tool to share content, feelings, thoughts, ideas, emotions, and etcetera. Through social media, citizens can gather, process and distribute information and communicate to fulfil their livelihood demand.

Most of the discourse related to citizen journalism in Bangladesh usually focuses on the tension between traditional journalism and citizen journalism (Sharma & Rahaman, 2018). Even how it is the reason for the 'spreading of misinformation as it is done by amateurs. From those narratives, it is easily noticeable that 'citizen journalism has considered an independent entity working on their (citizen journalists) own' (Moniruzzaman, 2021, pp. 232-233). There is a study gap while addressing citizen journalism from a mainstream media angle. This article aims to mitigate those gaps and discuss how mainstream media practices citizen journalism and what kind of challenges professional journalists face regarding citizen journalism. To fill up the knowledge gap from the previous research, we have set our research objective to identify the practices of citizen journalism from a mainstream media lens. The following research objectives are carried out to conduct this study;

1. To investigate the practices of citizen journalism in mainstream news media.
2. To understand the present state and challenges facing by both professional journalists and news outlets while practicing citizen journalism.
3. To understand the practices of mobile technologies and social media tools reshaping the mainstream media while using citizen journalism.

To conduct this study there are three research questions to answer;

1. How does mainstream news media practice citizen journalism?
2. What type of challenges do professional journalists and news outlets face while practicing citizen journalism?
3. How does mainstream media use mobile technology and social media tools to practice citizen journalism?

This article sheds light on how these changes influence Bangladeshi mainstream media and what insights experts are adding to this issue. Before continuing, it is vital to talk about how the audience has changed with the advent of social media. We also need to focus on the use of smartphone's content creation and the nature of citizen journalism' content in Bangladesh.

Democratic participatory theoretical framework has been applied in this study to understand citizen journalism's engagement and impact on mainstream media. In the late nineteenth and the early twentieth centuries, social theorists, like Denis McQuail, cautiously observed the 'great transformation in traditional and communal ways replaced by the fast-paced secular, urban living and to a great expansion in the scale of social activities' (McQuail, 2010, p. 53). Looking into the practicality, the media professionals and experts in broadcasting media emphasize the necessity of participatory journalism. Democratic participatory theory directly constructs citizen's active participation, where they have access to report or express their knowledge on the occurrences around them. A citizen's active role in mass media through proper communication channels is more prominent in a democratic set-up where the infrastructure works favorably. Therefore, citizen journalism has been described as the 'democratization of multimedia technologies by the people and for the people' (Okorie et al., 2012, p. 158). This concept signifies the underlying fundamental of citizen journalism, 'where mainstream journalism is not challenged rather: a press word equivalent to grassroots democracy' (Okorie et al., 2014, p. 16).

It is important to shed light on mass communication to understand the democratic participatory theory, and how they help construct society, and through which channels? The nature of the relation between media and society depends on the circumstances of time and space. As an audience, people tend to experience mass media based on the societal structure. There are two divergent segments with strong perspectives: Left (progressive or liberal) and Right (conservative). According to Denis, the Leftist theorists are critical of power exercised by the media in the hands of the state or large global cooperation (McQuail, 2010, p.53). Whereas Conservatives argue that liberal bias of the news creates damage to traditional values. Shifting from the political and ideological aspects, social theorists focus on two autonomous attributes that characterized communication and concentrate on media activities. Media-centric theory suggests media as the prime mover in the society appreciating technology's advancement for creating smooth communication. Contrary to the previous one, socio or society-centric theory mainly views the media as a reflection of political and economic forces (McQuail, 2010, p.12). At the crossroads of these ideas, whether media drives society or not, Denis McQuail concludes, it is certainly true that mass communication theory itself is so driven, tending to respond to each major shift of media technology and structure (McQuail, 2010, p.53). In addition, the public's participation- individually or collectively- in mainstream journalism generates those responses.

The idea of democratic participant theory generates from the urge to bring homogeneity in media by removing monopolization (public/private) centralization of the press and top-down approach (Bajracharya, 2018). Mass media's power initially bases on the observation of their greater reach and apparent impact on society. Pairing

it with better access to technological advancement, the citizen starts enjoying the freedom of expression in an interpersonal manner and in communal, without getting guided by any central authority to control it (Vil'anilam, 2016). Online platforms have turned into digital space for them to share their democratic views. Since the communication channel is not centralized, it creates more scope for audiences to become mainstream journalism participants. These shifting roles have eventually brought positive changes despite skepticism about the direct power of mass communication (McQuail, 2010, p. 53). Besides this speculation, user-generated contents are creating a finer impact on society through social media.

The citizen participation in mainstream media poses overwhelming concerns- whether citizen journalism will take over the mainstream professionals. Dan Gilmor pins it down as information is an ocean, and newsmakers can no longer control the tide as easily as they once did. Participatory journalism is almost free from censorships, legal issues, and official code of conducts (Gillmor, 2006). The Democratic Participant Media theory confirms citizen journalists can 'serve as a watchdog to the development process of a nation by contributing their opinions and thoughts on the political, social, and economic fields' (Okorie et al., 2014, p. 16).

Citizen journalism: Impact on mainstream journalism

The factor of credibility is a big issue when differentiating the characteristic features of mainstream and citizen journalism. With the access to new technology, mainstream media's predominant role in collecting news straight from the first source experiences a drastic change in sourcing the information from the field level and somewhat becomes dependent on citizen journalism. Carr et al. (2014) assumes that with the increase in citizen journalism, the need to understand how individual predispositions interrelate with news sources to impact the viewpoints of news credibility becomes more and more crucial. Also, this phenomenon using a web-based experiment and examines the influences one's predispositions toward the media and politics have on mainstream and citizen journalism's perceived credibility (Carr et al., 2014). In Bangladesh's perspective the presence of grassroots news reporting by the people and for the people has enabled bloggers to perform as citizen journalists. Before publishing any news, the regular practice in mainstream media is the gatekeepers edited, polished, and sometimes censored the news before presenting it to the audience (Haq, 2014, p. 190-191). Scholars have discussed various types of citizen journalism activities. According to Kern and Nam there are three different indicators of activities of citizen journalism: purpose, production and profit oriented (Kern & Nam, 2009). The first indicator, purpose, relates the news gathering process where citizen journalists can affect and contribute to the society forming a civic dialogue. The second indicator, production, indicates whether citizen journalism emphasizes the gatekeeping role from professional journalists or lets citizens control the production or both. The third dimension, profit oriented, indicates whether citizen journalism is profit oriented through subscriptions and advertisements or is not-for-profit oriented toward voluntary journalism.

Citizen Journalism: Impact on media

Chinese researcher Xin concurs with Greg and postulates that citizen journalism has an impact on media. He focuses on the political and social consequences of the upsurge of citizen journalism in China (Simons, 2016). He also notes that the mainstream media of China is still under tight control where social conflicts are escalating, and nationalistic sentiments are worsening. Moreover, he suggests that the impact of citizen journalism on mainstream journalism and participation of the public is mostly discoursed of Western democratic societies. Furthermore, they concur that one knows little about citizen journalism, and its political and social impact in nondemocratic societies, in this case the country of China (Xin, 2010).

Xin (2010) also conducted four case studies of citizen journalism practices in China. The results of the study, is that the impact of citizen journalism on Chinese mainstream media and society is of multifaceted domains. That there is evidence that citizen journalism is used by mainstream journalism as news source, and as well as an alternative channel for distributing politically sensitive information (Xin, 2010).

User-Generated Content

User-Generated Content refers to the content (image, video, text, or audio) captured or created and then uploaded online by a user. According to Licitar, they will commonly use their mobile phones to capture a photo of the event, create a video, write a tweet or a caption describing their surrounding and experiences in order to inform and connect with other people (Licitar, 2018, p. 5). All those contents qualify to be mainstream media newsworthy. Similarly, not all that scribbled on digital platforms can be dubbed as citizen journalism.

User-generated content is an essential part of the revolutionary changes in the media we have witnessed since the early 2000s. The growing competition in the news media industry has paved the path for citizen journalists to create their own content. This has led to the fact that citizen journalists fighting for their audience's attention, try to work as professional journalists. On the other hand, the mainstream news media is seeking cooperation with citizen journalists.

Thurman (2008) stated how citizen journalism affects the process of broadcasting news. In his study implemented upon nine major British news websites, he notes and argues that the mainstream online news media are criticized for being slow to publish the news when compared to citizen journalism which utilizes in particular, the social media sites to broadcast and more importantly to promote independent news-related content (Thurman, 2008). Traditionally, the mainstream media is marked with either silence or look another way when carrying sensitive news. Whereas user-generated content, digital news, and seamless live streaming cover news from different viewpoints.

Three characteristics of user-generated content

1. It reflects on the personal opinion of the user, not of an organization.
2. It is considered as creative content. Therefore, the user gets the chance to spice it up by adding something on his own.
3. Usually, user-generated content is circulated online, and therefore, it is open to all users (Khan, 2020).

Road map for User-Generated Content to User-Generated Stories in Mobile-first Journalism

It is undeniable that for citizen journalism, the essential component is user-generated content. Besides user-generated content, there is another method to create content, which is referred to as user-generated stories. There is a significant difference between user-generated content and user-generated stories. This part of the article will manifest the two types of citizen's engagements on mobile journalism platforms and the perceptive difference between them.

Mobile journalism (Mojo) has become a buzz word in the last couple of years. Mobile journalists are known by the abbreviation mojo. Mojo means you can do broadcast journalism with only a mobile phone. Undoubtedly, mobile journalism is an emerging form of storytelling. It is an ongoing conversation between journalist and user. In this respect, mobile journalism is not just a technological phenomenon but has wider social and cultural significance than media platforms such as print and radio. Further, he adds, Mobile journalists are reporters who use a mobile or cell phone to shoot stills or video with the mobile's camera, capture and edit video, compose stories with fold-away keyboards. In a nutshell, we can say that by doing Mojo, can do any type of journalism on the go (Khan, 2020, p. 40).

Ivo Burum and Stephen Quinn mentioned in their book a set of digital storytelling skills and tools dedicated to empowering citizens, journalism students, and professional journalists appropriate for convergent change processes happening in many countries. In Ivo Burum and Stephen Quinn's observation, 'mobile journalism is an innovative form of storytelling with smart mobile devices to create news reporting-related content' (Burum & Quinn, 2016a, p. 16).

Ivo Burum & Stephen Quinn have underlined a rationale for their book 'Mojo: The Mobile Journalism Handbook' that provides a road map for training people to create user-generated stories that enhance grassroots journalism by creating an awareness of what the authors call new buzzwords in digital language. According to Ivo Burum, this is mobile content produced to a broadcast-ready state that is not as easily subsumed by mainstream media's vertical content streams. Following this, Ivo Burum suggests a set of skills and mobile technologies required to better purpose user-generated content into more purposeful user-generated stories produced by citizens to create a more diverse and less marginalized public sphere (Burum & Quinn, 2016b, p. 39).

Analysts like, McChesney believes the 'accessibility of technologies and anywhere ability to communicate suggests we are in the midst of a communication and information revolution where a reporter or citizen shoots, edits, voices, and captions the story from the field' (McChesney, 2007, p. 3). In the last five or six years, quite a few pieces of content provided by citizen journalists finally made their way to mainstream media. For example, on October 22, 2019, Khaleda Akhter Lucky cut down the plants of the rooftop garden of a building called Nakshatrabari in the Dogormora area of Savar. Another lady named Sumaiya Habib captured the video of the incident and posted it on her Facebook timeline at 5:58 pm on the same day (UNB, 2019).

Materials and Methods

This study is based on both primary and secondary sources of data. The approach used for the generation of research data was desk study. We chose senior journalists and experts based on their work experiences in the relevant field for further studies. To understand the impacts, challenges, and opportunities of citizen journalism in the mainstream media, the study used in-depth interviews (IDI). The qualitative data was collected from those in-depth interviews with seven senior journalists and media managers from daily Prothom Alo, Ekattor Television, Jamuna Television, Oparajeo Bangla and academic Greg Simons and Suman Rahman. Simultaneously, two semi-structured interviews were conducted with citizen journalism project coordinators from daily Prothom Alo and Bdnews24. Those were selected by using purposive sampling method.

A standardized protocol of open-ended questions was used for both types of interviews. The differentiation was purely based on the participant's relation and experience with the content. For semi-structured, we opted for interviewees who were going to discuss it from their personal point of view, which they had experienced while working with citizen journalists. Here we followed the flexible interview protocol to guide the interviewees in a particular direction. It was important to provide them with supplementing follow-up questions to understand their thoughts, feelings and beliefs regarding citizen journalism. For the in-depth interviews, we had chosen interviewees from a strong organizational background where they could discuss the challenges they had faced while practicing citizen journalism. We had a defined and deliberate agenda while choosing this methodology.

As secondary data, the total number of 7 articles was collected from journals, periodicals, relevant publications, newspaper articles and govt. reports during 2019-2022. Based on the purposive sampling Prothom Alo and Bdnews24.com web platforms were selected for the study to see the strategies of citizen journalism projects on their websites. These two platforms are selected considering that they are actively practicing citizen journalism alongside their mainstream platforms. Whereas other mainstream news portals are not giving this option.

A total of 9 respondents participated in in-depth interview. Due to the COVID-19 pandemic, all the interviews were conducted remotely using online platforms. The average interview lasted around 30-40 minutes. Thematic analysis was used to analyze the qualitative data. Several types of research-related materials were reviewed to understand the real impact of citizen journalism in mainstream media and analyzed in multiple cases where the question of citizen journalism's influence was raised. Thus, the study analyzed five cases here that have been an outbreak in Bangladesh from 2013 to 2021. They were reported in different online news media and social media. For authentication, only cases that the authors verified were selected.

Prothom Alo and Bdnews24.com web platforms were selected for the study to see the strategies of citizen journalism projects on their websites. These two platforms are selected considering that they are actively practicing citizen journalism alongside their mainstream platforms. Whereas other mainstream news portals are not giving this option.

Results

Citizen Journalism practices in mainstream news media

The mainstream media of today has adopted a user-centered strategy, leaving the journalists to meet user needs. Henry Jenkins and other theorists saw user engagement as a crucial component of the new affective economy, in which the ideal media consumer was active, emotionally involved, and socially connected(Jenkins, 2006, p. 20).

With the help of different online platforms, users shuffle between them creating their own text, photo and video content and publishing it in mainstream media. Traditional news media companies such as Prothom Alo and Bdnews24 have a long relationship with citizen journalists because of their user-friendly websites where they can express their thoughts and encourage others to contribute to the conversation. The same pattern is noticeable in news TV channels where they are ready to incorporate citizen journalism as their open source. In this empowered and connected world, the value is placed on the open source where conversation is the kingdom. This is different from the old media models where content or distribution was king (Jarvis, 2005).

Prothom Alo

Prothom Alo is one of the influential daily newspapers in Bangladesh, established in 1998. Their online portal Prothomalo.com is the number one Bangladeshi as well as Bangla website in the world, based on traffic and page view.

Prothom Alo has always been keeping citizen journalism high on the priority ladder. By giving readers reliable news, the gatekeeper ensures their needs are met. With that credibility and seeing the shift in mainstream journalism, they

have introduced an online news portal (prothomalo.com) in the early 2006 and added a platform for citizen journalism. Respondent 1 (R1) said, in May 2019, Nagorik Shangbad (Citizen News) started its journey under the Prothom Alo online portal. In the beginning, Durporobash was published as a supplementary once a week; later, in 2012, it shifted to the online platform. Durporobash is a segment dedicated to expatriates where they have been penning, regularly, the bliss and plight and other aspects of expatriate life. And local readers write about incidents they witness or come across and send them to Nagorik Shangbad segment for publishing.

In Journalists as gatekeepers, PJ Shoemaker defines, 'the role of the mainstream journalist as a gatekeeper includes writing, editing, positioning, scheduling, repeating, and otherwise massaging information to become news' (Pamela et al., 2008, p. 73). However, with the new media expansion this role has narrowed down to a point where the traditional journalism largely depends on the amateur content to tell the story of what had transpired on the ground (Allan, 2017, p. 1). Respondent 1 (R1) proclaims from his experience on user-generated contents; the news outlet promotes content such as education, campus, study, travel, seeing and writing. Because this kind of engagement is merely to keep the content authentic and enable the readers to offer a platform where they can speak for themselves.

The traditional media is gradually feeling the need to incorporate citizen journalism into their news flow. This emerging sector can be a greater source of information to enrich their resources. But there is a certain hesitation which can be noticeable due to professional involvement. In Protham Alo's citizen, Respondent1 (R1) single-handedly manages journalism desk. He says now they can upload 5 or 6 news on an average because of the lack of human resources, hoping to see the increase in future both in terms of contributors and gatekeepers.

Bdnews24.com

Bdnews24.com started its journey as the first online-based news organization in June 2006, with an active online writer, Toufique Imrose Khalidi as their Editor in Chief. Being the first platform for citizen journalism, Bdnews24.com has over 500 journalists and photographers around Bangladesh and beyond. The news portal offers free-to-access 24/7 news sources. While the mainstream press media operates through multi-interrelated sectors, in Bdnews24.com, a single moderator under the main desk and IT. Effectively handles the online portal the moderator coordinates with the sources, then forward the content to the editorial team. The moderator Respondent 2 (R2) mentions that since citizen journalism is a new concept in Bangladesh, the audience used to mix it up with blogs at the beginning.

Regarding live streaming, video content or photo, mainstream media has to be more cautious. Respondent 2 (R2) says their news organization takes a particular interest when someone is live streaming from the location where the actual incident is happening. It is undeniable to acknowledge the first-person testimony of witnessing an occurrence and recording that with the digital camera or mobile phone was widely prized for making a vital contribution to mainstream media(Allan, 2017, p. 1).

Challenges: Professional Journalists and news outlets encounter

Lack of awareness regarding the concept of citizen journalism

Respondent 3 (R3) says that Bangladeshi media needs to decide whether they want to engage citizen journalists in their platforms, that could be a newsgathering process to production. Because the term citizen journalism appeared to capture something of the countervailing ethos of ordinary person's capacity to bear witness (Zeng et al., 2019, p.4). Thereby these ordinary people as reporters provide with useful information or share the footage of an incident, they cover which creates an ostensibly new genre of reporting (Zeng et al., 2019, p. 4). In a similar vein, Downie & Schudson (2009) propose citizen journalism as an alternative, voluntary, and non-profit journalism conduct from a wide range of spheres and voices in society, which can operate freely and independently from all sorts of restrictions applied by the government and mainstream media (Downie & Schudson, 2009). Respondent 3 (R3) has seen that several breaking news events are first noticed and shared with the mass as video footage by these growing numbers of localized citizen journalists.

In Bangladesh prospects, citizen contents in the mainstream media are still very low. Still, today, while reporting a case, the news agency mostly depends on the professional's information rather than on the local citizens who have witnessed the case. In her final note, Respondent 3 (R3) stresses the fact that the current scenario in Bangladesh about the use of citizen content is very low because most of the citizens are not aware of the concept of citizen journalism. She mentions that the citizens must be made aware first of the concept and process of citizen

journalism, and only then the concept of citizen journalism will flourish, interaction will be increased and be a legit news gathering source in Bangladesh.

Lack of morality and reliability

Collect, collaborate, and then disseminate- these are the three simple forms where journalists work. A closer look at these actions states that only by emphasizing the sources, the role of a journalist comes to seem comparatively minor (McNair, 1998, p. 6). Fact checking the internal credibility is one way to justify the course, but the main challenge appears when the audience questions the authenticity or credibility of the news. Here comes the moral and ethical obligation of the journalist both in terms of exploiting the source or the private space of the news source.

Apprehensively, Respondent 4 (R 4) states that the lack of morality of mainstream journalism in social media reflects the absence of practicing journalistic rules and regulations. As a result, the audience is facing confusion about information where their trust gets shaky. Bangladesh Press Council has a set of policies for journalists working for newspapers or agencies, which they need to abide by. This code of conduct helps the media and journalists act responsibly in their professional activities.

In 2002, the press council act was amended. However, newspapers, news agencies, and journalists are not complying with the code of conduct or morality in many cases. With the 21st century's technological advancement, mainstream media has started harnessing social media as a source for their news. It is noticeable that the mainstream media outlets' competition over uploading news on social media first sometimes put their ethics in a compromising situation. Dr Shafiul Alam Bhuiyan, Professor at Film & Media Studies, Dhaka University, said in an interview to Deutsche Welle (DW) when it comes to ethics in journalism in a general sense, we can safely say that is not obeyed properly, which, along with other factors, attributes to the competition about who can be the first to publish some news by any means (DW, 2021).

For mainstream journalist's irresponsible or partial attitude, people cannot pin their trust in them. Respondent 5 (R5) highlights some key responsibilities of mainstream journalism and suggests important considerations journalists must follow carefully. He identifies professional journalism as the only type of mainstream journalism. His thought echoes with Jürgen Huberman's theory that if we situate journalists as a key facilitator of the public sphere (Habermas, 1991, p. 5), then the question we must ask who speaks through the news (Franklin & Carlson, 2011, p.1). In that respect, if the journalist fails to verify the content beforehand, then the blame goes to him. The reason is apparent that the reporter's task is to assembly rather than the construction of the meaning (Bell, 1991). From audience's perspective, this ordinary structure often escapes our scrutiny, and they straightway associate the journalists with the news (Franklin & Carlson, 2011, p. 1).

While discussing the main challenge, which mainstream journalism is facing today is the spread of fake news via social media platforms. Respondent 5 (R5) says the main responsibility of a journalist is to probe before publishing any news. Respondent 5 (R5) mentions that;

> *Social media does not dominate the mainstream media, where the respondent identifies the mainstream media as a news medium and social media as a medium solely for communication purposes. There might be multiple chances that an incident could be witnessed by citizen journalist first hand, and they immediately shared that on online, readers then look for credible reporting from a professional news site.*

In such cases, Respondent 5 (R5) states that mainstream media journalists only publish news after investigating it thoroughly. Furthermore, in the Bangladeshi context, Respondent 5 (R5) mentions and stresses that citizen journalism- the new form of journalism- is in a fledgling state because anyone can access mass communication via technological advances. With the power to respond, ordinary citizens practice their democratic right overlooking the fact they need proper education, training, and collaboration skills (Franklin & Carlson, 2010). According to Respondent 5 (R5);

> *For a citizen, it is very difficult to perform one's dutiful task as a journalist, firstly due to the process involved in retrieving the accurate information of an event, or a phenomenon, when one is a sole individual, rather than being a corporation of a news agency.*

With an optimistic note, Respondent 5 (R5) concludes that if these citizens join together hand in hand to establish citizen journalism in Bangladesh, it can disseminate accurate information and thus become a reliable source of information besides mainstream journalism. And only that might help citizen journalism to flourish in Bangladesh (Dhaka Tribune, 2021).

Rumor is putting citizen journalism at risk

The overwhelming challenges for the mainstream news portals are the possible risk of spreading fake news. With the advancement of technology and people's access to information 24/7, credible news organizations have the potential to distribute false news in the form of breaking news errors (Zimdars & McLeod, 2020). While talking to Respondent 6 (R6), he says, today what we understand about fake news by definition is completely different from what it was twenty years ago.

> *With the help of the internet, fake news spread with such a magnitude that it can be difficult to restrain from reaching a significant number of users since the internet was massively accessible to everyone. The circulation of fake news sometimes exceeds the circulation of proper news on social media and online portals*.

An article from a fake news website claiming, Pope Francis shook the world, endorsing Donald Trump for president- it engendered almost a million shares by readers during 2016's USA election (Richard et al., 2018). This kind of very made-up information to polarize voter's opinion during election time is the political component of fake news (Quandt & Singer, 2009).

In Bangladesh's context, citizen journalists are prominently active on social platforms, and their unfiltered contribution certainly increases the risk of creating and spreading fake news. The creator of Hashtag Our Stories, Yusuf Omar, expresses his concern about the spread of false information on social media. For instance, when a fire breaks out somewhere, people take no time to upload pictures or videos and share those, some of which were actually captured from past fire incidents. People even propagate death rumors (Prothom Alo, 2019).

From the deep-rooted superstitions, a sudden rumor starts spreading regarding head required for Padma Bridge. In July 2019, social media was overflowing with the news that the Padma Bridge construction would require severed human heads. It went viral to the extent that the Padma Bridge Construction Project's chief office circulated a notice asking not to pay heed to such rumors and terming the rumor as baseless. When examining the situation, it is clear to note that false news is both a sign of and a problem with a larger issue (Zimdars & McLeod, 2020). Taking the lead on the incident and how that vague idea stirs people in general, Respondent 6 (R6) points out fake news is a constructive reality.

> *It is an easy way to manipulate people's emotions because it tends to mislead and misguide the audience, and it is kind of persuasive influence and communication, which is not honest, it is deceiving.*

Nevertheless, the question remains why do people spread such news when there is no real gain from here? This argument can be justified with the concept that these informants are not engaging in actual news coverage instead generating profit through social media circulation of false information mimicking the style of contemporary news (Zimdars & McLeod, 2020). After that, many leading news outlets reported the apprehension brewing out of this rumour at Padma Bridge and its vicinity.

The complexity of fake news becomes severe when mainstream news portals fall for that and circulate it without verifying it. That leads to them in a vulnerable state where both audience and professional experts question their moral judgment. The death of Taslima Begum Ranu is a classic example. On July 20, 2019, Taslima Begum Ranu was mistaken as a child smuggler and beaten to death. It took only seven to eight minutes to kill her by beating and thrashing her head against the wall. The mob flared up to the extent that they even kept beating after her lifeless body went beyond all pain. People around the spot captured the video, getting it viral through social media. Later, mainstream media gave it extensive coverage. The video clip of a mob killing Ranu, obtained from citizen journalists, was uploaded on the Facebook page of Daily Prothom Alo. Usually, the phrase fake news refers to entirely fabricated content masquerading as news to turn a profit which is not always true. News outlets do not spread false news for profit, it is not their strategy, says Melissa Zimdars, inaccuracies in terms of the false report immediately corrected or retracted (Zimdars & McLeod, 2020, p. 2).

While discussing the outbreak and impact of fake news on any news platform regardless of which segments of journalists are generating it, Respondent 6 (R6) narrates,

> *It is not just the problem of citizen journalists; this is much deeper. Because this is going down to the basics of politics and not only politics; fake news does not necessarily solely a political component, an economic component as well.*

Reflecting on these above issues, what could be the strategy to stop fake news from generating social and mainstream media? From his expertise on this very topic, Respondent 6 (R6) points out, there will always be a temptation for not only from the citizen journalists but also from the mainstream to use fake news for whatever reason. The lines between news and fake news are getting blurrier (Zimdars & McLeod, 2020). There is a massive division increasingly growing in society regarding political, social, and religious ideologies. Respondent 6 (R6)

suggests, it is important to train the audience, few people at a time, anticipating the moves on any particular sections. Even, Yusuf Omar also believes that the solution lies in educating the audience on mass media. People must be educated on how to spot fake news so that they do not spread it around. Because blocking or censoring news is constraining the audience's right to access information.

Trained manpower limits the output

Creating media content suitable for this platform of social media requires training and logistics, both of which are in dire shortage in the country, which is why mainstream media cannot fully harness the benefits of social media. Due to the lack of training and training materials, many people are questioning this genre of journalism. Foreign institutions for higher education may come forward to promoting this new-genre journalism specific to the digital platform.

'Hashtag Our Stories' co-founder Yusuf Omar advised Bangladeshi media outlets to emphasize user-generated content. He claims that Bangladesh has a lot of user-generated material. If media outlets only publish certain pieces from them, a new genre will emerge.

> *I think many media houses could not reach that level. You don't yet have enough manpower to dedicate a team to video editing for Facebook, YouTube, and Instagram and other digital tasks (Prothom Alo, 2019).*

Respondent 7 (R7) mentions that his news outlet often reproduces contents for new media as a TV news channel. These contents are first published on mainstream media, i.e. news media in this case. The respondent further mentions that these contents are reproduced and broadcasted via social media using his news outlets social media team. On that note, Respondent 7 (R7) puts his emphasis on: To produce social media content, one needs to be acquainted with the tools and have adequate knowledge about social media.

Mobile Technologies and Social Media Tools Empower Citizen Journalism

The fundamental nature of journalism is collecting and collaborating information and then disseminating those so that the recipient is benefited. Interactive journalism is the key to the potential outcome and successful engagement. Respondent 8 (R8) puts his emphasis:

> *The core point of journalism is that we want interactive communication to make it work. The more interactive our communication gets, the more readers we can connect with us.*

Despite, the first and prime objective of journalism mainstream media has failed to capture the interactive part. In this respect, traditional print news media faces a conceivable limitation compared to the uprising social media platform. Because it is time-consuming, not easy to access, and a set protocol must be maintained even before the reader or audience can see their response or feedback on print.

> *Another side of this discourse is that the impact on mainstream journalists becomes more relevant with the increasing levels of user-generated content, internet, mobile and social media in Bangladesh. Respondent 9 (R9) has echoed potential job openings for reporters. According to him, besides additional reporting skills, mobile and social media skills are the fundamental requirements for both new reporters and senior journalists. Today's news comes faster than ever due to citizen journalists who publish newsworthy content instantly from the field.*

Over time, it is vivid that user-generated contents have drawn increasing public and scholarly recognition of their importance to journalism (Quandt & Singer, 2009, p. 138). Citizen journalists not only provide the news; most of the time, but their participation in news platforms also adds accuracy. This dramatic change's primary reason is the ability for ordinary citizens to self-publish (Cooper, 2017). On cyberspace, giving extra advantage to mainstream media. For example, Respondent 8 (R8) says:

> *Suppose I said that 5 people died in an accident. But one audience member commented that I know 7 people died there in the accident, I was present at the spot. We used to get some support from our audiences like this. The published comments used to work as a supplement of the news. The news became more justified for these comments.*

In The online journalism handbook, Paul Bradshaw and Lilsa Rohumaa emphasized the media revolution of the last decade where anyone can broadcast 24/7 the world, share and exchange information in the real time (Bradshaw, 2013). There was a time when individuals had limited options regarding expressing their frustrations or raising their voice on a social platform, or even pointing out the social discrepancies. Now, with access to the internet, it becomes readily available for him to talk about all the burning issues without even exposing himself. The access to social media as a content sharing platform has made it easier where citizen journalists can share their thoughts, opinions, sometimes even defy censorship (Bradshaw, 2013). Talking about the same issues, Respondent 8 (R8) refers:

> *'In fact, some news contents of social media have gone viral on its own for which the government even had to make some changes in policy making as well.'*

In the context of Bangladesh, the advancement in technology and access to social media have developed simultaneously. This multiplicity helped to galvanize newspapers online strategies and persuade them to invest more in terms of technology as Bradshaw sees it (Bradshaw, 2013). The constantly growing dependency on social media's content has created a disadvantage to mainstream journalism and their online site. Respondent 8 (R8) has seen over time, and people are getting adoptive towards the selected social media sites than to the newspapers designated online sites. Respondent 8 (R8) refers:

> *'Maybe in some places, they have overpowered mainstream media already. The main damage or change that has caused social media is, no one goes to Prothom Alo.com now.'*

Most of the time, technology is mistaken as a strategy to get closer to the audience; instead, it should be treated as a tool. Because technology does not change societies or social processes just by coming into being but they can affect social processes through both mundane and innovative use (Earl & Kimport, 2011).

Recommendation and Limitations

'If journalism is literature in a hurry, online journalism is even more hurried than that' (Haq, 2014, p. 186). There is a significant gap noticeable between citizen journalism and mainstream media. The lack of proper initiative to develop these resources points out the difficulties the press and media houses face. Citizen journalism is flourishing in Bangladesh because whenever ordinary people encounter any problem, they flag it using social media platforms. Interviewees have suggested if we can give proper training to the citizen journalists on how to use mobile technology and social platforms to disseminate their news than they can connect with a greater audience. As technology has always been at the 'forefront of newsgathering and the journalistic process' (Jamil & Appiah-Adjei, 2019, p. 43). This step can lead to a more democratic participatory environment where traditional media houses can gather legit news from grassroots sources and interact with them via citizen journalism.

The scope of public speaking keeping the interest of ordinary people's opinion enables them to act as a news source, which also lets them exercise the power to respond (Franklin & Carlson, 2011). However, there is a vivid gap between creating user-generated content to user-generated stories. Citizen journalism focuses on the stories more than the content since the first one generates spontaneously. The trusted online news portals such as Prothomalo.com and bdnews24.com encourage them to create content for publishing houses editorial policies.

This article's significant limitation is that it fails to capture the core of citizen journalists' perspective while discussing citizen journalism. Further research and investigation would justify their thoughts and how and why they contribute to the mainstream media, less not reshaping it. As a prosumer[i], citizen journalists contribute to the mainstream news portals with or without any monetary commitments. Over time, it becomes evident the relationship between the source, and then the receiver has been altered; the receiver has gained the same power as the sender (Haq, 2014, p.179).

Conclusion

The narrative of this paper is to understand the practices of citizen journalism by mainstream news media, what kind of challenges they are facing and how mobile technologies and social media are creating an impact in Bangladesh. Considering the fact that citizen journalism is a new concept, which is massively generating content for both the traditional field and social media yet seeking validation. The challenge is evident due to the lack of structural framework and credibility of the news and the news creators. Journalists being the 'gatekeeper' establishes that every information has to go through a set of protocols, such as gathering, fact checking, editing, and disseminating for the audience (Pamela et al., 2008). Marching with that experts consider citizen journalists as the 'watchdog' who do not receive their full acceptance in the mainstream as their fellow parts (Okorie et al., 2014). For primary data collection, we have conducted extensive semi-structured and in-depth interviews. The respondents have shared their opinions and views regarding citizen journalism, citizen journalists' morals, limitations, shortcomings, advantages, and prospects. These narratives emphasize the growing impact of citizen journalism in mainstream media (Franklin & Carlson, 2011).While participating actively in social media to bring justice or reformation, citizen journalism stresses that, this model of the new news source is have the power to speak publicly.

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Syeda Sadia Mehjabin: Field research, data acquisition, data interpretation, and writing original draft;
Mamunor Rashid: Data analysis, reviewing, editing, corresponding to editor and reviewers.

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References
Adornato, A. (2017). Mobile and social media journalism: A practical guide. CQ Press.
Allan, S. (2017). Introduction: Photojournalism and citizen journalism. In Photojournalism and Citizen Journalism, Routledge. pp. 1-10.
Bajracharya, S. (2018, May 18). Democratic-participant Theory of Mass Communication. *Businesstopia*. https://www.businesstopia.net/mass-communication/democratic-participant-theory-mass-communication
Bangladesh Bureau of Statistics (BBS) (2022, March). Bangladesh Statistics 2020. https://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/a1d32f13_8553_44f1_92e6_8ff80a4ff82e/2021-06-30-09-23-
Bangladesh Telecommunication Regulatory Commission (BTRC) (2022, March 15). Internet Subscribers in Bangladesh. http://www.btrc.gov.bd/site/page/347df7fe-409f-451e-a415-65b109a207f5/Internet-Subescribers
Bdnews24.com (2020, March 29). Home internet use in Bangladesh rises sharply amid coronavirus shutdown (no date) *bdnews24.com*. Available at: https://bdnews24.com/technology/2020/03/29/home-internet-use-in-bangladesh-rises-sharply-amid-coronavirus-shutdown (Accessed: December 8, 2022).
Bell, A. (1991). The language of news media (pp. 84-85). Oxford: Blackwell.
Bradshaw, P. (2013). The online journalism handbook: Skills to survive and thrive in the digital age. Routledge.
Burum, I & Quinn, S. (2016a). Mojo: The Mobile Journalism Handbook. Focal Press, Burlington. pp. 11-25.
Burum, I & Quinn, S. (2016b). MOJO: The Mobile Journalism Handbook. Focal Press, Burlington. pp. 28-45.
Carr, D. J., Barnidge, M., Lee, B. G., & Tsang, S. J. (2014). Cynics and skeptics: Evaluating the credibility of mainstream and citizen journalism. Journalism & Mass Communication Quarterly, 91(3), 452-470.DOI: 10.1177/1077699014538828
Chadwick, N. (2014). Revolutionizing the Newsroom: How Online and Mobile Technologies Have Changed Broadcast Journalism. Elon Journal of Undergraduate Research in Communications, 5(1). Retrieved from http://www.inquiriesjournal.com/a?id=969
Cooper, G. (2017). UGC creators and use of their content by mainstream media. In Digital Technology and Journalism. Palgrave Macmillan, Cham. pp. 71-90. https://doi.org/10.1007/978-3-319-55026-8_4
DataReportal-Global Digital Insights (2022, February 15). Digital 2022: Bangladesh. Available at: https://datareportal.com/reports/digital-2022-bangladesh (Accessed: December 8, 2022).
Deutsche Welle (2021, March 19). It is actually a crisis of television channels. *Deutsche Welle* (DW) Available at: https://www.dw.com/bn/this-is-actually-the-crisis-of-television-channels-Professor-Shafiul Alam Bhuiyan/audio-56924689 (Accessed: December 02, 2022).
Deuze, M., Bruns, A., & Neuberger, C. (2007). Preparing for an age of participatory news. Journalism practice, 1(3), 322-338. DOI: 10.1080/17512780701504864
Dhaka Tribune (2021, March 10). Madrasa teacher beats child mercilessly in Chittagong. The *Dhaka Tribune*. https://www.dhakatribune.com/bangladesh/nation/2021/03/10/madrasa-teacher-s-torture-video-goes-viral.
Downie, L., & Schudson, M. (2009). The reconstruction of American journalism. Columbia Journalism Review.
Earl, J., & Kimport, K. (2011). Digitally enabled social change: Activism in the internet age. Mit Press.
Ergas, H., Pincus, J., & Schnittger, S. F. (2018). The crucial role of public interest journalism in Australia and the economic forces affecting it. Available at SSRN 3433489.

Franklin, B. & Carlson, M. (2011). Journalists, sources, and credibility. London: Routledge.

Franklin, B., & Carlson, M. (Eds.). (2010). Journalists, sources, and credibility: New perspectives. Routledge.

Gayen, K. (2020, January 22). (Uncertain) Future of Journalism in Bangladesh. *The Daily Star*.https://www.thedailystar.net/star-weekend/news/uncertain-future-journalism-bangladesh-1833094

Gillmor, D. (2006). We the media: Grassroots journalism by the people, for the people. O'Reilly Media, Inc.

Habermas, J. (1991). The structural transformation of the public sphere: An inquiry into a category of bourgeois society. MIT press.

Haq, F. (2014). Online Journalism in the Developing World: the Case of Bangladesh the Case of Bangladesh.https://www.academia.edu/10063160/Online_Journalism_in_the_Developing_World_the_Case_of_Bangladesh_By_and_Author_Fahmidul_Haq_

Hill, S., & Bradshaw, P. (2018). Mobile-First Journalism: Producing News for Social and Interactive Media. Routledge. London, https://doi.org/10.4324/9781315267210

Jamil, S. & Appiah-Adjei, G. (2019). 'Journalism in the era of mobile technology: The changing pattern of news production and the thriving culture of fake news in Pakistan and Ghana,' *World of Media. Journal of Russian Media and Journalism Studies*, 1(3), 42–64. Available at: https://doi.org/10.30547/worldofmedia.3.2019.2.

Jarvis, J. (2005). Who wants to own content? Buzz Machine. https://buzzmachine.com/2005/08/23/who-wants-to-own-content/

Jenkins, H. (2006). New York University Press. Convergence Culture: where old and new media collide. New York University.

Kern, T., & Nam, S. H. (2009). The making of a social movement: Citizen Journalism in South Korea. *Current Sociology*, 57(5), 637-660.DOI: 10.1177/0011392109337649

Khan, K. (2020). Mobile Journalism: Samoyer Sangbadikota. (1st. Ed.). Shamogro Prokashoni, Dhaka. p. 40

Kinfu, Z. and Khan. K. (2013). Bangladesh: History & Development Tendency of Mainstream Media & New Media. Moscow. Nobel Press.

Licitar, J. (2018). Građansko novinarstvo (Doctoral dissertation, University of Zagreb. Department of Croatian Studies).p.4-5.

Lita, R. (2022). How smartphones are changing the face of news journalism. [Online] *Al Jazeera Media* Institute. Available at: <https://institute.aljazeera.net/en/ajr/article/1862> Accessed 16 September 2022.

McChesney, R. W. (2007). Communication revolution: Critical junctures and the future of media. New Press.

McNair, B. (1998). The sociology of journalism. Oxford University Press. p.6

McQuail, D. (2010). McQuail's mass communication theory. Sage publications.

Moniruzzaman, M. (2021). Citizen Journalism in Bangladesh and Its Legal Aspects. International Journal of Multidisciplinary Informative Research and Review. (1) 5, 232 - 243.

Okorie, N., Oyedepo, T., & Usaini, S. (2012). Internet, blogs and citizen journalism: promises and pitfalls to national development. Journal of Media and Aesthetics, 158-171.

Okorie, N., Oyedepo, T., & Usaini, S. (2014). Internet and citizen journalism: Perspectives and issues in the global broadcast landscape. *Journal of Language and Communication*. 1(1), 16-19.

Pamela J. Shoemaker, Tim P. Vos & Reese, S., D. (2008). Journalists as gatekeepers. In Wahl-Jorgensen and Kand Hanitzsch T (Eds), Handbook of Journalism Studies. (1st. Ed.). NY: Routledge, New York. pp. 73-87.

Prothom Alo (2019, 19 June). The future of mobile journalism is bright. *Daily Prothom Alo* https://en.prothomalo.com/opinion/%E2%80%98The-future-of-mobile-journalism-is-bright%E2%80%99

Quandt, T., & Singer, J. B. (2009). Convergence and cross-platform content production. In The handbook of journalism studies.Routeledge. pp. 150-164.

Richard, W., Lake, E. & Cambridge, E. (2018). 'SO MUCH FAKE NEW' what is 'fake news', what is Theresa May's new security unit and what were Donald Trump's Fake News Awards? The Sun.

Sharma, S. & Rahaman, A. (2018). Citizen Journalism in Bangladesh: Journalism with Fear? In: First International Conference on Media, Communication and Journalism. Chittagong.

Simons, G. (2016). The impact of social media and citizen journalism on mainstream Russian news. *Russian Journal of Communication,* 8(1), 33-51. DOI: 10.1080/19409419.2016.1140590

Thurman, N. J. (2008). Forums for Citizen Journalists? Adoption of User Generated Content Initiatives by Online News Media. New Media & Society, (10)1, 139-157, 2008, Available at SSRN: https://ssrn.com/abstract=1111692

UNB (2019, October 24). Police detain rooftop tree-cutting woman in Savar. Available at: https://unb.com.bd/category/Bangladesh/police-detain-rooftop-tree-cutting-woman-in-savar/31921(Accessed: September 02, 2022).

Vil'anilam, J. V. (2016, June). Democratic Participant Media Theory. Media magazine. http://mediamagazine.in/content/democratic-participant-media-theory.

Xin, X. (2010). The impact of 'citizen journalism' on Chinese media and society. Journalism Practice, 4(3), 333-344. DOI: 10.1080/17512781003642931

Zeng, X., Jain, S., Nguyen, A., & Allan, S. (2019). New perspectives on citizen journalism. Global Media and China, 4(1), 3-12.

Zimdars, M., & McLeod, K. (2020). Fake News: Understanding Media and Misinformation in the Digital Age. The MIT Press, London, UK.

[i] Alvin Toffler (1980), in his book The Third Wave, argues that consumers are a phenomenon of the Industrial Age. As society moves toward the Post-Industrial Age, so will the number of pure consumers decline? They will be replaced by 'prosumers,' people who produce many of their own goods and services. (Philip Kotler 1986, p. 510)