

## Exploring Disaster Vulnerability of Children in Urban Informal Settlements: A Built Environment Perspective

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**Abstract** – This study investigates the heightened vulnerability of children residing in disaster-prone informal settlements in the southwestern coastal city of Khulna, Bangladesh. The study focuses on both social and physical factors contributing to children's vulnerability, particularly in relation to the built environment. Employing a case study approach, this qualitative research combines socio-economic analysis to explore non-physical drivers and spatial mapping with built environment assessments to identify housing and infrastructure deficiencies. The research follows three specific objectives: identifying children's living conditions, assessing the built environment's vulnerability to flooding and cyclonic storms, and evaluating the subsequent impacts on children's health, education, and psychosocial well-being. Findings are triangulated through thematic interpretation, providing a comprehensive view of how both social and built environmental factors converge to heighten risks for children. The results highlight the need for child-centered disaster risk management strategies, with a focus on resilient housing, infrastructure and basic services to protect vulnerable populations.

**Keywords** – Disaster risks, children's vulnerability, disaster-adaptive built-environment, spatial mapping, informal settlement

### I. INTRODUCTION

Bangladesh, a low-lying deltaic landscape, faces significant challenges due to its vulnerability to climate change and natural disasters. Its geographical position, meteorological features, and dense population make it especially prone to hazards like floods, cyclones, droughts, tidal surges, and river erosion, particularly in coastal areas, which comprise 21% of its total land. These areas frequently experience floods, sea-level rise, and erosion, worsened by climate change. [1] Urban informal settlements (UIS) in these regions are particularly vulnerable, where populations live in inadequate housing with poor infrastructure.

Khulna, Bangladesh's third-largest city with around 1.5 million residents, is one of the cities most vulnerable to climate change impacts. [2] The city's more than 520 informal settlements house a significant portion of its population. These settlements are densely populated, with poor drainage and waste management, making them highly susceptible to natural disasters. [3][4] Khulna's informal settlements have also seen an influx of climate refugees from coastal districts following major cyclones like Sidr (2007) and Aila (2009). This migration has fueled the growth of informal settlements, which lack proper urban planning and zoning regulations. As a result, infrastructure is substandard, with poorly built roads and bridges, hindering evacuation and emergency services during disasters. [5] The built environment of informal settlements plays a critical role in shaping children's vulnerability to disasters. In Khulna's Rupsha Informal Settlement, precarious living conditions and lack of basic services heighten disaster risks for children. Substandard housing is particularly susceptible to damage from floods and cyclones, increasing the risk of injury and displacement for children, who also face limited access to healthcare, clean water, and education. [6] The

psychological toll of living in disaster-prone areas is profound for children, who experience trauma from displacement and loss of shelter. Additionally, their education is frequently disrupted when schools are damaged or destroyed, forcing many children to drop out due to financial strain or displacement. [7]

This article explores the vulnerability of children in urban informal settlements from a built environment perspective, focusing on Khulna's Rupsha Informal Settlement. It examines the quality of housing, infrastructure gaps, and spatial layouts to understand how these factors heighten disaster risks for children. The findings aim to inform policies and interventions to enhance resilience for children in these high-risk areas, contributing to disaster risk reduction efforts with a child-centered approach.

#### *The Setting*

The history of floods in Khulna, Bangladesh, highlights the region's ongoing vulnerability to natural disasters, particularly affecting informal settlements where children are among the most vulnerable. Significant floods in 1988 and 1998 caused widespread damage, disrupting infrastructure, displacing communities, and increasing health risks, especially in informal settlements. [8] Waterlogging, a frequent issue exacerbated by poor drainage, rapid urbanization, and the loss of natural channels, worsens the impact of heavy rainfall and prolongs flooding. [9] [10] In these settlements, waterlogging creates severe health hazards by fostering waterborne diseases and compromising sanitation, with children particularly affected. [11] The damage to poorly built homes further endangers residents, disrupting education and causing long-term psychological impacts. [12] Despite mitigation efforts, climate change and inadequate infrastructure remain persistent

challenges.<sup>[13][14]</sup> Khulna is also highly susceptible to cyclones and storm surges due to its proximity to the Bay of Bengal. Cyclones Sidr (2007) and Aila (2009) caused extensive damage to infrastructure and homes in informal settlements, leading to displacement, loss of life, and increased health risks from contaminated water and overwhelmed sanitation systems.<sup>[15][16][17]</sup>

## II. MATERIALS AND METHOD

This research employs a qualitative case study approach to investigate children's disaster vulnerability in the Rupsha informal settlement of Khulna, Bangladesh. The study integrates socio-economic analysis to examine non-physical factors and spatial mapping alongside built environment assessments to evaluate physical risks, such as housing and infrastructure deficiencies.

### *Study Area*

The Rupsha informal settlement, located along the Rupsha River in Khulna City Corporation (KCC), is highly exposed to climate-related hazards like cyclonic storms and flooding. The settlement, home to 3,700 households, lacks essential services, with prevalent illiteracy and labor-intensive jobs. Since the 1930s, informal housing adaptations have increased disaster risks. The study focuses on the intersection of built environment factors and socio-economic vulnerabilities, specifically regarding children's well-being.



Fig. 1 Satellite map of the study area

### *Data Collection*

The research follows a mixed-method approach, combining pilot surveys, participant observation, in-depth interviews, and key person interviews. A stratified sampling method, focusing on four age groups (6-12, 13-18, 18-30, 30-60) with gender balance, was used to ensure representation. Spatial mapping and built environment studies, including participatory mapping by children, were employed to document interactions between children's activities and the physical environment.

### *Data Analysis*

Data analysis involved thematic interpretation through descriptive analysis, supported by maps, drawings, charts, and photographs. Built environment analysis included dwelling plans, space utilization, and disaster adaptation. Thematic triangulation ensured validation across data sources, contributing to a comprehensive understanding of children's disaster vulnerability in informal settlements.

## III. RESULTS

### *Site and Surroundings*

Rupsha Slum in Khulna is surrounded by diverse commercial and industrial activities that contribute significantly to noise, dust, and air pollution. Heavy traffic along Strand Road exacerbates these environmental hazards, negatively affecting the living conditions of the residents, particularly the children. Traffic congestion not only worsens air quality but also increases the risks associated with everyday mobility, making the streets unsafe for children. The settlement's location near the Rupsha River further compounds these challenges, as it was historically established to adapt to periodic river flooding. Despite the presence of a river embankment, the settlement has three distinct elevations: upper, middle, and lower. The homes in the lower elevations are particularly vulnerable to water ingress during even minor rainfall, leading to severe water logging. During the monsoon season, prolonged water logging significantly damages homes, roads, and communal areas, contributing to the spread of waterborne diseases, which disproportionately affect children.

Efforts to manage flooding, including the construction of two ponds and an open drainage system, have proven largely ineffective due to poor waste management and inadequate maintenance of drainage facilities. The ongoing water logging problem is a stark reminder of the inadequacies in infrastructure that plague informal settlements like Rupsha. The residents' health and well-being, especially that of children, are further compromised by the combination of pollution, poor sanitation, and flood-prone living conditions. Cyclone vulnerability is also a major concern, especially in a settlement where many homes are built with substandard materials. Double-story structures made with inferior materials are more prone to damage during cyclones, while single-story homes, constructed with more resilient materials, tend to withstand storms better. However, the inconsistency in construction quality throughout the settlement highlights the need for standardized disaster-resilient building practices, as homes built with low-grade materials are particularly dangerous for children during extreme weather events. (figure 2,3).



Fig. 2 Vulnerability map for Flood and Waterlogging



Fig. 3 Vulnerability map for Cyclone and Storm

### House Form

The housing in Rupsha Settlement consists of various types, including single-storey, double-storey, and stilted structures, reflecting the diverse adaptive strategies employed by the residents to make the most of limited space and resources. The layout is characterized by row houses clustered along narrow lanes. Due to limited land, most residents adapt by integrating all household activities within a single indoor space, often using temporary partitions to delineate areas for different

purposes, such as sleeping, cooking, and leisure. This multifunctional use of space is common in informal settlements where housing constraints force families to creatively maximize every square foot.

Single-storey houses typically accommodate around four family members. These homes often have service areas located at the front, while outdoor kitchens are positioned adjacent to the lane for convenience. This configuration allows residents to make use of external communal spaces for household activities such as cooking, thereby freeing up indoor space (figure 4).

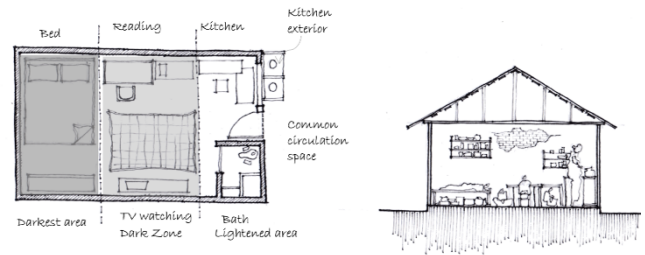


Fig. 4 Plan and section of a single story house

Double-storey houses, on the other hand, tend to have services like toilets and storage on the lower floor, with bedrooms and semi-outdoor spaces such as verandas on the upper floor. In some cases, the upper level is also used for cooking and additional sleeping areas. Ladders are frequently employed for vertical circulation within these homes, as staircases would take up valuable space (figure 5).

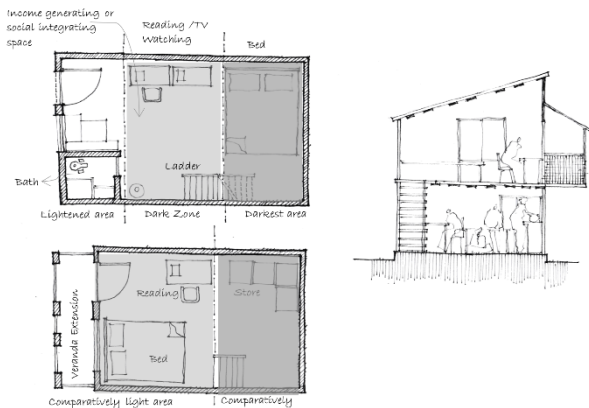


Fig. 5 Plan and section of a double story house

Stilted houses are another common architectural response to the persistent water logging issues in Rupsha. Raised above ground level, these structures offer some protection from flooding, particularly during the rainy season when low-lying areas of the settlement are frequently inundated. However, many stilted houses are constructed using low-quality materials such as timber, unreinforced concrete pillars, and corrugated iron sheets. These materials are vulnerable to rust and damage from high winds, especially during cyclonic events. The structural weaknesses of these houses are further exacerbated by the use of inadequate support structures, making them highly vulnerable to collapse during storms. Children living in these homes are particularly at risk of injury during extreme weather, as roofs, plinths, and wells are often the first structural elements to fail (figure 6).

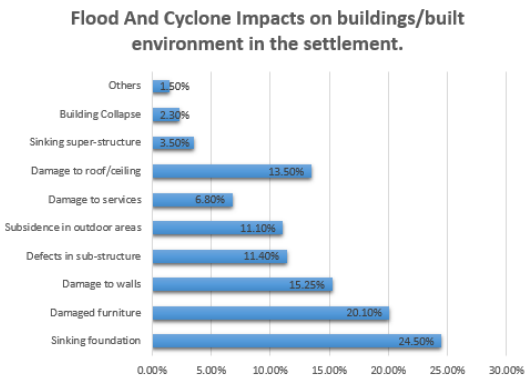


Fig. 6 Disaster impacts on built environment

### Infrastructure

The Rupsha settlement faces numerous infrastructure-related challenges, particularly concerning essential services such as drainage, water supply, sanitation, and waste management. The inadequate drainage system is a major issue in the settlement, contributing to frequent and severe water logging, especially during the monsoon season. Poor waste disposal practices and a lack of maintenance further exacerbate the drainage problem, with stagnant water creating ideal conditions for the spread of diseases, particularly among children. The community relies on shared deep tube wells for drinking water, but these wells become inaccessible during floods as rising water tables compromise their functionality. Additionally, the improper siting of these wells further limits their effectiveness, leaving residents, including children, without access to clean drinking water during critical periods.

Sanitation in the settlement is equally problematic. The community toilets are overcrowded and poorly maintained, and during floods, these facilities become inaccessible. This leads to the spread of human waste into communal areas, further increasing the risk of disease transmission. Flooding often renders the toilets unusable, and children are particularly vulnerable to the resulting public health hazards. A resident noted that during the rainy season, the toilets emit unpleasant odors and become completely waterlogged, making them impossible to use. The lack of proper sanitation infrastructure in the settlement highlights the pressing need for improved services to mitigate the health risks faced by children and other vulnerable populations.

### Spatial Aspects

The spatial layout of Rupsha informal settlement is characterized by single- and double-storey row houses organized along narrow spines that branch off Rupsha Strand Road. These narrow lanes serve multiple purposes, functioning as thoroughfares, communal spaces, and areas for cooking, bathing, and social interaction. This multifunctional use of space reflects the complex social and functional dynamics of the settlement, where every square meter is utilized to meet the residents' diverse needs. Children in the settlement are particularly adept at navigating these constrained environments, making use of the limited space available to them for activities such as homework, play, and rest.

Within their homes, children adapt to their confined surroundings by using shared spaces for multiple purposes. For instance, the same area may be used for studying during the day, then converted into a sleeping space at night. Mealtime further transforms these spaces into communal dining areas, reinforcing the versatility of the home environment. Leisure activities, including watching television, also take place in these multifunctional spaces, highlighting the adaptability of children in making the most of their surroundings. Despite the challenges posed by limited space and poor indoor lighting, children engage in a range of activities within these constrained environments, demonstrating their resourcefulness in balancing educational and recreational needs. Even infants participate in this dynamic use of space, as caregivers create stimulating environments for early development within the confines of small, shared living areas (figure 7,8,9).



Fig. 7 Map showing children activity from 7am to 12pm



Fig. 8 Map showing children activity from 12 to 5 pm



Fig. 9 Map showing children activity from 5 to 9 pm

Outdoor play is also a significant aspect of children’s lives in Rupsha, but the lack of dedicated open spaces or recreational facilities forces children to play in the narrow lanes near their homes. These lanes, which are shared with mothers and other family members engaged in household chores, offer a space for play and supervision. However, these outdoor areas are not without risks. Flooding and water logging frequently turn the lanes into hazardous zones, exposing children to contaminated water and increasing the likelihood of injury during play. The preference for outdoor play also heightens children’s vulnerability during cyclonic events, as they remain exposed to flying debris and structural damage from poorly constructed buildings.

#### Children’s Well-being Assessment

Disasters such as flooding and cyclonic storms severely disrupt the health, education, and mental well-being of children in the Rupsha settlement. During floods, the narrow lanes in the settlement become conduits for waste, including human waste, which contaminates the water supply and poses serious public health risks. Children are particularly vulnerable to waterborne diseases such as dysentery, which spread rapidly in these conditions. The combination of contaminated water and inadequate sanitation facilities creates a perfect storm for the outbreak of illnesses, with children bearing the brunt of these public health crises.

Floodwaters also inundate homes, making it difficult for families to prepare food, leading to food shortages. This increases the risk of malnutrition, particularly for younger children who are more vulnerable to nutritional deficits. Children often play in the floodwaters, unaware of the health risks, and are exposed to a range of illnesses, including skin rashes, respiratory infections, and fevers. The structural vulnerabilities of homes during storms and cyclones further compound these health risks, as children are at greater risk of injury from collapsing buildings (figure 10).

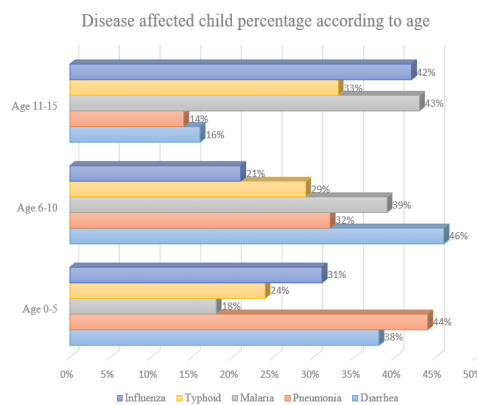


Fig. 10 Disease affected children percentage according to age

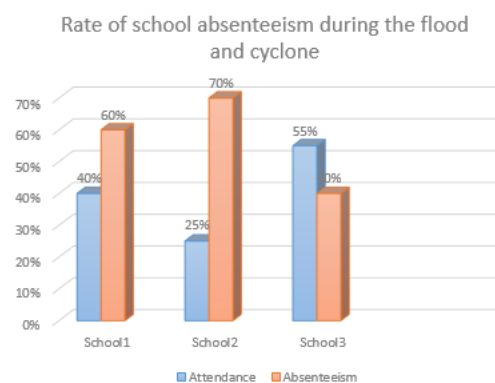


Fig. 11 School absenteeism rate during disaster

The impact of disasters on children’s education is profound. Flooded roads and school buildings create formidable barriers to school attendance, with many children unable to navigate waterlogged paths to reach their classrooms (figure 11). At home, the cramped living conditions and unsanitary environment make it difficult for children to focus on their studies, particularly for younger students who often do homework at their doorsteps. The frequent flooding also damages study materials, further hindering their academic progress. The poor infrastructure of schools in the area exacerbates these problems, with many schools suffering from structural damage during storms. Delays in repairing these schools prolong closures, disrupting the academic calendar and reducing children’s interest in learning over time.

Psychological well-being is another critical area affected by disasters. Children in Rupsha experience a range of emotional and psychological issues following floods and cyclones, including anxiety, fear, and sadness. These feelings are often exacerbated by the cramped living conditions in which children find themselves during and after a disaster. The inability to socialize, engage in play, or study in a comfortable environment contributes to a sense of isolation and helplessness. Children often report sleep disturbances, with some experiencing nightmares about floods and storms. One child recalled a dream in which they were floating in floodwaters and woke up in fear, unable to sleep afterward. The trauma of living through repeated disasters leaves a lasting impact on children’s mental health, with many developing symptoms of depression, anxiety, and post-traumatic stress disorder.

The social isolation that results from disaster events is particularly harmful to children's mental well-being. Parents often restrict outdoor play due to safety concerns, further limiting children's opportunities for social interaction and exacerbating their sense of isolation. The psychological toll of these disasters underscores the need for targeted interventions, including counseling services and emotional support programs, to help children cope with the long-term effects of their experiences.

#### IV. DISCUSSION

The physical structure of Rupsha's informal settlement plays a critical role in children's vulnerability to floods and cyclones. Child-centered design features such as elevated plinths, durable construction materials, effective sanitation, and proper drainage systems are vital for ensuring their safety during disasters. Elevated plinths can protect homes from flooding creating safer spaces for children to live and play, while resilient construction materials can enhance the strength of buildings, reducing the risk of structural collapse. In addition, accessible sanitation facilities, which remain functional during disasters, can ensure that children's hygiene is maintained, preventing the spread of diseases. Proper drainage systems are equally important, as they prevent water logging, which can otherwise exacerbate disaster risks and impede mobility.

The spatial organization of Rupsha's settlement directly impacts children's vulnerability during disasters. Waterlogged lanes caused by inadequate drainage restrict mobility, preventing children from accessing key spaces for socialization, play, and education. This disruption of routine activities negatively affects their physical and emotional well-being. School closures during disasters compound this issue by disrupting education, a vital stabilizing force in children's lives. Schools not only provide learning opportunities but also serve as safe spaces where children can maintain a sense of normalcy during crises. Furthermore, the closure of local shops, which serve as hubs for social interaction, adds to the emotional strain experienced by children. Addressing these issues requires careful spatial planning to improve safety, accessibility, and resilience in the areas where children live, learn, and socialize. Enhancing these aspects can reduce the long-term impacts of disasters on children's development.

Children's perspectives on floods highlight the distinct vulnerabilities they face, particularly in informal settlements where poor housing and sanitation conditions heighten the risks. Children depend on the adults around them, and when preventive measures or early warnings are lacking, their exposure to danger increases. To reduce these vulnerabilities, disaster preparedness measures must be designed with children's needs in mind. Empowering households with knowledge on flood preparedness and improving coordination between agencies to prioritize children's health and safety are essential. Additionally, ensuring children's education during disasters is a priority, as missed learning time and diminished educational quality have long-lasting effects. Stronger school buildings, disaster-resilient infrastructure, and road maintenance are crucial for keeping schools accessible even during floods, ensuring that children's education is not disrupted.

The psychological toll of disasters on children is significant. Anxiety, fear, sadness, and even aggression are

common reactions to the uncertainty and chaos caused by floods and cyclones. Many children in Rupsha report feelings of panic and sadness, compounded by a constant fear of future disasters. These emotional challenges often lead to difficulties in concentration and learning. Early psychosocial interventions are crucial to help children cope with these emotional strains. Providing counseling and support in the aftermath of disasters can help children process their experiences, alleviate anxiety, and develop resilience.

#### *Recommendation*

To improve disaster resilience in Rupsha, it is crucial to focus on child-centered urban planning and infrastructure upgrading. Urban planners should prioritize the creation of safe zones and recreational areas for children, which can double as emergency shelters during disasters. Housing designs must incorporate elevated plinths, durable construction materials, and child-friendly features that ensure safety during floods. Furthermore, upgrading communal infrastructure such as bridges and pathways is vital to enhance the mobility and safety of children in their daily activities.

Urban spaces in Rupsha should accommodate diverse needs, ensuring that play areas are safe and flood-resistant. In addition, disaster-resilient educational and community spaces with adaptable designs are essential to provide continuity during crises. Such spaces should be able to withstand the physical impacts of disasters, ensuring that children's education and social development remain uninterrupted. Improving sanitation and access to essential services is another critical area of focus. Upgrading drainage systems and constructing raised community toilets will prevent waterlogging and ensure sanitation during floods. Ensuring access to safe drinking water and creating community kitchens on raised platforms can address health and nutrition needs during disaster events. Strengthening school structures, building elevated pathways, and preparing temporary learning centers will ensure uninterrupted education for children even during crises. These spaces, equipped with proper sanitation and shelter, will provide stability and psychosocial support to children as they recover from the impact of disasters. Collectively, these initiatives can safeguard children's well-being and foster resilience in the face of recurring natural hazards.

#### V. CONCLUSION

This study reveals the multiple dimensions of children's vulnerability in Rupsha's informal settlement. The findings highlight the importance of child-friendly urban planning and infrastructure development to mitigate the impact of floods and cyclones on children. By focusing on the built environment and the unique needs of children, the research underscores the need for improved disaster preparedness, resilient infrastructure, and early psychosocial support for affected children. Addressing these challenges holistically can significantly enhance the resilience of children and their communities in disaster-prone informal settlements.

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