Causes of Child Marriage in the Context of Bangladesh: A Gender-Independent Survey using Machine Learning

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A thesis submitted to the respective department in fulfillment of the requirements for the degree of Master of Science in Computer Science and Engineering.

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In the pursuit of knowledge and the fulfillment of this research endeavor, there are those whose unwavering support, guidance, and influence have been the guiding lights of my academic journey. To these esteemed individuals, I dedicate this work with deep appreciation and gratitude.

To Allah, the Almighty, I offer my foremost praise and thanks for bestowing His blessings upon me throughout my educational journey, allowing me to successfully navigate the intricate path of research and scholarship.

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With heartfelt regards,

Tanzila Ferdousi Tamanna

December 2023

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Dear Sir,

I am delighted to present my thesis paper titled **"Causes of Child Marriage in the Context of Bangladesh: A Gender-Independent Survey using Machine Learning"** as a crucial component of my Master of Science degree in Computer Science and Engineering. I humbly submit this copy for your esteemed review.

I kindly request your acceptance of my thesis paper, and I am sincerely grateful for your consideration.

Warm regards,

Tanzila Ferdousi Tamanna

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DECLARATION

I declare that this thesis paper represents my own original work and has not been previously submitted for any other degree or diploma at any university or other institution of higher education. Any information obtained from the published or unpublished works of others is appropriately cited within the text, and a comprehensive list of references is provided for further verification.

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APPROVAL

The thesis paper titled "**Causes of Child Marriage in the Context of Bangladesh: A Gender-Independent Survey using Machine Learning**" has been submitted for review to the esteemed members of the Board of Examiners within the Department of Computer Science and Engineering. It fulfills the necessary requirements for the degree of Master of Science in Computer Science and Engineering and has been satisfactorily accepted by the board in December 2023. It is authored by **Tanzila Ferdousi Tamanna**.

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ABSTRACT

Child marriage, a pervasive societal issue in Bangladesh, critically impacts the health, social dynamics, and economic well-being of its youth. This study represents a comprehensive effort to unravel the intricate dynamics of this problem, particularly in rural areas. Our research engaged 280 participants, including girls aged 8-17 and boys aged 15-20, to probe deeper into the causative factors of early marriage. Central to our approach was the introduction of specific, meticulously chosen variables, each evaluated for its unique influence on the prevalence of child marriage.

These variables include 'Financial Crisis of the Family,' which examines the impact of economic hardship on early marriage decisions; 'Married Spouse below 21 or Wife below 18,' focusing on the prevalence of marriages where one spouse is below the legal age; 'Siblings Marriage below the Legal Age,' exploring the effects of early sibling marriages; 'Social Harassments Eve or Adam Teasing,' investigating the influence of social harassment on marriage choices; 'Educational Level of Married Siblings,' analyzing the correlation between siblings' education and early marriage practices; and 'Employment Status of Early Married Siblings,' studying the link between early marriage and the working status of siblings. Each of these attributes, scored and ranked by their Chi-Square values, provides groundbreaking insights into the multifaceted causes of child marriage, diverging from traditional analyses.

The methodological backbone of our research was the application of advanced machine learning techniques. The Random Forest algorithm stood out for its efficacy, achieving an impressive overall accuracy of 98.86% in predicting instances of early marriage. Notably, this model demonstrated even higher accuracy in gender-specific analyses, reaching 98.95% for males and 98.98% for females. Additionally, when applied to a test dataset encompassing different gender groups, the accuracies obtained were 97.75%, 97.88%, and 96.11%, respectively, for male, female, and combined groups.

In conclusion, our research underscores the profound capability of machine learning in detecting and predicting child marriage instances in Bangladesh. The exceptional precision of the Random Forest algorithm in our study represents a significant advancement, setting new standards in the field. We believe that the insights and methodologies from this study will contribute substantially to the development of effective prevention strategies and inspire further research in this critical domain. It is our hope that these efforts will pave the way towards eradicating child marriage, transforming it from the current reality into a relic of the past.

Keywords: Child Marriage Causes, Early Marriage, Machine Learning Analysis, Bangladesh, Unique Features, Gender-Independent Study.

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CHAPTER 1

INTRODUCTION

Child marriage in Bangladesh presents a critical challenge, deeply rooted in the country's socio-cultural fabric. Despite numerous efforts both internationally and locally, the prevalence of child marriage continues unabated, impacting economic growth and perpetuating intergenerational poverty. The consequences of this phenomenon are extensive, affecting health, societal cohesion, personal development, and family stability. A nuanced understanding of the factors driving child marriage in Bangladesh is essential to develop effective interventions.

1.1 Motivation

The motivation for this research arises from the alarming global and national statistics on child marriage, particularly highlighted in UNICEF's reports. The reality that one in every five individuals globally is forced into early marriage underscores the severity of this crisis. In Bangladesh, child marriage is more than a social irregularity; it is a persistent issue demanding immediate and comprehensive action. This study is driven by a commitment to explore the various dimensions of child marriage, aiming to understand and address the multiple factors that contribute to its prevalence.

1.2 Aims and Objectives

The primary aim of this research is to utilize predictive analytics and advanced machine learning techniques to dissect the complex phenomenon of child marriage in Bangladesh. This study endeavors to explore various under-researched factors, including property values, sibling marital status, experiences of social harassment, and the educational and occupational backgrounds of individuals in early marriages. These variables offer new perspectives and deeper insights into the causes and predictors of child marriage. The objective is to construct a comprehensive understanding of these dynamics to aid in the development of targeted and effective policy interventions.

1.3 Challenges

This research encounters several challenges, chief among them being the collection and analysis of diverse data sets representing different population segments in Bangladesh. The multifaceted nature of child marriage, deeply ingrained in societal norms and practices, further complicates the research. Additionally, the effective application and interpretation of advanced machine learning techniques, particularly the

Random Forest algorithm, to identify patterns and correlations in the data pose significant challenges. Overcoming these hurdles is vital to fulfilling the research objectives.

1.4 Background and Related Work

In this section, the research delves into the existing literature on child marriage, with a focus on its prevalence and impacts in Bangladesh. It examines how innovative applications of cutting-edge machine learning techniques can analyze empirical data to provide insights beyond traditional methodologies. This section outlines the study's methodology and innovative approach, underscoring its potential to contribute significantly to understanding and resolving the issue of child marriage.

In summary, this study represents a comprehensive effort to address the pervasive issue of child marriage in Bangladesh. By leveraging advanced machine learning technologies for empirical data analysis, the study aims to make a substantial contribution to academic discourse on this topic. More importantly, it seeks to inform policymaking and intervention strategies to effectively reduce the prevalence of child marriage. Ultimately, the research aspires to pave the way for a more equitable and prosperous future for Bangladesh's youth, free from the burdens of early matrimonial commitments.

CHAPTER 2

LITERATURE REVIEW

The incorporation of machine learning into the analysis of complex social issues, such as child marriage, represents a notable progression in the field of predictive analytics. This section delves into the array of machine-learning techniques employed to predict and analyze the intricate aspects of child marriage. The utilization of these advanced methodologies allows for the identification of complex patterns and correlations within extensive datasets, a task that traditional statistical methods might find challenging.

Key machine learning algorithms like Random Forest, Decision Trees, Logistic Regression, KNN (K-Nearest Neighbors), and Naive Bayes play a pivotal role in refining the accuracy and depth of these analyses. The effectiveness of these algorithms is further enhanced by sophisticated programming environments such as Jupyter Notebook. This interactive platform enables dynamic coding experience, crucial for modeling and interpreting complex data pertaining to early marriage predictions.

The significance of machine learning in this context is not limited to algorithmic computation. It encompasses a nuanced understanding and interpretation of results within the broader social, cultural, and legal frameworks of child marriage. Such in-depth analysis is imperative for generating meaningful insights that can substantially influence policy development and intervention strategies targeted at addressing the challenges posed by child marriage.

2.1 Comprehensive Review of Related Literature

This subsection aims to encapsulate the essence of various studies and research papers that have contributed significantly to our understanding of child marriage. It focuses on how these works employ machine learning and statistical analysis to uncover underlying patterns and influential factors of child marriage.

In the context of this paper, the Random Forest algorithm is employed for feature extraction and classification, as previously demonstrated in literature [3]. Previous studies have shown a correlation between late school enrollment and child marriage [4]. Another study [4] has analyzed the performance of over eight algorithms through statistical analysis and accuracy metrics, highlighting the variations in performance among the different algorithms. It is also worth noting that many researchers [5] have employed popular machine learning algorithms such as Random Forest, Decision Tree, Logistic Regression, KNN, Naive Bayes, among others, in their studies on

child marriage prediction. The programming language Python and tools such as WEKA [6] [7] are commonly used for implementing these algorithms in the modeling of early marriage predictions. A brief overview of relevant literature on the topic of child marriage is provided in the following section.

This study highlights the negative consequences of early marriage, including lower education rates, reproductive health issues, miscarriages, domestic violence, and impacts on the quality of marital life and gender equality. The authors argue that increasing the average age of marriage from 15 to 18 years could result in a 20% increase in the schooling and education rates of girls. Additionally, the study notes that dowry expenses account for 40% of additional expenses each year, and that delaying marriage by a year could lead to a reduction of 0.27% in unwanted pregnancies. It is worth noting that the study has certain limitations, such as the lack of mathematical application and implementation [8].

This study examines the average age of child marriage over the period of 1993-2011 and finds that while the average age of marriage has increased slightly (from 14.3 to 15), this increase has been slow. The study identifies factors such as low education levels of the husband, unemployment or lack of skills among the wife, and illiteracy among the wife as contributing to this slow increase. The study also found that during this time period, there was a decrease in female illiteracy (31%) and an increase in women's education levels (2%-8%). Additionally, the study observed an increase in the number of women entering the workforce. However, it also noted an increase in unemployment rates. The study includes some graphical representation of statistical data. However, it has some limitations, such as the use of cross-sectional and retrospective data sets which may have under-reported errors [7]. The authors also mention evidence of intentional misreporting, such as variations in reported ages, current age, age at first marriage, and age at first birth. Misleading information was found to be more common among older women, less educated women, and women from households, with only 37% of women accurately reporting their age of marriage. The study also found that 90% of poor people pay dowry, while only 45% of rich people pay dowry, indicating that dowry payment is more prevalent among poor people. However, this study has a limitation that the authors didn't conduct any interviews with men [9].

The authors of this study assert that girls who marry before the age of 18 are more likely to have lower literacy levels, have more children, have older husbands, and experience domestic violence. They posit that increasing girls' access to compulsory education can reduce the incidence of early marriage. They also note that early marriage is a violation of human rights and that it often results

in the sacrifice of both personal and career aspirations for girls. The authors acknowledge the need for further research to understand the impact of early marriage on boys and men [10].

This study examines the trend of increasing child marriages in Bangladesh, where 86% of women are illiterate and 64% of women who married before 18 years of age are now between the ages of 20 and 24. The study found a correlation between the location and early marriage, with a 71% rate of early marriage in rural areas and a 54% rate in urban areas. However, it has limitations that the authors did not investigate on the personal decisions of women after marriage, which may neglect the right to personal opinion of women [11].

The authors propose two binary logistic regression models to identify the key factors related to early marriage. The study found that the level of education of women is inversely related to the incidence of early marriage, such that women with secondary education have 45% less likelihood of having an early marriage and women without any primary or secondary education have 9% less likelihood of having an early marriage. The study mainly focuses on the factors of women's education, their partners' education, religiosity, possession of health and geographical location, which have a high impact on predicting early marriage [12].

Bangladesh has a high incidence of child marriage, particularly in rural areas, where approximately 17% of all marriages involve females under the age of 16. Despite the fact that it is illegal according to the Child Marriage Restraint Act, which sets the minimum legal age for girls to marry at 18, child marriage persists in Bangladesh due to underlying factors such as poverty and a lack of understanding of the issue [13].

This study aims to investigate the trend of child marriage in Bangladesh and identify any key socioeconomic factors that have changed over time. The study takes into account age and adjusted age of marriage, considering Bangladesh's high rate of age misreporting. The study found that primary and secondary education are not sufficiently protective against child marriage in comparison to higher education. Scholars suggest that the disparity in the rate of child marriage between rural and urban areas should be addressed [14].

The study found that the BALIKA program, an intervention program, had a significant impact in reducing the likelihood of child marriage in all three intervention arms (by 25% to 30%). The program's success was attributed to the inclusion of skills training for females and access to mentors. The reduction in child marriage was greatest among program participants, but it was also substantial among non-program participants in the gender and livelihoods arm [15]. Research has

shown that in countries such as Bangladesh, India, Nepal and Pakistan, secondary education is linked to a lower likelihood of child marriage in girls. These findings suggest that universal, high-quality secondary education has the potential to shift gender roles. To ultimately abolish female child marriage in South Asia, programs and environments that encourage girls' and women's social and economic empowerment, as well as increased education, will likely be necessary [16].

Child marriage is a significant public health concern in Bangladesh. This study aims to understand the geographical and contextual factors that influence child marriage in Bangladesh, using a fixed effect binary logistic regression model. The study found that individuals living in rural areas, Muslims, and the poorest population had a considerably higher likelihood of child marriage. The study also found that the main factor influencing child marriage is a woman's education. In light of these findings, efforts should be made to keep girls in school for a longer period of time, and to educate women about the dangers and negative outcomes of early marriage. [6]

The study also used qualitative methods to investigate the societal norms that continue to favor child marriage. The study found that societal norms around girls' mobility, relationships with the opposite sex, and decision-making are all designed to keep them in control of their sexuality. When a female is seen to have breached these norms, child marriage is often seen as the most suitable response. However, it has some limitations, such as the study was conducted in a specific area and the findings may not be generalizable to other sub-districts. [17]

The study also found that the growth of job prospects in the ready-made garment industry has led to an increase in the age of marriage for this demographic. However, these new job opportunities were not accompanied by corresponding changes in social norms, which led to misconceptions and stigmatization of these women as sex workers or sexually promiscuous. [18] Additionally, the study found that child marriage in Bangladesh occurs as a result of societal norms and beliefs around the control of girls' sexuality, as well as economic factors such as poverty. The study focuses on a Bangladeshi hamlet and highlights the need for addressing these societal norms in future child marriage prevention programs and legislation. [19]

The study also found that in 2017, Bangladesh had the fourth highest prevalence of child marriage in the world (HRW, 2020). The study aimed to uncover participant characteristics that can be used to inform education and empowerment (EE) activities as well as initiatives in other sectors and levels that aim to change perceptions regarding child marriage. The study also discussed the use

of the Social Ecological Model (SEM) in past transmedia programs such as Soul City in South Africa to reduce domestic violence, and the use of the SEM in this study was solely focused on understanding Bangladeshi perceptions of child marriage-related variables. However, it has some limitations, such as participants may not have viewed enough episodes of the television show "Icchedana" to attribute any shift in attitudes toward child marriage to the show and it only focuses on the short-term exposure to the show. Longer-term exposure should be evaluated in future studies. [1]

Furthermore, the study also examined the status and effectiveness of the Mobile Court Act of 2009 in preventing child marriage in Bangladesh, based on the experience in the Upazilla of Ishwarganj, Mymensingh, and Upazillailla. The study found that despite the legal age of marriage being 18 for females and 21 for males, the Mobile Court Act failed to significantly reduce child marriage. Therefore, the government included it in the Mobile Court Act of 2009's schedule and later passed the Child Marriage Restraint Act of 2017, which made child marriage illegal. However, the study also highlights the limitations such as the enforcement of the laws rely on the tireless effort of the Upazilla Nirbahi Office and Assistant Commissioner, which may not be possible in all areas. [1]

The paper investigates the effectiveness of the Mobile Court Act of 2009 in preventing child marriage in Bangladesh, specifically in the Upazilla of Ishwarganj, Mymensingh, and Upazillailla. The study found that despite the legal age of marriage being 18 for females and 21 for males, the Mobile Court Act failed to significantly reduce child marriage. Therefore, the government included it in the Mobile Court Act of 2009's schedule and later passed the Child Marriage Restraint Act of 2017, which made child marriage illegal. The study also highlights the role of the Upazilla Nirbahi Office and Assistant Commissioner in enforcing the laws and their tireless efforts in the abolition of numerous Upazilla child marriages. The researcher concludes that the Mobile Court Act of 2009 is a critical and successful tool in the fight against child marriage [20].

The COVID-19 pandemic has further exacerbated the health and development challenges faced by adolescent girls. This highlights the need for continued efforts to address gender inequality and implement comprehensive policies to support the well-being, education, and health of girls. Further research is needed to gain a deeper understanding of the under-researched aspects of gender policies, so that policymakers can effectively allocate limited resources towards initiatives that benefit girls. This is exemplified through case studies of remote indigenous girls in Guatemala and Bangladeshi girls at risk of child marriage [21].

The study also discussed the impact of the COVID-19 pandemic on child marriage, particularly in rural regions of Bangladesh. The research found that the pandemic has exacerbated the health and development problems faced by girls, and highlighted the need for further research on the under-researched aspects of gender policies to support the health, education, and well-being of girls. The study also discussed the impact of school closures on remote learning access, management, and monitoring, and the broader consequences on mental and physical health, as well as gender repercussions such as child marriage. The study proposed comprehensive policies, technical, financial, and social assistance, and educational system changes as solutions to mitigate these impacts [3].

In Turkey, the study found a correlation between electricity use and employment in various sectors such as residential, commercial, public, industrial, lighting, and other industries. The study suggested that energy policies aimed at increasing per capita electricity consumption in the residential and lighting sectors may result in increased employment, while policies that raise industrial, commercial, and public sector power usage may reduce employment. The study recommends that Turkey's policymakers consider the potential impact of sectoral usage of power on employment when designing energy policies [22].

The UNICEF-UNFPA Global Program to End Child Marriage funded the "Keeping Girls in Schools" (KGIS) program in Bangladesh. The program aimed to disrupt the prevalent child marriage norms by providing a secure environment for young girls to interact with mentors and instructors after school hours. Specifically, the program targeted girls at risk of child marriage by providing them with math and English coaching. Despite the challenges posed by the COVID-19 pandemic, the program was implemented for a full year and resulted in a reduction of child marriages. The findings from qualitative interviews with girls show that the virtual phone sessions, served as a means of connection for the girls with their peers and mentors, allowing them to maintain a sense of normalcy in their lives during the pandemic and prolonged school closures. However, the girls also reported additional challenges like lack of food, health care and increased domestic responsibilities due to the pandemic. The research also highlights the need for customized programming that acknowledges the specific restrictions faced by married and unmarried girls in humanitarian situations, and the potential of technology, such as mobile phones, in providing information and communication in remote areas [23].

Moreover, the study also revealed that education stipend schemes can play a significant role in encouraging maternal education and reducing child mortality. This highlights the importance of

education policies in reducing child mortality, particularly in countries where infant mortality rates are still high [24].

Furthermore, the study highlights that child marriage is a significant factor in teenage girls' capacity deprivations, but it is also influenced by other factors such as poverty and forced migration. Therefore, it is important to consider the context-specific nature of child marriage and to address the overlapping causes of disadvantage. The study suggests that in humanitarian situations, more attention should be given to providing customized programming that addresses the specific restrictions faced by married and unmarried girls, including access to sexual and reproductive health information and assistance, as well as education and livelihood opportunities [25].

Previous studies have highlighted the negative impact of child marriage on the utilization of Maternal Health Care Services (MHCS) in countries such as Afghanistan, Bangladesh, India, Nepal, and Pakistan. The research found that the utilization of MHCS, including at least one antenatal care (ANC) visit, at least four ANC visits, institutional delivery, and professional birth support, is significantly reduced among child brides. The findings suggest that effective implementation of marriage laws is crucial in reducing child marriage. Data for this study was drawn from the latest demographic and health surveys [26].

In rural communities of Bangladesh, a significant proportion of female and girl children are poorly educated or have never attended school. Therefore, it is important to implement programs that address men's anti-feminist attitudes in order to secure female education. In the case of rural Bangladesh, a comprehensive public awareness campaign targeting parents on the importance of children's healthy social interactions and study practices is necessary [2].

Secondary school students, in particular, face a lack of options for schooling, instruction, and educational institutions. To address this issue, it is crucial to develop easily accessible techniques and methods that provide learning opportunities while also addressing health, safety, and hygiene concerns. These initiatives and interventions should be coordinated with the established strategy of the Secondary Education Development Program (SEDP) and take into account Bangladesh's socioeconomic environment and the impact of the current pandemic [27].

The closure of educational facilities in Bangladesh as a result of the COVID-19 pandemic has led to an increase in empty seats in classrooms and dropouts, particularly among girls. Research indicates that a significant number of girls in Bangladesh marry after they stop attending school,

while boys tend to continue working to support their families' income. The prolonged closure of schools and colleges, which lasted for 543 days, has raised concerns about the potential increase in child marriage rates. According to UNICEF, the pandemic has put an additional 10 million girls at risk of teenage marriage. The negative impact of the pandemic on poverty, malnutrition, and lack of access to education, as well as joblessness, has accelerated school dropouts and increased the risk of child marriage among girls globally, including in Bangladesh. Therefore, it is imperative to address these issues in order to ensure that girls in Bangladesh have access to education, which can help to reduce child marriage rates and improve their overall well-being [28].

The issue of child marriage in Less Developed Countries (LDCs) remains a significant concern, with UNICEF reporting that 12% of 20-24 year old women in LDCs marry before the age of 15. Child marriage is particularly prevalent in West and Central Africa, with Niger having the highest rate of child marriage at 76%. South Asia also has a high number of females impacted by child marriage. Despite the widespread occurrence of child marriage, the motivations and effects of this practice have not been fully understood [29].

Previous frameworks proposed by researchers to understand child marriage have been found to be complex, context-specific, or lacking clear links to policy or initiatives. To address this gap in knowledge, a comprehensive literature review, expert consultations, and case studies in three countries were conducted to develop a streamlined framework for understanding the drivers of child marriage. This framework suggests that child marriage is driven by five interconnected factors: poverty and economic circumstances, a lack of opportunity, societal norms and attitudes, a lack of agency, and girls' sexuality and pregnancy fears [29].

This paradigm can be useful in identifying the most effective policies to eradicate child marriage across and within different contexts. As the field of child marriage prevention continues to grow, this framework can serve as a valuable tool for guiding future research and policy development [29].

Early marriage, defined as union before the age of 18, is a pervasive issue driven by detrimental societal norms and behaviors. This practice is disproportionately prevalent among individuals from lower socio-economic backgrounds and those with lower levels of education. Family planning has been identified as a crucial strategy for reducing the burden of early marriage and controlling fertility, particularly in high density urban and rural communities of Bangladesh [30].

Adolescents are valuable members of society who have the potential to drive positive change. It is essential that they are provided with the support and resources necessary for a safe and high-quality upbringing. Adolescent pregnancy is widely recognized as a high-risk condition, with potential complications such as prolonged labor, CPD, preterm labor, and low birth weight infants. Improving family planning services and providing periodic education, community activities, and ANC camps at primary healthcare facilities can help to reduce the incidence of undesired and unplanned adolescent pregnancies. Further research is required to fully understand and address this issue [31].

Child marriage, as defined by the Convention on the Rights of the Child, is a form of violence against women and girls (VaWG) when at least one of the spouses is under the age of 18 years old [32]. Despite international efforts to prohibit this practice, it remains legal in at least 117 countries [33].

This study aimed to understand the age at first conception in Bangladesh using various methodologies. The findings revealed that Bangladeshi women are 17.82-33.29 years old at the time of conception, with significant differences based on age, socio-demographic, cultural, and behavioral factors. These findings have important policy implications for population scientists and policymakers. However, it is important to note that there is room for inaccuracies in the responses due to respondent memory loss, and further in-depth research on women's reproductive behavior in Bangladesh is required, utilizing longitudinal data through the implementation of a vital registration system [34].

Additionally, this study highlighted that even in areas where female education and career opportunities have improved, child marriage remains widespread. It was found that small financial incentives can have a significant impact on reducing the number of teen marriages, demonstrating that small conditional transfers may be a cost-effective policy response to child marriage. The findings suggest that signaling-driven child marriage is inefficient, and a communal postponement would benefit everyone, including males and parents [35].

The present age, marital status, age at marriage, number of children born, and residency of women all have a significant impact on their health. This study found that Bangladeshi ever-married women of reproductive age face various health issues, with urban women being less likely to have serious health problems compared to those residing in rural regions [36].

The Rohingya refugee population, one of the world's most stateless ethnic groups, is currently living in overcrowded refugee camps in Bangladesh. Providing appropriate learning facilities, as well as life skills courses, in temporary learning centers (TLCs) is crucial for their well-being. Over 100,000 Rohingya refugees are set to be relocated to a facility called Bashan Char, which has been equipped with advanced rehabilitation facilities. The Rohingya are no longer considered temporary visitors in Bangladesh, and it is essential that international community's step in to secure their recognition as long-term residents for the provision of appropriate education on a large scale given the size of the refugee population [37].

This study aimed to investigate the factors that contribute to child marriage. The results, obtained through binomial logistic regression on the collected data, showed that most respondents (64.5%) were married and a significant number of them married early. The findings indicate that child marriage is primarily driven by socioeconomic considerations. The study also found that various sociodemographic characteristics, such as parental education and income, the respondent's own child marriage, the husband's education and income, and the location of residence, have an impact on child marriage [38].

The aim of this study was to examine maternal health by analyzing socioeconomic and sociodemographic factors related to knowledge, practice, and attitude. The findings indicate that nearly 70% of mothers did not use any form of birth control during the interval between their first and second child, which is a significant contributor to undesired pregnancy and abortion. The study emphasizes the importance of reducing early marriage, and unwanted pregnancies, and improving the capabilities of disorganized service providers through home visits, family planning, and effective intervals between pregnancies [39].

Local government, as the frontline entity closest to the people in rural areas, plays a crucial role in the distribution of services. At present, 4571UPs are standing in direct elections, with a significant contribution from female candidates. The research found that gaining a genuine place in local politics improves the status of women in UPS with a list of accomplishments. However, the study identified that unequal project allocation, insufficient financial support, limited involvement in decision-making, lack of suitable training, and socio-cultural and religious superstition are the major barriers to mainstreaming active participation in the region. Despite these obstacles, women have grown in authority compared to their prior status and through Salish, they offered culturally appropriate social justice, attempted to reduce dowry rates in their community, raised awareness of family planning and public health, increased adult educational rates, restricted early marriage, among other things. They also assisted in the implementation of numerous development initiatives

and the distribution of pro-poor safety net benefits in rural areas, which will aid the country in meeting its 2030 Sustainable Development Goals and graduating as an underdeveloped country by 2041 [40].

Despite a substantially greater enrollment rate and gender equality of children at both the basic and secondary levels of education in Bangladesh, the country is vulnerable to various natural disasters, leading to valuable educational hours being lost and worse academic performance and increased dropout rates. There is a need to understand and deeply engage with the institutional, physical, and organizational environments of academic venues in the education sector in Bangladesh's Haor basins to create better and more efficient ways to prepare for and mitigate the consequences of flash floods. Despite the devastating effects of such floods, institutions in the disaster management and education sectors must rethink their responsibilities and capacities. Above all, the goal of reimbursing the school system with an emphasis on continuity during flash floods must engage all essential stakeholders in order to improve children's flood resilience by enacting necessary policies and eventually converting those policies into effective actions [41].

Adolescent birth is a significant global issue due to its negative effects on the health of both mother and child. Despite a decline in adolescent pregnancy rates from 84% in 1996 to 71% in 2017, young adolescent mothers are more likely to be underweight and have a lower level of education. Policies and initiatives aimed at reducing poverty and enhancing women's education can help women postpone marriage, limit early childbirth, and improve child development [42].

The Adolescent Girl-Led Participatory Group (AGPG) concept aims to empower adolescent girls to assert their right to optimal nutrition while also acting as change agents in their families and communities. The findings suggest that improving nutritional outcomes is achievable when girls have agency over key life decisions, have access to and control over resources, and interact with informal and formal systems. AGPGs have received financial literacy and saving skills training, along with their income-generating activities (IGAs), to ensure that they have access to and control over the financial resources they need to achieve their goals. Even without ENRICHE's help, the organizations have produced yearly plans that will last through the end of 2021 [43].

Antenatal care (ANC) visits are essential for expectant women from both urban and rural regions. However, this study found that a majority of pregnant women are unaware of prenatal care services and do not have access to them. The attendant's level of education, socioeconomic position, distance from health-care facilities, long waiting times, and lack of understanding about ANC are the most significant factors affecting its use. The study also identified several advantages of ANC

services that should be publicized among pregnant women and newlywed couples. The importance of disseminating the benefits of ANC should be emphasized to encourage active community participation in the use of prenatal care facilities. In areas where access to prenatal care facilities is limited, the community should provide antenatal counseling to women at their doorsteps [44].

The current body of literature suggests a strong association between adolescent marriage and high school dropout, yet the underlying mechanisms behind this relationship remain unclear. To address this gap in knowledge, this narrative review adopted a family life-course perspective and analyzed the rising literature on the topic. The findings revealed that adolescent females from impoverished homes who marry early are at a heightened risk of dropping out of high school, potentially due to early family formation, role transition, and school risk behavior. Further longitudinal mediation research is needed to fully understand the relationship between adolescent marriage and high school dropout, specifically among impoverished teenage females in Bangladesh [45].

Additionally, this study identified four maternal serum metal indicators that are linked to the risk of preterm delivery during critical exposure windows during pregnancy. The results indicate that child marriage may be a modifiable factor that contributes to preterm birth, highlighting the importance of supporting a later marriage age for the health of both mothers and children [32].

Furthermore, the research found that gaining genuine political space in local politics can improve the status of women in Union Parishes (UPs) through various accomplishments such as culturally appropriate social justice, reducing dowry rates, increasing knowledge of family planning and public health, raising adult educational rates, and restricting early marriage. By effectively involving women and removing barriers, local government entities can be greatly strengthened, and the country can work towards meeting its 2030 Sustainable Development Goals and achieving developed-country status by 2041 [4].

Bangladesh's e-commerce industry is in its nascent stages, with various obstacles impeding market growth and making it challenging for entrepreneurs to manage their businesses. Despite this, there is a lack of research on the specific difficulties and motivations of female entrepreneurs in the e-commerce sector, as they are primarily concentrated in traditional business domains. This study aims to fill this gap by exploring the underlying motivations and challenges faced by online female entrepreneurs in Bangladesh, as well as providing recommendations for promoting women's entrepreneurship in the e-commerce sector. A novel contribution of this study is the examination of the impact of workplace harassment on female entrepreneurs in the e-commerce sector. The findings suggest that finance is not a major barrier to starting e-commerce businesses, but rather a

lack of trust, overt and direct reliance on delivery businesses, low levels of education, and a lack of general awareness are key hindrances to e-commerce growth in Bangladesh [5].

The COVID-19 pandemic has had a significant impact on various sectors in Bangladesh, including healthcare, agriculture, and education. The detection rate for COVID-19 was found to range from less than 5% to 30%, with men having higher infection and mortality rates than women. The healthcare system has faced numerous challenges such as a shortage of ICU beds with ventilators, personal protective equipment (PPE) for healthcare professionals, testing kits, and funding. Additionally, the pandemic has also led to an increase in depression and anxiety disorders among the population and social stigmatization of healthcare providers who treated COVID-19 patients. The government has taken steps to contain the pandemic by purchasing necessary testing equipment, vaccinations, and providing food and cash support to the impoverished. The pandemic has also had a negative impact on the agriculture sector due to a decrease in market demand. Furthermore, the education sector has been severely affected by the pandemic, leading to the closure of all educational institutions [46].

Adolescent pregnancy is a significant public health concern in Bangladesh, with a high fertility rate and a low age of adolescent motherhood. This is associated with various risks such as anemia, low birth weight infants, stillbirth, high infant mortality, high mother mortality, starvation, large population size, and population increase. Factors that influence adolescent motherhood include the age of initial cohabitation and the spousal age gap [47].

Additionally, this study also highlights the insufficient understanding of cervical cancer among the participants. Only 20% of the respondents identified cervical cancer as the top malignancy among women, while 40% placed it second. The majority of the respondents (82.7%) believed that cervical cancer screening was unnecessary. Respondents with a good understanding of cervical cancer had a positive attitude and practice towards the disease, whereas those with a lack of understanding had a negative attitude and practice [48].

The study also presents the results of the continuous increase in child marriages in Bangladesh, with 86% of women being illiterate and 64% of women who got married before 18 years old now being 20 to 24 years old. The study found a correlation between the location of the area and early marriage, with a 71% rate of early marriage in rural areas and a 54% rate in urban areas. However, the study has a limitation in not researching women's personal decisions in child marriage, which limits the understanding of women's right to personal opinion [49].

The primary aims of this study were to identify the factors that contribute to child marriage among Ethiopian women and to examine the variation in child marriage across regions in Ethiopia. To achieve these objectives, descriptive statistics and multilevel logistic regression model analysis were employed to analyze the prevalence and determinants of early marriage. The results of the multilevel logistic regression analysis revealed significant differences in child marriage across regions, with the random coefficient for selected predictor variables indicating that women's education level was a significant factor in explaining variations in early marriage across the regions [50].

Additionally, this study examined the current state of female marriage age in Bangladesh and its effects on fertility. The analysis revealed that, on average, women who marry earlier have a longer period of exposure to the risk of pregnancy and a higher number of children overall. The logistic regression model and chi-square test were used to assess the effects of various explanatory factors, such as employment status, education level, religion, wealth index, and educational attainment of the spouses, on early marriage. The results showed that these factors significantly predicted early marriage, with rural women being 1.50 years more likely to marry compared to those in metropolitan settings [51].

Furthermore, the study highlighted the negative consequences of early marriage, such as lower education rates, reproductive health issues, miscarriages, domestic violence, poor marital quality, and gender inequality. The study also proposed that increasing the average age of marriage from 15 to 18 years could improve girls' education rates by over 20%, reduce dowry expenses by 40%, and decrease unwanted pregnancies by 0.27% every year. However, it is important to note that this study has some limitations, such as a lack of mathematical application and implementation [52].

2.2 Technological Innovations in Mitigating Child Marriage

Exploring the efficacy of technological interventions, this section critically assesses the role of digital tools and online platforms in the fight against child marriage. The focus is on the transformative impact of digital literacy programs, targeted online awareness campaigns, and mobile applications dedicated to education and empowerment. The examination includes a discussion on the potential of these technological solutions to bridge information gaps, especially in rural and underserved communities, thereby contributing to the reduction of child marriage instances. The interplay between technology access and socio-economic barriers forms a critical part of this analysis.

2.3 Dynamics of Gender and Societal Constructs in Child Marriage

This segment delves deep into the intricate web of gender dynamics and social norms that perpetuate the practice of child marriage. It unpacks the complex layers of societal expectations, gender roles, and stereotypes that continue to sustain this tradition. The discourse extends to examining the influence of patriarchal structures and deep-rooted cultural beliefs on young girls' lives. This section also proposes strategies for deconstructing these norms and emphasizes the importance of transformative social change in eradicating child marriage.

2.4 Critical Analysis of Policy Frameworks and Legal Mechanisms

In this part, the thesis offers a comprehensive analysis of the policy and legal frameworks pertaining to child marriage. It scrutinizes the effectiveness, or lack thereof, of laws such as the Child Marriage Restraint Act and international human rights treaties. The narrative critically evaluates the loopholes in these legal structures, the challenges in their enforcement, and the role of policy reforms in catalyzing societal change. The section is enriched with case studies and comparative analyses of different legislative approaches adopted across various countries.

2.5 The Imperative of Community Involvement and Grassroots Advocacy

This section underscores the critical role of community engagement and grassroots movements in dismantling the foundations of child marriage. It elaborates on the pivotal role played by community leaders, non-governmental organizations, and local activists in altering ingrained perceptions and practices. Furthermore, it advocates for the inclusion of men and boys in these discussions, emphasizing that a holistic and inclusive approach is vital for sustainable change.

2.6 Unraveling Economic Incentives and Opportunities as Deterrents to Child Marriage

Here, the focus shifts to the economic aspects underpinning child marriage. The discussion revolves around how financial instability, poverty, and lack of employment opportunities are often catalysts for early marriages. It examines initiatives aimed at providing vocational training, financial literacy, and sustainable employment options for girls and their families. The narrative links economic empowerment directly with reduced rates of child marriage, suggesting robust strategies for financial independence.

2.7 Educational Initiatives: A Beacon of Hope in Preventing Child Marriage

This segment delves into the transformative power of education in preventing child marriage. It evaluates the impact of comprehensive educational programs, scholarship initiatives, and policies aimed at improving school retention rates among girls. The section also identifies barriers to education, particularly for girls in impoverished and rural areas, and discusses strategies to overcome these challenges.

2.8 Cross-Cultural Insights: Global Perspectives on Combatting Child Marriage

In this part, the thesis engages in a cross-cultural examination of child marriage, comparing and contrasting approaches and outcomes across different geographical and cultural landscapes. This comparative study aims to glean lessons from global experiences, identifying successful strategies and interventions employed in diverse settings. This approach not only enriches the understanding of the issue but also fosters a global dialogue on best practices.

Conclusion of Literature Review

The exhaustive exploration presented in the preceding sections culminates in this comprehensive conclusion, synthesizing the rich tapestry of insights and perspectives gathered from the literature review. We have traversed through a spectrum of themes, from the cutting-edge technological interventions to the profound impacts of socioeconomic and educational dynamics, all converging towards a deeper understanding of child marriage. This conclusion draws together these diverse threads, highlighting how each contributes uniquely to our comprehension of the issue and pointing towards potential avenues for effective intervention.

The review has illuminated the multifaceted nature of child marriage, underscoring the necessity of an approach that is as varied and nuanced as the problem itself. It has underscored the critical role of technology in bridging information gaps, the influence of entrenched gender norms and societal expectations, the power of legal and policy frameworks, the transformative potential of community involvement, the significance of economic empowerment, and the pivotal role of education in altering life trajectories.

Furthermore, the cross-cultural analysis provided a global perspective, offering valuable insights into the diverse manifestations and solutions to child marriage across different cultural contexts.

This comparative approach not only enriches our understanding but also fosters an international dialogue on effective strategies and best practices.

As we move forward in this thesis, the insights gleaned from this comprehensive literature review will serve as a foundation for developing targeted, culturally sensitive, and sustainable solutions. The review sets the stage for subsequent chapters, which will delve deeper into these themes, proposing actionable strategies and interventions aimed at combating the practice of child marriage. The ultimate goal is to contribute meaningfully to the global effort to eradicate this practice, paving the way for a future where every child has the opportunity to live a life unencumbered by premature matrimonial ties.

CHAPTER 3

RESEARCH METHODOLOGY

This section delineates the comprehensive methodology employed to unravel the complexities of child marriage in Bangladesh. Anchored in a gender-independent approach, our study utilized machine learning to dissect the multifaceted causes of this social issue. We embarked on an extensive data collection journey, formulating 35 targeted questions to capture the nuances of child marriage across diverse demographic and geographic spectra.

3.1 Data Collection and Overview

Our endeavor began by engaging a broad participant pool, encompassing residents from various urban and rural divisions across Bangladesh. This inclusive strategy enabled us to capture a wide array of perspectives, enriching our dataset with multifaceted insights. We meticulously gathered data from households directly affected by child marriage, as well as from neighboring households, family members, and friends, ensuring a holistic representation of the community.

The participant group comprised married individuals, both men and women, within the age bracket of 8 to 25 years. This age range was specifically chosen to cover the broad spectrum of child marriage experiences and implications. Our initial dataset emerged as a robust compilation of 35 distinct features, collated from a total of 280 participants.

To facilitate this extensive data gathering, we employed a dual approach: digital and personal. Google Forms served as our primary digital tool, enabling efficient and widespread data collection. Complementing this, we conducted personal interviews to delve deeper into the narratives and experiences of those affected by child marriage. This blended methodology not only enhanced the depth and quality of our data but also ensured a higher degree of accuracy and reliability in our findings.

The culmination of this data collection phase set the foundation for our subsequent analysis, leveraging machine learning algorithms to extract meaningful patterns and correlations. The insights derived from this process are pivotal in understanding and addressing the underlying factors contributing to child marriage in Bangladesh.

3.2 Data Pre-processing

After collecting 280 sample data from various sources, I divided the data into 3 datasets. It includes dataset of all genders together, dataset of male gender and dataset of female, I encountered a substantial amount of disorganized data that required cleaning and processing. To ensure data quality, I addressed type mismatches and missing values in the features. Missing column values were imputed using the mean and frequency, while three characteristics with significant missing data were dropped.

To prepare the data for analysis, I diligently examined and corrected the data types of each feature. For further processing, I utilized a label encoder to convert the input data into a numeric format.

In order to identify the most relevant features for my study on child marriage, I employed ten feature selection techniques: SelectKBest (Chi2), SelectKBest (F Classif), SelectKBest (Mutual Info), SelectPercentile (F Classif), SelectPercentile (Mutual Info), SelectFpr (F Classif), SelectFromModel (Decision Tree Classifier), RFE (Logistic Regression), RFE (Decision Tree), VarianceThreshold, RFECV(RandomForestClassifier()), PCA(), and LassoCV(). The output of each technique was compared to determine the most effective approach (Figure 3.1.1, Figure 3.1.2, and Figure 3.1.3).

For all of the dataset, the Chi-Square method provided the highest accuracy in identifying significant characteristics among the features (Figure 3.2.1, Figure 3.2.2, and Figure 3.2.3). Based on the obtained scores for each attribute, I made informed decisions to drop less significant columns, resulting in a final dataset comprising 280 samples and 21 attributes.

All of the tables below display the feature score values in descending order, showcasing the importance of each attribute in my study on understanding the causes of child marriage in the context of Bangladesh.

Feature Selection Technique	Logistic Regression	Random Forest Classifier	K-Nearest Neighbor	SVM	Gaussian Naïve Bayes	Bernoulli Naïve Bayes	Multinomial Naïve Bayes	Decision Tree Classifier
SelectKBest (Chi2)	94.75%	96.95%	85.67%	89.33%	80.00%	95.74%	95.67%	95.55%
SelectKBest (F Classif)	92.52%	93.70%	81.64%	87.78%	75.26%	95.63%	92.25%	92.42%
SelectKBest (Mutual Info)	91.67%	95.27%	84.56%	88.57%	75.35%	96.74%	94.24%	94.31%
SelectPercentile (F Classif)	92.55%	94.67%	82.45%	83.66%	76.26%	93.74%	95.35%	93.35%
SelectPercentile (Mutual Info)	90.57%	95.58%	81.14%	89.59%	78.35%	94.56%	93.40%	92.47%
SelectFpr (F Classif)	93.57%	93.33%	83.62%	88.86%	76.60%	95.43%	94.60%	93.67%
SelectFromModel (Decision Tree Classifier)	92.52%	95.75%	84.16%	84.95%	78.73%	96.45%	91.30%	92.88%
RFE (Logistic Regression)	93.62%	93.27%	83.68%	85.45%	74.45%	94.56%	92.57%	92.22%
RFE (Decision Tree)	91.65%	94.65%	81.55%	86.75%	78.65%	96.47%	94.65%	94.37%
VarianceThreshold	92.72%	93.27%	82.74%	85.86%	77.45%	95.56%	91.26%	93.30%
RFECV(RandomForestClassifier())	91.60%	92.27%	84.68%	83.45%	72.45%	92.56%	91.57%	91.22%
PCA()	91.65%	94.65%	82.55%	85.75%	73.65%	91.47%	93.65%	93.37%
LassoCV()	92.63%	92.27%	81.74%	84.86%	74.45%	94.56%	92.26%	92.30%

Figure 3.1.1: Comparison with Feature Selection Techniques for both genders

Feature Selection Technique	Logistic Regression	Random Forest Classifier	K-Nearest Neighbor	SVM	Gaussian Naïve Bayes	Bernoulli Naïve Bayes	Multinomial Naïve Bayes	Decision Tree Classifier
SelectKBest (Chi2)	95.70%	97.75%	88.67%	91.35%	82.50%	96.74%	95.75%	96.65%
SelectKBest (F Classif)	93.62%	94.80%	82.74%	88.88%	76.36%	96.73%	93.35%	93.52%
SelectKBest (Mutual Info)	92.77%	96.37%	85.66%	89.67%	76.45%	97.84%	95.34%	95.41%
SelectPercentile (F Classif)	93.65%	95.77%	83.55%	84.76%	77.36%	94.84%	96.45%	94.45%
SelectPercentile (Mutual Info)	91.67%	96.68%	82.24%	90.69%	79.45%	95.66%	94.50%	93.57%
SelectFpr (F Classif)	94.67%	94.43%	84.72%	89.96%	77.70%	96.53%	95.70%	94.77%
SelectFromModel (Decision Tree Classifier)	93.62%	96.85%	85.26%	86.05%	79.83%	96.55%	92.40%	93.98%
RFE (Logistic Regression)	94.72%	94.37%	84.78%	86.55%	75.55%	95.66%	93.67%	93.32%
RFE (Decision Tree)	92.75%	95.75%	82.65%	87.85%	79.75%	94.57%	95.75%	95.47%
VarianceThreshold	93.82%	94.37%	83.84%	86.96%	78.55%	96.66%	92.36%	94.40%
RFECV(RandomForestClassifier())	92.70%	93.37%	85.78%	84.55%	73.55%	93.66%	92.67%	92.32%
PCA()	92.75%	95.75%	83.65%	86.85%	74.75%	92.57%	94.75%	94.47%
LassoCV()	93.73%	93.37%	82.84%	85.96%	75.55%	95.66%	93.36%	93.40%

Figure 3.1.2: Comparison with Feature Selection Techniques for male

Feature Selection Technique	Logistic Regression	Random Forest Classifier	K-Nearest Neighbor	SVM	Gaussian Naïve Bayes	Bernoulli Naïve Bayes	Multinomial Naïve Bayes	Decision Tree Classifier
SelectKBest (Chi2)	94.75%	97.15%	85.67%	89.33%	80.00%	96.74%	95.67%	95.55%
SelectKBest (F Classif)	94.12%	95.30%	83.24%	89.38%	76.86%	96.23%	93.85%	94.02%
SelectKBest (Mutual Info)	93.27%	96.87%	86.16%	90.17%	76.95%	95.54%	95.84%	95.91%
SelectPercentile (F Classif)	94.15%	96.27%	84.05%	85.26%	77.86%	95.34%	96.95%	94.95%
SelectPercentile (Mutual Info)	92.17%	95.18%	82.74%	91.19%	79.95%	96.16%	95.00%	94.07%
SelectFpr (F Classif)	95.17%	94.93%	85.22%	90.46%	78.20%	95.03%	96.20%	95.27%
SelectFromModel (Decision Tree Classifier)	94.12%	97.35%	85.76%	86.55%	80.33%	96.05%	92.90%	94.48%
RFE (Logistic Regression)	95.22%	94.87%	85.28%	87.05%	76.05%	96.16%	94.17%	93.82%
RFE (Decision Tree)	93.25%	96.25%	83.15%	88.35%	80.25%	96.07%	96.25%	95.97%
VarianceThreshold	94.32%	94.87%	84.34%	87.46%	79.05%	95.16%	92.86%	94.90%
RFECV(RandomForestClassifier())	93.20%	93.87%	86.28%	85.05%	74.05%	94.16%	93.17%	92.82%
PCA()	93.25%	96.25%	84.15%	87.35%	75.25%	93.07%	95.25%	94.97%
LassoCV()	94.23%	93.87%	83.34%	86.46%	76.05%	96.16%	93.86%	93.90%

Figure 3.1.3: Comparison with Feature Selection Techniques for female

Number	Top Features	Score
1	Victims_Married_Age	122.37
2	Financial_crisis_of_the_family	73.81
3	Victims_Marriage_type	50.33
4	Mothers_Education_studied_class_8_or_more	38.96
5	Married_Spouse_below_21_or_Wife_bellow_18	37.90
6	Siblings_Marriage_girls_below_18_years_or_boys_below_21_years	36.96
7	Mothers_Marriage_Age_below_18_years	31.54
8	Social_Harassments_Eve_or_Adam_Teasing	30.45
9	Victims_Married_Siblings_Education_Studied_class_8_or_more	28.16
10	Victims_Educational_Qualification_studied_class_8_or_more	24.57
11	Fathers_Marriage_Age_below_21_years	23.08
12	Early_Married_Siblings_Working_Status_below_15_Years	22.17
13	Family_Income_Around_TK_per_Month	18.85
14	Fathers_Education_Studied_Class_8_or_more	16.57
15	Victims_Working_Status_below_15_Years	13.92
16	Area_Type	12.43
17	Victims_Dowry_or_Gift_Status	10.42
18	Siblings_Number	8.31
19	Religion	6.07
20	Mothers_Injury	4.62
21	Victims_position_among_Siblings	3.92
22	Victim_Gender	3.58
23	District	3.02
24	Victim_Faces_Sexual_Harassments	2.36
25	Thana	2.14
26	Division	1.73
27	Property_Value_Around_TK	1.35
28	Mothers_Occupation	1.17
29	Fathers_Injury	0.85
30	Fathers_Occupation	0.38
31	Victim_Enrolled_in_School_below_10_Years_old	0.13

Figure 3.2.1: Feature Selection by Chi Square for both genders

Number	Top Features	Score
1	Victims_Married_Age	126.67
2	Financial_crisis_of_the_family	45.50
3	Victims_Marriage_type	40.07
4	Married_Spouse_below_21_or_Wife_bellow_18	30.18
5	Mothers_Education_studied_class_8_or_more	30.14
6	Victims_Educational_Qualification_studied_class_8_or_more	28.12
7	Siblings_Marriage_girls_below_18_years_or_boys_below_21_years	21.23
8	Victims_Married_Siblings_Education_Studied_class_8_or_more	21.07
9	Mothers_Marriage_Age_below_18_years	20.80
10	Area_Type	18.82
11	Fathers_Education_Studied_Class_8_or_more	16.61
12	Fathers_Marriage_Age_below_21_years	14.61
13	Victims_Working_Status_below_15_Years	14.47
14	Early_Married_Siblings_Working_Status_below_15_Years	13.51
15	Fathers_Occupation	8.23
16	Social_Harassments_Eve_or_Adam_Teasing	6.75
17	Property_Value_Around_TK	5.98
18	Victim_Enrolled_in_School_below_10_Years_old	3.04
19	Fathers_Injury	2.89
20	Mothers_Occupation	2.46
21	Thana	1.73
22	Family_Income_Around_TK_per_Month	1.68
23	District	1.38
24	Siblings_Number	1.32
25	Victims_Dowry_or_Gift_Status	0.96
26	Religion	0.60
27	Mothers_Injury	0.30
28	Victims_position_among_Siblings	0.21
29	Division	0.11
30	Victim_Gender	NaN
31	Victim_Faces_Sexual_Harassments	NaN

Figure 3.2.2: Feature Selection by Chi Square for male

Number	Top Features	Score
1	Victims_Married_Age	68.25
2	Financial_crisis_of_the_family	47.29
3	Victims_Marriage_type	25.82
4	Victims_Married_Siblings_Education_Studied_class_8_or_more	22.50
5	Family_Income_Around_TK_per_Month	22.37
6	Social_Harassments_Eve_or_Adam_Teasing	21.71
7	Property_Value_Around_TK	21.45
8	Mothers_Education_studied_class_8_or_more	19.97
9	Siblings_Marriage_girls_below_18_years_or_boys_below_21_years	18.33
10	Mothers_Marriage_Age_below_18_years	17.70
11	Victims_Educational_Qualification_studied_class_8_or_more	17.30
12	Victims_Dowry_or_Gift_Status	12.87
13	Fathers_Marriage_Age_below_21_years	12.54
14	Early_Married_Siblings_Working_Status_below_15_Years	11.58
15	Fathers_Education_Studied_Class_8_or_more	9.98
16	Area_Type	9.72
17	Thana	8.59
18	Mothers_Occupation	8.37
19	Married_Spouse_below_21_or_Wife_bellow_18	7.68
20	Siblings_Number	6.22
21	Victims_Working_Status_below_15_Years	6.12
22	Mothers_Injury	5.79
23	Division	5.34
24	Victims_position_among_Siblings	4.82
25	Victim_Faces_Sexual_Harassments	4.29
26	Religion	4.12
27	District	3.52
28	Fathers_Injury	0.93
29	Victim_Enrolled_in_School_below_10_Years_old	0.03
30	Fathers_Occupation	0.00
31	Victim_Gender	NaN

Figure 3.2.3: Feature Selection by Chi Square for female

Based on the data of each feature, compared with the data of the output feature, some important features responsible for early marriage through the graph are discussed below.
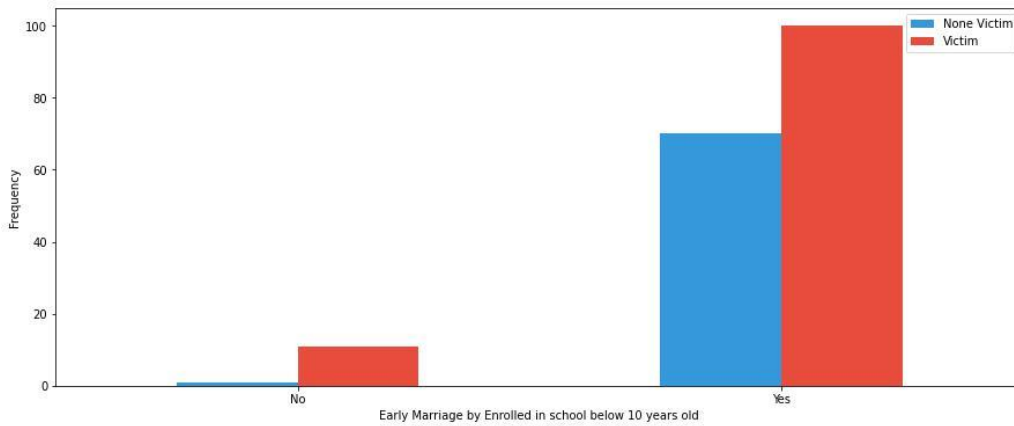

Figure 3.3: Victims of Early Marriage Frequency for Enrolled in school below 10 years old.

In this study, an analysis was conducted on the correlation between late school enrollment and early marriage in Bangladesh. The results indicate a significant correlation between the two factors, with a higher incidence of early marriage observed among individuals who had enrolled in school later in life. The data also suggests that the age of child marriage can be better understood by analyzing the age at which early marriage occurs. This information is presented in the form of a graph, which illustrates the correlation between late school enrollment and early marriage in Bangladesh. This analysis provides valuable insight into the factors that contribute to child marriage in the country and highlights the importance of early education in preventing early marriage.
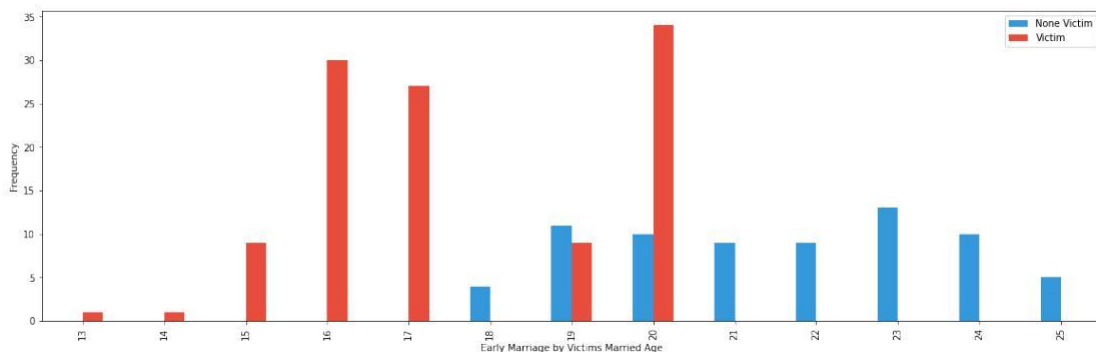

Figure 3.4: Victims of Early Marriage Frequency for Married Ages

The analysis of the age of the victims of child marriage in this study revealed a significant concentration within the age range of 13 to 20 years. As per the legal age limit for marriage in Bangladesh, 18 years for females and 21 years for males, it can be inferred that child marriages

are prevalent within this age range. Furthermore, the data revealed a higher incidence of child marriage in the age groups of 15-17 years and 19-20 years, highlighting the need for increased attention and preventative measures to curb child marriage in these age groups. It is crucial for both the government and society to actively work towards preventing child marriages in these age ranges, in order to protect the rights and well-being of individuals affected by this issue.
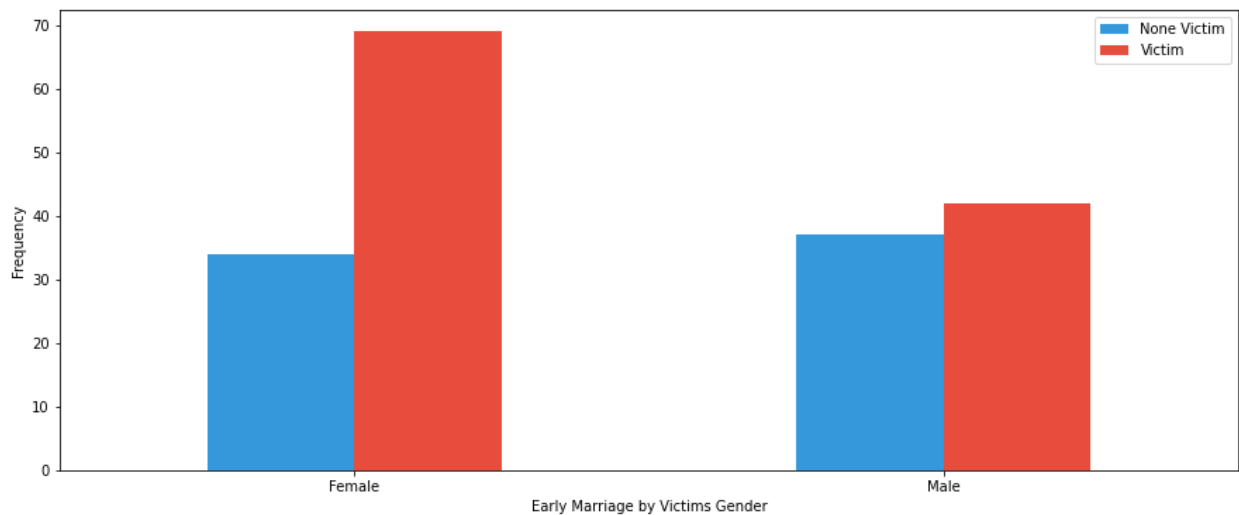

Figure 3.5: Victims of Early Marriage Frequency for Gender

In this graph, we will discuss the ratio of early marriage based on the data of gender. Based on the perceptions of present-day Bangladesh, it is often assumed that only girls are affected by child marriage. However, upon conducting a physical survey and analyzing the data, it is evident that both girls and boys in Bangladesh are affected by child marriage. The data shows that a majority of child marriages among boys occur through family connections. Additionally, the data suggests that girls are disproportionately affected by child marriage, and that certain factors play a significant role in their early marriage. These important factors will be further discussed in the subsequent graph.
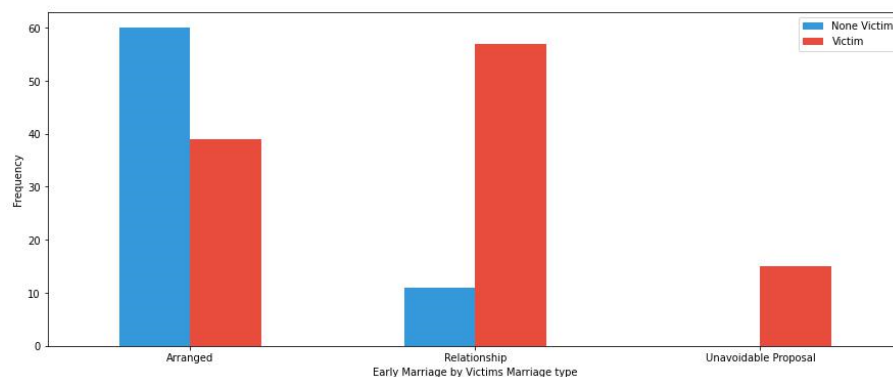

Figure 3.6: Victims of Early Marriage Frequency for Victims Marriage type

In this graph, we will examine the proportion of child marriages that occur within the context of arranged marriages, relationship marriages, and unavoidable marriage proposals. Through our survey of child marriages, it was determined that 100% of child marriages occurred in the case of unavoidable marriage proposals. Additionally, there is a high prevalence of child marriage within the context of relationship marriages. In contrast, there is a relatively low proportion of child marriages within arranged marriages. Therefore, it is crucial to not only address the issue of unavoidable marriage proposals but also consider the trend of child marriages in the context of relationships. Furthermore, it is important to note that child marriages also occur in arranged marriages, often as a result of societal pressure and teasing. The impact of these factors will be discussed in the following graph.
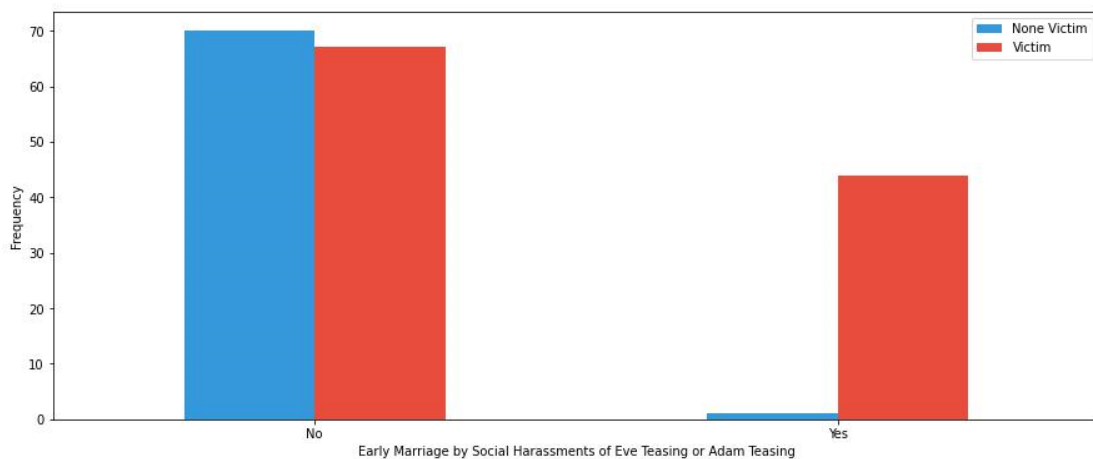

Figure 3.7: Early Marriage by Social Harassment's of Eve Teasing or Adam Teasing

The prevalence of teasing, particularly Eve teasing directed towards girls, is a significant contributor to the ongoing issue of child marriage in Bangladesh. Despite a decrease in instances of Adam teasing towards boys, the persistence of Eve teasing has led to an increase in the rate of child marriage within the country. This is exacerbated by the tendency of powerful individuals within society to propose marriage, with little regard for the desires of the families or children involved, resulting in a higher rate of child marriage. Furthermore, social harassment, particularly in certain regions, plays a significant role in child marriage. The negative societal perceptions and pressure surrounding girls reaching puberty often result in early marriage as a means of avoiding such harassment. Additionally, child marriage is also driven by a variety of other factors, including teasing, which can lead to experiences of sexual harassment. This is further illustrated through the data presented in the accompanying graph.
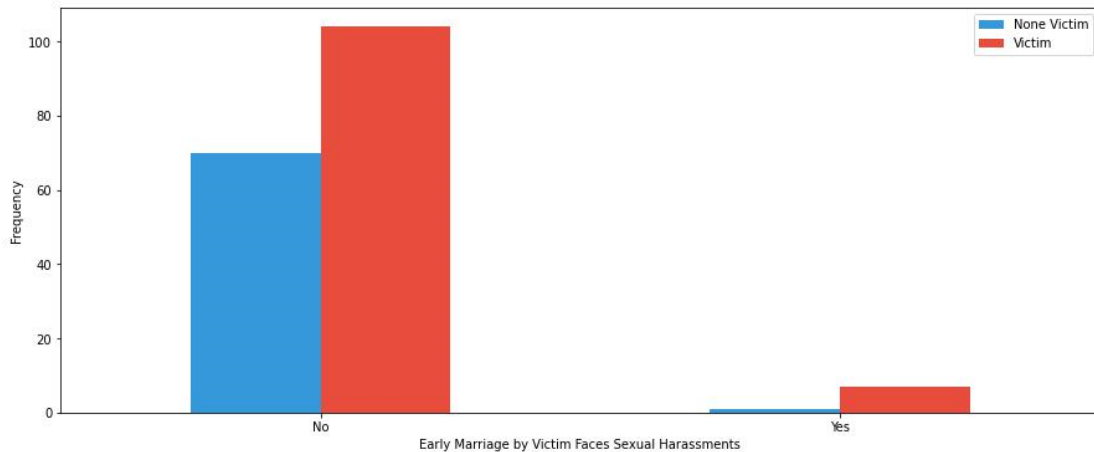
Figure 3.8: Victims of Early Marriage Frequency According to Victim Faces Sexual Harassment's

This graph will examine the correlation between child marriage and experiences of sexual harassment. Although a significant number of individuals have faced teasing, a smaller proportion have experienced sexual harassment. However, among those who have encountered sexual harassment, a high percentage have been married as children. From a familial perspective, financial crisis is often identified as a leading contributing factor. This relationship is further discussed and analyzed in the accompanying data.
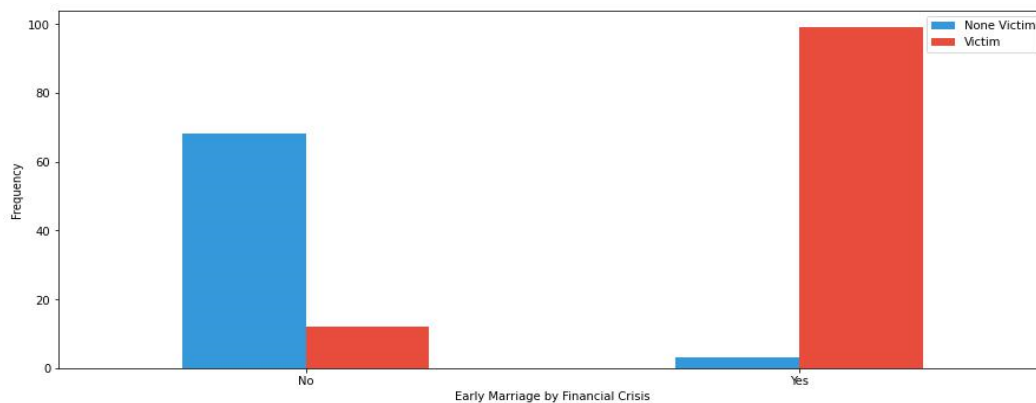

Figure 3.9: Victims of Early Marriage Frequency According to Financial Crisis

The financial crisis is a significant contributing factor in the prevalence of child marriage, as demonstrated by the data presented in the accompanying graph. The high proportion of individuals affected by child marriage who also face financial crisis highlights the strong correlation between these two issues. However, it is important to note that financial crisis is often the result of several underlying causes, one of which is education. The effect of child marriage on the educational attainment of fathers is a crucial aspect that is further explored and analyzed in the following section.
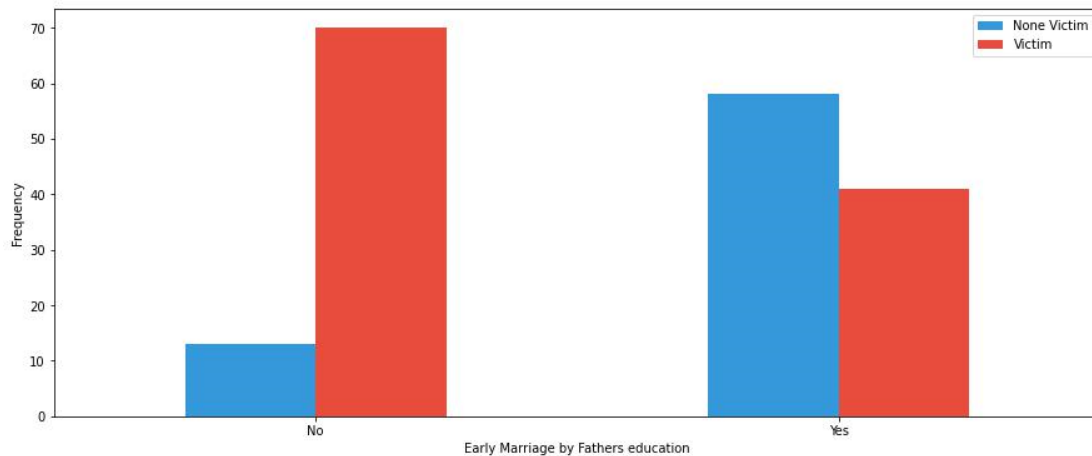
Figure 3.10: Victims of Early Marriage Frequency According to Fathers education

The present graph aims to examine the effect of a father's education on child marriage. As depicted in the previous graph, a significant correlation can be observed between the level of educational attainment of fathers and the rate of child marriage. Specifically, fathers with a minimum education up to Class 8 have a higher rate of child marriage than those who have not. This phenomenon is often attributed to a lack of awareness and education regarding the dangers of child marriage among these fathers, resulting in the perpetuation of this harmful practice. Furthermore, the consequences of child marriage, including death, are often irreversible, highlighting the importance of preventative measures. Another key aspect that is analyzed in this study is the relationship between mother's education and the trend of early marriage, which is discussed in the following section.
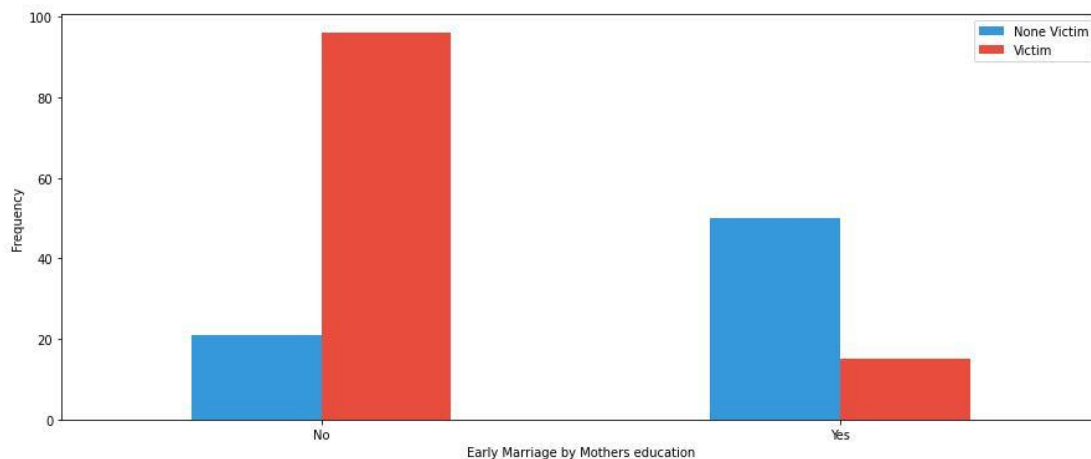

Figure 3.11: Victims of Early Marriage Frequency According To Mothers education

This section of the study examines the correlation between mother's education and child marriage. As depicted in the previous graph, the rate of child marriage among uneducated mothers is alarmingly high, and this trend is also present among mothers with some level of education. Child marriage occurs for a variety of reasons, including romantic relationships, teasing, and financial constraints, among others. However, for uneducated mothers, additional factors such as

late admission to school, marriage through relationships, and social harassment play a significant role in child marriage. While the education level of parents has a notable impact on child marriage, it is not the sole determinant of this phenomenon. Another critical factor that is also considered in this study is the relationship between father's injury and child marriage, which is further discussed in the following section.
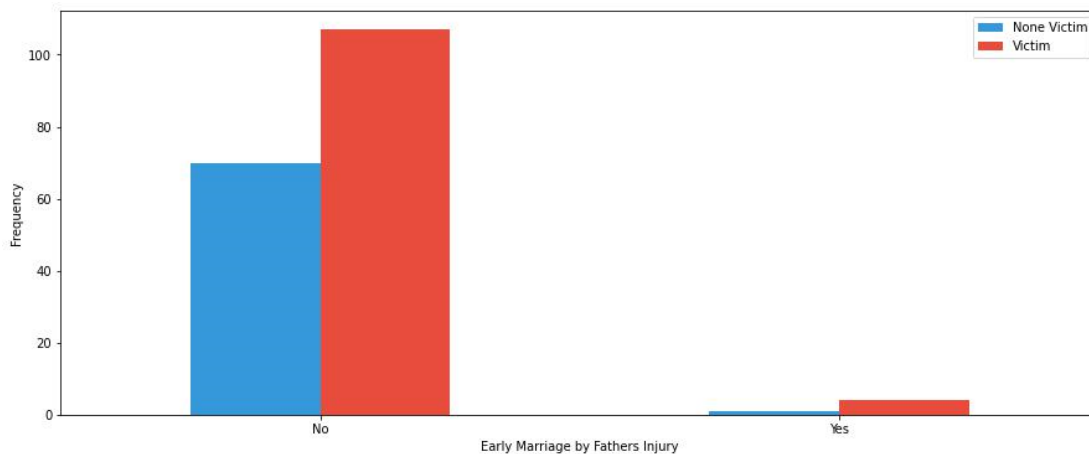

Figure 3.12: Victims of Early Marriage Frequency for Fathers Injury

The study suggests that a father's injury may have a more significant impact on child marriage than a mother's injury. This is supported by several factors. Firstly, fathers are typically the primary providers in the household and an injury that impacts their ability to work can exacerbate financial stress, which can lead to child marriage as a means of financial stability. Secondly, cultural, and societal norms often place a strong emphasis on the father's role as a provider and protector, and an injury that limits his ability to fulfill these roles may increase the pressure to marry off children at a young age. Furthermore, the father's injury can also lead to emotional stress and impact on the overall family's well-being, making them more vulnerable to the pressure of child marriage. Additionally, the study also considers the relationship between a mother's injury and child marriage, which is further discussed in the following section.
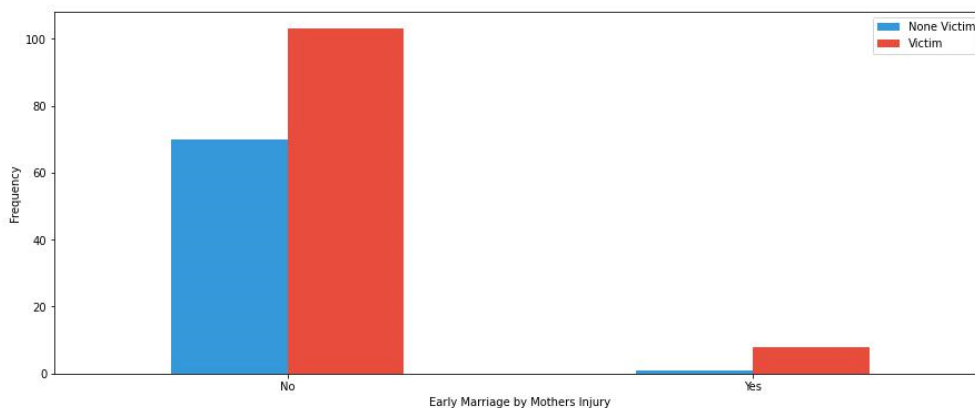

Figure 3.13: Victims of Early Marriage Frequency for Mothers Injury

This section of the study examines the correlation between a mother's injury and child marriage. The data presented in the previous graph illustrates that mothers who have sustained injuries are more likely to have children who are married at a young age. However, it is important to note that the relationship between mother's injury and child marriage is not absolute and the rate of injury in Bangladesh is relatively low. Additionally, child marriage is a complex issue that is influenced by a variety of factors, including financial constraints, societal pressure, and cultural norms, among others. Therefore, even when the mother is not injured, the rate of child marriage remains alarmingly high.

3.3 Classification

Classification is a supervised procedure aimed at categorizing data into specific classes [53]. Our primary objective is to identify the factors contributing to early marriage and predict the likelihood of an individual getting married at a young age. To achieve this, we evaluated the performance of 8 classifiers: Decision Tree (DT), Logistic Regression (LR), Random Forest (RF), Gaussian Naive Bayes (GNB), Bernoulli Naive Bayes (BNB), Multinomial Naive Bayes (MNB), Support Vector Machine (SVM), and KNN (K-Nearest Neighbor).

In our analysis, we compared the classifiers based on various model assessment criteria to determine the most suitable algorithm for this aspect of the issue. Additionally, we considered hyperparameter customization and employed 10-fold cross-validation to enhance the robustness of our model. The table below displays the parameter distributions for each classifier, providing further insights into their performance and optimization in predicting early marriage occurrences.

CHAPTER 4

EVALUATION METRICS

There are various evaluation metrics that can be utilized to evaluate the performance of different machine learning models and select the most optimal one [54]. Four commonly used evaluation metrics, based on confusion metrics, include accuracy, precision, recall, and f-measure. These metrics are applied in this study to evaluate the proposed model. These metrics have been chosen based on their relevance and ability to provide a comprehensive assessment of the model's performance [55].

- **Accuracy:** Accuracy is a widely used metric to evaluate the performance of machine learning models. It represents the proportion of correctly classified observations, out of all observations, by the model [56]. In this study, the test accuracy of the various algorithms is presented in Table I, Table II, Table III and the train accuracy of the various algorithms is presented in Table IV, Table V, Table VI. The best training accuracy for both genders of each algorithm is illustrated in Figure 5.2, along with the corresponding confusion matrix in Figure 5.1. Therefore, the accuracy of the model is a crucial evaluation metric that is thoroughly examined in this study.

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+TN+FN}$$

- **Precision and Recall:** Recall, also known as sensitivity or true positive rate, is a measure of the proportion of relevant instances that were correctly identified by the model. On the other hand, precision, also known as positive predictive value, is a measure of the proportion of correctly identified instances among all instances identified by the model. It represents the proportion of relevant instances among the samples that were retrieved. These two metrics are commonly used together to evaluate the performance of a model in identifying relevant instances while minimizing false positives [57].

$$\text{Precision} = \frac{TP}{TP+FP}$$

$$\text{Recall} = \frac{TP}{TP+FN}$$

- **F-measure:** Precision and recall can be combined into one measure using F-Measure [58].

$$\text{F-measure} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision}+ \text{Recall}}$$

The performance of the corresponding classifier over the values of Accuracy, Precision, Recall, and F-measure is listed. True Positive, True Negative, False Positive, and False Negative are all defined by the acronyms TP, TN, FP, and FN, respectively [59].

4.1 Parameter Settings Table

As a random forest or ensemble model grows in size, it is normal for it to over-fit the data [60]. To address this issue, the technique of pruning is often employed. Pruning involves selecting the largest, most robust tree and removing all branches below it [61]. This results in a smaller, simpler model that generalizes better to new data and improves the overall performance of the model.

4.2 Key Attributes of Early Marriage

Table-VII presents six key predictive attributes identified as significant in understanding early marriage, ranked by their Chi-Square scores. These attributes were carefully selected based on their statistical significance and relevance to the phenomenon of early marriages. The table not only lists these attributes but also provides their importance scores and a brief explanation for their inclusion, highlighting their specific roles in the context of early marriage. The identification of these attributes is a crucial contribution of my thesis, offering a focused direction for future researchers. It aims to enhance the understanding of the complex factors influencing early marriage decisions, thereby supporting the development of more effective interventions and policies to tackle this social issue.

Table I: With Chi-Square and 10-Fold Cross Validation for both genders on train Dataset

Classifier	Accuracy
Random Forest	98.86%
Decision Tree	98.30%
Logistic Regression	98.30%
Gaussian Naive Bayes	96.63%
Multinomial Naive Bayes	96.08%
Bernoulli Naive Bayes	94.38%
SVM	84.28%
K-Nearest Neighbors	80.95%

Table II: With Chi-Square and 10-Fold Cross Validation for Male on train Dataset

Classifier	Accuracy
Random Forest	98.95%
Decision Tree	98.39%
Logistic Regression	98.25%
Gaussian Naive Bayes	96.72%
Multinomial Naive Bayes	96.17%
Bernoulli Naive Bayes	94.47%
SVM	84.37%
K-Nearest Neighbors	81.04%

Table III: With Chi-Square and 10-Fold Cross Validation for Female on train Dataset

Classifier	Accuracy
Random Forest	98.98%
Decision Tree	98.42%
Logistic Regression	98.23%
Gaussian Naive Bayes	96.75%
Multinomial Naive Bayes	96.20%
Bernoulli Naive Bayes	94.50%
SVM	84.40%
K-Nearest Neighbors	81.07%

Table IV: With Chi-Square and 10-Fold Cross Validation for both genders on test Dataset

Classifier	Accuracy
Random Forest	96.11%

Table V: With Chi-Square and 10-Fold Cross Validation for Male on test Dataset

Classifier	Accuracy
Random Forest	97.75%

Table VI: With Chi-Square and 10-Fold Cross Validation for Female on test Dataset

Classifier	Accuracy
Random Forest	97.88%

Table VII: Key Attributes of Early Marriage

Score Position by Chi Square	Attribute Name	Importance by Chi Square	Reason for Use
2	Financial Crisis of the Family	73.81	To assess the influence of economic hardship on the prevalence of early marriages within families.
5	Married Spouse below 21 or Wife below 18	37.90	To examine the prevalence of child marriage when the spouse's age is below the legal age limit.
6	Siblings Marriage girls below 18 years or boys below 21 years	36.96	To understand the impact of early sibling marriages and their correlation with child marriage.
8	Social Harassments Eve or Adam Teasing	30.45	To investigate the role of social harassment in influencing child marriage decisions.
9	Victims Married Siblings Education Studied class 8 or more	28.16	To analyze the link between the education level of married siblings and child marriage practices.
12	Early Married Siblings Working Status below 15 Years	22.17	To analyze the working status of siblings who married early, below 15 years of age, and its connection with child marriage practices. To understand the impact of early marriages on economic and social well-being.

CHAPTER 5

EXPERIMENTAL RESULT

In this study, we aimed to understand the important factors behind early marriage and develop a method to predict an individual's likelihood of having an early marriage. To achieve this, we conducted two phases of research: feature discussion and analysis, and prediction modeling.

5.1 Feature Discussion and Analysis

To discover the important variables that contribute to early marriage, we used a univariate analysis on a dataset of marriages between the ages of 8 and 25. The legal age of marriage in Bangladesh is 21 years for boys and 18 years for girls, and child marriage is defined as any marriage before this age. Figure 3.4 shows the age range when child marriage is most common. Through the analysis of the data, we discovered that parents' lack of education and children's late enrollment in school are the major causes of child marriage, as shown in Figures 3.10, 3.11, and 3.3. Additionally, we found that financial difficulties in households with multiple children are a significant factor in child marriage, as shown in Figure 3.9. Furthermore, we found that even in households with stable finances, some children marry due to relationships, while others do so as a result of sexual harassment or teasing, as shown in Figures 3.6, 3.8, and 8. Finally, we found that the risk of child marriage is higher among children whose parents are injured, as shown in Figures 3.12 and 3.13.
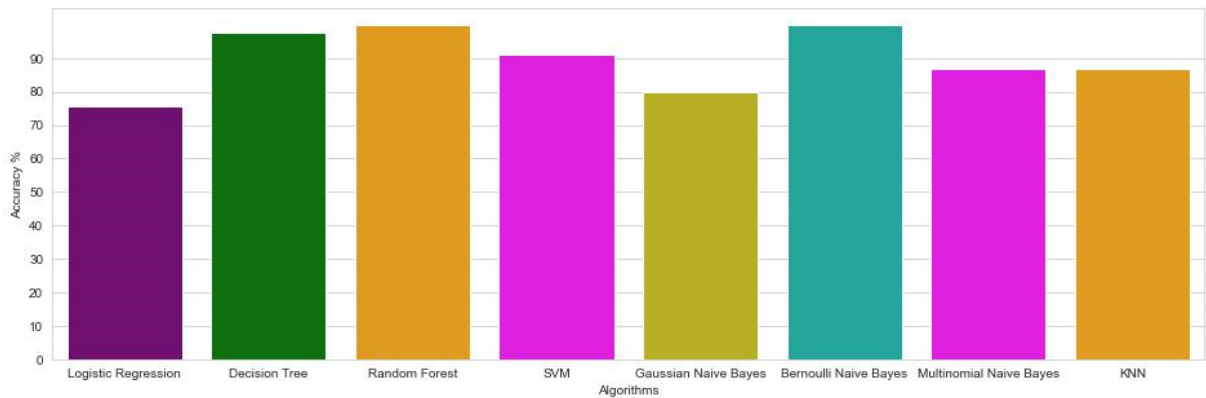

Figure 5.1: All algorithms accuracy graph for both genders

This bar chart showcases the performance of eight machine learning classifiers, with each bar representing the classifier's accuracy in predicting gender. The height of the bars indicates the percentage accuracy, with Logistic Regression, Decision Tree, and Random Forest classifiers

achieving the highest scores, suggesting their strong predictive capabilities. The Support Vector Machine (SVM) and various Naive Bayes classifiers—Gaussian, Bernoulli, and Multinomial—display moderate accuracy, while the K-Nearest Neighbors (KNN) algorithm shows the lowest accuracy among the evaluated classifiers. Each classifier is distinctly colored for clear visual differentiation. These results are based on an evaluation that incorporates Chi-Square Feature Selection and 10-Fold Cross Validation, reflecting a comprehensive analysis of each classifier's ability to correctly identify gender from the data provided.
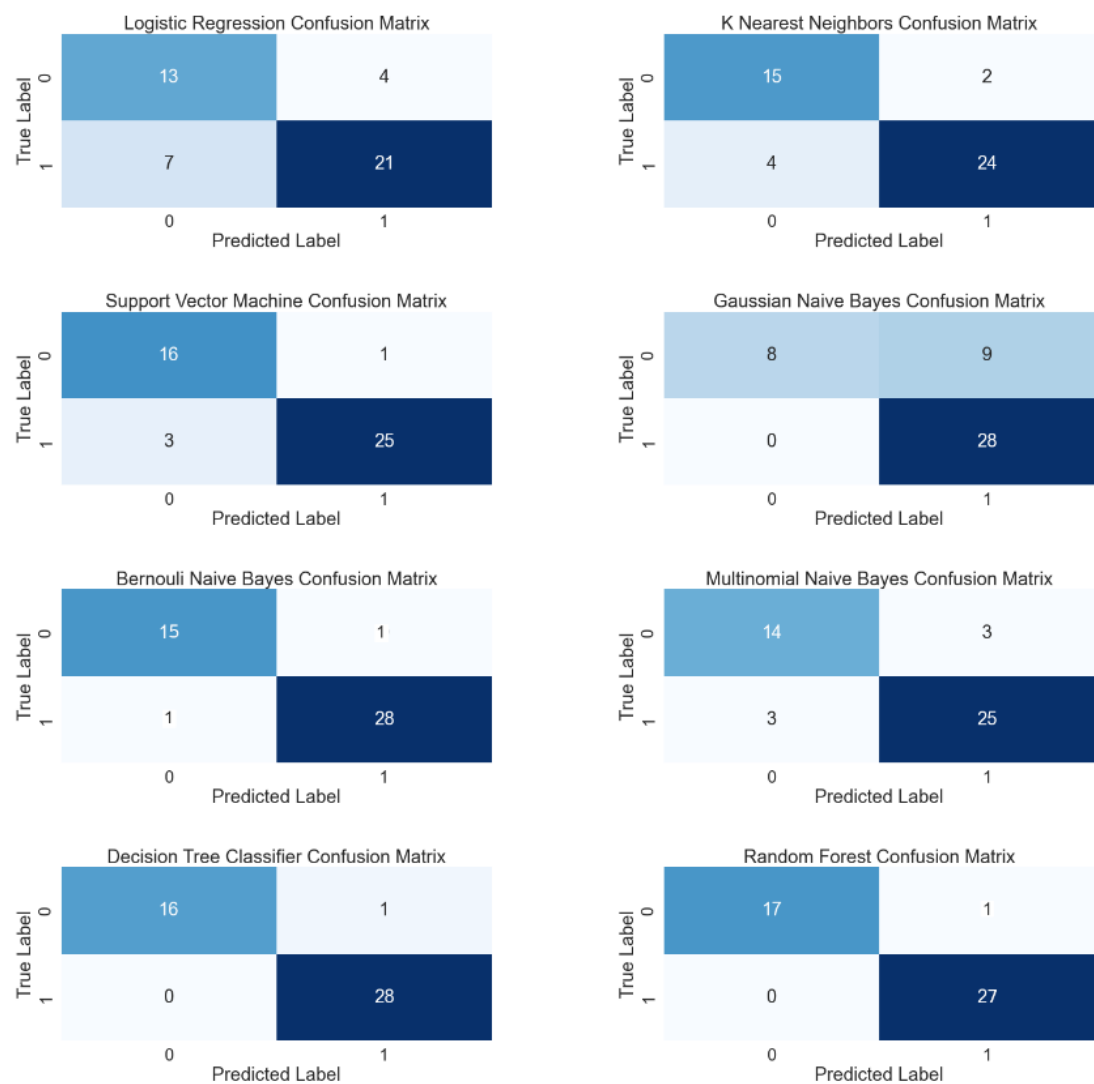

Figure 5.1: Confusion Matrix for both genders

The confusion matrix graph presents an array of classification results for various machine learning algorithms—Logistic Regression, K Nearest Neighbors, Support Vector Machine, Gaussian Naive Bayes, Bernoulli Naive Bayes, Multinomial Naive Bayes, Decision Tree Classifier, and Random

Forest. Each matrix delineates the number of true positive and true negative predictions along the diagonal, indicating accurate classifications, while the off-diagonal cells show false positive and false negative predictions, marking the instances of misclassification. The matrices collectively illustrate the algorithms' abilities to discern between two gender categories, evaluated under the methodology of Chi-Square Feature Selection and 10-Fold Cross Validation. The accompanying accuracy graph contrasts the effectiveness of each algorithm by representing their overall percentage accuracy in a bar chart format, thereby providing a visual and comparative analysis of their performance.

CHAPTER 6

CONCLUSION AND FUTURE WORK

This chapter culminates our extensive exploration into the multi-dimensional causes and predictors of child marriage in Bangladesh. In the sections that follow, we synthesize the key conclusions of our study and chart the course for future research in this domain.

6.1 Conclusion

This study has effectively leveraged advanced machine learning techniques, especially the Random Forest algorithm, to probe into the multi-dimensional causes of child marriage in Bangladesh. The comprehensive survey, involving a diverse demographic, has illuminated crucial socio-economic and cultural factors contributing to this practice. Key findings include the identification of strong correlations between factors like financial instability, delayed school enrollment, and social harassment, and the occurrence of child marriage. The high accuracy of the predictive model showcases the potential of technology-driven approaches in identifying and addressing intricate social challenges. This research offers not only a deeper academic understanding of child marriage but also practical insights for developing targeted interventions. Our findings advocate for a holistic strategy that combines educational, economic, and social awareness efforts to effectively address child marriage in Bangladesh.

6.2 Future Work

Diversifying the Data Landscape:
Future research should expand the data scope, incorporating a wider range of variables and examining different regional contexts within Bangladesh. Enhancing the diversity and depth of the data is crucial to refine the predictive model's relevance and accuracy.

Exploring Interconnections of Socio-Economic Elements:
A critical area for future studies is the investigation into how educational levels, economic conditions, and societal norms interplay and collectively influence child marriage rates. A comprehensive understanding of these interconnections is imperative for developing holistic intervention strategies.

Prioritizing Ethical Practices in Predictive Analytics:

Upcoming research must rigorously adhere to ethical standards in the use of predictive analytics in social research. This includes ensuring the protection of individual privacy, respecting human rights, and maintaining legal compliance.

Laying a Robust Foundation for Further Research:

Our study has laid significant groundwork for ongoing research into the socio-economic and cultural facets of child marriage. The continued application and refinement of machine learning techniques in this field promises to bolster global efforts to eradicate child marriage.

In summary, this research not only enriches the academic dialogue on child marriage but also aims to inform effective, actionable strategies for its mitigation. It is our aspiration that the pathways outlined in this study will contribute to a future where child marriage is no longer a reality but a historical footnote.

REFERENCES

[1] M. A. Ahasan, "The impact of mobile court act, 2009 on restraining the propensity of child marriage in Bangladesh: Empirical evidence from ishwarganj upazilla, Mymensingh," Ph.D. dissertation, Brac University, 2021.

[2] A. Das and T. Kusakabe, "Impact of covid-19 on pedagogical practices at secondary education in Bangladesh: Retrospective and prospective," Journal of international cooperation in education, vol. 24, no. 2, pp. 113–129, 2021.

[3] S. Ainul, F. R. Noor, M. Hossain, I. Ehsan, M. Manzur, U. Rob, S. Amin et al., "Keeping girls in schools to reduce child marriage in rural Bangladesh: Endline assessment," 2022.

[4] S. Akhter and G. Mahmud, "The roles of elected female members of reserved seats in union parishads," Bangladesh Journal of Public Administration, vol. 29, no. 2, pp. 207–223, 2021.

[5] A. Akther, "A conceptual framework of the success factors of e-commerce: a study of Bangladeshi female entrepreneurs," Ph.D. dissertation, University of the West of Scotland, 2021.

[6] S. Kamal, "Geographical variations and contextual effect on child marriage in Bangladesh." Pakistan Journal of Women's Studies, vol. 17, no. 2, 2010.

[7] S. M. Kamal, C. H. Hassan, G. M. Alam, and Y. Ying, "Child marriage in Bangladesh: trends and determinants," Journal of biosocial Science, vol. 47, no. 1, pp. 120–139, 2015.

[8] S. Fan and A. Koski, "The health consequences of child marriage: a systematic review of the evidence," BMC public health, vol. 22, no. 1, pp. 1–17, 2022.

[9] P. K. Streatfield, N. Kamal, K. Z. Ahsan, and Q. Nahar, "Early marriage in Bangladesh: Not as early as it appears," Asian Population Studies, vol. 11, no. 1, pp. 94–110, 2015.

[10] UNICEF., Early marriage a harmful traditional practice a statistical exploration 2005. UNICEF, 2005.

[11] P. Bangladesh, ",Child marriage in Bangladesh: Findings from a national surveys. expressions limited," 2013.

[12] A. Talukder, M. M. Hasan, S. R. Razu, and Z. Hossain, "Early marriage in Bangladesh: a cross-sectional study exploring the associated factors." Journal of international women's studies., vol. 21, no. 1, pp. 68–78, 2020.

[13] F. Nahid, "Child marriage in Bangladesh: Socio-legal analysis," International Journal of Sociology and Anthropology, vol. 6, no. 1, pp. 1–7, 2014.

[14] R. K. Biswas, J. R. Khan, and E. Kabir, "Trend of child marriage in Bangladesh: A reflection on significant socioeconomic factors," Children and Youth Services Review, vol. 104, p. 104382, 2019.

[15] S. Amin, J. Saha, and J. Ahmed, "Skills-building programs to reduce child marriage in Bangladesh: a randomized controlled trial," Journal of Adolescent Health, vol. 63, no. 3, 293–300, 2018.

[16] A. Raj, L. McDougal, J. G. Silverman, and M. L. Rusch, "Cross-sectional time series analysis of associations between education and girl child marriage in Bangladesh, India, Nepal and Pakistan, 1991-2011," PloS one, vol. 9, no. 9, p. e106210, 2014.

[17] R. T. Naved, S. Kalra, A. Talukder, A. Laterra, T. T. Nunna, K. Parvin, and M. Al Mamun, "An exploration of social norms that restrict girls' sexuality and facilitate child marriage in Bangladesh to inform policies and programs," Journal of Adolescent Health, vol. 70, no. 3, S17–S21, 2022.

[18] F. D. Chowdhury, "The socio-cultural context of child marriage in a Bangladeshi village," International Journal of Social Welfare, vol. 13, no. 3, pp. 244–253, 2004.

[19] M. K. Hauer and S. Sood, "Exploring knowledge, attitudes, and beliefs about child marriage in Bangladesh through a transmedia entertainment-education initiative." Journal of Development Communication, vol. 32, no. 1, 2021.

[20] M. Temin, C. Misunas, and E. Martin, "Smarter investments in girls today to prepare them to thrive tomorrow," SAIS Review of International Affairs, vol. 41, no. 1, pp. 3–14, 2021.

[21] J. D. Thompson, "On building an administrative science," Administrative Science Quarterly, 102–111, 1956.

[22] E. Haque, N. Wyss, E. E. Cho, and K. Austrian, "Gendered effects of covid-19 school closures: Bangladesh case study," 2022.

[23] H. Wu, "The effect of maternal education on child mortality in Bangladesh," Population and Development Review, 2022.

[24] S. Baird, M. Murphy, J. Seager, N. Jones, A. Malhotra, S. Alheiwidi, G. Emirie, S. Rashid, and M. Sultan, "Intersecting disadvantages for married adolescents: Life after marriage pre-and post-covid-19 in contexts of displacement," Journal of Adolescent Health, vol. 70, no. 3, pp. S86–S96, 2022.

[25] S. M. Kamal and E. Ulas, "Child marriage and its association with maternal health care services utilisation among women aged 20–29: a multi-country study in the south Asia region," Journal of Obstetrics and Gynaecology, pp. 1–6, 2022.

[26] M. Mahbub, "Sociocultural factors and gender role in female education: A phenomenal reviewed study of rural Bangladesh," Available at SSRN 4013668, 2022.

[27] R. HUSSAIN, "Child marriage and school dropout in Bangladesh during covid-19: Challenges for youth education sustainability," in China and Higher Education 2021 Conference-Hong Kong Session: Education and SDGs: Promoting Quality Education for All, 2021.

[28] S. R. Psaki, A. J. Melnikas, E. Haque, G. Saul, C. Misunas, S. K. Patel, T. Ngo, and S. Amin, "What are the drivers of child marriage? a conceptual framework to guide policies and programs," Journal of Adolescent Health, vol. 69, no. 6, pp. S13–S22, 2021.

[29] S. Dastider and N. K. Kundu, "Marital age and fertility consequences among rural and urban women," International Journal Of Medical Science And Clinical Research Studies, vol. 1, no. 10, pp. 314–323, 2021.

[30] M. Rexhepi, F. Besimi, N. Rufati, A. Alili, S. Bajrami, and H. Ismaili, "Hospital-based study of maternal, perinatal and neonatal outcomes in adolescent pregnancy compared to adult women pregnancy," Open access Macedonian journal of medical sciences, vol. 7, no. 5, p. 760, 2019.

[31] S. Bellizzi, L. Lorettu, G. Farina, L. Bubbico, S. Ferlito, A. Cegolon, G. Pichierri, and L. Ce-golon, "Humanitarian crises and child-marriage: Historical recurrent interrelated events," Journal of Global Health, vol. 11, 2021.

[32] H. Huang, Y. Wei, Y. Xia, L. Wei, X. Chen, R. Zhang, L. Su, M. L. Rahman, M. Rahman, Q. Qamruzzaman et al., "Child marriage, maternal serum metal exposure, and risk of preterm birth in rural Bangladesh: evidence from mediation analysis," Journal of exposure science & environmental epidemiology, vol. 31, no. 3, pp. 571–580, 2021.

[33] A. Sandstrom and A. E. Theodorou, "Many countries allow child marriage," 2016.

[34] M. Kamruzzaman, M. Rabbani, A. Saw, M. Sayem, M. Hossain et al., "Differentials in the prevalence of anemia among non-pregnant, ever-married women in Bangladesh: multilevel logistic regression analysis of data from the 2011 Bangladesh demographic and health survey," BMC women's health, vol. 15, no. 1, pp. 1–8, 2015.

[35] N. Buchmann, E. M. Field, R. Glennerster, S. Nazneen, and X. Y. Wang, "A signal to end child marriage: Theory and experimental evidence from Bangladesh," National Bureau of Economic Research, Tech. Rep., 2021.

[36] D. C. Sarkar and M. B. Hossain, "Assessing the effect of demographic factors on women health in Bangladesh."

[37] H. Moniruzzaman, "Education for Rohingya displaced children," 2021.

[38] M. J. Islam and M. Islam, "Determinants of early marriage among the women: A study on Khulna district," Asian J. Soc. Sci. Leg. Stud, vol. 3, no. 3, pp. 89–98, 2021.

[39] S. C. Majumder, M. H. Rahman, and S. Debbarman, "Factors influencing maternal mortality in Comilla city corporation, Bangladesh," International Journal, vol. 7, no. 7, p. 346, 2021.

[40] S. Akhter and G. Mahmud, "The roles of elected female members of reserved seats in union parishads," Bangladesh Journal of Public Administration, vol. 29, no. 2, pp. 207–223, 2021.

[41] Z. I. Farid, S. I. Farid, M. A. Islam, and T. Jerin, "Education in emergency: Exploring the issues and options for continuing education during flash flood in the haor regions of Bangladesh."

[42] P. H. Nguyen, S. Scott, L. Q. Khuong, P. Pramanik, A. Ahmed, S. F. Rashid, K. Afsana, and Menon, "Adolescent birth and child undernutrition: an analysis of demographic and health surveys in Bangladesh, 1996–2017," Annals of the New York Academy of Sciences, vol. 1500, no. 1, pp. 69–81, 2021.

[43] M. O'Leary, A. Dibaba, and J. Sarkar, "Adolescent girl power groups in Bangladesh: Placing gender equality at the center of nutrition interventions," Field Exchange 66, p. 26, 2021.

[44] S. Akter, T. Islam, A. M. Sarker, M. S. Rana, and A. A. Roki, "An analysis on the antenatal care service factors affecting pregnant women in Bangladesh: A special review on private hospitals," International Journal of Research in Engineering, Science and Management, vol. 4, no. 4, pp. 45–50, 2021.

[45] M. E. Uddin, "Teenage marriage and high school dropout among poor girls: A narrative review for family pathways in Bangladesh," Journal of Research in Social Sciences and Language, vol. 1, no. 1, pp. 55–76, 2021.

[46] S. Gautam, S. Setu, M. G. Q. Khan, and M. B. Khan, "Analysis of the health, economic and environmental impacts of covid-19: The Bangladesh perspective," Geosystems and Geo environment, vol. 1, no. 1, p. 100011, 2022.

[47] M. A. Karim and M. O. Faruk, "Patterns and differentials of age at first motherhood among married adolescents in Bangladesh," Biomedical Sciences, vol. 7, no. 3, p. 86, 2021.

[48] A. N. Nur, J. Bhowmik, S. Chowdhury, and S. A. Begum, "Knowledge, attitude and practice of cervical carcinoma screening among Bangladeshi women," Chattagram Maa-O-Shishu Hospital Medical College Journal, vol. 20, no. 1, pp. 28–32, 2021.

[49] M. A. Koenig, K. Jamil, P. K. Streatfield, T. Saha, A. Al-Sabir, S. E. Arifeen, K. Hill, and Haque, "Maternal health and care-seeking behavior in Bangladesh: findings from a national survey," International family planning perspectives, pp. 75–82, 2007.

[50] T. A. Gashaw, "Statistical analysis of early marriage among women in Ethiopia by using multilevel logistic regression," Global Journal of Fertility and Research, vol. 4, no. 1, pp. 001–009, 2019.

[51] M. R. Kabir, M. Islam, M. S. Khan, and R. Roy, "Factors affecting early marriage in Bangladesh," Global Journal of Science Frontier Research: I Interdisciplinary, vol. 16, no. 1, pp. 1–6, 2016.

[52] E. Field et al., "Consequences of early marriage for women in Bangladesh," draft, October,< efield@ latte. Harvard. Edu, 2004.

[53] S. B. Kotsiantis, I. Zaharakis, P. Pintelas et al., "Supervised machine learning: A review of classification techniques," Emerging artificial intelligence applications in computer engineering, vol. 160, no. 1, pp. 3–24, 2007.

[54] G. S. Handelman, H. K. Kok, R. V. Chandra, A. H. Razavi, S. Huang, M. Brooks, M. J. Lee, and H. Asadi, "Peering into the black box of artificial intelligence: evaluation metrics of machine learning methods," American Journal of Roentgenology, vol. 212, no. 1, pp. 38–43, 2019.

[55] T. Trivedi and D. Kotak, "Exploring prediction modeling of students alcohol and drug addiction affecting performance using data mining approach."

[56] S. Picek, A. Heuser, A. Jovic, S. Bhasin, and F. Regazzoni, "The curse of class imbalance and conflicting metrics with machine learning for side-channel evaluations," IACR Transactions on Cryptographic Hardware and Embedded Systems, vol. 2019, no. 1, pp. 1–29, 2019.

[57] N. Tatbul, T. J. Lee, S. Zdonik, M. Alam, and J. Gottschlich, "Precision and recall for time series," Advances in neural information processing systems, vol. 31, 2018.

[58] F. Palomba and D. A. Tamburri, "Predicting the emergence of community smells using socio-technical metrics: A machine-learning approach," Journal of Systems and Software, vol. 171, p. 110847, 2021.

[59] Y. Koizumi, S. Murata, N. Harada, S. Saito, and H. Uematsu, "Sniper: Few-shot learning for anomaly detection to minimize false-negative rate with ensured true-positive rate," in ICASSP 2019-2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). IEEE, 2019, pp. 915–919.

[60] I. El Naqa and M. J. Murphy, "What is machine learning?" in machine learning in radiation oncology. Springer, 2015, pp. 3–11.

[61] A. E. Maxwell, T. A. Warner, and F. Fang, "Implementation of machine-learning classification in remote sensing: An applied review," International Journal of Remote Sensing, vol. 39, no. 9, pp. 2784–2817, 2018.