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FRAMING THE CHALLENGES OF URBAN FLOODING ON ACCESSIBILITY:

A CASE OF PULBAZAR, BANEPA

By
Apsana Shrestha

A THESIS

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Supervisor / Program Coordinator	External Examiner
Dr. Ajay Chandra Lal	**Er. Kishore K. Jha**
Department of Architecture	Senior Urban Planner
IOE, Pulchowk Campus	

External Examiner

Ar. Yek Raj Adhikari

Joint Secretary (MOUD)

Date: October 2022

DECLARATION

I hereby declare that the thesis entitled "Framing the Challenges of Urban Flooding on Accessibility: A Case of Pulbazar, Banepa" which is being submitted to the Department of Architecture and Urban Planning, Pulchowk Campus, Institute of engineering, Tribhuvan University in partial fulfilment of the requirements for the degree of Masters in Urban Planning (MSUrP) is a research work carried out by me, under the supervision of Dr. Ajay Chandra Lal, between start date to completion date. I declare that the work is my own and has not been submitted for a degree of another University.

Apsana Shrestha

076/MSUrP/002

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ABSTRACT

Urban flooding is a worldwide phenomenon which is witnessed more often in a growing urban city in developing countries. The insufficiency of drainage system that cannot withstand with the current precipitation due to climate change, urbanization haphazard planning causes stormwater runoff in a city area creating inundation that lasts from few hours to even few days known as Urban Flooding. These urban floods paralyze the surface transportation of a city. Especially the daily commuters bear heavy economic and financial losses. This paper aims to assess the accessibility disruption faced by daily commuters who travel via Araniko road, Pulbazar section road and identify major cause of the flood in the study area. The research also tries to explore adaptive & mitigative measures that should both be incorporated simultaneously to cope with the annual flooding scenario in the study area.

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076MSUrP002

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LIST OF ABBREVIATION

ADB : Asian Development Bank

BMP : Best Management Practice

CTS : Commuter Travel Survey

DAO : District Administrative Offices

DEOC : District Emergency Operation Centers

DHM : Department of Hydrology and Meteorology

DRC : Democratic Republic of Congo

DRM: Disaster Risk Management

DRRM : Disaster Risk Reduction and Management

DWRI : Department of Water Resources and Irrigation

FRM : Flood Risk Management

FRR : Flood Risk Reduction

GDP : Gross Domestic ProductGI : Green Infrasturcture

GLOF : Glacial Lake Outburst Flooding

GTFS : General Transit Feed Specification

HEF : Hourly Expansion Factor

IFRM : Integrated Financial Resource Management

ISDR : International Strategy for Disaster Reduction

IUWM : Integrated Urban Water Management

LULC : Land Use and Land Cover

MOEWRI : Ministry of Energy, Water Resources and Irrigation

MOF : Ministry of Finance

MoFAGA : Ministry of Federal Affairs and General Administration

MoHA : Ministry of Home Affairs

MOUD : Ministry of Urban Development

NAPA : National Adaptation Program of Action

NDRRMA : National Disaster Risk Reduction and Management Authority

NPC : National Planning Commission

NRA : National Reconstruction Authority

PCU: Passenger Car Unit

PMIA : Provincial Ministries of Internal Affairs

PMPI : Provincial Ministries of Physical Infrastructure

SUDS : Sustainable Urban Drainage System

WECS : Water and Energy Commission Secretariat

WSUD : Water Sensative Urban Design

GLOSSARY OF TERMS

Best Management Practices

A building or method in stormwater management that is intended to avoid the discharge of one or more pollutants to the ground surface, hence reducing the possibility of wash-off by rainwater.

Catchment

A topographically delimited area with a single exit point for surface water. It may typically include tributary streams and flow routes in addition to the main stream.

Detention Tank

A facility above or below ground, such as a pond or tank, that momentarily holds rainwater runoff and then releases it at a lesser speed than the drainage facility system.

Detention

The release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, the difference being held in temporary storage.

Drain

A buried pipe or another type of conduit (closed drain). A ditch (open drain) for draining excess surface or ground water. (To) Drain means to create channels, such as open ditches or closed drains, for surplus water to be eliminated by surface flow or interior flow. Percolation is the process through which water (from the earth) is lost.

Embankment

A structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.

Flood Zoning

Definition of areas, based on flood risk, within floodplain appropriate for different land uses.

Floodplain

Area susceptible to inundation by a base flood including areas where drainage is or may be restricted by man-made structures which have been or may be covered partially or wholly by flood water from the base flood.

Floodplain Regulation

Laws defining acceptable use of land in defined areas, thus controlling the extent and type of future development.

Hydrology

The science of the behavior of water in the atmosphere, on the surface of the earth and within the soil and underlying rocks. This includes the relationship between rainfall, runoff, infiltration and evaporation.

Infiltration

The downward movement of water from the soil surface at ground level into the underlying subsoil. Water infiltrates into the soil profile and percolates through it.

Inundation

The act of intentionally flooding land that would otherwise remain dry.

Land Use Planning

Control and supervision of land use in floodplain (zoning, regulation, acquisition, relocation).

Recharge

Replenishment of groundwater by downward infiltration of water from rainfall, streams and other sources. Natural recharge occurs without assistance or enhancement by man. Artificial recharge occurs when the natural recharge pattern is modified deliberately to increase recharge.

Retention Pond

Ponds or pools with extra storage capacity to reduce surface runoff during rainy events. They are made out of a permanent pond area with manicured banks and surroundings to give extra storage capacity during heavy rains.

Runoff

The flow of water across the ground or an artificial surface generated by rain falling on it.

Sediment

Sediment is naturally occurring material that is broken down by weathering and erosion processes and is then moved by the action of fluids such as wind, water, or ice, as well as gravity acting on the particle itself.

Water Sensitive Urban Design

An approach to urban planning and design that takes advantage of this wonderful resource while minimizing the harm it causes to our rivers and streams.

Chapter One: Introduction

1. INTRODUCTION

1.1.Background

Urban Flooding is brought about by heavy rain falling on built-up surfaces with limited drain capacity. Therefore, the definition of an urban flood can be summed up as "excessive runoff in developed urban areas, where the stormwater has nowhere to go due to low drainage system capacity, creating inundations." Each of the above variables – increasing urbanization, more rainfall due to climate change, and old or insufficient drainage infrastructure – creates problems that must be addressed separately (Ilam Vazhuthi & Kumar, 2020). Urban flooding is a complicated issue brought on by the simultaneous occurrence of several of these factors. Urban flooding is on the rise and has gradually turned into a common occurrence, especially since past few decades, in most growing cities.

Increase in the frequency of urban flood events is becoming a global phenomenon, posing a significant challenge to planners worldwide (Ilam Vazhuthi & Kumar, 2020). The consequences of such calamities are extremely complex in developing countries such as Nepal, which are more susceptible than developed countries. These flood incidents can range in magnitude from a small-scale neighborhood incident to a large disaster that floods urban regions for several hours to several days.

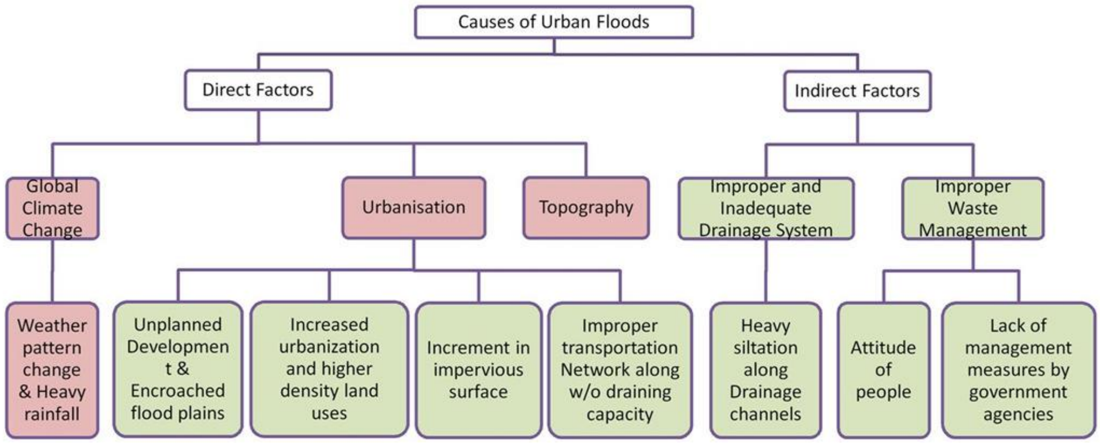


Figure 1: Causes of Urban Flood, Source: (Ilam Vazhuthi & Kumar, 2020)

Floods in cities interrupt ground transportation and cause major economic losses (Kadaverugu et al., 2021). Flooding impairs transportation systems in developing-country cities. Floods impair transportation network capacity, either directly by destroying roads or indirectly by accumulating floodwater on the road surface, rendering the road impassable. (He et al., 2020). Commuters would face enormous socio-economic expenses because of these disruptions, including longer travel lengths and times.

Flash flooding can happen in hilly and mid-hill areas when heavy rain falls in a brief period of time, causing high surface water flow into existing streams and rivers. Floods can breach existing river channels due to the huge volumes of water generated by surface water runoff, posing a risk to local urban settlements and existing infrastructures. It has a detrimental influence on the surrounding housing/infrastructure, transportation systems, traffic congestion, health dangers owing to stagnant water, and sewage contamination of storm water, resulting in a rise in economic, social, and human losses.

Urban floods are a man-made calamity due to overburdened drainage, frenetic and unregulated building, and a disregard for natural topography and hydro-geomorphology. The term "urban flood" is a misnomer. Flooding in urban areas is induced not only by unusually heavy rains, but also by our cities' misguided approach to urbanization (Mitashi Singh, 2019).

1.1.1. Flood Disaster Overview in International Context

According to the Organization for Economic Cooperation and Development, floods cause more than $40 billion in damage worldwide each year. Losses in the United States are close to $8 billion per year. Death tolls have increased in recent decades to more than 100 people a year. Some of the world's biggest floods have killed millions of people in China's Yellow River Valley. (Nunez, 2019).

1.1.2. Flood Disaster Overview in National Context

Flooding is the most common natural catastrophe in Nepal. The most severe form of flooding occurs from rivers (fluvial) in the Terai region. In addition to river flooding during the monsoon, other flood hazards include flash floods caused by excessive rainfall in high areas, Glacial Lake Outburst Flooding (GLOF), landslide-induced flooding, and infrastructure flooding (such as embankment failure) (ADB, 2019).

Floods in Nepal killed 7,599 people, affected 6.1 million people, and cost the country $10.6 billion USD between 1954 and 2018. Every year, on average, 100 individuals are killed.

Floods occurring frequently particularly during the monsoon season, resulting in substantial loss of life, property, and livelihood. According to the desinventar database (1971-2016), a total of 4,160 flood incidents were reported during the 45-year period, resulting in human losses and damages in all regions of Nepal. Figure 1 reveals that the number of incidents was highest in Province 2 (26.47%), while it was lowest in Karnali (4.83%). Similarly, Baghmati province and province 2 have a greater (54.47%) than other provinces in terms of human death and losses. Figure 1 also reveals that the percentage of human injuries caused by floods was highest in Bagmati province (34.15%). In terms of house damage, disaster records published by desinventar show that 98,818 houses were damaged between 1971 and 2016. It reveals that most buildings (45.34%) were damaged in Province 2 and that 70% of individuals were affected by the flood disaster.

The estimated economic losses due to flood events in province 2 are likewise substantial (45.14%), totaling 3335.36 million rupees (B. R. Shrestha et al., 2020).

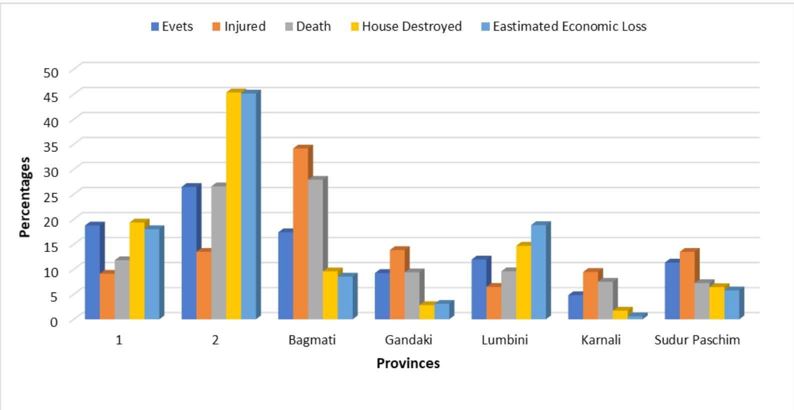


Figure 2: Flood Disaster in Nepal

1.2. Study Area

Every year the Urban Flood inundates in the study area i.e. Pulbazar Banepa, blocking the Araniko Highway. The Araniko Highway is one of the major routes that connects Kathmandu valley and Kavre District. The highway also connects to Terai Region via BP highway from Dhulikhel. Large number of people travel from Kavre district to Kathmandu Valley daily for job and study purpose via Araniko highway.

In the study area rain triggers flood at Punyamata Chandeswori river. The flood waterlogs Pulbazar in Banepa causing blockade to section of Punyamata river bridge and approached road. Sections of the Araniko Highway between Kathmandu and Banepa are prone to chronic flash flooding every monsoon season. Water from a nearby stream overflows into the road because of insufficient drainage, and compound walls that act like dams along natural floodplains of rivers (Machamasi, 2021). The Pulbazar area has always been inundated due to rising water levels due to the narrowing of the river.

Figure 3: Inundation Area (Pulbazar Flooding)

During the monsoon sudden flash flood blocks the Araniko Highway halting the transportation causing negative impact to daily commuters and the local people which ultimately results in the social and economic loss to the people. The flooding lasts from few hours to even a day and it is a repetitive evet that occurs every time it rains heavily during the monsoon. As per some locals such scenario is developed 10-15 times in one monsoon season.

Figure 4: Inundated area of Banepa (2021 Flooding) Source:RONB 2021, Twitter

Figure 5: Pulbazar Flood/Inundation, 2022 Flooding

1.3.Need and importance of the Research

Flooding is closely related with climate change and the change in urban land use pattern with the replacement of porous soft surface with built ups and hard surface. Floods in cities have halted surface transportation and accessibility and caused significant economic losses. While direct loss in housing/infrastructure by flooding can be seen. There is also huge indirect economic loss due to the obstruction of road networks halting the transportation and accessibility. Many students, workers, employees travel via Araniko highway to Kathmandu valley daily and they are adversely affected by the flood in monsoon. Being the only defined route to Kathmandu valley, flooding halts all the activities and causes immense economic loss. According to studies, flooding is expected to become more common in the future because of climate change and urbanization. The impact of flooding on transportation and accessibility has received very little attention. Further study and mitigative and adaptive measures must be introduced to cope with the ongoing situation in the present and future.

According to Pradhan-Salike & Raj Pokharel, (2017) Climate Change and Urbanization are the major drivers for Urban Flooding and the future climate change and current pace of urbanization will increase the Pluvial Flooding and urban drainage control infrastructure intended for current climate conditions will be incapable of dealing with future climate conditions. Both tendencies result in the expansion of impermeable surfaces, which, when combined with climate change, increases the risk of pluvial and river flooding (ADB, 2019).

The cause and impacts should be understood and addressed properly, if not it will worsen the situation in the near future. Therefore, to cope with the annual flooding scenario and accessibility obstruction caused by it, the research has its significant importance.

1.4.Problem Statement

Floods kill about 175 people in Nepal each year, with yearly economic losses reaching USD 140 million. Nepal ranks ninth in the world in terms of relative physical exposure to fluvial flooding, with potential damage to physical assets amounting to 1.4% of its GDP. Increased economic and construction activity in floodplains will certainly worsen the economic damage associated with floods in the coming years unless complete flood protection or risk-sensitive urban planning is implemented (ADB, 2019).

Changes in the environment/Climate has already increased flooding across nation, and the pace of unmanaged urbanization adds to it as well. As this trend continue in the future the risk and damage will continue to rise.

In the study area rain triggers flood at Punyamata & Chandeswori river. The flood waterlogs Pulbazar and tarkari bazar in Banepa causing blockade to section of Punyamata river bridge and approached road. Sections of the Araniko Highway between Kathmandu and Banepa are prone to chronic flash flooding every monsoon season. Water from a nearby stream overflows into the road because of insufficient drainage, and compound walls that act like dams along natural floodplains of rivers (Machamasi, 2021).

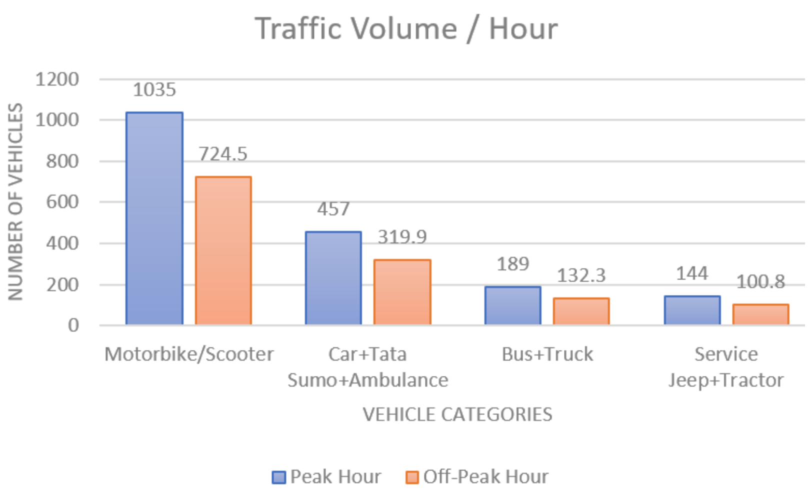


Chart 1: Traffic volume per hour in the Study Area

Note: Traffic Volume Survey conducted for 3 consecutive days including 2 weekdays and a weekend during peak hour. Peak Hour Volume multiplied by 0.7 as HEF to obtain Average Traffic Volume.

Chart 1 shows the average traffic volume per hour in the study area, where a total of 1800 vehicles commute is disrupted if flooding halts transportation for an hour. When converted into Passenger Car unit (PCU), 1492 PCU commute is disrupted. The survey also found 5-6 emergency service i.e. ambulance commute in an hour which suggests that those services are worst hit by the traffic disruption by the flooding/inundation. Huge economic & financial loss is also incurred through the traffic disruption.

1.5.Research Purpose

When the city floods due to heavy rain, the major hit regions include difficulty in transportation of goods and services, breakdown in the public service sector, school closures, and so on. These circumstances have brought the city to a halt.

Changing climate will probably have a significant impact on the frequency and severity of major flood events. Flash flooding will become more common as extreme precipitation increases. Because of the rate of urbanization and the pattern of urban development, urban drainage systems are under-designed, overworked, and poorly maintained, making them quickly choked. Unregulated development and intrusion into public lands and high-risk areas by both land brokers and squatters is worsening flood danger.

Shifting land use patterns, growing urbanization, and insufficient planning control are producing substantial problems for flood risk management in general and in particular. Strengthening land use planning practices, such as building a comprehensive system for land zoning and other development controls, will aid in the management of the issue of new development causing additional flood risks.

The main tasks include accessing the challenges faced by daily commuter and identifying major cause of Urban Flooding in Pulbazar, Banepa and its direct and indirect consequences in terms of transportation & accessibility. The purpose of the research is also to adapt and mitigate the challenge of urban flooding by studying hydrological data, flood risk maps from the secondary sources. This study assesses and overcomes these challenges and proposes strategic interventions of the effect of flooding on transportation networks and accessibility in Pulbazar, Banepa.

1.6.Research Objective

The major objective is to access the accessibility disruption faced by daily commuters who travel via Araniko road, Pulbazar section.

The other objectives are;

- To identify major cause of flood in the study area and its direct and indirect consequences in general and terms of transportation & accessibility.
- To explore strategic intervention to adapt & mitigate for facilitating the accessibility in the region.

1.7.Scope & Limitation of the Research

The study focuses on the assessment of annual flooding in the Pulbazar Section in Banepa. The study concentrates on how urban flooding affects transportation and most importantly daily commuters. The study also identifies its major causes through KII and expert suggestions. Mapping and hydrological data from secondary sources will be studied to explore adaptive and mitigative measures to cope the annual flooding scenario.

Limitations:

- The study focuses on cause and impacts of flood on accessibility rather than direct infrastructural loss caused by the annual flood.
- The study does not address the immediate effects of floods, such as loss of life, property damage, crop destruction, animal loss, non-functioning infrastructural facilities, and worsening of health due to waterborne infections.

1.8.Expected Outputs

After the research of the following topic it is expected to identify major cause of flood and what impact it has on accessibility especially to daily commuters. Areas under worst flood risk in terms of traffic congestion would be identified. Transportation and Accessibility which is the main concern of the research is addressed through strategic interventions.

Chapter Two: Conceptual Framework & Research Methodology

2. CONCEPTUAL FRAMEWORK & METHODOLOGY

The methodologies of the thesis work will be presented in this chapter. The choice of research methodologies will be discussed first, followed by data collection methods, technique, and justification for choosing the case study area.

Flooding is a recurring natural as well as man-made event and has its tangible as well as intangible impact to the surrounding and people leaving nearby. This study's ontological perspective is that urban flooding is a result of climate change and urbanization, with direct consequences for infrastructure damage, property loss, and vegetation loss, as well as indirect consequences for transportation and accessibility. Studies suggest that the more intense rainfall is bound to happen as an impact of climate change and more urban areas are prone to inundation due to urban flooding because the current urbanization and urban drainage infrastructure cannot withstand with the rainfall in future. Urban flooding is a natural phenomenon and thus based entirely on the objective reality.

Epistemologically, the valid source of knowledge for this study is the study of land use maps and rainfall data over a certain time frame, to analyze how the impervious surface has been increasing and to what extent rainfall is increasing that is causing inundation in the urban areas. The study is also backed up by the interpretation of the spatial observations and literature study. Analysis of the impact urban flooding has on Accessibility is measured by daily commuter survey and transport survey over a certain time duration and by interviewing the key informants.

2.1.Research Paradigm

The Research falls under post-positivist paradigm. In post positivist paradigm, the idea of truth or reality can’t be universal and same phenomenon under study might show different result when the research area or the research subject is altered. In the research, the cause and impact of flooding in Pulbazar area might not be the same in other urban flood prone areas.

Post positivism is the modified dualist where the findings can be probably true, Critical theory that is the subjectivism or value-mediated findings and the constructivism are the subjectivist or the created findings.

Under this paradigm, the research will have aspects of the urban flooding, its history in different time frame and reason for flooding and its impact it has upon Accessibility.

Both quantitative and qualitative data findings are achieved. Quantitative data in the form of structure of survey questionnaire, rainfall data, land use maps. Qualitative data are achieved by filed observation and key informant interviews.

2.2.Research Design & Methodology

The research is based on inductive thinking. An inductive approach includes specific limited observations, patterns and regularities generalization, and tentative hypothesis which extends to the general conclusion or theories. Urban flooding is a specific problem and general conclusion is reached by various studies and observation. It is a form of bottom up approach.

The study employs a mixed methods case study design, which is a sort of mixed methods study in which quantitative and qualitative data collection and analysis.

2.2.1. Literature Review

A literature review is a written analysis of notable books and other information on a particular subject. Scientific journal articles, books, government papers, Web sites, and other sources may be included in the review. The literature review describes, summarizes, and evaluates each source.

Review of literature about flooding and its types. Review of urban flood and its major cause and impacts caused by it to the urban transportation. Secondary data available from the internet and other necessary data from municipality. Study of the risk map and Hydrological model from secondary sources.

2.2.2. Identification of study area

Pulbazar, Banepa is identified as the study area, as major part of the Araniko highway inundates during the monsoon halting the transportation.

2.2.3. Formulation of Objective

The objective is formulated such that it majorly incorporates the impact of flood on Accessibility and identifying the major cause of flood in the study area.

2.2.4. Data Collection

To conduct the necessary analysis as per the set objective both primary and secondary data are collected from several sources. The primary data is based on direct interviews with the locals and concerned stakeholders in Banepa Municipality and through various visual methods such as satellite imagery, maps and field observations. The secondary data collection is done both during the initial literature review phase and during the research phase as seen necessary while conducting the primary data collection and while analyzing and interpreting the data collected.

2.2.5. Field survey and KII

Questionnaire survey to bus operators and the daily commuters about the inconvenience caused by traffic obstruction during flooding. Key informant interviews with the concerned authorities and environmental engineer.

2.2.6. Data Processing

The data obtained from primary and secondary sources are further analyzed to find out the major cause of flooding, its impact mainly to daily commuters and private bus operators and possible measures to cope with the ongoing scenario is explored and then conclusion is drawn.

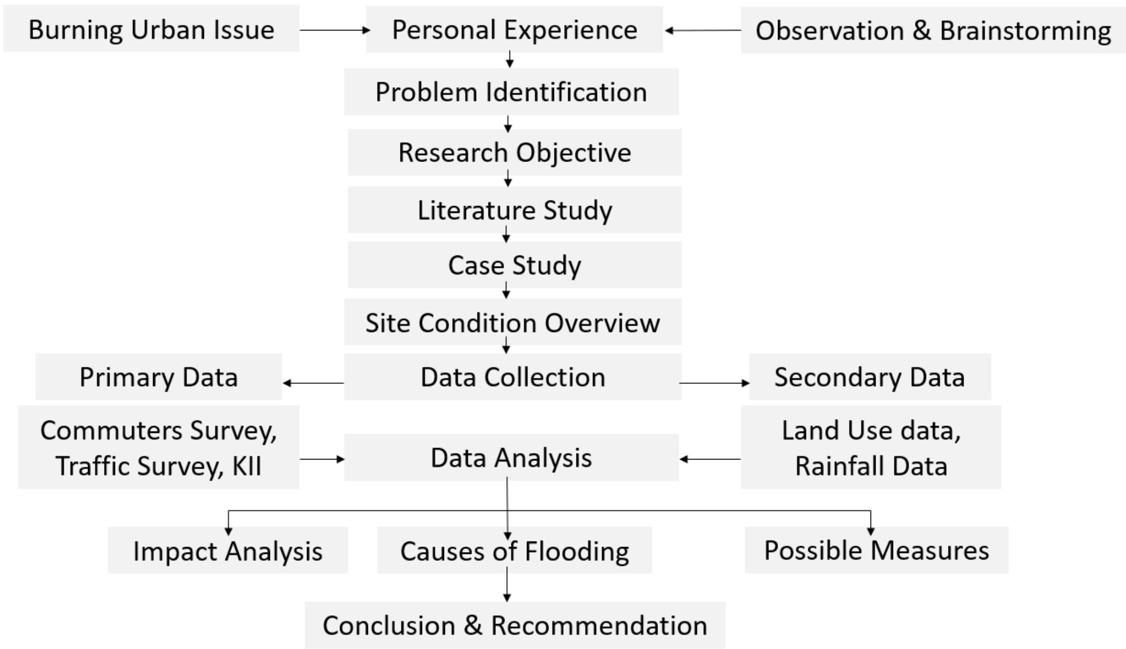


Figure 6: Methodology Chart

Chapter Three: Literature Review

3. LITERATURE REVIEW

3.1.Urban Flooding

Urbanization presents various challenges to city administrators, planners, and policymakers, with urban flooding emerging as a major issue. Urban flooding is a result of inappropriate design, encroachment on water bodies and drainage, habitation of low-lying areas, modification of catchments, and climate change.

Urban floods are predicted to become more common, with a longer flooding season and flooding in newer locations with changing climate (NIUA, 2016). Urban flooding has been reported all around the world, and it is increasingly common in developing countries and cities. Regular events of urban flooding can be seen in the urban areas of Nepal in the past decades causing huge economic losses and disruption in the transportation and accessibility.

Urban flooding is a common occurrence throughout Asia. Almost every city is prone to some sort of urban flooding, and city dwellers are especially vulnerable. Farmland, vegetation cover, and bare soil have all been converted into urban built-up areas. Water runs off the concrete structures as a response, generating pluvial flooding or urban flooding (Atta-ur-Rahman et al., 2016).

3.2.Flood Classification

Flood can be classified into two categories; according to the duration of flood and according to its appearance (Abdrabo et al., 2022).

3.2.1. According to Duration

- Long-standing floods: May extend to a week or longer
- Short-standing floods or “flash floods”: Usually extend to approximately 6 h or less

3.2.2. According to Appearance

- River or stream floods
- Urban floods that occur in creeks or streets in urban areas
- Dry water-collector floods such as mountain sides and slopes
- Coastal floods caused by low atmospheric pressure on the sea surface

Table 1: Types of Flooding, Causes and Duration

Flooding type	Causes		Period
	Natural	Anthropogenic	
Urban flood	Fluvial Coastal Flash Pluvial Groundwater	- Inappropriate drainage and sewage capacity for the rainfall amount - Lack of land cover permeability due to increased urbanization - Drainage system failure and lack of appropriate interventions	Various timescales starting from hours and extending to days
Pluvial flood	Convective, thunderstorms severe rainfall, breakage of ice jam glacial lake burst earthquakes resulting in landslides	- Land use changes - Urbanization - Increase in surface runoff	Varied periods depending on existing conditions
Coastal flood (tsunami, storm surge)	Earthquakes Submarine volcaniceruptions subsidence coastal erosion	- Urban sprawl in coastal zones - Damaging of coastal natural flora (e.g., mangroves)	Events usually occur in short time periods and may take a long time to recede
Groundwater flood	High water table level combined with heavy rainfall embedded effect	- Development in low-lying areas - Interference with natural aquifers	Long durations
Flash flood	Can be caused by river pluvial or coastal systems; convective thunderstorms; glacial lake outburst floods (GLOFs)	- Sudden failure of water-retaining structures - Inadequate drainage infrastructure	Typically, last a few hours

Source: (Abdrabo et al., 2022)

3.3.Causes of Urban Flooding

Flooding is becoming more common in emerging cities as a result of both human actions and meteorological/hydrological reasons, with the former being even more prevalent (NIUA, 2016). The following are some of the factors that lead to urban flooding:

i. Planning issues: Increased population, development in low-lying areas, encroachment on drainage systems
ii. Technical issues: Excessive impermeability causes more runoff than drainage capacity, inappropriate waste disposal causes clogged drains, and high intensity - high load of runoff.
iii. Meteorological issues: Exacerbated by changing climate, resulting in extreme events, NASA studies indicate that the urban heat island effect also results in increased rainfall over urban areas.
iv. Policy issues: Lack of integrated flood control implementing agency.

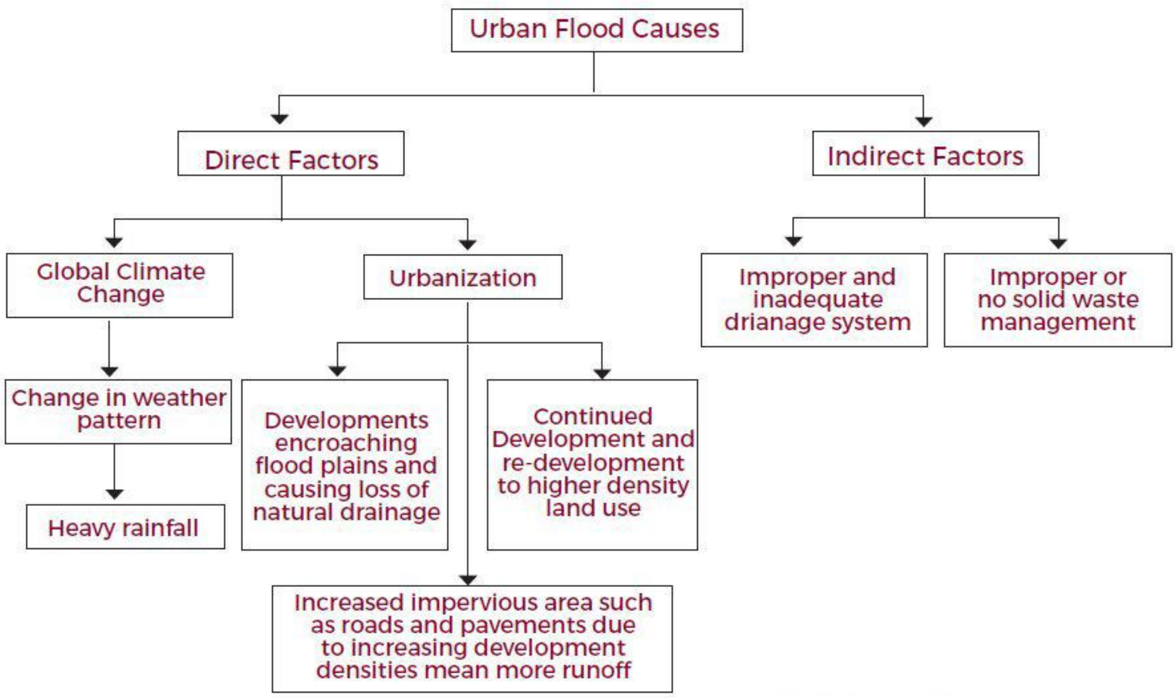


Figure 7: Causes of Urban Flood
Source: (NIUA, 2016)

3.4.Factors causing Urban Flooding

There are basically three factor that cause urban flooding; Metrological factor, Hydrological factor and human factor (Ilam Vazhuthi & Kumar, 2020).

3.4.1. Meteorological Factors

The global warming and increased precipitation play a significant part in the devastating floods that occur across the country. A study by (Pradhan-Salike & Raj Pokharel, 2017) predicts a 40% rise in flooding for a 25-year return period when current and future climates are considered.

3.4.2. Hydrological Factor

Flooding occurs when the rate of surface runoff exceeds the rate of absorption during rainfall. Rapid urbanization has a major impact on surface runoff and hydrology. Among them are:

i. Limiting the natural variation in river course
ii. Deforestation and soil erosion
iii. Increased impervious surface area and lower infiltration, resulting in increased runoff
iv. Wastewater reaching rivers and lakes, producing siltation and further diminishing natural drain capacity.

3.4.3. Human Factor

Human intervention in the natural environment has escalated the urban flood risk. These anthropogenic influences might be a direct result of urbanization and encroachment, as well as pollution, which disrupts the regular flow of water through drainage channels. Floods on a massive scale have been caused by negligence and a lack of a robust governing system.

i. Urbanization

The rate of urbanization increases impervious surface, which limits surface water infiltration and boosts stormwater runoff from buildings, roads, and other hard surfaces. Thus, urbanization and the risk of flooding are directly related, according to the definition of urban flooding.

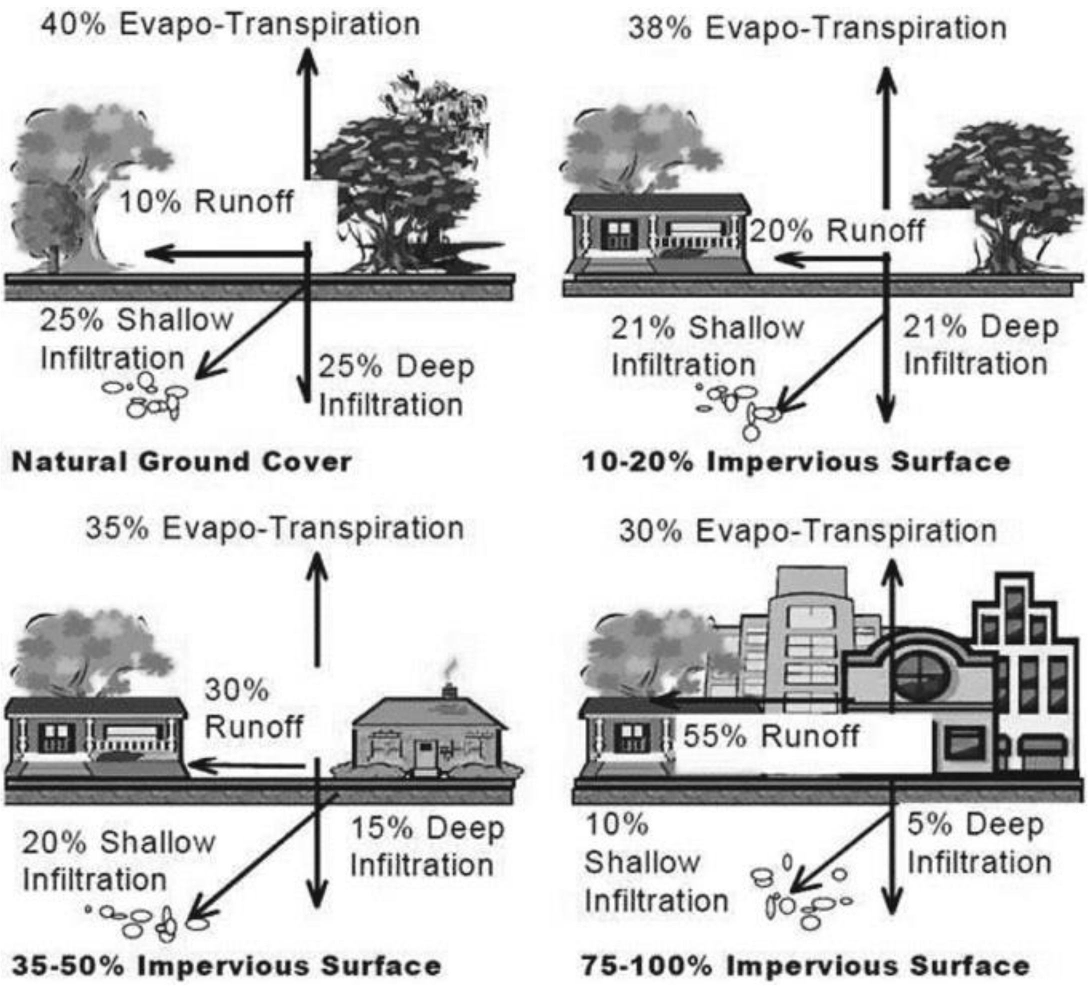


Figure 8: Urbanization impact on water cycle change
Source: (Abdrabo et al., 2022)

i. Encroachment

In-migration and densification of an urban area results in demand of land for housing. People slowly starts to encroach towards the low-lying areas near the flood plain. In worst-case scenarios, these encroachments may completely cover the catchment area and leave no evidence of the water body's presence.

ii. Pollution

Infrastructures for solid waste management, sewer lines, stormwater drains are insufficient and improperly managed for the growing demand of urban scenario. As a result, improper solid waste disposal into bodies of water occurs, as does neglected street waste blocking drainage channels. The resultant chocking and siltation limits flow capacity even further during a flood event.

iii. Illegal mining activities

Unauthorized river sand mining reduces the natural bed of rivers and lakes, causing soil degradation and reducing the waterbody's water holding capacity, as well as increasing the pace and scale of stormwater flow and changing the usual flow of water (Ilam Vazhuthi & Kumar, 2020).

iv. Interreference in the drainage system

Poorly planned construction of road networks and other infrastructures like bridges hampers the flow of water which results in flood. In many cases, rajkulo, natural drain etc. are altered for the sake of infrastructure construction which affects the natural flow of water and causes inundation and flooding in the urban areas.

v. Absence of administrative framework

Lack of proper administrative framework, policies for land use also exacerbates the effect of urban flood.

3.5.Impacts of Urban Flooding in Urban Areas

Urban flooding has a wide range of repercussions, particularly in terms of both direct and indirect economic losses. Flooding in an urban area might affect more than just one sectors. Some of the impacts are listed below;

i. Transport and Accessibility Disruption
ii. Infrastructure damage
iii. Damage to public and private property
iv. Disruption of power supply and telecommunication
v. Deprived of Emergency Services

The losses generated by the urban flood might be direct or indirect and can be divided into tangible and intangible losses.

i. Tangible losses

Losses that can be objectively measured and ascribed an economic value. These losses may be either direct or indirect:

- Direct - Structural damage to buildings, property damage, damage to infrastructure

- Indirect - Economic losses, Traffic disruption, and emergency costs

ii. Intangible Losses

Indirect losses comprise loss of human life, secondary health issues, epidemics, and environment degradation, which are difficult to quantify in monetary terms (Ilam Vazhuthi & Kumar, 2020).

- Direct - casualties, Health effects, ecological losses
- Indirect – post-flood recovery process, mental damage to the people

3.6.Flood Risk Management

The FRM cycle is composed of the following five basic steps: a). risk assessment, b). risk treatment (strategy), c). strategy implementation, d). monitoring and evaluation of the strategy, and e). development and modification of risk goals and policies (Abdrabo et al., 2022).

Figure 9: Flood Risk Management
Source: (Abdrabo et al., 2022)

3.7. Mitigation Measures for Flood Risk reduction

Flood risk reduction measures are classified as structural or non-structural:

Structural measures are often big public undertakings requiring formal permission from one or more government entities, moderate-to-major planning and design work, and moderate-to-large capital investments, operation, and maintenance obligations.

- Construction of Detention/Retention facilities
- Building Banks & Dams
- Upstream Storage & Diversion Works
- Floodwalls
- Culvert alteration or replacement

Non-structural interventions typically need little or no construction and can be easily applied by individuals, businesses, or other private groups. Nonstructural interventions often necessitate small-to-moderate capital inputs.

- Land use regulation
- Institutional Control
- Elevated buildings
- Land acquisition and relocation
- Flood Prediction & early warning System

Structural measures are often protective, whereas non-structural measures are reductional. A comprehensive integrated mitigation strategy comprising structural and nonstructural mitigating measures should be linked to existing urban planning and management strategies (Abdrabo et al., 2022).

3.8.Flood Risk Reduction Tools in Urban Planning and Landscape

FRR scientific study has relied heavily on urban planning technologies.

3.8.1. Land Use Control & Flood Zoning

As stated in the United Nations International Strategy for Disaster Reduction (ISDR) (2004), inadequate or non-existent land use planning enhances the vulnerability of communities vulnerable to natural disasters.

Though planning system is accountable for long-term land use decisions and is not entirely responsible for disaster risk reduction, it plays a significant role in disaster risk reduction. Four likely roles of spatial planning in FRR, as identified by Fleischhauer (2008), are as follows:

i. Eliminate future urban expansion in flood-prone zones
ii. Classify different land use settings for flood-prone areas
iii. Regulate land use or zoning plans
iv. Achieve flood hazard alteration

3.8.2. Building Codes

Create guides or guidelines for each district or building's flood prevention criteria.

3.8.3. Flood proofing & Building Elevation

Direct water forces, erosive forces, or a combination of both can damage buildings and other infrastructure during flood occurrences. Thus, there are many techniques for flood proofing of the properties.

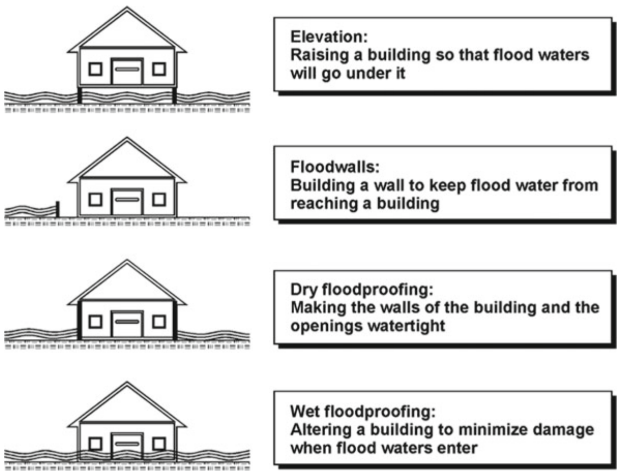


Figure 10: Techniques to fight floods in cities
Source: (Abdrabo et al., 2022)

3.8.4. Sustainable infrastructure for stormwater management

Sustainable drainage is a strategy that is commonly used in urbanized areas that are prone to various sorts of flooding caused by heavy rain. Stormwater is routed directly into drainage networks in urbanized settings, since built-up areas and paved roadways are impermeable to water. The fundamental idea behind sustainable infrastructure is to use landscape components to direct water from roofs and roadways underground rather than into the water system.

In recent years, there has been an increase in the complexity of urban stormwater management, and there have been numerous concepts, methods, and approaches used to lessen the risk of flooding. These principles, methods, and strategies have been employed by specialists from several fields around the world. This section will look at some of the urban planning tools, strategies, and techniques for FRR in urban areas, including: best management practices (BMPs) and low impact development (LID) between 1949 and 1990 in the United States; water-sensitive urban design (WSUD) in the 1990s in Australia; sustainable urban drainage systems (SUDS) in the 2000s in the United Kingdom; green infrastructure (GI) and green-gray infrastructure; integrated urban water management (IUWM) and sponge cities in 2014-2015 in China (Abdrabo et al., 2022). The main common goals for all these tools, strategies and techniques are as follows:

- Reduce impermeable surface runoff volumes and flow rates
- Limit the effect of urbanization on flooding
- Enhance water quality and minimize runoff pollution
- Maintain the natural flow system in watercourses.
- Create an appealing wildlife habitat in urban watercourses.
- Allow for evaporation and transpiration from vegetation and surface water.
- Facilitate natural groundwater/aquifer replenishment.

3.8.5. Sustainable infrastructure tools for stormwater management

Various tools have been utilized and integrated to implement the various sustainable infrastructure initiatives outlined in the previous section. These many methods are broken down into three groups in the following section: recharge (infiltration) tools, detention tools, and retention tools.

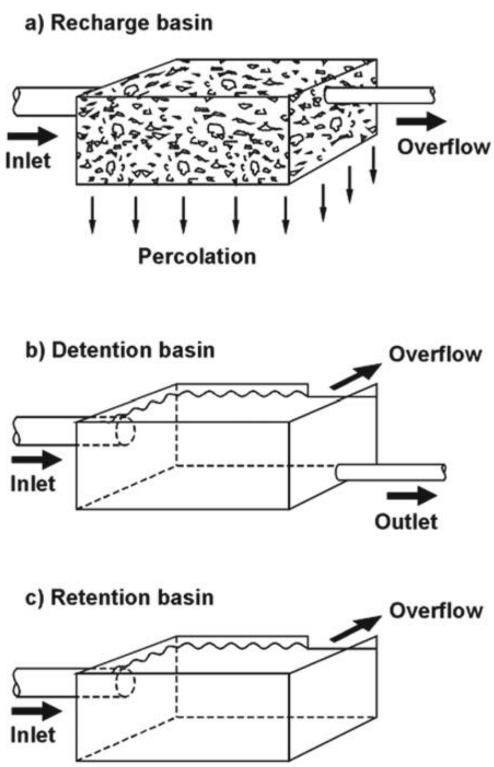


Figure 11: Sustainable Infrastructure for Stormwater management tools

Chapter Four: Case Study

4. CASE STUDY

4.1.Flooding Impact of Transit & Accessibility: A Case of Kinshasa

4.1.1. Overview

The study by He et al., (2020) conducts a detailed study of the impact of flooding on Kinshasa's transportation networks in the Democratic Republic of the Congo (DRC). Kinshasa is presently a megacity with a population over 14 million people.

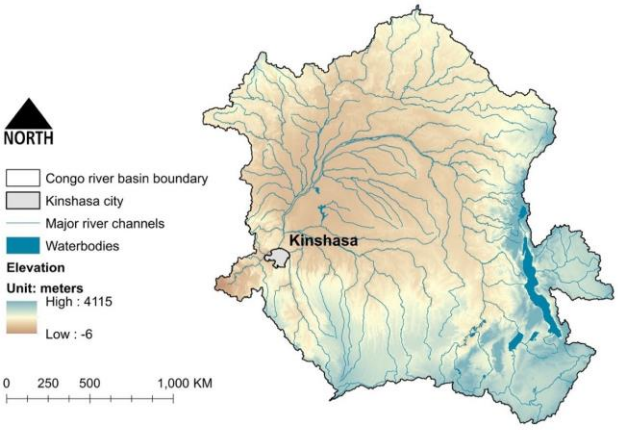


Figure 12: Hydrological Network within Congo River Basin

Kinshasa has already seen many flash floods caused by heavy rains following lengthy periods of drought. Flooding and landslides caused by successive days of heavy rain affected nine Kinshasa communes in January 2018, affecting around 15,700 people and killing 51. (International Federation of Red Cross and Red Crescent Societies, 2018).

4.1.2. Data & Preprocessing

The Japan International Cooperation Agency's (JICA) Kinshasa Commuter Travel Survey (CTS) reports data on local commuting patterns as well as socioeconomic attributes at both the household (income/expenditure, number of vehicles, members, etc.) and individual (age/sex, work/school type and place, industrial category, income, vehicle availability, etc.) levels. Static GTFS (General Transit Feed Specification) feeds for five major modes of public transportation were collected for this investigation under normal (dry) and flooded (wet) conditions. This data package includes flood extent and depth estimates for both pluvial and fluvial floods during 10 return periods, and the study also employs a 2D hydrologic flood model, which is more effective in mapping flood plains and modeling dynamic water flows.

4.1.3. Analysis & Results

The purpose of this research was to determine how pluvial and fluvial floods affect Kinshasa's transportation system in terms of transit operations, employment accessibility, road segment criticality, and economic loss (due to travel delay).

4.1.3.1.Flood Impact on Transit Networks

Changes in Headway: It was observed that during the rainy season, all transport networks that were surveyed under dry and wet circumstances had an increase in headways. Hence average travel time under wet condition is increased as compared to dry condition.

Blockage of roads & Changes in routes: The evaluation found that initial routes were relocated owing to flooding. However, determining the exact cause of rerouting is difficult because floods, as well as other confounding variables such as road closures, traffic fatalities, or regulatory penalty, can all result in changes to initial itineraries.

4.1.3.2.Accessibility

Table 2: Accessibility Condition during dry & wet scenario

Network Type	Dry Condition Accessibility	Wet Condition Accessibility
Walk	9.1%	8.9%
Drive	84.7%	73.7%
Public Transit (mean waiting time)	20.4%	15.4%

Wet condition accessibility is comparatively low as compared to the dry condition accessibility in terms of Walking, Driving & Public Transit.

4.1.3.3.Economic Cost

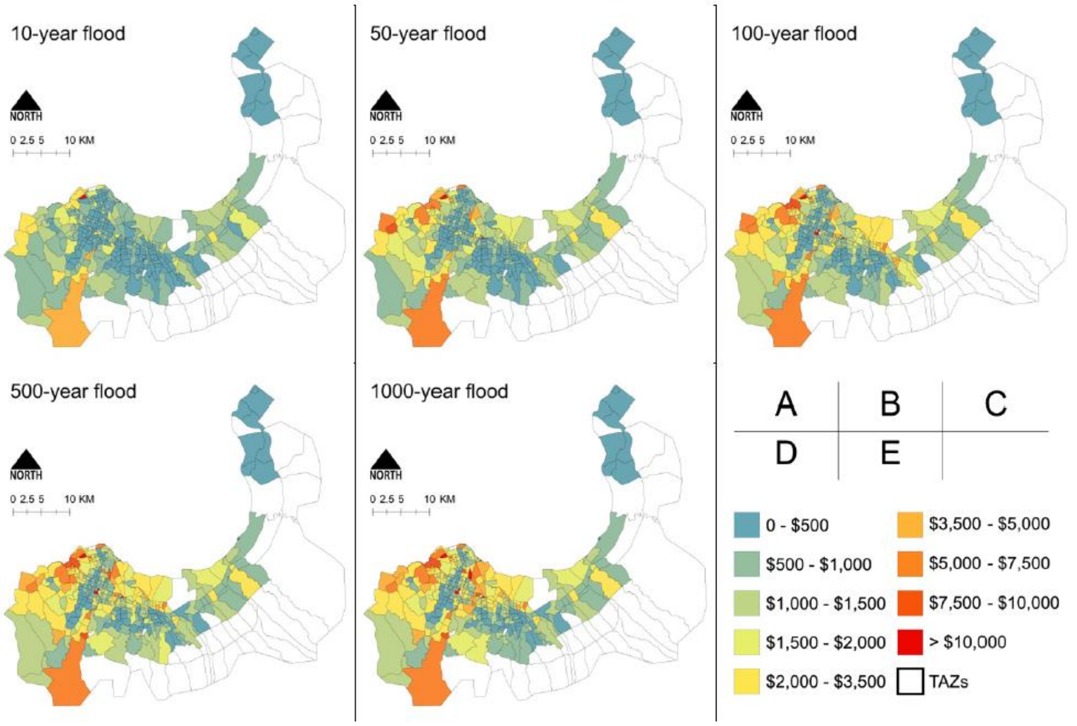


Figure 13: Daily total cost from flood-related commuting delays under five flooding scenarios

Travel time delay is one of the many elements of flood disruption on transportation that must be considered when determining disruption costs. Previous research has mostly focused on how to quantify the advantages of transportation investments, which accrue in the form of trip time reductions. If we estimate that the Kinshasa transportation network is disrupted by floods for 28 days on average, the yearly amount lost to floods is $32,648,000. It should be noted that these figures represent a conservative assessment of the costs of floods in Kinshasa because they only account time lost for commuting and not direct damages or any indirect expenses such as disrupted supply chains.

4.1.4. Conclusion

The integration of pluvial and fluvial floods with varying return periods has an impact on all modes of transportation in Kinshasa, DRC, resulting in reduced vehicle speeds, road closures, extended daily commute patterns, limited employment accessibility, and economic expenditures due to travel delays.

The study yielded a number of other findings and conclusions. First, job accessibility lowers when roads are rainy. The fraction of employment that can be accessed within an hour will decline by 0.1% on average for the walking network, 10.9% for the driving network, and 5.0% for the public transport network (He et al., 2020).

4.2. Adapting to Urban Flooding: Bharatpur

4.2.1. Overview

Bharatpur is located in Chitwan district, on the left bank of the Narayani River. in 2014, Bharatpur municipality was designated as a sub-metropolitan city (covering an area of 77.91 km2), and subsequently as a metropolitan city in 2016. (with a total area of 418.8 km2). The study area is in the municipality, which is the metropolitan city's core region.

Flooding in cities is more likely when unplanned urban growth and development disrupts the natural flow of water. The study looks into the drainage system's insufficient capacity and the unplanned discharge of solid waste, which increases the risk of waterlogging and flooding. According to the study, appropriate solid waste management along with enhanced drainage infrastructure and management could be used as adaptation measures to lessen the danger of urban flooding and waterlogging in a variety of climatic and non-climatic scenarios (Pervin et al., 2020).

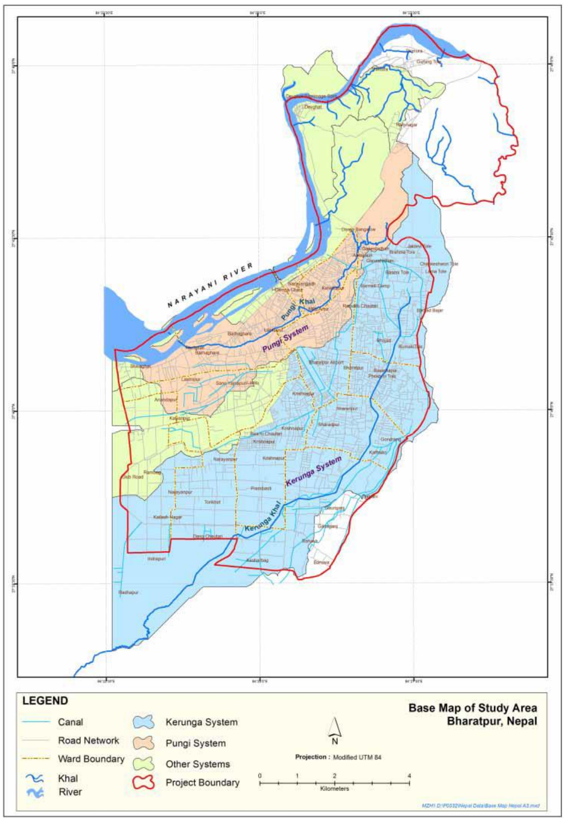


Figure 14: Study Area
Source: (Pervin et al., 2020)

4.2.2. Flooding & Drainage System

The Pungi canal and Kerunga canal are the two principal drainage canals that go through Bharatpur City. In study area, there is no backwater issue. Flooding happens even after moderate rainfall because runoff is unable to locate an adequate drainage pathway to reach the preexisting canals. In some areas of the city, the waterlogged condition lasts anywhere from a few hours to 1-2 days. When it stops raining, the runoff slowly travels along natural drainage systems until it reaches the canals.

4.2.3. Land Use Patterns

The majority of Bharatpur's land area is agricultural (52%) and forest (21%). The amount of land use change is quite significant, as the population growth rate is over 6% yearly, yet there is no defined plan for urban development in Bharatpur city, thus there is a risk of unpredictable urbanization.

4.2.4. Solid Waste Management

An approach based on public-private partnerships is used to manage solid waste. About 70-80% of the household pay the fee for waste collection & disposal whereas the remainder don't really pay the service price and dispose of waste in open areas and sewers. In addition, due to inconsistency in collecting waste by the authorized waste collector, households often leave their waste outside for collection, which is then collected by rag pickers, who dissipate the waste in search of recyclable and reusable materials, and the waste ultimately ended up in open spaces, on streets, and in sewage disposal.

4.2.5. Results

As water flows through canals by gravity, there is no backwater effect. The Pungi canal's drainage capacity is insufficient in some locations, contributing to floods in various localities. Since the drainage capacity of the Kerunga canal is sufficient to discharge the storm water that it receives, flooding does not occur in the Kerunga canal watershed.

Climate change would cause run-off during the monsoon season to increase in 2030 and even more in 2050, increasing inundation.

<u>Rehabilitation, expansion and re-sectioning of drainage channels</u>

To enhance the drainage situation from the reference case, rehabilitation/expansion/re-sectioning of the existing deficient canals, as well as the construction of certain new drains, were incorporated into the Pungi canal system.

<u>Solid Waste Dumping in the Drainage System</u>

The depth of the canals in the Pungi and Kerunga systems is predicted to decline by 10 cm per year. Thus, a proper solid waste management system is implemented.

4.2.6. Findings

The anticipated cost of repairing existing drainage channels and building three new drains in Bharatpur is USD 0.38 million, which will prevent floods on 94 acres of property in the Pungi canal watershed. More new drains are needed to avoid local floods as cities grow, which is not planned and is not considered in this work.

To be more precise, under the current scenario, flooding threatens 12.7% of Bharatpur's land area. Flood risk areas in Bharatpur can be reduced by as much as 5.5% with structural modifications paired with efficient solid waste management. However, if solid waste is not adequately managed, the area under flood risk in Bharatpur increases to 7.6% in five years, implying that structural improvements without properly integrating good solid waste management become essentially worthless in lowering flooding risk in these cities (Pervin et al., 2020).

4.3.The Sponge City, China

Faced with rising urban floods, Chinese cities are embracing nature and constructing "sponge cities" (Walsh, 2022). Rather than relying on "gray infrastructure" like levees, pipes, dams, and channels, sponge cities growing adoption to absorb and release water during seasons of severe rain and drought.

Sponge city is a development pattern that, with proper planning, construction, and administration, may store, infiltrate, and hold urban runoffAfter Professor Kongjian Yu proposed it in 2013, the'sponge city concept' has provided a chance for Chinese cities to pursue new integrated urban water management (IUWM) approaches (Daisy Gill, 2021).

As water becomes China's "most vital resource," sponge city initiatives strive to control and reduce flooding, water pollution, and water scarcity in metropolitan areas. These are new types of Chinese eco-cities that offer a comprehensive plan to presumably improve continuing growth and urbanization processes by explicitly considering the urban water cycle.

Objective: Reduce the environmental impact of urban development.

- By 2020, each city should have a sponge city covering 20% of its built-up area.
- By 2030, 80% of the built-up area in each city shall be created as a sponge city.

Sponge City might be used in cities around the world to battle flooding, absorption of carbon dioxide, boost animal and plant life, and increase green spaces.

Kongjian Yu, dean of Peking University's College of Architecture, initiated sponge city research and has spent more than 20 years advocating for its use in China. He considers that the existing method of creating large concrete barriers and covering all absorbent surfaces is doomed to fail and that towns should rather embrace nature-based flood prevention options.

4.3.1. Why Sponge Cities: Urban Comprehensive Water Problem

Since June 2021, 24 provinces in China have experienced severe floods, with over 443 rivers affected. Due to unprecedented urbanization and climate change, the country is experiencing severe flooding with 67% of China's population now living in flood-prone areas. To address this issue, the government devised the concept of sponge cities, which are locations meant to soak up as much additional water as possible, preventing it from flooding cities and conserving it for future use. The government has combined storage tunnels, rain gardens, wetlands, and bioswales to create these sponge cities.

Flood

Surface flooding flooded 154 cities (23%) in 2016. In 2012, surface flooding killed 79 people in Beijing.

Water Shortage

In China, 400 cities (60%) face the issue of water scarcity. 30-50m drop in groundwater level

Water Pollution

Water Pollution is one of the major growing problem in China.

The Low Impact Development in developing and developed cities has helped to reduce surface water runoff from 80% to less than 40% as compared to the Traditional Development.

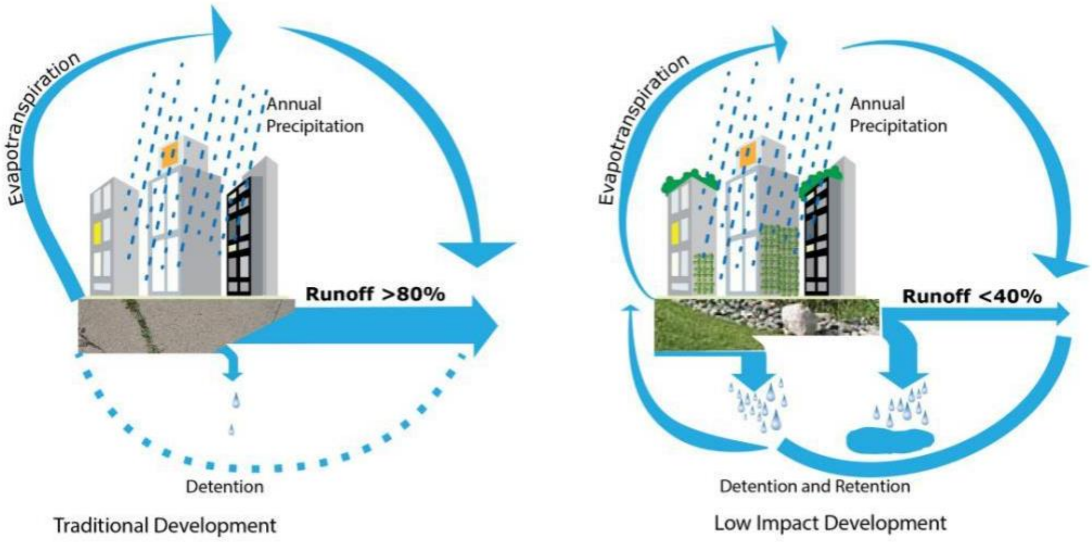
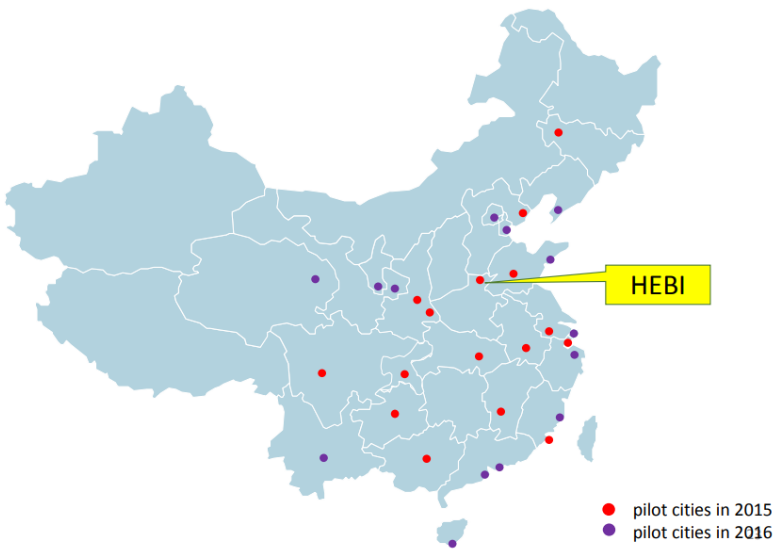


Figure 15: Comparison of Conventional Design & LID Design

4.3.2. Practices: How Sponge City?

Rather than fast-flowing water channels, sponge cities gradually decreases the water in meandering streams with no concrete walls and plenty of area to spread out during heavy rains (Walsh, 2022).



Pilot cities were selected in 2015 and another few cities added in 2016 for the implementation of Sponge cities.

Figure 16: Pilot Project for Sponge Cities in China

Stopping Floods

According to Yu, devoting 1% of land to water drainage will avert the majority of flooding. Yu claims that in the case of biblical, once-in-a-1000-year floods, devoting 6% of land to water drainage would be adequate to limit the damage (Walsh, 2022).

Cleaning Water

The permeable soils and natural rivers used in sponge city designs are good for cleaning water and lowering pollution. The evaporation of rainwater can chill the city. Theoretically, it could also be included into the water delivery system for uses like irrigation and street cleaning while lowering tap water usage.

Fight Climate Change

Catastrophic weather events increase in frequency as climate change gets worse. These increase the unpredictability of rainfall in cities and run the risk the current overwhelming systems.

Compared to gray infrastructure, sponge city infrastructure requires substantially less energy to maintain. Heat reduction effects lessen dependency on air conditioning, while it lessens the workload on water treatment plants. Less materials are needed for construction, notably less concrete. Large green spaces in sponge cities absorb carbon dioxide.

Advocates claim that if they were implemented globally, this might significantly impact climate change, lowering the risk of global flooding (Walsh, 2022).

Chapter Five: An Overview of Study Area

5. AN OVERVIEW OF STUDY AREA

5.1.Location

Banepa Municipality, a historical and religious place of Kavrepalanchowk district is in Province 3, Nepal. Geo-politically, the Nagarpalika is about 25 kilometers east from the capital city, Kathmandu. The Nagarpalika is surrounded by Mandandeupur Nagarpalika on the north, Panauti Nagarpalika on the south, Dhulikhel Nagarpalika on the east and Changunarayana, and Suryabinayak Municipalities of Bhaktapur district on the west.

The Municiplaity is extended from 85° 27' 45.972" east to 85° 33' 57.709" eastern longitudes and 27° 36' 1.868" north to 27° 41' 40.206" northern latitudes with having an area of 56 sq.km with 10291.93 m north-south length and 10314.58 m east-west width.

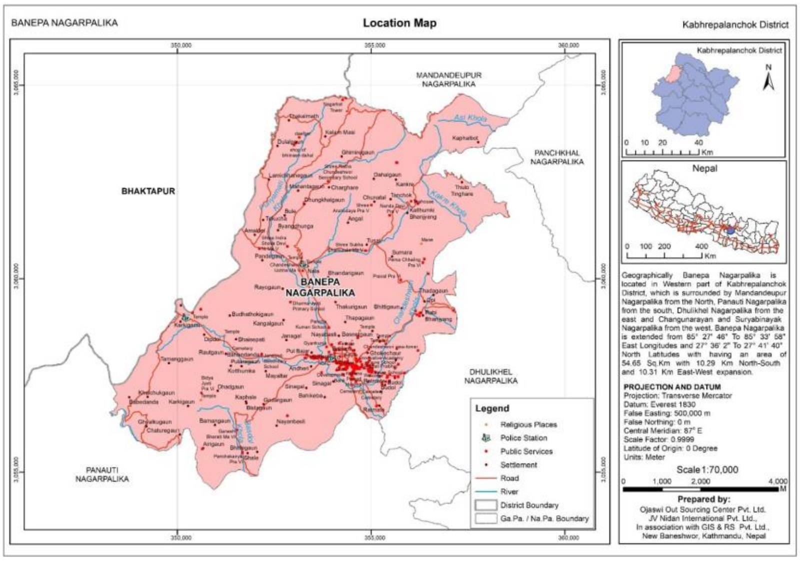


Figure 17: Location Map
Source: Municipality Profile

5.2.Settlement & Administrative Unit & Demography

The Municipality covers the area of 56 square kilometers forming 14 municipal wards. The wards vary in their land area and population.

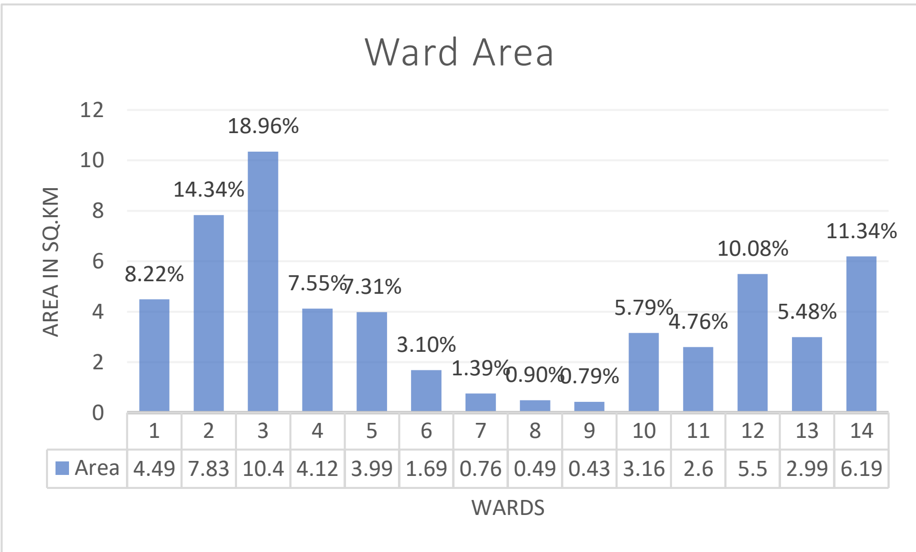


Chart 2: Banepa Municipality: Ward Area, CBS 2017

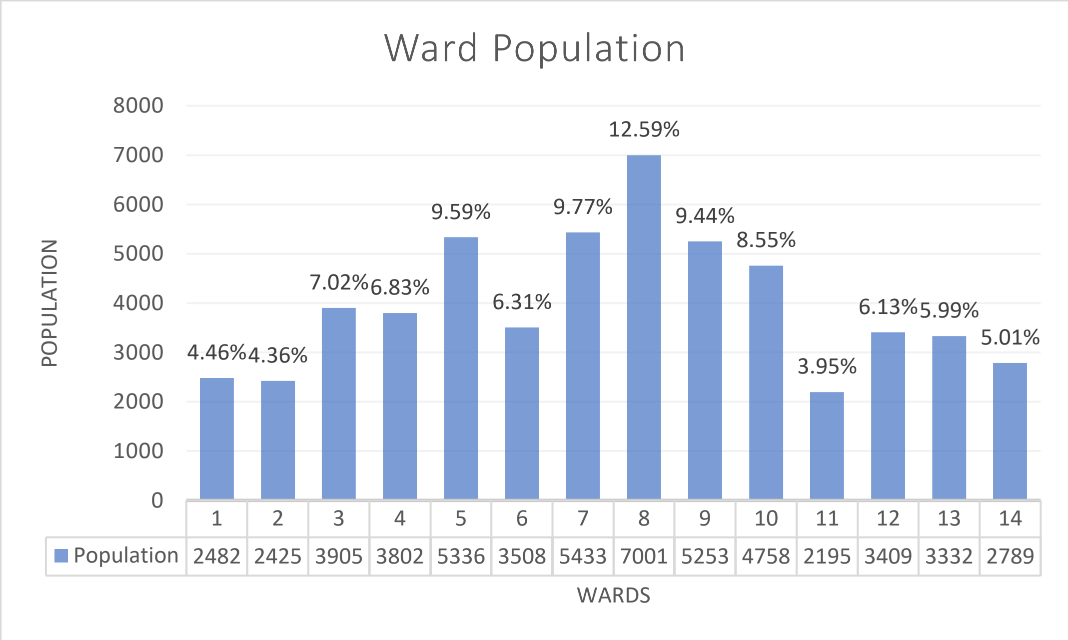


Chart 3: Banepa Municipality: Ward Population, CBS 2017

The study area lies in ward-10 with and area of 3.16 sq.km and total household number 1146 and with a total population of 4758. The population density of the study area is person 1505.69/sq.km.

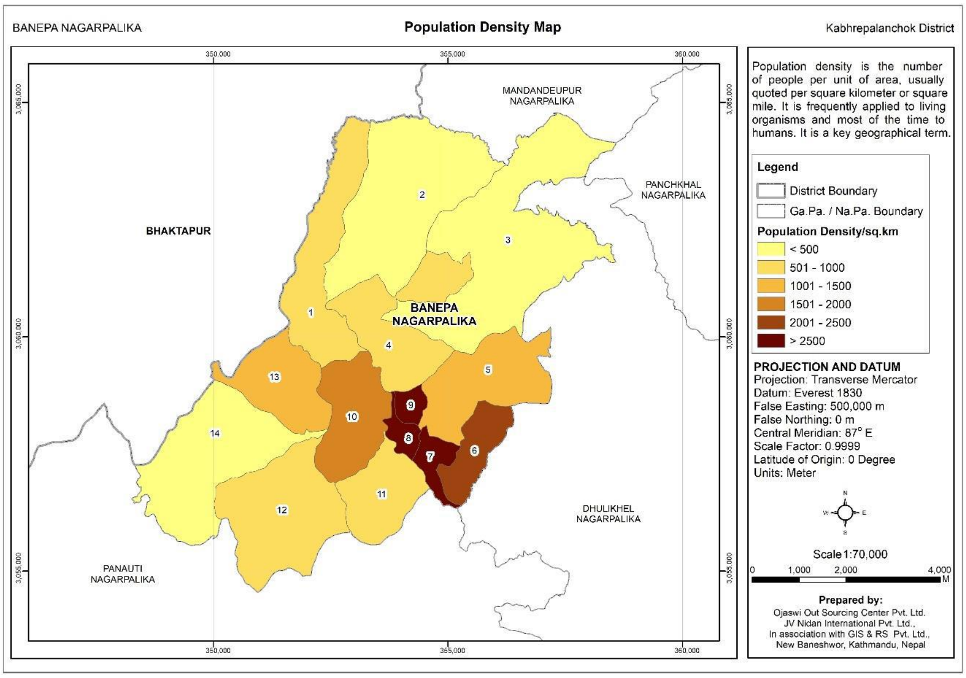


Figure 18: Banepa Municipality Map: Population Density Map
Source: Municiaplity Profile

5.3.Population Growth Trend in Banepa Municipality

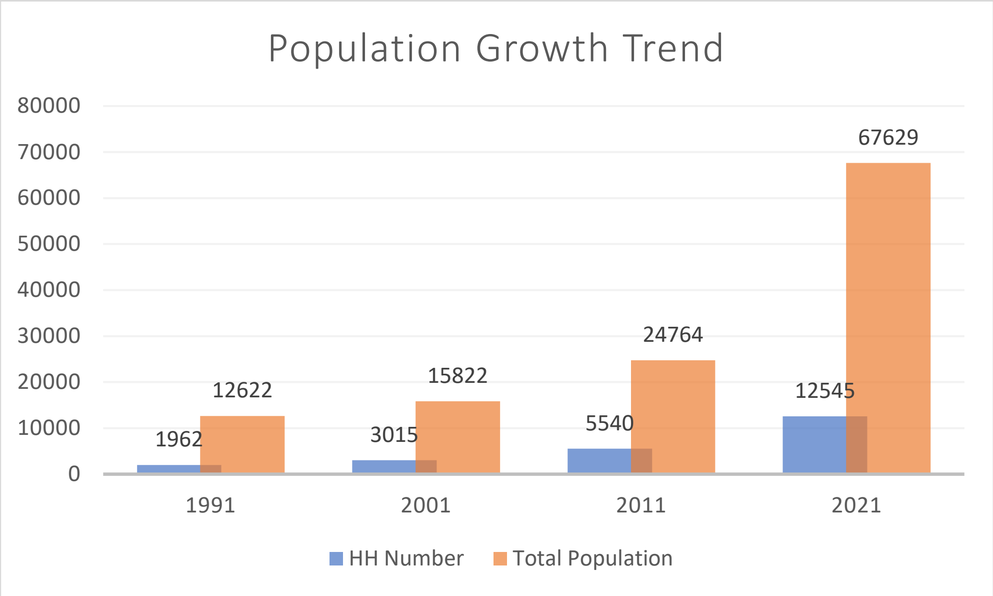


Chart 4: Banepa Municipality: Growth Trend, Source:CBS

The chart shows population growth trend in four decades; 1991, 2001, 2011 & 2021. Massive growth in population can be seen in the last decade from 2011-2021.

5.4.Climatic Condition

Banepa Nagarpalika falls in sub-tropical monsoon climatic region. The average temperature and rain fall determined the weather of the Nagarpalika in which summer is hot and wet and winter is cold and dry. The maximum temperature in the months of April, May, June, July and August is recoded around 25 degree Celsius and in the minimum temperature records at the month of December January less than 5 degree Celsius. The average annual rain fall of the Nagarpalika records 1190 Millimeter of ten years (2007-2016). Based on annual temperature range and amount of rainfall as well as weather condition, there are four seasons having their cyclical characteristic. The four seasons with their effective months are.

- Pre-monsoon: summer season (March-May).
- Monsoon: rainy season (June-September)
- Post Monsoon: Autumn (October-November)
- Winter: (December-February)

5.5.Present Land Use & Land Cover

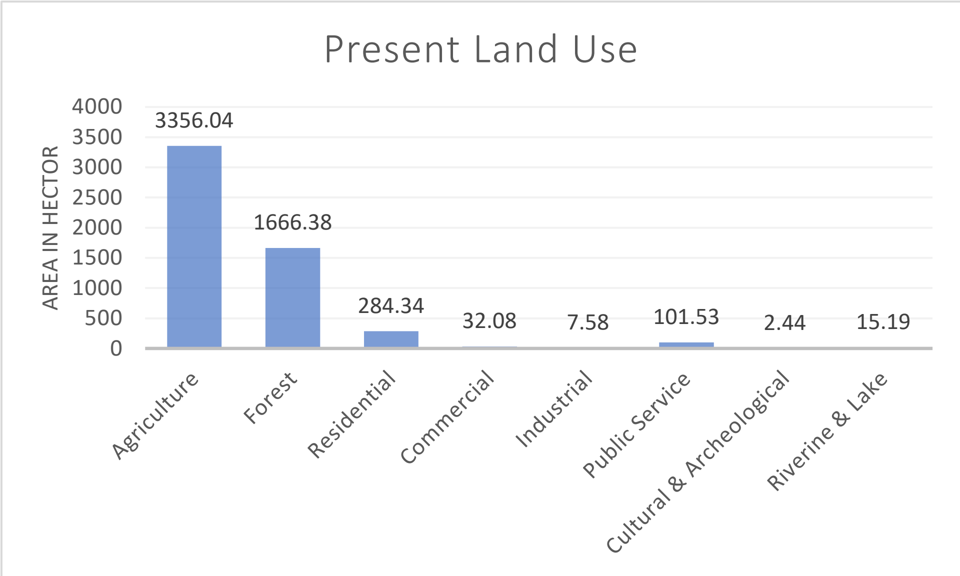


Chart 5: Banepa Municipality: Present Land Use
Source: Municipality Profile

The Municipality contains eight different land use types. According to the current land use table and numbers, agriculture covers the most land (55.93%), followed by forest (35.84%), and residential (5.29%). Likewise, public service area and Commercial Area covers 1.86% and 0.59% respectively.

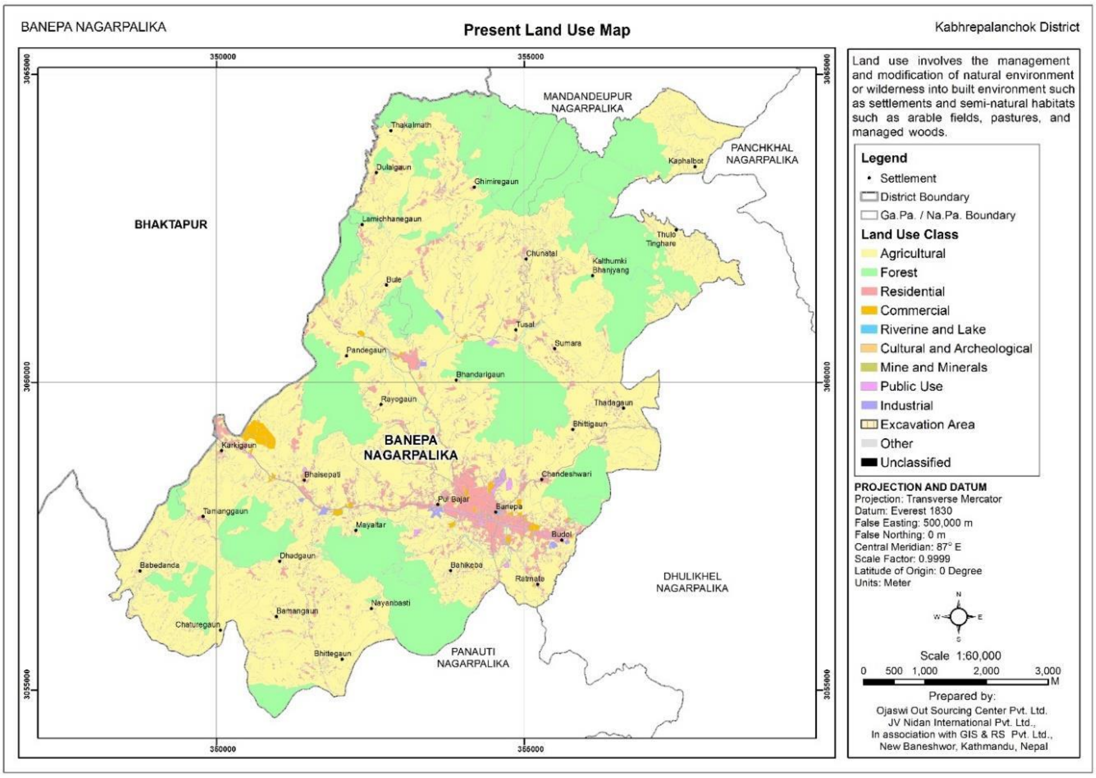


Figure 19: Banepa Munciipality: Present Land Use Map, Source: Municipality Profile

5.6.Drainage/Hydrology

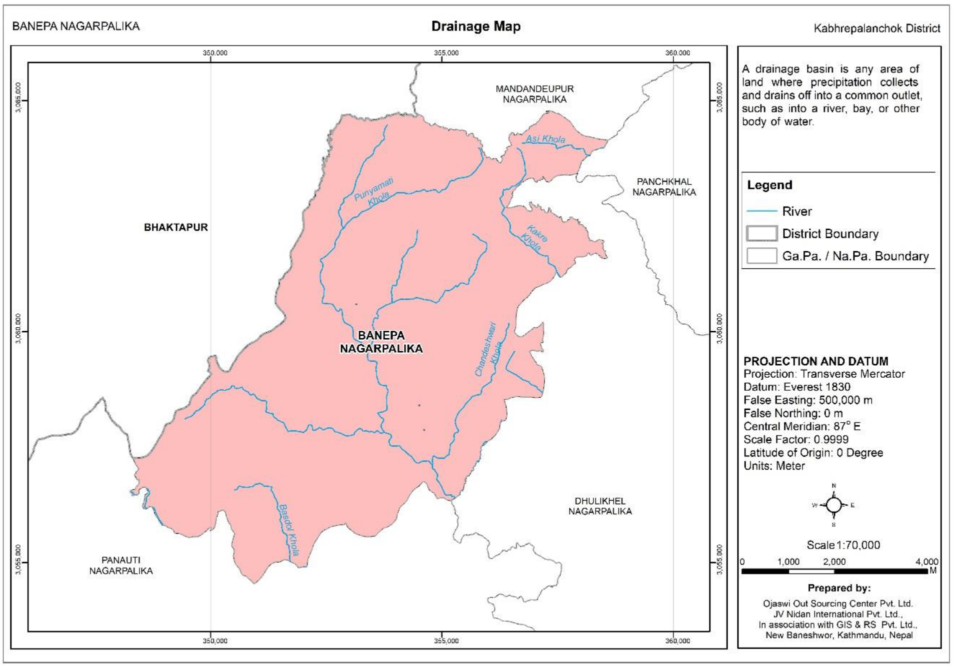


Figure 20: Banepa Municipality: Natural Drainage Map
Source: Municiplaity Profile

No any major rivers follow through Banepa Nagarpalika. But few streams - Basdol, Chandeshwori, Kakre, Asi and Punymati, run within the Nagarpalika. They remain shallow or dry in winter season. These streams are the sources of inundation in rainy season. Due to torrential rain, water from canals and other rivulets mixed into these streams.

5.7.Riverine & Lakes

Riverine and lake area covers 15.19 hectors (0.28%) of municipality total area. The river (68.21%) leads the Nagarpalika Riverine and Lake Area, followed by kulo (25.70%) and pond (4.47%) (*Banepa Municiplaity Profile*, n.d.).

Table 3: Riverine & Lake, (Banepa Municiplaity Profile, n.d.)

SN	Description	Area (ha)	Percentage
1	River	10.36	68.21
2	Kulo	3.90	25.70
3	Pond	0.68	4.47
4	Sand	0.15	1.01
5	Other	0.09	0.60
	Grand Total	**15.19**	**100.00**

5.8. Flood Risk

Flood events are common in monsoon season in Banepa Nagarpalika that attributed to its geographical conditions together with rainfall pattern in Nepal. Many seasonal streams flow along the river valley that are damaging arable lands and sometimes cause human casualties. Punyamata River is one of the prominent rivers in Banepa Nagarpalika which flows in long stretch and creates flooding problems in different sections along the river sides. Result showed that the Nagarpalika with area of 0.36% is high, 0.40% is medium and 99.24% low risk levels of flood (*Banepa Municiplaity Profile*, n.d.).

5.8. Municipal By-Laws, Programs & Policies

5.8.1. Basic Construction Criteria for Settlement Development, Urban Planning & Buiding Construction, 2072

Protected Areas (Area Ga) Special Rules

<u>River Protected sub-areas</u>

- Punyamata River- 15 m from each sides of the river
- Chandeswori River, Kadh River, Dhag River- 7 m from each sides of the road.
- River Setbacks would be directly turned into ROW in future.

5.8.2. Basic Construction Criteria for Settlement Development, Urban Planning & Buiding Construction, 2074

- Punyamata River- 15 m from each sides of the river
- River Setbacks would be directly turned into ROW in future.

5.8.3. Policy Budget and Program Decision Book, FY 2078/79,

<u>Vision- “Krishi, Byaapar, Paryatan ra Purawadhaar, Samriddha Banepa Nagarko Adhaar”</u>

5.8.3.1. Infrastructure Development

Road:

- The work of construction of Punymata Corridor has been started and important areas of Chandeswori, Chasi Khola have been identified, the work of construction of Corridor will be continued along with the green belt on the right and left sides of the corridor.

5.8.3.2. Forest, Environment & Disaster Management

Forest & Environment:

- A policy will be taken to conserve the ponds and parks within the city area. Also, the construction program of recharge pond will be kept at a suitable place.

Waste Management:

- The work of river improvement, garbage disposal will be continued.

Disaster Management:

- Necessary actions will be taken to prevent river erosion and flooding within the urban area.
- Plans will be made to control the rivers and streams which are extremely vulnerable from the point of view of disasters, using embankment and bio-engineering.
- Pre-disaster preparedness, rescue and restoration works will be carried out by establishing necessary task force.
- Strict rules will be implemented for building permit process to construct building risk-free.

5.9. Review of Flood Hazard Assessment

A study by Thapa, (2012) has chosen Punyamata River of length 4950.05m and Chandeshwori River of length 1065.86m for the flood hazard assessment. The elements at risk due to a flood hazard stand at high risk to destruction due to factors such as continuous population growth, absence of organized disaster reduction approaches and loopholes in the traditional coping mechanisms. Thus, the study aims to delineate flood plains of Punyamata and Chandeshwori river of Banepa Municipality to predict vulnerability scenario for chosen study area.

Flood inundation maps for the Chandeswori and Punyamata rivers were created using HEC-RAS and the HEC-GeoRAS extension for ArcGIS for return periods of 2, 10, and 500.

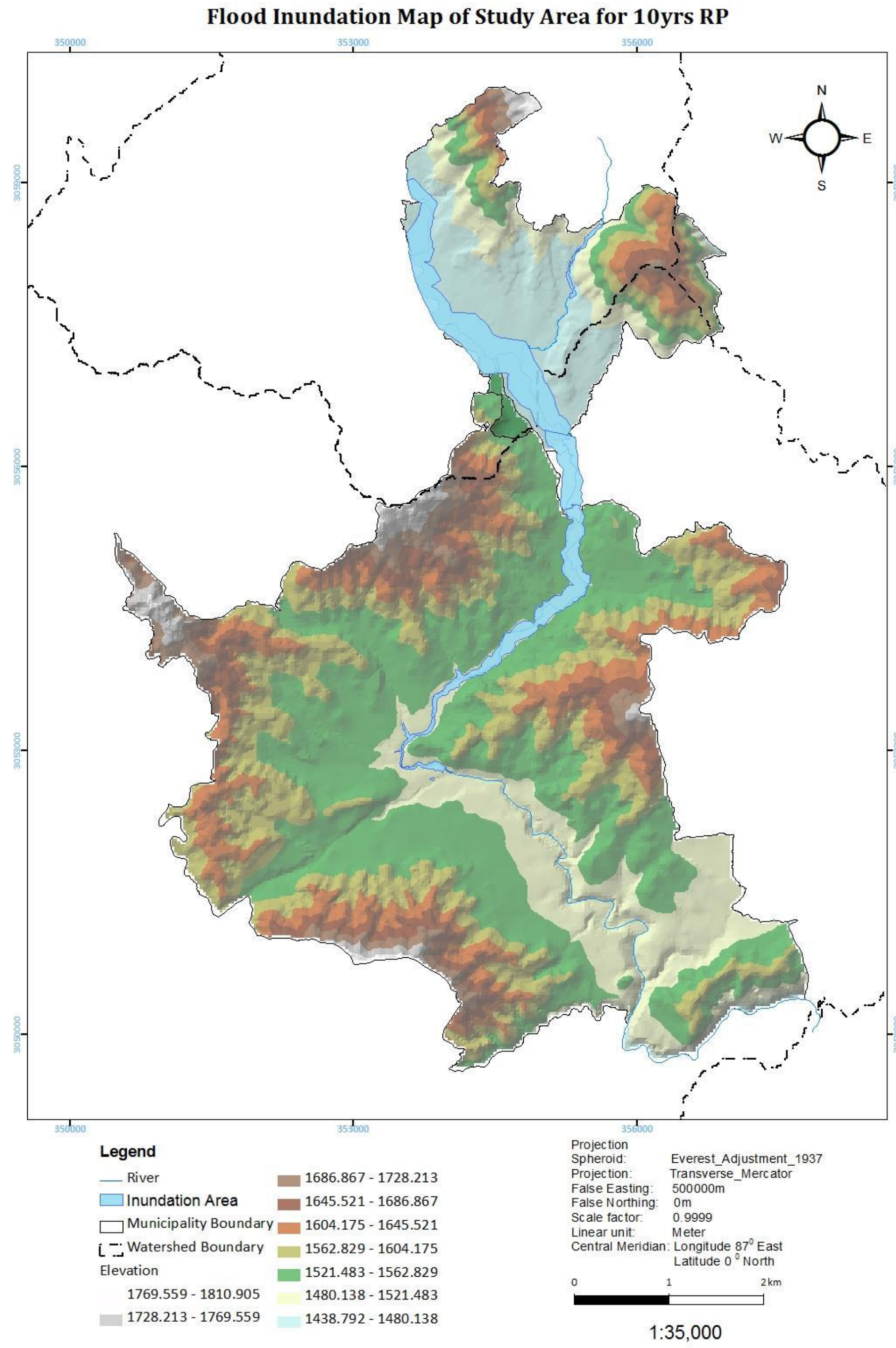


Figure 21: Flood Inundation Map of Study Area for 10yrs Return Period
Source: (Thapa, 2012)

Flood inundation maps for the 10-year return period (RP) show that 50.17 hectares of land in Banepa Municipality are in a substantial flooding region (Thapa et al., 2017).

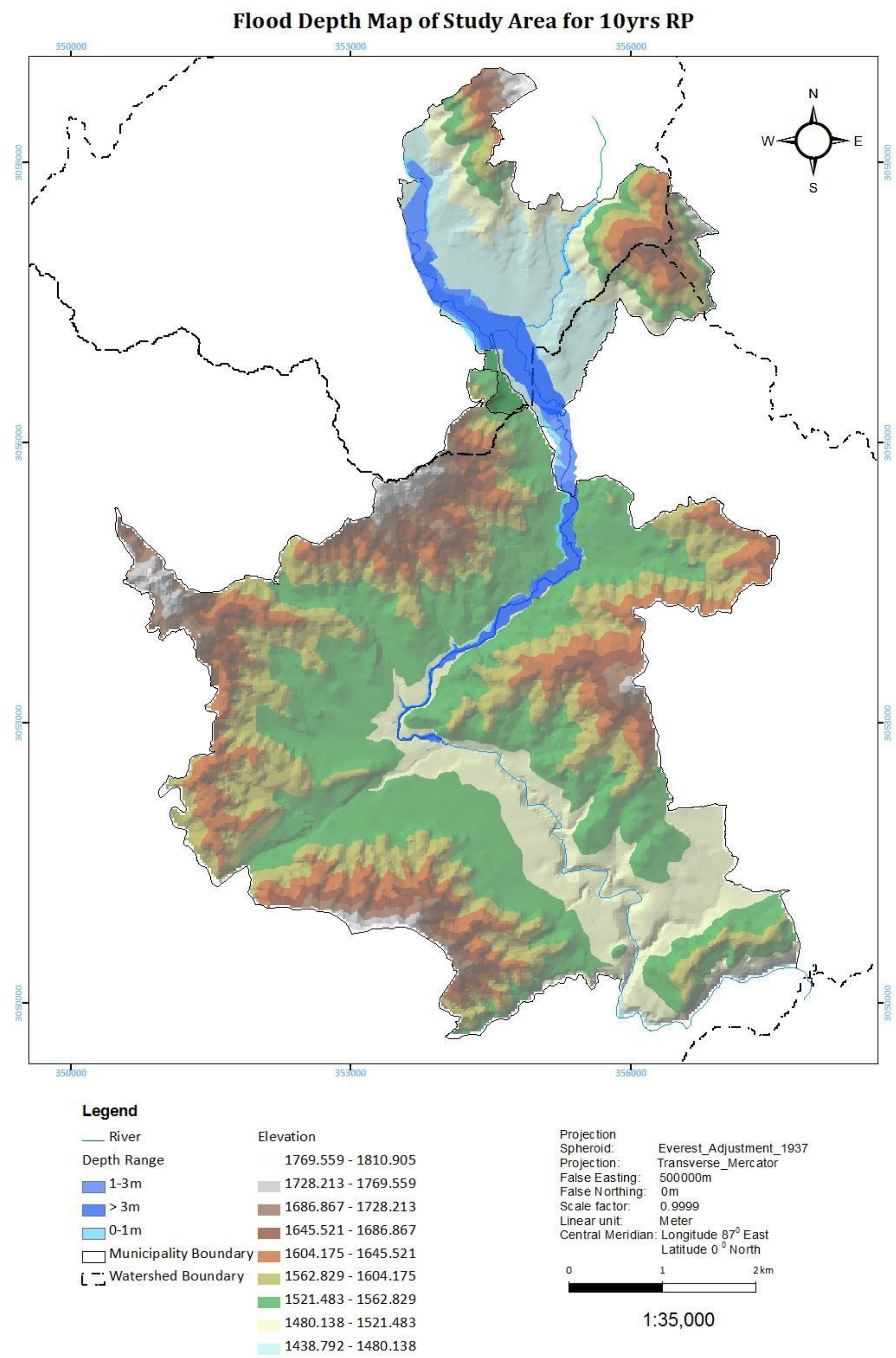


Figure 22: Flood Depth Map of Study Area for 10yrs Return Period
Source: (Thapa, 2012)

From the analysis it is found that the variation of flood water depth ranges from 0.00012207m to 8.44m.

The analysis from Punyamata river shows that in 2 years of RP, 21% of the land will be inundated under the depth of 1m whereas 58% of it will be under the depth of 1-3m and the remaining 21 % will be inundated by the depth greater than 3m. Likewise, in 10 years of RP, percentage of landuse under the influence of up to 1m will be 19 and same in between 1 and 3m will be 29 whereas 52% of the landuse will be influenced by depth greater than 3m. And, for 500 RP, mainly 9% of the land will be inundated by depth up to 1m followed by 91% of the landuse by the depth in between 1 and 3m. Similarly, the analysis of Chandeshwori River shows that 53% and 47% of landuse will be inundated under the depth of 1m and in between 1 and 3m respectively. For 10 years of RP, the percentage is 47 and 53 whereas; it is 39 and 61 respectively in case of 500 years.

Chapter Six: Field Observation & Data

6. FILED OBSERVATION & DATA

5.1.Catchment Area

Figure 23: Punyamata Catchment Area
Source: Webinar by Sanjay Manandhar

Punyamata River Catchment Area:

From Nagarkot on the northern side to Kashivanjhyang on East and Nala Tukucha on the eastern side, the catchment area with around 23sq.km and perimeter 20.9km. all the water from these area outlets from Pulbazar bridge. Even heavy rainfall in Nagarkot basin might affect in Banepa Municipality.

"Flooding in Banepa is not only associated to rainfall in Banepa but heavy rainfall in Nala, Bhaktapur and Nagarkot area will have adverse effect on the area, since water from all those areas finally discharges through Punyamata River. And during massive flow, the river can't bear such volume which causes flooding in the Punyamata river"

-KII, Nabin Thapa, Banepa Residency

5.2.Present Condition of the Bridge

The bridge is 13 meter in length and depth is 3 meters at present. Encroachment towards the river has decreased the natural waterway of river. There is also lack of proper solid waste management. Sediment deposition as well as wastes generated from the households accumulates on the river sides further narrowing the actual riverway and that has led to the decrease of river bed level.

Figure 25: Present Condition of Pulbazar Bridge

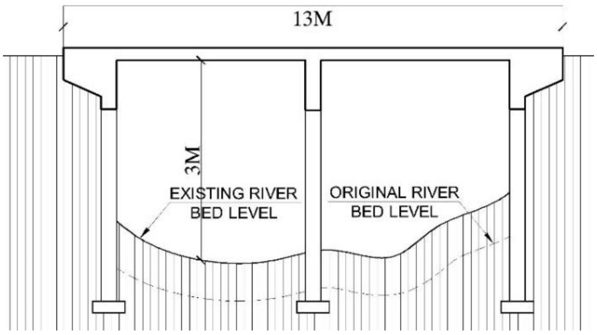


Figure 24: Tentative Cross Section of Bridge

During excessive rainfall and high flood level, the river hasn't crossed the bridge level yet but the water inundation in the study area rises to a maximum depth of 3 feet halting the accessibility.

<u>Runoff Volume Capacity of Bridge</u>

Bridge Span = 13M
River depth = 3M &
Average velocity of river water in plain = 0.8 m/s

- Average water flow from Punyamata Bridge = (13X3X0.8 = **31.2 Cubic meter/sec)**

<u>Peak Runoff Volume</u>

Catchment area (A) = 23Sq.Km
Runoff Coefficient (C) = 0.5
Maximum Rainfall Intensity (I) = 125mm (Nagarkot Station, 2012) Source:DHM

- Peak Runoff Volume (Q) = **399.30 Cubic meter/sec**

(Using the formula Q=CIA)

The above calculation shows that the peak runoff volume is $400m^3/s$ while the capacity of the bridge is only $31.2m^3/s$. This shows the inefficiency of bridge to discharge the water generated from its catchment area. Thus, during excessive rainfall, flood occurs causing inundation in the low-lying areas.

5.3.Causes of Flood / Inundation in the Study Area

5.3.1. Depletion of Rajkulo

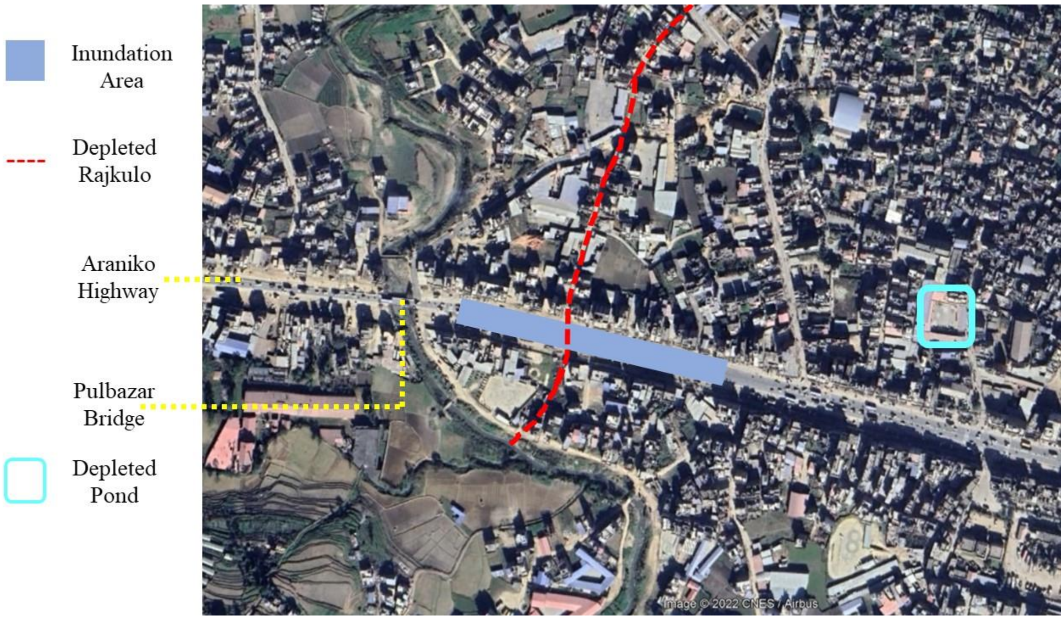


Figure 26: Inundation in the Study Area

"Back then, the river used to be wide and clean we could even swim. Since the past 20 years I have witnessed flood and inundation in Banepa. There used to be a natural Rajkulo to east side of the river, where inundation happens at present. Water from north side of the area used to accumulate and then drains out from Rajkulo. Also, after the construction of driving center, which is raised 2 feet above the road level stormwater drainage has been obstructed and waterlogs in study area causing inundation which lasts from 1-2 hours to 4-5hours causing traffic disruption."

-KII (Rajaram Palanchoke, 63 Years, Permanent residence of Banepa)

Working of Rajkulo:

Rajkulo or Royal Canal is a type of canal found in Nepal that provides water for irrigation, stone spouts and ponds and dates back to Lichhchavi Period. Back then, the royal engineers diverted water from sources on the northern part towards their settlements. There isn't much information on how long it took to build, or even who built it—just the names of kings who not only took credit for it, but also bathed in the water that gushed out the other end (Aryal, 2005).
The Raj Kulos were more than just waterways. They combined water supply with irrigation, demonstrating the delicate urban-rural balance. Along the way, the Raj Kulo watered rice fields, filled ponds and wells, provided a continuous flow of clean water to cities, and helped regulate ground water levels by recharging aquifers. Also, it used to be a way out for water discharge during excessive rainfall and flooding scenario.

The Rajkulo is more important than ever today. It is more than just a solution to the issue of water scarcity. It will not only bring in water, restore old ponds, and get water flowing out of the hitis if it returns to the cities, but it will also maintain a great aspect of our history and legacy (Bisht, 2011).

Figure 27: Water Source to Settlement in Banepa

In Banepa, Since Kirati and Lichchavi period, water supply from Dhungedhara has been in practice. temple of Ganesha, It is said that a dam was built and water was brought to these stone streams from Ganesh temple source. So, from these reservoirs Banepalihave been drinking water from stone streams for 50-60 years.

5.3.2. Highway Engineering, Depression area/ Curve Setting

The inundation section in the study area is little sunken from both the sides, which is about 1-1.5m below the high flood level. High flood level during maximum precipitation reaches the bridge level but has not crossed above the bridge level.

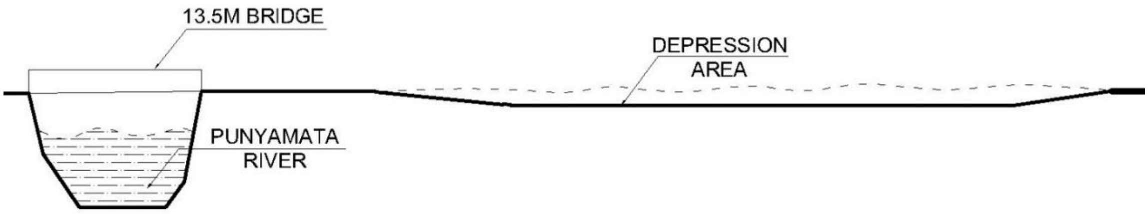


Figure 28: Tentative Road Section of the Stud Area

Due to the depletion of the Rajkulo and overwhelming water in river during flooding, water accumulates in the given section of the road. The water from inundation gradually decreases when volume of water in the river decreases usually after few hours.

5.3.3. Land Use & Land Cover Change (LULC)

Land cover refers to the physical form of land, such as forest or open water, but land use describes how people use the land. Land cover data indicates how much of a region is covered by forests, marshes, impermeable surfaces, crops, and other types of land and water. There are two sorts of water: wetlands and open water. Land use refers to how people use the land, whether for development, conservation, or a combination of the two.

Satellite and aerial photography can be used to determine land cover. Satellite photography cannot be used to assess land use. Land cover maps provide information to managers to assist them better comprehend the current terrain. Land cover maps from numerous years are required to see change over time (National Ocean Service, 2021).

Nepal is one of the South Asian countries that is rapidly urbanizing. Large and medium cities, including metropolitan, sub-metropolitan, and municipal areas, account for most of the urbanization.

Banepa municipality is regarded as one of Nepal's fastest expanding urban municipalities due to its commercial hub, accessibility of highways and urban roads, tourist appeal to religious and historical places, healthcare services, educational facilities, and so on (Twayana et al., 2020).

Table 4: Land Cover Data

	1992		2002		2012		2020	
Land Cover	Area	%	Area	%	Area	%	Area	%
Forest	41.88	38.36	40.68	37.27	37.13	34.02	33.61	30.79
Agriculture	60.89	55.79	59.01	54.06	56.72	51.96	52.77	48.34
Built-up	5.19	4.76	7.12	6.53	11.52	10.55	17.59	16.11
Barren	1.17	1.08	1.68	1.54	3.76	3.45	5.17	4.74

(R. Shrestha et al., 2021) from their study in Banepa & Dhulikel Municipality over the time frame of 38 years (1992-2020), 1992, 2002, 2012 and 2022 observes that forest and agricultural land were decreased by 8.27 sq. km (7.57%) and 8.12 sq. km (7.44 %) respectively, whereas built-up and barren areas were increased by 12.39 sq. km (11.3 6%) and 3.99 sq. km (3.66 %) respectively.

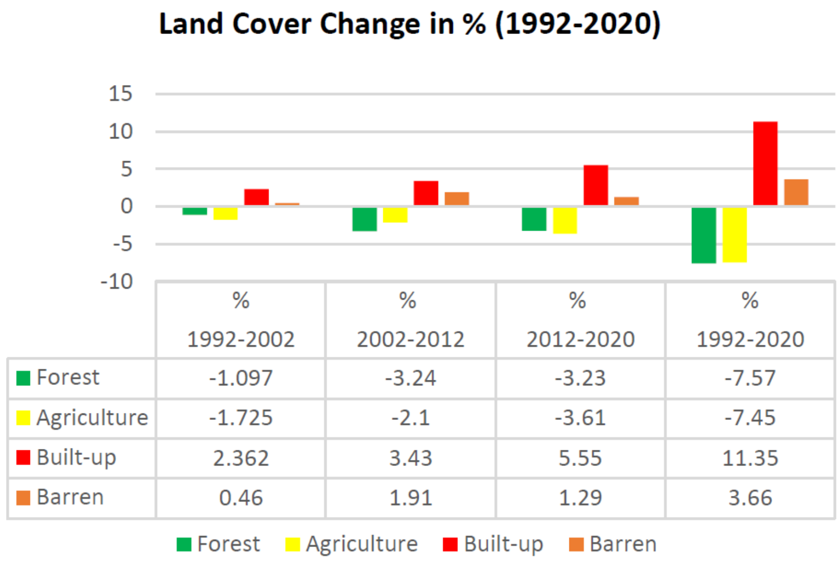


Figure 29: Land Cover change in percentage
Source: (R. Shrestha et al., 2021)

5.3.3.1.Factors causing Built-Up expansion in the Municipality

The major built-up expansion since 1992-2020 in Banepa core city is due to the Internal migration of the people from rural areas such as; Dholalghat, Ramechap, Bethanchowk etc for the accessibility of the services and livelihood facilities(Twayana et al., 2020). Moreover, newari communities had also pulled into the commercial trade since the 90's which ultimately rise urban growth of the city since 90s to 2020. Similarly, real estate business had also altered the LULC of the banepa since 2000 because people were exploiting their arable land for housing development which has created the rapid urbanization in banepa until 2020. Besides all these growing population had also altered the LULC of banepa by expanding the builtup areas simultaneously(Twayana et al., 2020).

5.3.3.2.Future Land Use Land Cover Scenario

A study by (Sijan Bhandari, Rabina Twayana, 2021) predicts that agriculture and forest land are expected to decrease by 2.56 % and 2.62 % respectively in 2032 from 2020. Similarly, the barren land will be decreased by 0.57 % whereas the built-up will be increased by 5.73 % by 2032 since 2020.

If this trend continues of increase then, more agricultural land would be converted to Built-Up areas, causing increased urbanization which will add pavements and other impermeable surfaces. These surfaces have low water retaining capacity, hence cities are more likely to inundate with the present condition and capacity of drainage system that is available now.

5.3.4. Urbanization

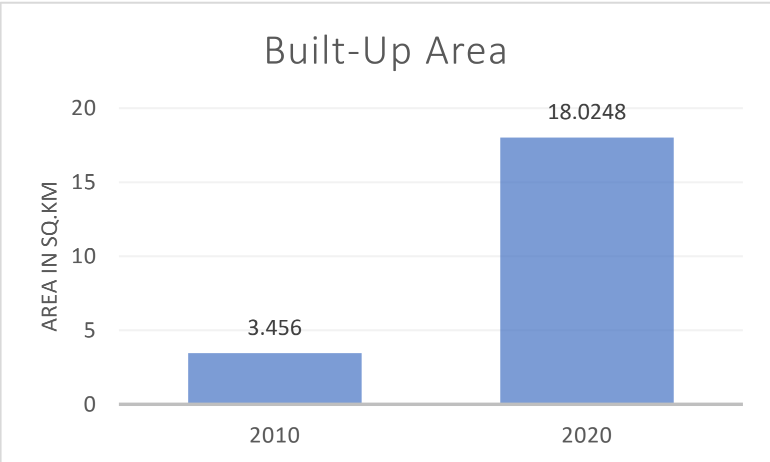


Chart 6: Banepa Municipality: Built Up Area Change

Urbanization has led to the increment of concrete surfaces in the city which are impervious. Impervious surface has very low water infiltration capacity. As a result of which surface runoff increases and water remains on the surface.

The chart above shows the increment of built up area in the last 10 years. Built up area has increased by 421% since the last decade in the municipality. More built up area means more impervious surface added on land. This in turn increases surface runoff in the urban areas. And with no proper drainage system, a city tends to inundate.

Figure 30: Banepa Municipality: Satellite Image 2001

Figure 31: Banepa Municipality: Satellite Image 2001

Figure 32: Aerial View of Banepa from Airplane, 1974 A.D.
Source: Peter Von Mertens (While returning to Kathmandu from Lukla)

5.3.5. Climate Change

Besides the land cover change factor, climatic factor also plays an important role in Urban flooding in the developing regions.

Climate change has resulted in the heavy precipitation/ heavy rainfall globally. Although floods are not always caused by heavy rainfall, but their likelihood does increase. In areas where urban flooding is on the rise, even moderate amounts of rainfall can result in significant damage.

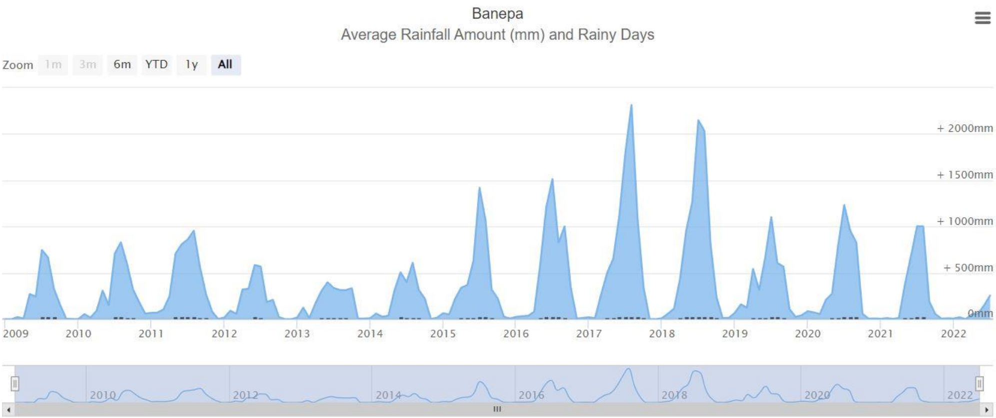


Figure 33: Annual Average rainfall in Banepa

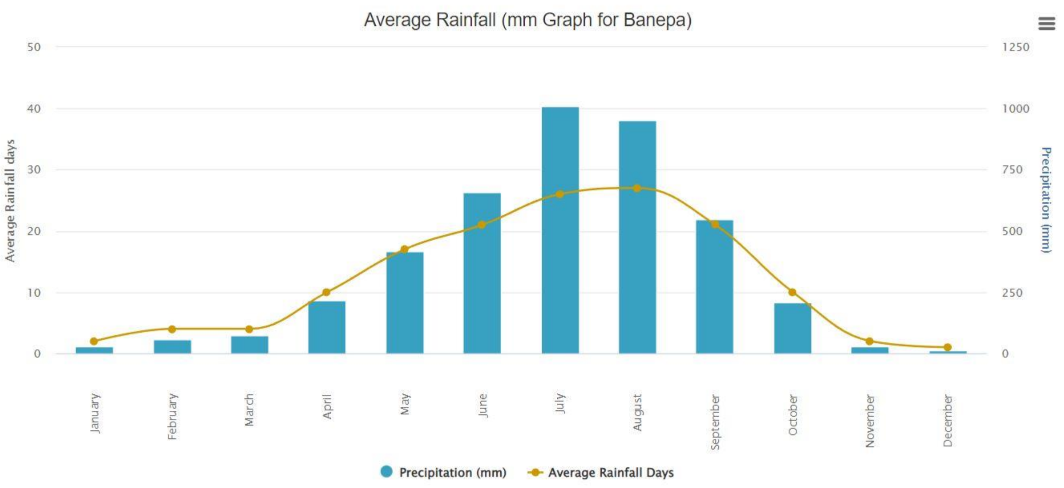


Figure 34: Monthly Average rainfall in Banepa

5.3.6. Improper Drainage System

The existing drainage is insufficient to cater present water flow. Stream which use to be there in the past has been diverted using culvert pipes. In worst case, when water level rises in the river, the river water backflows to the study area worsening the situation.

5.3.7. River Encroachment

Rapid Urbanization has led to increase in the built-up areas. In search of area with low land value people tend to settle nearby the floodplain area not knowing the consequence of its hazard. Moreover, land poling projects are also happening near the flood plain area.

The Corridor project in Punayamata river also has somehow encroached the river by constructing walls & roads on the sides.

5.3.8. Waste / Sediment / Debris Deposition

Solid waste from households, debris accumulation from plotting in the upstream areas, sand deposition from surface drains eventually adds extra layers to the river network which narrows the stream section and rises stream bed level. The process continues and flow capacity of river decreases, which means the volume of water which river could discharge is decreased.

5.4.Traffic Volume Survey

A traffic volume survey was carried out for three consecutive days including two week days and one weekend. Traffic volume survey was performed during the peak hour from 8:30 am – 9:30 am. Vehicles were categorized into 7 categories namely; Motorbike/Scooter, Bus, Car, Service Vehicle (jeep, tractor), Truck, Tata Sumo/Hiace and Ambulance.

Two-way traffic data was collected separately, later added together to find the average total traffic volume during the peak hour. Later 7 categories were grouped to 4 categories viz.

a. Two-wheeler: (Motorbike/Scooter)
b. Four-Wheeler Small: (Car + Tata sumo + Ambulance)
c. Four-Wheeler Small: (Service Jeep + Tractors)
d. Four-Wheeler Big: (Bus + Truck)

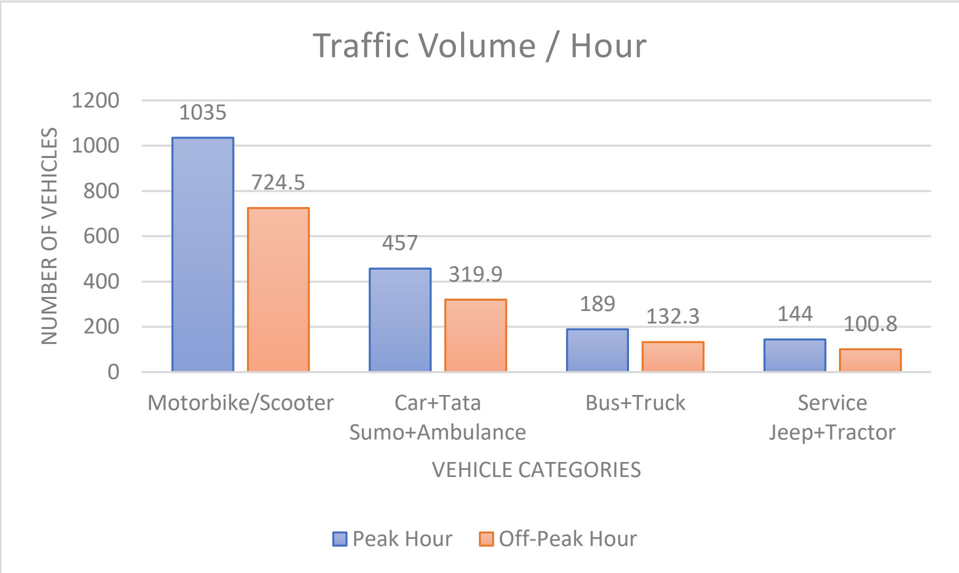


Chart 7: Traffic Volume / hour

(Note: Traffic volume off-peak hour was calculated considering the peak hour factor as 0.7)

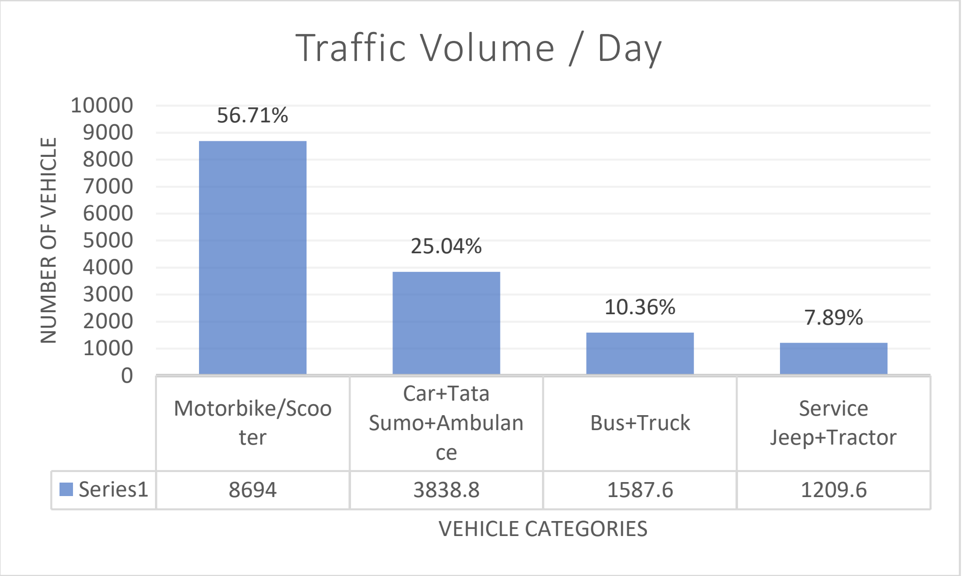


Chart 8: Traffic Volume / Day

(Note: Considering the HEF (hourly expansion factor) as 12 traffic volume per day was calculated)

Daily Traffic Volume gives the idea of the total flow of different categories of vehicle in a day. In the study area, Araniko Highway, Pulbazar Section road, Motorbikes are with the heaviest flow of 56.71 % followed by Cars 25.04% and the least is Bus with 7.89%.

From the Daily traffic flow, total person travelling is calculated applying the following factors:

- Motorbike/Scooter- 1.2 persons
- Car + Tata Sumo + Ambulance: 2 persons
- Bus + Truck: 30 persons

The factors give total person travelling in a day, from which total sample size is calculated. And applying Confidence level 95% and Confidence Interval 10, sample size for stratified random sampling size is calculated.

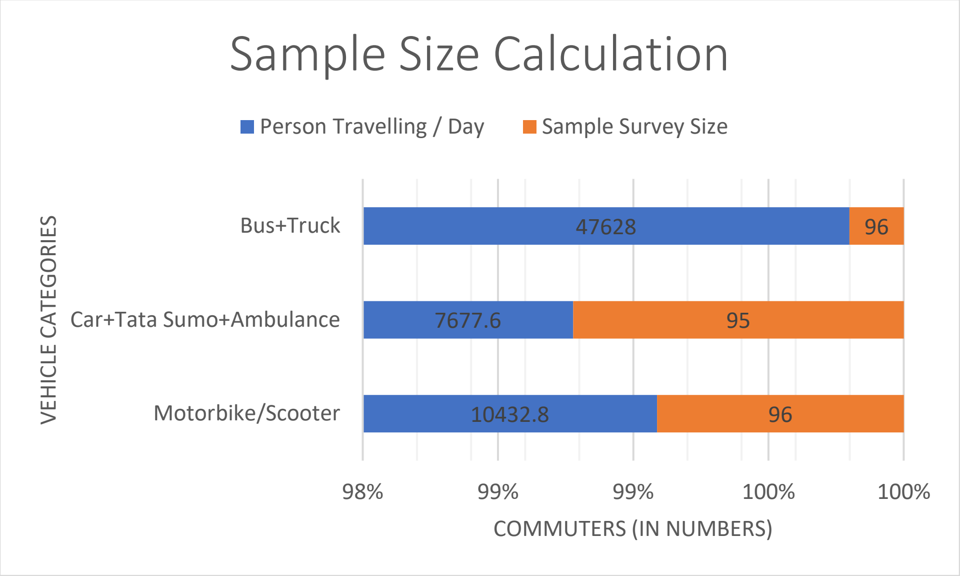


Chart 9: Sample Size Calculation

From the sample size calculation, a total of 287 Daily Commuter Survey needs to be carried out. Out of which, 96 commuters travelling via Motorbike, 95 commuters travelling via car and 96 commuters travelling via bus needs to be carried out for the stratified random sampling.

Daily commuter survey was then carried out for a total of 243 Daily Commuter. Out of which, 53 commuters travelling via Motorbike, 29 commuters travelling via car and 160 commuters travelling via bus was carried out through stratified random sampling method.

Chapter Seven: Data Analysis & Findings

7. DATA ANALYSIS & FINDINGS

7.1.Daily Commuter Survey

Daily commuter survey was carried out for a total of **243 Daily Commuter**. Out of which, 53 commuters travelling via Motorbike, 29 commuters travelling via car and 160 commuters travelling via bus was carried out through stratified random sampling method. The results obtained are discussed below in the form of charts and graphs.

7.1.1. Sex Composition

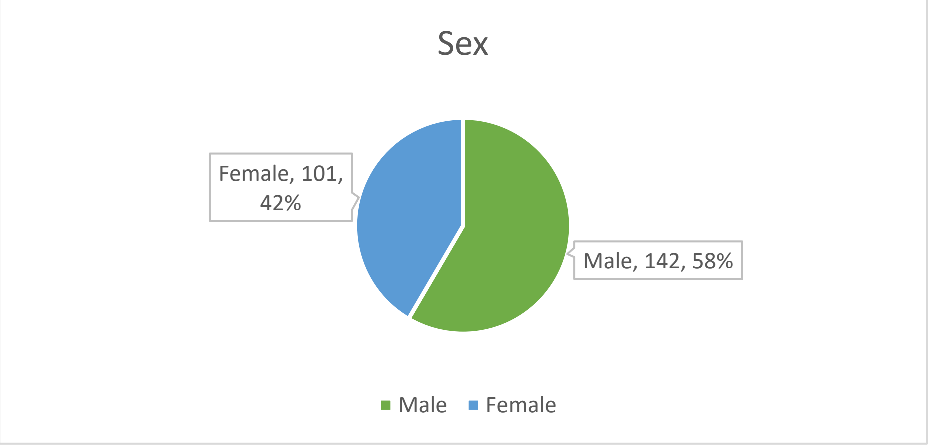


Chart 10: Sex Composition

A total of 243 Daily Commuters were surveyed, out of which, 101 were female respondents and 142 were male respondents.

7.1.2. Age Group

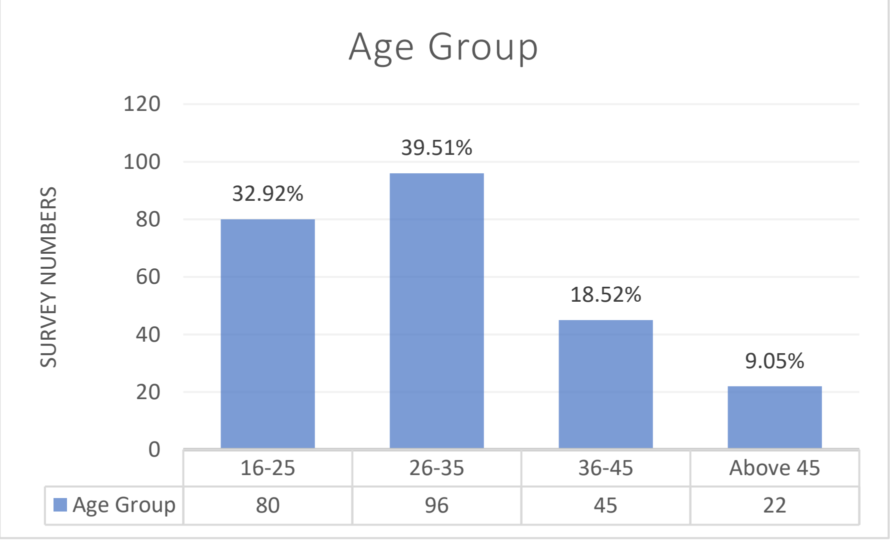


Chart 11: Age Group

Out of the surveyed commuters, age grouped 26-35 were of the majority with 39.51 % and the least age group was above 45 years with only 9.05%.

7.1.3. Commuting Time

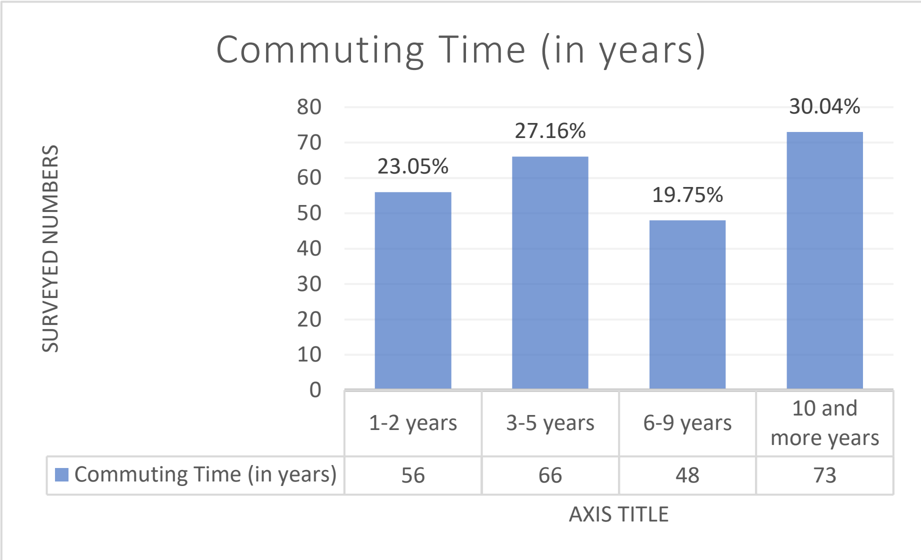


Chart 12: Commuting Time (in years)

The stratified random sampling survey shows that maximum of the respondent is commuting this route for more than 10 years.

7.1.4. Purpose of Commute

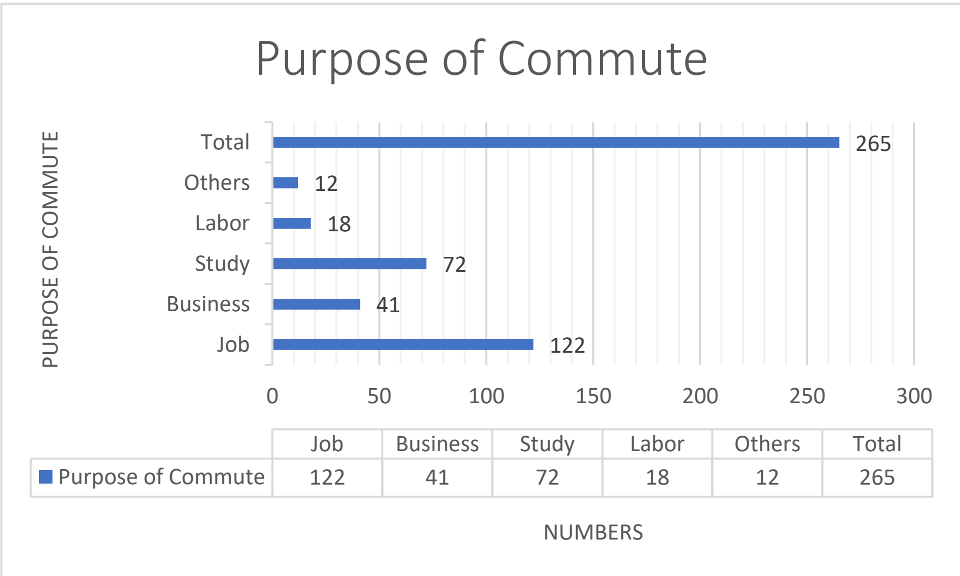


Chart 13: Purpose of Commute (in total)

The survey shows that majority of the commuter travels for job and employment purpose. And commuter travels for more than one purpose also.

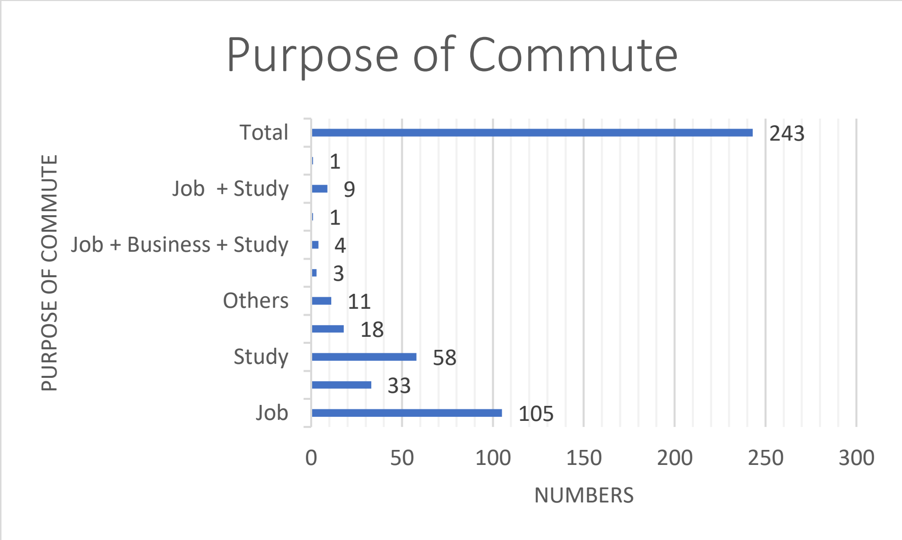


Chart 14: Purpose of Commute (Individual)

The chart 8 shows multiple commuting purpose of respondents.

7.1.5. Mode of Transport

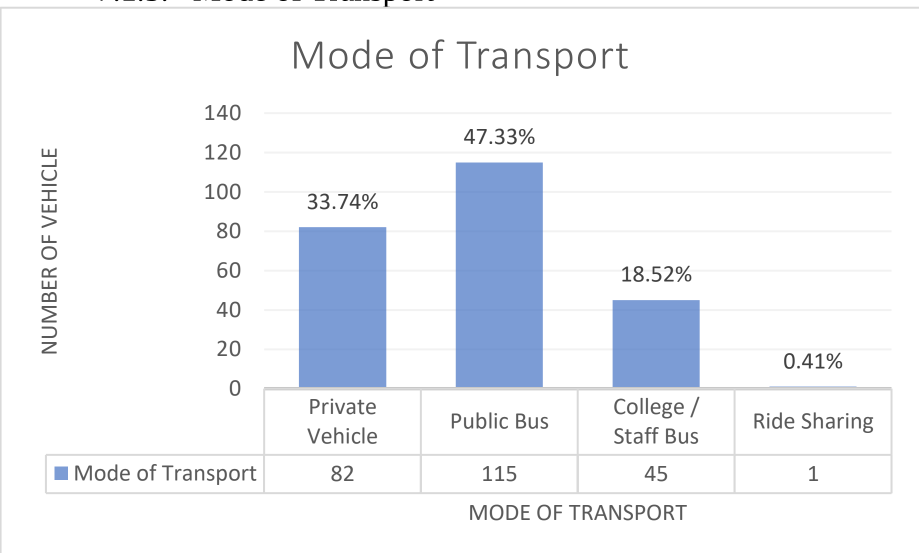


Chart 15: Mode of Transport

Chart 9 shows mode of transport with maximum Public Vehicle users which is 47.33% followed by Private vehicle user which is 33.74%. A respondent with Ride Sharing means of transport was also found from the survey.

Out of 82 private vehicle commuters, from Chart 10, 53 commutes daily via motorbike/scooter and 29 commutes daily via Car.

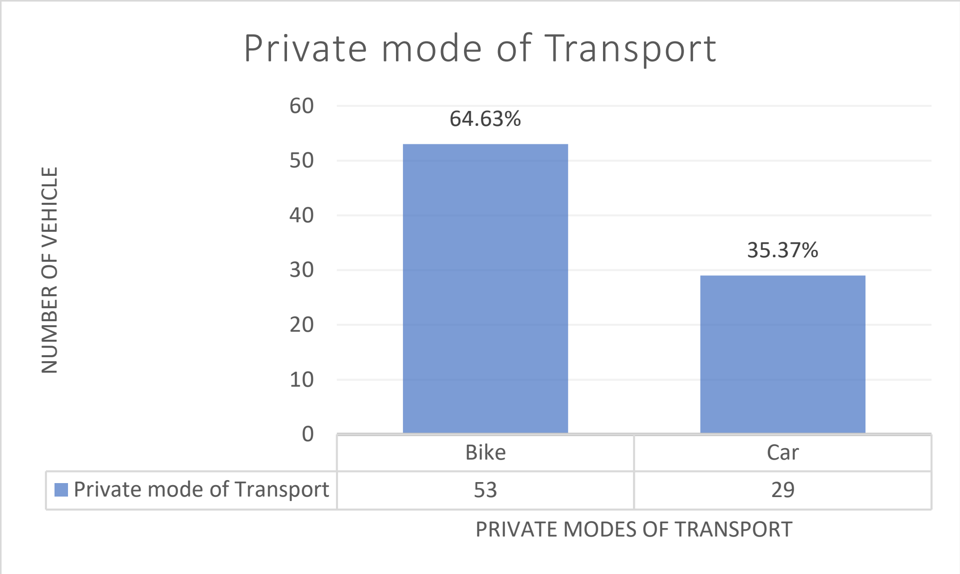


Chart 16: Private mode of Transport

7.1.6. Commute Duration

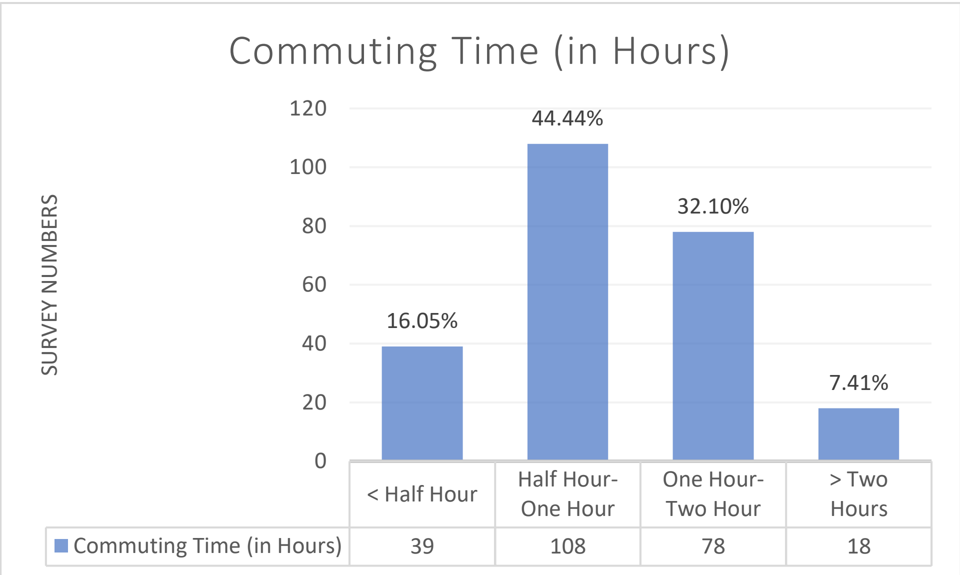


Chart 17: Commuting Duration

Chart 11 shows that 44.44% of daily commuters travel duration is between half hour to one hour, followed by 32.10% of commuters travel duration between one hour to two hour and the least 7.41% of commuters travel duration greater than two hours.

7.1.7. Commute Disturbance due to Flood

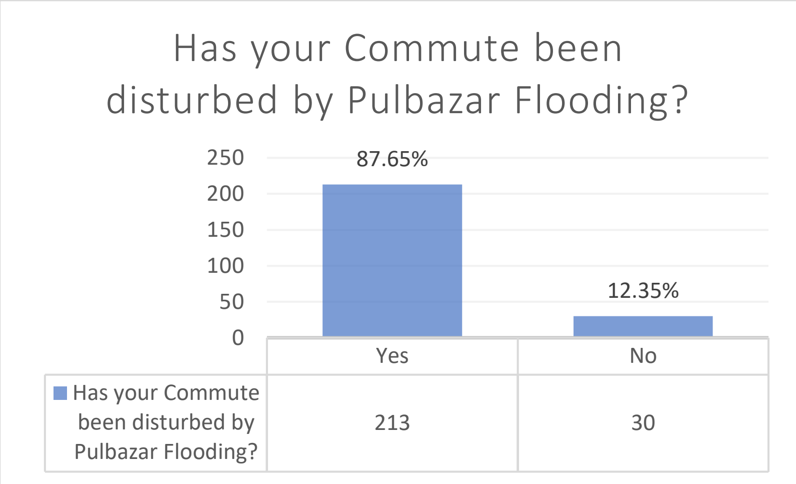


Chart 20: Commute Disturbance due to Flood

Out of the 243-survey carried out, 213 respondents commute has been disturbed by the Pulbazar flooding and the rest 30 respondents haven't yet faced the flooding scenario.

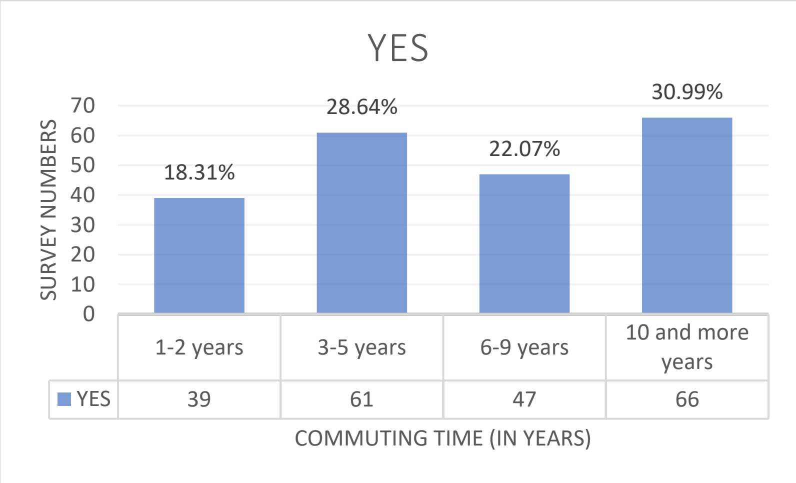


Chart 19: Commuting time of Flooding Disrupted Commuters

Out of the 213 respondents whose commute has been disrupted by Flood, maximum commuters have been commuting for 10 years and more.

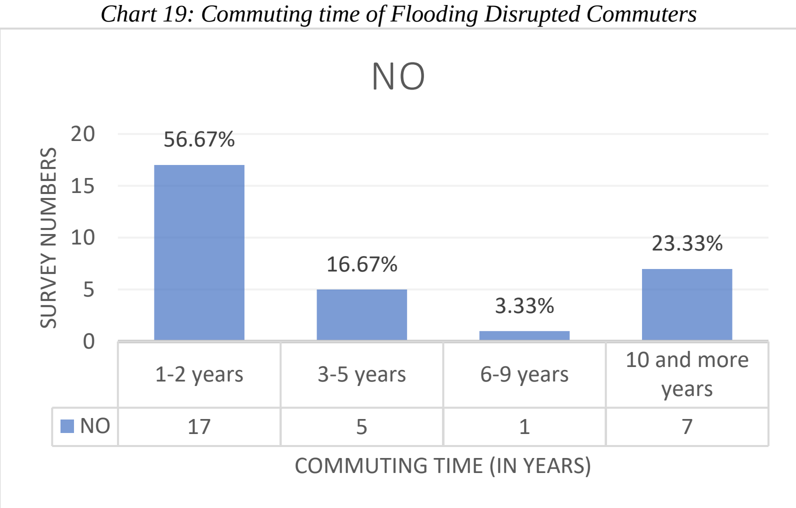


Chart 18: Commuting Time of Commuters Undisrupted by Flood

Out of the 213 respondents whose commute has been not been disrupted by Flood, maximum commuters have been commuting for 1-2 years only.

7.1.8. Commute Disruption

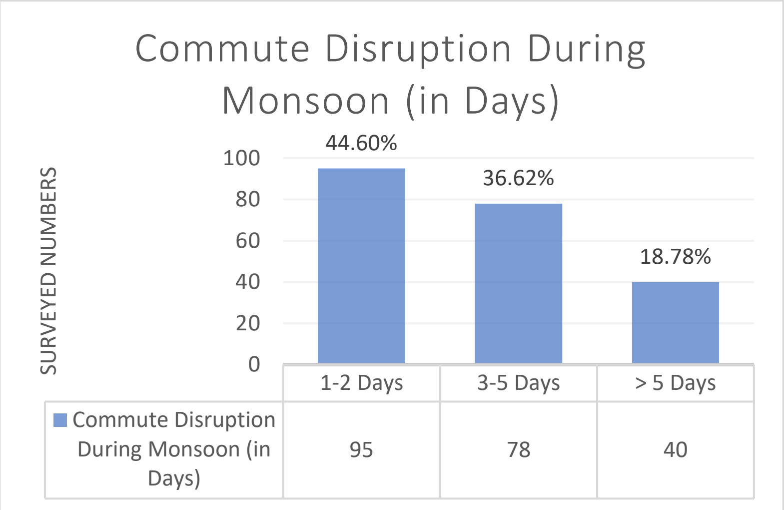


Chart 21: Commute Disruption in Monsoon (in Days)

Maximum respondents i.e. 44.6% of daily commuters have faced commute disruption for 1-2 days in a monsoon season. While only 18.78% commuters have faced commute disruption for more than 5 days.

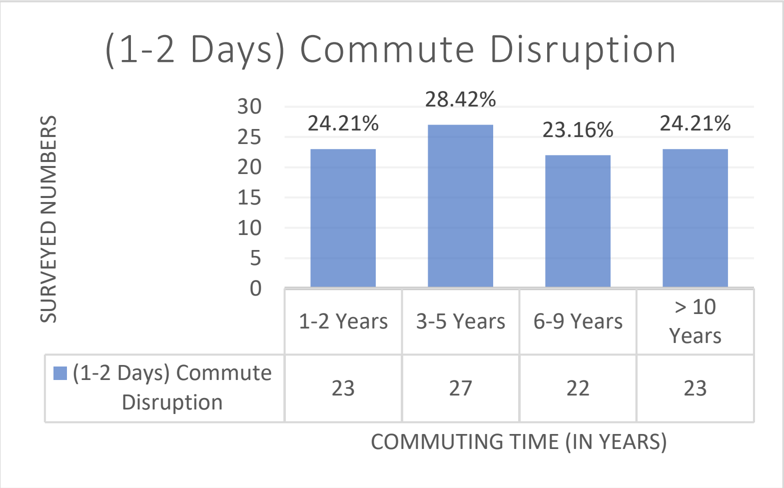


Chart 22: 1-2 Days Commute Disruption

Out of 95 respondents facing commute disruption for 1-2 days in a monsoon season, 28.42% of respondents have been commuting the route for 3-5 years.

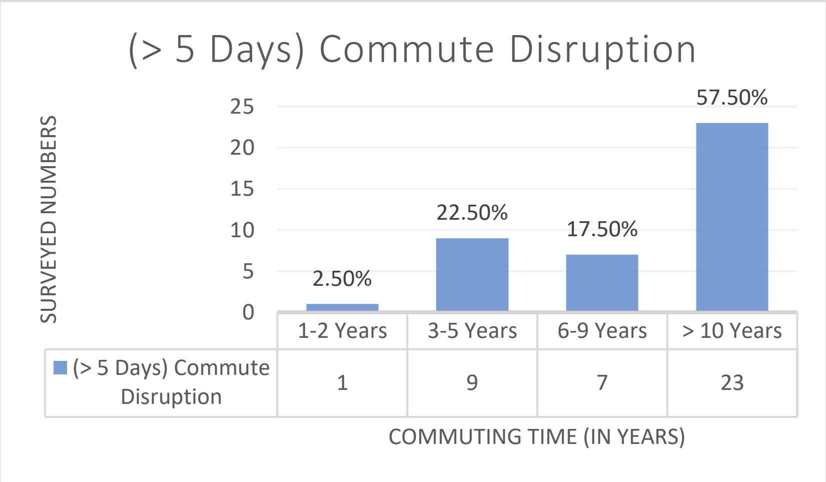


Chart 23: >5 days Commute Disruption

57.50% of respondents facing commute disruption for more than 5 days are the ones who has been commuting the route for more than 10 years.

7.1.9. What do you do when flooding disrupts the commute?

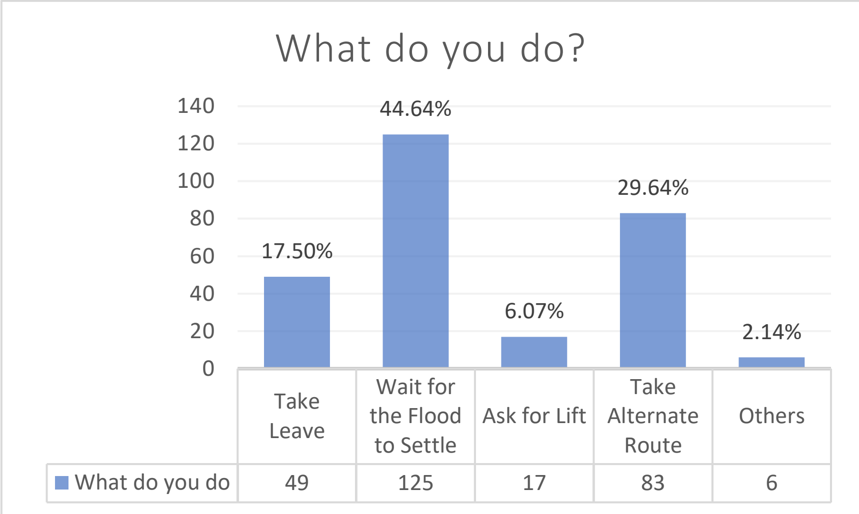


Chart 24: What do you do when flooding disrupts commute

44.64% of the respondents waits until the flood settles down while 29.64% of respondents take alternate route and some take leave. Respondent also take risk and drive slow from the flooded area.

Two alternate Routes were mentioned during the survey;

a. Tindobato – Nala - Bhaktapur Route
b. Tindobato – Policestation - Pulbazar Route

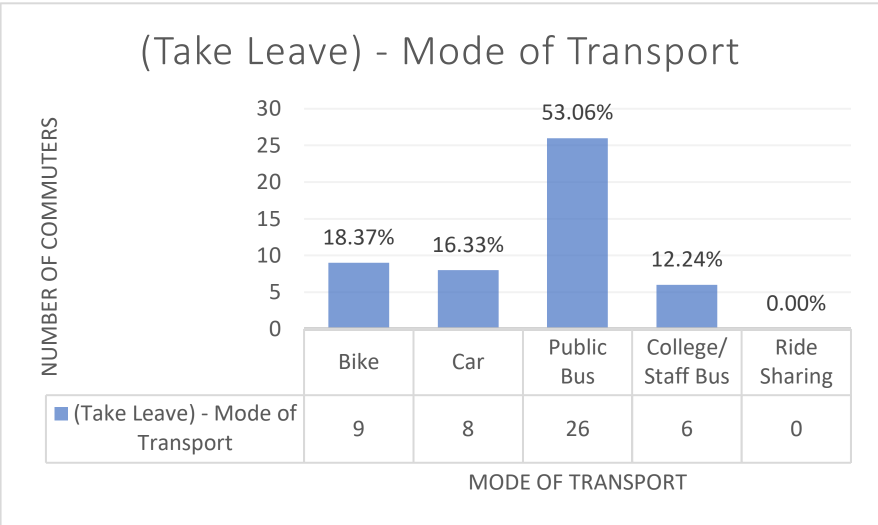


Chart 25: Commuters mode of transport who Takes leave

The survey shows that maximum commuters who travel via Public Bus takes leave when flooding disrupts the commute. While very less 18.37% of Bike commuters and 16.33% of car Commuters also take leave during flooding disruption.

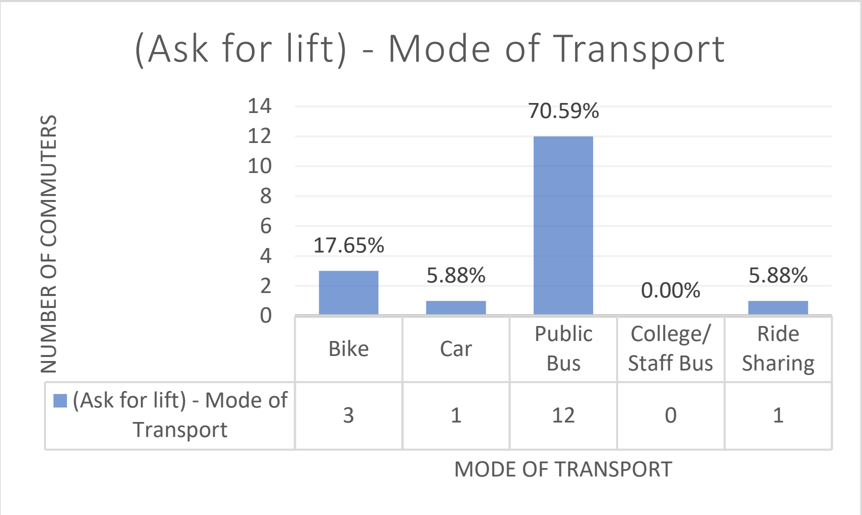


Chart 26: Commuters mode of transport who Ask for Lift

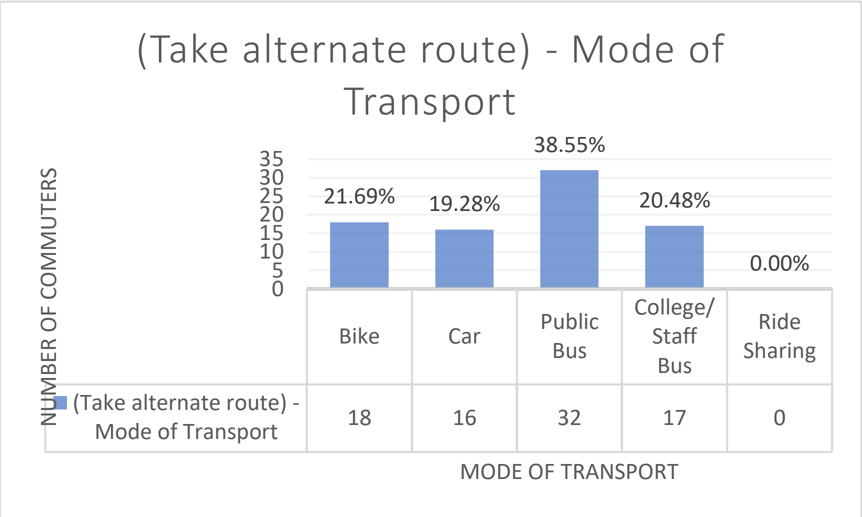


Chart 27: Commuters mode of transport who Takes Alternate Route

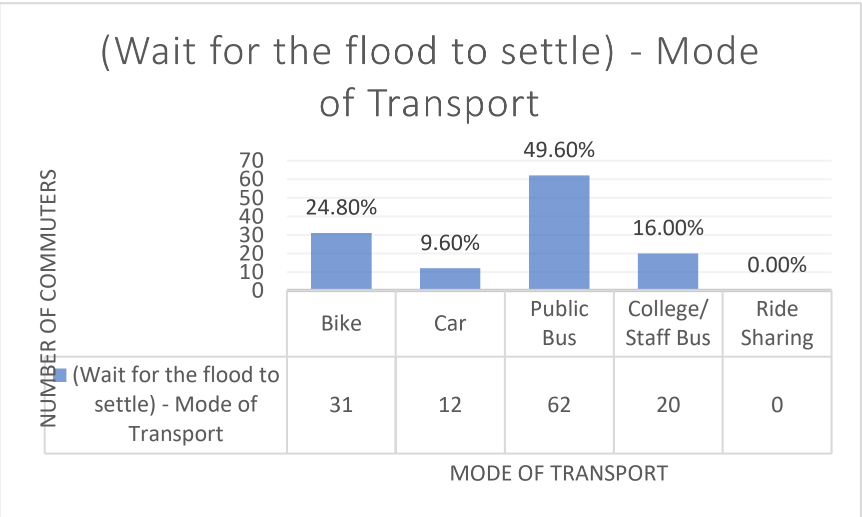


Chart 28: Commuters mode of transport who Waits for Flood to Settle

7.1.10. How long is the commute delayed?

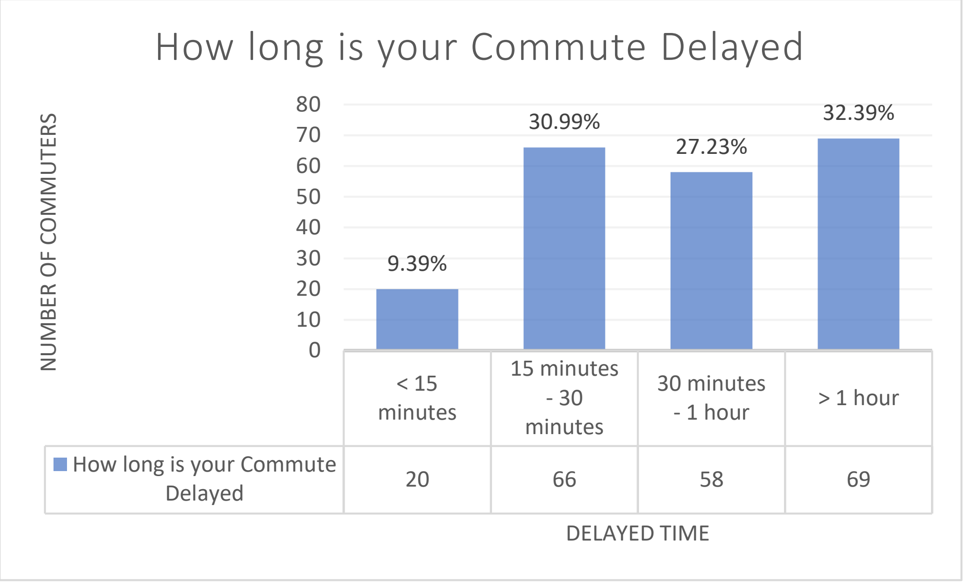


Chart 29: Commute Delay

7.1.11. Have you missed any important events?

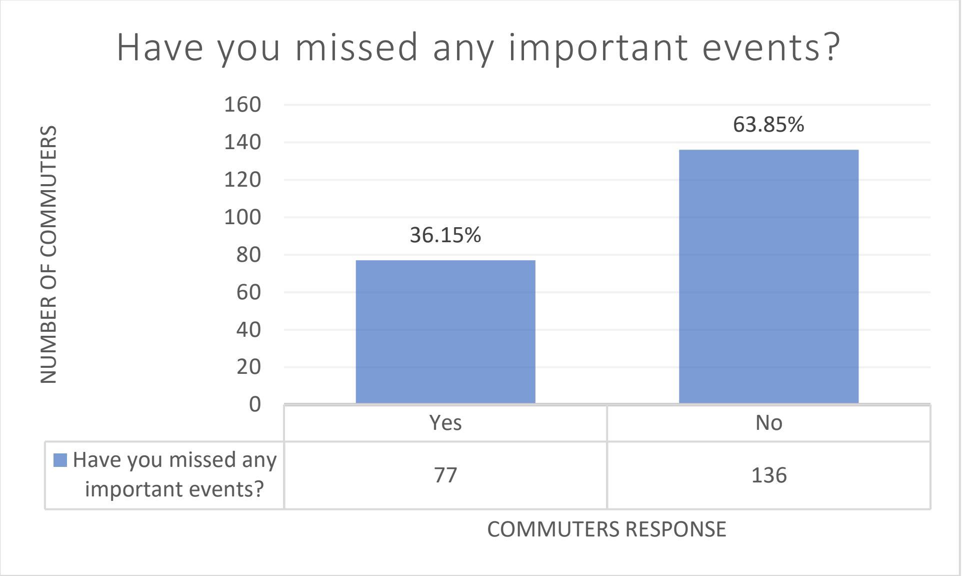


Chart 30: Missed Important events due to Flooding Disruption

7.1.12. Loss Incurred due to Flooding Disruption

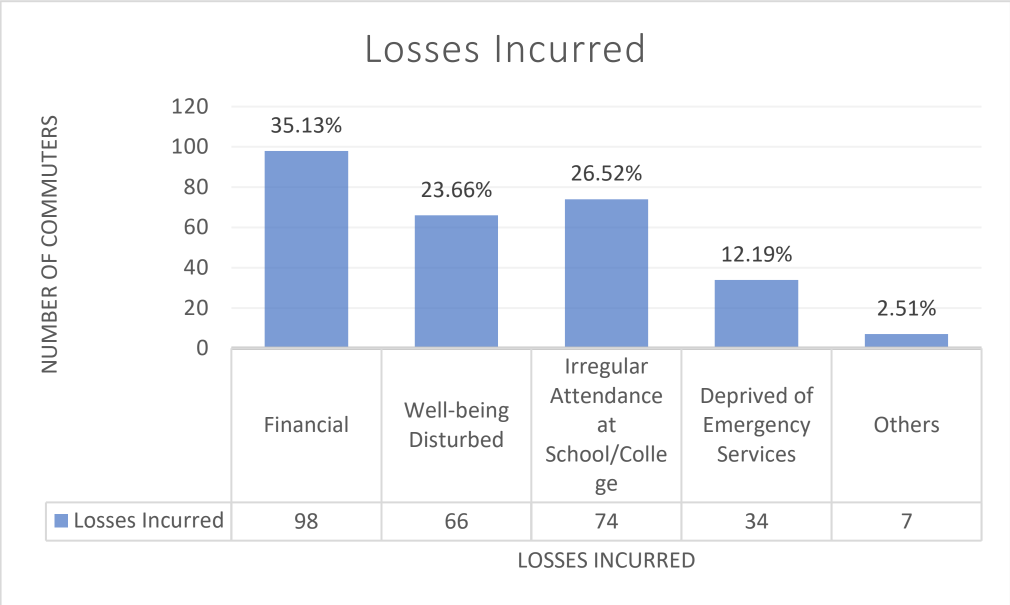


Chart 31: Loss Incurred due to Flooding Disruption

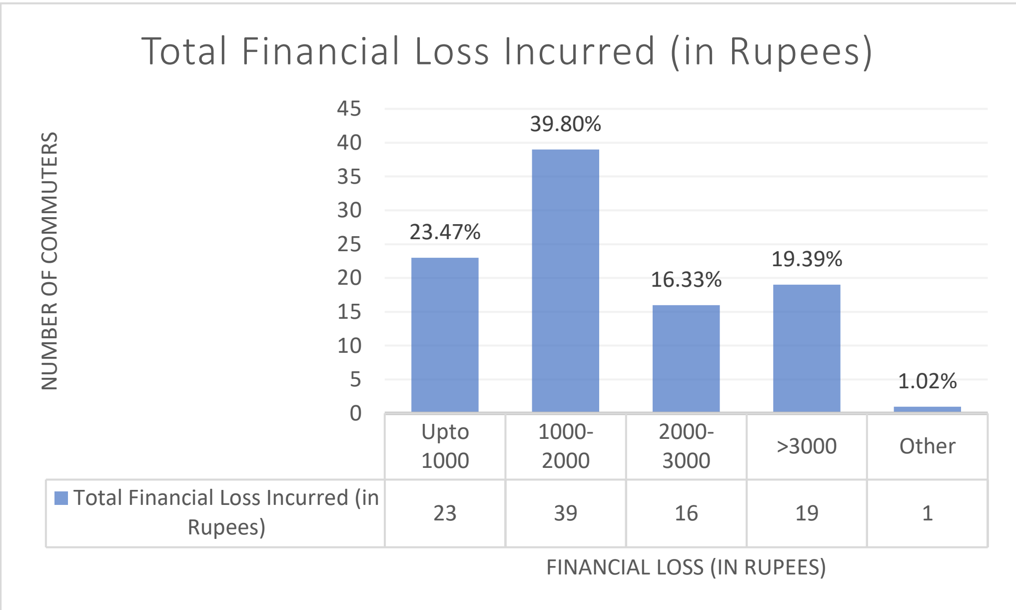


Chart 32: Total Financial Loss Incurred (in Rupees)

A total of 35.13% respondents showed Financial loss due to Flooding Disruption, while others showed economic losses like well-being disturbed, time delay, irregular attendance and deprived of emergency services.

7.1.13. Inconvenience Level

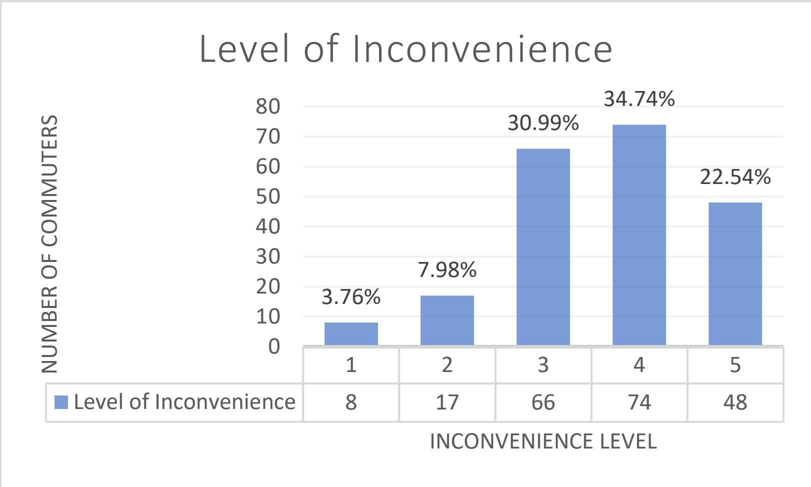


Chart 35: Inconvenience Level

5 being highly inconvenient to commute during the flooding disruption, 34.74% respondents have stated level 4 as their inconvenience level.

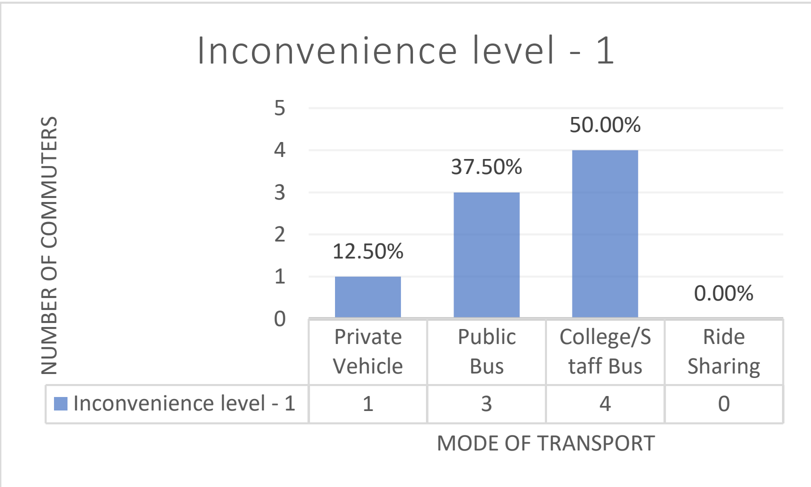


Chart 34: Inconvenience level 1

Respondents commuting through College/ Staff bus showed very less (1) inconvenience level.

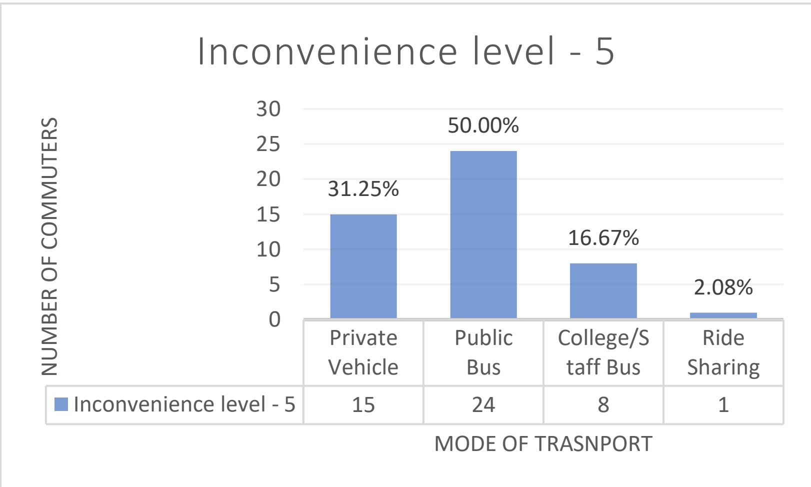


Chart 33: Inconvenience Level 5

Respondents commuting through Public bus showed very high (5) inconvenience level.

7.1.14. What should be done to increase accessibility during flooding?

Among the 213 respondents who has faced disruption in their commute, their responses have been listed below;

Most of the respondents were concerned about the improvement of drainage system. Along with that, surveyors responded that roads should be designed by proper hydrological analysis. Disaster Risk plan should be made and implemented efficiently. Since 30% of the respondents use alternate route while in the case of traffic disruption due to flooding, the surveyors responded with the provision of efficient alternative routes. The major alternate route that commuters use is Nala-Bhaktapur road, and another is Banepa Police Office road. Early warning system to alert the commuters beforehand the scenario takes place so as to make use of the alternate route.

Other responses were timely maintenance of the bridge, river widening and increase the depth by cleaning the sediment deposited on the river bed. Local government should be more responsible and participate actively in flood management. Retaining walls on both side of river. Awareness program to be conducted. Revival of the depleted rajkulo to facilitate proper drainage. Stop river encroachment and provide necessary floodplain for water to flow.

7.2. Private Bus Operator Survey

7.2.1. Kavre Punyawati Yatayat Pvt. Ltd.

Source: KII, Subha Raj Joshi (President- Kavre Punyawati Yatayat Pvt. Ltd.)

Established Date:

Kavre Punyawati Yatayat was established in 2075 B.S. after the abolishment of syndicate. Before the system was run by Kavre Minibus sewa Samiti.

- Total Number of Registered Buses: 144
- Total Number of Buses in operation: 90 (Panauti-Banepa-Kathmandu Route)

Flooding Disruption on Bus Commute

The Pulbazar Flooding that occurs every year disrupts the bus commute for 10-12 days in one monsoon season which lasts for around 1-2 hours. According to the Chairman, Subha Raj Joshi, this year flooding has not caused any disturbance since river cleaning and widening work is being carried out by the municipality.

Action taken during Flooding

Traffic disruption mainly occurs when the surface water runoff cannot take place in Tindobato-Pulbazar section road due to poor drainage system. The inundated water level rises upto 2-3 feet in height. Sometimes the buses take risk and drive through the inundated area and sometimes the buses take alternate route from Nala-Bhaktapur road. During heavy rainfall, even Nala-Bhaktapur road is not so reliable, so the only option is to wait until the flood settles.

Loss Incurred due to Commute Disruption

The loss incurred when a bus misses 1 trip is usually between Rs. 3500-4000/trip. So, per hour delay or increase in travel time may financially affect the bus owner subsequently. So far there is no record of mechanical loss of the vehicle due to flood.

Suggestion / Opinion from the Chairman

Elevate the pool and roads to a certain height that flooding will have no/ very less impact to accessibility during flooding.

7.2.2. Kavre Bus Pvt. Ltd.

Source: KII, Rajan Bhalu (Staff- Kavre Bus Pvt. Ltd.)

Established Date:

Kavre Bus Pvt. Ltd. was established in 2075 B.S. after the abolishment of syndicate. Before the system was run by Kavre Minibus sewa Samiti.

- Total Number of Registered Buses: 185
- Total Number of Buses in operation: 110 (Dhulikhel-Banepa-Kathmandu Route)

Flooding Disruption on Bus Commute

According to the interviewer Rajan Bhalu, Pulbazar Flooding has not caused any significant disruption in the bus commute because the tyres are big and affects only small four-wheeler and two-wheeler vehicle.

Action taken during Flooding

During the flooding scenario, the buses either takes alternate rote via Nala-Bhaktapur or wait for the flood to settle

Loss Incurred due to Commute Disruption

There have not been significant losses yet in the record, but the travel time of vehicle might increase while taking alternate route and waiting for the flood to settle.

Suggestion / Opinion from the Chairman

Department of Road should take necessary actin to solve this problem as soon as possible.

Besides there are other registered private bus operators (Helambu Yatatat & Bagmati Tipper Byabasaya Sangh) as well.

Chapter Eight: Results & Discussion

8. RESULTS & DISCUSSION

8.1.Results from Daily Commuter Survey & Bus Operator Survey

Several questions regarding accessibility inconvenience were asked to 243 daily commuters who travel via Araniko highway, Pulbazar section road.

Considering the average traffic volume per hour i.e. 1492 PCU and the responses from daily commuters a total of approximately NRS. 50 lakh financial loss is incurred if traffic disrupts for an hour. Other economic losses incurred are disturbance of well-being, irregular attendance and deprived of the emergency services. The survey also shows about one third of the commuters already uses alternate route as an adaptive measure or coping strategy.

Adaptive measures and few mitigative measures to cope with flooding scenario and make accessibility convenient even during the flood have been developed from the commuters themselves. Some of the possible solutions/ measures are discussed below;

Adaptive measures:

Alternate Route: From the survey it is found that 29% of the commuters take alternate route during traffic disruption due to flooding. Among them maximum i.e.; 40% of the commuters are private vehicle user. Also, 38% of alternate road user are Public vehicle.

Figure 35: Alternate route via Nala-Bhaktapur Road

Since the alternate route is narrow and there is chance of landslide, proper maintenance should be done so that such routes can be used efficiently in flooding scenarios as an alternate access.

Mitigative Measures:

River widening & Drainage system management are the mitigative measures that needs to be implemented to lessen the flood consequence. Also, the participation of local government in policy making is crucial for flood management in the study area which basically includes restriction of any kind of construction in the flood plains, stop illegal encroachment, identify disaster prone areas and set necessary by-laws for such areas.

8.2.Results from Site Study, Literature & Case Study

From the intensive site study, literature reviews and case study, it is found that firstly flood should be controlled to ease accessibility in the study area. The solution varies from short term to long term and Mitigative measures to prevent flooding and inundation scenario in the study area. Some of the possible solutions/ measures are discussed below;

8.2.1. Short term Solutions

8.2.1.1.Inspection, Repair & Maintenance before Monsoon

From the climatic chart, maximum rainfall occurs between June-July-August. So, before climate takes its action, there needs to be inspection, repair and maintenance work to improve the condition. Drain cleaning, sediment removal from river will also help increase the flow of volume of water from the river.

"This year the municipality has been working on cleaning the river and sediment removal works before monsoon season. Around 28-29 lakhs have been used for the process. Excavator has been provided by Department of Roads (DoR) for the cleaning process. The municipality aims at constructing resting wall and implementing Corridor plan soon. Budget insufficient has created obstruction in the process."

-Mayor Shanti Ratna Shakya (Banepa Municipality)

8.2.1.2.Rainwater harvesting

Rainwater harvesting would somewhat decrease the surface water runoff in a city area. Thus, if every household adopts rainwater harvesting, inundation problem would be solved to some extent.

8.2.2. Mid Term Solution

8.2.2.1.Pervious Pavement

Permeable pavement has the potential to reduce surface runoff and flood peak, as well as postpone peak time. The permeable road has a superior effect on lowering runoff coefficient and flood peak, effectively relieving urban drainage pressure and lowering the risk of stormwater floods.

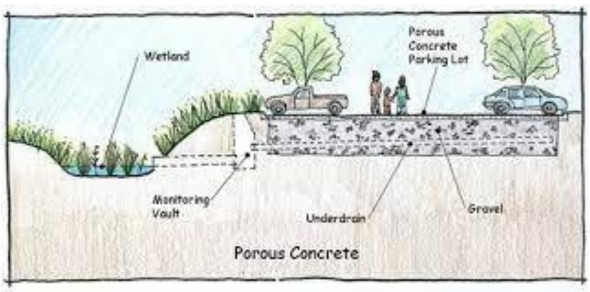


Figure 36: Porous Concrete as Pervious Pavement

Besides use of pervious surface also acts as a Sponge City. Helps in flood mitigation and helps during dry and drought season.

8.2.2.2.Proper Drainage System

Well facilitated drainage system that can cater not only present but future water flow should be designed to solve the flooding problem.

8.2.3. Long term Solution

8.2.3.1.River Widening

River restoration contributes to flood risk management by enhancing rivers' natural ability to hold water. Because flood risk is defined as damage times occurrence, flood risk management must aim to reduce either the damage or the likelihood of flooding, or both. River restoration minimizes the possibility of high water levels while also improving the river's natural functioning (ECCR, 2019).

8.2.3.2.River Corridor

There has been a malpractice in the municipality regarding the river corridor project. Walls has been raised on both sides of the river and above which roads are constructed further narrowing the river. The setback which municipality has set for construction which is 15M from the edge of river, is found not followed. Thus, such practices should be discouraged, and necessary flood plain should be allocated for the river and by-laws should be strictly followed and implemented. The municipality should have proper inspection regarding this issue.

Figure 37: Building Construction in the Flood Plain area

8.2.3.3.Detention Basins in the depression area

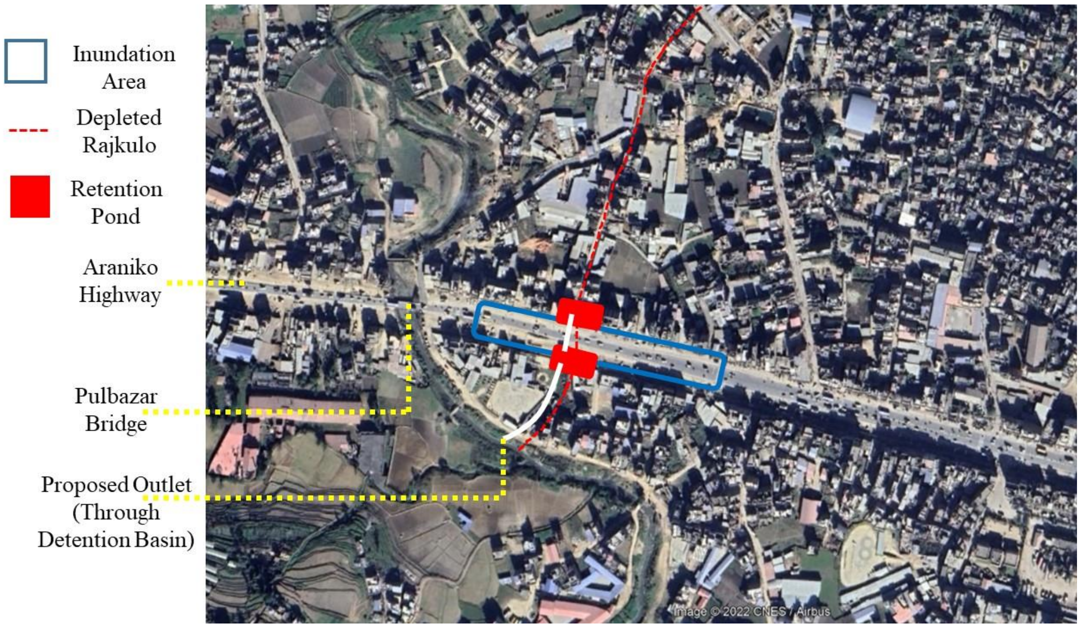


Figure 38: Detention Basin Concept for Stormwater collection

Water from northern side settlements all accumulates in the study area, and with no proper drainage system, the water accumulates for certain time and gradually settles down when water volume in the river decreases.

Figure 39: Stormwater Detention Basin Installed below Parking Lot

A stormwater detention vault is a subsurface structure designed to manage excess stormwater runoff on a built site, typically in an urban context. When there is inadequate area on the site to absorb the runoff or build a surface facility such as a detention basin or retention basin, this form of best management practice may be chosen (Wikipedia, 2022).

Underground stormwater retention enables for large amounts of runoff to be stored in a compact footprint area. Corrugated metal pipe, aluminum, steel, plastic, fiberglass, pre-cast or poured-in-place concrete can all be used to make storage containers.

The outflow is frequently a restricted-flow detention vessel drain with a weir for debris collection. Detention vessels slow the flow of water downstream, which may result in a delayed post-rainfall water level peak (Wikipedia, 2022).

8.2.3.4.Riverine & Lakes (Waterbody) Coverage

At present the riverine & lakes cover only 15.19 hectors of the municipality area which is just about (0.28%) of the total area. As per Kongjian Yu, dean of Peking University's College of Architecture, if 1% of land is dedicated to water drainage, most flooding may be prevented. Yu claims that in the case of biblical, once-in-a-1000-year floods, devoting 6% of land to water drainage would be adequate to limit the damage (Walsh, 2022).

But if we look at the Municipality scenario in the past few decades the ponds are disappearing in the name of construction. Such malpractices need to be discouraged and the municipality should bring new plans & projects to further emphasize and increase the water body areas which can be acted as natural retention and detention during excessive rainfall to withhold water for few hours.

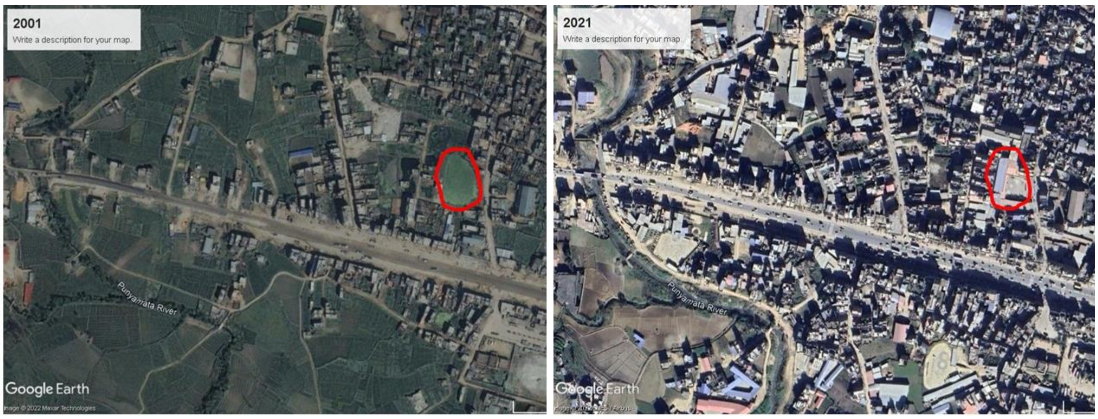


Figure 40: Depleting Water Bodies over the past two decades

Under Policy Budget and Program Decision Book, FY 2078/79, under the Forest & Environment section it is mentioned that A policy will be taken to conserve the ponds and parks within the city area. Also, the construction program of recharge pond will be kept at a suitable place.

So, considering the study from Yu, 1% land area allocation for water drainage and the municipality program to conserve ponds within cities, and construction of recharge ponds should be given top priority to fight with the global climate change and combat the yearly flooding scenario in the study area.

[Webinar Discussion on Banepa Pulbazar Flooding]

"Cannot be solved in short time. Was waiting for foreign aid but no. Nepal government responsible for financing. Due to budget, it is taking more time. Right of way (ROW) of river in downstream needs to be cleared, or else not possible"

-Suman Yogesh, Bhaktapur Road Division Office Head

"Road level and Bridge height increment should not be kept as a priority as it may only worsen the scenario in the Northern part of the settlement creating an artificial dam. Rather focus should be how to easily discharge the accumulated water."

-Sanjay Manandhar, Planning officer, Land Management

"Since hume pipe is in lower level than high flood level about 1-1.5m. So, when water level in river increases first the water accumulates on the eastern side causing inundation and blocks traffic."

-Kanchan Chandra Bade, Former Industries Minister

"Inundation in the study area is not caused by water returning from the river. From upper settlement. There was rajkulo which has been depleted in due course of time."

-Ratna Ranjit, Businessman

"Retention & Detention pond concept can be used to collect the stormwater and surface water and in that way water flow can be delayed"

-Anup Shrestha, (Flood Mapping Expert) Banepa Residency

Chapter Nine: Conclusion & Recommendation

9. CONCLUSION & RECOMMENDATION

The major part focuses on identifying the impacts of flood on accessibility and the challenges faced by the daily commuter in the study area. Also, the study focuses on identifying factors that is causing flood/inundation in the study area in relation to climatic factor, urbanization and human factors. Climate change and heavier precipitation has a huge role to play in increasing flood hazard, along with that urbanization and change in land use type increases surface runoff.

One of the major impacts of flood is on accessibility which is being overlooked as the data shows that almost 90% of the surveyed respondents has experienced flooding disruption. In addition to that, significant financial and economic loss is being incurred. The challenge to mitigate the effect of flooding on accessibility in the study area is spread across policy interventions of various improper urban practices. Thus, policymakers must comprehend the sensitivity of the topography and natural drainage pattern to make better planning decisions. The focus should be on evaluating the present and future urban drainage to manage the rising danger of urban. The only way to reduce the effects of urban floods is to change the way our cities are planned.

Recommendation

Looking at the site condition and scenario, it is recommended that both Adaptive measure as a short-term solution and Mitigative measures as a long-term solution may be implemented simultaneously to abate the flood risk and ease the accessibility during flooding. Other recommendations are;

- Proper management and maintenance of the alternate routes, in addition to that Early Warning System should be developed.
- Width of the bridge should be increased to cater the peak volume flow of water, with proper hydrological modelling.
- Identification of Recharge Ponds with proper Hydrology Analysis. The Municipality vision should be to increase the Riverine & Lakes area from 0.28% to 1% as suggested from the studies.
- The design of surface transportation infrastructures like roads and bridges must comprehend with the proper hydrological modelling.

- Drainage system to be effectively designed considering the Urbanization, climate change and its return period.
- Flood vulnerability mapping should be the primary step involved in risk reduction and Strict control on the land use with respect to vulnerability mapping should be implemented to reduce the tangible and intangible losses.
- River-front water development plans and allocation of floodplain areas to manage flood control plans.

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ANNEX

ANNEX A: QUESTIONNAIRE SURVYE FOR DAILY COMMUTER

Questionnaire Survey for Daily Commuter

Thesis Title:

"Framing the challenges of Urban Flooding on Accessibility- A Case of Pulbazar Banepa"

Research Objective:

To assess the transportation and accessibility inconvenience faced by the daily commuters through that route during the flood.

A Brief Introduction:

Every year the Urban Flood (Flash Flood) inundates in the study area i.e. PulbazarBanepa, blocking the Araniko Highway. The Araniko Highway is one of the major routes that connects Kathmandu valley and Kavre District. During the monsoon sudden flash flood blocks the Araniko Highway halting the transportation causing negative impact to daily commuters and the local people which ultimately results in the social and economic loss to the people. The study aims at assessing the disruption in accessibility faced by the daily commuters and proposing strategic interventions through adaptive and mitigative measures.

Consent from the Respondent

I would like to state that this research is purely for an academic purpose and I am simply interested in your candid and honest opinion. I assure you that strict confidentiality will be maintained, and the information furnished by you will be used only for the academic purpose. Would you be willing to participate voluntarily in the survey?

Yes ☐ No ☐

Name

……………………………………………………………………………………………

……………

Age

- O 16-25
- O 26-35
- O 36-45
- O Above 45

Sex

- O Male
- O Female
- O Prefer not to say
- O Others

Journey Origin

……………………………………………………………………………………………

……………

Journey Destination

……………………………………………………………………………………………

……………

How long have you been commuting this route?

- O 1-2 years
- O 3-5 years
- O 6-9 years
- O 10 and more years

Purpose of commute

- □ Job/Employment
- □ Business
- □ Study

- Labor
- Others

Specify Other (Purpose of Commute)

………………………………………………………………………………………

……………

Mode of Transport

- O Private vehicle
- O Public Bus
- O College/Staff Bus
- O Ride Sharing (Pathao/Indriver)

Specify Private mode of transport

- O Bike
- O Car

How long is your commute distance?

- O Less than 1 hour
- O Half hour – One hour
- O One hour – Two hour
- O More than 2 hours

Has your commute ever been disturbed by Pulbazar Flooding?

- O Yes
- O No

<u>(If Yes, only then proceed the questions below)</u>

How many days during monsoon flooding disrupts your commute?

- O 1-2 days
- O 3-5 days
- O More than 5 days

What do you do?

- O Take leave
- O Wait for the flood to settle
- O Ask for lift
- O Take alternate route
- O Other

Specify (Alternate route)

……………………………………………………………………………………………
……………

Specify (Other)

……………………………………………………………………………………………
……………

How long is your commute delayed?

- O < 15 minutes
- O 15-30 minutes
- O 30 minutes – 1 hour
- O >1 hour

Have you missed any important events?

- O Yes
- O No

If yes, (Specify)

……………………………………………………………………………………………
……………

What loss do you think you have incurred due to the disruption in movement?

- O Financial Loss
- O Wellbeing disturbed
- O Irregular attendance at school/college
- O Deprived of emergency services being halted
- O Other

Specify Other (Loss Incurred due to flooding)

……………………………………………………………………………………………
……………

What Financial loss do you face if flooding disrupts your commute for a day?

O Up to 1000
O 1000-2000
O 2000-3000
O >3000
O Other

Specify (Other)

……………………………………………………………………………………………
……………

Describe your level of inconvenience to travel during flooding? (5 being highly inconvenient)

O 1
O 2
O 3
O 4
O 5

In your opinion what should be done to improve accessibility during flooding?

……………………………………………………………………………………………
……………

ANNEX B: QUESTIONNAIRE SURVYE FOR BUS OPERATOR

Questionnaire Survey for Bus Operator

Thesis Title:

"Framing the challenges of Urban Flooding on Accessibility- A Case of Pulbazar Banepa"

Research Objective:

To assess the transportation and accessibility inconvenience faced by the daily commuters through that route during the flood.

A Brief Introduction:

Every year the Urban Flood (Flash Flood) inundates in the study area i.e. PulbazarBanepa, blocking the Araniko Highway. The Araniko Highway is one of the major routes that connects Kathmandu valley and Kavre District. During the monsoon sudden flash flood blocks the Araniko Highway halting the transportation causing negative impact to daily commuters and the local people which ultimately results in the social and economic loss to the people. The study aims at assessing the disruption in accessibility faced by the daily commuters and proposing strategic interventions through adaptive and mitigative measures.

Consent from the Respondent

I would like to state that this research is purely for an academic purpose and I am simply interested in your candid and honest opinion. I assure you that strict confidentiality will be maintained, and the information furnished by you will be used only for the academic purpose. Would you be willing to participate voluntarily in the survey?

Yes ☐ No ☐

Name of private bus service operator

……………………………………………………………………………………………

……………

Established Date (in B.S.)

……………………………………………………………………………………………

……………

Total number of registered buses

……………………………………………………………………………………………

……………

Total number of buses in operation.

……………………………………………………………………………………………

……………

Has pulbazar flooding disrupted the commute?

- O Yes
- O No

If yes, how many days during monsoon flooding disrupts bus commute?

……………………………………………………………………………………………

……………

What do buses usually do?

- ☐ Take risk and drive slowly
- ☐ Take alternate route
- ☐ Wait for the flood to settle
- ☐ Miss the trip commute

Specify Alternate route

……………………………………………………………………………………………

……………

How feasible is alternate route for the commute?

- O Very feasible
- O Somehow feasible
- O Less feasible
- O Not feasible

What should be done to make alternate route feasible and properly accessible?

…………………………………………………………………………………………
……………

What are the losses incurred if flooding disrupts for a day?

- ☐ Financial loss
- ☐ Traffic Congestion
- ☐ Travel time increased
- ☐ Others

Specify Others

…………………………………………………………………………………………
……………

Total financial loss incurred? (in Rupees)

…………………………………………………………………………………………
……………

Total mechanical loss incurred in vehicle repair and maintenance?

…………………………………………………………………………………………
……………

In your opinion what should be done to increase accessibility during flooding?

…………………………………………………………………………………………
……………

ANNEX C: LIST OF COMMENTS IN THE THESIS DEFENCE

S.N.	Comments	Response
1.	Flood Inundation Map Elaboration (its coverage)	Addressed in Pg. No. 44-46
2.	Data Analysis synchronization in objective and findings.	Addressed in Pg. No. 9 & 77-82
3.	Case study Bharatpur (canal capacity or problem in canal)	Addressed in Pg. No. 29
4.	Runoff volume calculation (Coefficient)	Addressed in Pg. No. 49
5.	Direct & Indirect Cause Clarification (manmade or natural)	Addressed in Pg. No. 2-3
6.	Type of Disruption (mode of transport)	Addressed in Pg. No. 7
7.	Alternate route (mode of vehicle)	Addressed in Pg. No. 68-69
8.	Highlight Commuter Survey	Addressed in Pg. No. 62-73
9.	Focus how to better accessibility can be improved in recommendation.	Addressed in Pg. No. 85

ANNEX D: PAPER IOEGC

त्रिभुवन विश्वविद्यालय
Tribhuvan University
इन्जिनियरिङ अध्ययन संस्थान
Institute of Engineering

डीनको कार्यालय
OFFICE OF THE DEAN

GPO box- 1915, Pulchowk, Lalitpur
Tel: 977-5-521531, Fax: 977-5-525830
dean@ioe.edu.np, www.ioe.edu.np
गोश्वारा पो.ब. नं- १९१५, पुल्चोक, ललितपुर
फोन- ५५२१५३१, फ्याक्स- ५५२५८३०

Date: September 20, 2022

To Whom It May Concern

This is to confirm that the paper titled "*Framing the Challenges of Urban Flooding on Accessibility*" submitted by **Apsana Shrestha** with Conference ID **12101** has been accepted for presentation at the 12th IOE Graduate Conference being held in October 19 – 22, 2022 at Thapathali Campus, Kathmandu.

Khem Gyanwali, PhD
Convener,
12th IOE Graduate Conference

IOE Graduate Conference
[Placeholder for Publication Information]

Framing the Challenges of Urban Flooding on Accessibility

Apsana Shrestha [a], Dr. Ajay Chandra Lal [b],

[a] *Department of Architecture, Institute of Engineering, Pulchowk Campus, Kathmandu, Nepal*
[b] *Institute of Engineering, Pulchowk Campus, Kathmandu, Nepal*
[a] apsana.shr@gmail.com [b] ajay@ioe.edu.np

Abstract

Urban flooding is a worldwide phenomenon which is witnessed more often in a growing urban city in developing countries. The insufficiency of drainage system that cannot withstand with the current precipitation due to climate change, urbanization haphazard planning causes stormwater runoff in a city area creating inundation that lasts from few hours to even few days known as Urban Flooding. These urban floods paralyze the surface transportation of a city. Especially the daily commuters bear heavy economic financial losses. The major objective of the paper is to assess the accessibility disruption faced by daily commuters who travel via Araniko road, Pulbazar section road and identify major cause of the flood in the study area and also explore the strategic interventions to facilitate accessibility in the region. The research is based on case study approach. A total of 243 daily commuter survey was done through stratified random sampling method. According to the research and survey, sudden flash floods inundates the highway halting transportation which occurs 10-12 days in one monsoon season. Majority of the commuters wait for the flood to settle while only few with private vehicle takes alternate route via Nala. The vast majority of commuters incurs financial loss and the commuters described commute as highly inconvenient to travel during flood/inundation. The research concludes that improvement of alternate routes as an adaptive measure and proper management of artificial drainage system as a mitigative measure should both be incorporated simultaneously to cope with the annual flooding scenario in the study area.

Keywords

Urban Flooding, Inundation, Drainage System, Urbanization, Climate Change, Daily Commuter

1. Background

Flooding disrupts transportation systems in urban areas in developing country cities. While flooding has caused immediate damage to housing and infrastructure, accessibility and transportation are also severely hindered, resulting in significant indirect economic loss. Floods reduce transportation network capacity, either directly through physical destruction rendering roads unusable or through floodwater accumulation on the road surface rendering the road impassable [1]. Due to these disruptions, which include increased travel distances and times, commuters would incur significant socioeconomic costs.

Flooding is closely linked to both climate change and the shift in how urban land is used, where porous soft surfaces have been replaced by built-up and hard surfaces. Overburdened drainage frenzied and unregulated construction, no regard to the natural topography and hydro-geomorphology all make urban floods a man-made disaster. The term urban flood is a misnomer. The problem of flooding in urban areas is not only due to overflowing rivers, but the uninformed way in which our cities are coping with urbanization also plays a large role [2].

Globally floods cause more than 40 billion dollar in damage worldwide annually [3]. In Nepal, on average, floods cause over 175 deaths each year and average annual economic losses exceeding USD 140 Million [4].

According to studies, flooding is expected to become more common in the future because of climate change and urbanization and the current drainage infrastructure will not be able to withstand future flooding scenario. The impact of flooding on transportation and accessibility has received very little attention. Further study with possible mitigative and adaptive measures have to be introduced to cope with the ongoing situation in the present and future.

2. Literature Review

Flooding in cities is caused by poor design, encroachment on water bodies and drainage, settlement in low-lying areas, watershed changes, and climate change. With climate change, urban floods are expected to be more frequent there is likely to be longer flooding season and newer areas would experience flooding [5]. According to [6] flood can be classified into two categories; according to duration: Long standing Short standing, and according to appearance: River flood, Urban Flood, Coastal flood and Dry water flood.

Global Climate Change and Urbanization are direct factor for causing urban flood while haphazard development, inadequate drainage system, improper solid waste management are indirect factors. In developing cities flooding is becoming frequent due to both human factors and meteorological/hydrological factors, with the former factor being more predominant. Urbanization, River encroachment, Pollution, Illegal mining activities, Interference in the drainage system and absence of administrative framework are basically human factors that escalates the risk of urban flood.

Urban flooding has a wide range of repercussions, particularly in terms of both direct and indirect economic losses. Flooding in an urban area might affect more than just one sectors. Some of the impacts are; Transport and Accessibility Disruption, Infrastructure damage, Damage to public and private property, Disruption of power supply and telecommunication Deprived of Emergency Services. The research focuses on the transport accessibility disruption in particular. And with proper knowledge of its cause the research also intends to explore possible adaptive and mitigative ways to cope with the annual flooding scenario.

Two case studies were done to explore the possible ways to mitigate urban flood of similar context; Adapting to Urban Flooding: Bharatpur and The Sponge City, China. The finding from Bharatpur case study suggests that structural solutions without properly integrating effective solid waste management become almost ineffective in reducing flooding risk and if solid waste not managed properly, the area under flood risk goes back up to 7.6 percentage in Bharatpur in five years. And the sponge city concept adopted in China is a development mode that can store, infiltrate and detain urban runoff through the appropriate planning, construction and management. Study suggest that if 1% of land is allocated to water drainage, then most flooding will be stopped. In the case of biblical, 1-in-1000-year floods, 6 percentage of land allocated to water drainage would be enough to stop the damage [7].

3. Research Setting

Every year the Urban Flood inundates in the study area i.e. PulbazarBanepa, blocking the Araniko Highway. The Araniko Highway is one of the major routes that connects Kathmandu valley and Kavre District. The highway also connects to Terai Region via BP highway from Dhulikhel. Large number of people travel from Kavre district to Kathmandu Valley daily for job and study purpose via Araniko highway.

In the study area rain triggers flood at Punyamata Chandeswori river. The flood waterlogs Pulbazar in Banepa causing blockade to section of Punayamata river bridge and approached road. Sections of the Arniko Highway between Kathmandu and Banepa are prone to chronic flash flooding every monsoon season. Water from a nearby stream overflows into the road because of insufficient drainage, and compound walls that act like dams along natural floodplains of rivers [8]. The Pulbazar area has always been inundated due to rising water levels due to the narrowing of the river.

During the monsoon sudden flash flood blocks the Araniko Highway halting the transportation causing negative impact to daily commuters and the local people which ultimately results in the social and economic loss to the people.

Figure 1: Urban Flooding in Banepa

4. Methodology

The research is based on mixed method case study design which is a type of mixed methods study in which the quantitative and qualitative data collection, results, and integration are used to provide in-depth evidence for a case(s) or develop cases for comparative analysis. Quantitative data in the form of structure of survey questionnaire, rainfall datas, land use maps. Qualitative datas are achieved by filed observation and key informant interviews.

Sample size was calculated using confidence level 95% and margin of error 10, where 243 daily commuter survey was carried out to find the quantative data done through Kobo Toolbox. Also filed survey was carried out to analyze the existing scenario and Key Informant Interview with locals and experts were done to find the actual cause for the annual flooding/inundation in the study area.

5. Data Sets and Analysis

The major part of the research focuses on identifying the impacts of flood on accessibility and the challenges faced by the daily commuter in the study area. Also, the study focuses on identifying factors that is causing flood/inundation in the study area in relation to climatic factor, urbanization and human factors.

A sample of 243 daily commuter survey was done through stratified random sampling method to find out the challenges and commute disruption faced by daily commuter. Out of the total survey, 42% respondents were female 58% were male. Age group below 16 was not considered eligible for the survey, besides them all age group were surveyed upon. Commuters traveling through both private vehicle public bus were surveyed to find out their inconvenient level independently. The results found that commuters had more than one purpose for the commute. 88% of the commuters responded their commute has been disturbed by Pulbazar Flood and the rest haven't yet faced the flooding scenario. The results show that commute disrupts varying from 1-2 days to more than 5 days in one monsoon season. And the commuters must either take leave, wait for the flood to settle or take alternate route via Nala. Most private vehicle users are familiar with taking alternate route. Others commute is either delayed or commute is completely disrupted for the day. Commuters responded that delay lasted more than an hour causing them different losses; financial loss, well-being disturbance, irregular attendance and deprived of emergency services deprived. A total of 35.13% respondents showed Financial loss due to Flooding Disruption ranging from Rs. 1000-3000 per day, while others showed economic losses like well-being disturbed, time delay, irregular attendance and deprived of emergency services. 5 being highly inconvenient to commute during the flooding disruption, 34.74% respondents have stated level 4 as their inconvenience level.

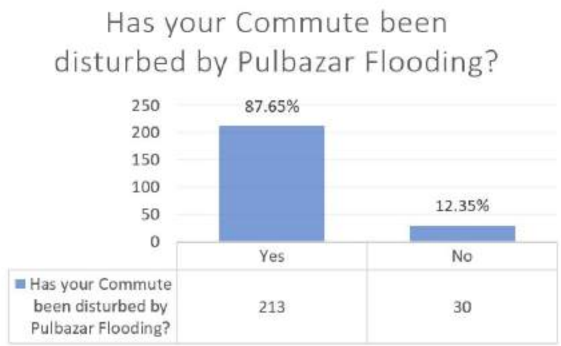

Figure 2: Commute Disturbed by Pulbazar Flooding

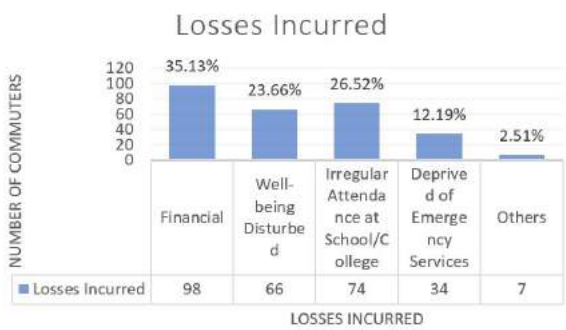

Figure 3: Loss Incurred to Daily Commuter

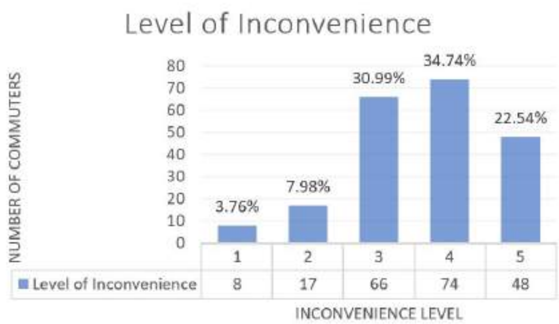

Figure 4: Level of Inconvenience during Flooding

The study from field observation shows that the catchment area extends from Nagarkot on the northern side to Kashivanjhyang on East and Nala Tukucha on the eastern side, with area around 23sq.km and perimeter 20.9km. All the water from these area outlets from pulbazar bridge. Even heavy rainfall in Nagarkot basin might affect in Banepa Municipality.

"Flooding in banepa is not only associated to rainfall in Banepa but heavy rainfall in Nala, Bhaktapur and Nagarkot area will have adverse effect on the area, since water from all those area finally discharges through Punyamata River. And during massive flow, the river cant bear such volume which causes flooding in the Punyamata river" -KII, Nabin Thapa, Banepa Residency

The data from overview of study area shows that there has been massive growth of population between year 2011 and 2021. Between the year 2010 and 2020, built-up has increased by 400%, which indicates the expansion of imperious surface causing utmost stormwater runoff overburdening the existing drainage system.

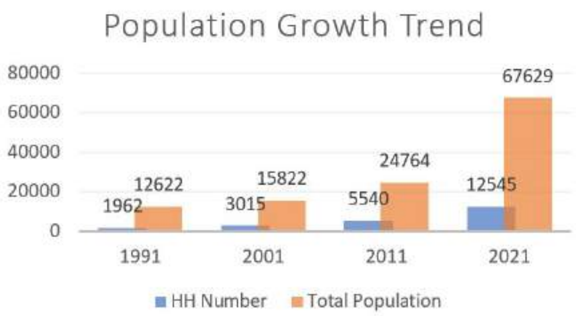

Figure 5: Population Growth Trend in Banepa Municipality

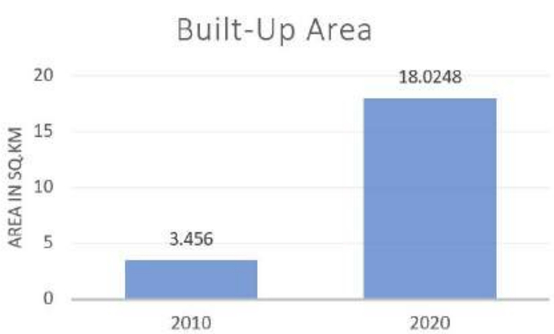

Figure 6: Built-Up Expansion between year 2010 2020

From a KII with Rajaram Palanchoke, who is a 63 year old permanent residence of Banepa, there used to be a Rajkulo to east side of the river, where inundation happens at present. Water from north side of the area used to accumulate and then drains out from Rajkulo. Also, after the construction of driving center, which is raised 2 feet above the road level stormwater drainage has been obstructed and waterlogs in study area causing inundation which lasts from 1-2 hours to 4-5hours causing traffic disruption.

Figure 7: Depleted Rajkulo in the study area

Besides the land cover change factor, climatic factor also plays an important role in Urban flooding in the developing regions. Climate change has resulted in the heavy precipitation/ heavy rainfall globally. Although floods are not always caused by heavy rainfall, but their likelihood does increase. In areas where urban flooding is on the rise, even moderate amounts of rainfall can result in significant damage.

6. Findings

6.1 Findings from Daily Commuter Survey

Findings from daily commuter survey suggest that both adaptive mitigative measure should go together to cope with flooding scenario.

Adaptive measures: From the survey it is found that 29% of the commuters take alternate route. Among them maximum i.e.; 40% of the commuters are private vehicle user. Also, 38% of alternate road user are Public vehicle. Since the alternate route is narrow and there is chance of landslide, proper maintenance should be done so that such routes can be used efficiently in flooding scenarios. Also early warning system would alert the commuters beforehand guiding them to use alternate route.

Figure 8: Alternate route in the area

Mitigative Measures: River widening Drainage system improvement are the mitigative measures that needs to be implemented to lessen the flood consequence. The Local government should be more responsible and participate actively in flood management taking necessary actions.

6.2 Findings from Site Overview, Literature Case Study

The findings suggest Short-term, Mid-term Long-term solution to mitigate the flooding and make ease for accessibility in the particular route. Short-term solution includes; Inspection, Repair Maintenance before Monsoon and Rainwater Harvesting. Mid-term solution includes; Pervious Pavements and Proper Drainage System to cater present future water runoff. Long-term solution includes; River Widening and Detention Basin in the depression area.

Figure 9: Detention Basin in Depression Area

7. Conclusion and Recommendation

One of the major impact of flood is on accessibility which is being overlooked as the data shows that almost 90% of the surveyed respondents has experienced flooding disruption. In addition to that, significant financial and economic loss is being incurred. The challenge to mitigate the effect of flooding on accessibility in the study area is spread across policy interventions of various improper urban practices.

Looking at the site condition and scenario, it is recommended that both Adaptive measure as a short-term solution and Mitigative measures as a long-term solution may be implemented simultaneously to abate the flood risk and ease the accessibility during flooding.

Proper management and maintenance of the alternate routes, in addition to that Early Warning System should be developed. Width of the bridge should be increased so as to cater the peak volume flow of water. Identification of Recharge Ponds with proper Hydrology Analysis. The Municipality vision should be to increase the Riverine Lakes area from 0.28% to 1% as suggested from the studies. Drainage system to be effectively designed considering the Urbanization, climate change and its return period. Flood vulnerability mapping should be the primary step involved in risk reduction and Strict control on the land use with respect to vulnerability mapping should be implemented to reduce the tangible and intangible losses. River-front water development plans and allocation of floodplain areas to manage flood control plans.

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