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A Study on Land Use Policies of Khulna Structure Plan 2000-2020 in the Light of Climate Change Induced Flood Scenario

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Abstract

Khulna, the third largest metropolis of Bangladesh has been identified as one of the 15 most vulnerable coastal cities under climate change and it is believed that this scenario will be exacerbated with time by cyclone, saline water intrusion, submerging of low-lying areas, and tidal and urban floods, etc. The city accommodates around 1.3 million people. The poorly drained city is approximately 2.5m above mean sea level. Climate change effects, especially sea level rise and flooding which is a major concern for the development of the city, was not considered when the structure plan 2000-2020 was prepared. The first objective of the research is to analyze the land use policies under Structure Plan and second is to assess the potential flood damage using secondary data, namely Digital Elevation Model of Flood for 2020 and stage-damage functions for different major land uses with Geographic Information System grid-based approach. It was found that climate change would cause damage to property depending on type of land uses. Maximum damage estimated for residential sector is 49% and next to commercial and other sector (39%). Minimum damage is estimated to industrial sector after agriculture use. Proposed commercial land uses are recommended to review for relocation in flood free areas. This research would provide a better understating of the future flood risk and facilitate the decision makers to review the existing and proposed land uses for taking mitigation and prevention measures.

Introduction

Khulna, the third largest metropolis (about 45 km²) in Bangladesh (Khulna City Corporation, 1984) has been identified as one of the 15 most vulnerable cities under climate change impact and it has been considered as one the most vulnerable coastal cities (Roy, 2009). Location of Khulna City is shown in Figure 1. According to the land use survey undertaken for Khulna's Master plan, about 46% of the Khulna City Corporation (KCC) area is occupied by residential use and about 18% of it is agriculture. Near about 15% lands is under industrial use, small percentage (about 5%) of land is under commercial use (Khulna Development Authority, 2002b:19). The land use pattern of Khulna City has been substantially influenced by the flow of the Rupsha and Bhairab Rivers. As a deltaic plain the land is flat and poorly drained. The whole metropolitan area is approximately 2.5m above the mean sea level. The whole metropolitan area is approximately 2.5m above the mean sea level. Such low topography of the city is an obstacle to the development of a proper land use plan (Asian

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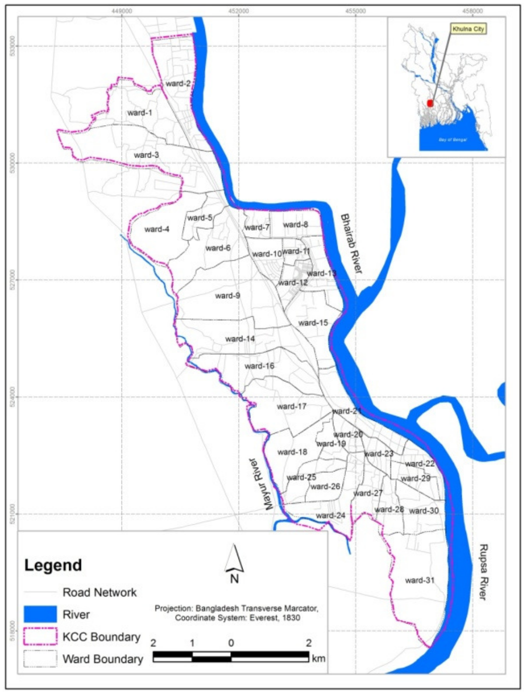
Development Bank, 2010:3). Climate change caused by sea level rise is adding to this problem and the situation is likely to be aggravated.



Source: The map is prepared by the researcher

Fig. 1: Khulna City with Respect to Bangladesh

Apart from this, the major concerns for Khulna City are frequent and increased level of floods, storm surges, intensity of cyclones, water logging, saline intrusion, and sedimentation and river erosion (Roy, 2009), which are expected to be particularly severe due to the consequences of climate change because of its geographical location. Lately, Institute of Water Modelling has carried out a study titled as "Bangladesh: Strengthening the Resilience of the Water Sector in Khulna to Climate Change" financed by Asian Development Bank. The study was developed and analyzed several climate change scenarios in order to assess the impact of climate change on the water sector of Khulna using several mathematical models. The Urban Drainage Model was able to show different water logging conditions of Khulna City. It showed that for 2020, a plausible low scenario of 10 cm was selected and a plausible high scenarios of 25 cm (Asian Development Bank, 2010:47). The model was based on different input data viz. precipitation, surface runoff, existing drainage facilities, existing catchments, sea level rise, etc. Khulna Development Authority (KDA) prepared the Urban Structure Plan in 2000 for the proper growth management of Khulna City till 2020 maintaining almost all possible factors namely transport, physical and social factors, land use etc. (Khulna Development Authority, 2002b:5). However, climate change issues were not considered. There is a pressing need to have sufficient understating of the future flood risk of this city, which can facilitate the decision makers in making timely changes in the policy of their structure plan, i.e. climate change adaptation planned.

Flood Scenario in Bangladesh

Floods are common in Bangladesh, where floodplains constitute about four-fifths of the landmass. The country is situated at the end of the catchment area of the GBM (Ganges-Brahmaputra-Meghna) river systems, occupying only about 7.5 percent of the combined catchment area. Since this small fraction of the catchment area has to manage drainage of over 92 percent of the water volume, over 80 percent of it being discharged in about five months period during the monsoon, floods frequently hit and cause havoc in the deltaic plains. Every year, Bangladesh's low-lying areas get inundated by seasonal floods. From time immemorial, people living in the delta have been experiencing rainy season and have adapted to such annual events over the centuries and found ways to take advantage of it. The 1988 and 1998 floods were the two most severe in living memory, when over 60 percent land suffered flooding and about half the population was directly affected.

Four types of floods are often observed in Bangladesh, flash floods, riverine floods, rainfall-induced floods and storm surge floods. In a hydrological year, the flooding season may start as early as May and can continue until November. The flood season generally begins with flash floods occurring as early as in late April and early May. Generally observed in the northern and eastern parts of the country, flash floods usually occur after a heavy downpour in the neighboring hills and mountains and are characterized by a very sharp rise in the water level in rivers and subsequent overbank spillage with a high flow velocity. Flash floods are also marked by a relatively rapid recession of water from the floodplains. With the onset of monsoon all the major rivers start swelling to the brim and bring flood water from upstream when rising water levels cross river banks, spillage occurs. Such events are common in every hydrological year and termed as river induced flooding.

Localized floods are often triggered by heavy rainfall episodes, either within the sub-basin or in upper catchment areas. Bangladesh receives, on an average, some 2,200 mm rainfall annually, ranging from 1,100 mm in the west to 5,000 mm or more in the northeast. Local excessive rainfall often generates high volume of runoff in the rivers and creeks in excess of their drainage capacity and termed as rainfall induced flooding. About 2.8 million hectares of the coastal areas of Bangladesh consist of large estuarine channels, extensive tidal flats and low-lying islands. Storm surges generated by tropical cyclones bring tidal bores of up to 9 meters high. Although numerous embankments protect most of the southern coastal, high tidal bores often overtop those and storm surge flood is occurred. Tropical cyclones are most likely to occur during pre- and post-monsoon periods (April-May and October-November, respectively).

Flood Damage Estimation Methods

Flood damage estimation is an important issue in urban areas especially in the coastal urban areas for the decision makers in the field of flood control, mitigation, adaptation, insurance, taking any future projects that are likely to be affected by the potential flood, assessing the Structure Plan, etc. It has been shown that there is no standardization of future flood damage methodology. Various methods are used by different organizations for different purposes without any national consensus. There are basically two methods in carrying out flood damage estimations. One is to carry out a thorough questionnaire survey of affected population and properties to estimate the incurred loss. The other is to use what are known as stage-damage functions which describe the damage extent to different types of property for a given inundation depth and inundation duration (Herath, 2003:110). In simplest word, approach to flood damage is generally two type viz. parcel-based approach and GIS grid-based approach.

The parcel-based approach keeps detailed information of the socio-economic activities, e.g. the family housing, factories and stores, etc. at parcel level. The respective stage-damage curve is then applied to each parcel with the estimated flood depth at that point for its damage assessment (Dutta and Herath, 1998:113). The regional damage is the loss sum of all parcels for the entire flooding area. The data needed for this approach including land parcel maps and socio-economic activities on each parcel. These data are multifarious and difficult to establish and maintain. This is especially true in the developing countries that suffer most often from the natural hazards like flood. This is comparatively difficult due to collecting and maintaining gigantic database of different types of data.

GIS grid-based Flood Loss Estimation approach is comparatively newer, which is used for loss estimation of post and future floods as well as for real-time loss estimation. Although a parcel-based flood damage assessment is more accurate but is also not very practical because it needs gigantic and detailed information at the parcel level. The grid-based approach requires data that are comparatively easier to collect. The grid-based approach is based on a grid data model which divides the region into grid cells of equal area. The socio-economic activities are considered to be homogeneous within each cell and are aggregated into a single value and assigned to that cell. The data needed for this model can be derived from the aggregated census data that is more available than the individual ones. The flood damage is then estimated from the average flood depth and the aggregated census data for each cell using the stage-damage curve. The regional flood damage is calculated from the summation of loss estimation of each cell.

Research Methodology

This research was largely based on data and information from secondary sources. This includes spatial distribution of potential flood due to climate change, stage-damage function curves for different land uses, land use plan and policies enunciated in the Structure Plan for Khulna Development Authority, the existing land uses and any other relevant information of the study area. At the end of the research, the outcome is validated and check by the primary data especially the field survey on different potential flood affected areas of the city and taking interviews with the city stakeholders and managers.

The key principles behind the damage assessment need to be considered carefully. Often, two approaches, such as a financial and an economic viewpoint are considered. The financial viewpoint takes into consideration the losses incurred to individual households or businesses. An economic viewpoint takes a broader perspective, considering as it does the net change in welfare to a country or a region(University of Exeter, 2011). Here the financial perspective is considered. In this research, damage obviously direct tangible flood damage, is defined as “loss of value of elements at risk (buildings, inventories, infrastructure, goods, cultural and ecological assets) compared to pre-flood conditions and loss of production caused by a flood”. Direct tangible damage can be defined as the "damage caused by direct contact with flood water that can be readily quantified in monetary terms"(University of Exeter, 2011). It is the most studied type of damage. The estimation of direct tangible damage is the collection of the data, are highly dependent on the data that are available, which is highly variable between the cities. Data types that the researcher must consider are a) inundation characteristics, b) land-use data and c) asset value data and relative damage functions or absolute damage functions.

For estimating the damage, it is necessary to assign damage functions in each grid cell. According to the land use category, damage function was assigned to each grid cell. Binary Maps for each land use were created (shown in Figure 2). Each land use on the map was showed by 0 and 1. 1 stands for the presence of a particular land use and 0 for its absence on the other hand. Four damage maps for each land use were created using stage-damage function for the respective land use. It is resulted from the functions of land use, flood depth and duration and flood damage. Flood damage maps are the resultant from adding four damage maps, which represents the probability of a particular type of land use being damaged from flooding of certain depth and duration.

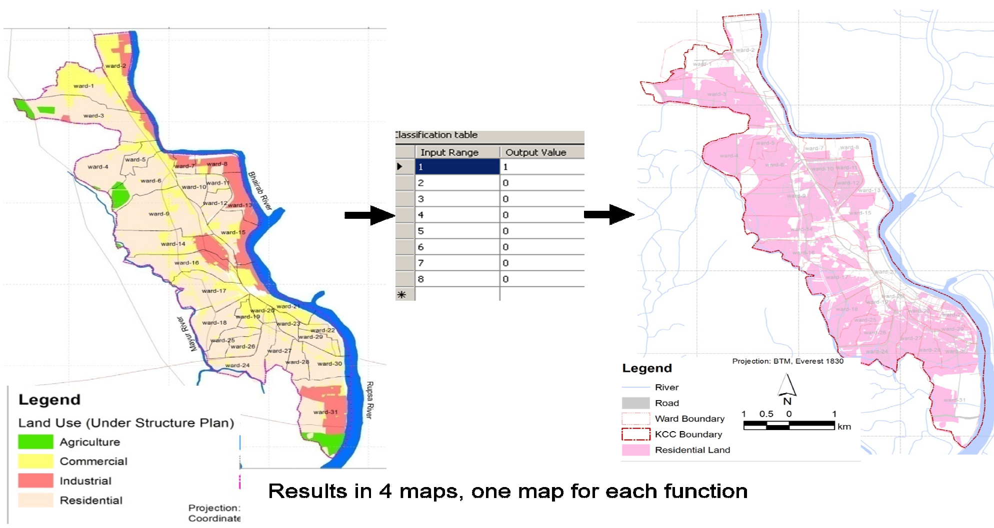


Fig. 2: Binary maps for all damage functions

Potential Flood scenario for 2020 is shown in Figure 4. Overlaying flood damage maps for 2020 upon the proposed land use of the existing plan, the appropriateness of the policies and proposals in regards to climate change induced flood effects were analyzed. In this connection, land use plan, policies and proposals were examined. At the same depth of inundation and duration, damages to the different land uses are different. Some land uses have more damage than others. This is why, depending on the calculated amount of damage due to potential flood for four major land uses, preferable land uses are proposed for minimizing loss. Finally this research provided a set of guidelines to take necessary adaptation measures regarding the development of KCC area.

This research followed several steps, which are outlined in Fig.3.

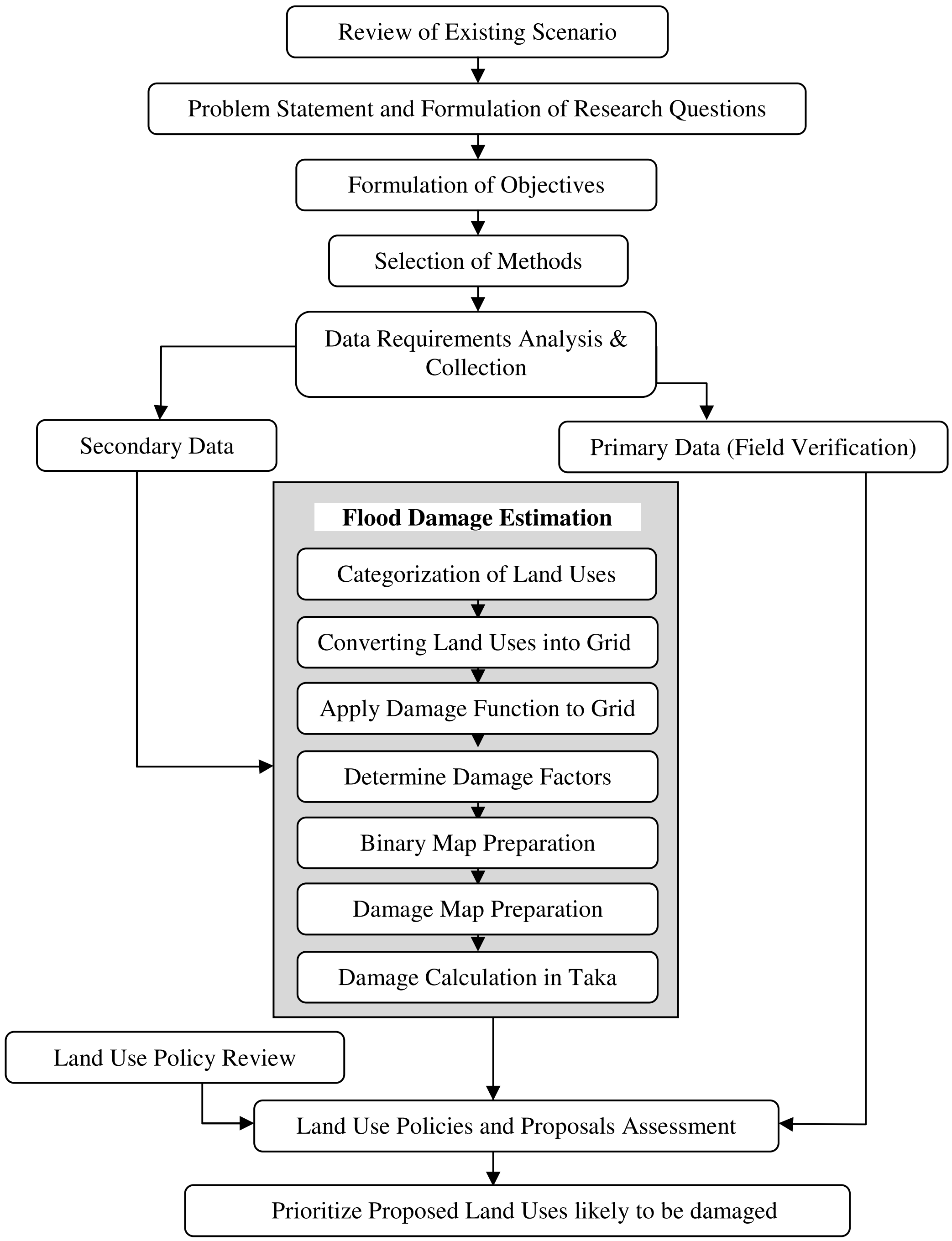
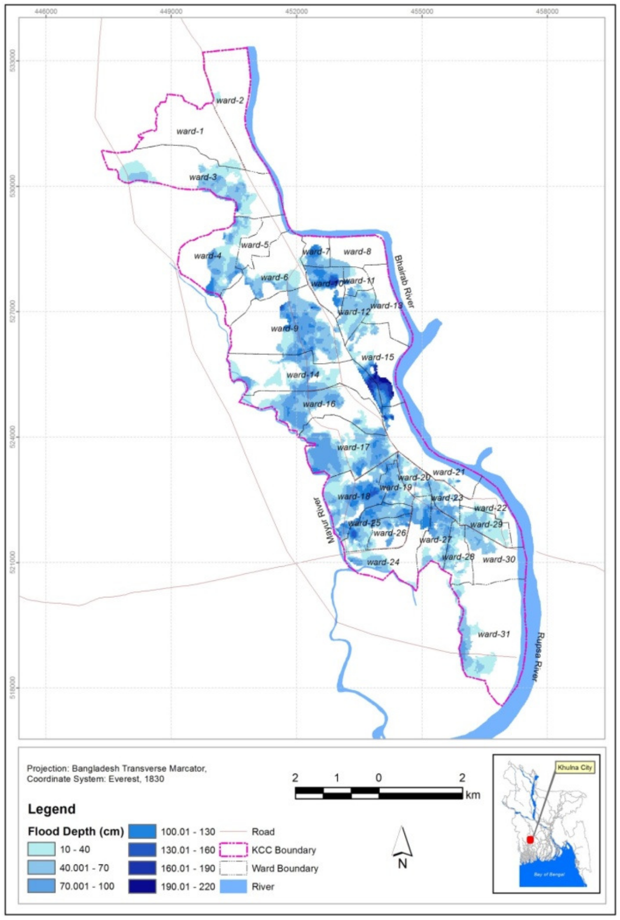


Fig. 3: Methodological Approach of the Research



Source: Asian Development Bank, 2010

Fig. 4: Flood Scenario for 2020 with Climate Change in Khulna City

Research Findings

Several supporting statements in the decision making process have come out from different perspective viz. drainage system, potential flooding, land use scenario, etc. All these findings express its performance especially the strength and weakness of the city, which will determine its future operations. Findings are outlined in the following.

a) Drainage facilities are concentrated in the core areas and its surroundings. Except natural drains, there is no man made drainage stem outside municipal areas. Drainage network is not well connected to each another.

b) There is no underground storm water drainage system within the city. Existing drainage facilities in the fringe and sub-urban areas are inadequate and unsatisfactory.

c) The KDA or KCC areas in the town are not subject to direct flooding from the Bhairab-Rupsha River, but the low-lying areas situated on the western and southern part of the city are flooded by the rain and tidal flooding during monsoon season.

d) The reasons for water logging have been identified as improper operation and maintenance of khals/drains, blockage in the existing khals/drains, absence of integrated network comprising secondary and side drains, haphazard expansion of the settlements which obstructs the natural drainage system, uncontrolled and haphazard disposal of solid waste into the drainage system and siltation in drainage channels with consequent reduction of discharge capacity.

e) Range of the potential water logging is 10 cm and 220 cm respectively. Maximum inundation area is 6.64 sq. km (37.82% of the total inundated area within the city) lies between 41 cm to 70 cm and found at all wards except 1 and 2. Average inundation flood depth is 109 cm.

f) Wards having maximum area under inundation are found at 3, 4, 9, 14, 16, 17, and 18 which are situated in the western low-lying area of the city. Maximum inundated ward is 17 located in the western low-lying area and near the city hub, which is 9.51% of the inundated area. Wards having minimum inundation are 1, 2, 5, 8, 11, 13, 21, and 22.

g) Water logging area which causes damage covers 38% area of the City. Ward 12, 18, 19 and 23 are inundated most and it is 88, 84, 95 and 94 percent consecutively of their total area. Maximum wards are inundated at average depth except 1 and 2. Percentage of the inundated area above the average inundated depth is low.

h) In the rainy season, when incessant rain occurred, the runoff did not flow to the river which entailed water congestion. Duration of this water congestion remained for 2-3 days. Plinth level of some houses was raised so that water did not flow up to the bed room or some people constructed water blocking wall around their houses.

i) Residential and commercial land uses are spread over all wards whereas agricultural land uses are limited to wards 3, 4, 6, 14 and 31. Industrial Land uses are distributed over wards 2, 3, 5-9, 11, 13-16, 21 and 31.

j) Major industrial land uses are laid beside the Rupsha-Bhairab River and commercial land uses in the main hub of the city along the major road sides. Agricultural land uses are scanty and located at the western and southern low-lying areas.

k) Agricultural land use is inundated up to 70 cm whereas commercial is up to 190 and industrial up to 160 cm. Residential land use is inundated between lowest to maximum inundation depth.

l) 6.37 sq. km land is proposed for commercial, industrial and residential land uses in the agriculture area in 2020, of which around 32% of the residential and 5% of the commercial land use will be inundated. In the proposed area of the structure plan no industrial land will be inundated. In the built-up areas around 57% of the residential and 29% of the commercial land will be inundated. 2.35% of the industrial land use will be flooded in the built environment of the city.

Recommendations

As per the Structure Plan, some low-lying areas in the western side of the city are declared as areas not suitable for future development and retained the present land use which is agriculture. Practically it has been noticed that those areas are being encroached by the people for bringing up residence and some areas have already been developed. In this context, it is necessary to strengthening the monitoring system of the city authority which will stringently take care of the policies and proposals clearly mentioned in the structure plan.

Total estimated damage on different land uses (both existing and proposed land uses) for 2020 by climate change induced flooding is Tk. 1959 million and it was estimated in 2012. This is significant amount of damage is more than the budget for 2011-2012 (Tk. 1800 million) and around one-third of the budget for 2012-2013 (Tk. 3090 million). Climate change induced flood was projected without improved drainage system. It was recommended that drainage system should be improved to tackle over drainage problems to reduce the potential damage.

Damage for four major land uses has been assessed for two scenarios viz. existing built-up areas and another is proposed areas of which the present land use is agriculture. Both areas are concern for potential urban flooding. Existing built-up areas have drainage facilities with other many facilities especially road, infrastructure, etc. To reduce the potential damage, it is not feasible to relocate the existing use in many cases. But some uses from a particular area may shift considering the potential damage. In this regard, mitigation and adaptation measures should be taken, though the net impact is not reduced to zero after implementation of adaptation measures. As such, it is important to use other auxiliary method to reduce the impact of climate change on economic and social enterprises as well as on households. Feasibility of such measures will be studied carefully during the feasibility studies of the project to be taken and a detailed plan needs to be chalked out to reduce the impacts further. Along with these, drainage conditions and drainage facilities must be augmented. Planned development is the precondition to ensure the better drainage condition with drainage facilities and finally minimizing the potential damage. On other hand, proposed areas to be damaged should be reviewed further before implementation, as at the time of policy and proposal under the structure plan preparation, climate change impact was not studied. It is good to state that no industrial locations fall under the proposed areas to be damaged by the potential flood.

Potential flood is predicted with climate change without taking any adaptation measures. This implies that potential urban flooding is predicted with taking no improvement in the future. Damage is calculated on the general land use in regards of the potential flood. If object oriented land use (building foot print areas only) is taken into the damage calculation, potential damage might be more realistic and more specific areas (building foot print) under damage will come out rather than aggregated areas. Damage is calculated based on the potential urban inundation depth for major land uses. It has been noticed from the field survey that practically in the low-lying areas people are building with plinth level high to be safe from urban flooding. As a result damage calculated in this research for those areas will be overestimated.

Conclusion

Every research has some strength with some limitations. In this connection, entire scope of the research was not achieved due to some technical limitations. Future research works can address some limitations of this study. Potential damage estimation is the toughest job due to uncertainty in the future. More precise potential damage means the damage to be occurred in future will be nearer to the reality. Potential damage is quite impossible to meet the reality in the future. To the best of knowledge and experience, the researcher tried to incorporate the maximum possible uncertain factor in predicting the potential damage. What has been carried out in this research will be the great help of other researchers who will do works in this arena.

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