ISSN (Print) : 2790-4903
ISSN (Online) : 2959-2305

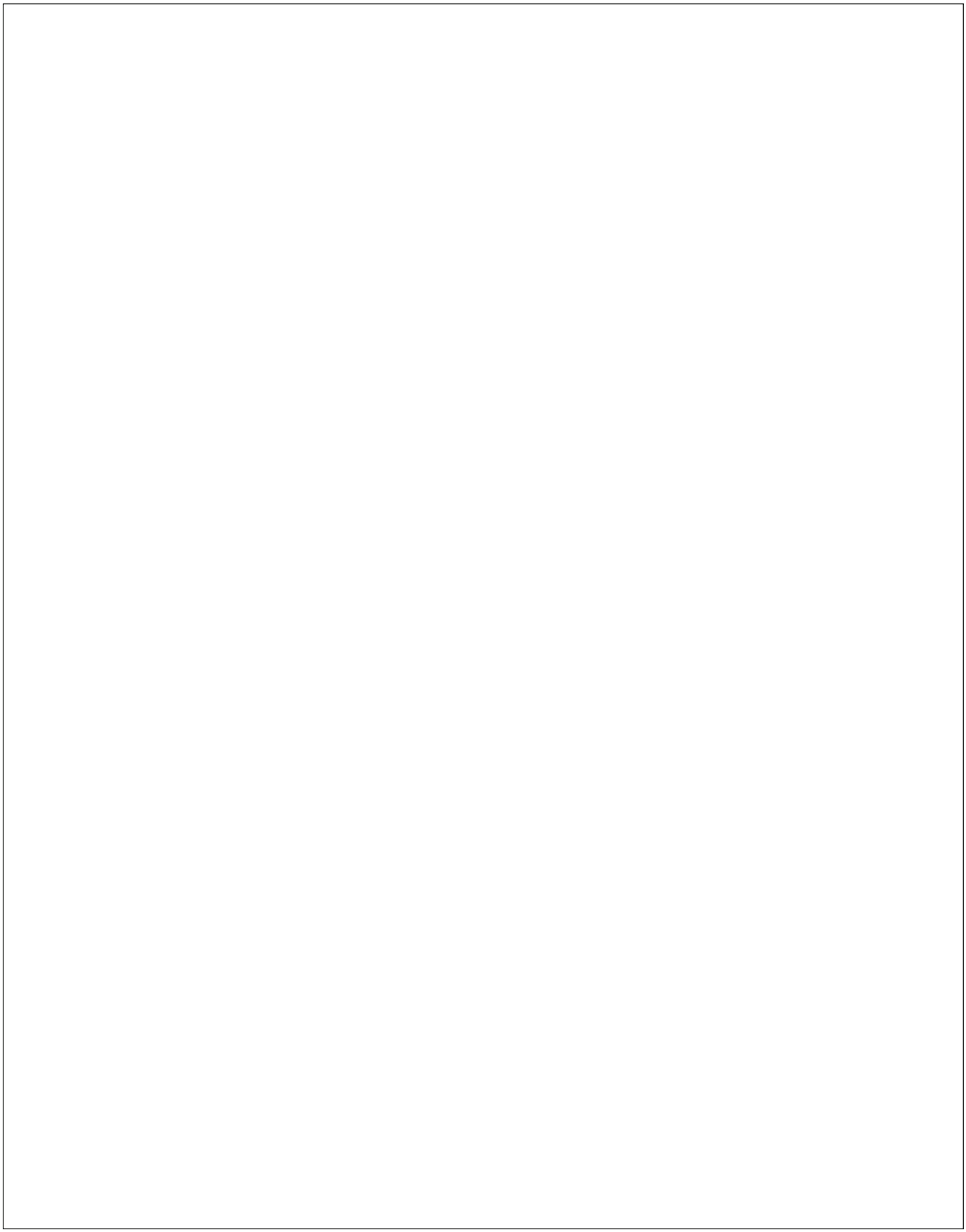
RPSU RESEARCH JOURNAL

■ VOLUME - IV ■ ISSUE - I ■ AUGUST - 2025

R. P. SHAHA UNIVERSITY
- an institution of Kumudini Welfare Trust of Bengal (BD) Ltd.

RPSU RESEARCH JOURNAL

VOLUME- IV, ISSUE-1
AUGUST 2025



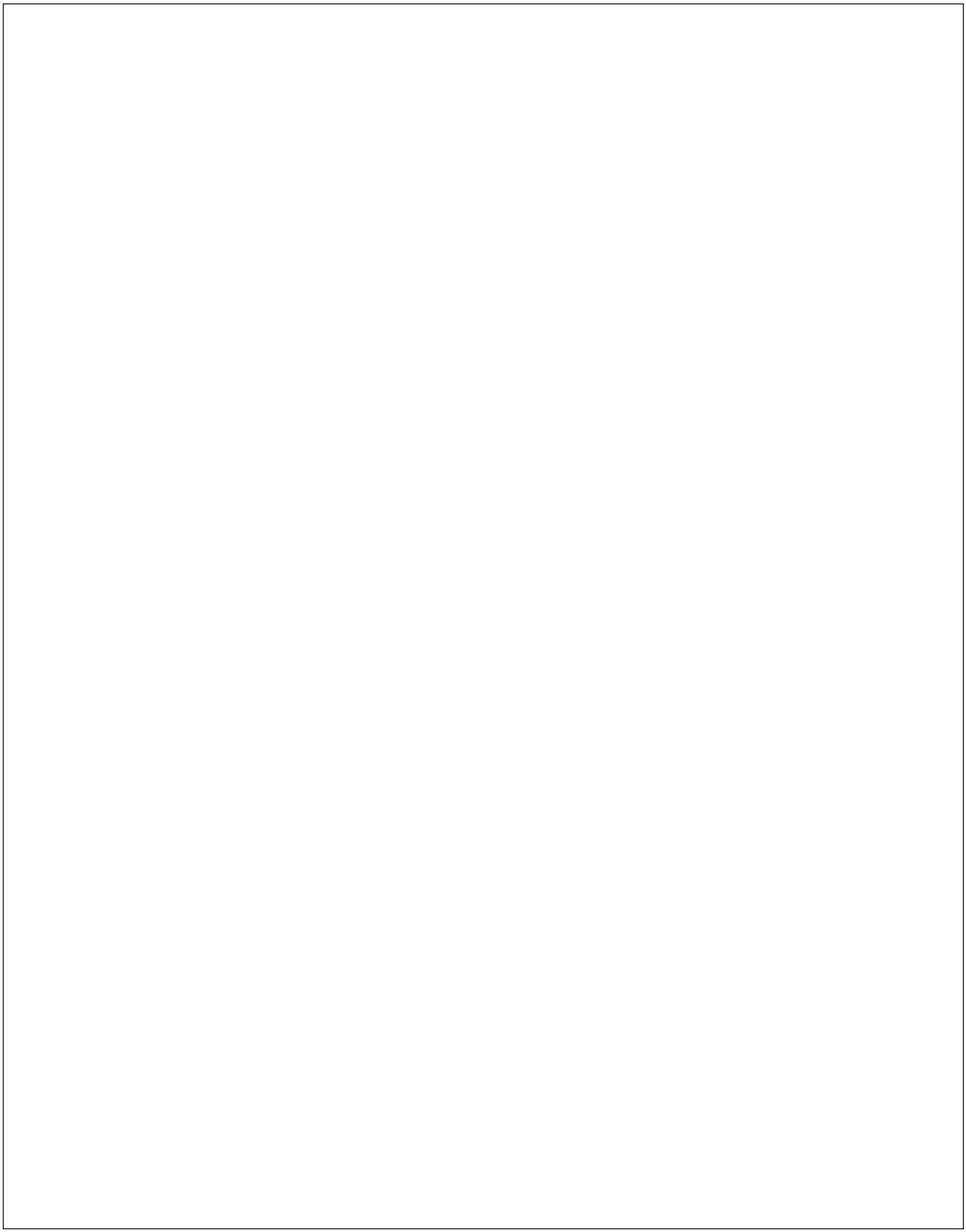
RPSU RESEARCH JOURNAL
ISSN: 2790-4903 (Print), 2959-2305 (Online)

VOLUME- IV ISSUE-1 AUGUST 2025

Published and Copyright Protected by
R. P. Shaha University
25, Sultan Gias Uddin Road, Shitalakhya
Narayanganj Bangladesh

Printed By
S.B. Printers
203, Fakirerpool, Culvert Road (2nd Floor), Motijheel C/A, Dhaka-1000
Mobile : 01926-973022, 01707-973022

Complementary Price:
Individual: Tk.300 (US $ 25)
Organization: Tk.500 (US $ 40)



Editors' Note

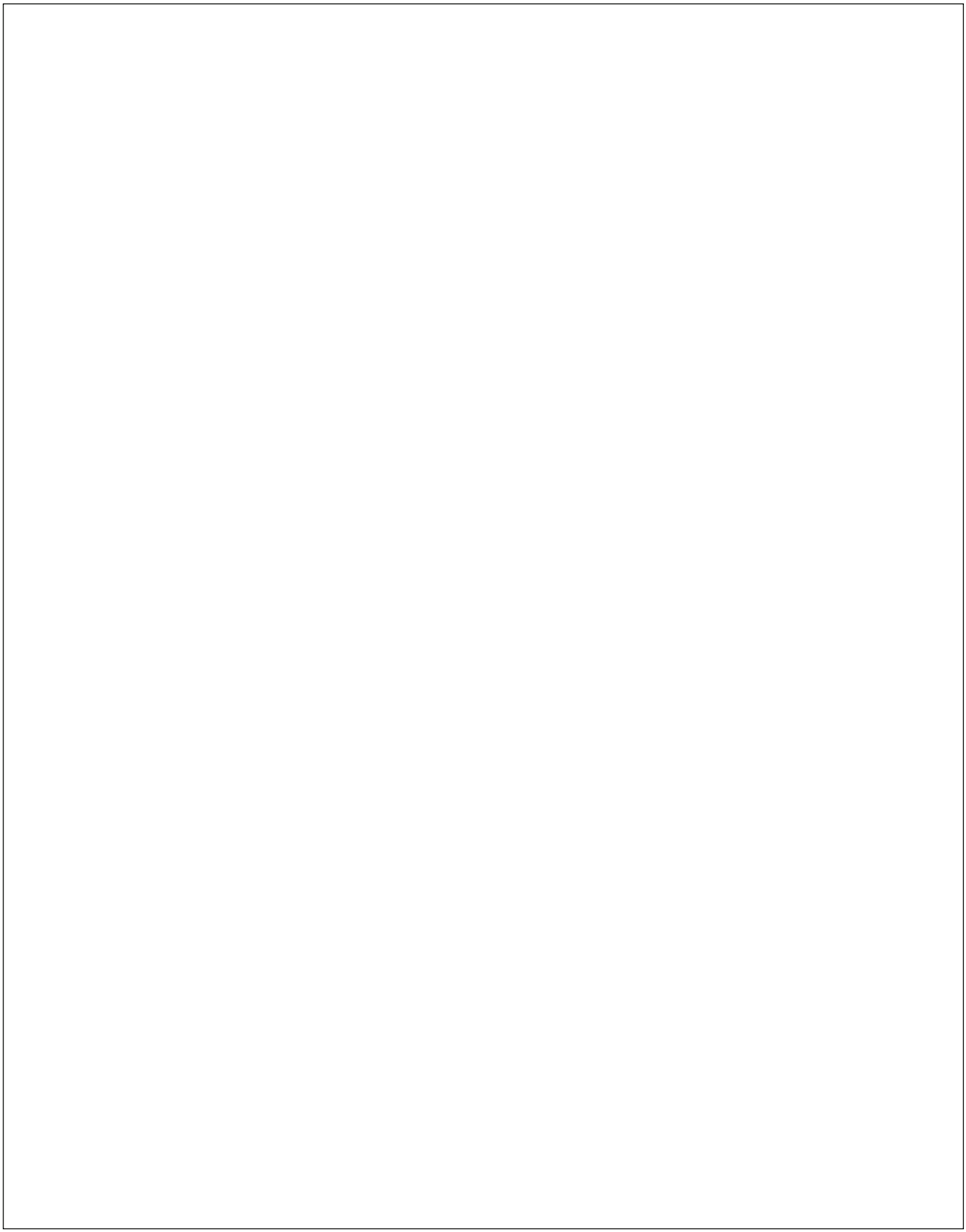
It is with great pride and enthusiasm that we present the August 2025 issue of the RPSU Journal of Multidisciplinary Research. This edition brings together a diverse range of scholarly contributions spanning the fields of health, technology, sustainability, and the social sciences.

Highlighted within are pivotal studies on childhood tuberculosis and oral hygiene awareness, as well as empirical research on fintech adoption among Bangladeshi youth. The issue also features forward-thinking innovations, including the development of biodegradable vegan leather and IoT-based automation systems. Additionally, a compelling literary analysis examines the theme of psychological conflict in Robert Frost's poetry.

Together, these articles reflect the journal's ongoing commitment to promoting rigorous academic research and engaging with the critical challenges of our time. We hope this volume sparks meaningful dialogue and encourage interdisciplinary collaboration.

Professor Md. Nazmul Hasan, PhD
Executive Editor
RPSU RESEARCH JOURNAL
Director, IQAC and CRI
R. P. Shaha University

CONTENTS



Moment Generating Functions of Some Continuous Distributions

Professor Manindra Kumar Roy, PhD
Vice Chancellor, R. P. Shaha University, Narayanganj
Corresponding Author: Prof. Dr. Manindra Kumar Roy, vc@rpsu.edu.bd

ARTICLE INFO

Keywords: Moment Generating Function, Student's t, F, Pareto, Noncentral F, Beta, Lognormal Distribution

RECEIVED
2 July 2025

ACCEPTED
10 August 2025

PUBLISHED
31 August 2025

DOI:
https://doi.org/10.5281
/zenodo.16485641

ABSTRACT

In this paper, moment generating functions of some continuous distributions, viz., Student's t. F, Pareto, Noncentral t, Noncentral F, Beta and Lognormal distributions have been developed in a very simple forms from which moments of these distributions can be derived easily.

1. Introduction

Moment generating function (mgf) is a very important tool for finding the moments of a distribution. So far statisticians derived the mgfs of many distributions to find the moments of those distributions. But in the case of some distributions, they argued that the mgfs of them do not exist although their r-th raw moments exist. Mood, Graybill

and Boes (1974) found that in the case of Student's t, F and Pareto distributions the mgfs do not exist. The same comments had been given by Patel, Kapadia and Owen (1976). In that case the r-th raw moments had been derived from the expression $E(X^r)$. In this paper, we showed that the mgfs of Student's t, F and Pareto distributions also exist and from them the r-th raw moments had been calculated. The mgfs of noncentral t and noncentral F-distributions had also been derived.

Johnson and Kotz (1970) derived the mgf of beta distribution in such a complicated form that the moments of this distribution cannot be derived easily from that mgf. Here we showed the mgf of beta distribution from which the moments can be derived easily.

In the case of lognormal distribution Heyde (1963) said that the distribution could not be defined by its moments. Here we showed the mgf of lognormal distribution and its r-th raw moment had been derived directly from that mgf.

2. Main results

To find the mgfs of the above mentioned distributions, we developed the following theorem:

Theorem 1. If the r -th raw moment (μ_r') for any continuous distribution with probability density function $f(x); -\infty < x < \infty$, exists, then the mgf of that distribution also exists.

Proof: If the mgf of a random variable X exists, then it is defined by

$$\begin{aligned} M_X(t) &= E[e^{tX}] \\ &= \int_{-\infty}^{\infty} e^{tx} f(x)dx \\ &= \int_{-\infty}^{\infty} \sum_{r=0}^{\infty} \frac{(tx)^r}{r!} f(x)dx \\ &= \sum_{r=0}^{\infty} \frac{t^r}{r!} \int_{-\infty}^{\infty} x^r f(x)dx \end{aligned}$$

Now, by definition

$$\mu_r' = \int_{-\infty}^{\infty} x^r f(x)dx$$

So we have

$$M_X(t) = \sum_{r=0}^{\infty} \frac{t^r}{r!} \mu_r'$$

i.e., the coefficient of $t^r/\mathrm{r}\,!$ is the r -th raw moment of X . So we can say that for the existence of μ_r', there must exist mgf of X.

We now derive the mgfs of some distributions in the forms of some theorems.

Theorem 2. If the random variable X follows t-distribution with degrees of freedom n, then its mgf is defined by

$$M_X(t) = \sum_{r=0}^{\infty} \frac{t^{2r}}{(2r)!} n^r \frac{\Gamma\left(\frac{1}{2}+r\right)\Gamma\left(\frac{n}{2}-r\right)}{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{n}{2}\right)} \; ; n > 2r$$

Proof: By definition,

$$M_X(t) = \int_{-\infty}^{\infty} e^{tx} \frac{dx}{\sqrt{n}B\left(\frac{1}{2},\frac{n}{2}\right)\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}}}$$

$$= C \int_{-\infty}^{\infty} \sum_{r=0}^{\infty} \frac{(tx)^r}{r!} \frac{dx}{\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}}}$$

Where

$$C = \frac{1}{\sqrt{n}B\left(\frac{1}{2},\frac{n}{2}\right)}$$

Now, since for odd values of r, the value of the integral becomes zero, we replace r by 2 r , and thus get

$$M_X(t) = 2C\int_0^{\infty}\sum_{r=0}^{\infty}\frac{(tx)^{2r}}{(2r)!}\frac{dx}{\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}}}$$

$$= C\sum_{r=0}^{\infty} n^{r+\frac{1}{2}}\frac{t^{2r}}{(2r)!}\int_0^{\infty}\frac{\left(\frac{x^2}{n}\right)^{r-\frac{1}{2}}d\left(\frac{x^2}{n}\right)}{\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}}}$$

$$= \sum_{r=0}^{\infty}\frac{t^{2r}}{(2r)1}n^r\frac{B\left(\frac{1}{2}+r,\frac{n}{2}-r\right)}{B\left(\frac{1}{2},\frac{n}{2}\right)} \text{ [puttirg the value of } C\text{]}$$

$$= \sum_{r=0}^{\infty}\frac{t^{2r}}{(2r)1}n^r\frac{\Gamma\left(\frac{1}{2}+r\right)\Gamma\left(\frac{n}{2}-r\right)}{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{n}{2}\right)}\ ; n > 2r$$

This completes the proof.
Hence we get

$$\mu_{2r} = n^r\frac{\Gamma\left(\frac{1}{2}+r\right)\Gamma\left(\frac{n}{2}-r\right)}{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{n}{2}\right)}\ ; n > 2r$$

Theorem 3. If the random variable X follows F-distribution with n_1 and n_2 degrees of freedom, then its mgf is defined by

$$M_X(t) = \sum_{r=0}^{\infty}\frac{t^r}{r!}\left(\frac{n_2}{n_1}\right)^r\frac{B\left(\frac{n_1}{2}+r,\frac{n_2}{2}-r\right)}{B\left(\frac{n_1}{2},\frac{n_2}{2}\right)};\quad n_2 > 2r$$

Proof: We have

$$M_X(t) = \int_0^\infty e^{tx} \frac{\left(\frac{n_1}{n_2}\right)^{\frac{n_1}{2}} x^{\frac{n_1}{2}-1} dx}{B\left(\frac{n_1}{2}, \frac{n_2}{2}\right)\left(1+\frac{n_1}{n_2}x\right)^{\frac{n_1+n_2}{2}}}$$

$$= C\int_0^\infty \sum_{r=0}^\infty \frac{(tx)^r}{r!} \frac{x^{\frac{n_1}{2}-1} dx}{\left(1+\frac{n_1}{n_2}x\right)^{\frac{n_1+n_2}{2}}}, \text{ where } C = \frac{\left(\frac{n_1}{n_2}\right)^{\frac{n_1}{2}}}{B\left(\frac{n_1}{2}, \frac{n_2}{2}\right)}$$

$$= C\sum_{r=0}^\infty \frac{t^r}{r!} \int_0^\infty \frac{x^{\frac{n_1}{2}+r-1} dx}{\left(1+\frac{n_1}{n_2}x\right)^{\frac{n_1+n_2}{2}}}$$

$$= C\sum_{r=0}^\infty \frac{t^r}{r1}\left(\frac{n_2}{n_1}\right)^{\frac{n_1}{2}+\mathrm{r}} \int_0^\infty \frac{\left(\frac{n_1}{n_2}x\right)^{\frac{n_1}{2}+x-1} d\left(\frac{n_1}{n_2}x\right)}{\left(1+\frac{n_1}{n_2}x\right)^{\frac{n_1+n_2}{2}}}$$

$$= C\sum_{\mathrm{r}=0}^\infty \frac{t^r}{r1}\left(\frac{n_2}{n_1}\right)^{\frac{n_1}{2}+\mathrm{r}} B\left(\frac{n_1}{2}+r, \frac{n_2}{2}-r\right); n_2 > 2r$$

Putting the value of C, we get the required result.
Consequently,

$$\mu_r' = \left(\frac{n_2}{n_1}\right)^r \frac{B\left(\frac{n_1}{2}+r, \frac{n_2}{2}-r\right)}{B\left(\frac{n_1}{2}, \frac{n_2}{2}\right)}; n_2 > 2r$$

Theorem 4. If the random variable X follows the Pareto distribution

$$f(x; k, \theta) = \frac{\theta k^\theta}{x^{\theta+1}}; k < x < \infty$$

then its mgf is defined by

$$M_X(t) = \sum_{r=0}^\infty \frac{t^r}{r!} \frac{\theta k^r}{(\theta - r)}$$

We omit the proof. Obviously,

$$\boldsymbol{\mu'_r = \frac{\theta k^r}{\theta - r}}$$

Theorem 5. If a random variable X follows a non-central t distribution with degrees of freedom n and non-centrality parameter λ, then its mgf is defined by

$$M_X(t) = \sum_{r=0}^{\infty} \frac{t^{2r}}{(2r)!} \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k!} n^r \frac{B\left(r+k+\frac{1}{2}, \frac{n}{2}-x\right)}{B\left(\frac{1}{2}+k, \frac{n}{2}\right)} \; ; n > 2r$$

Proof: By definition,

$$M_X(t) = \int_{-\infty}^{\infty} e^{tx} \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k!} \frac{x^{2k}dx}{n^{\frac{1}{2}+k} B\left(\frac{1}{2}+k, \frac{n}{2}\right)\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}+k}}$$

$$= \int_{-\infty}^{\infty} \sum_{r=0}^{\infty} \frac{(tx)^r}{r!} \sum_{k=0}^{\infty} C_k \frac{x^{2k}dx}{\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}+k}} \text{ , where } C_k = \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k1n^{\frac{1}{2}+k} B\left(\frac{1}{2}+k, \frac{n}{2}\right)}$$

Now, since for odd values of r, the value of the integral becomes zero, we replace r by $2r$, and thus get

$$M_X(t) = 2\int_0^{\infty} \sum_{x=0}^{\infty} \frac{(tx)^{2r}}{2r!} \sum_{k=0}^{\infty} c_k \frac{x^{2k}dx}{\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}+k}}$$

$$= \sum_{r=0}^{\infty} \frac{(t)^{2r}}{2r!} \sum_{k=0}^{\infty} c_k n^{r+k+\frac{1}{2}} \int_0^{\infty} \frac{\left(\frac{x^2}{n}\right)^{r+k-\frac{1}{2}} d\left(\frac{x^2}{n}\right)}{\left(1+\frac{x^2}{n}\right)^{\frac{n+1}{2}+k}}$$

$$= \sum_{r=0}^{\infty} \frac{(t)^{2r}}{2r!} \sum_{k=0}^{\infty} c_k n^{r+k+\frac{1}{2}} B\left(r+k+\frac{1}{2}, \frac{n}{2}-r\right)$$

Putting the value c_k, we get the required result. Obviously,

$$\mu_r' = \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k!} n^r \frac{B\left(r+k+\frac{1}{2}, \frac{n}{2}-r\right)}{B\left(\frac{1}{2}+k, \frac{n}{2}\right)} ; n > 2r$$

Theorem 6. If a random variable X follows a non-central F distribution with degrees of freedom n_1 and n_2 and non-centrality parameter λ, then its mgf is defined by

$$M_X(t) = \sum_{r=0}^{\infty} \frac{t^r}{r!}\left(\frac{n_2}{n_1}\right)^r \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k1} \frac{B\left(\frac{n_1}{2}+k+r, \frac{n_2}{2}-r\right)}{B\left(\frac{n_1}{2}+k, \frac{n_2}{2}\right)} ; n_2 > 2r$$

Proof: By definition,

$$M_X(t) = \int_0^{\infty} \sum_{r=0}^{\infty} \frac{(tx)^r}{r!} \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k!} \frac{\left(\frac{n_1}{n_2}\right)^{\frac{n_1}{2}+k} x^{\frac{n_1}{2}+k-1} dx}{B\left(\frac{n_1}{2}+k, \frac{n_2}{2}\right)\left(1+\frac{n_1}{n_2}x\right)^{\frac{n_1+n_2}{2}+k}}$$

$$= \sum_{r=0}^{\infty} \frac{t^r}{\Gamma!} \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k1} \left(\frac{n_2}{n_1}\right)^r \int_0^{\infty} \frac{\left(\frac{n_1}{n_2}x\right)^{\frac{n_1}{2}+k+\mathrm{r}-1} d\left(\frac{n_1}{n_2}x\right)}{B\left(\frac{n_1}{2}+k, \frac{n_2}{2}\right)\left(1+\frac{n_1}{n_2}x\right)^{\frac{n_1+n_2}{2}+k}}$$

$$= \sum_{r=0}^{\infty} \frac{t^r}{\Gamma!}\left(\frac{n_2}{n_1}\right)^r \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k1} \frac{B\left(\frac{n_1}{2}+k+r, \frac{n_2}{2}-r\right)}{B\left(\frac{n_1}{2}+k, \frac{n_2}{2}\right)}$$

This completes the proof. Obviously,

$$\mu_r' = \left(\frac{n_2}{n_1}\right)^r \sum_{k=0}^{\infty} \frac{e^{-\lambda/2}\left(\frac{\lambda}{2}\right)^k}{k1} \frac{B\left(\frac{n_1}{2}+k+r, \frac{n_2}{2}-r\right)}{B\left(\frac{n_1}{2}+k, \frac{n_2}{2}\right)} ; n_2 > 2r$$

Theorem 7. If a random variable X follows the beta distribution

$$f(x; p, q) = \frac{1}{B(p,q)} x^{p-1}(1-x)^{q-1}; 0 < x < 1$$

then its mgf is defined by

$$M_X(t) = \sum_{r=0}^{\infty} \frac{t^r}{r!} \frac{B(p+r,q)}{B(p,q)}$$

We omit the proof. Clearly,

$$\mu_r' = \frac{B(p+r,q)}{B(p,q)}$$

Theorem 8. If the random variable X follows a lognormal distribution with parameters μ and σ^2, then its mgf is defined by

$$M_X(t) = \sum_{r=0}^{\infty} \frac{t^r}{r1} e^{\mu r + \frac{1}{2} r^2 \sigma^2}$$

We omit the proof. Obviously,

$$\mu_x' = e^{\mu r + \frac{1}{2} r^2 \sigma^2}$$

3. Conclusion

The results obtained in the paper in the form of theorems for some continuous distributions may be applied for finding moment generating function as well as moments of other distributions.

References

Heyde, C. C. (1963). On a property of the lognormal distribution. Journal of the Royal Statistical Society, Series B, 25, 392-393.

Johnson, N. L. and Kotz, S. (1970). Continuous Univariate Distributions-2. A Wiley-Interscience Publication.

Mood, A. M., Graybill, F. A. and Boes, D. C. (1974). Introduction to the Theory of Statistics. McGraw-Hill International Book Co.

Patel, J. K., Kapadia, C. H. and Owen, D. B. (1976). Handbook of Statistical Distributions. Marcel Dekker, Inc.

Psychological Conflict in Robert Frost's "Stopping by Woods on a Snowy Evening"

A. K. Zunayet Ahammed[1], Mst. Rokeya Khatun[2]

[1]Dean and Associate Professor of English, School of Arts and Social Sciences, R. P. Shaha University

[2]Assistant Professor of English, Asian University of Bangladesh, Savar, Dhaka, Bangladesh

Corresponding author: A. K. Zunayet Ahammed, zunayet1972@gmail.com

ARTICLE INFO

Keywords: Woods, obligation, psychology, conflict, responsibility

RECEIVED
13 May 2024

ACCEPTED
15 April 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17240001

ABSTRACT

This research article aims at exploring the psychological conflict in Robert Frost's "Stopping by Woods on a Snowy Evening." The poet, in the poem, depicts an aesthetic diversion and admiration of natural beauty against the messy existence of a man. Tossed between the temptations the world offers to a man and his desire to pursue his chosen path of commitments; the speaker seeks for the meaning of life. Although the universal enigmatic question of indecisiveness is presented in the poem through a series of symbols, imagery, metaphor, personification and carefully chosen words and dictions, the speaker consequently overcomes the inner conflict of his mind and resolves to carry on performing his responsibility to continue his journey of life until his death. So, employing a qualitative method, the researchers examine how deftly the poet has delineated psychological conflict in the poem.

1. Introduction

Robert Frost (1874-1963) is one of the most famous American poets of the 20th century, even one of America's rare "public literary figures, almost an artistic

institution" (Stine and Marowski 110). His poetry deals with the life of common people, simple subject matter, a wide range of emotions, human interaction with nature, the beauty of nature, the potential dangers of rural New England, and above all his own vision of life. Frost, on one hand, treats nature as a strange force that can annihilate humans. On the other hand, he has also seen the heroic scuffle of humans against nature. His poem "Stopping by Woods on a Snowy Evening" shows his vision of life along with other characteristic features. The poem is seemingly simple but intensely insightful. In a letter to Louis Untermeyer, Frost called the poem "my best bid for remembrance" (Tuten and Zubizarreta 347). In the poem, the poet expresses sheer truths through the awe-inspiring presence of nature, which reflects the speaker's broad outlook and realistic approach. The poet strives to establish a relationship between the speaker and his natural surroundings in spite of having a psychological conflict in his mind, the conflict between the allure of nature and the responsibilities of life. While riding on horseback by the snowy woods through a landscape, the speaker stops there being enthralled by the serenity and solitude of the woods when the woods epitomize personal desire and a respite from the odds of reality. At the same time, the speaker is also driven by a sense of duty as the researchers find him in a dilemma "promises to keep, /And miles to go before I sleep," (Frost, lines 14-15). Here, lies the conflict. So, this study investigates this never-ending psychological conflict going on in all human hearts which ultimately highlights Frost's vision of life in "Stopping by Woods on a Snowy Evening."

2. Objective of the Study

The objective of the study is to comprehensively understand the psychological conflict as introduced by Robert Frost in "Stopping by Woods on a Snowy Evening."

3. Literature Review

Conducting a critical analysis of various scholarly works on Robert Frost's "Stopping by Woods on a Snowy Evening," the researchers examined diverse interpretations of the poem offered by different scholars. Through this review, they aimed to identify existing research gaps and uncover opportunities for further exploration and study in this area. Some researchers have already worked on different literary works by Robert Frost. A few of them concentrated on the poem 'Stopping by Woods on a Snowy Evening.' Most of them in their writings noted the disparity between the real world and the imaginary world. The researchers in this study have reviewed and analyzed several research articles such as "Stylistic Analysis of Robert Frost's Poem 'Stopping by Woods on a Snowy Evening'" by Muhammad Ahmad Hashmi, Muhammad Asim

Mahmood & Muhammad Ilyas Mahmood published in *International Journal of English and Education*, ISSN:2278-4012, Volume:9, Issue:3, July 2020 where the researchers talk about the stylistic part of the poem. In another article "Re-looking at Robert Frost's 'Stopping by Woods on a Snowy Evening' by Md. Saiful Islam Published in *Advances in Social Sciences Research Journal*-Vol. 6, No. 10, the writer tries to find a possible new religious meaning of this poem. "A Critical Reading of Robert Frost's Poem 'Stopping by Woods on a Snowy Evening'" by Shridhar Bhat and G. Shankar published in *IJCRT*, Vol. 5, Issue1, February 2017, ISSN: 2320-2882 in which the author tries to bring out a subtle tension between the timeless attraction of the nature and the pressing obligations of the present moment. In "Poetic Structure in Robert Frost's 'Stopping by Woods on a Snowy Evening' by Marion A. Davis published in INQUIRY,2009, Vol.1, No. 12., Mr. Davis states that the narrator is simply looking over the scenery while contemplating mood. In "Biographical Analysis of Robert Frost's "Poem 'Stopping by Woods on a Snowy Evening'" by Kurt Salac Candelas published in Asian Journal of Multidisciplinary Studies, Vol. 4, Issue 11, October 2016, Candilas ventures to explore symbolic interpretation revealing the poet's downfalls and his worth emulating fatherless and husband character via biographical literary theory.

To sum up, different aspects of Frost's "Stopping by Woods on a Snowy Evening" have been critically analyzed by different researchers. But, the psychological conflict in the poem is not depicted well by any researcher. This research intensively addresses the psychological conflict in the text. Moreover, here the researchers attempt to capture the relationship between man and nature and also highlight the conflict between wishes and obligations men often face in their lives. They have also tried to evaluate different scholars' criticism of the poem and endeavor to provide this study with a new veneer that was not previously explored. The researchers viewed that no work has been done on the title "Psychological Conflict in Robert Frost's Stopping by Woods on a Snowy Evening" in detail. So, **t**he selection of the title is justified and this research article will serve as a beneficial resource for the researchers in future.

4. Materials and Methods

This research will be a qualitative one based on the close reading of the poem "Stopping by Woods on a Snowy Evening**"** by Robert Frost. The research methodology employed here encompasses a comprehensive utilization of secondary sources while the text has been used as a primary source. Data collection is conducted through the analysis of academic articles apart from the thorough analysis of the main text. The essence of these writings also helps the researchers append new features to the exertion. The researchers, furthermore, have gone through different books,

journals and discussions for well-run information to enrich the research. The researchers have also tried to evaluate different scholars' analyses of the poem and endeavored to provide this study with a new layer that was unexplored by other researchers in the past. The research methodology emphasizes proper citation and referencing to uphold the accuracy and appropriateness of the sourced information.

5. Discussions

Robert Frost's poetic works predominantly center around the rural life of New England, employ the unadorned vernacular of the region. Despite his focus on commonplace subject matter, Frost adeptly elicits a spectrum of emotions within his poems. Much of his poetry delves into the dynamics of human interaction with the natural surroundings. While he recognizes the innate beauty of nature, he also discerns the potential perils of it. Nevertheless, his themes serve as wellsprings of inspiration and innovation. His poem 'Stopping by Woods on a Snowy Evening' leaves an indelible impression by vividly portraying the captivating essence of the natural world. In this poem, a juxtaposition of outward serenity and inner profundity becomes apparent.

Generally Robert Frost's poetry expresses fundamental truths about the human condition. Using a straightforward language, symbols, imagery, personifications and repetition, the poet offers a meditation on life's ultimate essence in "Stopping by Woods on a Snowy Evening". This poem serves as a platform for the poet's unvarnished commentary on the inherent, and often contradictory, emotions residing within human beings. In the poem, the poet does not merely represent a picturesque, enchanting, and dark forest; rather, he refers to the psychological discord between a desire for oblivion and a sense of obligation. Ultimately, the sense of obligation emerges triumphant in this internal struggle and the speaker chooses to keep his promises and continue his journey before death.

The poem "Stopping by Woods on a Snowy Evening" has a regional setting and atmosphere. By the looks of it, the poem is a moving description of a series of local pictures. While traveling to watch snow falling through the tree, and to see the overall fascinating beauty of nature, the speaker stops near a forest of a landlord in the snowy evening far away from human habitation; the horse is the only companion of the speaker. The place with its snowflakes, frozen lakes, and frosty atmosphere attracts the speaker who feels enticed to enjoy it. The snowy scene, the evocative image of the poem, makes some deep appeal to the speaker. He declares:

> Whose woods these are I think I know.
>
> His house is in the village though;
>
> He will not see me stopping here

To watch his woods fill up with snow.

……..

……

Between the woods and frozen lake

The darkest evening of the year. (Frost, lines 1-8)

Here, the poet brings the motifs of risk and decision characterizing both the choice of the two paths- temptation of the woods and the call of duty. The poem also employs the landscape, people, habits, customs, and manners of a particular region which are, of course, some selective features of the New England landscape, which the researchers find in many other poems of Frost. Frost's portrayal of the scene records his minute observation and accurate description. In a sense, the poem can be taken merely as a memorable recreation of a winter evening.

Again, the deeper analysis of the poem's symbolic connotations reflects Robert Frost's modern sensibility in the poem. The speaker's unknown identity and destination add mystery to the poem. The woods, within the context of the poem, assume an enigmatic symbolism, evoking a strong sense of mystery. The pervasive whiteness of the snow, coupled with the temporal setting of the winter evening, brings an association with impermanence and mortality. Consequently, the poem may be interpreted as a depiction of an individual contemplating the notion of death. The entire landscape portrayed in the poem exhibits a stark lifelessness and darkness, with the frozen lake serving as a testament to the winter season's severity. These elements collectively contribute to the speaker's inclination to relinquish life. But, the ringing of the horse's harness bell sadly reminds the speaker of his earthly obligations and responsibilities while the horse personifies human characteristics and the harness bells symbolize humans' inner conscience. Eventually, this realization dawns upon the speaker, prompting introspection as reflected in the lines below:

He gives his harness bells a shake

To ask if there is some mistake.

The only other sound's the sweep

Of easy wind and downy flake. (Frost, lines 9-12)

Although it seems that in "Stopping by Woods on a Snowy Evening" Frost simply deals with rural subject matters, his poem offers experiences that are typical of the

modern man. Here Frost shows the essential loneliness of the modern man. The loneliness, fragmentation, ambiguity, and complexity that the poet represents within the speaker proves Frost a very modern poet too. Again, in the attitude of the speaker, the researchers find the modern man's sense of indecision and hesitation, as they find in T. S. Eliot's 'The Love Song of J. Alfred Prufrock' where Prufrock too suffers from indecision at a critical juncture of his life, as Eliot states that this ambivalent attitude towards life and death is characteristic of a modern man.

In treating nature Frost also shows his modern sensibility. The subject matter of Frost's "Stopping by Woods on a Snowy Evening" has much to do with nature. The poem has many elements of a physical nature like woods, frozen lake, easy wind, downy flake, frost, snow, etc. all of which are taken from the natural landscape of New England, the region in which Frost used to live. Although Frost deals with these natural elements, he, unlike William Wordsworth and other Romantic poets, conveys no romantic notion of nature, does not search for any spiritual quality, and does not recognize any divine presence in nature. The poet only relates that "The woods are lovely, dark, and deep," (Frost, line 13). He presents a very realistic picture of nature. The researchers note that in many poems Frost describes the destructive characteristics of nature too, for example, in "The Hill Wife." Yet, in this poem, a symbolic meaning can be deduced from Frost's description of nature. As the poem is open to multiple interpretations, and the symbols can be read in different ways, the woods symbolize something mysterious.

Much like Robert Frost's other literary works, "Stopping by Woods on a Snowy Evening**"** describes an initial veneer of simplicity. On its surface, it appears to be a simply straightforward narrative of a horse rider who momentarily contemplates a pause in his journey. But, when a reader goes into the depth of the poem and goes through the final stanza of it, he discerns that the poem is not as simple as it seems to be, it rather delves into psychological terrain, touching upon a universal existential quandary faced by individuals. More importantly, the researchers can take into consideration Frost's use of th*e* conjunction *'*But*'* which nicely draws a border line between temporary pleasure and responsibilities making life meaningful. The word *'*But*'* implies that the work is of greater value than the pursuit of worldly comforts. Again, the repetition of the line "And miles to go before I sleep," (Frost, line 14) in the last stanza of the poem emphasizes the speaker's commitments to life and its responsibilities. The speaker does not want to stay in the lovely woods anymore because h*e* has lots of responsibilities to do. This sense of duty endures amidst the internal conflict. The following often quoted beautiful, meaningful and philosophical lines precisely echo the psychological conflict and philosophy of life:

The woods are lovely, dark and deep,
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep. (Frost, lines 13-16)

Based on the above discussion, it appears that the poet wants to give a message - motion is life, not to stop. Through the depiction of human psychological conflict, the poem teaches and poignantly reminds humans about their responsibilities. Man ought to realize that performing duties is of greater value than the pursuit of temporary worldly pleasures. Here, the speaker, the meditative master of the horse, is highly committed to the responsibilities of his life. His consciousness keeps him moving forward ignoring all momentary temptations of the world.

6. Conclusion

To sum up, this research paper explores the conflict between personal desires and societal obligations, reflecting the complex nature of human psychology and the tension arising in an individual's mind as seen in "Stopping by Woods on a Snowy Evening". Although the universal, enigmatic question of indecisiveness is presented in the poem, the speaker ultimately resists all temptations and the hazards of the materialistic world, prioritizing his commitment to fulfill his promises and persevere until death. Frost's portrayal of this internal struggle echoes deeply, as it mirrors the choices we all face between fleeting pleasures and enduring responsibilities. The poem's haunting beauty lies in its ability to capture the seductive pull of escape while celebrating the quiet triumph of duty, reminding us that the path of integrity, though arduous, is ultimately more fulfilling. Through this searching, Frost invites us to reflect on our lives to find strength in our commitments.

Works Cited

Bhat, Shridhar. "A Critical Reading of Robert Frost's Poem 'Stopping by Woods on a Snowy Evening.'" *IJCRT (International Journal of Creative Research Thoughts)*, vol. 5, no. `, Feb. 2017.

Candelas, Kurt Salac. "Biographical Analysis of Robert Frost's Poem 'Stopping by Woods on a Snowy Evening.'" *Asian Journal of Multidisciplinary Studies*, vol. 4, no. 11, Oct. 2016.

Davis, Marion A. "Poetic Structure in Robert Frost's 'Stopping by the Woods on a Snowy Evening.'" *INQUIRY*, vol. 1, no. 12, 2009.

Frost, Robert. “Stopping by Woods on a Snow Evening.” *Selected Poems*, Friends’ Book Corner, Dhaka, 2013, pp. 146–147.

Hashmi, Muhammad Ahmad, et al. “Stylistic Analysis of Robert Frost’s Poem ‘Stopping by Woods on a Snowy Evening.’” *International Journal of English and Education*, vol. 9, no. 3, July 2020.

Islam, Md. Saiful. “Re-looking at Robert Frost’s ‘Stopping by Woods on a Snowy Evening.’” *Advances in Social Sciences Research Journal*, vol. 6, no. 10, 2019.

Stine, Jean C., & Daniel G. Marowski, (editors). *Contemporary Literary Criticism*, Detroit: Gale Research, 1983.

Tuten, Nancy Lewis, & and John Zubizarreta. *The Robert Frost Encyclopedia*. Greenwood Publishing. 2011.

The Dynamics of Fintech Adoption Among Bangladeshi Youth: A UTAUT2 Model Perspective

Md. Nazmul Hasan, PhD
Professor, Department of Business Administration
Corresponding Author: Md Nazmul Hasan, nazmul_bba@rpsu.edu.bd

ARTICLE INFO

Keywords: Fintech Adoption, Performance Expectancy, Social Influence, Trust, UTAUT2, Theory of Planned Behavior

RECEIVED
3 September 2024

ACCEPTED
22 December 2024

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17240168

ABSTRACT

Bangladesh's rapid economic progress and technological advancement have significantly impacted its financial technology (fintech) sector. This study investigates the factors influencing fintech adoption among Bangladeshi youth, employing the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model and the Theory of Planned Behavior. The findings reveal that Performance Expectancy, Facilitating Conditions, and Trust positively influence fintech adoption intention, highlighting the importance of user-friendly, reliable, and secure fintech solutions. Interestingly, Social Influence negatively impacts adoption intention, suggesting skepticism towards peer recommendations. The study also finds that Effort Expectancy and Hedonic Motivation do not significantly affect adoption intention, indicating a focus on practicality and utility over ease of use and enjoyment. Service Quality significantly impacts User Behavior, emphasizing the need for high-quality customer service to maintain user engagement. These insights provide valuable guidance for fintech companies aiming to enhance adoption and user satisfaction by focusing on critical factors influencing user perceptions and behaviors. This research expands the UTAUT2 model by incorporating information quality and willingness to pay, offering a comprehensive framework for understanding fintech adoption in developing countries like Bangladesh. Overall, the study enhances the theoretical framework of FinTech adoption by integrating context-specific variables and providing empirical evidence from a developing country perspective.

In practical, FinTech companies should invest in customer service training and infrastructure to deliver a positive user experience, fostering long-term user retention.

1. Introduction

Bangladesh's economic progress is increasingly linked to its technological infrastructure, particularly in the realm of financial technology (fintech). Fintech combines finance and advanced technology to enhance financial transactions, making them more accessible and efficient. This fusion involves not only technology and processes but also ecosystems that facilitate smoother commercial activities, including payments, lending, stock trading, and currency exchanges (Venkatesh & Brown, 2001). Over recent years, Bangladesh has experienced significant digital growth. By 2024, the country has seen a substantial increase in digital engagement, with internet usage growing significantly. The number of smartphone users has also increased, mirroring this digital expansion (Alalwan et al., 2017). By 2020, the Bangladeshi economy was valued at around $85–90 billion and is forecasted to skyrocket to $800 billion by 2030. Factors such as enhanced digital access, rising incomes, and a burgeoning youth population contribute to this growth (World Bank, 2021). Additionally, the post-COVID-19 era has positioned Bangladesh as a key player in the fintech sector, only second to the United States in terms of market potential (Andersen & Jakobsen, 2018).

According to the World Bank Findex Report 2021, a significant portion of adults in Bangladesh remain unbanked, and many do not use technology for financial transactions. Challenges include poor information quality, high service fees, inaccessible banking services, and low trust in financial institutions (World Bank, 2021). Addressing these issues is critical for the adoption of fintech solutions among Bangladeshi youth. This is particularly important as the country's financial sector evolves through innovations such as green finance and technologies that promote sustainable practices. Moreover, the pandemic has forced people to rely more on digital technologies, significantly altering consumer behavior towards fintech (Firmansyah et al., 2022; Venkatesh et al., 2012). The government's initiatives, like the Digital Bangladesh Mission, aim to enhance internet connectivity and foster a tech-savvy environment. The upcoming introduction of 5G technology is expected to revolutionize the fintech landscape in Bangladesh, similar to trends observed in the global south (Rahman et al., 2020). Despite significant advancements in financial technology, studies exploring fintech adoption in Bangladesh are scarce, particularly those focusing on youth. Existing research often overlooks the interplay of social and

contextual factors unique to developing countries. This study bridges this gap by applying UTAUT2 and TPB frameworks to examine fintech adoption among Bangladeshi youth, incorporating localized variables like information quality and readiness to pay for services.

This study integrates the Theory of Planned Behavior to analyze how the younger generation in Bangladesh interacts with fintech. The Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Theory of Planned Behavior (TPB) are widely used frameworks for understanding user behavior and technology adoption. Meanwhile, TPB emphasizes the role of attitudes, subjective norms, and perceived behavioral control in predicting intentional behavior, offering insights into how external influences and individual perceptions shape decision-making. Integrating these models provides a comprehensive lens for analyzing technology acceptance and user behavior dynamics. Considering the dynamic socio-economic factors unique to Bangladesh, this research adds new dimensions to the model by including information quality and readiness to pay for services. These additions aim to better understand the link between consumer intentions and fintech adoption, thereby enriching the fintech literature and guiding marketers in developing targeted strategies to tap into the untapped potential within this sector (Ajzen, 1991).

2. Theoretical Framework and Hypothesis Development

The UTAUT model, initially proposed by (Venkatesh & Brown, 2001), serves as a foundational theoretical framework aimed at explaining and predicting user engagement with technology. In order to better explain technology adoption, this model synthesizes components from earlier models and emphasizes four key factors: performance expectancy, effort expectancy, social impact, and facilitating conditions. The same authors released an improved version of UTAUT2 in 2012, adding to the framework with new components like price value, habit, and hedonic motivation. These components help to further elucidate the comprehensive dynamics of technology usage. The model suggests that these factors significantly shape user behavior and intentions, subsequently affecting actual technology usage, with variables like age, gender, and experience playing a moderating role in these influences (Hussain & Papastathopoulos, 2022). UTAUT2 is frequently employed to evaluate technology adoption scenarios, including the use of FinTech services, mobile applications, and other digital systems, as demonstrated in studies by Alalwan, Dwivedi, and Rana (2017). The application of the UTAUT2 model in this research is particularly relevant for delving into the determinants influencing the effective use of FinTech services.

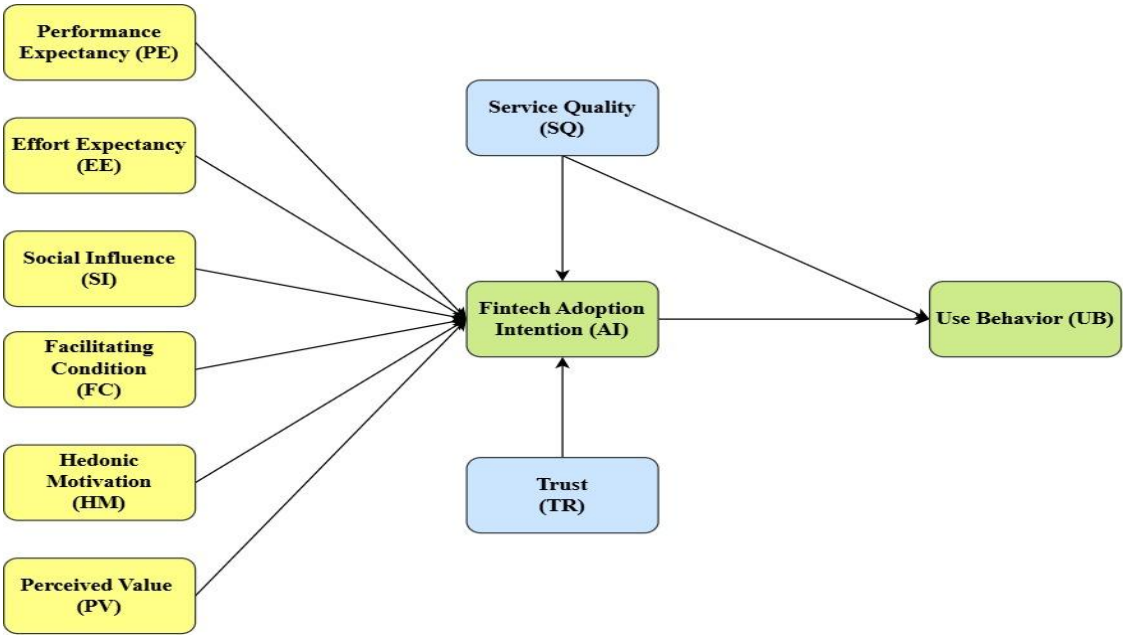


Figure 1: Conceptual Framework of Fintech Adoption Intention

2.1. Performance Expectancy

Performance expectation (PE) refers to a user's belief in the extent to which a specific technology or system will improve their capacity to complete activities or achieve goals (Venkatesh et al. 2012). It essentially assesses consumers' expectations that technology would improve their productivity by simplifying or streamlining their jobs (De Blanes Sebastián et al. 2023; Martinez and McAndrews 2023). Users are more likely to acquire and use technologies that they believe would improve their productivity or performance (Bajunaied et al. 2023). Ensuring that user experiences meet these performance requirements is crucial for widespread acceptance and use of digital financial services (Basri et al., 2022). Users are more likely to use digital financial services if they consider them to simplify transactions, provide convenience, and improve financial management (Arner et al. 2020; Nawayseh 2020; Senyo and Osabutey 2020). These studies demonstrate a substantial relationship between performance expectancy and technology adoption. Thus, we propose the following hypothesis:

H_1. Performance expectancy positively influences users' fintech adoption intention."

2.2. Effort Expectancy

Effort Expectancy (EE) assesses how easy consumers find understanding and controlling technology (Bajunaied et al. 2023; Venkatesh et al. 2012). The design of user interfaces, the technology's usability, the difficulty of activities required, and the general ease of contact with the system all have an impact on effort expectation. Expected effort has a big impact on consumers' intents to utilize mobile money services. Similarly, an investigation on e-banking in Spain reveals customers likeliness to accept FinTech services because of the easy utilization of these technologies for financial transactions. Thus the following hypothesis can be stated;

H_2. Effort expectancy positively influences users' fintech adoption intention.

2.3. Social Influence

The impact of social influence (SI) is magnified when people understand that significant personalities or groups in their social circles support a technology and push for its adoption (Chen et al, 2022;Venkatesh et al., 2012). A study on FinTech adoption in Spain found that peer recommendations and endorsements had a substantial impact on individuals' decisions to utilize FinTech services (De Blanes et al.,2023). Similarly, testimonials and social media discussions help users grasp the value and reliability of mobile payment systems. The following hypothesis is proposed:

H_3. Social impact has a substantial beneficial effect on users' intentions to adopt fintech.

2.4. Hedonic Motivation

The pleasure or happiness people derive from utilizing technology is known as hedonic motivation (HM) (Dzandu et al. 2022). This idea concedes that individuals are motivated by hedonistic features of technology, including enjoyment, amusement, or social connection, in addition to pragmatic or utilitarian reasons (George and Sunny 2020, 2022). It emphasizes how powerful a tool for influencing user behavior is the perception of pleasure and fulfillment from using technology. According to a research by Yang et al. (2023), gamified features increase the hedonic value of applications and have a beneficial impact on users' intents to use them. Even if their main goal is investing, users who find stock trading applications interesting and pleasurable are more likely to use them (Lee et al. 2022). The significance of pleasure and happiness in propelling the uptake of technological services is shown by these studies. Based on this understanding, the study presents the following hypothesis:

H_4. Hedonic motivation positively impacts users' fintech adoption intention.

2.5. Price Value

Price value (PV), the ratio of the monetary expenses incurred to the perceived advantages of utilizing FinTech technologies. . A favorable price value occurs when the advantages users perceive from a technology significantly outweigh the monetary expenses, thereby strongly influencing their adoption decisions (Venkatesh et al. 2012). Perceived cost reductions, such as lower fees compared to traditional banking, had a favorable influence on consumers' intentions to utilize mobile banking services, according to a study on customer preparedness for FinTech in Bangladesh. Similarly, the affordability of digital payment apps emerged as a crucial factor driving their adoption, particularly in cost-sensitive regions (Carè et al. 2023). Additionally, the perception of lower fees and cost savings influenced decisions to adopt robo-advisory services (Back et al. 2023). Therefore, the following hypothesis can be derived
H_5. Price value positively affects users' fintech adoption intention.

2.6. Facilitating Conditions

The availability of infrastructure, support networks, and resources required for people to utilize a given technology efficiently is referred to as a "facilitating condition" (FC). According to Asif et al. (2023), in order to effectively utilize FinTech services, people need to have access to a mobile device, have a service subscription with a telecoms provider, and be adept in using their mobile devices. These enabling factors can greatly increase interest in and promote the uptake of FinTech services (Aduba et al., 2023). According to research by Bajunaied et al. (2023), consumers' faith in and use of FinTech products are directly impacted by their ability to receive technical help. Furthermore, initiatives to promote digital literacy and training programs are essential for encouraging the use of FinTech (Ong et al. 2023). Drawing from this literature, the study proposes the following hypothesis:
H_6. Facilitating conditions significantly positively affect users' fintech adoption intention.

2.7. Fintech Adoption Intention

Fintech adoption intention (AI) pertains to persons inclination and determination to practice FinTech services, whereas actual utilization is the concrete expression of this behavior (Venkatesh et al., 2012). This idea is derived from the theory of planned behavior (Ajzen 1992), which signals a behavior's intent to be engaged in is a strong indicator of when it will be carried out. Research has confirmed the predictive power of fintech adoption intention with regard to the actual use of technology, including that conducted by Venkatesh et al. (2003) using the UTAUT model. The ambition to adopt fintech is seen to come before using fintech services in practice. People are

more likely to demonstrate this in their usage behavior when they have a strong goal to interact with technology (Ajzen 1991). The aim of adopting fintech acts as a mediator between consumers' real FinTech service usage behavior and their attitudes, perceptions, and outside influences. In light of the above discussion, following hypothesis is derived:

H_7. Fintech adoption intention positively influences users' use behavior in FinTech services.

2.8. Trust

Trust (TR) is the confidence and assurance that clients have in the unwavering quality, security, and integrity of FinTech stages and suppliers. Customers that have faith in FinTech vendors will inevitably express a desire to utilize their services. A concentrate by Bongomin and Ntayi (2019) on portable cash reception pinpointed trust as a vital component foreseeing the utilization conduct of FinTech administrations. Clients who are sure that their monetary data is secure and their protection is maintained are more disposed to think about utilizing FinTech stages (Chauhan 2015). FinTech suppliers that participate in clear and straightforward correspondence with respect to their safety efforts, information the board, and security arrangements are probably going to improve trust, in this manner supporting the use of their administrations (Kilani et al. 2023). Moreover, clients habitually depend on the encounters of their companions to decide reliability. Positive surveys, high evaluations, and solid suggestions can significantly affect trust, which thus impacts purchasers' tendencies to embrace and effectively use FinTech administrations. Laying out and holding trust is basic for FinTech suppliers hoping to increment take-up and long-haul commitment. Based on these insights, this study proposes the following hypotheses:
H_8. Trust positively affects users' intention to apply FinTech services.

2.9. Service Quality

The service quality (SQ) of Fintech plays a vital role in its adoption by influencing trust, convenience, transparency, and user satisfaction. Trust and reliability are essential for users to feel confident in Fintech platforms. Features like robust fraud detection and reliable functionality reassure users about the security of their funds, while disruptions or errors undermine trust and deter adoption. Fintech's appeal also lies in its convenience and ease of use. High-quality platforms ensure users can complete tasks quickly and intuitively, such as making payments or applying for loans (Venkatesh et al, 2012). User-friendly apps attract customers, while poor design or slow response times discourage them. Similarly, effective customer support

reduces barriers, addressing technical concerns through real-time assistance and fostering confidence. Customization and personalization further drive adoption by delivering tailored services like expense tracking or investment advice, enhancing user satisfaction and loyalty (Frederiks et al, 2022). Additionally, transparency in fees and terms builds trust, reducing hesitation and encouraging broader adoption. High-quality services also ensure speed and efficiency, meeting modern user expectations with fast transactions and real-time updates. Finally, security and compliance protect users' data, while adaptability to diverse needs expands Fintech's reach in underserved markets. In summary, high service quality fosters trust, convenience, and confidence, ensuring user satisfaction and driving Fintech adoption. Therefore, we can state the following hypothesis,

H9: Service Quality significantly influence the adoption intention of Fintech.

H10: Service Quality significantly influence the use behavior of Fintech.

3. Research Methodology

3.1 Sampling and Target Population

Generation Y, or Millennials, states to individuals born between 1981 and 1996, following Generation X and preceding Generation Z. They are highly tech-savvy, having grown up during the rise of the internet, mobile phones, and social media. Millennials are often well-educated, prioritizing personal and professional growth. They value meaningful work, work-life balance, and flexible, collaborative environments. Socially conscious, they care about issues like climate change and social justice, often aligning purchases with ethical values. As digital natives, they heavily use online platforms for communication, shopping, and entertainment, preferring experiences over possessions and expecting personalized, seamless interactions.

When selecting students from various higher education institutions in Bangladesh, the researchers utilized a judgmental sampling approach. The participants were from ‘Y generation’. The selection process was designed to ensure equal participation opportunities for all students. An electronic survey was distributed via email and WhatsApp groups, facilitated by the respective institutions. From the initial 405 completed responses, 349 were deemed suitable for detailed analysis due to data quality issues and significant deviations. This resulted in an actual response rate of 86%. Respondents profile are as follows: 52.14% were male and 47.86% were female. Regarding age distribution, 37.24% were between 18 and 22 years, 37.53%

between 22 and 26 years, and 25.23% were between 26 and 30 years old. In terms of education, 52.72% were professionals, 21.48% had earned bachelor's degrees, and 25.80% had earned postgraduate degrees.

3.2 Questionnaires

This research has selected respondents those who have relevant knowledge and open to respond. The questionnaire was separated into two parts: A and B. Part A includes demographic information such as age, gender, educational qualifications, phone types, employment, and dwelling area/district, among other things. Part B asks questions on the many constructs offered in the study model, as stated in Table 4.

4. Results

We carried out several statistical tests to evaluate multivariate assumptions. First, the mean is determined, and the lowest and maximum standard deviations are displayed in **Table 1**. The dataset's normality was then ascertained using the Kolmogorov-Smirnov test. As shown in **Table 2,** the p-values for this test were all below 0.05, indicating that the dataset does not follow a normal distribution.

Table 1: Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
PE	349	3.5319	1.84798	1.00	19.17
EE	349	3.6152	3.02143	1.00	27.50
HM	349	2.7778	1.09738	1.00	5.00
FC	349	3.5567	2.26274	1.00	27.50
SI	349	3.1348	1.11704	1.00	5.00
PV	349	4.5839	3.87240	1.00	36.00
AI	349	4.0804	8.54947	1.00	99.00
US	349	2.8564	1.12925	1.00	5.00
TR	349	4.1277	0.90367	1.00	5.00
SQ	349	3.6879	2.51392	1.00	19.83

Table 2: Kolmogorove-Simrov Test

		PE	EE	HM	FC	SI	PV	AI	US	TR	SQ
N		349	349	349	349	349	349	349	349	349	349
Normal Parameters[a,b]	Mean	3.53	3.62	2.78	3.56	3.13	4.58	4.08	2.86	4.13	3.69
	Std.	1.85	3.02	1.10	2.26	1.12	3.87	8.55	1.13	0.90	2.51
Most Extreme Differences	Absolute	.224	.309	.183	.255	.133	.443	.443	.097	.196	.280
	Positive	.224	.309	.157	.255	.061	.443	.443	.095	.167	.280
	Negative	.146	.204	.183	.176	.133	.277	.359	.097	.196	.202
Test Statistic		.224	.309	.183	.255	.133	.443	.443	.097	.196	.280
Asymp. Sig. (2-tailed)		.000[c]	.000[c]	.000[c]	.000[c]	.000[c]	.000[c]	.000[c]	.003[c]	.000[c]	.000[c]
a. Normal Distribution.											
b. Lilliefors Significance Correction.											

4.1 Model Fitness

After assessing the multivariate assumptions, the model fitness testing was initiated. The following data table provides the lists of various reliability and validity statistics for different constructs or variables (e.g., BI, EE, FC). Here's a breakdown of what each column represents and the interpretation of these values.

Table 3: Model Fitness of Fintech Adoption

Variables	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
UB	0.880	0.880	0.807
EE	0.865	0.869	0.711
FC	0.853	0.854	0.694
HM	0.788	0.737	0.618
PE	0.824	0.843	0.651
PV	0.830	0.837	0.746
AI	0.851	0.854	0.771
SI	0.768	0.768	0.683
SQ	0.777	0.783	0.692
TR	0.775	0.791	0.688

4.2 Interpretations of the Model Fitness:

The values above 0.7 of Cronbach's alpha indicating high reliability and good correlation among items. These measures are considered more robust than Cronbach's Alpha as they account for different indicator loadings. Average Variance Extracted (AVE) with values above 0.5 indicating that the construct explains more than half of the variance, suggesting adequate convergent validity. Constructs such as UB, EE, FC, HM, PE, PV, AI, SI, SQ, and TR generally demonstrate high reliability values, along with strong validity (AVE values above 0.5). These indicators affirm that the constructs are robust measures of their respective domains.

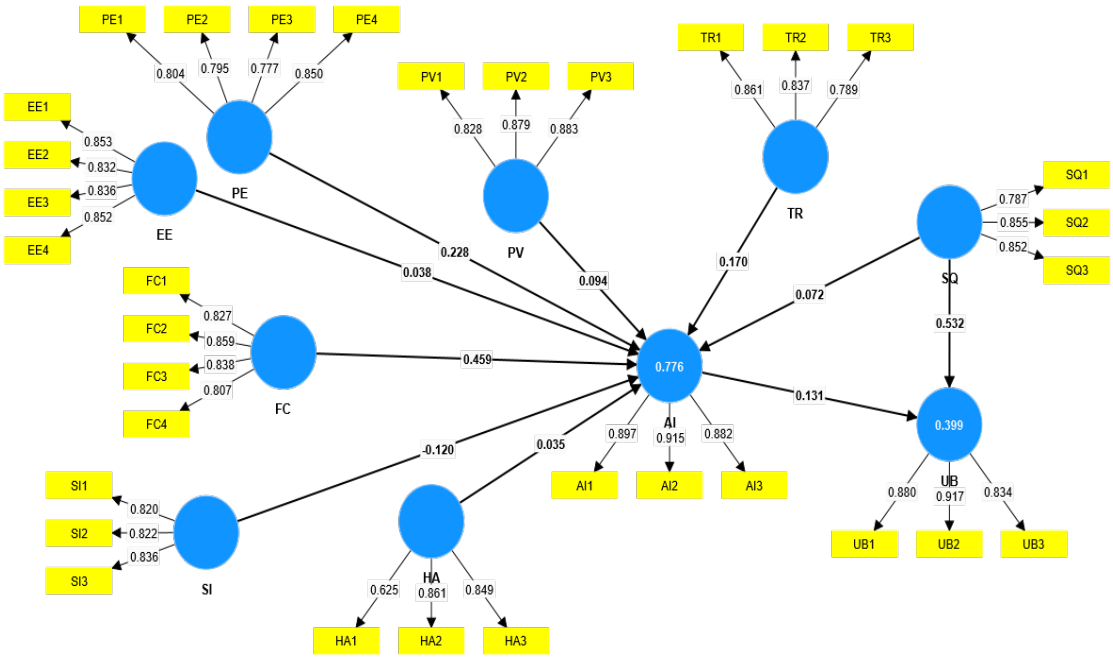


Figure 2: Measurement Model

4.3 Discriminant Validity

Values close to or below 0.85 indicate good discriminant validity, suggesting constructs are distinct. Most values in your matrix fall below this threshold, implying minimal overlap. Values above 0.85, such as UB and PE (0.883) and TR and UB (0.872), suggest potential overlap and may require further investigation. Lower values, like UB and AI (0.584) and UB and SI (0.544), strongly support discriminant validity. Moderate values around 0.7-0.8, such as EE and FC (0.862) and TR and PV (0.872), suggest acceptable discriminant validity but require careful interpretation.

Overall, HTMT results mostly support good discriminant validity, with a few exceptions needing further validation (**Table 4**).

Table 4: Heterotrait-monotrait ratio (HTMT) - Matrix

Variables	UB	EE	FC	HM	PE	PV	AI	SI	SQ	TR
UB										
EE	0.797									
FC	0.604	0.862								
HM	0.702	0.746	0.779							
PE	0.883	0.790	0.775	0.752						
PV	0.759	0.654	0.650	0.876	0.732					
AI	0.584	0.639	0.575	0.782	0.875	0.704				
SI	0.544	0.600	0.639	0.784	0.568	0.687	0.573			
SQ	0.749	0.799	0.764	0.771	0.551	0.779	0.770	0.661		
TR	0.772	0.729	0.755	0.721	0.546	0.872	0.824	0.717	0.789	

4.4 Structural Model

The bootstrapping approach was utilized to examine the claimed association between the dependent and independent variables using the path coefficient (β) and t test at a significance threshold of 0.05 ($p < 0.05$). Based on the provided data, we can conclude that several factors significantly influence Artificial Intelligence (AI) and User Behavior (UB). The relationships of AI with UB, Facilitating Conditions (FC), Performance Expectancy (PE), Price Value (PV), Social Influence (SI), and Trust (TR) are all statistically significant. Specifically, Facilitating Conditions, Performance Expectancy, and Trust have strong positive impacts on AI, while Social Influence has a negative impact. Additionally, AI itself and Service Quality (SQ) significantly influence User Behavior, with Service Quality showing a notably strong positive impact.

Table 5: Hypothesis Testing

Hypothesis	Path	Beta Value *(β)*	Sample mean (M)	(STDEV)	T statistics	P values
H1	**AI -> UB**	0.131	0.130	0.056	2.332	0.020
H2	**EE -> BI**	0.038	0.037	0.046	0.838	0.402
H3	**FC -> BI**	0.459	0.459	0.065	7.081	0.000
H4	**HM -> BI**	0.035	0.035	0.051	0.690	0.490
H5	**PE -> BI**	0.228	0.226	0.054	4.238	0.000
H6	**PV -> BI**	0.094	0.094	0.043	2.171	0.030
H7	**SI -> BI**	-0.120	-0.114	0.041	2.887	0.004
H8	**TR -> BI**	0.170	0.171	0.044	3.912	0.000
H9	**SQ -> RC**	0.532	0.532	0.056	9.558	0.000
H10	**SQ -> BI**	0.072	0.070	0.050	1.425	0.154

Conversely, Effort Expectancy (EE), Hedonic Motivation (HA), and Service Quality (SQ) do not significantly influence AI. The non-significant relationships indicate that these factors do not have a measurable impact on AI in this dataset. The overall findings highlight the importance of Facilitating Conditions, Performance Expectancy, Price Value, Social Influence, and Trust in shaping AI outcomes, as well as the critical role of AI and Service Quality in affecting User Behavior. Further analysis or visualizations could provide additional insights into these relationships.

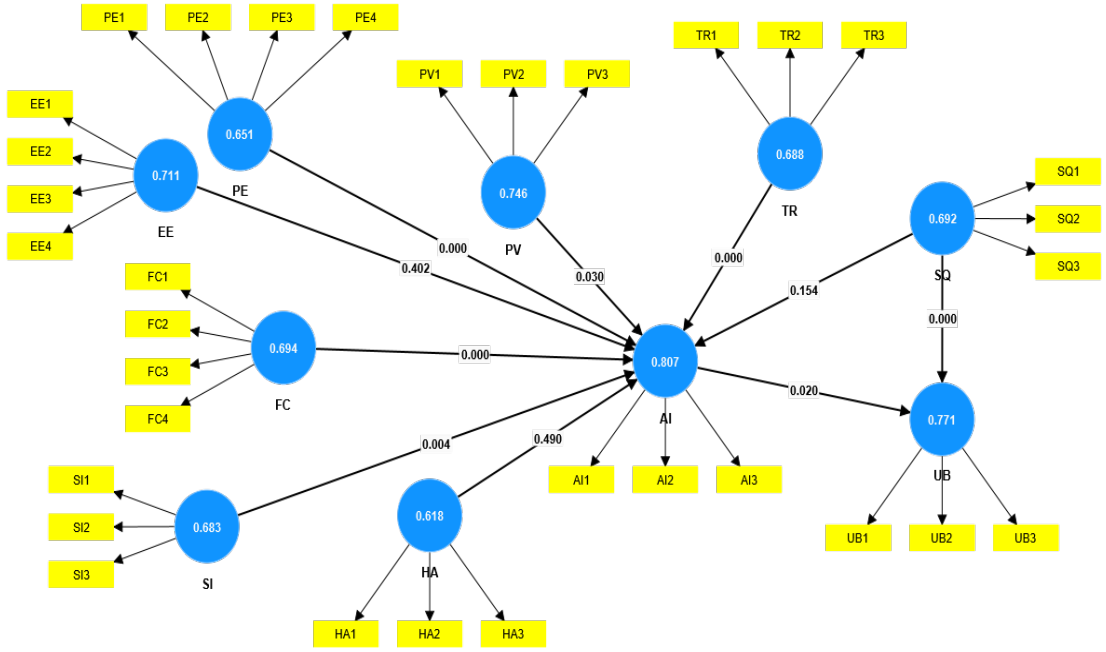


Figure 1: Path Analysis

5. Discussion and Findings

The study underscore the critical importance of several key factors in influencing both FinTech adoption intention (AI) and user behavior within the FinTech sector. Performance Expectancy (PE), Facilitating Conditions (FC), and Trust (TR) emerged as significant positive influencers on AI. This implies that consumers are more likely to utilize fintech technologies when they believe these technologies will enhance their performance, are supported by adequate resources and infrastructure, and are trustworthy. The strong positive impact of these factors highlights the need for FinTech companies to focus on building reliable, user-friendly, and supportive environments that foster trust and enhance perceived performance benefits. Interestingly, Social Influence (SI) showed a negative impact on AI, which could indicate that users might be skeptical of peer recommendations or overly cautious about new technologies despite social endorsements. These above findings show similarity with the existing researches of FinTech adoption (Pavlo et.al 2006, Zeithaml et.al 2018, Venkatesh et. al 2016).

On the other hand, Effort Expectancy (EE) and Hedonic Motivation (HM) did not show a significant influence on AI, indicating that ease of use and enjoyment might

not be as crucial for users when deciding to adopt FinTech technologies. This could be due to the functional and goal-oriented nature of financial technologies where practicality and utility outweigh the pleasure of use. Additionally, the analysis revealed that Service Quality (SQ) significantly impacts User Behavior (UB), emphasizing that high-quality service can lead to increased user engagement and satisfaction. These insights suggest that while foundational elements such as trust, performance benefits, and facilitating conditions are vital for initial FinTech adoption, maintaining high service quality is key to sustaining user engagement. Overall, these findings provide valuable guidance for FinTech companies aiming to enhance AI adoption and user satisfaction by focusing on critical factors that influence user perceptions and behaviors.

In sum, the study highlights the critical importance of Performance Expectancy (PE), Facilitating Conditions (FC), and Trust (TR) as significant positive influencers of Fintech Adoption Intention (AI). Interestingly, Social Influence (SI) negatively impacts AI, possibly reflecting users' skepticism about peer recommendations. Effort Expectancy (EE) and Hedonic Motivation (HM) are not significant predictors, suggesting that practical utility outweighs ease of use and enjoyment. Practical implications for FinTech providers include prioritizing trust-building, robust infrastructure, and high service quality to sustain user engagement.

5.1 Theoretical Contributions

The study adds to the theoretical understanding of FinTech by expanding the UTAUT2 model to the setting of Bangladesh. By include new dimensions like as information quality and willingness to pay for services, the study gives a more thorough framework for understanding the elements impacting FinTech adoption intention. The findings underscore the relevance of traditional UTAUT2 constructs like Performance Expectancy, Facilitating Conditions, and Trust, while also highlighting the nuanced role of Social Influence, which contrasts with its typical positive impact in other contexts. This study further contributes to the literature by exploring the insignificant impact of Effort Expectancy and Hedonic Motivation on the intention to adopt FinTech, indicating that practical and utilitarian factors might be more influential than ease of use and enjoyment in the realm of financial technologies. This insight challenges existing assumptions in technology adoption models and calls for further exploration into context-specific factors that may moderate these relationships. Overall, the study enhances the theoretical framework of FinTech adoption by integrating context-specific variables and providing empirical evidence from a developing country perspective.

5.2 Practical Contributions

The significant positive influence of Performance Expectancy (PE), Facilitating Conditions (FC), and Trust (TR) on FinTech adoption intention (AI) suggests that companies should prioritize the development of technologies that demonstrably enhance user performance and simplify tasks. Ensuring robust and reliable infrastructure, along with clear communication of security measures, can build user trust and encourage adoption. Such as, platforms like PayPal have built trust through robust security measures, such as encryption and fraud protection, which are clearly communicated to users, thereby encouraging broader adoption. These findings further emphasize the significance of providing sufficient resources and support mechanisms to ensure the seamless operation of FinTech apps.

Moreover, the negative impact of Social Influence (SI) on AI indicates that marketing strategies relying solely on peer recommendations or social endorsements may not be effective. Instead, a focus on individual user experiences and the tangible benefits of the technology might be more persuasive. Take, for example, the customer service offered by companies like Revolut or Chime, which are known for their responsive and helpful customer support teams. The significant role of Service Quality (SQ) in influencing User Behavior (UB) emphasizes that high-quality customer service and user support are crucial for maintaining user engagement and satisfaction. FinTech companies should invest in customer service training and infrastructure to ensure a positive user experience that can lead to long-term user retention.

Limitations and Future Research Directions

Notwithstanding, this research has also several limitations. Firstly, the results may have limited generalizability because of the judgmental selection method and the focus on Generation Y students from Bangladeshi higher education institutions. The sample may not fully represent the diverse demographics of the entire Bangladeshi population, including older generations or those not engaged in higher education. This sampling approach could lead to biases in understanding the broader adoption behaviors and preferences towards FinTech services. Secondly, the cross-sectional design of the study restricts the ability to determine causal relationships between the variables. While significant relationships were identified between constructs like Performance Expectancy, Facilitating Conditions, Trust, and FinTech adoption intention, a longitudinal study would provide more robust insights into how these relationships evolve over time. Additionally, the reliance on self-reported data through surveys may introduce common method biases, as responses could be influenced by social desirability or respondents' current mood and context.

Subsequent studies have to think about enlarging the sample to encompass a more varied cross-section of the Bangladeshi populace.
Incorporating participants from diverse age cohorts, educational levels, and geographic regions will augment the applicability of the results and furnish a more comprehensive perspective on FinTech adoption practices in Bangladesh. Likewise, examining different user segments, such as small business owners or rural residents, could uncover unique factors influencing FinTech adoption in these groups. Longitudinal studies are recommended to explore the dynamic nature of FinTech adoption over time. Such studies can provide deeper insights into how user perceptions and behaviors change with continued exposure to and experience with FinTech services. Finally, comparative studies between Bangladesh and other developing countries could highlight cultural and contextual differences in FinTech adoption, offering broader implications for global FinTech strategies and policies.

References

Amtzis, R. (2014). Crowdsourcing from the ground up: How a new generation of Nepali nonprofits uses social media to successfully promote its initiatives. *Journal of Creative Communications, 9*(2), 127–146.

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179-211.

Alalwan, A. A., Dwivedi, Y. K., & Rana, N. P. (2017). Factors influencing adoption of mobile banking by Jordanian bank customers: Extending UTAUT2 with trust. International Journal of Information Management, 37(3), 99-110.

Andersen, S. C., & Jakobsen, M. L. (2018). Political pressure, conformity pressure, and performance information as drivers of public sector innovation adoption. International Public Management Journal, 21(2), 213-242.

Rahman, M., Islam, M., & Azad, M. A. K. (2020). The impact of 5G on the financial sector of Bangladesh: Expectations and challenges. Journal of Financial Services Marketing, 25(2), 123-134.

Venkatesh, V., & Brown, S. A. (2001). A longitudinal investigation of personal computers in homes: Adoption determinants and emerging challenges. MIS Quarterly, 25(1), 71-102.
(Alalwan et al., 2017)

Andersen, S. C., & Jakobsen, M. L. (2018). Political pressure, conformity pressure, and performance information as drivers of public sector innovation adoption. *International Public Management Journal, 21*(2), 213–242. doi:10.1080/10967494.2018.1425227.

Arner, D. W., Barberis, J., & Buckley, R. P. (2015). The Evolution of FinTech: A New Post-Crisis Paradigm? Research Paper No. 2015/047, Hong Kong: University of Hong Kong, Faculty of Law. https://dx.doi.org/10.2139/ssrn.2676553

Awa, H. O., Ojiabo, O. U., & Orokor, L. E. (2017). Integrated technology-organisation-environment (TOE) taxonomies for technology adoption. *Journal of Enterprise Information Management, 30*(6), 893–921. https:// doi.org/10.1108/JEIM-03-2016-0079

Bhatnagar, N., & Gopalaswamy, A. K. (2017). The role of a firm's innovation competence on customer adoption of service innovation. *Management Research Review, 40*(4), 378–409. https://doi.org/10.1108/MRR-11-2015-0280

Changchit, C., Lonkani, R., & Sampet, J. (2017). Mobile banking: Exploring determinants of its adoption. *Journal of Organisational Computing and Electronic Commerce, 27*(3), 239–261. https://doi.org/10.1080/10919392.2017.1332145

Chiesa,V., & Frattini, F. (2011). Commercializing technological innovation: Learning from failures in high-tech markets. *Journal of Product Innovation Management, 28*(4), 437–454. https://doi.org/10.1111/j.1540-5885.2011.00818.x

Utami, A. F., Ekaputra, I. A., & Japutra, A. (2021). Adoption of FinTech Products: A Systematic Literature Review. *Journal of Creative Communications*, *16*(3), 233-248. https://doi.org/10.1177/09732586211032092

Chen, X., Teng, L., & Chen, W. (2022). How does FinTech affect the development of the digital economy? Evidence from China. *The North American Journal of Economics and Finance, 61*, 101697. doi:https://doi.org/10.1016/j.najef.2022.101697

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982–1003. https://doi.org/10.1287/mnsc.35.8.982

De Luna, I. R., Liébana-Cabanillas, F., Sánchez-Fernández, J., & Muñoz-Leiva, F. (2018). Mobile payment is not all the same: The adoption of mobile payment systems depending on the technology applied. *Technological Forecasting and Social Change.* https://doi:10.1016/j.techfore.2018.09.018

Demirguc-Kunt, A., Klapper, L., Singer, D., Ansar, S., & Hess, J. (2018). *The global findex database 2017: Measuring financial inclusion and the FinTech revolution*. The World Bank.

Dutta, S., & Folta, T. B. (2016). A comparison of the effect of angels and venture capitalists on innovation and value creation. *Journal of Business Venturing, 31*(1), 39–54. https://doi.org/10.1016/j.jbusvent.2015.08.003

Dorobantu, S., Kaul, A., & Zelner, B. (2017). Nonmarket strategy research through the lens of new institutional economics: An integrative review and future directions. *Strategic Management Journal, 38*(1), 114–140. https://doi.org/10.1002/smj.2590

Eng, T. Y., & Quaia, G. (2009). Strategies for improving new product adoption in uncertain environments: A selective review of the literature. *Industrial Marketing Management, 38*(3), 275–282. https://doi.org/10.1016/j.indmarman.2008.01.003

Eze, S. C., Awa, H. O., Okoye, J. C., Emecheta, B. C., & Anazodo, R. O. (2013). Determinant factors of information communication technology (ICT) adoption by government-owned universities in Nigeria: A qualitative approach. *Journal of Enterprise Information Management, 26*(4), 427–443. https://doi.org/10.1108/JEIM-05-2013-0024

Fakhoury, R., & Aubert, B. (2017). The impact of initial learning experience on digital services usage diffusion: A field study of e-services in Lebanon. *International Journal of Information Management, 37*(4), 284–296. https://doi.org/10.1016/j.ijinfomgt.2017.03.004

Farah, M. F., Hasni, M. J. S., & Abbas, A. K. (2018). Mobile-banking adoption: Empirical evidence from the banking sector in Pakistan. *International Journal of Bank Marketing, 36*(7), 1386–1413. https://doi.org/10.1108/ IJBM-10-2017-0215

Firmansyah, E. A., Masri, M., Anshari, M., & Besar, M. H. A. (2023). Factors Affecting Fintech Adoption: A Systematic Literature Review. *FinTech*, *2*(1), 21-33. https://doi.org/10.3390/fintech2010002

Frederiks, A. J., Costa, S., Hulst, B., & Groen, A. J. (2022). The early bird catches the worm: The role of regulatory uncertainty in early adoption of blockchain's cryptocurrency by fintech ventures. *Journal of Small Business Management, 62*(2), 790–823. https://doi.org/10.1080/00472778.2022.2089355

Firmansyah, E. A., Masri, M., Anshari, M., & Besar, M. H. A. (2023). Factors Affecting Fintech Adoption: A Systematic Literature Review. *FinTech*, *2*(1), 21-33. https://doi.org/10.3390/fintech2010002

Hussain, M., & Papastathopoulos, A. (2022). Organizational readiness for digital financial innovation and financial resilience. *International Journal of Production Economics, 243*, 108326. doi:https://doi.org/10.1016/j.ijpe.2021.108326

Kelly, S., Kaye, S. A., & Oviedo-Trespalacios, O. (2023). What factors contribute to the acceptance of artificial intelligence? A systematic review. *Telematics and Informatics*, *77*, 101925. doi:https://doi.org/10.1016/j.tele.2022.101925

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2016). Unified Theory of Acceptance and Use of Technology: A Synthesis and the Road Ahead. *Journal of the*

Association for Information Systems, 17(5), 328-376. This study provides an in-depth analysis of how PE, FC, and TR positively influence technology adoption across various domains, including FinTech. doi: https://doi.org/10.17705/1jais.00428

Pavlou, P.A. and Fygenson, M. (2006) Understanding and Predicting Electronic Commerce Adoption: An Extension of the Theory of Planned Behavior. MIS Quarterly, 30, 115-143.doi:https://doi.org/10.2307/25148720

Rizvi, S. K. A., Rahat, B., Naqvi, B., & Umar, M. (2024). Revolutionizing finance: The synergy of fintech, digital adoption, and innovation. *Technological Forecasting and Social Change, 200*, 123112. doi:https://doi.org/10.1016/j.techfore.2023.123112

Wang, J., Shahzad, F., Ahmad, Z., Abdullah, M., & Hassan, N. M. (2022). Trust and Consumers' Purchase Intention in a Social Commerce Platform: A Meta-Analytic Approach. *Sage Open*, *12*(2). doi:https://doi.org/10.1177/21582440221091262

Zeithaml, V. A., Bitner, M. J., & Gremler, D. D. (2006). Services Marketing: Integrating Customer Focus across the Firm. Boston, MA: McGraw-Hill/Irwin.
doi:http://library.wur.nl/WebQuery/clc/1809666

Oral Hygiene Practices and Awareness among Pharmacy Students of R. P. Shaha University in Bangladesh: A Retrospective Study

Muaj Ibne Sahid[1], Md Faiazul Haque Lamem[2], Rafsan Jany[3], Bristy Saha[2], Maimuna Hasan[1]

[1]Assistant Professor, Department of Pharmacy, R. P. Shaha University, Bangladesh
[2]Research Assistant, Department of Pharmacy, R. P. Shaha University, Bangladesh
[3]Lecturer, Department of Business Administration, R. P. Shaha University, Bangladesh
Corresponding author: Muaj Ibne Sahid, sahid_phr@rpsu.edu.bd.

ARTICLE INFO

Keywords: Oral hygiene, Pharmacy students, Dental awareness, Dental hygiene practices, Preventive dental care

RECEIVED
14 July 2024

ACCEPTED
25 July 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17239591

ABSTRACT

Oral health is a fundamental component of overall well-being, yet it remains a neglected aspect of personal care among many populations. Pharmacy students, as future healthcare providers, are expected to possess both knowledge and personal practices. This retrospective cohort study involved undergraduate pharmacy students from various academic years at R. P. Shaha University in Narayanganj, Bangladesh. Using a structured paper-based questionnaire, the research assessed student's awareness and practices related to oral hygiene, focusing on their knowledge, behaviors, and influencing factors. A representative sample of students revealed that 65.4% brush their teeth twice daily, with a predominant use of toothpaste (97.44%) over traditional methods like meswak (2.56%). The study reveals a concerning trend, with 82.1% of students neglecting preventive dental care, yet 83.3% are mistakenly satisfied with their oral health. Notably, 25.6% of students reported never having visited a dentist, and only 3.8% sought dental care annually, indicating a reactive rather than proactive approach to oral health. Furthermore, Herbal toothpaste is less favored, with only 24.4% usage, and only 33.3% use mouthwash, highlighting a gap in comprehensive oral hygiene practices.

Gender differences were evident, with female students more likely to use mouthwash (38.6%) than male students (19.0%). Findings highlight the need to promote awareness for better oral health.

1. Introduction

Maintaining optimal dental well-being involves ensuring the mouth and its adjacent components are free from disease (Fox, 2010). It is a fundamental aspect of overall health and well-being (Gift & Atchison, 1995; Dolan et al., 2006; Sabbah et al., 2007). Proper dental care is crucial for maintaining healthy teeth and gums, as well as for preserving oral functionality (Abdollahi & Radfar, 2003; Puy, 2006). While there is limited data on oral health status among pharmacy students in Bangladesh, a study on teeth status and oral health-related quality of life among the elderly in Bangladesh revealed significant oral health issues impacting their overall quality of life. (Eusuf Zai, 2013). Introducing oral health education into the pharmacy curriculum could help address these gaps and better equip pharmacy students to care for their future patients. Dental caries is widespread in Bangladesh, presenting challenges for pharmacy students who need to understand its implications when providing medication counseling. Consequently, pharmacy students require a solid grounding in oral health education to identify potential risks and offer appropriate recommendations. Unfortunately, there is evidence that oral health education is frequently overlooked in pharmacy curriculum worldwide, leading to inadequate knowledge and preparedness among pharmacy students (Ogunbodede et al., 2015).

According to multiple studies, young people in Bangladesh show a high prevalence of dental problems (Ahmed et al., 2021; Islam et al., 2019). Poor oral hygiene practices and dietary habits, such as consuming junk food, exacerbate the issue (Karim & Hossain, 2020). Investing in young people's oral health through targeted interventions can foster positive behaviors and improve overall health outcomes (AlGhamdi & Burnett, 2018).

While no specific studies have focused on oral health education among Bangladeshi pharmacy students, evidence from neighboring countries indicates the urgency of addressing this issue. For instance, a study evaluating oral health knowledge and behaviour among Pakistani pharmacy students discovered significant deficiencies (Fida et al., 2017). Participants showed limited understanding of the oral health complications arising from long-term medication use, emphasizing the need for enhanced oral health education in the pharmacy curriculum. Addressing this gap requires collaborative efforts between pharmacy institutions, regulatory bodies, and healthcare professionals.

Integrating oral health components within pharmacy courses would facilitate greater exposure to relevant topics and foster improved student comprehension. Ultimately,

investing in oral health education for pharmacy students benefits individual learners and future patients. Improved knowledge and practices contribute significantly to holistic patient care, reducing dental caries and other oral health concerns.

2. Methods and Materials

2.1 Study Design

This retrospective investigation was conducted in January 2024 at R. P. Shaha University in Narayanganj-1400, Bangladesh. The study's primary objective was to assess the awareness and practices related to oral hygiene among undergraduate pharmacy students. Specifically, the study aimed to evaluate the students' knowledge of oral hygiene, identify the oral hygiene practices they follow, and explore the factors influencing their awareness and practices. This study's results are expected to enhance educational strategies on oral hygiene, particularly for future healthcare professionals.

2.2 Study Population

The study was conducted exclusively with students from the Department of Pharmacy at the university campus. Due to time and logistical constraints, a representative sample was selected for the study. As stated by Zikmund (2003), the sample size (n) can be calculated using the formula $n = p\ (1 - p)\ (Z\ /\ E)^2$. For this study, assuming maximum variability with a proportion of 0.50, a 95% confidence level ($Z = 1.96$), and a margin of error of 11.1% ($E = 0.111$), the sample size was calculated as $n = 0.5\ (1 - 0.5)\ (1.96\ /\ 0.111)\ 2 = 0.25 \times 311.9 = 77.98$, which rounds to 78. Hence, a sample size of 78 is deemed sufficient for the study.

2.3 Data Collection Procedure

A structured, paper-based questionnaire was developed through an extensive review of relevant literature to assess participant's oral hygiene knowledge and practices. The study adhered to ethical guidelines and received approval from the Institutional Research Review Committee of R. P. Shaha University. Informed consent was obtained verbally from all participants to ensure voluntary participation and confidentiality of their responses.

2.4 Data Analysis

The data were entered into IBM SPSS Statistics (Version 25) for statistical analysis. Descriptive statistical methods were employed to summarize the data, with frequency

distributions, pie charts, and bar graphs used to represent student's oral hygiene knowledge and practices.

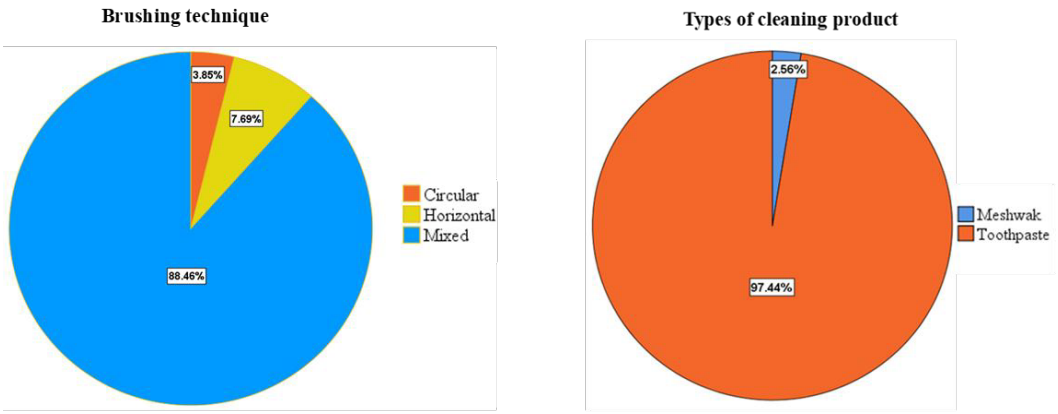
3. Results

The study sample consisted of individuals across various age groups, with 33.3% aged between 18-20 years, 62.8% aged between 21-23 years, and 3.8% aged between 24-26 years. Gender distribution was predominantly male, comprising 73.1% of the participants, while females comprised 26.9%. Regarding academic years, the distribution shows that 41.0% of participants were in their 1st year, 30.8% in their 2nd year, 24.4% in their 4th year, and 3.8% in their 3rd year (Table 1). This breakdown reflects the distribution of student engagement in this study.

Table 1: Demographic characteristics of the sample population (n=78).

Variable	Total Number	%
Age group (in years)		
18-20	26	33.3%
21-23	49	62.8%
24-26	3	3.8%
Gender		
Male	57	73.1%
Female	21	26.9%
Academic Years		
1st Year	32	41.0%
2nd Year	24	30.8%
3rd Year	3	3.8%
4th Year	19	24.4%

While our study focused on general oral hygiene behaviors, further results show that circular brushing 88.46% is the most common technique among students, 7.69% of respondents use a horizontal brushing technique, and 3.85% use a mixed technique, highlighting a potential area for improvement. Additionally, while toothpaste dominates as the cleaning product 97.44%, Meswak usage, only 2.56%, indicates a cultural influence on oral hygiene routines that warrants further exploration (Figure 1a; b).



(a) (b)

Figure 1: (a) Brushing Technique; (b) Types of cleaning method.

Afterward, the study investigated the oral hygiene practices of participating students (Table 2). It shows most students brush their teeth twice daily, accounting for 65.4%, while 29.5% brush once daily. A smaller fraction, 5.1%, brushes more than twice a day. Regarding brushing timing, 75.6% of students brush before breakfast and after dinner, whereas 15.4% brush after meals. Only 1.3% brush before breakfast and after dinner, and 7.7% do not maintain a consistent brushing schedule. Regarding the duration of each brushing session, 55.1% of students spend approximately 2 minutes brushing their teeth, 20.5% brushing for 1 minute, and 24.4% brushing for more than 4/5 minutes. Regarding regularity, 70.5% brush both in the morning and at night, while 29.5% brush only in the morning. Toothbrush replacement habits show that 66.7% of students change their toothbrush monthly, 30.8% replace it only when it is broken, and 2.6% change their toothbrush yearly. Lastly, the type of products used for brushing indicates a preference for chemical products among 75.6% of students, whereas 24.4% use herbal products. These findings highlight the diverse oral hygiene practices among the student population, emphasizing the need for consistent and effective oral health education.

Table 2: Oral-health-related practice among the students (n=78).

Questions	n	n %
How many times a day do you brush your teeth?		
More than two times	4	5.1%
Once Daily	22	29.5%
Twice Daily	51	65.4%

Brushing time (in the morning/ night)		
After the morning meal and after the night meal	12	15.4%
Before the morning meal and after the night meal	1	1.3%
Before Morning Meal and after Night Meal	59	75.6%
Does not maintain time	6	7.7%
How much time do you take for each brushing?		
1 min	16	20.5%
2 mins	43	55.1%
More than 4/5 mins	19	24.4%
Brushing time		
Both at night & and in the morning	55	70.5%
Only at morning	23	29.5%
How often do you change the toothbrush?		
Change when broken	24	30.8%
Monthly	52	66.7%
Yearly	2	2.6%
What kind of product do you use for brushing?		
Chemical	59	75.6%
Herbal	19	24.4%

Our further investigation provides insights into oral-health-related awareness among students, focusing on their dental visit frequency (Table 3); the data reveal that 25.6% of students have never visited a dentist, and only 3.8% visit annually. Notably, 26.9% of individuals go to the dentist only when they have a dental problem, while 43.6% visit as needed. Regarding scaling procedures, the majority, 82.1%, have never undergone one, with only 7.7% having the procedure in the past year and 9.0% within the last six months. Just 1.3% reported a recent scaling procedure. Despite the infrequent dental visits and lack of preventive care, 83.3% of students are satisfied with their oral health, while 16.7% are not. Despite limited engagement in routine dental care, this high satisfaction rate indicates a potential gap in awareness about the importance of regular dental visits and preventive procedures like scaling.

Table 3: Oral-health-related awareness among the students (n= 78).

Question	n	n %
How often do you visit the dentist?		

Never	20	25.6%
Once a year	3	3.8%
When you have a dental Problem	21	26.9%
When necessary	34	43.6%
The most recent time you underwent a scaling procedure?		
In 1 Year	6	7.7%
In 6 months	7	9.0%
Never	64	82.1%
Recently	1	1.3%
Do you think you are satisfied with your oral health?		
No	13	16.7%
Yes	65	83.3%

We also collected responses from students regarding the last time they visited a dentist. The data in (Figure 2) reveals that a significant proportion, 37.18%, reported never having visited a dentist, indicating a potential gap in regular dental care. Another 5.13% of the students had their last visit within the past year, and another 5.13% either stated "None" or visited one year ago. Smaller groups of students reported varying times since their last dental visit: 2.56% each for timeframes such as two months ago, three months ago, six months ago, and ten years ago. The remaining responses were more dispersed, with 1.28% each reporting a visit at numerous other intervals, ranging from one week to several years ago, including specific occasions like birthdays or vague timeframes such as "once upon a time."

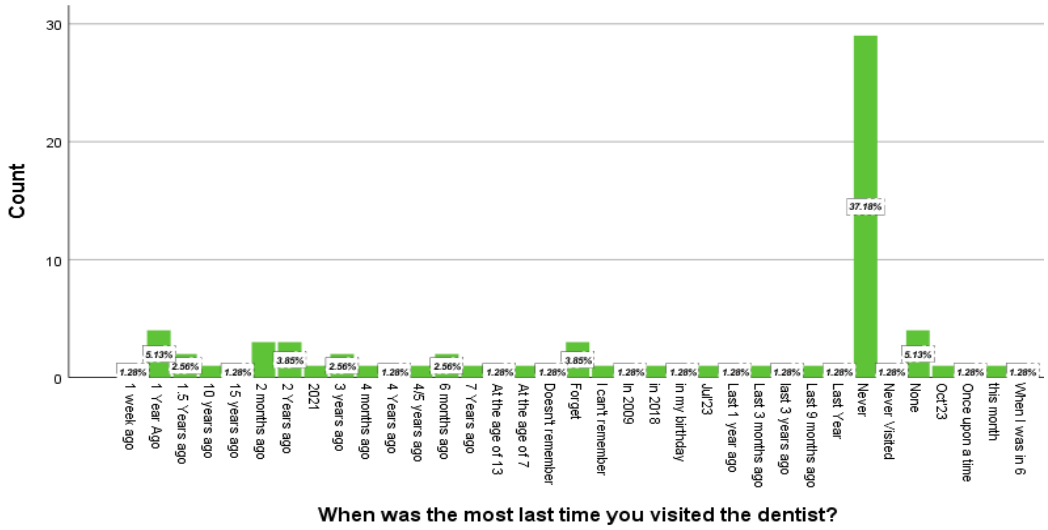


Figure 2: The student's most recent visit for a dental checkup

Oral habits among students were also observed, with comparisons made between responses from female and male students in (Table 4); regarding the use of mouthwash solution, a higher percentage of male students, 81.0%, reported not using mouthwash compared to female students, 61.4%. Conversely, 38.6% of female students use mouthwash, significantly more than 19.0% of male students. In total, the majority of students, 66.7%, do not use mouthwash, while 33.3% do.
Most students practice cleaning their tongues, with 89.5% of female and 85.7% of male students reporting doing so. Only a tiny percentage, 10.5% of female and 14.3% of male students do not clean their tongues.
In terms of experiencing toothaches, 73.7% of female and 76.2% of male students reported not suffering from toothaches. Overall, 25.6% of the students are dealing with this issue. Regarding tooth loss, a higher percentage of male students, 90.5% have not lost any teeth compared to female students, 84.2%. Only 14.1% of the students reported experiencing tooth loss.

Table 4: Oral-health-related hygiene habits among the students. (n = 78)

Question	Response	Female (n %)	Male (n %)	Total (n) %
Do you use a mouthwash solution?	No	35 (61.4 %)	17 (81.0 %)	52 (66.7 %)
	Yes	22 (38.6 %)	4 (19.0 %)	26 (33.3 %)
Do you clean your Tongue?	No	6 (10.5 %)	3 (14.3 %)	9 (11.5%)
	Yes	51 (89.5 %)	18 (85.7 %)	69 (88.5 %)
Do you suffer from toothache?	No	42 (73.7 %)	16 (76. 2%)	58 (74.4 %)
	Yes	15 (26.3 %)	5 (23.8 %)	20 25.6 %)
Have you lost any of your teeth?	No	48 (84.2 %)	19 (90.5 %)	67 (85.9 %)
	Yes	9 (15.8 %)	2 (9.5 %)	11 (14.1 %)

4. Discussion

The study revealed a predominantly majority of young participants aged between 21 and 23 years, 62.8%; most % were in their first year of study, 41.0%, indicating a relatively fresh cohort in higher education settings. Oral hygiene practices among the students demonstrated a solid adherence to twice-daily brushing at 65.4%, with the majority brushing for approximately two minutes per session at 55.1%. A similar study in Bangladesh focusing on adolescents demonstrated similar trends in oral hygiene practices. A significant proportion of students brushed their teeth twice daily, and most used toothpaste (Haque et al., 2016); additionally, while toothpaste was the dominant cleaning product 97.44%, the minimal use of traditional methods like

meswak 2.56% reflects cultural influences that merit further exploration. The study revealed a concerning lack of regular dental visits among the student population. Nearly a quarter of 25.6% had never visited a dentist, and only a tiny percentage visited annually, 3.8%. This is significantly lower than the recommended guidelines for preventive care (American Dental Association, 2023). However, notable gaps in optimal oral hygiene were observed, such as the prevalent use of circular brushing technique 88.46% and the infrequent use of mouthwash 33.3%, a notable difference is observed in the use of mouthwash (Opoku et al., 2024); the Indian study reported higher usage rates compared to our findings. Despite the high self-reported satisfaction with oral health, 83.3%, the infrequent dental visits, with 25.6% never having visited a dentist and 82.1% never having undergone a scaling procedure, indicate a potential underestimation of the importance of professional dental care. Gender differences were also evident, with female students more likely to use mouthwash 38.6% compared to male students 19.0%, and a higher percentage of male students reported not having lost any teeth 90.5% compared to female students 84.2%. The data express the necessity for enhanced oral health education to promote consistent dental visits and preventive care practices, addressing behavioral and educational gaps to improve overall oral health outcomes among students. The study reveals several concerning trends regarding student's dental health practices and perceptions. A significant 25.6% of students reported never visiting a dentist, while 26.9% only sought dental care when faced with problems, indicating a reactive rather than preventive approach to oral health. Additionally, 82.1% have never undergone a scaling procedure, suggesting a lack of routine professional cleaning. Despite these gaps in preventive care, 83.3% of students expressed satisfaction with their oral health, revealing a potential disconnect between their perceived and actual dental health needs. This misalignment points to a critical need for enhanced education and awareness about the importance of regular dental check-ups and preventive measures to maintain optimal oral health.

5. Conclusion

The study indicates a mix of commendable and concerning trends in oral hygiene practices among pharmacy students at R. P. Shaha University. While daily brushing habits and awareness of proper techniques are relatively strong, the lack of routine dental visits and limited use of preventive services such as scaling and mouthwash point to significant educational and behavioral gaps. The high rate of self-reported satisfaction with oral health, despite poor professional dental engagement, suggests a disconnect between perceived and actual oral health needs. These insights indicate the critical need for targeted oral health education initiatives that emphasize the importance of preventive care, regular dental checkups, and broader oral hygiene

practices. Strengthening such awareness within future healthcare professionals is vital not only for their personal well-being but also for their role in promoting oral health within the broader community.

Acknowledgment

The authors extend their sincere gratitude to the Department of Pharmacy, R. P. Shaha University, for providing the essential facilities and support required to conduct this research. The authors also gratefully acknowledge the participation of the students, whose cooperation and spontaneous responses were instrumental in gaining valuable insights into oral hygiene practices.

Conflict of Interest: The writers do not have any competing interests.

References

Abdollahi, M., & Radfar, M. (2003). A review of drug-induced oral reactions. Journal of Contemporary Dental Practice, 4, 10.

Ahmed, T., Kabir, S., Rahman, M. M., & Haque, S. (2021). Prevalence and determinants of periodontal diseases among young adults in urban slums of Dhaka city, Bangladesh: An analytic cross-sectional study. BMC Oral Health, 21(1), 1-10.

AlGhamdi, S. M., & Burnett, C. L. (2018). Oral Health Knowledge, Attitudes, Practices, and Barriers Among Community Pharmacies in Saudi Arabia. Journal of Dental Research, Dental Clinics, Dental Prospects, 12(1), 20-25.

American Dental Association. (2023). Dental checkups and cleanings. Oral Health Group. https://www.oralhealthgroup.com/oral-health/american-dental-association-statement-on-regular-dental-visits-1002386023/

Dolan, T. A., Gooch, B. F., & Bourque, L. B. (2006). Associations of self-reported dental health and general health measures in the Rand Health Insurance Experiment. Community Dentistry and Oral Epidemiology, 191(1), 1–8.

Eusuf Zai, S. Z., Jamayet, N. B., & Alam, M. K. (2013). A study of teeth status and oral health related quality of life among elderly in Bangladesh. International Medical Journal, 20(5), 610-614.

Fida, M., Shahid, S., Qureshi, A. A., Shafique, S., Malik, S., Khurshid, M., & Aziz, N. (2017). Oral health knowledge and behavior amongst pharmacy students of Pakistan—A cross sectional study. BMC Oral Health, 17(1), 1-8.

Fox, C. (2010). Evidence summary: What do we know from qualitative research about people's care-seeking about oral health? British Dental Journal, 209, 225–231.

Gift, H. C., & Atchison, K. A. (1995). Oral health, health, and health-related quality of life. Medical Care, 44(7), 601–608.

Haque, S. E., Rahman, M., Itsuko, K., Mutahara, M., & Kayako, S. (2016). Effect of a school-based oral health education in preventing untreated dental caries and increasing knowledge, attitude, and practices among adolescents in Bangladesh. BMC Oral Health, 16(1), 44.

Islam, N., Chowdhury, F. K., Karim, M. R., Ahmad, S. U., Alam, M. J., & Mahmud, J. (2019). Assessment of periodontal status among medical college students in urban area of Bangladesh. International Journal of Medical Science and Public Health, 8(3), 128-131.

Karim, M. R., & Hossain, S. (2020). Perception towards oral health and related factors among university students in Bangladesh. European Journal of Integrative Medicine, 31, 100811.

Ogunbodede, E. S., Oluwatosin, O. G., Salami, A. T., & Lawson, O. O. (2015). Oral health promotion by community pharmacists in Nigeria: Current perspectives and future directions. Journal of Pharmacy and Bioallied Sciences, 7(Suppl 1), S94-S97.

Opoku, P., Salu, S., Azornu, C. K., Ansu-Gyeabour, E., & Mensah, E. (2024). Oral health knowledge, practice and associated factors among Junior High School students of Koforidua, Ghana: A cross-sectional study. BMC Oral Health, 24(1), 449.

Puy, C. L. (2006). The role of saliva in maintaining oral health and as an aid to diagnosis. Medicina Oral, Patología Oral y Cirugía Bucal, 11, E449–E455.

Sabbah, W., Tsakos, G., Chandola, T., Sheiham, A., & Watt, R. G. (2007). Social gradients in oral and general health. Journal of Dental Research, 86(11), 992–996.

Enhancing Profitability through Effective Supply Chain Management in Duck Farming Business in Bangladesh

Dr. Sabyasachi Sarker
Lecturer, R. P. Shaha University, Narayanganj, Bangladesh.
Corresponding Author: Dr. Sabyasachi Sarker, sabyasachi_bba@rpsu.edu.bd

ARTICLE INFO

Keywords:
Effective supply chain management, Duck farm, Bangladesh livestock industry. Supply Chain Management, Department of Livestock Services, Bangladesh

RECEIVED
29 July 2024

ACCEPTED
28 July 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17240326

ABSTRACT

Bangladesh's livestock sector has become the most essential part of economic development. The poultry industry is one of the major revenue-generating sectors in Bangladesh. During the 1990's the primary source of chicken meat and eggs was collected from backyard processing in Bangladesh. However, with the advent of commercial broiler and layer farming in the nation, these commercial farms have become the primary source of chicken meat and eggs since the mid-1990s. There was strong evidence of a significant animal protein shortage in Bangladesh, and the country's present production of animal proteins is sufficient these days to meet demand, as per the information by the Department of Livestock Services, Bangladesh. Among all company categories in Asia, livestock-related businesses are expanding at the quickest rate. The pace at which milk, meat, and eggs are consumed is rising daily. Since all these products are perishable, the makers primarily adhere to a high standard of food security up until the point at which the consumers consume the product. Businesses that focus on livestock mostly sell raw meat, eggs, milk, and items manufactured from milk. One of the most popular poultry species with a big economic impact is the duck. In Bangladesh, duck farming to produce meat and eggs has a bright future. In rural places, duck farming is still primarily done using traditional farming methods without the use of modern technology. In this study, the researcher worked on how rural area farms can benefit from rearing ducks and how effectively the supply chain process will help them enhance their profitability in the market.

Introduction

Globally, businesses are changing day by day with the fastest technology and support of artificial intelligence. To purchase, produce, transfer, or sell the correct products in the proper numbers and locations, supply chains cannot be instantly repositioned. Instead, the market is now characterized by fierce rivalry, cost measurement, micro-marketing, and changeable consumption patterns (Wu, Haoyan, Zhijie Li, Brian King, Zina Ben Miled, John Wassick, and Jeffrey Tazelaar, 2017). Consequently, a supply chain must be envisioned where materials, processes, and organizations can be easily modified in response to changing conditions. Thus, to effectively handle the growing problems, supply networks must become more intelligent. (Wu, Ing-Long, Chuang, Cheng-Hung, Hsu, Chien-Hua, 2014). The terms "the smart supply chain," "the digital supply chain," and "the intelligent supply chain" are only a few of the terms used in literature to characterize supply chain management. In those papers, the terms "the digital supply chain" and "the smart supply chain management" are used simultaneously. A new digital era brought forth by the fourth industrial revolution has given rise to a supply chain (Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C., 2019).

Livestock is one of the fastest-growing industries in Bangladesh, contributing about 16.52% of GDP from the livestock and agricultural sector. As per the livestock economy by the Department of Livestock Services mentioned that in 2022-2023, around 87.10 Lac metric tons of meat and 2337.63 crore eggs were produced. The contribution by the livestock sector to Bangladesh's GDP in 2021-22 has increased at an average rate of 5.39% over the previous five years, which shows a significant production of livestock meat and eggs in the country. In Bangladesh, duck farming is not segregated from chicken or any other bird rearing. This framing is jointly counted as poultry rearing. The help of the Bangladesh government and non-government organizations, which are known as NGOs, supports these farmers to rear the ducks and provide medical care with artificial insemination to increase production. By using this technology, more farmers are investing in duck rearing farms. Duck farming plays a vital role in North Bengal areas where most of the rivers and channels are located.

Churchil, R.R., and Jalaludeen A. (2022) mentioned in their studies that Local human population growth happened mostly around rivers in the early civilizations. The domestication of these poultry species began in China in the first century BC as a result of frequent human interactions with waterfowl, particularly ducks. Duck production is a significant part of agriculture in Asian nations. Ducks have a number of benefits, including flock behavior, exceptional wetland grazing capacity, and disease tolerance. In paddy farming, ducks serve as both natural fertilizer producers and bug hunters. Ducks help to increase rice yield and profitability overall by

lowering weed populations and enhancing the physical characteristics of the soil. The primary barriers, on the other hand, are the following: the reduction of water bodies, contamination of pastures, challenges in gathering inputs such as feed, medicine, and birds, difficulties in marketing, and the emergence of diseases such as avian influenza epizootics. To guarantee the availability of essential inputs such as the preservation of duck genetic resources, birds, feed, biology, medicine, veterinary services, finance and training, establishment of farmer-producer groups, and marketing support, local governments must develop comprehensive action plans and policies. Standardized grading and criteria are necessary to safeguard the interests of the community that farms ducks (Churchil, R.R., Jalaludeen, A., 2022).

Literature Review

A vertical integration mode of supply chain exists in livestock production. Where completely owned by the company. From the purchasing of the raw material to final production the cost of those production processes is internalized by the company. Another Supply chain mode is advanced supply chain management where the company maintains the flow of the supply chain like a Company with a Farmer. These two kinds of supply chain modes exist in livestock supply chain management (YuXun and Li Cuixia, 2012). Demand and supply are one of the major issues in the economy where the demand for a product and the supply of the product should be equal. But in the livestock sector, the demand for the product is high, and the price of that product is also high, but the demand couldn't be fulfilled because of the supply. In that case, the purchasing power is dependent on only high-income groups in developing countries. (Steven J. Staal, 2015).

Literature review on duck farming is not available. Few of the research studies have been conducted on that. Jowel Debnath, Debajyoti Sarkar, and Tapan Kumar Das (2020) mentioned in their studies that Desi ducks are better acclimated and resistant to disease than foreign duck breeds. For the duck rearing system to yield the best possible return on investment in terms of eggs and meat, housing, nutritional management, the ability for hatching percentage, general health management, and care and management of ducklings are all significant. This review study included information on duck-rearing procedures, the socioeconomic status of duck rears, production performance, disease incidence, and health management of Indigenous ducks in India, all while considering the current duck-rearing situation (Jowel Debnath, Debajyoti Sarkar, and Tapan Kumar Das, 2020). In 2022, Sarker. S, and Singh. P has mentioned in research that a sustainable supply chain needs a strong chain of command where suppliers to distributors can easily track the products and they can share the feedback with the companies that manufacture livestock products (Sarker, S. & Singh, P., 2022). The market's supply chain for duck meat consists of

two different kinds of distribution networks. The duck farmer and supplier, the restaurant that sold duck meat, and the consumer market were the origins of Channel One. Conversely, channel two began with the duck farmer, then moved on to the distributor, supplier, and restaurant owners selling duck meat to customers. In the duck meat supply chain, duck farmers in channel one achieved the highest added value ratio, while those in channel two obtained the highest profit ratio. Distribution channel one is favored in the duck meat supply chain due to its shorter chain and subsequently reduced pricing.(Nanang Febrianto, Budi Hartono and Alditya Putri Yulinarsari, 2021).

Research Gaps

1. There is limited empirical evidence on the direct relationship between Supply Chain Efficiency (SCE) and profitability in the context of duck farming in Bangladesh. Further research is needed to assess the impact of supply chain practices on financial performance.
2. The specific effects of Technological Adoption (TECH) on profitability in the duck farming sector have not been extensively studied. More research is required to identify the most effective technologies and their contributions to profitability.
3. While input availability is known to be crucial for farming operations, its precise impact on the profitability of duck farming in Bangladesh is underexplored. Research should focus on how input availability affects productivity and financial outcomes.
4. There is a lack of comprehensive studies examining the role of Market Access (MA) in influencing the profitability of duck farming businesses. Investigating how market dynamics and distribution networks affect profitability could provide valuable insights.

Objectives of the Study

Objective 1: To examine the impact of Supply Chain Efficiency (SCE) on the profitability of duck farming businesses in Bangladesh. This objective aims to determine how improvements in supply chain processes can enhance financial outcomes.

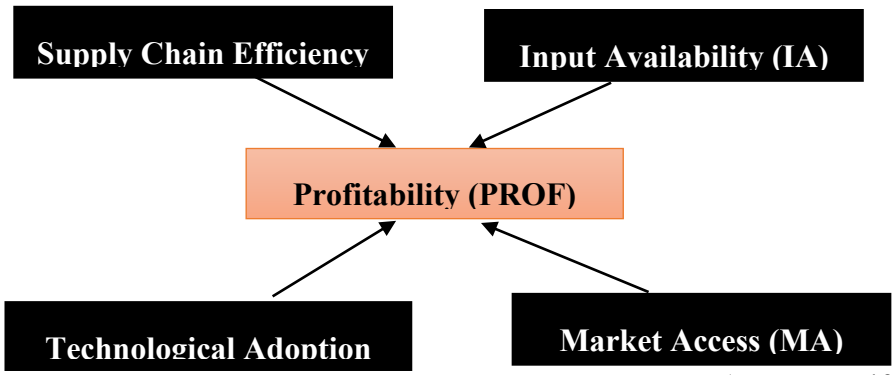
Objective 2: To assess the role of Technological Adoption (TECH) in improving the profitability of duck farming businesses in Bangladesh. This objective focuses on identifying the benefits of integrating modern technologies in farming operations.

Objective 3: To evaluate the influence of Input Availability (IA) on the profitability of duck farming businesses in Bangladesh. This objective seeks to understand the importance of having reliable access to essential farming inputs.
Objective 4: To analyze the effect of Market Access (MA) on the profitability of duck farming businesses in Bangladesh. This objective explores how efficient market reach and distribution contribute to financial success.

Hypotheses of the Study

H_1: Supply Chain Efficiency (SCE) positively influences Profitability (PROF) in duck farming businesses in Bangladesh. This hypothesis suggests that improvements in the efficiency of supply chain operations, such as reducing costs and enhancing service delivery, will lead to increased profitability.
H_2: Technological Adoption (TECH) positively affects Profitability (PROF) in duck farming businesses in Bangladesh. This hypothesis posits that the integration of modern technologies and digital tools in farming operations will enhance productivity and profitability.
H_3: Input Availability (IA) has a positive impact on Profitability (PROF) in duck farming businesses in Bangladesh. This hypothesis indicates that reliable access to essential inputs like feed, medicine, and ducklings will result in higher profitability by maintaining farm productivity.
H_4: Market Access (MA) positively influences Profitability (PROF) in duck farming businesses in Bangladesh. This hypothesis asserts that effective market access, characterized by efficient distribution and market reach, will increase the profitability of duck farming operations.

Conceptual Framework



(Source: Self-created)
Figure 1: Theoretical Framework

Supply Chain Efficiency (SCE): This variable represents the effectiveness with which the supply chain operates, focusing on the seamless flow of materials, information, and products from suppliers to end consumers. High supply chain efficiency is crucial in reducing costs and improving service delivery, which can significantly impact the profitability of duck farming businesses (Wu et al., 2017).
Technological Adoption (TECH): Technological adoption refers to the extent to which modern technologies and digital tools are integrated into duck farming operations. This includes the use of automated systems, data analytics, and other innovations that enhance production efficiency and decision-making processes. Embracing technology is essential for optimizing supply chain operations and boosting productivity in the duck farming sector (Ardito et al., 2019).
Input Availability (IA): Input availability denotes the accessibility and reliability of essential resources such as feed, medicine, and ducklings. Consistent and timely access to these inputs is critical for maintaining the health and productivity of duck farms. Challenges in obtaining necessary inputs can hinder production and profitability (Churchil & Jalaludeen, 2022).
Market Access (MA): Market access involves the ability of duck farmers to reach and sell their products in local and national markets. It includes factors like transportation infrastructure, market information, and the presence of intermediaries. Effective market access ensures that farmers can distribute their products efficiently, which is vital for sustaining profitability (Febrianto et al., 2021).
Profitability (PROF): Profitability is the dependent variable representing the financial gain or return on investment from duck farming operations. It is measured by calculating revenue minus expenses. Profitability serves as a key performance indicator for assessing the success of supply chain strategies and other operational decisions within the industry (Sarker & Singh, 2020).

Methodology

The methodology of this study adopted a quantitative research approach to examine the factors influencing the profitability of duck farming businesses in Bangladesh. The target population included individuals and organizations directly involved in the duck farming sector, such as farm owners. The sample consisted of 100 respondents who were actively engaged in duck farming in Bangladesh. The study used stratified random sampling to ensure representation from each stakeholder group and to enhance the generalizability of the findings. Data was collected through face-to-face interviews, and then the results were input into Google Forms. This combination was selected to ensure broad coverage and to accommodate varying levels of accessibility among participants.
Each variable was measured using five Likert scale items, where 1 indicated strong disagreement and 5 indicated strong agreement. The variables included supply chain

efficiency, technological adoption, input availability, market access, and profitability. The questionnaire was designed to capture the respondents' direct experiences and perceptions related to these variables.

Structural Equation Modeling (SEM) was selected as the analytical technique because it allows for the simultaneous estimation of multiple relationships among observed and latent variables. SEM was conducted using Smart Partial Least Squares 4 (Smart PLS 4). This tool was appropriate for the study due to its suitability for small sample sizes, its ability to handle complex models with multiple constructs, and its effectiveness in exploring causal relationships.

This methodological framework enabled a detailed analysis of the interconnected factors that affect profitability in the duck farming sector of Bangladesh. The structured design and analytical strategy ensured clarity, accuracy, and relevance in understanding the dynamics of the industry.

Table 1: Presentation of variables

Variable	Questions	Reference
Supply Chain Efficiency (SCE)	1. Our supply chain processes are highly efficient in reducing costs.	Wu et al., 2017
	2. We consistently achieve timely delivery of products to the market.	
	3. Our supply chain operations are well-coordinated and streamlined.	
	4. We effectively manage supply chain risks and disruptions.	
	5. Our supply chain efficiency contributes significantly to our profitability.	
Technological Adoption (TECH)	1. We have integrated modern technologies into our farming operations.	Ardito et al., 2019
	2. The use of technology has improved our production efficiency.	
	3. We rely on digital tools for decision-making in our farm management.	
	4. Technological adoption has positively impacted our profitability.	
	5. We actively invest in new technologies to enhance our farming processes.	
Input Availability (IA)	1. We have consistent access to high-quality feed for our ducks.	Churchil & Jalaludeen, 2022
	2. The availability of veterinary services is reliable and timely.	

	3. We can easily procure necessary inputs such as medicine and ducklings.	
	4. Input availability has a direct impact on our farm's profitability.	
	5. We face minimal challenges in obtaining essential resources for our operations.	
Market Access (MA)	1. We have effective access to local and national markets for our products.	Febrianto et al., 2021
	2. Our transportation infrastructure supports efficient distribution.	
	3. We have sufficient market information to make informed decisions.	
	4. Our market access contributes positively to our profitability.	
	5. We face minimal barriers in reaching our target markets.	
Profitability (PROF)	1. Our business consistently generates profits from duck farming.	Sarker & Singh, 2020
	2. We have experienced growth in profitability over the past few years.	
	3. Our financial performance is stable and predictable.	
	4. Profitability is a key measure of our business success.	
	5. We regularly assess and improve factors influencing our profitability.	

(Source: Self-Created)

Analysis and Discussions

Table 2: Factors Loading with Communality and Redundancy, Convergent Validity and Average Variance Extracted (AVE)

Construct	Item	Factor Loading	Communality	Redundancy (P-value)	Average variance Extracted (AVE)
PROF					0.65803
	PROF1	0.735	0.643	0.026	
	PROF2	0.731	0.6143	0.056	
	PROF3	0.759	0.686	0.0157	
	PROF4	0.742	0.679	0.0345	
	PROF5	0.812	0.609	0.00254	
SCE					0.6285
	SCE1	0.862	0.577474	0.0052	
	SCE2	0.728	0.698415	0.000218	
	SCE3	0.863	0.56611	0.00745	
	SCE4	0.831	0.633379	0.000278	
	SCE5	0.706	0.65957	0.000365	
TECH					0.61634
	TECH1	0.746	0.651085	0.000381	
	TECH2	0.868	0.589462	0.000518	
	TECH3	0.757	0.534159	0.000137	
	TECH4	0.775	0.634754	0.00641	
	TECH5	0.805	0.651845	0.003178	
IA					0.62315
	IA1	0.738	0.68413	0.00614	
	IA5	0.823	0.598418	0.008469	
	IA3	0.782	0.698513	0.00354	
	IA4	0.787	0.574563	0.00841	
	IA5	0.734	0.631478	0.003585	
MA					0.639457
	MA1	0.818	0.549836	0.006328	
	MA2	0.787	0.639741	0.002315	
	MA3	0.743	0.65847	0.002319	
	MA4	0.812	0.543982	0.01036	
	MA5	0.792	0.639745	0.01132	

(Source: Smart Partial Least Squares output)

- ✓ Communality values above 0.5 indicate inclusion in factor analysis. All values exceed 0.5.

- ✓ Factor loadings >0.7 indicate sufficient variance extraction. All factor loading scores are >0.7.
- ✓ P-values <0.05 indicate statistical significance. All p-values are <0.05.
- ✓ AVE scores >0.5 ensure adequate convergence. All AVE scores exceed 0.5.

Table 3: Reliability and convergent validity

Item	Cronbach's α	Composite Reliability rho(A)	Composite Reliability rho(C)	VIF
PROF	0.751	0.747	0.818	1.91
SCE	0.713	0.764	0.834	1.46
TECH	0.739	0.835	0.751	1.09
IA	0.788	0.854	0.769	1.21
MA	0.860	0.745	0.772	1.9
Optimum Values	>.7	>.7	>.7	<5

(Source: Smart Partial Least Squares output)

Table 3 shows that all variables meet the criteria: Cronbach's α, Composite Reliability rho(A), and rho(C) are all >0.7, and VIF is less than 5. VIF values below 5 indicate no significant multicollinearity.

Table 4: Outer model –Discriminant Validity (Fornell-Larcker Criterion: Correlation matrix of Constructs and Square Root of AVE (in Bold).

	PROF	SCE	TECH	IA	MA
PROF	0.781	-	-		
SCE	0.684	0.7885	-		
TECH	0.346	0.384	0.782		
IA	0.527	0.610	0.219	0.753	
MA	0.368	0.413	0.285	0.189	0.587

(Source: Smart Partial Least Squares output)

The Fornell-Larcker criterion checks discriminant validity by ensuring the square root of a construct's average variance extracted (AVE) is greater than its correlation with

any other construct. In this study, all constructions meet this criterion, confirming discriminant validity.

Table 5: Cross-loading analysis

	PROF	SCE	TECH	IA	MA
PROF1	0.766	0.585	0.089	0.030	0.084
PROF2	0.765	0.598	0.088	0.130	0.327
PROF3	0.815	0.581	0.128	0.234	0.169
PROF4	0.659	0.491	0.324	0.167	0.152
PROF5	0.623	0.326	0.137	0.189	0.418
SCE1	0.599	0.894	0.257	0.256	0.237
SCE2	0.469	0.745	0.047	0.351	0.149
SCE3	0.525	0.802	0.011	0.452	0.238
SCE4	0.406	0.686	0.014	0.306	0.328
SCE5	0.365	0.752	0.032	0.195	0.543
TECH1	0.258	0.493	0.623	0.203	0.208
TECH2	0.143	0.579	0.740	0.136	0.162
TECH3	0.079	0.045	0.713	0.319	0.008
TECH4	0.07	0.048	0.881	0.247	0.113
TECH5	0.093	0.062	0.831	0.308	0.480
IA1	0.038	0.051	0.564	0.658	0.327
IA2	0.046	0.033	0.227	0.849	0.179
IA3	0.318	0.456	0.219	0.742	0.308
IA4	0.235	0.413	0.226	0.763	0.179
IA5	0.354	0.328	0.336	0.892	0.234
MA1	0.157	0.327	0.028	0.452	0.862
MA2	0.218	0.564	0.057	0.321	0.785
MA3	0.167	0.346	0.310	0.018	0.694
MA4	0.256	0.103	0.276	0.304	0.604
MA5	0.341	0.302	0.143	0.179	0.808

(Source: Smart Partial Least Squares output)

Gefen and Straub (2005) state that discriminant validity is achieved when items correlate weakly with other constructs, except their own. Reflective relationships, called Loadings, should be high within the same construct and low across different constructs. Table 3 confirms high within-construct loadings and weak cross-construct correlations, validating the outer model for cross-loading analysis.

Table 6: Outer model –Discriminant Validity (HTMT Ratio), Threshold: HTMT<0.9

	PROF	SCE	TECH	IA	MA
PROF				-	-
SCE	0.5655				-
TECH	0.052	0.534			
IA	0.148	0.187	0.479		
MA	0.117	0.1479	0.652	0.202	

(Source: Smart Partial Least Squares output)

Accordance with Franke & Sarstedt (2019) if the HTMT value is significantly below the critical value of 0.9 to establish discriminant validity. Here we can see that the value is below 0.9. So, it can be said that the model is valid and established.

Table 7: Inner model; Path Coefficients of tested model & Hypothesis Testing and Structural Model Evaluation

Hyp	**Relationship**	**B**	**Mean**	**Std. Dev**	**R2**	**Q2**	**f2**	**t-statistic**	**sig.**
H1	SCE→PROF	0.387	0.916	0.1	0.42	0.0012	0.74	0.725	0.031**
H2	TECH→PROF	0.264	0.955	0.05	0.51	0.0352	0.68	0.824	0.0076**
H3	IA→PROF	0.213	0.948	0.01	0.535	0.026	0.57	0.766	0.0042**
H4	MA→PROF	0.299	0.981	0.02	0.537	0.0046	0.369	0.759	0.000625***

(Source: Smart Partial Least Squares output)

Note: *p<0.05; **p<0.01, ***p<0.001; n.s= not significant; (two-tailed test). R = Rejected; (A) = Accepted.

- ✓ Beta coefficients (B) estimate path relationships in the structural model, indicating consistency across items. The cutoff value for B is >0.20, and all values in Table 6 meet this threshold.

- ✓ R Square (R2) explains variance in endogenous variables due to exogenous variables. Values of 0.42, 0.51, 0.535, and 0.537 are moderate, aligning with Cohen's and Chin's benchmarks.

- ✓ Q-square (Q2) measures predictive relevance, with all values above zero indicating good model fit.

- ✓ F-Square (f2) Assess the effect size when removing an exogenous variable. Values of 0.74, 0.68, 0.57, and 0.369 indicate a large effect, per Cohen's benchmarks.

Table 8: Inner Model (parameters)

Assessment	Name of Index	Guideline	Source
Collinearity	VIF (Variance Inflator Factor)	Multi-Collinearity occurs in model when for specific indicators VIF values are 5 and above	García-Carbonell, Martín-Alcázar and Sánchez-Gardey (2015)
Path Coefficient	Path Coefficient	t value ≥ 2.33 (one-tailed), p value < 0.05	Hair et al. (2017)
R-square	Coefficient of Determination	0.26 - Substantial0.13 - Moderate0.02 - Weak	Cohen (1988)
f-square	Effect Size	0.35 - Large0.15 - Medium0.02 - Small	Cohen (1988)

(Source: Inner Model Parameters)

Table 9: Goodness-of-fit indicators

Fit indices	Structural model value	Recommended value	References
Gfi	0.987	> .90	Hair et al. (2010)

Agfi	0.920	> .80	Hu and Bentler (1999)
Nfi	0.964	> .90	Hu and Bentler (1999)
Cfi	0.985	> .90	Bentler and Bonett (1980)
Rmsea	0.031	< .08	Hu and Bentler (1999)
Srmr	0.046	< .07	Hu and Bentler'(1999)

(Source: Smart Partial Least Squares output)

Goodness-of-Fit Measures for the Structural Model (Table 8):

- ✓ *Goodness-of-Fit Index (GFI):* The Value 0.987, which is higher than the suggested value of 0.90, indicates a strong fit between the model and observed data.
- ✓ *Adjusted Goodness-of-Fit Index (AGFI)* Value 0.920 is higher than the suggested value of 0.80. Reflects a good fit, considering adjustments for the number of parameters.
- ✓ *Normed Fit Index (NFI)* Value 0.964 shows the Higher than the suggested value of 0.90, indicating a high level of fit between the model and data.
- ✓ *Comparative Fit Index (CFI)* Value is 0.985, Greater than the recommended value of 0.90, suggesting a reasonable fit between the model and the observed data.
- ✓ *Root Mean Square Error of Approximation (RMSEA)* Value 0.031 is under the advised value of 0.08, demonstrating a satisfactory match between the model and data.
- ✓ *Standardized Root Mean Square Residual (SRMR)* Value is 0.046 meets the suggested value of 0.07, and indicates a good fit for the structural model.

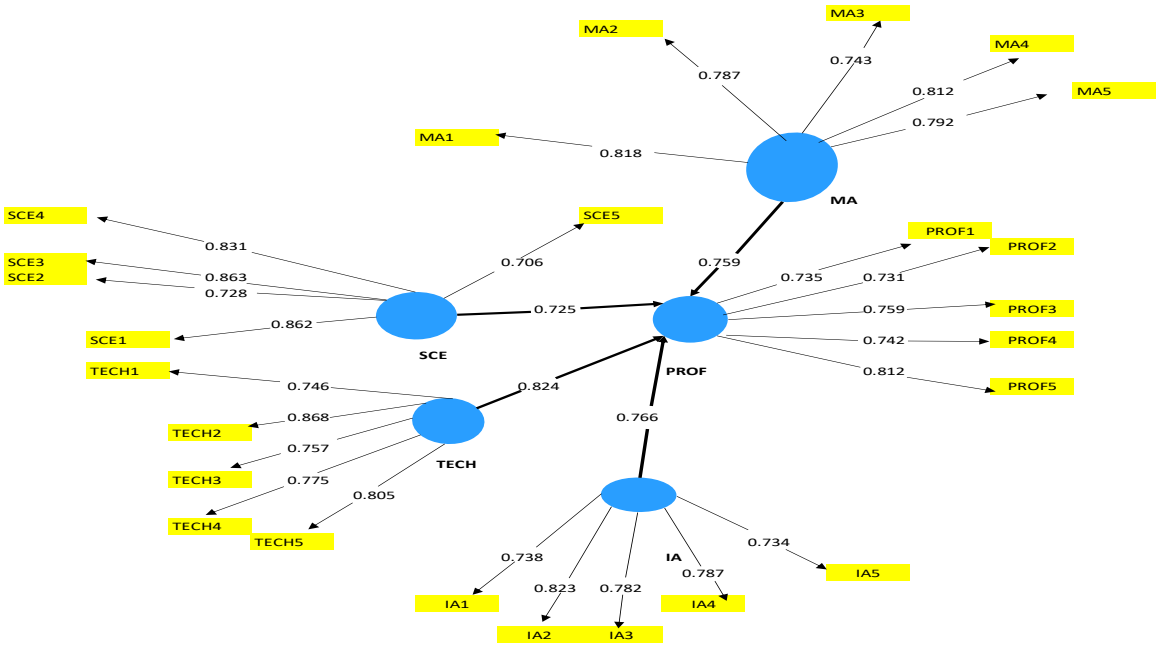


Fig 2: Bootstrapped model

(Source: Smart Partial Least Squares output)

Findings

An efficient supply chain brings lower production efficiency costs for farming business. It also improves how products are delivered. When operations run smoothly, farms save money. They also use resources better. This directly helps duck farms earn more profit. So, better supply chain efficiency means better financial results. Using new technology helps farms grow faster. It improves productivity. It also brings new ways of working. These changes help farms work smarter. This saves time and money. As a result, farms earn more. So, adopting technology gives a strong push to profitability. Farms need a steady supply of feed, water, and veterinary care. If these inputs are easy to get, farms can work without delay. This avoids losses. It keeps production levels stable. In the end, this supports long-term profit. Farms must reach the market on time. If they can sell their products easily, they get better prices. More buyers mean more sales. This boosts income. So, market access has a direct link to profit. Managers must make supply chains simple and fast. They should reduce costs and speed up delivery. Using good systems for transport and stock will help. This will cut waste and increase farm profit. Managers should bring in helpful tools like automatic feeders or data tracking. Training workers is also important. If

they use tools well, work becomes easier. This brings better results and higher profit. Farm owners must ensure that food, water, and vet care are always there. They should work closely with suppliers. They must also look for other supply sources. This reduces the chance of delays. Smooth input flow means steady profit. Managers should find new ways to sell. They can partner with shops or sell online. Reaching more customers helps us to sell faster and at better prices. This improves business income. They should review every part of the process often. Checking supply chains, tech use, input supply, and markets will help. This lets them make good decisions. It also helps farms grow and stay profitable.

Conclusion

The significant factors influencing profitability in the duck farming sector in Bangladesh were focused on in some studies. The research underscores the critical role of supply chain efficiency, technological adoption, input availability, and market access in enhancing profitability. Efficient supply chain management is crucial for reducing costs and improving delivery times, directly impacting profitability. By streamlining logistics and inventory processes, duck farming businesses can achieve better resource utilization and cost savings. Technological adoption is equally important, as it modernizes farming practices and enhances productivity. The implementation of new technologies requires investment in both equipment and training, ensuring farm workers are equipped to leverage these tools effectively. Furthermore, securing consistent input availability is vital for maintaining production levels and avoiding disruptions. Establishing strong relationships with suppliers and exploring alternative sources can help mitigate risks associated with input shortages. Market access is another critical area, where strategic partnerships and the use of digital platforms can expand customer reach and improve product pricing. Overall, the study emphasizes the need for strategic planning and continuous improvement across all operational areas to enhance profitability. Managers in the duck farming industry can utilize these insights to develop targeted strategies that align with business goals and ensure long-term success. The findings contribute valuable knowledge to the field of agricultural business management, offering practical implications for boosting profitability in a competitive market.

References

Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C. (2019). Towards Industry 4.0: Mapping digital technologies for supply chain management-marketing integration. Business Process Management Journal.

Churchil, R.R., Jalaludeen, A. (2022). Duck Farming: Opportunities, Constraints and Policy Recommendations. In: Jalaludeen, A., Churchil, R.R., Baéza, E. (eds) Duck Production and Management Strategies. Springer, Singapore. https://doi.org/10.1007/978-981-16-6100-6_16

DLS. Annual Progress Report 2009, Department of Livestock Services, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh, Farm gate, Dhaka.

Delgado, Christopher &Rosegrant, Mark & Steinfeld, Henning & Ehui, Simeon & Courbois,Claude. (1999). Livestock to 2020: The Next Food Revolution. Int Food Policy Res Inst IFPRI. 30. 10.5367/000000001101293427.

Franke, G. and Sarstedt, M. (2019), "Heuristics versus statistics in discriminant validity testing: a comparison of four procedures", Internet Research, Vol. 29 No. 3, pp. 430-447. https://doi.org/10.1108/IntR-12-2017-0515

Gefen, D., & Straub, D. (2005). A Practical Guide to Factorial Validity Using PLS-Graph: Tutorial and Annotated Example. Communications of the Association for Information Systems, 16, pp-pp. https://doi.org/10.17705/1CAIS.01605

Hair, Joseph & Black, William & Babin, Barry & Anderson, Rolph. (2010). Multivariate Data Analysis: A Global Perspective.

Hossan, S. (2023, January 10). *Livestock industry of Bangladesh: Growth, challenges and future opportunities*. Business Inspection BD. https://businessinspection.com.bd/livestock-industry-of-bangladesh/

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling, 6(1), 1–55. https://doi.org/10.1080/10705519909540118

Nanang Febrianto, Budi Hartono and Alditya Putri Yulinarsari, 2021, Value-Added Analysis of Duck Meat Supply Chain in Malang, Indonesia, American Journal of Animal and Veterinary Sciences 2021, 16 (3): 112.120

Pym RAE, EB Lanada and EY Morbos, 2002. Case studies of family poultry development. 2nd INFPD-FAO, Electronic conference. May 13-July 5, 2002.

Sarker, S., & Singh, P., (2022), A Review of Literature on The Sustainability of Supply Chain Management in The Bangladesh Livestock Industry. Webology, Vol 19, Issue 3, P 2079-2089

S. Sarker and P. Singh, (2020), Effective Supply Chain Strategy Through the Customer Focused Leadership in Livestock Industry, 2020. Turkish Journal of Physiotherapy and Rehabilitation; 32(3), P- 36929-36936

Steven J., Staal, (2015). Livestock marketing and supply chain management of livestock products. Indian journal of agricultural economics, 70(902-2016-68369), 42-63.

Wu, Haoyan, Zhijie Li, Brian King, Zina Ben Miled, John Wassick, and Jeffrey Tazelaar. 2017. "A Distributed Ledger for Supply Chain Physical Distribution Visibility" *Information* 8, no. 4: 137. https://doi.org/10.3390/info8040137

Wu, Ing-Long, Chuang, Cheng-Hung, Hsu, Chien-Hua, 2014. "Information sharing and collaborative behaviors in enabling supply chain performance: A social exchange perspective," International Journal of Production Economics, Elsevier, vol. 148(C), pages 122-132.

Yu, X., & Li, C. (2012). Research on the supply chain of livestock products mode based on third-party logistics. In Proceedings of 2011 International Conference on Engineering and Information Management (ICEIM 2011).

Design and Implementation of an SMS-based Fault Detection System Using Arduino STM32 Microcontroller

Md Lutfur Rahman[1], Rajib Mondal[2], Md Shariar Hasan[3], Md Abu Hena Shatil[4], Md Abdul Mannan[5], Rapsan Amin Anonto[6]

[1]Lecturer, Department of Electrical and Electronic Engineering, RPSU, Bangladesh
[2]Assistant Professor, Department of Electrical and Electronic Engineering, RPSU, Bangladesh
[3]Research Assistant, Department of Electrical and Electronic Engineering, AIUB, Bangladesh
[4]Associate Professor, Department of Electrical and Electronic Engineering, AIUB, Bangladesh
[5]Associate Dean, Department of Electrical and Electronic Engineering, AIUB, Bangladesh
[6]PhD Researcher, Department of Electrical and Computer Engineering, Morgan State University, USA
Corresponding Author: Md Lutfur Rahman, lutfur_eee@rpsu.edu.bd

ARTICLE INFO

Keywords: Fault detection, Arduino STM32 microcontroller, GSM module, Relay, Temperature sensor, Current sensor.

RECEIVED
22 March 2025

ACCEPTED
28 July 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17241107

ABSTRACT

The paper deals with safety features and notifies the manager of any industrial load. It includes sensors to monitor current, voltage, and temperature data continuously if something goes wrong. This study uses Arduino as a microcontroller to check sensor data and execute appropriate actions for the load. Upon detection of a fault by the sensor, the Arduino will trip the switch and disconnect the load. Additionally, a further feature is the utilization of GSM for fault detection and localization. Upon the occurrence of a defect, the GSM module delivers an SMS to notify and urge rapid action by field operators. In this system, the simulation model is set up into proteus 8.1 professional software.

1. Introduction

Industrial loads are very expensive and heavy. These loads use very high voltage and current to perform. This is the reason there are risks to the machines and workers. There are many ways to protect the machines. Different types of protections are used for different types of loads. Machines are usually damaged by voltage destruction, unstable current, and overheating. Many scientists in various countries work on research to strengthen the protection system. Fault analysis was complex and challenging in the past. Still, in today's scientific and engineering era, it has become advanced and convenient, due to the emergence of various accelerated and reliable computing technologies, such as MATLAB, ETAP, and others. Fast and dependable techniques for multiple problems necessitate an effective and efficient fault analysis method. The exact fault information is not only appropriate for fault recognition algorithms or prototypes but also for proper protective relay operation and the correct resolution of different fault types (R. Ramaswami and P. F. McGuire,1992, R. E. Brown, 2008, M.-S. Choi, S.-J. Lee, D.-S. Lee, and B.-G. Jin,2004, B. Das, 2006). Currently, electrical energy is essential in various industries, including textiles, chemicals, steel, mining petroleum, and manufacturing. The safety and security of electrical power systems are crucial elements that must be addressed to power stations on efficiently generating electricity (S. Ponnusamy, R. Samikannu, B. A. Tlhabologo, W. Ullah and S. Murugesan, 2020).

To prevent this problem a safety device has been implemented. In this paper, Arduino STM32 microcontroller is used to analyze the data from different sensors and take actions if any unwanted problem occurs. All the data will show in the display. The GSM module is used to communicate with the operator about the data. Another important part of this research paper is to protect expensive machines from any type of power issues. If voltage, current, and temperature rise beyond the limits, might be machines will be damaged even if it can cause a disaster.

To prevent the damage of expensive machines from power issues this automated system works as a protection device. The main aim of this paper is to detect the fault using various sensors to protect the machines from over voltage, over current, and over temperature as well as to cut off the power supply of the machine and send an SMS about the fault to the operator by using GSM module. Currently, there are several aspects that make mobile phones appear inseparable from human existence. With this benefit, the detection may be communicated by SMS on mobile phones. The addition of a detecting buzzing alert can make workers more aware of the defect and aid to notify others if everyone is not present at the workstation (C. Adrian and M. Galina, 2019).

2. Literature Review

The protection system was used at the end of the 19th century. The fusible link is used to protect the machines. These fuses were made out of lead, silver, and tin. When voltage or current increases the fuses trip and the circuit is open. Fuses could be used for one time. It should be changed manually after any fault. This was the main disadvantage. For this disadvantage, a circuit breaker was introduced. In the 1900, circuit breaker was oil-filled with a stored-energy spring mechanism. The circuit breaker has the advantage of being used many times. At that time, circuit breakers were a little heavier and bigger. A circuit breaker (CB) interrupts the input currents in the case of overload in the system.

The relay was invented in 1920. This relay could easily determine thermal overload and the trip-down down the machines. Fuse relays protect the input side against overcurrent and thermal ones protect the electrical machine against overheating. A protective relay is the device, which gives instruction to disconnect a faulty part in the system (Mohamed Rashad, Amer Nasr A. Elghaffar, 2024). Protection relays are the most important aspect of power system protection, facilitating the isolation of faulty sections of the electrical system (Eltamaly A, Amer Nasr A. Elghaffar, et al. 2021).

Relays compare the electrical variables of networks (such as current, voltage, frequency, power, and impedance) with predetermined values (Christophe Prévé, 2006, Ali Eltamaly, Amer Nasr A. Elghaffar, et al. 2019). When the monitored value reaches the threshold, after that the relay sends a tripping command to the circuit breaker when an abnormal scenario has been identified (Ali M. Eltamaly, Amer Nasr A. Elghaffar, et al. 2019, Ali M. Eltamaly and Amer Nasr A. Elghaffar, June 2017).

Different protective relay types such as distance relays, differential relays, overcurrent relays, etc. are available. There are two options on the relay: plug and time. While the plug setting is determined by the amount of current needed to pick up for the relay, the time setting determines when the relay operates (S. A. Shaikh, K. Kumar, A. R. Solangi, S. Kumar and A. A. Soomro, 2018). Currently, microprocessor-based digital and numeric relays are substituting conventional relays across every aspect of power system protection (Z. Q. Bo, X. N. Lin, et al. 2016).

Different types of protections are combined in modern protection systems, but it has taken years of development and research. The earlier protection module works mechanically. Numerous research papers have suggested methods for fault detection that reduces the period of time between the fault occurrence and the fault diagnosis (R. L. de Araujo Ribeiro, C. B. Jacobina, E. R. C. da Silva and A. M. N. Lima, 2003). Now, microcontroller-based protection system is induced. From the modern protection system, we can know what fault occurs and the current reading of the main power supply.

3. Control and Protection System

In new era, equipment protection has become one of the most important aspects of the industry. Without a protection system, industries cannot operate their machines effectively. Sometimes accidents occur in a variety of ways.

3.1. Over Voltage

Overvoltage is a common cause of damage to machines. Every machine operates within a voltage range. When a problem occurs in line voltage, the voltage rises above the range. As a result, overvoltage causes damage to machines. Voltage surges, or spikes, are the inverse of dips, an increase that might be practically immediate (spike) or last longer (surge). A voltage surge occurs when the voltage is 110% or higher than usual. The current invention pertains to variable voltage protection devices used to safeguard electronic devices against over-voltage transients generated by lightning, electromagnetic pulses, electrostatic discharges, ground loop-induced transients, or inductive power surges (Gerald R. Behling, San Jose; James B. Intrater, Santa Clara., 2002). When the circuit gets an overvoltage spike, the variable voltage material rapidly transitions to a low electrical resistance state, shorting the overvoltage to the ground. After the overvoltage has passed, the material instantly returns to its natural condition. In the majority of industrial applications, the machine is powered by a voltage-source inverter. These AC drive systems are sensitive to any voltage failure. When faults arise, the machine should be turned off. Five basic types of loads are used to represent equipment with varied load characteristics: resistive, capacitive, and inductive loads, resistive and capacitive paralleling loads, and resistive and inductive serial loads (J. He, Z. Yuan, S. Wang, J. Hu, S. Chen and R. Zeng, 2010).

Overvoltage and undervoltage can cause harm to the equipment. Each component of the equipment has a minimum and maximum voltage rating. In Bangladesh, the voltage ranges between 220 and 230 volts. In this system, the voltage limit is set at 210 volts to 240 volts. If the supply voltage rises due to a defect in the supply line and exceeds the limit Arduino detects, the machine will shut down promptly and send an SMS to the operator. The innovation provides an arrangement that protects sensitive electrical equipment. For example, voltage transients can affect integrated circuits. A protective feature, such as a voltage regulator or voltage sensor, has been implemented to prevent overvoltage damage to the machine. The feature sends a signal to the microcontroller, causing the power supply to shut down due to an excessively high voltage. Surge suppressors, voltage regulators, uninterruptible power supplies, and power conditioners are all potential solutions. Since, each machine has a voltage rating, and very heavy equipment has overvoltage protection. The machine

can work at a few voltages above the range. This suggested protective device can restrict the output voltage. The limit can be set based on the machine's rated voltage. This device can turn off the supply voltage if the line voltage exceeds a certain level. This device functions automatically and will turn on after the error is solved.

3.2. Over Current

The three main components of the electrical power system are distribution, transmission, and generation. A report has been created that shows that 80% of interruptions are observed on the consumer side due to the failure of the distribution system. A fault is an unwanted and unexpected state that stresses the network and increases expenses because of equipment breakdown. Blocking the excessive current flow is a must before harming any equipment.

Overcurrent is also the main issue for damaging machines. Overcurrent can occur for many reasons. If machines get overloaded, then they will drown out more current, which raises the current. When any short circuit happens internally, the line current rises significantly, which is the cause of overcurrent. There are many different kinds of defects, such as symmetrical and unsymmetrical faults.

Three-phase or symmetrical faults are the most serious type of failures that cause the most disruption in network accessories (Myeon-Song Choi, Seung-Jae Lee, Duck-Su Lee and Bo-Gun Jin, 2004). An overcurrent fault causes an extremely high current flow, which needs to be stopped before it harms any network segments. Protective relays and circuit breakers are essential components of the protection system design. Precise fault information is required not only for prototypes or algorithms for identifying faults, but also for the appropriate functioning of protective relays and the accurate correction of various fault kinds.

Every machine has its own current rating. Machines can do the work efficiently with proper and stable current. Overcurrent is very dangerous for machines. This proposed protection device can maintain a limit on output current. The limit can be set according to the machine's current rating. For any fault or short circuit to occur in the line, this device can cut off the power supply when the current gets beyond the limit. The impact of a failure on the system's performance decreases with speed of detection. It is also preferable to minimize the number of extra sensors as employing a significant number of additional sensors for fault detection would raise costs and decrease system dependability. This device is a prototype, so its current range is between 1-2 amps. For any fault, overload, or short circuit, the current will increase. In this situation, when Arduino measures the data and it gets a current reading over the range, it will turn off the load, the operator will be notified by SMS via the GSM module, and it will automatically power on when the fault disappears.

3.3. Over Temperature

Maintaining temperature is our big concern for machines safety. Temperature can rise due to over load or any internal mechanical damage, like bearing or moving parts. Those are reasons for rise the temp and machines get over heated. The main reason causing the motor to burn are current mode failure, a lack of phase, current imbalance, short circuits, leakage, and overcurrent (L. Q. Cartagena, S. E. Barbin and W. J. Salcedo, 2018). Extended over-loading of the motor temperature rise will surpass the permissible value, perhaps resulting in the premature aging of the insulation. When a bipolar power transistor overheats and experiences thermal instability, or runaway, the device malfunctions destructively. In addition, overheating shortens the product's lifespan. The lifespan and efficiency of the gadget will be extended by implementing over-temperature protection. As well as, Fuzzy logic control has demonstrated more efficiency in temperature response management compared to PI control in simulations for a plastic extrusion facility (Ravi S and Balakrishnan P A, 2010). To mitigate signal distortion in monitoring and control, the implementation of intelligent controllers, such as microcontrollers, is advisable (Ravi S, Rajpriya G and Kumarakrishnan, 2015).
Machines work efficiently in optimal temperature. Overheating will damage the machines. Machine can get over heated from over load. An integrated temperature detector is used to monitor the temperature. This protection device can measure the temperature and it can set a limit. Once a certain threshold level is exceeded, the output power is limited (G. Liao and J. Xi, 2011). temperature sensor will continuously measure the temperature. When any internal or mechanical problem occur, the temperature will rise and Excess heat can damage the device so there is a limit set on Arduino, which is 400 °C. when the temperature crosses the limit, the device will cut off the power supply. when it returns on normal, it will turn on the device automatically.

4. Working Principle

This system works are based on Arduino STM32 microcontroller. In this system voltage regulators, current sensors, and temperature sensors are used to detect current data. These sensors are getting actual readings continuously and sending the data to the Arduino. Arduino is programmed to check the data from the sensor and analyze the data. The data from the sensor will be shown on LCD. Arduino has been programmed with a range of data. If data from the sensor gets beyond the limit, the Arduino will send the signal to the relay, which will cut off the power supply of the machine. Then Arduino will send a signal with fault data to the GSM module. It will send a text message to the operator or maintenance department. Arduino will take

data continuously from the sensor so that when the fault is removed, Arduino analyzes the data from the sensor and will again send the signal to relay, which turns on the machines.

5. Block Diagram and Simulation

5.1. Block Diagram of Proposed System

Fig. 1. Shows the block diagram of the proposed system. Arduino STM32 was used as a microcontroller to control the whole system.

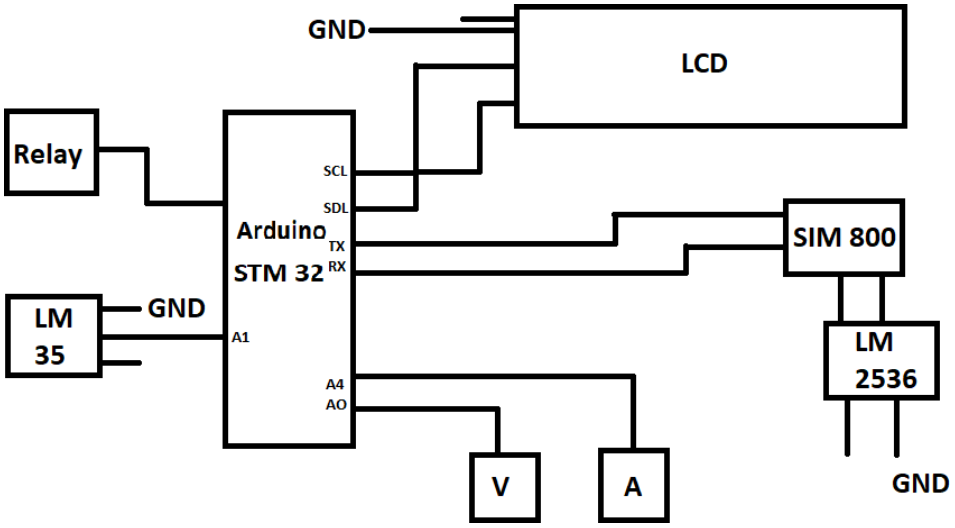


Fig. 1. Block diagram of the proposed system

5.2. Simulation

This project consists of electrical and electronic components. Proteus 8.1 professional software was used for the simulation. Fig. 2. shows the representing the main simulation of the system.

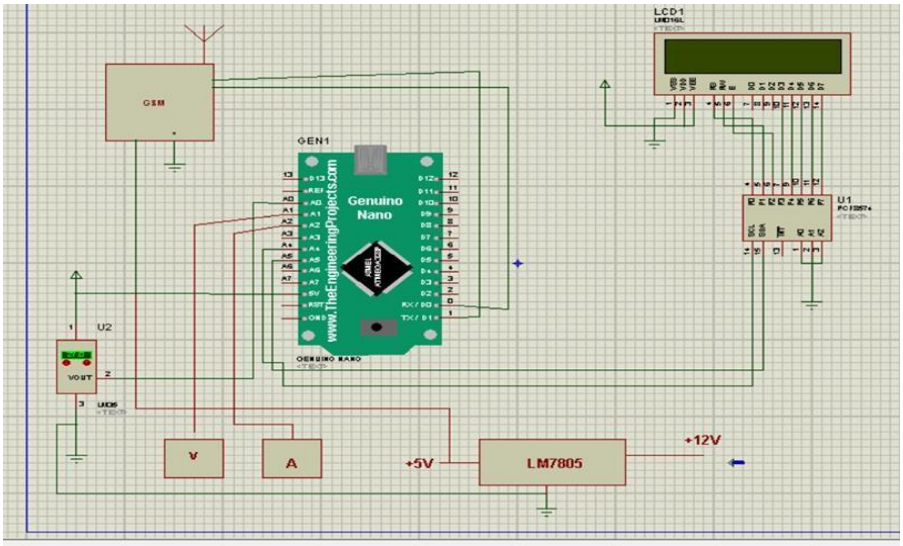


Fig. 2. Simulation of Protection System Proteus 8.1 Professional Software

6. Hardware Implementation and Results

A printed circuit board (PCB) was used to set the full system. On the other hand, A complete instruction of programming language needed to be saved to the microcontroller IC to get the function we want it to. The electronic components of the system were implemented in the printed circuit board (PCB). Fig. 3. Shows the main circuit board of the system.

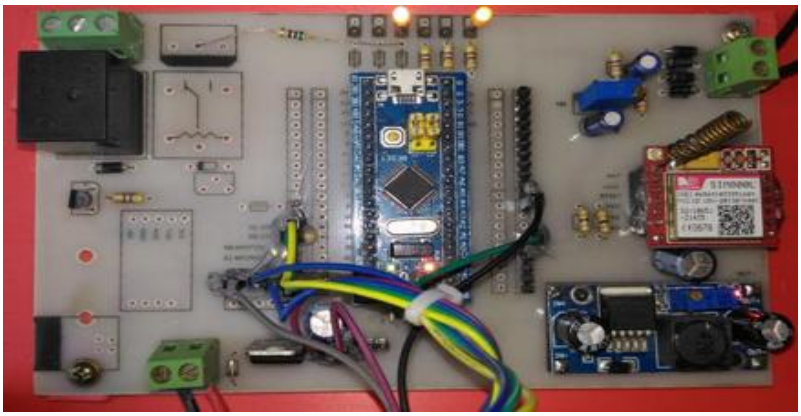


Fig. 3. Main Circuit Board

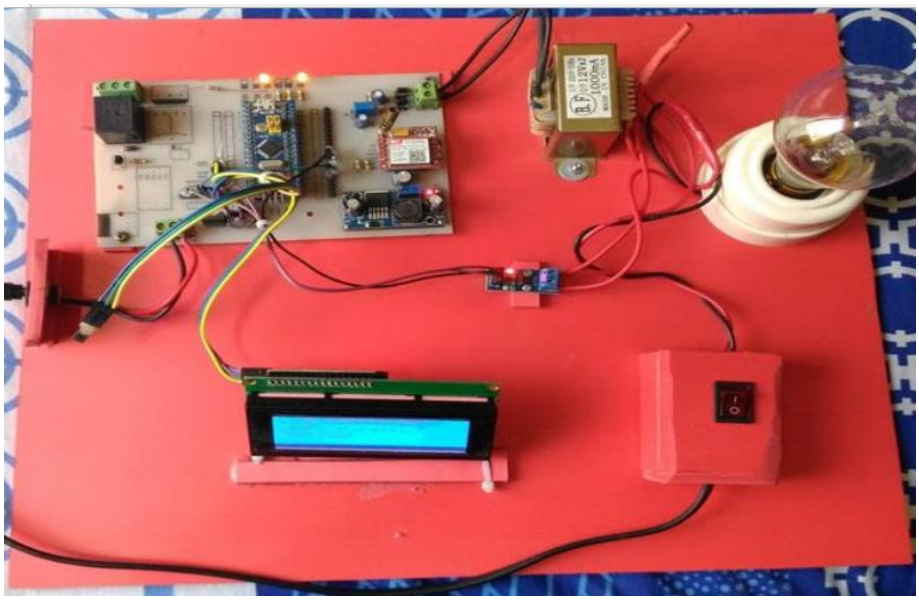


Fig. 4. Hardware Implementation

The whole process of hardware implementation has been described in the segment. Fig. 4. Shows the hardware implementation of the whole system has been given. For hardware implementation here used Arduino STM32, GSM module, voltage regulator, temperature sensor, current sensor, LCD display, transformer, relay, and many other components. Power adapter used to run Arduino and other module. All the component is mounted in a hardboard. Which mainly focuses on representing the whole prototype of the system.

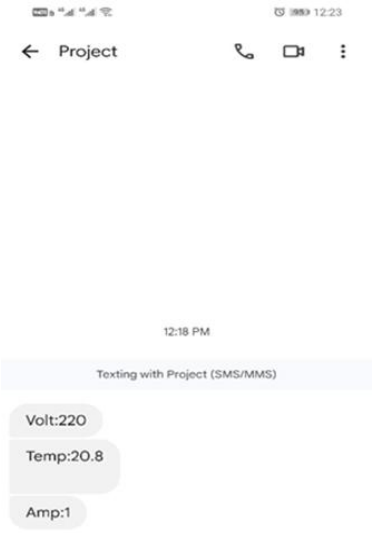


Fig. 5. Display reading **Fig. 6. SMS notification**

Fig. 5. Shows the display reading of the system. Here, a 220-volt AC supply is used to power the main load. A halogen bulb is used to show the current parameter and Fig. 6. SMS notification of the system.

The full system was done by multiple types of operation. Firstly, simulations were done by proteus 8.1 professional software and PCB design was done by express PCB software. On the other hand, the main hardware was implemented with various sensors and electrical components.

7. Conclusion

The main goal of this paper was to reduce the damage to machines or expensive loads from any fault in main power sources. This system works on an Arduino STM32 microcontroller. The most important part of this paper was to read the data from sensors and take immediate action by tripping the relay. Arduino analyzes the data from the voltage regulator, current sensor, and temperature sensor and shows the data in the LED display continuously. Arduino is programmed with code where a limit has been set. If any fault occurs and data from the sensor goes over the limit, the microcontroller will send the signal to trip the relay and send an SMS to the operator about the fault via the GSM module. Arduino will again send a signal to turn the relay on automatically when the fault is removed. The full system has been implemented

with many electrical components. Arduino was used as the brain of the system for getting data from sensors and analyzing the data. The system has been implemented successfully. By implementing this protection system, we can reduce the percentage of damage of expensive machines as well as industrial safety and assets.

References

R. Ramaswami and P. F. McGuire, (Jul. 1992) "Integrated coordination and short circuit analysis for system protection," IEEE Trans. Power Del., vol. 7, no. 3, pp. 1112–1120.

R. E. Brown, (Jul. 2008) "Impact of smart grid on distribution system design," in Proc. IEEE Power Energy Soc. Gen. Meeting, pp. 1–4.

M.-S. Choi, S.-J. Lee, D.-S. Lee, and B.-G. Jin, (Jan. 2004) "A new fault location algorithm using direct circuit analysis for distribution systems," IEEE Trans. Power Del., vol. 19, no. 1, pp. 35–41.

B. Das, (Jan. 2006) "Fuzzy logic-based fault-type identification in unbalanced radial power distribution system," IEEE Trans. Power Del., vol. 21, no. 1, pp.278–285.

Sukumar Ponnusamy, Ravi Samikannu, B A Tlhabologo, W Ullah and Srinivasan Murugesan (2020) "Design and development of microcontroller-based temperature monitoring and control system for power plant generators," IOP Conf. Ser.: Mater. Sci. Eng. 1055 012158.

Chandra Adrian and Mia Galina (June 2019) "Design and Implementation of Electricity Fault Detection System Using Microcontroller Arduino UNO," Journal of Electrical and Electronics Engineering Vol. 3, No. 1, pp.76-81.

Mohamed Rashad, Amer Nasr A. Elghaffar, (January 2024) "Electrical Protection And Control System Development Steps, An Overview" Acta Technica Corviniensis Bulletin Of Engineering," E–ISSN: 2067 – 3809.

Eltamaly A, Amer Nasr A. Elghaffar, et al. (eBook 2021) "AC Microgrid Protection Coordination" Chapter (8)," Wiley Book (Microgrid Technologies).

Ali M. Eltamaly, Amer Nasr A. Elghaffar, et al. (2019) "HVDC over HVAC Transmission System: Fault Conditions Stability Study, International Journal of Research Studies in Electrical and Electronics Engineering," pp 24–37.

Christophe Prévé. (2006) "Protection of Electrical Networks. E–book, British Library Cataloguing–in–Publication Data."

Ali Eltamaly, Amer Nasr A. Elghaffar, et al. (2019) "Advanced Control Techniques for Enhancing the Power System Stability at OOS Condition," Insight – Energy Science, Volume 2 Issue 1.

Ali M. Eltamaly and Amer Nasr A. Elghaffar. (June 2017) “Load Flow Analysis by Gauss–Seidel Method” A Survey, International Journal of Mechatronics, Electrical and Computer Technology (IJMEC).

S. A. Shaikh, K. Kumar, A. R. Solangi, S. Kumar and A. A. Soomro, (2018) “Short Circuit Analysis & Over current Relaying Coordination of IEEE 9-Bus System,” 2018 5th International Multi-Topic ICT Conference (IMTIC), Jamshoro, Pakistan, pp. 1-6.

Z. Q. Bo, X. N. Lin, et al. (2016) “Developments of power system protection and control. Protection and Control of Modern Power Systems,” Journal, 1:7

R. L. de Araujo Ribeiro, C. B. Jacobina, E. R. C. da Silva and A. M. N. Lima, (March 2003) “Fault detection of open-switch damage in voltage-fed PWM motor drive systems,” in IEEE Transactions on Power Electronics, vol. 18, no. 2, pp. 587-593.

Gerald R. Behling, San Jose; James B. Intrater, Santa Clara. (Apr. 16, 2002) “Over-Voltage Protection For Electronic Circuits,” Us 6,373,719 B1.

J. He, Z. Yuan, S. Wang, J. Hu, S. Chen and R. Zeng, (Jan. 2010) "Effective Protection Distances of Low-Voltage SPD With Different Voltage Protection Levels,” in IEEE Transactions on Power Delivery, vol. 25, no. 1, pp. 187-195.

Myeon-Song Choi, Seung-Jae Lee, Duck-Su Lee and Bo-Gun Jin, (Jan. 2004) “A new fault location algorithm using direct circuit analysis for distribution systems,” in IEEE Transactions on Power Delivery, vol. 19, no. 1, pp. 35-41.

L. Q. Cartagena, S. E. Barbin and W. J. Salcedo, (2018) “A New Sensor for Temperature Self-Protection of Integrated Circuits in CMOS Technology," 2018 IEEE MTT-S Latin America Microwave Conference,” (LAMC 2018), Arequipa, Peru, pp. 1-4.

Ravi S and Balakrishnan P A (2010) “Temperature response control of plastic extrusion plant using Matlab/Simulink,” Int. J. of Recent Trends in Eng. and Techol 3-4, pp 135-40.

Ravi S, Rajpriya G and Kumarakrishnan V (2015) “Design and development of microcontroller based selective harmonic elimination technique for three phase voltage source inverter,” Int. J. of Applied Eng. Research 10 13 pp 11562-78.

G. Liao and J. Xi, (2010) “Intelligent Monitoring and Overheating Protection System for Motor,” International Conference on Computing, Control and Industrial Engineering, Wuhan, China, pp. 308-311.

Exploring the Integration of Stream of Consciousness in the Writing Skill of the ELT Classrooms of Bangladesh at the Tertiary Level

A. K. M. Manzurul Islam[1], A. K. Zunayet Ahammed[2], Kanika Chakraborty[3]
[1]Assistant Professor, Department of English, R. P. Shaha University, Bangladesh
[2]Dean and Associate Professor of English, School of Arts and Social Sciences, R. P. Shaha University
[3]Lecturer, Department of English, R. P. Shaha University, Bangladesh
Corresponding author: A. K. Zunayet Ahammed, zunayet1972@gmail.com

ARTICLE INFO

Keywords: Bangladesh, ELT, stream of consciousness, tertiary level, writing

RECEIVED
10 March, 2025

ACCEPTED
20 June, 2025

PUBLISHED
31 August, 2025

DOI
https://doi.org/10.5281/zenodo.17241252

ABSTRACT
This paper investigates the incorporation, current approach, implications, challenges, and possible techniques for using stream of consciousness writing at the tertiary levels of the ELT classrooms in Bangladesh. The traditional style of writing or the strict narrative writing techniques, while structured, often constrict the development of students' creative writing skills. In contrast, Stream of consciousness writing skill offers an innovative alternative, enabling students to express and practice their creative writing potentials more freely and intensively. Adopting a stream of consciousness and thereby enjoying writing without following any strict narrative style will be a revolutionary approach to teaching writing at the tertiary levels of the Bangladeshi ELT classrooms. This article also identifies the possible challenges of incorporating stream of consciousness into writing skills and their effective recommendations. The authors applied mixed methods to this research and from various surveys investigated several techniques and examples of the current practice of incorporating stream of consciousness in the writing skill of ELT classrooms of Bangladesh at the tertiary level and their limitations.

Moreover, the research proceeds with a contrastive analysis between traditional creative writing techniques and the revolutionary stream of consciousness writing style. This vividly depicts the effectiveness of incorporating “stream of consciousness” into writing. This research serves as a valuable resource for educators and researchers, offering insights into the application of stream of consciousness writing in ELT and paves the way for further exploration in this field.

1. Introduction

The concept of "stream of consciousness," first introduced by philosopher William James in *The Principles of Psychology* (1890), refers to the continuous flow of inner dialogue and thought during conscious experience. This innovative idea later found creative expression in the literary works of Virginia Woolf and James Joyce, who adopted it as a distinct narrative style, characterized by the unstructured and free-flowing representation of thoughts. This unstructured technique, often exemplified in memoirs, captures the raw, unfiltered nature of introspection, allowing writers to explore their innermost thoughts and emotions authentically. This article examines the potential of stream of consciousness writing in English Language Teaching (ELT) classrooms of Bangladesh at the tertiary levels focusing on current practices, challenges, and strategies for effective implementation. By fostering creativity and originality, this approach empowers students to express thoughts, emotions, and fears freely, enabling them to construct unique plots and narratives. Unlike traditional free writing, it prioritizes the seamless transformation of thoughts into language, minimizing interruptions and self-censorship. As students adopt this technique, they often overcome writing apprehensions, achieving fluency and sophistication in their expressions. The study explores the pedagogical benefits of stream of consciousness writing, presenting it as a transformative tool that nurtures linguistic and cognitive abilities while boosting confidence and creative self-expression. Ultimately, this approach offers a natural, engaging way to enhance writing skills, motivating students to transcend traditional techniques and explore the full potential of their inner worlds.

2. Literature Review

The integration of literary techniques such as the stream of consciousness in English Language Teaching (ELT) classrooms is a new and emerging area of exploration in Bangladesh, particularly in developing writing skills at the tertiary level. Despite the limited research in this field, the approach has demonstrated significant potential in enhancing language proficiency. Shahidullah (1991) highlights the effectiveness of utilizing literary works to develop English skills, as reflected in his lesson plans and activities designed for Foundation Course (FC) language students, including the use

of William Shakespeare's poem "Crabbed Age and Youth" (Nusrat, 2015). His findings illustrate the value of literature as a resource for fostering language use, although his approach lacks structured tools or frameworks to help learners critically analyze elements such as form, content, themes, and techniques. Addressing this gap, this paper examines the theoretical underpinnings and pedagogical implications of using the stream of consciousness as a literary device in ELT, discussing its relevance and potential to enrich language instruction in the Bangladeshi context.

2.1 The Stream of Consciousness as a Literary Technique

Authors like James Joyce, Virginia Woolf, and William Faulkner famously employed the stream of consciousness technique in their works to portray the inner activities of the human mind in its raw and unfiltered state. Cohn (1978) in her *Transparent Minds* explores its narrative potential for replicating thought processes, emphasizing its fragmented, nonlinear structure. Richardson (2006) highlights that the technique furthers a deeper engagement with introspection, creativity, and the representation of subjective reality.

2.2 Writing Skill Development in ELT Classrooms

In ELT classrooms, writing is both a linguistic and cognitive activity that necessitates creativity, structure, and fluency. Hyland (2003) points out that effective writing instructions should have a balance process allowing learners to express their voice while mastering conventions. Additionally, Ferris and Hedgcock (2014) emphasize the role of task-based writing activities in engaging learners and developing advanced language proficiency. However, Alam (2007) in his long literature review of ELT, critiques the Western ELT experts' readymade formula for EFL/ESL learners to justify the usefulness of using literature 'their way' (from the Western perspective) and their constant changing of teaching methods, e.g. from Grammar-Translation method (which proved effective during our pre-liberation period) to the present day CLT approach (now a catch word in language teaching). Although he mainly speaks for secondary and higher secondary levels, he does not specifically mention teaching approach of tertiary level. His paper points toward a very important issue of using South Asian Literature in English or Translations which are more relevant to our students' experience. Traditional approaches of teaching writing often focus on accuracy over creativity in Bangladesh. It is high time to integrate creative elements to inspire learners. The integration of the stream of consciousness technique could provide learners with a means to explore personal expression while developing critical linguistic and cognitive skills.

Dimililer and Kurt (2019) in their research found collaborative writing as a more pleasant experience. They also discovered that students made good progress in terms of writing skills as well as their attitudes toward writing developed and changed in a positive way.

2.3 Relevance of Stream of Consciousness in ELT

Literature is considered a motivating material in many cultures across the globe. Bangladeshi students are also aware of this fact. From there school days they have been encouraged to read literature from their teachers in most cases. Since most Bangladeshi students have studied literature to improve language in schools and colleges in their mother tongue, they will find studying literature in English interesting and thought provoking. Introducing literature in classroom would not be difficult although many students may not have interest in this. However, like Chomsky's notion of 'grammatical competence' Culler has argued of learners' implicit quality of 'literary competence' (Lazar, 2005). Therefore, literature should be considered a valuable and stimulating material for our students, especially for writing. Widdowson (1986) states that literature is a good source for developing students' abilities to infer meaning and make interpretations because literary texts are rich in meaning that demand learners' active involvement in understanding the implied meaning. There is no 'wrong' or 'right' answer in literature; so, it encourages learners to write their own perspective. Maley and Peachey (2015) argue that creative writing activities help students experiment with language and enhance their confidence. The stream of consciousness can be a potential pedagogical tool as it deals with psychology as well. Utilizing the stream of consciousness allows students to focus on fluency and the free flow of ideas without the immediate focus of grammatical accuracy which serves the basic need of writing at tertiary level. This aligns with Krashen's (1985) Input Hypothesis, which stresses the importance of lowering affective filters to foster language acquisition.

2.4 Research Gaps

The integration of stream of consciousness techniques in ELT classrooms holds significant scopes, there is a lack in addressing its impact on writing skills in Bangladeshi tertiary-level classrooms. Future research could explore practical implementation strategies, teacher training modules, and the long-term effects of such interventions on learners' linguistic and cognitive development. By bridging the gap between literary techniques and language pedagogy, educators in Bangladesh can enrich the writing classroom with innovative approaches that align with global trends while addressing local challenges. This paper focuses on these facts.

3. Objective of the study

The objectives of this article are introducing and incorporating "stream of consciousness" at the tertiary levels of the Bangladeshi ELT classrooms, showing the current approach and practice of stream of consciousness writing through surveys, figuring out the possible challenges and how to face these, highlighting the priority of stream of consciousness writing over the traditional narrative style and the benefits and last but not the least identifying some possible techniques for stream of consciousness writing.

4. Methodology

Both qualitative and quantitative data have been utilized for the effective accomplishment of this research paper. Primary data has been gathered from interviews with teachers or faculty members and students of the tertiary level from different universities of Bangladesh. Twenty faculties and forty students from different public and private universities of Bangladesh participated in the online interviews. Quantitative as well as qualitative questionnaire has been used for the interviews which are shown in the appendix. Secondary data has been gathered from various publications, books and research articles.

5. Pedagogical Implications and Feasibility of Stream of Consciousness writing

Stream of consciousness demands active involvement in thinking process which is necessary for developing writing skills. Research on process-based writing instructions support the practicality of using stream of consciousness techniques into writing tasks. For example, brainstorming activities, freewriting, and reflective writing go well with this literary approach. Hedge (2005) suggests that such activities enable students to experiment with language in a low-stakes environment, thereby promoting fluency and creativity. Moreover, it can encourage students to adapt different proficiency levels. At an advanced level, students could analyze excerpts from literary texts. For lower proficiency levels, simpler topics or descriptive narratives may be more appropriate.

6. Challenges in the Bangladeshi Context

In literary texts, we can find a large range of authentic use of language, style and registers. A common argument against using literature in the language classroom is, literature uses deviant language, and the question is whether to use or not to use literature for language teaching. Nevertheless, the potential of using literature in language class is unlimited. Literature in language has immense possibilities to teach various kinds of language, as the language of literature breaks the usual rules of syntax, collocation and cohesion. However, limited resources, large classroom, exam-oriented instructions are the primary barrier to make successful any new approach in Bangladesh. The tertiary-level ELT classrooms in Bangladesh are often marked by large class sizes, limited resources, and a focus on exam-oriented instruction (Hamid & Baldauf, 2008). These factors challenge to the implementation of innovative methods such as the stream of consciousness. Additionally, teachers may lack training in integrating creative writing techniques into their pedagogy, as noted by Kabir (2019). However, studies like Alam (2020) suggest that Bangladeshi students show high levels of engagement and motivation when exposed to creative and contextually relevant materials. The integration of the stream of consciousness could, therefore, offer a way to make writing tasks more engaging while promoting critical thinking and self-perception in writing.

Incorporating stream of consciousness writing into the curriculum can be beneficial for improving overall English writing skills, but its effectiveness depends on the learning objectives and how it is integrated. It can be challenging for Beginners as some students will be still mastering basic grammar and vocabulary, stream-of-consciousness writing may feel overwhelming or confusing.

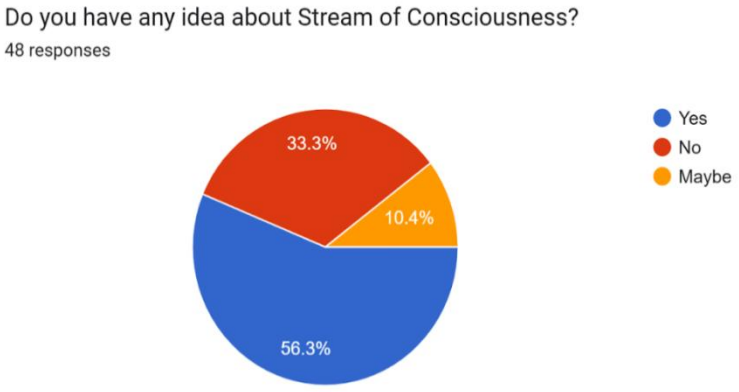
There might be some risks of overusing this technique. If overemphasized, this style might lead to a lack of focus on essential writing skills like argument development, organization, syntactic accuracy and clarity. The challenge of SOC writing is that students may find it critical to follow. Students may struggle to connect their thoughts with a coherent argument or story. Teachers should guide them to revise and structure the drafts after they finish their writing. In our culture, there is less focus on personal expression in writing. Teachers can create a safe space where students feel relaxed to engage themselves in more introspective or spontaneous writing. SOC writing in ELT arises spontaneity, fluency, and creativity. Incorporating SOC writing into lessons can help students get out of rigid writing structures and inspire them to write in more organic and expressive way.

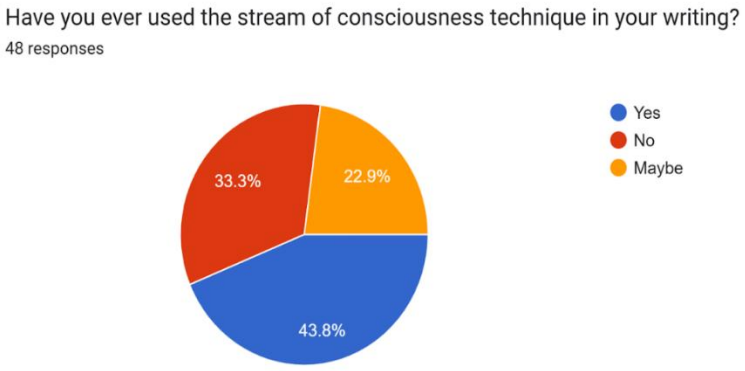
7. Data Collection, Analysis and Findings

Students and teachers/faculty members from different public and private universities of Bangladesh responded to the online questionnaire used for this research paper. The responses of the students and teachers/faculty members to the quantitative and qualitative questionnaire are shown below (The questionnaire is shown in the appendix):

7.1 Students' Responses to the Quantitative Questionnaire:

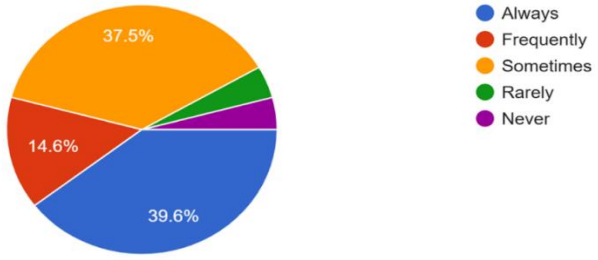
50 students from different public and private universities of Bangladesh participated in the online interview and their quantitative responses based on the quantitative questionnaire are shown below:





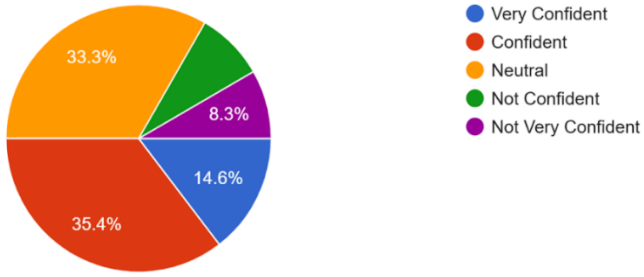
How often are you encouraged to write creatively in your ELT classroom?

48 responses



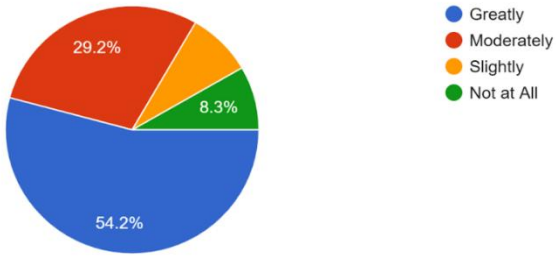
Rate your confidence in creative writing using unconventional styles (e.g., stream of consciousness):

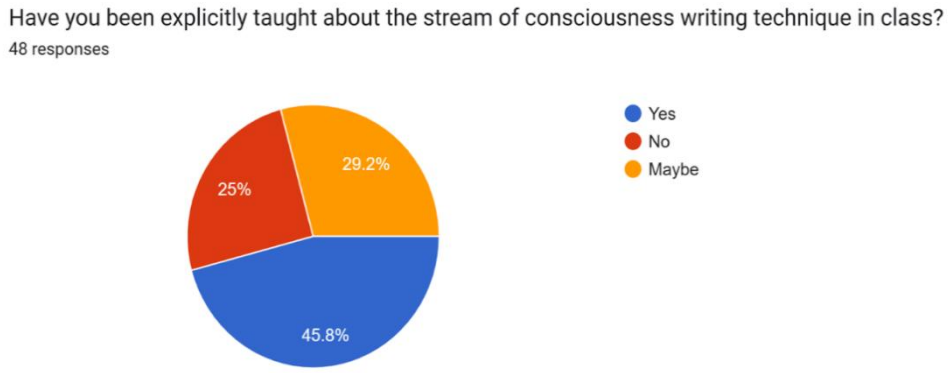
48 responses



To what extent do you think integrating stream of consciousness enhances writing skills?

48 responses





From the above pie charts it is evident that 56.3% students have ideas about SOC writing, 33% do not have any idea of SOC writing and 10.4% are in confusion. Besides, 43.8% students have used SOC writing technique, 33.3% students have not yet used SOC writing technique, and 22.9% students are confused. 14.6% and 39.6% students have been frequently and always encouraged respectively in creative writing whereas 37.5% are sometimes encouraged. In addition, 14.6% students are very confident, 35.4% are confident, 33.3% are neutral and 8.3% are not very confident in case of SOC writing. 54.2% students think SOC writing greatly enhances writing skills, 29.2% think it moderately enhances writing skills and 8.3% think SOC writing does not enhance writing skills at all. Moreover, 45.8% students opine that they have been taught about SOC writing technique in the class, 29.2% are confused and 25% students have opined that they have never been taught about SOC writing technique in the classroom.

7.2 Students' Responses to the Qualitative Questionnaire:

The qualitative responses of fifty students from different public and private universities of Bangladesh have been filtered out based on relevance, logic and effectiveness. The qualitative responses are filtered and organized based on the qualitative questionnaire which are shown below by category.

Incorporating stream of consciousness writing in the curriculum

SOC writing encourages creativity, self-expression, and fluency in writing. It is an effective way to intrigue learners to write freely exploring their feelings, emotions and thoughts. Incorporating stream of consciousness writing can improve English writing skills as it encourages creativity, enhances fluency and develops a deeper connection with language. It allows writers to freely express thoughts, fostering

originality and a personal style. However, it sometimes lacks syntactic clarification which may not suit all learners.

Incorporating stream of consciousness writing can enhance self-expression helping students overcome writer's block and develop their unique inner voice. However, it may lack potentially hindering grammar and proper organizational skills. It works best when it is balanced with more formal writing practices. It will boost up the confidence level to express the inner thoughts of the writers in their own ways. Initially, it may not seem so fruitful but as the learners are writing whatever is on their minds; their brain is forced to look for words and concepts they haven't explored previously. If the practice continues regularly, the progress will be visible in 5-6 months easily.

Stream of consciousness writing can significantly improve English writing skills. This technique encourages free-flowing thoughts, helping students express their ideas more naturally and creatively. It also improves critical thinking and narrative development, which are essential for effective writing. However, guidance is necessary to ensure students can structure their thoughts appropriately when needed. Stream of consciousness writing allows writers to witness the intricacies and complexities of the mind. It helps to capture a character's thought in a realistic way. It is an overall monologue or more than that.

SOC writing helps to improve students' ability to articulate abstract ideas. This technique also enhances their comfort with using language unconventionally, which is valuable for both creative and academic writing. It removes the mental block or tension of grammatical accuracy. It enhances the writing speed of learners. It encourages free expression, and personal style of writing. Stream of consciousness lets students freely express their thoughts without stressing over structure, grammar, or formal rules. Stream of consciousness often involves the use of language in unconventional ways to replicate the complicated pathways that thoughts take as they unfold and move through the mind.

Students' personal experiences or examples of how creative writing has impacted their language learning journey

Creative writing has helped the students explore and use a wider range of vocabulary, making their language skills more versatile. For example, while writing short stories as assignments, they had to describe settings and emotions vividly, which improved their descriptive skills. This practice not only boosted their confidence in writing but also enhanced their speaking abilities by familiarizing them with varied sentence structures.

Creative writing improved their vocabulary and helped them articulate their thoughts better.

Some students were asked to compose a fictional (poem) that has impacted their language learning journey. During creative writing practice sessions and assignments, crafting short stories and poems improved the students' vocabulary and grammar as they experimented with new words and sentence structures. It also boosted their confidence in expressing ideas uniquely. This creative freedom made learning the language more engaging and enjoyable.

Creative writing helps language learners' experiment with new vocabulary and sentence structures in a relaxed setting, improving fluency. It encourages emotional engagement with the language, making it more memorable. Many learners gain confidence by using the language freely without fear of mistakes. This technique fosters the habit of writing without anyone else's help. Many learners improve language skills through creative writing. For example, writing short stories or informal or fictional letters helps students practice vocabulary, sentence structure, and tone in a fun, engaging way. It builds confidence and fluency naturally.

By writing short stories about daily life, students not only practiced using new vocabulary in context but also expanded their ability to describe emotions, surroundings, and situations. This process helped them connect abstract language concepts with real-life scenarios, using the language more effectively. Exploring metaphors, rhythm, and symbolism gave them a sense of ownership over the language. The freedom to play with words without the constraints of grammar rules in early drafts made the learning process more enjoyable and less intimidating.

Through collaboration in a language exchange group, members often used creative writing prompts to share stories or reflections. This led to meaningful discussions, where participants corrected each other's work and gained insight into cultural perspectives. Writing creatively fostered collaboration, a deeper understanding of the language, and the ability to communicate complex ideas.

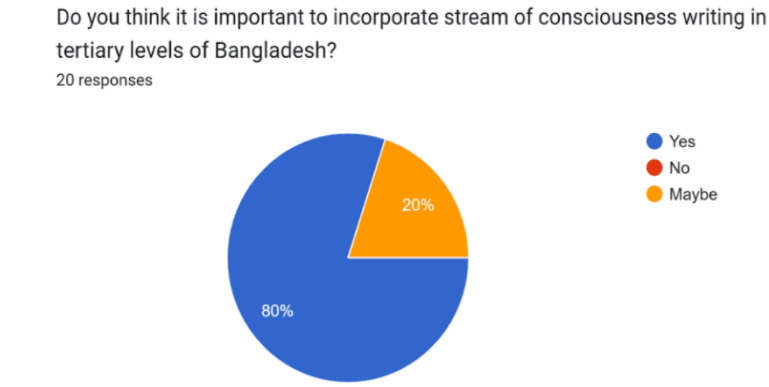
Some students in one semester as a team created a learning method called CFM (Creative Fusion Method) for an assignment. Some students struggled with English grammar and vocabulary. To improve, they were suggested by their teachers to keep a daily writing journal. At the beginning they felt nervous but soon they started writing poems and short stories on their own. As a result, after a few months they invented their essay writing improved much better than a year ago. Stream of consciousness writing allowed them to explore new vocabulary and experiment with sentence structures. For example, writing short stories helped them understand how to use descriptive language and dialogue effectively. It also made learning grammar more engaging, as they would apply rules naturally while crafting stories.

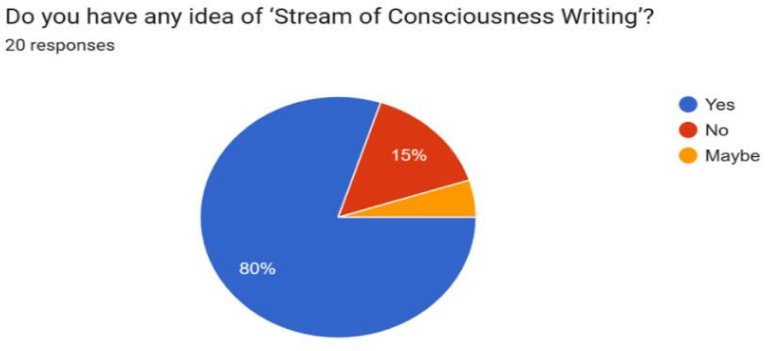
Additional support or resources needed to improve writing using the stream of consciousness technique

To improve writing using the stream of consciousness technique some students would need access to resources like examples from authors who excel in this style (e.g., Virginia Woolf, James Joyce). Workshops or guided exercises focusing on this technique would also help, along with constructive feedback from instructors or peers to refine their writing further.
Writing prompts, expert's feedback, and examples of notable stream-of-consciousness works. Students would benefit from guided exercises, examples from literary works, and feedback from experienced writers. Workshops focusing on fluidity and spontaneity could enhance their skills. Access to prompts and tools for organizing thoughts would also be beneficial.

7.3 Teachers Responses to the Quantitative Questionnaire:

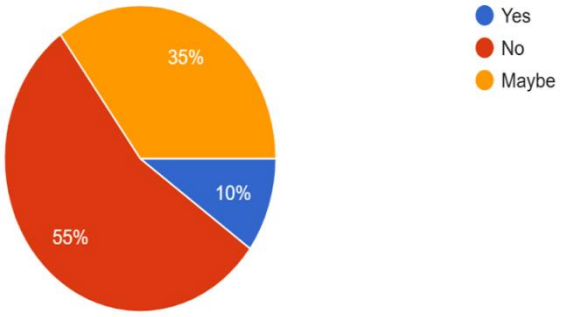
20 teachers from different public and private universities of Bangladesh participated in the online interview and their quantitative responses based on the quantitative questionnaire are shown below:





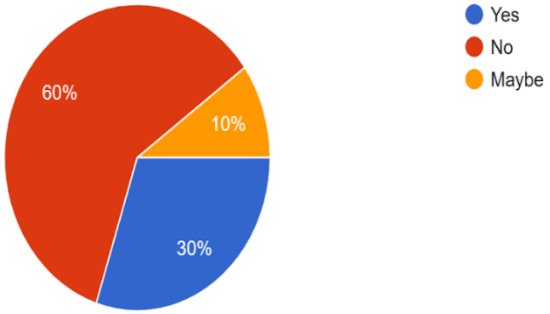
Do you think the traditional creative as well as free handwriting techniques applied to the Bangladeshi ELT classrooms at the tertiary levels are enough to develop the writing skills?

20 responses



Have you ever applied any technique of stream of consciousness writing in the ELT classrooms at the tertiary levels of Bangladesh?

20 responses



Analyzing the above pie charts prepared from teachers' quantitative responses to the quantitative questionnaire, it is evident that 80% teachers at the tertiary level have ideas about SOC writing whereas 15% teachers have no idea of SOC writing. 80% teachers think it is important to incorporate SOC writing in the ELT classrooms of Bangladesh at the tertiary level and 20% are confused. 10% teachers at the tertiary level of Bangladesh think that traditional creative and free writing techniques are enough to develop writing skills, 55% teachers think these are not enough to develop

writing skills and 35% teachers are confused. Last but not the least 30% teachers at the tertiary level of Bangladesh have already applied SOC writing in ELT classrooms, 60% teachers are yet to apply, and 10% teachers are still confused.

7.4 Teachers Responses to the Qualitative Questionnaire:

The qualitative responses of twenty teachers from different public and private universities of Bangladesh are filtered out and the most relevant, logical and effective responses are shown below based on the quantitative questionnaire which are categorized as headlines or points.

Possible and already applied techniques by the faculties at the tertiary level of Bangladesh for stream of consciousness writing in ELT

In the context of English Language Teaching (ELT) in Bangladesh, stream of consciousness (SOC) writing has gradually emerged as a creative and introspective method for enhancing students' writing fluency and self-expression. Teachers often begin such activities with brainstorming sessions, encouraging students to freely generate ideas before writing. This practice can take the form of mind mapping, where learners visually map their thoughts in a non-linear fashion, allowing for flexibility and association that align well with the principles of stream of consciousness writing. Some educators adopt a cognitive approach, focusing on the mental processes behind writing, thereby helping students to become more aware of their own thought patterns as they write.

Journaling is another key practice, where students are asked to maintain a daily or weekly stream-of-consciousness journal. These entries are often unstructured, allowing learners to reflect on personal experiences, random thoughts, or classroom themes. In doing so, students become more comfortable with expressing complex or abstract ideas in English. Techniques such as looping repetition and memory stream exercises encourage students to revisit and expand upon their ideas, fostering depth and continuity in their writing. For example, students might start a piece of writing, then go back and re-read it, picking out a particular word or sentence as the beginning of a new stream of thought.

Imaginative writing tasks also play an important role in promoting SOC in ELT. Students may be invited to envision themselves visiting a place like Saint Martin's Island and describe what they would do, see, or feel. These scenarios not only stimulate imagination but also encourage vivid, sensory-rich descriptions that mirror authentic internal monologues. Additionally, guided prompts help focus students' writing within an emotional or thematic boundary. Prompts like "Write about the last

time you felt truly at peace" or "Describe a place that makes you feel nostalgic" provide enough direction while still allowing mental wandering.

Teachers may also use dialogue with the self as a writing activity, in which students script conversations between their conscious and unconscious minds. This method offers a structured way to dive into self-reflection and is especially useful in exploring personal emotions or unresolved thoughts. Narrative essay practice, freewriting exercises, and internal monologue exploration are regularly incorporated into lessons to build fluency and confidence in using English for personal expression. Students are often encouraged to write continuously for a set time without worrying about grammar or coherence, capturing thoughts as they naturally unfold.

Reading and imitation of literary texts is another valuable tool. Exposure to writers like Virginia Woolf or James Joyce helps students understand how stream-of-consciousness techniques work in literary practice. After reading passages from *Mrs. Dalloway* or *Ulysses*, students are invited to mimic the unstructured flow and stylistic features in their own writing. This analytical and creative engagement with literature sharpens both comprehension and composition skills.

Visual and audio prompts further enrich the SOC writing experience. Teachers might use an image, a short video clip, or a piece of music to trigger emotional or sensory responses, allowing students to write freely in response. Peer-sharing sessions also play a critical role, as sharing personal writings in a supportive classroom environment boosts confidence, encourages collaborative learning, and helps learners appreciate diverse narrative voices.

Some classrooms in Bangladesh are experimenting with group-based SOC writing. In this setup, students collaborate in small groups to create a single stream-of-consciousness text. One student begins with a thought, and others add to it in sequence, either on paper or via a shared digital document. This real-time interaction fosters creativity, group dynamics, and collective expression.

With the increasing integration of technology in education, digital platforms like Google Docs or collaborative whiteboards are also being utilized for stream of consciousness writing. These tools allow students to write, edit, and comment in real time, maintaining the spontaneity and fluidity of the exercise while promoting interaction and immediate feedback. Such platforms not only modernize traditional writing practices but also cater to tech-savvy learners who feel more engaged in digital environments.

Ultimately, stream of consciousness writing in ELT classrooms across Bangladesh serves as a powerful tool to help students explore language in a deeply personal and organic way. By engaging in activities that range from journaling and narrative writing to imaginative exercises and literary imitation, students enhance their ability to express complex thoughts and emotions, all while developing their fluency and confidence in English.

7.5 Benefits of incorporating stream of consciousness into the writing skills of ELT classrooms

Incorporating stream of consciousness into ELT classrooms brings numerous benefits to students' writing development. It leads to better fluency, enhanced thinking capability, and more effective cognitive functioning. This approach enhances creativity and self-expression, helping learners articulate their inner thoughts more freely. It develops fluency and writing confidence by allowing students to write without fear of making mistakes, and encourages reflective and critical thinking through personal exploration. Narrative and descriptive skills also improve as students delve deeper into their thoughts and emotions.

Stream of consciousness writing strengthens emotional intelligence and empathy by prompting students to engage with their feelings and perspectives. It expands vocabulary and syntactic variety, as learners experiment with new language forms and expressions. The technique promotes deeper engagement with texts and ideas, helping students connect personally to what they read and write. It effectively removes writer's block and reduces the fear of errors, creating a low-pressure environment conducive to writing.

Additionally, it fosters a personal connection to writing, encouraging risk-taking and experimentation in language use. Free writing skills develop naturally through spontaneous writing, giving writers the freedom to express their thoughts and ideas without constraints. This freedom enhances imaginative power, adding new dimensions to writing abilities. Students explore their thoughts and emotions more authentically, which leads to more engaging writing and a deeper understanding of narrative voice.

The method reduces the pressure of controlled and technical writing, allowing students to focus on meaning and flow. It boosts confidence in writing, especially among learners who struggle with formal writing tasks. Finally, it creates opportunities for self-expression and connecting with one's inner voice, making the writing process more meaningful and personally rewarding.

7.6 Limitations of incorporating stream of consciousness writing in the ELT classrooms of Bangladesh at the tertiary level

Incorporating stream of consciousness writing into ELT classrooms at the tertiary level in Bangladesh faces several limitations. One major challenge is the lack of proper guidance for both teachers and students, which can make this technique difficult to implement effectively. The approach itself is not structured enough, which

may create confusion among learners who are more accustomed to organized and rule-based writing. Additionally, the existing syllabus often lacks upgradation or updates that include creative or experimental writing methods, making it harder to integrate stream of consciousness activities into mainstream curricula.

Another significant limitation is the lack of structure and coherence in students' writing, which may hinder their ability to develop academically acceptable texts. An overemphasis on freewriting may also interfere with the development of formal writing skills, which are essential for academic and professional success. Language proficiency gaps can further discourage students, leading to frustration and disengagement, especially if they struggle to articulate their thoughts in English.

Assessment and grading of stream of consciousness writing can be highly subjective, making it difficult for teachers to evaluate students' performance consistently. Time constraints within tight academic schedules may also limit opportunities for regular practice and feedback. Furthermore, many teachers lack training in creative writing techniques, which restricts their ability to guide students effectively in this form of expression.

Large class sizes common in Bangladeshi universities make it difficult to provide individualized feedback and guidance, which is crucial for nurturing writing skills. Finally, the cultural and academic focus on exam-oriented learning often conflicts with the open-ended, introspective nature of stream of consciousness writing. This mismatch can result in a lack of institutional support or acceptance of such non-traditional approaches within the broader educational framework.

7.7 Suggestion about the incorporation of stream consciousness writing at the tertiary levels of the ELT classrooms of Bangladesh

To effectively incorporate stream of consciousness writing into the ELT classrooms at the tertiary level in Bangladesh, several key suggestions can be implemented. Firstly, students should be encouraged to write freely in a way that brings out their authentic ideas and thoughts. This can help them build confidence and discover their own voice in English. To support this, the existing syllabus should be upgraded or updated to include creative and reflective writing components that align with modern teaching practices.

Proper classroom facilities must be ensured to create an environment conducive to personal and uninterrupted writing. There should be a structured approach to building better teaching frameworks, including comprehensive training for educators, adequate facilities, and access to relevant resources and materials. Teachers should initially emphasize creativity and self-expression over grammatical accuracy, helping students gain fluency before refining technical skills.

In addition, bilingual prompts and encouragement of personal journaling can bridge the gap between thought and language, especially for learners who may struggle to express themselves entirely in English. Constructive feedback should focus more on the flow of ideas and the clarity of expression rather than on strict grammatical correctness, thus fostering a supportive environment where students feel free to experiment.

Finally, launching well-designed practices of stream of consciousness writing, coupled with feedback and reward systems, can motivate students and reinforce positive engagement. Recognizing student efforts through encouragement or rewards can make the writing process more enjoyable and sustainable, gradually embedding stream of consciousness writing as a valuable tool in the language learning journey.

8. Recommendations

Balanced integration of SOC writing could be used as a warm-up or brainstorming activity, alongside lessons on structured writing. Teachers should intrigue the learners to revise their SOC writings into more polished works. Besides, they should teach them the significance of editing. Students need to tie this technique to the study literary works that incorporate SOC, e.g. James Joyce, Virginia Woolf to show its purpose and application in writing skill.

Incorporating SOC writing into English Language Teaching (ELT) can be an effective technique to modify writing skills, particularly in mastering fluency, creativity, and the natural flow of ideas. Teachers can engage students in timed freewriting sessions (e.g., 5–10 minutes), where they would write at a stretch without the concern of grammar, punctuation, or spelling.

Making students familiar with famous examples of SOC writings, such as the literary works of Virginia Woolf (e.g., *Mrs. Dalloway*) or James Joyce (e.g., *Ulysses*) and thereby make the students review, analyze and interpret the style, techniques and key features.

Teachers can inspire the students to keep a reflective journal to write their inner thoughts the moment they appear. Teachers should allow them to write without the pressure of structure and cohesion.

Furthermore, teachers can ask the students to create mind maps or lists of spontaneous thoughts based on a theme or topic.

Writing internal monologues or dialogues of characters can be a key technique is to emphasize the spontaneous overflow of thoughts and emotions.

Asking students to record themselves speaking their thoughts on a particular subject for 3–5 minutes and then transcribe the audio. This mimics the stream of consciousness style, where thoughts flow freely and are later organized into written form.

Moreover, teachers can make the students write memoirs, dialogues and complete stories to incorporate SOC.
Finally, since stream of consciousness writing can develop English writing skills, it needs to be complemented with structured writing instructions to ensure a well-rounded development of skills.

9. Conclusion

Stream of consciousness (SOC) writing offers significant benefits in English Language Teaching (ELT), fostering creativity, fluency, and self-expression among students. While learners accustomed to structured environments and teacher-led guidance may initially find SOC writing challenging, consistent practice helps them adapt and recognize its value. This technique encourages students to compare traditional, formal writing styles with the unstructured, expressive nature of SOC writing, revealing its potential to refine their language proficiency and academic writing skills. By engaging students with their raw thoughts and emotions, SOC writing serves as a creative outlet, enabling them to express feelings authentically and evolve into confident, prolific writers. Furthermore, it strengthens writing fluency by helping students capture the natural tone and rhythm of language while deepening their connection to cognitive processes. As a revolutionary pedagogical tool, incorporating SOC writing at the tertiary level in Bangladeshi ELT classrooms can empower students to explore the art of writing in a meaningful, impactful, and transformative manner.

References

Alam, F. (2007), Using Postcolonial Literature in ELT, Imperial Entanglements and Literature in English, Dhaka: writers. Ink, 373- 390.

Cohn, D. (1978). *Transparent minds: Narrative modes for presenting consciousness in fiction.* Princeton University Press.

Dimililer, C. & Kurt M. (2019). The Impact of Collaborative Writing and The Stream of Consciousness Technique on Writing. *Khazar Journal of Humanities and Social Sciences*, 22(3), 71-99. DOI:10.5782/2223-2621.2019.22.3.71

Ferris, D. R., & Hedgcock, J. S. (2014). *Teaching L2 composition: Purpose, process, and practice* (3rd ed.). Routledge.

Hamid, M. O., & Baldauf, R. B. (2008). Will CLT bail out the bogged down ELT in Bangladesh? *English Today, 24*(3), 16–24. https://doi.org/10.1017/S0266078408000254

Hedge, T. (2005). *Writing.* Oxford University Press.

Hyland, K. (2003). *Second language writing.* Cambridge University Press.

James, W. (1890). *The Principles of Psychology*. Harvard: Harvard University Press.
Kabir, M. (2019). Challenges in implementing creative writing techniques in tertiary classrooms in Bangladesh. *ELT Research Journal, 8*(4), 123–135.
Khan, R. (1999), Literature in The Language Classroom: Some Solutions to Handling Thomas Hardy's Tess of the D'Urberville, The Dhaka University Studies, 43-58.
Krashen, S. D. (1985). *The input hypothesis: Issues and implications.* Longman.
Maley, A., & Peachey, N. (2015). *Creativity in the English language classroom.* British Council.
Richardson, B. (2006). *Narrative dynamics: Essays on time, plot, closure, and frames.* Ohio State University Press.

Appendix 1

Teachers' Questionnaire

1. Do you have any idea of 'Stream of Consciousness Writing'?
   a. Yes
   b. No
   c. A little
   d. Confused
2. Do you think the traditional creative as well as free handwriting techniques applied to the Bangladeshi ELT classrooms at the tertiary levels are enough to develop the writing skills?
   a. Yes
   b. No
   c. Confused
3. Do you think it is important to incorporate stream of consciousness writing in ELT classrooms at the tertiary levels of Bangladesh?
   a. Yes
   b. No
   c. Sometimes
   d. Confused
4. Have you ever applied any technique of stream of consciousness writing in the ELT classrooms at the tertiary levels of Bangladesh?
   a. Yes
   b. No
   c. Sometimes
   d. Confused

5. If you have applied any technique of stream of consciousness writing in ELT which techniques have you applied?
6. What according to you can be the possible techniques of incorporating stream of consciousness writing in the ELT classrooms at the tertiary level?
7. What according to you are the benefits of incorporating stream of consciousness into the writing skills of ELT classrooms?
8. What according to you are the limitations of incorporating stream of consciousness writing in the ELT classrooms of Bangladesh at the tertiary level?

9. What is your suggestion or recommendation about the incorporation of stream of consciousness writing at the tertiary levels of the ELT classrooms of Bangladesh?
10. Are you yourself interested or motivated to incorporate stream of consciousness writing at the tertiary levels of the ELT classrooms of Bangladesh?
    a. Yes
    b. No
    c. Sometimes
    d. Confused

Appendix 2

Students' Questionnaire

1. Do you have any idea about Stream of Consciousness?
    - Yes
    - No
    - Maybe
2. Have you ever used the stream of consciousness technique in your writing?
    - Yes
    - No
    - Maybe
3. How often are you encouraged to write creatively in your ELT classroom?
    - Always
    - Frequently
    - Sometimes
    - Rarely
    - Never

4. Rate your confidence in creative writing using unconventional styles (e.g., stream of consciousness):
    - Very Confident
    - Confident
    - Neutral
    - Not confident
    - Not very confident
5. To what extent do you think integrating stream of consciousness enhances writing skills?
    - Greatly
    - Moderately
    - Slightly
    - Not at all
6. Have you been explicitly taught about the stream of consciousness writing technique in class?
    - Yes
    - No
    - Maybe
7. Do you think incorporating stream of consciousness writing in the curriculum can improve overall English writing skills? Why or why not?
8. Share any personal experiences or examples of how creative writing has impacted your language learning journey.
9. What additional support or resources would you need to improve your writing using the stream of consciousness technique?

Pattern of Childhood Tuberculosis in a particular Rural Area of Bangladesh

Dr. ABM Ali Hasan[1], Dr. Kazi Rakibul Islam[2], Mr. Mozharul Islam[3], Ms. Sanchita Rani Paul[3], Dr. Khadija Akter[3], Dr. Mukta Sarker[3], Dr. Supti Karmaker[3]

[1]Associate Professor, Department of Public Health, R. P. Shaha University
[2]Senior Lecturer, Department of Public Health, R. P. Shaha University
[3]Research Assistant, Department of Public Health, R. P. Shaha University.
Corresponding author: Dr. Kazi Rakibul Islam, rakib_mph@rpsu.edu.bd,

ARTICLE INFO

Keywords: Childhood Tuberculosis, Bacteriologically Confirmed TB, New Case, Morbidity, Rural Bangladesh

RECEIVED
17 May 2025

ACCEPTED
14 July 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17330823

ABSTRACT

Tuberculosis (TB) remains a significant cause of illness and death among children, especially those under 15 years old. Therefore, this study aimed to assess the types and distribution of childhood TB cases diagnosed at the DOTS center of Kumudini Hospital, a rural tertiary care facility in Mirzapur, Bangladesh. A retrospective cross-sectional study was conducted over the period from January to December 2023. Relevant demographic and clinical data were extracted from patient records and entered manually into Microsoft Excel. Descriptive statistical methods were applied to analyze the data. A total of 42 children were diagnosed. Among them, 26 (61.90%) were male and 16 (38.10%) were female. In terms of TB type, 50% had bacteriologically confirmed pulmonary TB, 40.48% had extra-pulmonary TB, and 9.52% were clinically diagnosed with pulmonary TB. The vast majority, 95.24%, were new cases, with only 4.76% being relapses. These findings revealed that childhood TB in this region predominantly affects older children and presents mostly as confirmed pulmonary TB. The high number of new cases underscores the urgent need for enhanced awareness, timely diagnosis, and community-driven TB control measures to reduce the disease burden among children in rural settings of Bangladesh.

1. Introduction

According to the World Health Organization (2023), tuberculosis (TB) is a bacterial infection caused by *Mycobacterium tuberculosis*, primarily affecting the lungs and transmitted through airborne particles expelled when an infected person coughs or sneezes. Although TB is preventable and curable with modern pharmacological treatments, it remains a leading cause of morbidity and mortality among children worldwide (World Health Organization, 2023; Dodd et al., 2017). Childhood tuberculosis has increasingly become a global public health concern. Diagnosing TB in children is particularly challenging, as it often presents with non-specific symptoms and lacks bacteriological confirmation in most cases, which complicates clinical identification and surveillance efforts (Marais & Graham, 2011). As a result, reliable data on childhood TB trends are scarce in the published literature, especially in resource-limited settings (Cruz & Starke, 2014). However, in regions where the adult TB burden is high, such as sub-Saharan Africa and South Asia, it is presumed that the incidence of childhood TB is also increasing (Yuen et al., 2014). The epidemiology and risk factors for TB in children can vary widely across geographic and socio-economic contexts, influenced by factors such as household exposure, malnutrition, poor ventilation, and HIV co-infection (Nelson & Wells, 2004). The WHO estimates that approximately 11% of all TB cases occur in children under 15 years of age, with the majority concentrated in low- and middle-income countries (LMICs) like Bangladesh (World Health Organization, 2022). Despite the significant burden of TB-related childhood mortality and morbidity, efforts to manage and prevent TB among children have historically received limited attention (Seddon & Graham, 2016).

In rural Bangladesh, TB continues to be a major health threat for children. Although national tuberculosis control efforts have advanced considerably, the diagnosis and treatment of childhood TB remain problematic due to atypical clinical presentations, difficulties in confirming bacteriological diagnosis, and limited access to appropriate diagnostic tools in peripheral health facilities (Hossain et al., 2013; National Tuberculosis Control Program, 2023). Environmental and systemic factors such as malnutrition, crowded living conditions, and delays in accessing healthcare further complicate the control of TB in rural areas (Ahmed et al., 2015). This study aims to assess the current pattern of childhood TB in a rural area of Bangladesh, focusing on demographic, clinical, and diagnostic characteristics of the cases reported at a rural tertiary hospital. By examining these patterns, the study intends to contribute to improved understanding and management of childhood TB within similar low-resource contexts.

2. Objectives

The primary objective of this study is

- to evaluate the types and distribution of childhood tuberculosis (TB) cases diagnosed in a tertiary care hospital located in a rural area of Bangladesh.

The specific objectives are:

- to analyze the age and sex distribution of childhood TB cases.
- to identify the proportion of pulmonary and extra pulmonary TB among children.
- to determine the proportion of bacteriologically confirmed, clinically diagnosed, and relapse cases.
- to assess the diagnostic methods used for confirming TB in children.
- to provide insights for future planning and awareness strategies to prevent childhood TB in rural communities.

3. Literature Review

Tuberculosis (TB) in children remains a significant public health challenge in many developing countries, particularly in rural areas where healthcare access and infrastructure are limited. In high-prevalence nations, childhood TB accounts for approximately 10–15% of the total TB burden (World Health Organization [WHO], 2021). Bangladesh, one of the 30 high TB burden countries, faces unique challenges in the diagnosis and management of childhood TB due to socio-economic constraints, limited healthcare infrastructure, and inadequate community awareness. Several studies have identified disparities in the prevalence and management of childhood TB between rural and urban regions in Bangladesh. Rural areas tend to have higher rates of undiagnosed or late-diagnosed cases, primarily due to barriers such as limited access to healthcare services and insufficient diagnostic tools (Islam et al., 2020). Children in rural Bangladesh often present with nonspecific clinical symptoms, including prolonged fever, weight loss, persistent cough, and lymphadenopathy (Rahman et al., 2019). These nonspecific symptoms, along with the paucibacillary nature of the disease in children, contribute to diagnostic delays. Extra-pulmonary tuberculosis (EPTB), particularly tuberculous lymphadenitis, is more common among children in rural Bangladesh. This trend has been attributed to delayed diagnosis and inadequate Bacillus Calmette–Guérin (BCG) vaccination coverage (Rahman et al.,

2019). Traditional diagnostic methods, such as sputum microscopy, lack sensitivity in pediatric populations. Newer diagnostic tools, such as the GeneXpert MTB/RIF assay, have shown promise; however, their availability and utilization in rural settings remain limited (Chowdhury et al., 2020). In Bangladesh, the Directly Observed Treatment Short-Course (DOTS) strategy recommended by the WHO is the standard treatment protocol for TB, including childhood TB. Despite this, treatment adherence in rural regions often suffers due to socio-economic factors such as poverty, long distances to health centers, and limited caregiver education (Kabir et al., 2018). Community health workers play a crucial role in improving treatment adherence and follow-up care, indicating the need for targeted community-based interventions. In conclusion, childhood TB in rural Bangladesh is characterized by delayed diagnosis, a high burden of EPTB, and significant treatment challenges. There is an urgent need for improved diagnostic facilities, enhanced training of rural healthcare providers, and increased public awareness to address the burden of childhood TB in these areas.

4. Methodology

A retrospective cross-sectional study was carried out at the Directly Observed Treatment Short-Course (DOTS) center of Kumudini Hospital, a rural tertiary healthcare facility situated in Mirzapur, Tangail, Bangladesh. The study encompassed one year from January 1 to December 31, 2023. During this time, 299 tuberculosis (TB) cases were diagnosed using a combination of diagnostic methods, including Chest X-ray, GeneXpert MTB/RIF assay, Fine Needle Aspiration Cytology (FNAC), biopsy, and Adenosine Deaminase (ADA) test. From these cases, 42 were identified as childhood TB, defined as TB occurring in individuals under 15 years of age. These 42 pediatric cases were selected purposively for analysis. Relevant demographic and clinical data were extracted from patient records and entered manually into Microsoft Excel. Descriptive statistical methods were applied to analyze the data. This study was approved by the Ethical Review Committee of Kumudini School of Public Health (KSPH/Admin/08/2023) and conformed to the Declaration of Helsinki. Participation of the respondents was voluntary. Informed consent was sought from the respondents at the beginning of the survey, and participants could withdraw from the study at any time.

5. Operational Definitions

- **Childhood Tuberculosis (Child TB):** Tuberculosis occurring in individuals under 15 years of age.

- **Bacteriologically Confirmed Pulmonary TB:** TB diagnosed through the identification of Mycobacterium tuberculosis using laboratory techniques such as GeneXpert or sputum microscopy.
- **Clinically Diagnosed Pulmonary TB:** TB diagnosed based on clinical symptoms and radiological evidence in the absence of bacteriological confirmation.
- **Extra-Pulmonary TB:** TB infection occurring in organs other than the lungs, such as lymph nodes, pleura, abdomen, bones, or meninges.
- **New Case:** A patient who has never been treated for TB or has taken anti-TB drugs for less than one month.
- **Relapse Case:** A patient who was previously declared cured or treatment completed and is now diagnosed with a recurrent episode of TB.
- **DOTS:** Directly Observed Treatment Short-Course, a WHO-recommended TB control strategy involving supervised treatment adherence.

6. Findings and Analysis

Out of 299 TB cases diagnosed in 2023, 42 (14.05%) were pediatric cases (under 15 years), while 257 (85.95%) involved adults. Among the children, 26 (61.90%) were male and 16 (38.10%) were female, indicating a male predominance. In terms of age distribution, 10 children (23.81%) were in the 0–<5 years age group, while the majority, 32 (76.19%), were aged 5–<15 years. Regarding the types of TB, 21 cases (50.00%) were bacteriologically confirmed pulmonary TB, 17 (40.48%) were extra-pulmonary TB, and 4 cases (9.52%) were clinically diagnosed pulmonary TB, suggesting that the most common form of TB in children was bacteriologically confirmed pulmonary TB. Furthermore, the majority of the pediatric TB cases (38 or 90.48%) were pulmonary, with only 4 cases (9.52%) being extra-pulmonary. Most of the cases (40 or 95.24%) were classified as new cases, while only 2 (4.76%) were identified as relapses. These findings highlight that childhood TB in this rural setting is predominantly pulmonary, affects older children more frequently, and is primarily composed of new cases, underscoring the need for early detection and stronger community-based TB awareness programs.

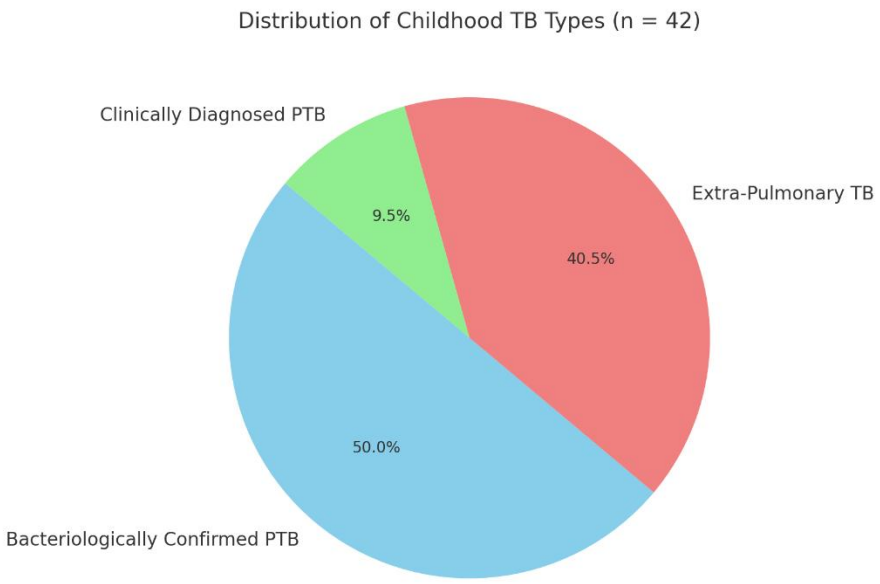


Figure 1. Distribution of Children by TB Types (n=42)

This figure shows that half of pediatric TB cases were bacteriologically confirmed pulmonary TB (50%), with clinically diagnosed pulmonary TB accounting for 40.5%, and extrapulmonary TB making up only 9.5%. The high proportion of confirmed pulmonary cases highlights the utility of laboratory diagnostics (e.g., GeneXpert) in this rural setting, while the relatively low extrapulmonary share may indicate under-detection of non-pulmonary forms.

Table 1: Distribution of TB Cases by adults and children (n=299)

Cases	**Frequency**	**Percentages**
Adult ≥ 15 years	257	85.95
Child < 15 years	42	14.05
Total	299	100.00

Children constituted 14.1% of all TB cases diagnosed in 2023, aligning with the WHO's estimate that 10–15% of TB cases occur in those under 15. This underscores the importance of pediatric TB surveillance even within predominantly adult caseloads.

Table 2: Distribution of Child TB cases by sex (n=42)

Sex	Frequency	Percentages
Male	26	61.90
Female	16	38.10
Total	42	100.00

A clear male predominance (61.9%) was observed among pediatric TB cases. This may reflect gender-based differences in exposure, healthcare-seeking behavior, or sociocultural factors influencing access to diagnosis.

Table 3: Number and percentage of Child TB cases by age group (n=42)

Age	Frequency	Percentage
0- <5 years	10	23.81
5-<15 years	32	76.19
Total	42	100.00

The majority of childhood TB cases (76.2%) occurred in the 5–<15 years age group, suggesting that school-aged children bear a greater burden in this rural population than those under five.

Table 4: Distribution of Children by TB Types (n=42)

Types of TB Cases	Frequency	Percentage
Bacteriological Confirmed PTB	21	50.00
Clinical Diagnosed PTB	17	40.48
Extrapulmonary TB	4	9.52
Total	**42**	**100.00**

Pulmonary TB—both bacteriologically confirmed and clinically diagnosed—comprised over 90% of cases, with extrapulmonary TB accounting for less than 10%. This pattern may reflect both the actual epidemiology and greater diagnostic focus on pulmonary disease in the DOTS center.

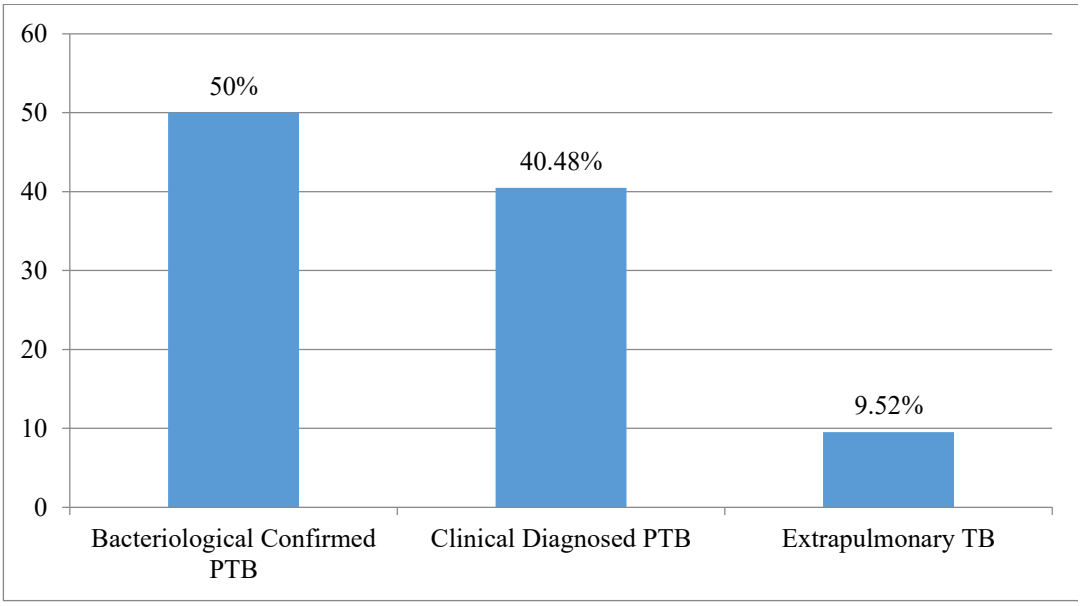


Figure 2. Distribution of Children by TB Types (n=42)

The visual representation corroborates Table 4, emphasizing that half of the cases were laboratory-confirmed pulmonary TB, and highlights potential gaps in detecting extrapulmonary TB.

Table 5: Distribution of Children by Types of TB cases (n==42)

Types of TB cases	**Frequency**	**Percentage**
Pulmonary	38	90.48
Extra pulmonary	4	9.52
Total	**42**	**100.00**

When grouped broadly, pulmonary TB overwhelmingly predominates (90.5%). Efforts to strengthen extrapulmonary TB diagnosis—such as expanded use of biopsy and FNAC—could improve detection of nodal, pleural, or other forms.

Table 6: Distribution of children by New and Relapse Case (n=42)

Type of cases	**Frequency**	**Percentage**
New Case	40	95.24

Relapse Case	2	4.76
Total	42	100.00

The very high proportion of new cases (95.2%) indicates effective primary case finding, while the small relapse rate (4.8%) underscores the need for ongoing adherence support to further minimize recurrence.

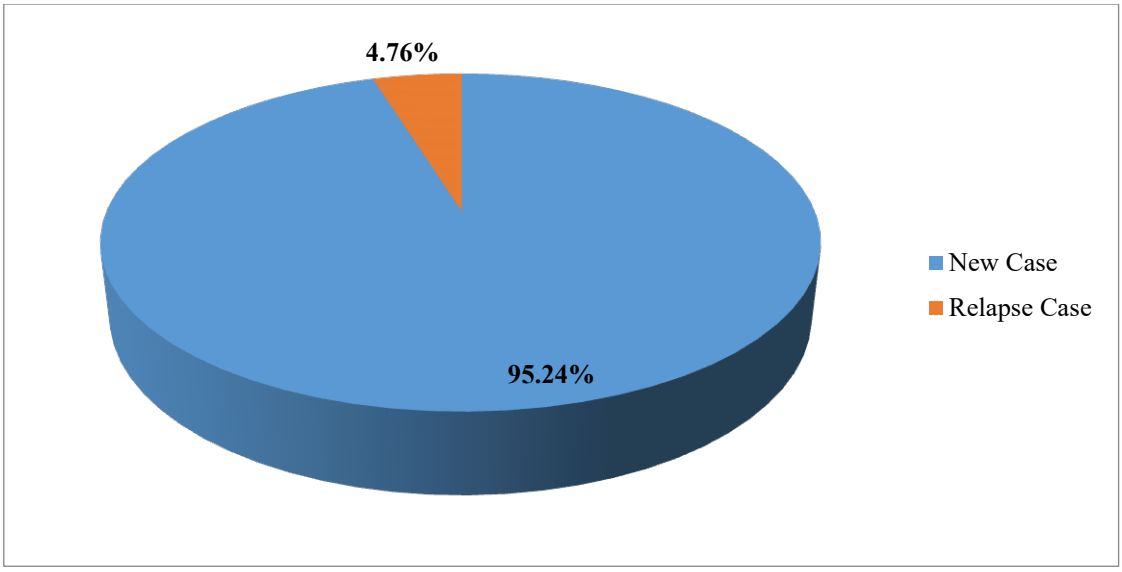


Figure 3: Distribution of children by New and Relapse Case (n=42)

This chart visually reinforces that nearly all pediatric cases are newly detected, pointing to successful initial notification but also highlighting an opportunity to monitor and support those at risk of treatment default or relapse.

7. Discussion

The findings of this study align with the global and national epidemiological patterns of childhood tuberculosis (TB). According to the study findings, childhood TB accounted for 14.05% of the total TB cases, which is consistent with the World Health Organization's estimate that children represent approximately 10–15% of the overall TB burden in high-prevalence countries like Bangladesh (WHO, 2023). This highlights the significant contribution of childhood TB to the national TB control challenge. This study shows that there is a male predominance (61.90%) among the child TB cases, which concurs with findings from similar studies conducted in India (Tsai et al., 2013). However, this contrasts with other research indicating a higher

prevalence among females or a more balanced sex distribution (Karim et al., 2012). These discrepancies may be influenced by sociocultural factors, healthcare-seeking behaviors, and possibly biological differences that warrant further investigation within the Bangladeshi context. The age distribution of TB cases, with the majority (76.19%) in the 5 to <15 years age group, differs from other studies, such as Hasan (2019), which reported a larger proportion of cases in younger children under five years. This variation may be attributable to differences in study settings; our study was conducted in a large tertiary hospital (Kumudini Hospital) in a rural area, whereas Hasan's work was conducted in a smaller secondary-level hospital. Environmental factors, demographic variations, and differing levels of community awareness and health service accessibility could explain this difference, emphasizing the need for more localized epidemiological studies. Regarding TB types, this study found that 50% of childhood TB cases were bacteriologically confirmed pulmonary TB, 40.48% clinically diagnosed pulmonary TB, and 9.52% extra-pulmonary TB. These proportions differ from other Bangladeshi studies, such as Qamruzzaman et al. (2025), which reported a higher incidence of extra-pulmonary TB in urban settings. This suggests potential variations between rural and urban epidemiology of childhood TB, possibly due to differences in healthcare access, diagnostic capabilities, and vaccination coverage. The predominance of pulmonary TB cases in our study may reflect better detection capacity for pulmonary disease or under diagnosis of extra-pulmonary forms in rural settings. This study revealed that 95.24% of childhood TB cases were new cases is encouraging and indicates effective case detection and registration within the studied population. However, the presence of relapse cases, albeit small (4.76%), highlights the need for continued monitoring and support to ensure treatment adherence. Overall, these results emphasize the persistent challenges in childhood TB diagnosis and management in rural Bangladesh, including limitations in bacteriological confirmation, diagnostic delays, and demographic disparities. Strengthening TB control efforts tailored to rural contexts, improving diagnostic infrastructure, and increasing community awareness are critical to reducing childhood TB morbidity and mortality.

8. Conclusion

This study highlights that childhood tuberculosis remains a significant public health concern in rural Bangladesh, with the majority of cases occurring among children aged 5 to under 15 years. Bacteriologically confirmed pulmonary tuberculosis is the most common form observed, and most cases are new rather than relapse. These findings underscore the ongoing burden of childhood TB and the challenges in early detection and management, particularly in rural settings. Addressing these challenges

is critical to improving childhood TB outcomes and advancing national TB control efforts.

9. Recommendations

1. **Enhance Community Awareness:** Implement targeted awareness programs in rural communities to educate caregivers and families about the signs, symptoms, and importance of early diagnosis and treatment of childhood TB.
2. **Strengthen Diagnostic Capacity:** Improve access to and availability of advanced diagnostic tools, such as GeneXpert MTB/RIF, at rural healthcare facilities to facilitate timely and accurate diagnosis of both pulmonary and extrapulmonary TB in children.
3. **Tailored TB Control Strategies:** Develop and implement context-specific TB control interventions that address the unique socio-economic and environmental factors influencing childhood TB in rural Bangladesh.
4. **Further Research:** Conduct comparative studies to explore differences in childhood TB patterns between rural and urban settings, and between secondary and tertiary healthcare centers, to inform evidence-based policy and practice.
5. **Improve Treatment Adherence Support:** Strengthen the role of community health workers and caregivers in supporting treatment adherence to reduce relapse cases and improve treatment outcomes among children with TB.

References

Ahmed, S., Rahman, M., & Hossain, M. (2015). Environmental and socio-economic factors influencing tuberculosis prevalence in rural Bangladesh. *Journal of Rural Health*, 31(2), 123–131.

Chowdhury, M. R., Islam, M. N., & Akter, F. (2020). Utilization of GeneXpert MTB/RIF assay in the diagnosis of childhood tuberculosis in rural Bangladesh. *Bangladesh Medical Journal*, 49(3), 45–52.

Cruz, A. T., & Starke, J. R. (2014). Childhood tuberculosis: A global perspective. *Tuberculosis Research and Treatment*, 2014, Article ID 790123. https://doi.org/10.1155/2014/790123

Dodd, P. J., Yuen, C. M., Sismanidis, C., Seddon, J. A., & Jenkins, H. E. (2017). The global burden of tuberculosis mortality in children: A mathematical modelling study. *The Lancet Global Health*, 5(9), e898-e906.

Hasan, M. (2019). Patterns of childhood tuberculosis in a secondary-level hospital in Bangladesh. *Bangladesh Journal of Medicine*, 30(1), 22–28.

Hossain, M. M., Kabir, M., & Rahman, M. (2013). Challenges in diagnosing childhood tuberculosis in rural Bangladesh. *International Journal of Tuberculosis and Lung Disease*, 17(7), 914–920.

Islam, M. N., Kabir, A., & Chowdhury, S. (2020). Disparities in childhood tuberculosis diagnosis and treatment in urban and rural Bangladesh. *Public Health Action*, 10(1), 15–20.

Kabir, M., Hossain, M., & Sultana, N. (2018). Treatment adherence among childhood TB patients in rural Bangladesh: Role of community health workers. *Health Policy and Planning*, 33(6), 698–704.

Karim, F., Zaman, K., & Ahmed, S. (2012). Gender differences in childhood tuberculosis in Bangladesh. *Pediatric Infectious Disease Journal*, 31(10), 1102–1106.

Marais, B. J., & Graham, S. M. (2011). Childhood tuberculosis: Global epidemiology and prevention strategies. *Clinical Chest Medicine*, 32(4), 667–686.

National Tuberculosis Control Program. (2023). *Annual report 2023*. Ministry of Health and Family Welfare, Bangladesh.

Nelson, L. J., & Wells, C. D. (2004). Global epidemiology of childhood tuberculosis. *The International Journal of Tuberculosis and Lung Disease*, 8(5), 636–647.

Qamruzzaman, M., Rahman, M., & Islam, M. (2025). Urban-rural differences in childhood tuberculosis in Bangladesh: A comparative study. *Journal of Infectious Diseases*, 27(1), 101–108.

Rahman, M., Chowdhury, S., & Islam, N. (2019). Clinical presentation and diagnosis of childhood tuberculosis in rural Bangladesh. *Bangladesh Journal of Child Health*, 43(2), 85–90.

Seddon, J. A., & Graham, S. M. (2016). Challenges and progress in childhood tuberculosis. *Current Opinion in Infectious Diseases*, 29(3), 255–262.

Tsai, C. C., Wang, L. F., & Lee, C. C. (2013). Gender differences in childhood tuberculosis epidemiology in India. *International Journal of Tuberculosis and Lung Disease*, 17(4), 529–534.

World Health Organization. (2022). *Global tuberculosis report 2022*. WHO Press.

World Health Organization. (2023). *Tuberculosis fact sheets*. https://www.who.int/news-room/fact-sheets/detail/tuberculosis

Yuen, C. M., et al. (2014). Epidemiology of childhood tuberculosis in high burden countries: Challenges and opportunities. *Pediatric Infectious Disease Journal*, 33(4), 421–426.

Phytochemical assessment, and estimation of hypoglycemic potentials of the dichloromethane extract of *Araucaria heterophylla* leaves

Md. Tariqul Islam[1] PhD, Subrato Kumar Barman[2], Muaj Ibne Sahid[3], and Md. Shafiqul Islam[4]

[1]Assistant Professor, Controller of Examinations, and Additional Director (ETL, IQAC), Department of Pharmacy, R. P. Shaha University, Narayanganj-1400, Bangladesh

[2]Lecturer, Department of Pharmacy, Daffodil International University, Dhaka, Bangladesh

[3]Assistant Professor, and Assistant Proctor, Department of Pharmacy, R. P. Shaha University, Narayanganj-1400, Bangladesh

[4]Associate Professor, Department of Pharmacy, Gopalganj Science and Technology University, Gopalganj-8100, Bangladesh

Corresponding author: Muaj Ibne Sahid, sahid_phr@rpsu.edu.bd

ARTICLE INFO

Keywords: Araucaria heterophylla, phytochemicals, diabetes, α-amylase, and glucose adsorption

RECEIVED
27 May 2025

ACCEPTED
23 July 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17242861

ABSTRACT

Diabetes mellitus (DM), a chronic metabolic illness, is described by long term imbalance in glucose homeostasis. This study was carried out to identify the various phytochemicals, and to evaluate the hypoglycemic endeavor of crude dichloromethane extract of *Araucaria heterophylla (A. heterphylla)* leaves. Extraction was carried out using dichloromethane as a solvent. Preliminary phytochemical assessment of the crude dichloromethane extract of *A. heterophylla* (DAH) indicated the existence of diverse phytochemicals, including flavonoids, sterols, terpenoids, phenols, and carbohydrates. The DAH exhibited α-amylase inhibitory capacity comparable to that of the standard acarbose. Additionally, DAH effectively adsorbed glucose in both low, and high glucose concentrations used in the study.

These findings indicate the potent hypoglycemic effects of the DAH *in-vitro*. The presence of the bioactive constituents may be related to the hypoglycemic activity of the plant extract. To detect the specific compounds responsible for these novel findings, more detailed study is required.

1. Introduction

Diabetes, a worldwide health risk, manifests persistent hyperglycemia. Hyperglycemia is indicated when blood glucose level is consistently high (World Health Organization, 2018). This complex disease mainly disturbs the metabolism of carbohydrates, protein, and fat. In recent years, the number of patients with hyperglycemia has augmented worldwide (Manikandan *et. al.,* 2013). Diabetes mellitus (DM), characterized by chronic hyperglycemia, encompasses several types based on underlying causes. Type 1 diabetes appears from an obvious deficiency of insulin due to permanent damage of pancreatic β-cells. While type 2 diabetes**,** the most prevalent form globally, results from inadequate insulin secretion, and/or the body's reduced sensitivity to insulin. Type 3 diabetes is secondary to other medical conditions such as pancreatitis, pancreatectomy, or because of certain drug therapies. Type 4 diabetes**,** commonly referred to as gestational diabetes, occurs during pregnancy when blood glucose levels exceed normal ranges but do not meet the diagnostic threshold for diabetes.

Diabetes poses a significant global health burden, and is a leading cause of severe diabetic related disorders like blindness, kidney failure, stroke, cardiovascular disease, and lower limb amputation. According to the WHO, diabetes was the lead cause for 1.6 million deaths in 2016 alone (World Health Organization, 2018). While various pharmacological treatments are available for managing diabetes, many are associated with limitations, including adverse side effects, and diminished long-term efficacy. Consequently, there is a growing interest in identifying, and developing novel therapeutic agents, particularly from natural sources, that offer improved safety profiles, and enhanced effectiveness in glycemic control.

Araucaria heterophylla, most known as Norfolk Pine, Norfolk Island Pine, Star pine, Triangle tree, Christmas tree, Living Christmas tree, Christmas Plant, and House Pine plant belongs to Araucariaceae family (Vennell, 2015). It is a large conical shaped tree with a huge erect stem reaching almost 30-80 metres. It has small, and narrow needle like leaves spreading horizontally (Patil *et. al.*, 2013) which is composed of essential oils, alkaloids, biflavone, and phenolic compounds (Michael *et. al.*, 2010). Young leaves are light-green, incurved, and about 1 cm long; adult leaves are dark

green, incurved, toothache (Bussmann, 2008). It has shown activity against toothache, and extracting teeth (Aslam *et. al.*, 2013).

Numerous studies have highlighted the diverse pharmacological activities of *A. heterophylla*. The resin extracted sequentially with chloroform, and a chloroform/methanol mixture has demonstrated cytotoxic properties, exhibiting moderate anticancer effects against colon, and breast cancer (Sattar *et. al.,* 2009). In addition, dose-dependent antiulcerogenic effects of the resin have been observed in ethanol-induced gastric ulcer models using Sprague Dawley rats, as testified by Sattar *et. al.,* (Sattar *et. al.,* 2009). The natural polysaccharide gum derived from *A. heterophylla* (AHG), obtained via aqueous extraction, and acetone precipitation, was found to be non-toxic in albino mice, with an LD_{50} value of 2000 mg/kg body weight (Divvela *et. al.,* 2016). Furthermore, the leaf powder has shown promising potential as a bioadsorbent, effectively removing Pb^{2+} ions from aqueous solutions, suggesting its utility as a cost-effective method for purifying contaminated water (Sarada *et. al.,* 2013). Antimicrobial properties of *A. heterophylla* leaves extract against pathogenic *Staphylococcus aureus*, *Escherichia coli*, and *Proteus vulgaris* was also reported (Goud *et. al.,* 2017). Additionally, studies have shown that the leaves can efficiently remove hexavalent chromium from aqueous solutions within 15 to 30 minutes, reinforcing their value as an economical, and effective bioadsorbent (Shukla *et. al.,* 2012). Previous investigations also reported mild antibacterial properties of *A. heterophylla* leaves extract against gram-negative bacterial strains (Sadia *et. al.,* 2019).

Given this wide range of bioactivities, this study aims at further exploration of the phytochemical constituents of the dichloromethane extract of *A. heterphylla* leaves, and also evaluation of the hypoglycemic activity *in-vitro*.

2. Materials and Methods

2.1 Extraction

The taxonomy identification of the plant (*Araucaria heterophylla*) was done by botanist from National Herbarium Bangladesh, and the identification code is DACB 48435. The plant *Araucaria heterophylla* Franco is a member of Araucariaceae family. The plant leaves were collected from R. P. Shaha University campus. Leaves were dedusted gently, and shade dried after cleaning. Dried leaves were then crushed into small powders by using a laboratory grinder. About 260 g of plant material was extracted with 2300 mL of dichloromethane. Approximately, 3.8% yield from 260 g plant parts.

2.2 Chemicals

Acarbose (Sugatrol, Pacific Pharmaceuticals Ltd.), α-amylase (Sigma-Aldrich), dimethyl sulfoxide (DMSO), glucose, hydrochloric acid, iodine, methanol, phosphate buffer, potassium iodide, and starch were bought from reliable local suppliers.

2.3 Phytochemical screening

The DAH initial phytochemical screening tests were carried out using Trease *et. al.,* methodology (Trease *et. al.,* 1989).

2.4 *α-amylase inhibition assay*

Modified starch-iodine colorimetric technique as described by Sudha *et. al.,* (Sudha *et. al.,* 2011) was used for *in-vitro* α-amylase inhibition assay of DAH. In the reaction blend contained 6.0 mL phosphate buffer at pH 6.9, 0.2 mL α-amylase solution at 100 µg/mL, and graded concentrations (250, 500, 1000, and 2000 µg/mL) of the test materials. After pre-incubation of this mixture at 37 °C for 10 minutes, 0.2 mL of 1% (w/v) solution of starch was added to initiate the enzymatic reaction, which was then kept for 15 minutes at 37 °C to complete the reaction. The enzymatic reaction was ended by adding 200 µL 1 M hydrochloric acid, followed by adding 0.3 mL of iodine reagent (10 mM iodine, and 2.5 mM potassium iodide). After the color change occurred, absorbance was taken at 620 nm using a UV-visible spectrophotometer. A dark-blue coloration indicated the presence of unhydrolyzed starch, a yellow color denoted complete starch hydrolysis, and a brownish hue suggested partial degradation.

In this study, no starch degradation was observed across the test samples. Acarbose, as the standard inhibitor, was tested at the same concentrations as that of test samples. The control reaction, which characterized 100% enzyme activity, was carried out without any test material. Additional control samples excluding the enzyme were included to account for any background absorbance contributed by the test compound itself.

Enzyme activity, and % α-amylase inhibition of the test compounds was calculated following formula:

$$Enzyme\ activity\ (EA) = Absorbance\ of\ test\ control - absorbance\ of\ test\ samples$$

$$\%\ \alpha - amylase\ inhibition\ = \frac{EA_{\ control}\ -\ EA_{\ test}}{EA_{\ control}} \times\ 100$$

2.5 Glucose adsorption capacity assay

The glucose adsorption capability of the sample was assessed based on the technique designated by Ou *et. al.,* (Ou *et. al.,* 2001), with minor modifications. At first, a 0.25% (w/v) solution of DAH was prepared, and added to 20 mL of glucose solutions having 10, 20, 50, 100, and 200 mM concentrations. After thorough stirring, the mixtures were kept at 37 °C using temperature controlled water bath for 6 hours to facilitate adsorption. Following incubation, the samples were centrifuged at 4800 rpm for 20 minutes. The amount of glucose remaining in the supernatant was then quantified by UV-visible spectrophotometry at 540 nm, as outlined by Yakoob *et. al.,* (Yakoob *et. al.,* 2016).

The bound glucose content was estimated based on the formula below:

$$Glucose\ bound = \frac{(G_1 - G_6)}{Weight\ of\ the\ sample} \times volume\ of\ solution$$

Here, G1 denotes the initial glucose concentration of the solution, while G6 refers to the glucose concentration measured after 6 hours of incubation.

3. Results

3.1 Phytochemical screening

The result of phytochemical screening has been showed in the table 1

Table 1: Results of phytochemical screening of DAH:

Chemical Groups	Test Methods	Result
Alkaloids	Mayer's Method	–
	Wagner's Method	–
	Hager's Method	–
Glycosides	Keller-Killiani Method	++
	Concentrate H_2SO_4 Method	+
	Salkowski's Method	++
Carbohydrates	Fehling's Experiment	++
	Molisch's Experiment	+
	Benedicts Experiment	+
Flavonoids	Ammonium Test	++
	Aluminium Chloride method	++
	Shinoda Experiment	–
	Ferric Chloride Experiment	++

Tannins	Lead Acetate Experiment	++
	Potassium Dichromate Method	++
Saponin	Foam Experiment	++
	Haemolysis Test	+
Phenols	Ellagic Acid Test	+
Terpenoids	Salkowski Method	++
Sterols	Salkowski Test	+
	Liebermann-Burchard Test	–
Proteins and Amino Acids	Biuret's Method	–
	Ninhydrin Experiment	–
Resins	Mohler's test	+
Fats and Fixed Oils	Stain Test	–

(++)→High quantity; (+)→Low quantity; and (-)→Absent

Data presented in Table 1, the results indicate that glycosides, carbohydrates, flavonoids, tannins, saponins, and terpenoids are prominently present in the DAH extract. Resins, sterols, and phenols are detected in lesser amounts, while alkaloids, proteins, amino acids, fats, and fixed oils are absent.

3.2 α-amylase inhibition assay

Figure 1 illustrates the percentage of α-amylase inhibition observed at concentrations such as 250, 500, 1000, and 2000 µg/mL of the DAH, and the standard, acarbose (STD). A clear dose-dependent increase in inhibitory activity was noted for DAH, with inhibition rates of 22.29%, 32.74%, 44.18%, and 68.25% at the respective concentrations. In comparison, the standard acarbose exhibited inhibition rates of 28.99%, 40.23%, 55.23%, and 85.29% at the same concentrations. Since higher percentages of inhibition correlate with stronger enzymatic activity suppression, these findings indicate that the DAH extract possesses notable anti-diabetic potential.

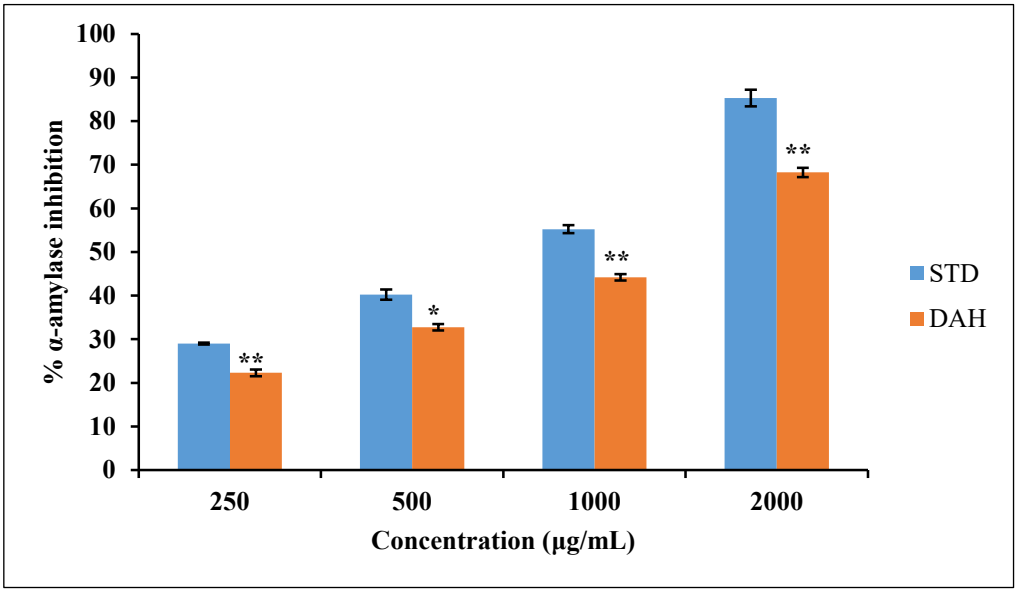


Figure 1: The α-amylase inhibitory capacity of DAH mentioned as the mean ± SD (n = 3). Statistical significance is indicated as *P<0.01, and P<0.001 when compared to the standard acarbose (independent samples t-test). STD = Standard acarbose, and DAH = Dichloromethane extract of *A. heterophylla*.

The IC_{50} of test and standard samples was calculated using linear regression analysis between % α-amylase inhibition, and concentration. The observed value is shown in table 2.

Table 2: IC_{50} value of DAH, and STD

Sample	IC_{50} (mg/mL)
DAH	1.26 ± 0.32*
STD	0.85 ± 0.09

Each value is expressed as mean ± SD (n = 3). DAH = Dichloromethane extract of *A. heterophylla*. **P* < 0.001 against standard acarbose (independent samples t-test).

3.3 Glucose adsorption capacity assay

Glucose adsorption capacity of DAH at various concentrations of glucose (10, 20, 50, 100, and 200 mM/mL) are shown in figure 2. The DAH showed effective glucose adsorption of 8.13 %, 13.20 %, 17.40 %, 20 %, and 30 % at 10, 20, 50, 100, and 200

mM/mL concentration of glucose, respectively. These results indicate that DAH had significant glucose adsorption ability.

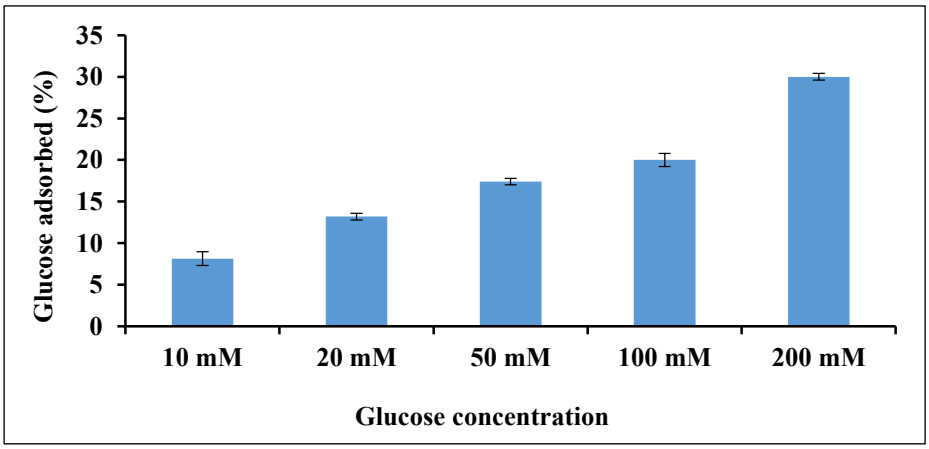


Figure 2: Glucose adsorption capacity of dichloromethane extract of *A. heterophylla*. Results are shown as mean ± SD (n = 3).

4. Discussions

Diabetes is a metabolic ailment manifested by persistent elevated level of blood glucose. Various plant-derived compounds have shown promise in managing diabetes by regulating blood glucose, and enhancing carbohydrate metabolism (Jugran *et. al.,* 2021). Key bioactive compounds contributing to diabetes management include simple phenolics, catechins, berberine, ginsenosides, curcumin, stevioside, gingerols, capsaicin, anthocyanins, resveratrol, genistein, and hesperidin. Additionally, several phytochemicals such as ascorbyl palmitate, berberine, caffeic acid, cassiaside, catalpol, ellagic acid, ferulic acid, galangin, mangiferin, and papaverine have demonstrated significant anti-diabetic effects, and potential in alleviating diabetes-related complications (Parveen *et. al.,* 2021).

Plant derived chlorogenic acid, ellagic acid, caffeic acid, gallic acid, and other phenolic or polyphenolic compounds; quercetin, rutin, kaempferol, genistein, chrysin like flavonoids; stilbenes, and lignans, have demonstrated anti-diabetic properties. These compounds help reduce glucose levels, and mitigate chronic conditions associated with hyperglycemia by offering antioxidant defense, and hindering starch digestion (Deka *et. al.,* 2022). In the management of elevated blood sugar, delayed starch digestion based on digestive enzymes restriction may offer substantial benefits for diabetic patients, complementing traditional diabetes treatments (Li *et. al.,* 2022). Precisely, the impeding of α-amylase has emerged as a substitute strategy to manage

type 2 diabetes, as it reduces glucose making from carbohydrate-rich foods, which is a primary contributor to postprandial hyperglycemia. This enzyme blocking strategy using inhibitors offers a noteworthy role in diabetes management (Jiang *et. al.,* 2021). Phenolic compounds are known for their notable hypoglycemic effects, because of their capacity to obstruct α-glucosidase, and stimulate cellular glucose uptake (San *et. al.,* 2021). Phytochemical analysis of DAH revealed the presence of several groups of bioactive compounds, including glycosides, carbohydrates, flavonoids, tannins, saponins, terpenoids, resins, sterols, phenols, alkaloids, proteins, amino acids, fats, and fixed oils (Table 1). *In-vitro* α-amylase inhibition assay demonstrated that all concentrations of DAH exhibited α-amylase blocking properties in a concentration dependent manner (Table 2, and Figure 1). The maximum α-amylase inhibition was observed at of 2000 µg/mL concentration with approximately 68.25% inhibition, while the standard acarbose showed 85.29% inhibition at the same concentration. This α-amylase inhibition capacity of DAH might be beneficial in lowering blood glucose in type 2 diabetes by limiting glucose availability for absorption or by slowing the rate of glucose absorption at the small intestine mucosal border. Several studies indicate that traditional α-amylase inhibitors slow the conversion of starch to glucose, thereby reducing blood glucose levels (Gupta *et. al.,* 2020). The phenolic, and flavonoid components found in DAH are likely linked to its α-amylase inhibitory activity, as supported by other research (San *et. al.,* 2021; & Xiao, 2022). The glucose adsorption capacity study demonstrated that DAH could effectively bind glucose, with its binding capacity showing a dependency on glucose concentration (Figure 2). Interestingly, DAH showed efficient glucose adsorption ability at both low (10 mM), and high (200 mM) concentrations. Therefore, the strong α-amylase inhibitory activity, coupled with the glucose adsorption ability of DAH, highlights its remarkable similarity, and suggests as a potential anti-diabetic candidate.

5. Conclusion

In conclusion, our *in-vitro* study showed that DAH has potent hypoglycemic properties which may be due to the bioactive phytochemicals like flavonoids, sterols, terpenoids, and poly-phenols. *In-vitro* hypoglycemic study opens the gate for further *in-vivo* study, and may thereby lead to explore the medicinal values of all components of *Araucaria heterophylla* plant.

References

Ali, H., Houghton, P.J., & Soumyanath, A. (2006). α-amylase inhibitory activity of some Malaysian plants used to treat diabetes; with particular reference to *Phyllanthus amarus*. *Journal of Ethnopharmacology*, 107(3): 449-455.

Aslam, M. S., Choudhary, B. A., Uzair, M. & Ijaz, A. S. (2013). Phytochemical and ethno-pharmacological review of the genus Araucaria–Review. *Tropical Journal of Pharmaceutical Research*, 12(4): 651-659.

Bernfeld, P. (1955). Amylases, alpha and β. *Methods in Enzymology I*. I(540), 149-158.

Bussmann, R.W. (2008). Antibacterial activity of northern-peruvian medicinal plants. *Arnaldoa*, 15(1): 127-148.

Deka, H., Choudhury, A., & Dey, B.K. (2022). An overview on plant derived phenolic compounds and their role in treatment and management of diabetes. *Journal of Pharmacopuncture*, 25(3), 199.

Divvela, H.N.D., Lohitasu, D., & Kolapalli, R.V. (2016). Isolation and acute oral toxicity studies of *Araucaria heterophylla* novel natural polysaccharide gum in albino mice. *World Journal of Pharmacy and Pharmaceutical Sciences*, 5(6):702-711.

Earle, C. (2015). *Araucaria heterophylla*. Retrieved from http://www.conifers.org/ar/Araucaria_heterophylla.php.

Goud, D.R., Reddy, G.R., Shivakoti, C., Ranjani, P.H., Kondi Vanitha, K., & Alluri Ramesh, A. (2017). Evaluation of antimicrobial activity of alcoholic extract of *Araucaria heterophylla* leaves. *World Journal of Pharmaceutical Research*, 6(2): 1287-1297.

Gupta, A., Kumar, R., & Pandey, A.K. (2020). Antioxidant and antidiabetic activities of *Terminalia bellirica* fruit in alloxan induced diabetic rats. *South African Journal of Botany*, 130, 308-315.

Jugran, A.K., Rawat, S., Devkota, H.P., Bhatt, I.D., & Rawal, R.S. (2021). Diabetes and plant-derived natural products: From ethnopharmacological approaches to their potential for modern drug discovery and development. *Phytotherapy Research*, 35(1), 223-245.

Jiang, S., Zhao, X., Liu, C., Dong, Q., Mei, L., Chen, C., Shao, Y., Tao, Y. & Yue, H. (2021). Identification of phenolic compounds in fruits of *Ribes stenocarpum Maxim.* By UHPLC-QTOF/MS and their hypoglycemic effects *in-vitro* and *in-vivo*. *Food Chemistry,* 344, 128568.

Li, X., Bai, Y., Jin, Z., & Svensson, B. (2022). Food-derived non-phenolic α-amylase and α-glucosidase inhibitors for controlling starch digestion rate and guiding diabetes-friendly recipes. *Lebensmittel-Wissenschaft & Technologie*, 153, 112455.

Manikandan, R., Anand, A.V., & Muthumani, G.D. (2013). Phytochemical and in vitro anti-diabetic activity of methanolic extract of *Psidium guajava* leaves. *International Journal of Current Microbiology and Applied Sciences, 2*(2):15-19.

Michael, H.N., Awad, H.M., El-Sayed, N.H. & Pare, P.W. (2010). Chemical and antioxidant investigations: Norfolk pine needles (*Araucaria excelsa*). *Pharmaceutical Biology*, 48(5): 534-538.

Ou, S., Kwok, K.C., Li, Y., & Fu, L. (2001). In vitro study of possible role of dietary fiber in lowering postprandial serum glucose. *Journal of Agricultural and Food Chemistry,* 49(2): 1026-1029.

Parveen, A., Sultana, R., Lee, S.M., Kim, T.H., & Kim, S.Y. (2021). Phytochemicals against anti-diabetic complications: targeting the advanced glycation end product signaling pathway. *Archives of Pharmacal Research*, 44, 378-401.

Patil, A.R., Darekar, A.B., & Saudagar, R. B. (2013). *Araucaria heterophylla*: the review. *World Journal of Pharmacy and Pharmaceutical Sciences*, 3(1) 221-232.

Sadia, S., Sarkar, B.K., Jerin, A., & Sahid, M.I. (2019). Inhibitory activity of methanolic extract of *Araucaria heterophylla* leaves against gram negative bacteria. *Jagannath University Journal of Life and Earth Sciences*, 5(2): 216-219.

San, H.T., Boonsnongcheep, P., Putalun, W., Mekboonsonglarp, W., Sritularak, B., & Likhitwitayawuid, K. (2020). α-Glucosidase inhibitory and glucose uptake stimulatory effects of phenolic compounds from *Dendrobium christyanum. Natural Product Communications*, 15(3), 1934578X20913453.

Sarada, B., Prasad, M.K., Kumar, K.K., & Murthy, ChVR. (2013). Potential use of leaf biomass, *Araucaria heterophylla* for removal of Pb^{+2}. *International Journal of Phytoremediation*, 15:756-773.

Sattara, E.A., Monemb, A.R.A., Ezzatb, S.M., El-Halawanyb, A.M., & Mouneird, S.M. (2009). Chemical and biological investigation of *Araucaria heterophylla* Salisb. Resin. *Z. Naturforsch*, 64(c): 819-823.

Shukla, D., & Vankar, P.S. (2012). Efficient biosorption of chromium (VI) ion by dry *Araucaria* leaves. *Environmental Science and Pollution Research,* 19(6): 2321-2328.

Sudha, P., Zinjarde, S.S., Bhargava, S.Y., & Kumar, A.R. (2011). Potent α-amylase inhibitory activity of Indian Ayurvedic medicinal plants. *BMC Complementary and Alternative Medicine*, 11(5).

Trease, G.E., & Evans, W.C. (1989). Pharmacognosy. 13th. Bailliere Tindall, London. 345-346.

Vennell, R. (2015). Invasive Species Report: *Araucaria heterophylla* (Salisb.) Franco. *University of Auckland.*

World Health Organization. (2018). Diabetes [Fact Sheet]. Retrieved from https://www.who.int/news-room/fact-sheets/detail/diabetes.

Xiao, J. (2022). Recent advances in dietary flavonoids for management of type 2 diabetes. *Current Opinion in Food Science*, 44, 100806.

Toward Biodegradable and Cost-Effective Vegan Leather: Alginate Composites with Natural Fillers for Eco-Friendly Textile Applications

Tanzil Hasnain Moin Roneet[1], Israt Jahan Sadia[2]
[1]Associate Professor and Head, Department of Fashion and Design, R. P. Shaha University, Narayanganj
[2]Researcher, Department of Fashion and Design, R. P. Shaha University, Narayanganj
Corresponding Author: Tanzil Hasnain Moin Roneet, moinroneet_tfd@rpsu.edu.bd

ARTICLE INFO

***Keywords*:** Sodium Alginate, Sustainable Materials, Biodegradable, Plant-based Alternatives, Fire Resistance, Cruelty-free Fashion

RECEIVED
18 May 2025

ACCEPTED
19 June 2025

PUBLISHED
31 August 2025

DOI:
https://doi.org/10.5281/zenodo.17239692

ABSTRACT

The environmental and ethical concerns associated with traditional leather production have intensified the demand for sustainable alternatives. This study investigates the development of plant-based vegan leather using sodium alginate combined with beetroot, coffee, and charcoal—aiming to provide a biodegradable, cost-effective, and cruelty-free material for Bangladesh's fashion industry. Sodium alginate, cross-linked with calcium chloride, served as the base polymer, while natural fillers enhanced texture, color, and functionality. The samples, developed under academic supervision, underwent water resistance, fire resistance, flexibility, and durability testing, with each test repeated three times to ensure reliability. Results revealed that beeswax treatment significantly improved water resistance, and charcoal-based samples exhibited the highest fire resistance, averaging 6 minutes before ignition. Fabric-backed variants demonstrated better structural integrity. Compared to commercial vegan leathers like Piñatex and apple leather, the developed material offers full biodegradability and greater cost efficiency. However, challenges such as scalability, long-term durability, and advanced mechanical validation remain. This research highlights the viability of sodium alginate-based vegan leather and emphasizes the need for industry collaboration, consumer awareness, and policy support to facilitate its adoption in Bangladesh's textile sector.

1. Introduction

The global fashion industry, one of the largest contributors to environmental degradation, faces mounting criticism for its reliance on conventional leather production, which involves deforestation, animal exploitation, and toxic chemical use (Ro, 2022). Traditional leather tanning processes, particularly chromium-based methods, release hazardous pollutants into ecosystems, endangering both environmental and human health (Alternative Leathers, n.d.). As consumer awareness of sustainability grows, the demand for ethical and eco-friendly alternatives has spurred innovation in plant-based vegan leathers (Watson & Wolfe, 2020).

Vegan leather, derived from agricultural by-products and biopolymers, offers a promising solution. Materials such as pineapple leaves (Piñatex), apple peels (Frumat), and mushroom mycelium (Mylo) have gained traction for their reduced carbon footprint and biodegradability (Panaprium, n.d.; Oliver Co. London, n.d.; Watson & Wolfe, 2020). However, many commercial vegan leathers rely on synthetic coatings like polyurethane (PU) to enhance durability, compromising their environmental benefits (Melina Bucher, n.d.). This underscores the need for fully biodegradable alternatives that balance performance and sustainability.

In Bangladesh, a hub for textile and leather exports, the shift toward sustainable materials aligns with global trends and local agricultural potential. The country's abundance of underutilized resources, such as beetroot, coffee grounds, and charcoal, presents opportunities for innovative material development (University of Colorado Boulder, 2021). Sodium alginate, a seaweed-derived biopolymer, has emerged as a viable binding agent due to its flexibility, low cost, and compatibility with natural additives (Reef, n.d.). Yet, limited research exists on its application in vegan leather, particularly in combination with locally sourced pigments and fillers.

This study addresses this gap by developing sodium alginate-based vegan leather infused with beetroot, coffee, and charcoal. By leveraging Bangladesh's agricultural waste, the research aims to create a cruelty-free, biodegradable material that outperforms existing synthetic and plant-based alternatives in cost and sustainability. The findings contribute to advancing eco-conscious fashion practices while addressing challenges such as scalability and consumer acceptance in emerging markets.

2. Literature Review

The rising global concern over the environmental and ethical implications of traditional leather production has spurred the development of plant-based alternatives. Vegan leather—produced from biodegradable, renewable resources—has emerged as a promising sustainable solution, particularly within the fashion industry (Ro, 2022).

This review critically examines the scientific foundations, sustainability metrics, and global trends in vegan leather, while identifying research gaps that justify the exploration of novel materials such as beetroot, coffee, and charcoal in combination with sodium alginate.

2.1 Material Science of Vegan Leather

The formulation of vegan leather is rooted in material science, particularly the use of biopolymers such as cellulose, alginate, lignin, and pectin. These substances emulate the fibrous collagen network found in animal hide, thereby offering structural integrity and flexibility (Watson & Wolfe, 2020). Reinforcement is often achieved through cross-linking agents like calcium chloride, while plasticizers such as glycerin enhance elasticity. Surface coatings derived from nanotechnology and natural waxes contribute to water resistance and durability (University of Colorado Boulder, 2021).
Compared to conventional leather, which relies on toxic chrome tanning, plant-based alternatives offer safer, more biodegradable solutions. However, their thermal stability and tensile strength vary depending on source materials and processing methods (Panaprium, n.d.). For instance, banana fiber demonstrates tensile strengths near 800 MPa, whereas cowhide averages 25–30 MPa.

2.2 Sources and Types of Vegan Leather

A variety of raw materials have been utilized for vegan leather production. These include pineapple leaves (Piñatex), cactus pulp (Desserto), apple peel (Frumat), mushroom mycelium (Mylo), and kombucha SCOBY (Suzanne Lee's BioCouture) (Melina Bucher, n.d.; Reef, n.d.). These plant-based materials are often derived from agricultural waste, offering dual environmental benefits: waste valorization and reduced reliance on synthetic or animal-based components.
Nevertheless, many commercial vegan leathers still incorporate polyurethane (PU) or polyvinyl chloride (PVC) coatings to enhance durability, which undermines their overall sustainability (Ro, 2022). Despite their eco-labeling, such synthetic components pose long-term environmental hazards due to poor biodegradability.

2.3 Vegan Leather in Bangladesh and Global Context

Bangladesh, with its rich agricultural base and textile expertise, offers significant potential for localized vegan leather production. Locally available materials such as banana fiber, jute, coconut husk, and beetroot can be leveraged to reduce dependency on imports (Israt, 2025). However, current initiatives remain fragmented due to limited infrastructure, high production costs, and low consumer awareness.

Globally, sustainable leather initiatives are expanding rapidly. Countries like Germany, the Netherlands, and Italy are leading efforts through green manufacturing policies, carbon footprint reduction, and ethical fashion campaigns (Watson & Wolfe, 2020). Simultaneously, leading brands are investing in alternative materials as part of broader corporate sustainability strategies.

2.4 Research Gaps and Opportunities

Most current research focuses on materials such as Piñatex, apple peel leather, and Mylo, often neglecting other regionally abundant bio-resources like coffee grounds and charcoal. Furthermore, many studies emphasize laboratory-scale material properties while ignoring field performance, scalability, and life-cycle impact assessments (Israt, 2025). The lack of real-world durability tests, consumer market research, and economic viability studies underscores the need for more integrated research frameworks.

2.5 Sustainability and Performance Metrics

Key performance metrics for vegan leather include carbon footprint, biodegradability, durability, and cost-effectiveness. Compared to synthetic vegan leather (e.g., PU or PVC), plant-based options tend to offer superior environmental profiles but may lack consistency in mechanical properties. Coffee-based composites, for instance, introduce natural oils and antioxidants that enhance texture but reduce fire resistance (Israt, 2025). Conversely, charcoal-based formulations exhibit excellent fire resistance but may require conditioning agents to prevent brittleness.

3. Research Objectives

This study aims to explore sustainable alternatives to conventional leather by developing plant-based vegan leather using locally available materials in Bangladesh. The specific objectives are

- to develop biodegradable vegan leather using beetroot, coffee, and charcoal as primary raw materials combined with sodium alginate as a natural binding agent.
- to evaluate the physical and functional properties of the developed vegan leather, focusing on flexibility, durability, water resistance, and fire resistance.
- to compare the performance of the developed materials against both traditional animal leather and commercial vegan leather products.

- to assess the feasibility and cost-effectiveness of producing alginate-based vegan leather using indigenous resources within the context of Bangladesh's fashion industry.
- to identify potential applications of the developed leather in sustainable fashion products such as accessories, footwear, and apparel.
- to contribute to the broader discourse on sustainable fashion, offering eco-friendly material innovation grounded in circular economy principles and agricultural waste utilization.

4. Methodology

A systematic experimental design was followed, covering material preparation, sample development, and property evaluation. All property tests were repeated in triplicate for data reliability. The methodology comprised the following key steps:

4.1. Material Selection and Preparation

- Sodium alginate was selected as the primary biopolymer due to its gel-forming and biodegradable properties.
- Beetroot, coffee grounds, and charcoal powder were used as natural fillers and colorants.
- Glycerin and soybean oil were incorporated as plasticizers and conditioners.
- Calcium chloride ($CaCl_2$) served as a crosslinking agent to enhance structural integrity.

Each raw material was sun-dried, ground into powder or paste, and then blended with sodium alginate solution to form a homogenous bio-composite. The entire experimental process was supervised and reviewed by Tanzil Hasnain Moin Roneet, Associate Professor, Department of Textile and Fashion, RPSU, ensuring academic oversight of the home-based laboratory setup.

4.2. Sample Development

Two types of samples were developed
- Standalone vegan leather sheets
- Fabric-backed composite leather

The mixture was poured into molds and allowed to set for 12 hours before crosslinking with $CaCl_2$ solution. The samples were air-dried for 3–4 days at room temperature. Beeswax was applied post-drying for waterproofing.

4.3. Testing and Evaluation

The prepared samples were evaluated through home-based tests for the following properties: The tests were conducted between March 15–20, 2025, under the supervision of Tanzil Hasnain Moin Roneet, Associate Professor, Department of Textile and Fashion, RPSU.

Each performance test (water, fire, flexibility, and bending strength) was conducted in triplicate across different days to account for consistency and reduce observational bias.

- Water resistance (via spray and droplet test)
- Fire resistance (measured time to ignition using a controlled flame)
- Texture and flexibility (qualitative observation)
- Bending strength and structural integrity (manual stress testing)

4. 4. Comparative Analysis

Results from the developed samples were compared with the physical attributes of traditional animal leather and commercially available vegan leathers (e.g., Piñatex, apple leather, cactus leather), referencing both laboratory data and published studies.

5. Results and Discussion

This section presents the experimental outcomes of developing alginate-based vegan leather using beetroot, coffee, and charcoal. The materials were tested for their water resistance, fire resistance, texture, flexibility, and structural integrity. Comparative analysis was also conducted against conventional and commercial vegan leather products.

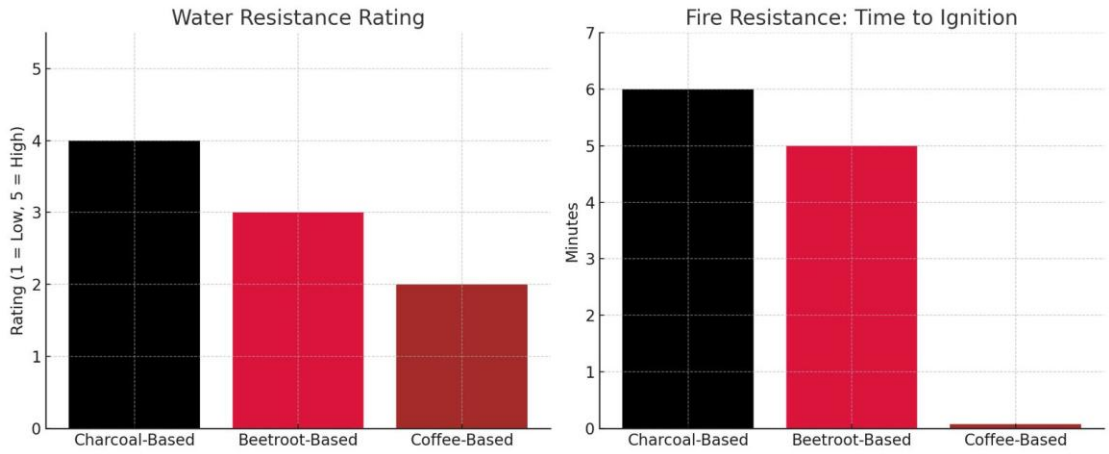


Figure 1. Water resistance ratings (left) and fire resistance performance (right) of vegan leather samples.

All test results were averaged over three trials conducted under controlled home-lab conditions.

Future work will incorporate statistical variance and standard deviation analysis to validate result robustness.

5.1. Texture, Flexibility, and Appearance

- Beetroot-based leather exhibited a smooth and pliable surface, with rich natural pigmentation. The sample was moderately elastic and had a leather-like feel.
- Coffee-based leather had a slightly coarse texture due to fine coffee granules and showed moderate flexibility. Its dark color mimicked conventional leather.
- Charcoal-based leather produced the firmest structure with high surface uniformity. It demonstrated superior dimensional stability but required conditioning for softness.

5.2. Water Resistance Performance

A five-minute water droplet test was conducted. The rating scale ranged from 1 (low resistance) to 5 (excellent resistance):

A five-minute water droplet test was conducted. The rating scale ranged from 1 (low resistance) to 5 (excellent resistance):

Table 1. Water Resistance Ratings of Vegan Leather Samples

Material	Water Resistance Rating (1–5)	Observation
Charcoal-Based	4	Surface beading, minimal absorption
Beetroot-Based	3	Minor dampness, slight water penetration
Coffee-Based	2	Noticeable absorption, required beeswax coating

5.3. Fire Resistance Test

Fire tests measured the time to ignition under direct flame (1 cm distance). The results were:

Table 2. Fire Resistance (Time to Ignition) of Vegan Leather Samples

Material	Time to Ignition	Observation
Charcoal-Based	6.0 minutes	High resistance; flame extinguished naturally
Beetroot-Based	5.0 minutes	Moderate resistance; slow combustion
Coffee-Based	0.075 minutes (4.5s)	Quick ignition; fast flame spread

5.4. Structural Integrity and Bending Strength

- Fabric-backed versions outperformed standalone leather in strength, offering higher resistance to cracking during bending.
- Charcoal-based leather, in particular, maintained structural integrity under repeated folds.
- The beetroot-based variant was more elastic but showed slight softening under stress.
- Coffee-based leather was least durable under bending, requiring reinforcement.

5.5. Comparison with Existing Alternatives

Table 3. Comparison of Developed Vegan Leather with Animal and Commercial Alternatives

Criteria	Animal Leather	Piñatex / Apple Peel	Developed Leather
Material Source	Animal hide	Agricultural waste (PU coated)	Beetroot/Coffee/ Charcoal + Alginate

Biodegradability	Low (due to tanning)	Moderate	High
Water Resistance	Naturally high	Moderate (needs coating)	High with beeswax treatment
Fire Resistance	Moderate	Low to moderate	High (Charcoal), Moderate (Beetroot)
Cost	High	High	Low (locally sourced)
Sustainability	Low	Moderate	High

5.6. Texture and Flexibility Evaluation

Samples were scored based on visual and tactile inspection using a 5-point scale (1 = poor, 5 = excellent):

Table 4. Texture and Flexibility Scores of Vegan Leather Samples

Material	Texture Score (1–5)	Flexibility Score (1–5)
Charcoal-Based	4	3
Beetroot-Based	5	4
Coffee-Based	3	2

Beetroot-based leather received the highest texture and flexibility scores, making it ideal for flexible fashion items.

Charcoal-based leather scored well in texture but was slightly stiffer.

Coffee-based leather had moderate texture but lower flexibility, requiring improvement for wearable applications.

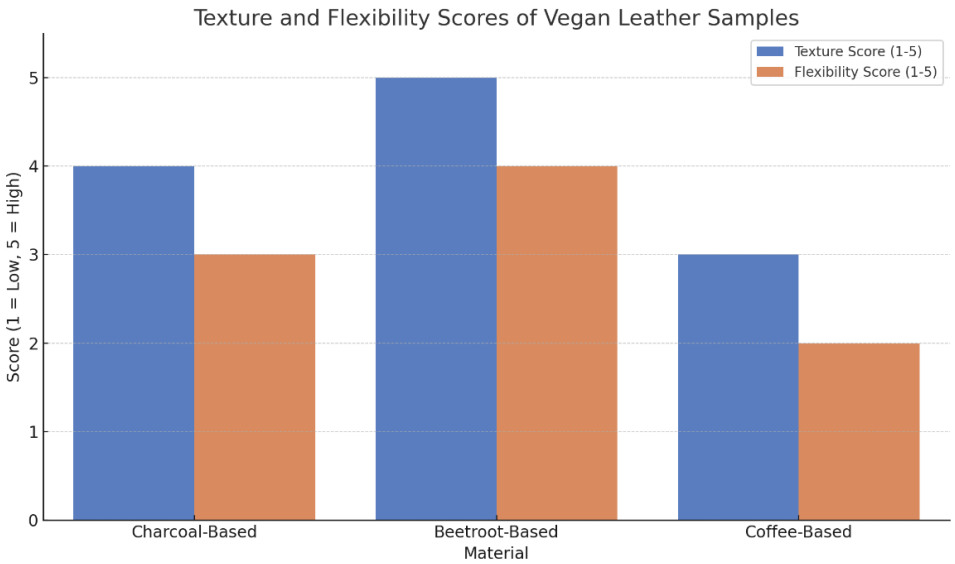


Figure 2: Texture and Flexibility Scores of Vegan Leather Samples

- **Beetroot-based leather** received the highest texture and flexibility scores, making it ideal for flexible fashion items.
- **Charcoal-based leather** scored well in texture but was slightly stiffer.
- **Coffee-based leather** had moderate texture but lower flexibility, requiring improvement for wearable applications.

5.7. Bending Strength and Cost Comparison

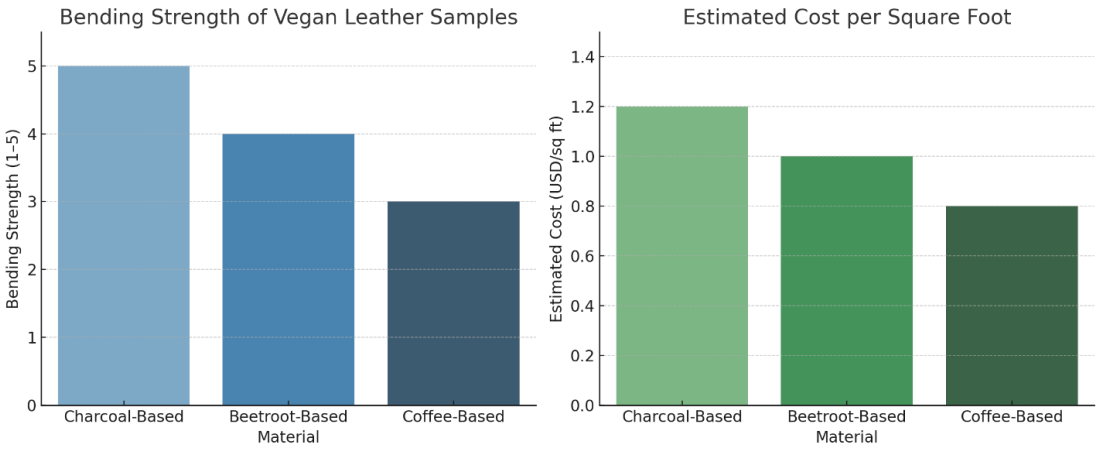


Figure 3: Bending Strength and Cost Comparison

Bending strength was rated based on resistance to cracking and structural retention during repeated folds. Estimated production costs per square foot were calculated based on material inputs and local resource availability.

Table 5. Bending Strength and Estimated Cost of Vegan Leather Samples

Material	Bending Strength (1–5)	Estimated Cost (USD/sq ft)
Charcoal-Based	5	1.20
Beetroot-Based	4	1.00
Coffee-Based	3	0.80

- **Charcoal-based leather** demonstrated the highest bending durability but was the most costly due to processing and conditioning needs.
- **Beetroot-based leather** struck a balance between strength and affordability.
- **Coffee-based leather** was the most cost-efficient but showed lower structural resilience.

6. Summary of All Performance Metrics

Table 6. Summary of All Performance Metrics of Vegan Leather Samples

Performance Metric	Charcoal-Based	Beetroot-Based	Coffee-Based
Water Resistance (1–5)	4	3	2
Fire Resistance (min)	6.0	5.0	0.075
Texture Score (1–5)	4	5	3
Flexibility Score (1–5)	3	4	2
Bending Strength (1–5)	5	4	3
Cost (USD/sq ft)	1.20	1.00	0.80

The results confirm that alginate-based vegan leather has the potential to serve as an eco-friendly, functional substitute for both animal and synthetic vegan leathers. Notably:

- **Charcoal-based leather** excels in fire resistance and structural stability, making it suitable for footwear and accessories.

- **Beetroot-based leather** combines color vibrancy and flexibility, ideal for fashion applications like bags and chokers.
- **Coffee-based leather**, while aesthetically pleasing, requires further optimization to improve fire and water resistance.

7. Conclusion and Future Recommendations

Conclusion

This study developed three types of biodegradable vegan leather using sodium alginate combined with beetroot, coffee, and charcoal—leveraging locally available resources in Bangladesh. Charcoal-based leather showed superior fire resistance and durability; beetroot-based variants were most flexible and visually appealing; coffee-based leather was cost-effective but less robust. The materials proved more affordable and environmentally friendly than commercial vegan leathers like Piñatex or apple leather. While results confirm the potential of alginate-based composites for sustainable fashion, challenges remain in scalability and mechanical validation. Pilot production, quality control, and industry collaboration are essential next steps. Overall, the study demonstrates a viable path toward cruelty-free, cost-effective, and eco-friendly leather alternatives suitable for fashion, accessories, and footwear.

Future Recommendations

Despite the promising results, several areas require further exploration:

Advanced Mechanical Testing

Future studies should incorporate lab-based tensile strength, tear resistance, and abrasion testing to validate the materials' usability for commercial applications.

Fireproofing Optimization

The integration of natural flame retardants (e.g., borax, kaolin clay, or wool protein) should be tested to enhance fire resistance without compromising biodegradability.

Waterproofing Enhancement

Although beeswax provided basic water resistance, other plant-based hydrophobic coatings should be explored for more effective moisture control.

Life-Cycle Assessment (LCA)

Comprehensive environmental impact assessments—including carbon emissions, water footprint, and end-of-life decomposition—should be conducted to quantify sustainability benefits.

Scalability and Industrial Production

Pilot-scale production trials are recommended to evaluate the feasibility of mass production, supply chain integration, and quality control.

Consumer Perception and Market Research

Surveys and focus groups with designers, retailers, and consumers could offer insights into acceptance, design preferences, and pricing tolerance.

Policy and Industry Collaboration

Partnerships with eco-conscious fashion brands and support from government bodies could accelerate mainstream adoption, especially through sustainability incentives or green certifications.

With proper research, industrial investment, and consumer education, plant-based vegan leather—particularly those developed in this study—can become a mainstream solution for a more ethical, affordable, and environmentally sustainable fashion industry.

References

Alternative Leathers. (n.d.). Eco-friendly leather alternatives: A comprehensive guide. Retrieved from https://www.alternativeleathers.com

Israt, T. (2025). Sustainable material innovation in Bangladesh: Challenges and opportunities for plant-based leather. Dhaka University Press.

Melina Bucher. (n.d.). Sustainable fashion and leather alternatives. Retrieved from https://www.melinabucher.com

Oliver Co. London. (n.d.). Apple leather: The future of sustainable fashion. Retrieved from https://www.olivercompanylondon.com

Panaprium. (n.d.). The most sustainable vegan leather alternatives. Retrieved from https://www.panaprium.com

Reef, J. (n.d.). Biopolymers in textile design: Applications of alginate and pectin. Journal of Sustainable Materials, 12(3), 44–58.

Ro, A. (2022). Fashion's carbon footprint: Leather, sustainability, and innovation. Environmental Fashion Review, 9(1), 21–33.

University of Colorado Boulder. (2021). Engineering sustainable textiles using agricultural waste and biopolymers. Retrieved from https://www.colorado.edu/research/textile-biomaterials

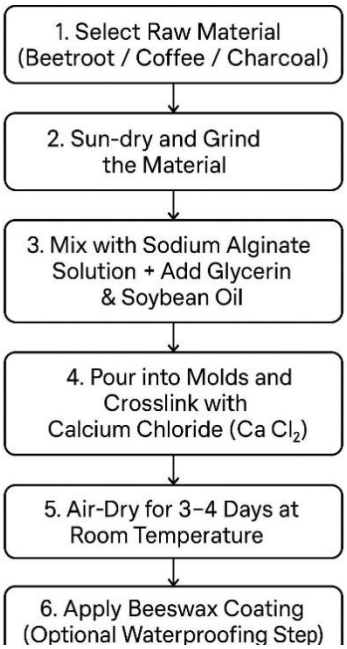
Watson, L., & Wolfe, M. (2020). The future of vegan leather: Innovations in plant-based materials. Journal of Ethical Fashion, 5(2), 59–72.

Appendix

Appendix A: Materials Used in Sample Preparation

Component	Function
Sodium Alginate	Biopolymer base; provides structure and flexibility
Calcium Chloride	Crosslinking agent; enhances strength
Glycerin	Plasticizer; improves softness
Soybean Oil	Conditioning agent; enhances durability
Beetroot	Natural colorant and fiber source
Coffee Grounds	Provides oil, texture, and color
Activated Charcoal	Adds strength, texture, and dark color
Distilled Water	Solvent; ensures purity
Beeswax	Natural waterproofing treatment

Appendix B: Flowchart of the Vegan Leather Development Process



Appendix C: Home-Based Test Protocols

C.1 Water Resistance Test Procedure

- Spray water lightly on sample surface.
- Observe surface beading, absorption, or penetration.
- Wipe with tissue after 5 minutes and record moisture level.

C.2 Fire Resistance Test Procedure

- Hold sample 1 cm from an open flame using tweezers.
- Record time until ignition.
- Observe burning behavior, smoke emission, and self-extinguishing capacity.

C.3 Flexibility and Bending Test

- Bend sample in multiple directions.
- Note any cracks, stiffness, or structural changes.

- Repeat test with both standalone and fabric-backed samples.

Examining the Impact of Financial Performance on Environmental Accounting Practices in the Banking Sector of Bangladesh

Md. Shafiqul Islam[1] and Md. Minhaj Uddin[1]
[1]Associate Professor, Department of Accounting and Information Systems, Jatiya Kabi Kazi Nazrul Islam University, Trishal, Mymensingh.
Corresponding Author: Md. Shafiqul Islam, PhD, shafiquejkkniu@gmail.com

ARTICLE INFO

Keywords: Firms Performance, Environmental Accounting, Firm Size, ROA, ROE

RECEIVED
11 May 2025

ACCEPTED
26 July 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17292945

ABSTRACT

This paper examined the effect of financial performance on environmental accounting and reporting practices in Bangladesh's banking sector. Following the random sampling method, this study collected secondary data from 20 listed banks' annual reports from 2012 to 2021. Multiple regression analysis was applied to test the linkage between banks' performance and their environmental accounting practices. The analysis revealed no statistically significant connection between financial performance and environmental accounting and reporting practices. However, a favorable linkage was found between firm size and environmental reporting practices. By emphasizing the financial and organizational stimuli influencing environmental reporting behaviors in the banking sector of Bangladesh, the study offers valuable insights for policymakers, regulators, and industry practitioners.

1. Introduction

The banking sector, a key player in fostering economic well-being and development in Bangladesh, acts as an intermediary between investors and borrowers, providing investment facilities and driving commerce and financial development through financial inclusion. The sector's role is crucial, and its contributions are vital, underscoring the importance of incorporating environmental considerations into the corporate practices of the Bangladeshi banking sector. Environmental practices serve as a medium of showing banks' commitment to environmental protection, communicate their activities' effects on environmental and their efforts to minimize environmental risks. Ongoing pressure from stakeholders, global reporting frameworks, society, and policymakers is compelling banks to adopt more transparent and accountable environmental practices. By adopting environmental accounting cultures, banks in Bangladesh can meet society's demands, evaluate and reduce environmental risks, identify opportunities for sustainable development, and enhance their goodwill among environmentally conscious people (Deb et al., 2020; Deb et al., 2022; Sobhani et al., 2012; Khan et al., 2010). Environmental disclosure practices can also create long-term value by reporting their environmental motto, plans, and environmental performance tools, aligning their business operations with sustainable goals (Dura & Suharsono, 2022; Kurniawan & Fitranita, 2024). One of the most important optional disclosures that denote sustainable company operations to protect the environment is an environmental accounting practice. It is emergency in lowering environmental crises and enhancing the environmental conditions today. As a result, environmental accounting (EAR) could act as a safety net by establishing corporate entities' accountability for their measures to save the environment in their corporate initiatives (Dilling, 2010). Additionally, EAR, CSR, sustainability reporting, and sustainability practices enhance an entity's reputation among owners and stakeholders, indirectly motivating corporate management to use environmental accounting and enhance the environment (Elijido-Ten, 2011). Even though there are no legal obligations, many companies choose to disclose environmental information voluntarily. This indicates that diverse internal and external factors influence the extent and quality of environmental accounting practices.

Several theoretical perspectives provided valuable insights into how a firm's financial performance can drive its environmental disclosures quality. According to Slack Resource Theory, companies with better financial scores have excess resources that can be used for voluntary environmental reporting, without jeopardizing their main operations. In the same way, Legitimacy Theory indicates that financially healthy firms are more likely to attract public attention, which in turn, compelling firms to legitimize their actions through transparent disclosure of environmental impacts. Additionally, the Resource-Based View (RBV) suggests that firms with strong

financial performance are better able to develop their internal competencies in regard to environmental management, which in result supports robust environmental disclosure. Taken together, these theories highlight that sound financial performance not only facilitates but also incentivizes organizations to be more active and transparent in environmental reporting.

Despite the increasing significance of environmental accounting practices in the banking sector, there seems to be a research gap, particularly investigating the effect of firm performance on environmental accounting behaviors within the Bangladeshi context. This gap presents an intriguing opportunity for further exploration. Examining how firms' performance affects environmental reporting cultures is vital for Bangladeshi policymakers, stakeholders, regulators, and businessmen to develop strategies and adopt initiatives that foster environmental sustainability. Previous studies extensively discussed how environmental accounting behaviors influence firm performance, while rare efforts have been made to examine the opposite relationship. Considering this situation, this study seeks to examine the effect of firm performance on environmental accounting practices in Bangladesh's banking sector. By conducting an empirical investigation, this study tries to provide valuable insights that are likely to add value to the current literature on environmental accounting and sustainability within the banking sector, providing practical contributions and practical implications for policymakers, regulators, and industry practitioners in Bangladesh.

2. Literature Review and Hypothesis formulation

2.1 Literature Review

A substantial body of literatures emphasizes the growing significance of environmental reporting in promoting the sustainable development. Several scholars have explained the connection between environmental reporting and firm performance from different perspectives.

Abed (2019) investigated the potential of green financial institutions in Iraq to support a sustainable economy, focusing policy interventions to ensure environmental responsibility across generations. Likewise, Eny & Rum (2019) and Shakkour et al. (2018) argued for integrating costs into corporate practices. Their results recommend that correct environmental accounting improves both efficiency and sustainable corporate growth.

In Southeast Asia, Islam& Rahman (2022) and Giang et al. (2020) highlighted on Bangladesh and Vietnam respectively, emphasizing the importance of green accounting in accelerating sustainability. Yet, these researches suggest that green accounting is perceived as cost-effect by many companies, which discourages widespread acceptance—particularly in developing countries.

Additionally, Deb et al. (2020) tested how green accounting efforts such as actions, investments, and strategies match with institutional and shareholder requirements in the banking sector. Their result demonstrated significant favorable linkage between bank performance and green reporting, although bank size has negative moderating effect on this connection.

Corporate governance attributes are considered as the prime factors of environmental disclosures quality. Masud et al. (2018) examined South Asian organizations and demonstrated that institutional ownership, board size, and independence favorably influence environmental sustainability reporting. Likewise, Osemene et al. (2020) emphasized the impact of investor composition and board committees and in finding the environmental reporting level across six African countries. Based on agency, legitimacy and stakeholder theories, the results indicate that well-governed organizations are more likely to accept transparent reporting practices.

The association between environmental reporting and performance is additionally explained by socio-political forces. Doan & Sassen (2020) performed a meta-analysis presenting that environmental reporting is weakly connected with actual environmental scoring. Wu et al. (2020) also performed similar study on Chinese firms, demonstrating that external stimuli like carbon disclosure information and media coverage considerably influence firm goodwill and competitiveness.

On the other hand, Yusoff & Daras (2014) revealed that environmental disclosures level among Malaysian industrial organizations is minimum which covers only 22% compliance level across main indicators. Singh et al. (2018) found similar finding in India, where such reporting is mainly qualitative and lack of standardization. In Nigeria, Beredugo & Biobele (2018) evidenced that environmental investments considerably impact business profitability and social responsibility approaches.

In the context of South Asia, Ekundayo & Odhigo (2021) and Tien et al. (2020) examined the interplay between sustainability efforts and environmental reporting. Their analysis outcomes highlight that corporate environmental strategy (CES) and corporate social responsibility (CSR) considerably lead to financial success, but gaps are found in the incorporation of these approaches into long-run corporate strategies.

Earlier studies have also identified how environmental management accounting (EMA) impacts on both financial and environmental performances. In Bangladesh, Deb et al. (2022) showed that EMA favorably and significantly affects financial performance (FP) and environmental performance (EP). In the same way, Dura & Suharsono (2022) presented that green reporting and financial success enhance long-term development, but green reporting can't foster growth until backed by financial outcomes. Islam et al. (2024) have showed that environmental reporting favorably and considerably influences the market performance, although this effect is insignificant for financial performance. Sobhan et al. (2025) found that despite poor reporting performance in Bangladesh, environmental disclosures have positive and

significant bearing on both accounting-based and market-based performance metrices. Besides, greater degree of board independence is found to increase this positive linkage. These outcomes support the view that integrating financial and environmental strategies is vital for sustained performance

Despite substantial research efforts focusing the environmental reporting relevance, a significant gap exists in explaining how company-specific financial performance indicators impact environmental accounting and disclosure practices—especially in the Bangladeshi context. The extent of research in Bangladesh does not directly examine how profitability, return on assets (ROA), or return on equity (ROE) drive environmental reporting practices.

Due to scarce empirical finding on the linkage between financial performance and environmental disclosure in the context of Bangladesh, it demands more research to explore whether better performing firms engage in enhanced transparency in environmental reporting. This study aims at addressing this gap by testing the connection between firm financial performance and environmental disclosure in the Bangladeshi context, and thus contributing new additions to the literature on corporate environmental reporting in emerging countries. Therefore, researchers focus on the research framework shown in figure 1:

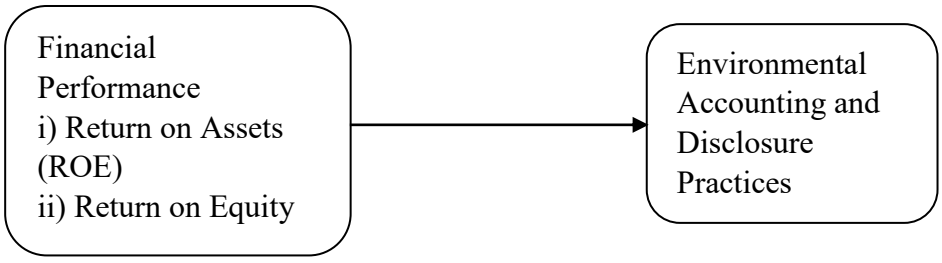


Figure-1: Conceptual Framework

2.2 Hypothesis development

In financial and operational aspects, highly performing companies may influence several activities, including environmental reporting efforts. Various earlier researches provided some arguments in this regard. Jones et al. (2007), revealed that several financial performance related variables including cash position, capital structure, working capital, and different asset-related ratios have positive bearing on the sustainability reporting. Similirly, Dilling (2010) have evidenced that companies with higher profits margins are more likely to generate high-quality sustainability reports. Masud et al. (2018) argued that higher financially performing firms with

higher ROE and ROA have more excellent resources and stability, leading to more investment in environmental practices and reporting activities. Singh et al. (2018) concluded that profitable companies face special monitoring from stakeholders such as regulators, customers, shareholders, and governments for better environmental practices. Firms with greater ROA and ROE always attempt to enter long-run strategic positions through environmentally sustainable reporting to create competitive advantage and enhance prospects (Tien et al., 2020). Additionally, financially well-off firms can invest more to comply with environmental compulsions, including sustainable environmental reporting mandates (Osemene et al., 2020). In the same way, Sitorous et al. (2024) have concluded that profitability plays moderating role on the influence of the board of directors and leverage on sustainability report disclosure. In line with this, Lin et al. (2025) argued that corporate financial performance (CFP) is positively linked with corporate sustainability performance (CSP). Finally, financially successful companies can create market differentiation and, thereby, an extra advantage when they showcase their environmental performance to meet the demands of environmentally conscious stakeholders (Giang et al., 2020). Likewise, high performance in terms of increased ROA and ROE can significantly influence environmental reporting practices through resource distribution initiatives, meeting stakeholders' needs, prioritizing sustainable efforts, confirming regulatory mandates, and market differentiation initiatives. Therefore, it is hypothesized that

H_1: Financial performance measured by Return on Equity (ROE) positively influences the enlivenment reporting practices.

H_2: Financial performance measured by Return on Assets (ROA) positively influences the enlivenment reporting practices.

3. Methodology

3.1 Papulation, sample and data:

This study's population comprises all 30 banks listed on the Dhaka Stock Exchange Limited in Bangladesh. Following the random selection method, we chose 20 banks out of the 30 listed on the Dhaka Stock Exchange as the sample size, constituting 66.67% of the total population, which provides statistical significance and confirms the generalizability of findings.

This study is mainly based on secondary data collected from various annual reports of listed banks. The data collection spans from 2012 to 2021, spanning a decade of information. The data for the most recent year, 2022-2023, for some banks are unavailable now, so researchers could not include the required data for 2022.

Researchers conducted a content analysis of the annual reports obtained from the banks' websites as environmental-related information is published in the companies' annual reports. The annual report is the most reliable source for examining the performance concerning any disclosure compared to any alternative source (Khan et al., 2013). The sample distribution is summarized in Appendix 1.

3.2 Model

To achieve the objective of this research, researchers used two research models (ROE model and ROA model) comprising dependent, independent and control variables. The following two equations expresse the research models:

(i) $EARD_{it} = \beta_0 + \beta_1 ROE + \beta_2 FAGE + \beta_3 FSIZE + \varepsilon$

(ii) $EARD_{it} = \beta_0 + \beta_1 ROA + \beta_2 FAGE + \beta_3 FSIZE + \varepsilon$

Where, EARDs refers to environmental accounting and disclosure score measuring the dependent variable. ROE and ROA are the independent variables measuring return on assets and return on equity respectively. The independent variable is firm performance as assessed by the environmental disclosure index, made through content analysis of six contents on environmental disclosure of the sample firms. β0 is the constant, and β1–3 is the slope of control and independent variables. FAGE and FSIZE, the control variables, indicate firm age and firm size respectively, (ε) indicates random error, (i) denotes sample firms and, (t) indicates the period.

3.3 Variable selection

Researchers built the environmental disclosure index to assess how the firm influences environmental disclosure, utilizing a coding approach. Under this methodology, if a bank reports any item of the environmental aspects, it gets one as a score, and otherwise 0. Earlier researches such as Islam et al. (2024), Tien et al. (2020), Giang et al. (2020), and Hosain et al. (2018) employed this approach to make the disclosure index. All environmental disclosure contents are divided into six categories, including 18 points. The categories chosen based on current Bangladesh Bank green policy guidelines and previous research are environmental regulation, waste management, environmental award, environmental audit, environmental cost, and energy usage. The EARD disclosure score index (EARD) is created for the 18 points.

By following the formula proposed by Cooke (1992), an unweighted environmental disclosure index (EDI) was utilized in this study to assess whether the sample firms

disclosed environmental information in their annual reports. The formula is as follows:

$$EARDs = \sum_{i=1}^{n} di$$

Here,

EARDs = Environmental Accounting and Reporting Score for each bank for a given year; and

di = 1 if the item is reported, or 0 otherwise and n = Total score of items

The variable construction and their measurement approach are exhibited in the following Table 1.

Table 1: Variable assessment

Constructs	Form	Assessments	Source
Independent Variables			
Firm Performance	ROA	Net profit after tax divided by total assets	Agyemang et al. (2023)
	ROE	Net profit after tax divided by shareholder equity	Islam et al. (2024)
Dependent Variable			
Environmental and Accounting Disclosure Index	EARD	The Environmental Disclosure Index is ascertained as the number of environmental items disclosed divided by the maximum number of environmental items disclosed multiplied by 100.	Wu et al. (2020) and Islam et al. (2024).
Control Variables			
Firm Age	FAGE	The natural logarithm of the number of years since the firm was listed.	Deb et al. (2022) and Islam et al. (2024).
Firm Size	FSIZE	The natural logarithm of total asset.	

4. Results Analysis

4.1 Descriptive Statistics

Table 2 shows the statistics of the variables considered in the research model involving average and standard deviations. The mean values for EARD, ROE, ROA, FAGE, and FSIZE are 10.3650, 11.75%, 0.94%, 27.33 years, and 9.1644, respectively, with corresponding standard deviations of 2.80555, 3.81%, 0.38%, 11.46 years, and 2.13264. On the hand, the minimum values for same variables are 4.74, 4.23%. 0.17%. 4.39 years, and 4.78 with corresponding maximum values of 15.87, 19.29%, 1.73%, 39.75 years, and 13.42. Standard deviation values indicate that there is a moderate amount of variability in each of the constructs considered around its average.

Table: 2 Descriptive statistics

Variable	Unit of measurement	Mean	Standard deviation	Minimum	Maximum	N
EARD	(Score)	10.3650	2.80555	4. 74	15.87	200
ROE	(%)	11.7514	3.80912	4.23%	19.29%	200
ROA	(%)	0.9410	0.37752	0.17%	1.73%	200
FAGE	(Years)	27.3300	11.45983	4.39	39.75	200
FSIZE	(Natural log of total assets)	9.0825	2.13264	4.78	13.42	200

Source: Researcher's Calculation

4.2 EARDs ranking of **Sample Banks**

Table 3 depicts the Environmental Accounting and Reporting Disclosures (EARDs) for 20 banks covering a decade, showing their respective percentages and rankings in EARDs. Bank Asia, Islami Bank Limited, and NCC Bank demonstrates top

performance in EARDs with percentages of 78.89%, 76.67%, and 71.67%, respectively, implying that they are strongly committed to environmental accounting and reporting. Whereas Jamuna Bank, Eastern Bank, and United Commercial Bank are mid-range performers in terms of EARDSs, with percentages ranging from 66.11% to 63.33%. Although they are not topper, they still show considerable level of commitment towards EARDs. Conversely, banks towards the bottom of the list, such as Trust Bank, One Bank, and Uttara Bank fall in bottom line, with percentages ranging from 47.78% to 35.56%, indicating efforts to be taken for improvement.

Table 3: EARDs rankings in 18 items from 2012-2021

Banks Name	EARDs (10 years)	Percentage (%)	Rank
BANK ASIA	142	78.89	1
ISLSMI BANK LIMITED	138	76.67	2
NCC BANK	129	71.67	3
JAMUNA BANK	121	67.22	4
EASTERN BANK	119	66.11	5
UNITED COMMERCIAL BANK	117	65	6
DHAKA BANK	114	63.33	7
DUTCH-BANGLA BANK	112	62.22	8
MERCANTILE BANK	104	57.78	9
SOUTHEAST BANK	101	56.11	10
BRAC BANK	100	55.56	11
STANDARD BANK	96	53.33	12
AL-ARAFA ISLAMI BANK	94	52.22	13
CITY BANK	94	52.22	13
PUBALI BANK	90	50	15
IFIC BANK	89	49.44	16
PREMIER BANK	88	48.89	17
TRUST BANK	86	47.78	18
ONE BANK	75	41.67	19
UTTARA BANK	64	35.56	20
Source: Researchers' Calculations			

4.3 Analysis of Co-relation Matrix

The table 4 displays the correlation matrix between Environmental Accounting and Reporting Disclosures (EARD), Return on Assets (ROA), Return on Equity (ROE), Firm Age (FAGE), and Firm Size (FSIZE). EARD is negatively correlated with ROA (-0.043), FAGE (-0.108), and positively correlated with ROE (0.013) and FSIZE (0.451), implying minimal linear relationships between EARD and ROA/ROE, EARD and FAGE, but significant linkage between EARD and FSIZE. Conversely, ROE and ROA is positively corelated with each other, providing a strong association between them. In these outcomes, none of the correlation coefficient values are greater than usually accepted threshold of **0.80**, implying that multicollinearity is not serious concern among the variables considered.

Table 4: Correlation Statistics

Constructs	EARD	ROA	ROE	FAGE	FSIZE
EARD	1.000				
ROA	0.043	1			
ROE	0.013	0.798**	1		
FAGE	-0.108	-0.029	-0.114	1	
FSIZE	0.451**	0.376**	0.344**	0.319**	1

**. Correlation is significant at the 0.01 level (2-tailed).
Source: Researchers' Calculation.

4.4 *Multicollinearity analysis*

According to Neter & Shakhar (1989), when the tolerance is less than 0.1 or variable inflation factor (VIF) score is above 10, the data violates the collinearity assumption. Table 5 displays the multicollinearity results, providing the tolerance values for the independent variables ranging from 0.901to 0.987, when the VIF values spans from 1.013 to 1.081 respectively. This demonstrates that the model does not suffer from multicollinearity issues and can be considered valid for conducting data analysis.

Table 5: Multicollinearity results

Variable	**Tolerance**	**VIF**
ROA	0.987	1.013
ROE	0.954	1.048
FAGE	0.901	1.081
FSIZE	0.931	1.072
Source: Researchers' Calculations		

4.5 *Divergent validity analysis*

In this study, the divergent validity is ensured utilizing Mahalanobis' distance, as advocated by McLachlan (1999). When the values calculated exceed the recommended threshold (18.47) for four independent variables, it indicates the existence of multivariate outliers. Table 6(A) shows that ascertained values for Mahalanobis' distance is 15.430 for ROE model (see table 6(B) and 11.392 for ROA model (see table 6 (B), which are lower than suggested value of 18.47, indicating no outlier is present in the models. Besides, Cook's distance was employed, recommended by Kim et al. (2001), to estimate the effect outliers, if any, on the regression model. Table 6(A) and 6(B) reveals that the values for Cook's distance remain below suggested value of 1.00, implying that the model is free from outlier's effect and thereby, confirming the divergent validity of this study.

Table 6 (A): Statistics for divergent validity for ROE model

	Minimum	Maximum	Mean	St. Deviation	N
Mahal. Distance	0.235	14.085	2.985	2.152	200
Cook's Distance	0.000	0.075	0.005	0.009	200
Dependent Variable: EARD Source: Researchers' analysis					

Table 6 (B): Statistics for divergent validity for ROA model

	Minimum	Maximum	Mean	St. Deviation	N
Mahal. Distance	0.139	11.392	2.985	2.110	200
Cook's Distance	0.000	0.067	.005	.008	200
Dependent Variable: EARD Source: Researchers' analysis					

4.6 Hypothesis testing results and Discussion

After satisfying the model's validity, researchers conducted analysis for testing hypothetical connections. The outcomes of hypothesis testing are exhibited in the Table-7 and Table-8. The beta co-efficient *(β)*, t-value, and p-value were used to evaluate each variable's significance in estimating EARD. Analysis results indicate that coefficients of ROE (*β=0.085*) and ROA (*β=0.089*) are favorable, revealing a positive association with EARD, but the relationships are not statistically important as

their p-values (ROE's p=0.506 and ROA's p=0.607) are greater than usual significant benchmark of 0.05. Earlier studies' findings provide mixed evidences regarding this finding. This finding is consistent with Admas et al. (2016) who suggested that performance measures such as ROA, ROE are not powerful tools of predicting companies' environmental accounting, and inconsistent with Tien et al. (2020), Giang et al. (2020) and Masud et al. (2018). This may be due to the fact that the other causes such as pressures from regulators, competitors and stakeholders, corporations' values may play significant bearing on influencing firms' environmental behavior in accounting. On other hand, FAGE is negatively connected with EARD with β=-0.107, t=-1.576, p=0.157 for ROE model, and β=-0.807, t=-1.568, p=0.245 ROA model respectively, indicating statistically insignificant relationship which matches with Admas et al. (2016) suggesting that older companies are not engaged in environmental reporting in comparison to younger ones. This may be due to factors of obstacle to change, variations in corporate values and culture of the firms. Finally, FSIZE is statistically significant in predicting the EARD as its coefficients (*β=0.426 for ROE model and β=0.328 for ROA model*) is positive with acceptable p-values of 0.002 and 0.003 respectively, suggesting that big firms are likely to have better environmental accounting and disclosures. The adjusted R-squared value for ROE model is presented as 0.1805, implying that 18.05% in EARD's variation can be explained by the independent variables. Similarly, and for ROA model it is shown as 0.1786, indicating that 17.86% in EARD's variation can be explained by the independent variables. Furthermore, F-values (0.001 for ROE model and 0.002 for ROA model) are statistically significant in explaining the EARD. This finding is matched with the finding of Clarkson et al. (2011) in which they argued that larger firms have greater capabilities in terms of financial resources, technological innovation and human resources, which in turn, engaging themselves in environmental accounting and reporting. Dhaliwal et al. (2011) also argued that big size firms are more inclined to environmental reporting due to pressures created by the stakeholders through scrutiny over the activities performed by the organizations.

Table 7: Results of Hypothesis Testing for Model-1(ROE)

Variables	Beta	t-value	P- value	Accept/Reject	R^2	f
ROE	0.085	0.693	0.506	Reject	18.05	4.189 (sig.0.001)
FAGE	-0.107	-1.576	0.157	Reject		
FSIZE	0.426	3.793	0.002**	Accept		

Note: **Significant at p<0.01.
Source: Researcher's calculations

Table 8: Results of Hypothesis Testing for Model-1(ROA)						
Variables	Beta	t-value	P- value	Accept/ Reject	R^2	f
ROA	0.089	0.798	0.607	Reject	17.86	3.410 (sig.0.002)
FAGE	-0.807	-1.568	0.245	Reject		
FSIZE	0.328	3.390	0.003**	Accept		
Note: **Significant at p<0.01. Source: Researcher's calculations						

5. Implications

The results from the analysis are significant for the Bangladeshi context in several ways. First, the insignificant association between ROA and EARD, ROE, and EARD suggests that Bangladeshi firms should consider factors beyond financial performance measures (ROE and ROA) when considering environmental accounting. Second, the considerable effect of firm size on EARD suggests that regulators, policymakers, and shareholders in Bangladesh ought to inspire smaller companies to accept environmental accounting practices via capacity development initiatives. Third, the inverse connection between firm age and ERD indicates that older firms in Bangladesh may encounter challenges in adopting environmental accounting due to several factors identified in the section above. So, regulators and policymakers in Bangladesh should come forward to remove the problems the older firms face by adopting environmental reporting practices and thereby ensure a sustainable reporting culture. Finally, low value of adjusted R^2 provides the necessity for capacity enhancement and consciousness building programs.

6. Limitations and scope of future research

Despite several implications, this research has some drawbacks that can provide avenues for future studies: Firstly, this study considers only the banking sector and has a limited sample size. Future researchers can include other sectors in the sample size to provide more extensive and robust outcomes. Secondly, the study fails to show causality due to the data's cross-sectional nature. Hence, future studies can conduct longitudinal research to test whether environmental reporting is affected by the dynamics of firm characteristics and other factors. Finally, the research adopts quantitative methods only. Future researchers are welcome to adopt qualitative

research methods, such as case studies and interviews, to generate better insights into the factors influencing Bangladeshi companies' environmental accounting behaviors.

References

Abed, H. A., & Sultan, S. J. (2019). The role of green financial institutions in achieving sustainable development: A vision in the possibility of its application in Iraq. *Gharee for Economics & Administration Sciences, 16*(2).

Abed, H. A., & Sultan, S. J. (2019). The role of green financial institutions in achieving sustainable development: A vision in the possibility of its application in Iraq. *Gharee for Economics & Administration Sciences, 16*(2).

Adams, C. A., Potter, B., Singh, P. J., & York, J. (2016). Exploring the implications of integrated reporting for social investment (disclosures). *The British Accounting Review, 48*(3), 283–296. https://doi.org/10.1016/j.bar.2016.03.002

Beredugo, S. B., & Mefor, I. P. (2012). The impact of environmental accounting and reporting on sustainable development in Nigeria. *Research Journal of Finance and Accounting, 3*(7), 55–63.

Clarkson, P. M., Overell, M. B., & Chapple, L. (2011). Environmental reporting and its relation to corporate environmental performance. *Abacus, 47*(1), 27–60. https://doi.org/10.1111/j.1467-6281.2011.00330.x

Cooke, T. E. (1992). The impact of size, stock market listing and industry type on disclosure in the annual reports of Japanese listed corporations. *Accounting and Business Research, 22*(87), 229–237. https://doi.org/10.1080/00014788.1992.9729440

Deb, B. C., Rahman, M. M., & Rahman, M. S. (2022). The impact of environmental management accounting on environmental and financial performance: Empirical evidence from Bangladesh. *Journal of Accounting & Organizational Change.* Advance online publication. https://doi.org/10.1108/JAOC-08-2021-0123

Deb, B. C., Saha, S., & Rahman, M. M. (2020). Does green accounting practice affect bank performance? A study on listed banks of Dhaka Stock Exchange in Bangladesh. *PalArch's Journal of Archaeology of Egypt/Egyptology, 17*(9), 7225–7247.

Dhaliwal, D. S., Li, O. Z., Tsang, A., & Yang, Y. G. (2011). Voluntary nonfinancial disclosure and the cost of equity capital: The initiation of corporate social responsibility reporting. *The Accounting Review, 86*(1), 59–100. https://doi.org/10.2308/accr.00000005

Dilling, P. F. (2010). Sustainability reporting in a global context: What are the characteristics of corporations that provide high quality sustainability

reports—An empirical analysis. *International Business & Economics Research Journal, 9*(1), 19–30.

Doan, M. H., & Sassen, R. (2020). The relationship between environmental performance and environmental disclosure: A meta-analysis. *Journal of Industrial Ecology, 24*(5), 1140–1157. https://doi.org/10.1111/jiec.12992

Dura, J., & Suharsono, R. (2022). Application of green accounting to sustainable development: Improving financial performance in the green industry. *Jurnal Akuntansi, 26*(2), 192–212.

Giang, N. M., Hanh, D. T. H., Linh, L. T. T., & Thuy, T. N. T. (2020). Overview of environmental accounting for sustainable development: Evidence from Vietnamese enterprises. *Journal of Asian Finance, Economics and Business, 7*(10), 977–985. https://doi.org/10.13106/jafeb.2020.vol7.no10.977

Hosain, M. S., Dey, M. M., & Sil, S. C. (2018). Effects of firm size, firm age and independent director on corporate social responsibility disclosure in Bangladesh: A study on banking sector. *Journal of Business, 11*(2), 241.

Islam, M. N., Uddin, M. M., & Hossain, S. Z. (2024). Do environmental reporting practices impact firm performance in Bangladesh? An empirical perspective. *Open Journal of Accounting, 13*(2), 15–31. https://doi.org/10.4236/ojacct.2024.132002

Jones, S., Frost, G., Loftus, J., & Van Der Laan, S. (2007). An empirical examination of the market returns and financial performance of entities engaged in sustainability reporting. *Australian Accounting Review, 17*(41), 78–87. https://doi.org/10.1111/j.1835-2561.2007.tb00449.x

Khan, A., Muttakin, M. B., & Siddiqui, J. (2013). Corporate governance and corporate social responsibility disclosures: Evidence from an emerging economy. *Journal of Business Ethics, 114*(2), 207–223. https://doi.org/10.1007/s10551-012-1336-0

Khan, H. U. Z. (2010). The effect of corporate governance elements on corporate social responsibility (CSR) reporting: Empirical evidence from private commercial banks of Bangladesh. *International Journal of Law and Management, 52*(2), 82–109. https://doi.org/10.1108/17542431011029406

Lin, Y., Zhang, Y., Wang, F., & Dong, Z. (2025). Who is more likely to become a sustainable corporation? An empirical research based on corporate sustainability performance. *Sustainable Development, 33*(3), 3728–3746. https://doi.org/10.1002/sd.3313

Masud, M. A. K., Nurunnabi, M., & Bae, S. M. (2018). The effects of corporate governance on environmental sustainability reporting: Empirical evidence from South Asian countries. *Asian Journal of Sustainability and Social Responsibility, 3*(1), 1–26. https://doi.org/10.1186/s41180-018-0021-7

Osemene, O. F., Ololade, R. A., & Eriki, P. O. (2020). Investigating the effects of corporate governance factors on environmental accounting reporting in six African nations. *Cogent Business & Management, 7*(1),1792414. https://doi.org/10.1080/23311975.2020.1792414

Shakkour, A., Alaodat, H., Alqisi, E., & Alghazawi, A. (2018). The role of environmental accounting in sustainable development: An empirical study. *Journal of Applied Finance and Banking, 8*(1), 71–87.

Singh, A., & Chakraborty, M. (2018). Environmental disclosure level and reporting quality in India. *International Journal of Business and Management Invention, 7*(6), 38–45.

Sitorous, C. I., Bukit, R. B., & Bulan, N. (2024). The influence of company size, board of directors and leverage on sustainability report disclosure with profitability as a moderation variable in LQ45 companies listed on the Indonesia Stock Exchange. *International Journal of Current Science Research and Review, 7*(5), 2673–2688.

Sobhan, R., Shohan, M. M. R., & Uddin, S. I. (2025). Environmental reporting and financial performance: The role of board independence. *Journal of Accounting & Organizational Change.* https://doi.org/10.1108/JAOC-05-2024-0149

Sobhani, F. A., Amran, A., & Zainuddin, Y. (2012). Sustainability disclosure in annual reports and websites: A study of the banking industry in Bangladesh. *Journal of Cleaner Production, 23*(1), 75–85. https://doi.org/10.1016/j.jclepro.2011.09.023

Tien, H. T. T., Thang, N. N., & Quyen, L. V. (2020). Corporate financial performance due to sustainable development in Vietnam. *Journal of Asian Finance, Economics and Business, 7*(3), 197–207. https://doi.org/10.13106/jafeb.2020.vol7.no3.197

Wu, D., Zhu, S., Memon, A. A., & Memon, H. (2020). Financial attributes, environmental performance, and environmental disclosure in China. *International Journal of Environmental Research and Public Health, 17*(23), 8796. https://doi.org/10.3390/ijerph17238796

APPENDIX-1

S.L	NAME OF THE COMPANIES	S.L	NAME OF THE COMPANIES
01.	BANK ASIA	11.	NCC BANK
02.	AL-ARAFA ISLAMI BANK	1 2.	PREMIER BANK
03.	BRAC BANK	13.	UNITED COMMERCIAL BANK

04.	CITY BANK	14.	TRUST BANK
05.	DHAKA BANK	15.	UTTARA BANK
06.	DUTCH-BANGLA BANK	16	STANDARD BANK
07.	EASTERN BANK	17.	JAMUNA BANK
08.	ONE BANK	18.	PUBALI BANK
09.	IFIC BANK	19.	MERCANTILE BANK
10	ISLAMI BANK LIMITED	20.	SOUTHEAST BANK

APPENDIX-2

Serial No.	Issue of Compliance	
01.	Any mention of Environmental Regulation.	
02.	Involvement of Environmental Experts in the Organization	
03.	Environmental Impact of Principal Product and Services	
04.	Any steps on Tree Plantation	
05.	Environmental Related Cost	
06.	Online Banking	
07.	Air Pollution Management	
08.	Environmental Award	**Source:** Bangladesh Bank Policy Guidelines and related literatures
09.	Energy Usage Information	
10.	Training on Environmental Management Systems	
11.	Encouragement of Renewable Energy Consumption	
12.	Any Mentioned Environmental Policy	
13.	Environmental Audit	
14.	Water Pollution Management	
15.	Green Marketing	
16.	Any Steps in Carbon Management	
17.	Any Steps regarding Waste Management	
18.	Methods of Waste Management	

An Energy Efficient IoT Based Smart Home Automation and Automated Water Pump Control System

Rajib Mondal[1], Md Lutfur Rahman[2], Md Hasan Bepari[3], Umme Hani Riya[3], Md Abu Hena Shatil[4], Rapsan Amin Anonto[5]

[1]Assistant Professor, Department of Electrical and Electronic Engineering, RPSU, Bangladesh

[2]Lecturer, Department of Electrical and Electronic Engineering, RPSU, Bangladesh

[3]Research Assistant, Department of Electrical and Electronic Engineering, RPSU, Bangladesh

[4]Associate Professor, Department of Electrical and Electronic Engineering, AIUB, Bangladesh

[5]Ph.D Researcher, Department of Electrical and Computer Engineering, Morgan State University, USA

Corresponding Author: Md Lutfur Rahman, lutfur_eee@rpsu.edu.bd

ARTICLE INFO

Keywords: Arduino UNO, IoT, Ultrasonic Sensor, Relay Module, Telegram Application, ESP8266 Wi-Fi module

RECEIVED
22 March 2025

ACCEPTED
09 August 2025

PUBLISHED
31 August 2025

DOI
https://doi.org/10.5281/zenodo.17243400

ABSTRACT

The Internet of Things (IoT), which allows for communication between humans and machines, has a significant impact on daily lives. This research article will invent technology and ideas that allow humans to communicate with machines more effectively and efficiently. In this paper, we basically presented an energy-efficient IoT-based smart home automation system. This system is based on the Telegram application, which is controlled by an ESP8266 Wi-Fi module. The most popular feature of Telegram is that it can handle commands from users and provide appropriate command functionality. Additionally, in this research, an automated pump system is used, which automatically fills the water tank when the water level goes down and turns off the pump when the tank is full.

1. Introduction

We are shifting toward the internet era, where every accessible item will be managed and connected to the internet. According to a study, there will be 75.44 billion Internet of Things (IoT) connected devices installed globally within 2025 (M. S. Mahamud, M. S. R. Zishan, S. I. Ahmad, A. R. Rahman, M. Hasan, and M. L. Rahman, 2019). The main purpose of home automation is to make life as easy as possible through the utilization of an IoT system. For instance, this is achieved by enabling lights to be turned on or off remotely (T. R. Beegum, 2017). This paper's focus is to devise a method for effective and economical conversion of an existing house into a smart home. In this study, we have suggested an energy-efficient Internet of Things (IoT)-based smart home automation system. A user can operate their home appliances with this technology at any time and from any location. Here, the Telegram messaging app is used, which provides better advantages with an IoT framework and with the most notable flexibility in network arrangement. Both the control device and the IoT device can be situated anywhere, as long as internet service is accessible (Soni, Gaurav, et al., 2021). In order to enable the control of home devices through Telegram, an ESP8266 Wi-Fi module development board is used. This Arduino-compatible gadget may be used to interact directly or through a relay with the automation target. IoT devices could be controlled with simple instructions via the Telegram app when the required setup is finished. Additionally, by evaluating the data obtained from the ultrasonic sensor, Arduino in this study regulates the water pump's activation and deactivation. (Dhillon, Javed, et al. 2021).

2. Literature Review

In recent years, IoT technology has gained prominence for its incorporation into daily life. IoT's capacity to provide seamless communication between humans and machines has opened up many prospects for innovation and efficiency improvement. This section reviews literature on IoT, Telegram, and automated systems in complaint management and water supply control. (Adinegoro, Prasetyo, et al. 2020). The literature has extensively examined IoT-driven smart homes. Security, energy management, and resource allocation could be monitored and controlled by IoT devices and sensors. These apps can improve life and ease educational processes. (Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M., 2015).

Telegram, an emerging instant messaging service, has grown rapidly thanks to its strong feature set and developer-friendly environment. Previous studies have integrated Telegram with customer service and IoT device control, proving its

versatility and efficacy. (Baumgartner, Antonioli, D., & Zingirian, N., 2019). Efficient complaint management is essential for student and staff satisfaction in educational institutions. The use of IoT technologies has improved complaint processing. IoT sensors could identify temperature changes, equipment failures, and security breaches and send notifications, as well as reduce response times and improve user satisfaction. (Gupta, P., & Kumar, N., 2020).

Technology in communities and home appliances has made water pumps important to daily life, especially for household users (S. J. Sukoco, A. Setiawan, M. I. Suhermin, S and Rahim 2017, D. Cooper R. A. Pasquina, P. F. and Fici-Pasquina L 2011, Nam T and Pardo T. A. 2011, Cook D J and Das S. K. 2005, Napitupulu D, 2018). Research has also focused on water supply automation. Automated pump systems monitor storage tank levels and manage pumps to maintain water delivery. These efficient technologies conserve water by preventing waste. (Han, D., Lian, J., Liu, L., & Fan, W., 2019). Telegram interaction with IoT systems is new. Researchers have investigated using Telegram for IoT device and communication. Telegram can take user commands and offer real-time updates, making it perfect for remote IoT management and monitoring (Muslih, Muhamad, et al. 2018). While the integration of IoT with Telegram for complaint management and automation offers numerous benefits, it also presents challenges. These include security concerns, data privacy issues, and the need for robust authentication mechanisms to prevent unauthorized access to sensitive systems.

3. Objectives

- To design an efficient smart home system that minimizes time, effort, cost, and human error.
- To leverage IoT technology for seamless remote control and automation of household devices via the internet.
- To promote energy efficiency and water conservation through the integration of smart technologies.

4. System Description

4.1. Arduino UNO

An open-source platform for basic electronics prototyping is the Arduino Uno board. Since it features an Atmel ATmega328P microprocessor, it is ideal for introducing microcontrollers and embedded programming. (Sadikin, Nanang, Marliana Sari, and Busye Sanjaya. 2019). It's 32KB flash memory includes 2KB of SRAM and 0.5KB utilized by the bootloader. It also includes a 16MHz clock speed and a 1KB EEPROM. The server, loads, and all of the sensors are connected through Arduino.

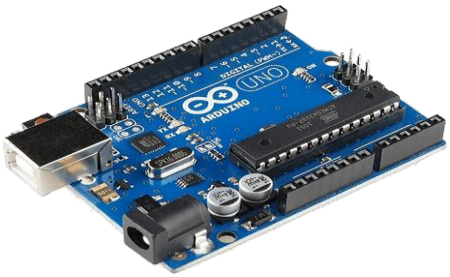


Fig.01. Arduino UNO Board

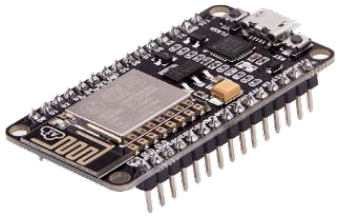


Fig.02. ESP 8266 Wi-Fi Module

4.2. NodeMCU ESP 8266 Wi-Fi Module

The Node MCU is an open-source software and hardware development environment based on an affordable architecture on a chip known as the ESP8266. The ESP8266, invented and manufactured by Espressif Systems, has the essential components of a computer: CPU, RAM, networking (WiFi), and even an updated operating system. This makes it an excellent choice for IoT-based research. (Parihar, Yogendra Singh. 2019).

4.3. Ultrasonic Sensor

Ultrasonic sensor's echo pin is connected with Arduino's pin No.7, trig pin is connected with Arduino's pin No. 8, Vcc pin with Arduino's 5V, and GND pin with Arduino's GND pin. Arduino's 10th no. The pin is connected to the relay module, and there is also a buzzer which is connected to Arduino's 9th no. pin (Carullo, Alessio, and Marco Parvis,2001).

4.4. Relay Module

Relay is an electromechanical device that can be used to make or break an electrical connection. A relay is essentially a mechanical switch that may be turned on or off by an electrical signal rather than by hand. It is made up of a flexible movable mechanical component that can be controlled electronically by an electromagnet. Moreover, this relay's operation is limited to electromechanical relays. (Vogel, Burkhard, and Burkhard Vogel. 2011).

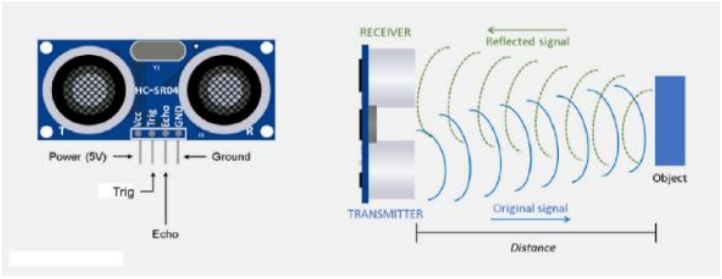


Fig.03. Ultrasonic Sensor

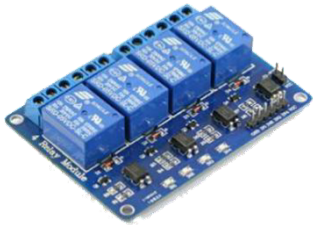


Fig.04. Relay Module

5. Architecture Model with Flow Chart and Simulation

5.1. Architecture Model of Proposed System

Fig. 05 shows the block diagram of the proposed system. A user sends commands via the Telegram app on their smartphone through the internet. The ESP-8266 receives these commands and controls multiple devices via a relay module. The Telegram application was used to control the whole system. Fig. 6 shows the block diagram of the water pump control system. The ultrasonic sensor detects the distance of an object and sends data to the Arduino Uno. Based on the sensor input, the Arduino controls the relay module. The relay module then switches the motor on or off using power from the power supply.

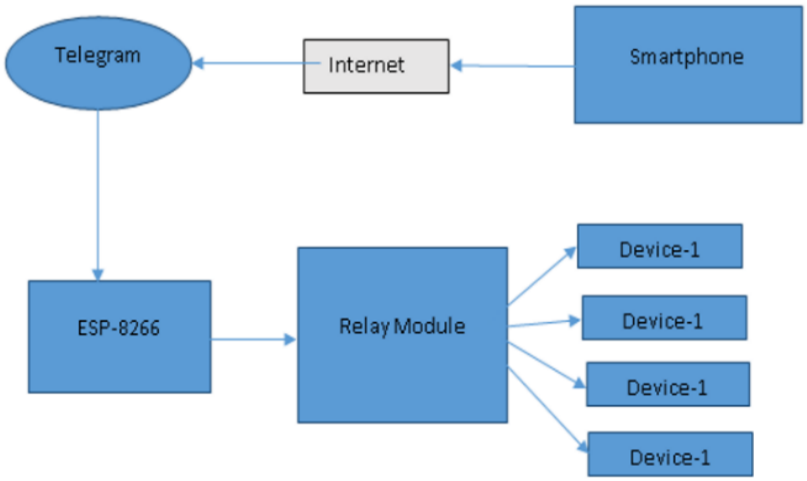


Fig.05. Architecture Model of the proposed Control System

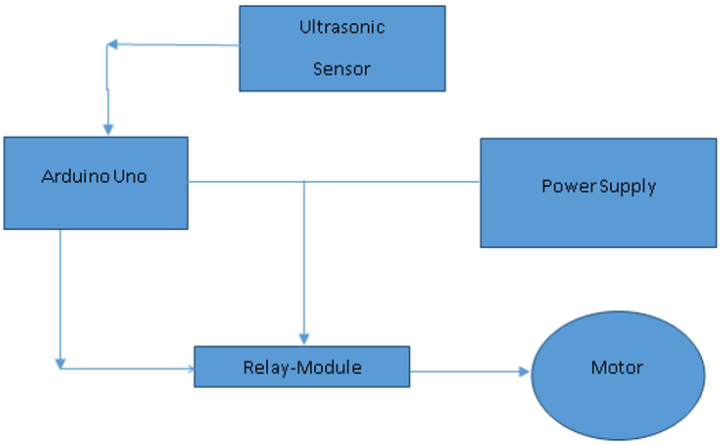


Fig.06. Architecture Model of the Automated Water Pump Control System

5.2. Flow Chart

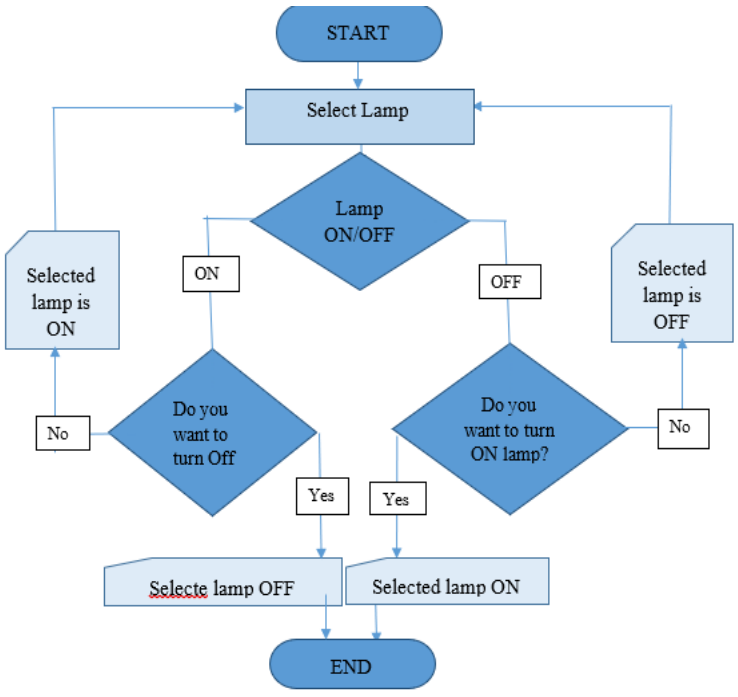


Fig. 07. An IoT Based Smart Home Automation Lamp Control System.

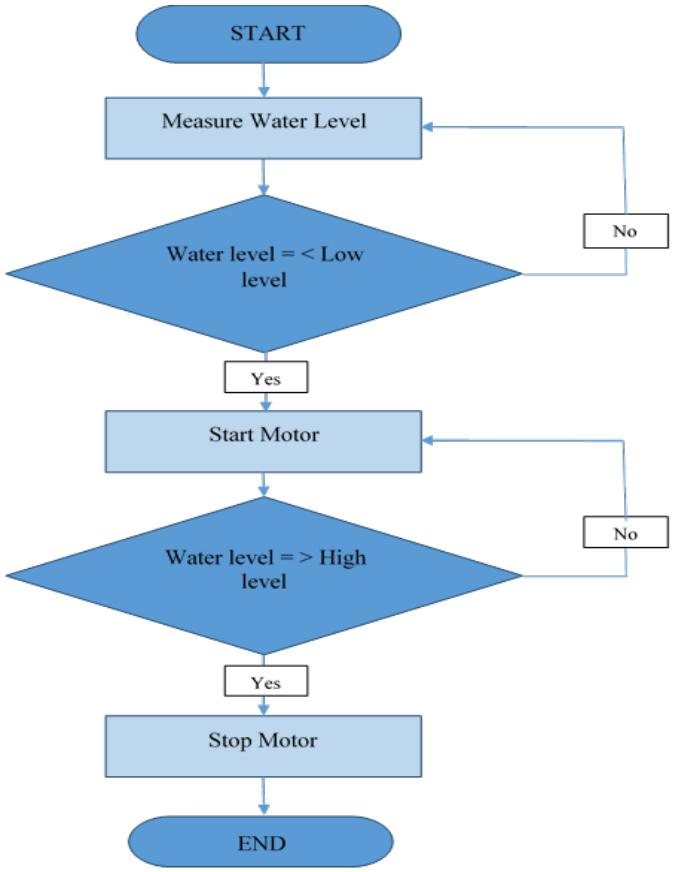


Fig. 08. Automated Water Pump Control System

Fig. 07 shows the flow chart of an IoT-based smart home automation lamp control system. This flowchart describes the process of selecting and controlling a lamp. After selecting a lamp, the system checks if it is ON or OFF. If ON, it asks if you want to turn it OFF; if OFF, it asks if you want to turn it ON. Based on user input, the lamp is either switched ON or OFF, and the process ends. and Fig. 08, and an automated water pump control system. This flowchart automates motor control based on water level. It starts by measuring the water level and checking if it is below the low threshold. If yes, the motor starts and keeps running until the water reaches the high level. Once the high level is detected, the motor stops and the process ends.

5.3. Simulation

This system consists of electrical and electronic components. Fig.09. shows the representation of the main circuit diagram of the design and construction of the home device control system, and Fig. 10 shows the circuit diagram of the water pump control system.

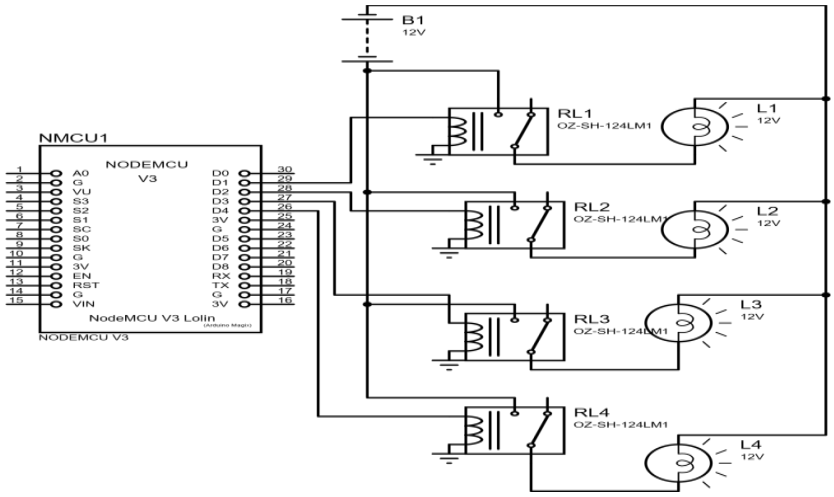


Fig. 09. Simulation of Design and Construction of Smart Home Automation

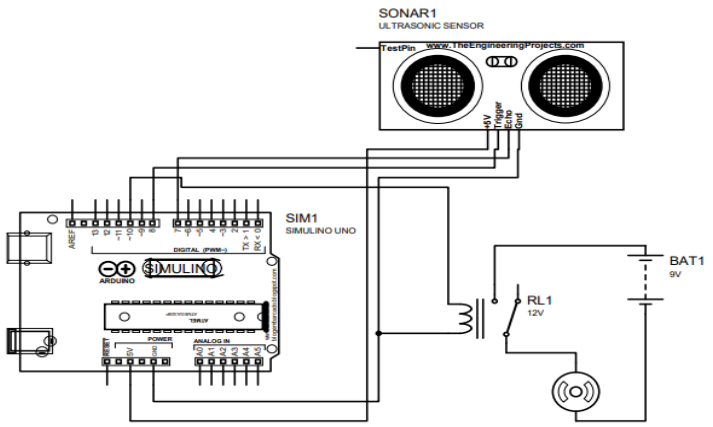


Fig. 10. Simulation of the Water Pump Control System

6. Architecture Model

The whole process of hardware implementation has been described in the segment. Fig. 11 shows the hardware implementation of the whole system.

Fig. 11. Hardware Model of the Proposed System

7. Results and Cost Analysis

Table 01. The total number of connecting power of customers.

Appliances	Power (W)	Quantity	Total Watt
Light	18 20	10 10	380
Fan	65	5	325
Ac	1000	2	2000
Washing machine	500	1	500
Blender	500	1	500
Egg bitter	260	1	260
Rice cooker	700	1	700

Oven	1000	1	1000
Refrigerator	500	2	1000
Water heater	1000	1	1000
Electronic Iron	800	1	800
TV	100	1	100

Table 02. Power saving analysis of the customer.

Bill Month	Consumption	Monthly Bill	Saved Power	Saved Money
March 2024	364	2231	69.16	423
April 2024	562	4161	106.78	790
May 2024	397	2450	75.43	452
June 2024	428	2763	81.32	570
July 2024	332	2018	63.08	378
August 2024	582	4370	110.58	830
September 2024	406	2533	77.14	470
October 2024	314	1898	59.66	357
November 2024	801	3138	152.19	1140
December 2024	520	3724	98.8	691
January 2025	428	2612	81.32	530
February 2025	520	3724	98.8	632

Here, table 01. and table 02. respectively shows the total number of connecting power and power saving analysis of customers.

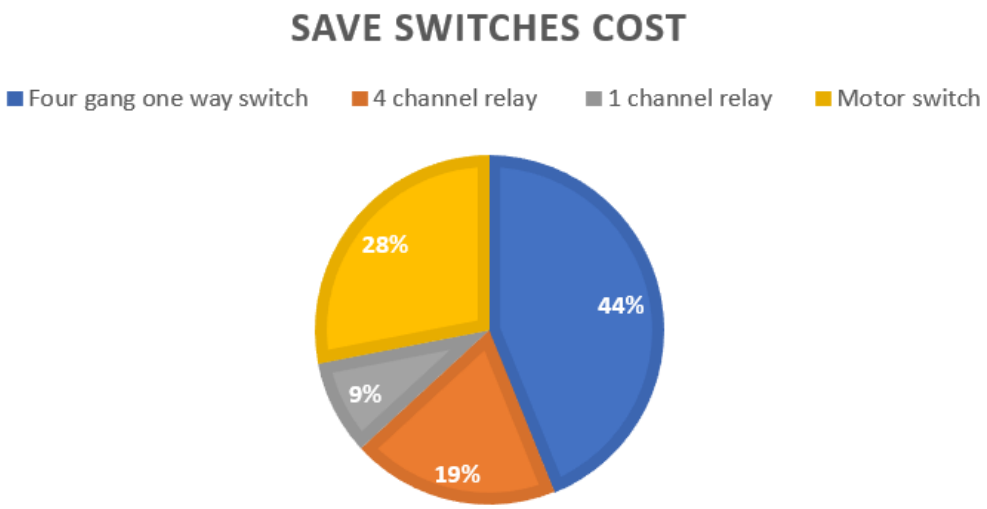


Fig. 12. Switch Costs Analysis

A smart home has few switching costs. Only the relay module switch can operate the whole system. In this system, there is no need for a manual switch. The cost analysis of the smart house is displayed in Fig. 12.

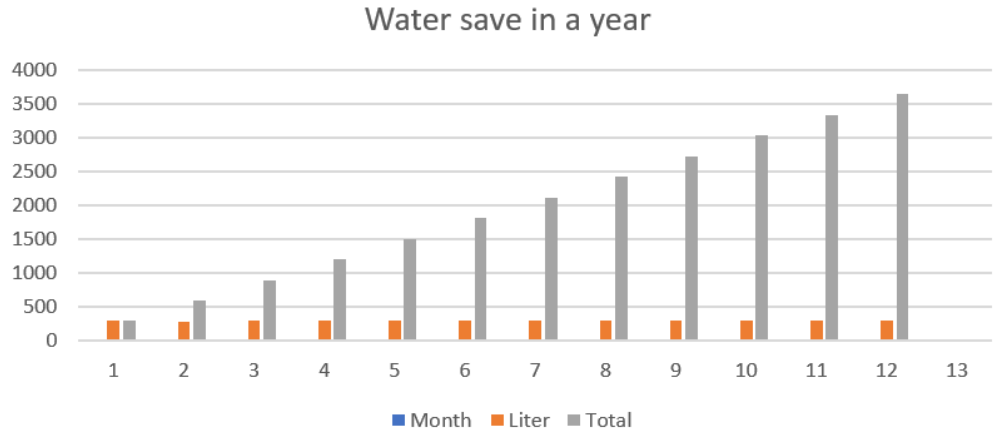


Fig. 13. Water Save Analysis

Smart homes reduced 44% the switching cost. Fig. 13, Fig. 14, and Fig. 15, respectively, show water saving analysis, power consumption analysis, and power and money saving analysis.

The automation pump utilized in projects for smart homes also conserves a significant amount of water. Nearly 36,500 liters of water can be saved annually, as shown in Fig.13. The automated water pump system contributes to the conservation of both water and electricity. It eliminates the need for manual operation, ensuring efficient usage.

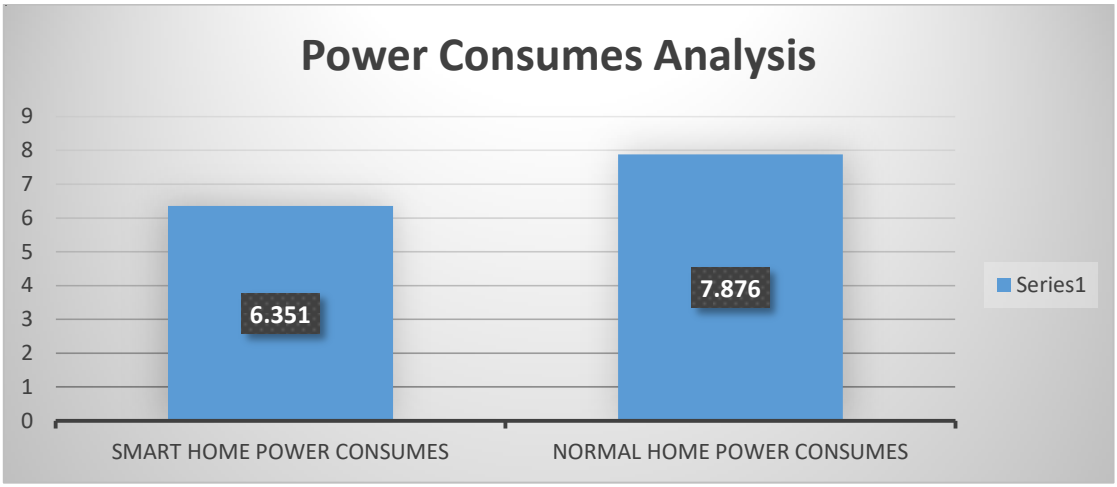


Fig. 14. Power Consumption

The power loss of smart homes is low. Neither a system error nor a power outage has occurred. Fig.14. shows the power consumption analysis. This figure addresses the topic of savings analysis. It delves into discussions concerning power consumption, monthly expenses, conserved energy, and the financial savings achieved.

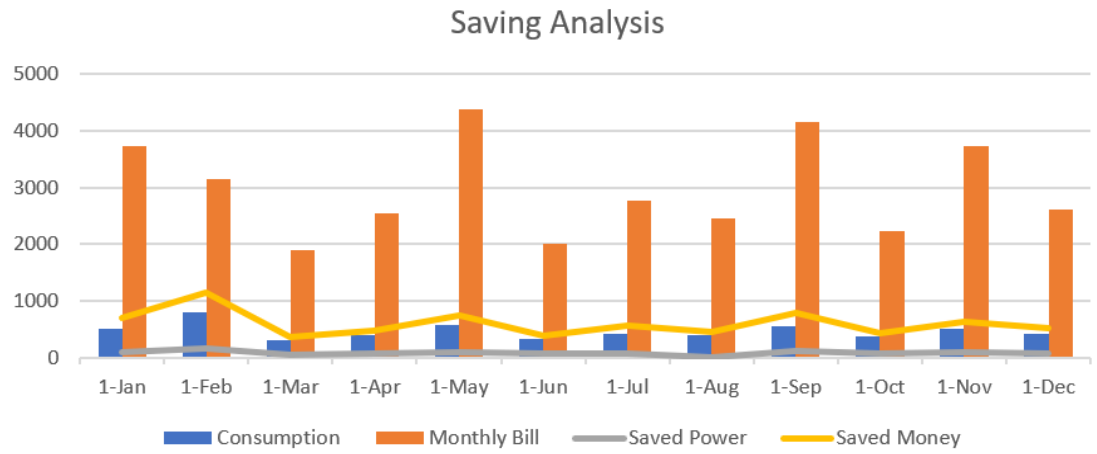


Fig. 15. Power and Money Save Analysis

The Fig.15. provides a comprehensive overview of the analysis for each month of the year. This research demonstrates the implementation of an IoT system to control home appliances and the management of a water tank using an Arduino Uno and an ultrasonic sensor.

8. Advantages and Applications

Advantages:
Remote Monitoring – This system can be controlled from anywhere in the world.
Cost and Energy Savings – With comprehensive information on the work and energy consumption of each smart device, this model merely optimizes the use of each smart device and modifies the smart home settings in a more economical manner.
Environmental Impact – Energy savings contribute to lessening the harm done to the environment and ensure the living of a greener life in addition to lowering expenses.
Comfort – People have always desired to have everything in a more pleasant and convenient way, and smart homes are perhaps the greatest achievement in this direction.
Automatic Water Pump Control – It keeps the water level in the tank constant and automatically turns on and off the water pump, allowing us to save water and minimize our electricity bill.

Applications:
• This system could be used in our home appliances.
• Control industrial equipment because this can save electricity, time, and effort.
• This system could be used in an office, College, University, etc.
• This smart home system is very suitable for people who travel often. They can control the home appliance from anywhere in the world, and they can be aware of the fact that which of home appliances are ON and which are OFF.

9. Conclusion

The main goal of this system is to use IoT to make human life more affordable and comfortable. People are seeking a more flexible lifestyle these days since they are so occupied with their professional obligations. IoT has a significant role in the present situation. Certainly, the most significant uses of the Internet of Things are in home automation. People can live more easily and comfortably by utilizing it. In this system, a method to develop a smart home automation system based on Internet of

Things software has been implemented and tested with the built prototype. Using most of the newest technology available, it focuses on the safety and security aspects of home automation. The Node MCU ESP-8266 and Arduino Uno were the technologies employed in this research. The Arduino Uno served as the system's main control unit, to which other sensors and devices were linked, and the system was controlled by the Telegram application. Compared to other IoT-based home automation systems, this one is easier to operate. We feel that humans are able to distinguish between smart lives and ordinary lives by using the Internet of Things.

References

M. S. Mahamud, M. S. R. Zishan, S. I. Ahmad, A. R. Rahman, M. Hasan and M. L. Rahman, (2019)"Domicile - An IoT Based Smart Home Automation System," International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST), Dhaka, Bangladesh, pp. 493-497.

T. R. Beegum, (2017) "Energy aware virtual backbone construction using cluster heads in Wireless Sensor Network," 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, India.

Soni, Gaurav, et al. (2021) "Design and implementation of object motion detection using telegram." 2021 International Conference on Technological Advancements and Innovations (ICTAI). IEEE.

Dhillon, Javed, et al. (2021) "IoT based water level monitoring and motor control system." 2021 4th International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE). IEEE, 2021.

Adinegoro, Prasetyo, et al. (2020) "The design of a telegram IoT-based chicken coop monitoring and controlling system." JPSE (Journal of Physical Science and Engineering) pp: 56-65.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A survey on enabling technologies, protocols, and applications. IEEE Communications Surveys & Tutorials, 17(4), 2347-2376.

Baumgartner, Antonioli, D., &Zingirian, N. (2019). Design and implementation of a Telegram bot for a sensor monitoring system. In 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 6175-6181).

Gupta, P., & Kumar, N. (2020). Internet of Things (IoT) for Smart ampuses: A Comprehensive Review and Future Directions. IEEE Access, 8, 193459-193477.

Suyono J Sukoco A Setiawan M I Suhermin S and Rahim R (2017) Impact of GDP Information

Technology in Developing of Regional Central Business (Case 50 Airports IT City Development in Indonesia) J. Phys. Conf. Ser. 954 1 p. 12045
Ding D Cooper R A Pasquina P F and Fici-Pasquina L (2011) Sensor technology for smart homes Maturitas 69 2 p. 131–136
Nam T and Pardo T A (2011) Conceptualizing smart city with dimensions of technology, people, and institutions in Proceedings of the 12th Annual International Digital Government Research Conference on Digital Government Innovation in Challenging Times - dg.o '11 p.282
Cook D J and Das S K (2005) Smart Environments: Technology, Protocols and Applications
Napitupulu D (2018) Analysis of Student Satisfaction Toward Quality of Service Facility J. Phys. Conf. Ser. 954 1 p. 12019
Han, D., Lian, J., Liu, L., & Fan, W. (2019). Design and implementation of a real-time monitoring system for smart water supply in agriculture based on the Internet of Things. Sensors, 19(4), 792.
Muslih, Muhamad, et al. (2018) "Developing smart workspace based IOT with artificial intelligence using telegram chatbot." 2018 International Conference on Computing, Engineering, and Design (ICCED). IEEE.
Sadikin, Nanang, Marliana Sari, and Busye Sanjaya. (2019) "Smarthome using android smartphone, arduino uno microcontroller and relay module." Journal of Physics: Conference Series. Vol. 1361. No. 1. IOP Publishing.
Parihar, Yogendra Singh. (2019) "Internet of things and nodemcu." journal of emerging technologies and innovative research pp: 1085.
Carullo, Alessio, and Marco Parvis. (2001) "An ultrasonic sensor for distance measurement in automotive applications." IEEE Sensors journal.
Vogel, Burkhard, and Burkhard Vogel. (2011) "Modules 1–4." The Sound of Silence: Lowest-Noise RIAA Phono-Amps: Designer's Guide pp: 679-691.

RPSU RESEARCH JOURNAL

INSTRUCTIONS TO AUTHORS

RPSU Research Journal is a multi-disciplinary peer-reviewed journal published in English annually, with ISSN. It covers the experimental and theoretical works of research areas including English, Law, Business, Science, Engineering, Pharmacy and Textile. The articles submitted to the journal undergo a rigorous three-stage peer-review process where the submitted papers are first reviewed by the editorial board, then plagiarisms in the articles if any are checked and finally, they are sent to the subject experts. Original research papers, short review articles, book reviews are considered for publication in this journal.

SUBMISSION OF MANUSCRIPTS

The authors are requested to follow the following rules:

1. Three hard copies of manuscripts written in English along with one soft copy in MS Word or Latex should be submitted to the Executive Editor. The papers should be typed on good quality bond paper of A4 format with 1‖ margins (right, left, top, bottom), double-spaced, using Times Roman 12-point font.

2. The title of each article should be brief, clear, and specific.

3. Each manuscript should have a cover page bearing the (i) full title ;(ii) name(s) and academic or professional affiliation(s) of the author(s) ;(iii) mailing addresses of the author(s); and (iv) e-mail addresses of the corresponding author(s).

4. The first page of the paper should contain the(i) title again; (ii) abstract (double-spaced and italic); keywords (about 5 words/phrases) followed by AMS/STMA subject classification;(iv) main text; (v) acknowledgment (if necessary) and (vi)references; (vii) appendix (if necessary).

5. The abstract should be concise, factual and no more than 300 words. The abstract should comprise the purpose(s) of the paper, research design/methodology and major findings. References in abstract can only be included if they are extremely essential.

6. The manuscript should be preferably arranged in the following sequences: Introduction; Materials and methods; Discussions; Conclusions; Recommendation (if any); Acknowledgment (if necessary) and References Tables should be typed in the body of the text and numbered serially in Arabic numerals in order in which they are mentioned in the text. Each table should bear a descriptive title and be referred in the text by the respective numbers.

7. Reference in the text should be cited within first brackets quoting author's name and the year of publication in the appropriate place such as (Roy, 2019), (Roy & Paul, 2020). In case of more than two authors such as (Roy et. al., 2004) The list of references should be arranged alphabetically according to the last name of the first author. A Comma (,) should separate more than two references when put within the same bracket. Common examples are given below:

BOOK:

Sekaran, U, (2000). Research Methods for Business-A skill Building Approach, John Wiley and Sons, New York

JOURNAL ARTICLE

Begum, S. and Shamsuddin, A.F.M. (1998). Exports and Economic Growth in Bangladesh, Journal of Development Studies, 35(1), 89-114

JOURNAL ARTICLE FROM THE WEB

Iqtiaruddin Md. Mamun (2017) Debates and Denouncements Value Added Tax (VAT) and Supplementary Duty Act, 2012, vol.45.no.3

http://www.icmab.org.bd/images/stories/journal/2017/May-June/5.Of%20all.pdf

ARTICLES FROM THE NEWSPAPER

Daily Star (2019) Govt plan 3-tier VAT rate,15 March, retrieve from: https//www.the dailystar.net/back page/news/govt-plans-3-tier-vat-rate-1715398

GALLEY PROOFS

All galley proofs should be sent to the corresponding authors for corrections. The corrected proofs should be returned to the Executive Editor within one week of receipt.

Reviewers Panel

Professor Dr. Md. Rezaul Karim
Professor,
Department of Statistics
University of Rajshahi

Professor Dr. Mohit Ul Alam
Professor & Dean, English Language & Literature
Premier University, Chittagong

Professor Ahmed Reza
Department of English
Jahangirnagar University

Shaikh Masrick Hasan, PhD
Associate Professor
Department of Finance
Jagannath University

Professor Dr. S. M. Abdur Rahman
Professor
Department of Clinical Pharmacy and Pharmacology
University of Dhaka

Professor Dr. Imrana Yasmin
Professor
Department of Marketing
University of Dhaka

Professor Dr. Utpal Kumar Das
Professor
Department of EEE
Dhaka University of Engineering & Technology, Gazipur

Professor Dr. Md. Maniruzzaman
Professor
Department of English
Jahangirnagar University,
Savar, Dhaka

Professor Dr. Sanjoy Kumar Dey
Professor
Department of Neonatology
Bangladesh Medical University

Professor Dr. Anwarul Haque Joarder
Professor
Department of Computer Science and Engineering
Northern University of Business & Technology, Khulna

Professor Golam Sarwar Chowdhury
Professor
Department of English
Notre Dame University Bangladesh

Professor Dr. Mohammad Abu Misir
Professor
Department of Finance
Jagannath University

Professor Dr. Sukalyan Kumar Kundu
Professor
Department of Pharmacy
Jahangirnagar University

Professor Dr. Razia Begum
Professor
Department of Marketing
University of Dhaka

Dr. Chitta Saha
Associate Professor
School of Engineering and the Built Environment
Birmingham City University, UK

Professor Golam Sarwar Chowdhury
Professor
Department of English
Notre Dame University Bangladesh

Professor Aminur Rahman,
Professor and Head
Department of Neurology
Sir Salimullah Medical College, Dhaka-1100

Professor Dr. Md. Rafiqul Islam Khan
Professor
Department of Pharmacy
University of Rajshahi

Professor Dr. Md. Aslam Hossain
Professor
Department of Pharmaceutical Chemistry
University of Dhaka

Uttam Kumar Roy
Associate Professor
Institute of Leather Engineering and Technology
University of Dhaka

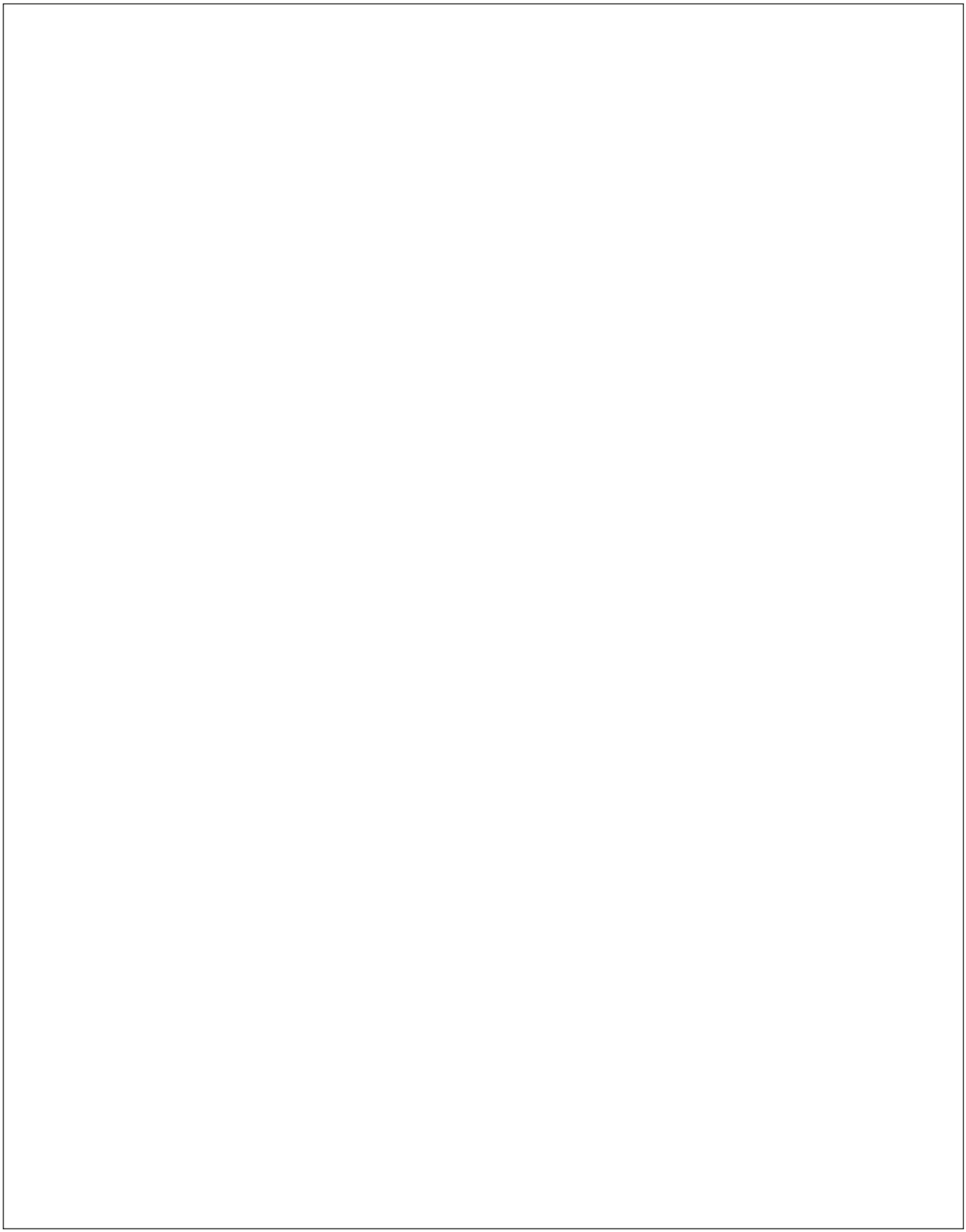
Professor Dr. Md. Iqbal Hossain
Professor
Department of Accounting
University of Chittagong

Dr. Mohammad Quamruzzaman
Head, Department of EEE
World University of Bangladesh, Dhaka
Bangladesh.

Md. Maksudur Rahman
Associate Professor
Department of Graphic Design
Faculty of Fine Art
University of Dhaka

Professor Dr. Mohammad Morshedur Rahman
Professor
Department of Accounting
University of Chittagong

Professor Dr. Jamal Uddin Ahmed
Professor
Department of EEE
University of Chittagong



R. P. SHAHA UNIVERSITY

25 Sultan Gias Uddin Road, Shitalakhya, Narayanganj 1400, Bangladesh
Tel: +88-02-7635000, Cell: +88-01709-667100/03
E-mail: info@rpsu.edu.bd; web: www.rpsu.ac.bd