

# Journal of Economics and Business

**Mohir, Md. Mohirul Islam, and Shawon, Shaolin. (2020), Prioritization of Storm Water Drain Construction for an Urban Area in the Chittagong Hill Tracts Region of Bangladesh, Vol.3, No.1, 223-231.**

ISSN 2615-3726

DOI: 10.31014/aior.1992.03.01.191

The online version of this article can be found at:  
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Published by:  
The Asian Institute of Research

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# Prioritization of Storm Water Drain Construction for an Urban Area in the Chittagong Hill Tracts Region of Bangladesh

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## Abstract

Developing the urban drainage system is now a common issue in most developing countries like Bangladesh. Due to rapid urbanization, drainage related problems are identified as high priority by Municipal residents. Therefore, Municipal Drainage System needs to be developed in such a way that it functions in the long term resulting optimization of the used resources. Storm water flood hazard due to inadequate drain is a major concern in the Municipalities in the Chittagong Hill Tracts (CHT) Regions of Bangladesh. To address the issue, drainage master plans have been prepared for the three Municipalities in the CHT under the Urban Governance and Infrastructure Improvement Project (UGIIP) of Local Government Engineering Department (LGED) funded by Asian Development Bank (ADB). Under this master plan, 78 independent drains are proposed that would be implemented over a period of 10 years. The problem of the master plan implementation is that the available fund for drain construction in each year is a fraction of the total requirement. Considering the situation, the aim of the study is to develop a priority ranking schedule for drain construction. Development of the Multi-Criteria framework for prioritization of storm drain works is the methodology for this research. The outcome of the research is the year-wise implementation schedule of drain construction over the planning period based on available funds for a particular year.

**Keywords:** Multi-Criteria Analysis, Drain Deficiency, Social Vulnerability, Priority Ranking

## 1. Introduction

Stormwater flood hazard is a growing concern in urban areas of the Chittagong Hill Tracts (CHT) of Bangladesh. The flood damage is increasing with the change in land use due to the expansion of urban areas. Because of hill topography, flooding occurs in a very short time, and the hazard is quite severe due to flash floods. The existing drains are inadequate to drain the storm runoff. With the financial assistance of ADB, drainage master plans have been prepared for three Municipalities in the CHT under the UGIIP project LGED. One of those is the Drainage Master Plan for Bandarban Municipality (LGED, 2006a). The storm runoff of Bandarban Municipality is discharged to the Sangu river that flows through the town (Figure 1). There is 26.9 km of storm drains in the Municipality Area. A total of 17.8 km of new drains has been proposed in the Master Plan (LGED, 2006a).

Geographically, Bandarban Municipality is a high land area and the town experiences flash floods of different extent almost every year. The magnitude of flood hazard depends on multiple factors such as hydrological, topographical, land use, socio-economic and environmental characteristics of the catchment. Therefore, the Multi-Criteria approach is essential for decision making regarding prioritization of storm drain works. Multi-criteria decision making in water management planning has been emphasized in the National Water Policy (Ministry of Water Resources, 1999). Development of the Multi-Criteria framework for prioritization of storm drain works is the ultimate goal under this study.

## **2. Materials and Methods**

A questionnaire survey has been carried out to assess public response to stormwater flood hazards. The survey has covered 190 households which were obtained on the basis of statistical sampling formula. The distribution of 190 households among 9 Wards is in the proportion to Ward population. The purpose of the survey is to assess the flood situation and its consequences. The respondents identified the location of the flood-affected area, causes of the stormwater flood and public life disruption due to storm waterflood.

Area-elevation relationship has been developed based on the contour map of the study area. The volume-elevation relationship has been derived from the area-elevation relation. A rainfall depth of 123 mm has been used to estimate runoff volume. Based on runoff volume, the flooded area has been identified using volume-elevation and area-elevation relationships. Besides flooding, runoff ways along hill slope areas make disruption to the public and private properties. The runoff ways along hill slope areas have been identified based on the contour map.

A total of 78 independent drains with a length of 17.8 km have been proposed in the Master Plan for Bandarban Municipality. Five criteria have been selected to represent storm flood hazards that would serve as the basis for prioritization of drain construction. These criteria are drain deficiency, flood magnitude, population suffering, damage characteristics, and social vulnerability. The magnitude of five criteria has been calculated for every drain. The standardized value of each criterion is added for a drain to get a total score for the drain with the help of the Linear Additive Model. The scores of 78 drains are ranked in order of decreasing magnitude, and the rank represents priority order. The series of 78 ranks is to be divided into 10 segments to set the year-wise implementation schedule of 78 drains over 10 years. The segments are to be such that the total drains in a segment can be implemented using the budget for that year.

## **3. Objectives of the Study**

The objectives of the study are as follows :

- i) to predict inundation area and consequent damage due to stormwater flooding in the selected urban area in the CHT, and
- ii) to develop indicators for multi-criteria assessment of storm flood hazard for the prioritization of storm drain construction over the planning period in the study area.

## **4. Chittagong Hill Tracts**

Chittagong Hill Tracts (CHT) is the main hill area in Bangladesh and it is covered by tertiary hills. It is located in the southeast part of the country (Figure 1), comprised of Rangamati, Khagrachari and Bandarban hill districts and consists of 25 upazilas of Bangladesh. The population of CHT is 13,42,740 (BBS, 2001). It has an area of 13,180 sq.km, making up approximately 10% of the total area of Bangladesh. Although the population density in this region is as low as 102 persons/sq.km, the ratio of cultivable land per person in CHT region is only 1.04 hectare as most part of the region is covered with numerous hills, ravines, cliffs and dense vegetation (LGED, 2006b). The soils are characterized by low fertility. Tasing-Dong, the highest peak of Bangladesh is located in the Bandarban district.

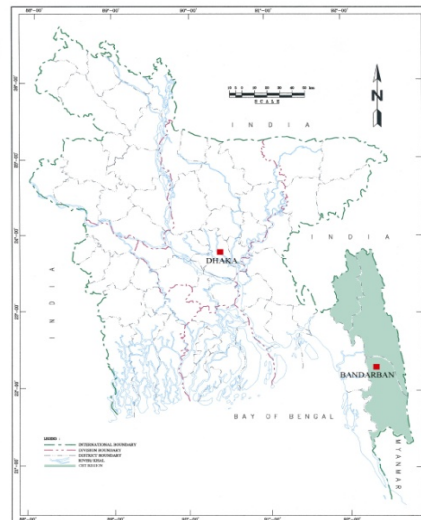


Figure 1 : Chittagong Hill Tracts Regions of Bangladesh

The tribal people who differ culturally from the majority population of Bangladesh are predominantly Buddhists, with small numbers of Hindus. They differ linguistically and in their social organization, marriage customs, birth and death rites, food, agriculture techniques and other social and cultural customs from the people of the rest of the country. According to numbers, the Chakma remains the dominant followed by Marma, Tripura, Tanchangya, Mro, Bawm, Khyang, Pankhu, Khumi, Lushai, Chak and others.

## 5. Study Area

Bandarban, Khagrachari, and Rangamati were originally a sub-division of Chittagong Hill Tracts District. Bandarban sub-division emerged as a district on the 4<sup>th</sup> April 1981 and Bandarban Municipality was established in May 1984. Drainage master plans have been prepared for Bandarban, Rangamati and Khagrachari Municipalities in the CHT under the Urban Governance and Infrastructure Improvement Project (UGIIP) of Local Government Engineering Department (LGED). Considering the availability of secondary data and maps, Bandarban Municipality has been selected as the study area.

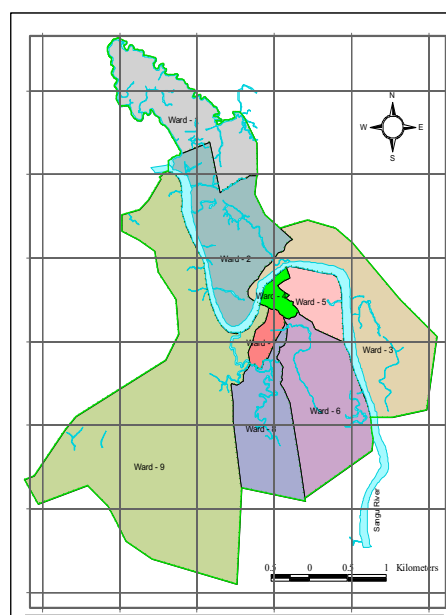


Figure 2 : Bandarban Municipality of Bangladesh

## 6. Existing Storm Drains

To drain the storm runoff from urban catchments, some drains have been constructed. There is 26.89 km of storm drains in the Bandarban Municipality area. The drain system in Bandarban Municipality is not network type. There is no branching. Every drain is a single branch drain and discharges stormwater individually from a particular catchment directly to khal / river. Major portion of the drains have been constructed with the Government contribution to development program. Also during recent years, drains have been implemented under the Municipal Service Project (MSP) of LGED. The distributions of existing drains among different wards are presented in Table 1.

Table 1 : Distribution of existing storm drains of Bandarban Municipality

Ward No	Existing Drains		Proposed Drains	
	No of drains	Total Length (m)	No of drains	Total Length (m)
1	5	1535	20	4400
2	7	3794	03	535
3	6	2051	10	1699
4	20	1367	05	614
5	16	2681	14	3475
6	17	7380	08	3316
7	9	3724	05	1407
8	4	1603	05	1067
9	5	2750	08	1280
Total	89	26885	78	17793

Source : LGED, 2006a

## 7. Introduction to Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex multi-criteria problems that include qualitative and quantitative aspects of the problem in the decision-making process (Mendoza and Macoun, 1999). It is the formal technique recommended for evaluating strategies and ranking them according to multiple decision criteria. MCA is a comprehensive and effective means of structuring a decision problem by providing a transparent method of determining objectives and criteria. It serves as an ideal platform for participatory planning, involving stakeholders, technical experts and analysts. Another important advantage of MCA is that it does not require all effects to be translated into a common unit of value or significance. This allows the analyst to work with different kinds of indicators and units of measurement. National Water Policy of Bangladesh (Ministry of Water Resources, 1999) has emphasized multi-criteria decision making in water management.

## 8. Steps of Multi-Criteria Analysis

The following steps are generally followed for conducting a Multi-Criteria Analysis:

- Determination of the scores with respect to the criteria
- Determination of the standardized scores
- Determination of the weights for criteria
- Ranking based on the total score

In Multi-Criteria Analysis, the score of each criterion is multiplied by the weight of that criterion and then all those weighted scores are added together to get overall value.

## 9. Scale of Criteria Measurement

Five criteria have been selected to assess extent of storm flood hazard. List of criteria and their indicators is given in Table 2. A scale of 0 to 20 has been adopted for every criteria so that the range of total score based on five

criteria becomes 0 to 100. The values of the criteria have been standardized to express their magnitude in the range of 0 to 1. Then the standardized value has been multiplied by 20 to bring in the scale of 0 to 20. Logic behind the criteria selection and the procedure followed to estimate their magnitude are discussed in the following section.

### 9.1 Drain Deficiency Criterion

Absence of drain is the main cause of storm waterflood. The shortage of drain in a Ward is the indicator of drain deficiency. The Ward with a greater shortage is likely to be more prone to storm floods. Therefore the Ward with less drain facility should get higher priority in drain construction.

This criterion has been calculated by the following equation.

$$DD_k = [1 - (E_k / T_k)] * 20 \quad \dots\dots\dots \blacktriangleright (1)$$

Where,  $DD_k$  = Drain Deficiency in the k-th Ward

$E_k$  = Length of existing drain in meter in the k-th Ward

$P_k$  = Length of proposed drain in meter in the k-th Ward

$T_k$  = Length of total requirement of drain in meter in the k-th Ward  
 $= E_k + P_k$

### 9.2 Flood Magnitude Criterion

Flood hazard is also dependent on flood magnitude which is reflected by flooded area and depth of flood. The intensity of hazard increases with the increase of flood depth. It has been known from the consultation meeting with local people that no damage has been occurred for less than 0.3m flood depth. A minimum flood depth of 0.3m has been considered as a threshold value for flood hazard. The magnitude of this criterion has been standardized by dividing by the largest value among all drain catchments. This criterion has been calculated by the following equation.

$$FM_i = (A_i / A_{max}) * 20 \quad \dots\dots\dots \blacktriangleright (2)$$

Where,  $FM_i$  = Value of flood magnitude criterion for the catchment of i-th drain.

$A_i$  = Area in hector in the catchment of i-th drain subject to flood depth of at least 0.3m or runoff way in hills

$A_{max}$  = Maximum value of  $A_i$  among all drain catchment.

### 9.3 Population Suffering Criterion

People living in the area subject to storm flood suffer directly by the flood. This type of suffering is a major concern. The number of people in the flooded area of the catchment of drain has been considered as an indicator of this criterion. But it is a difficult task to measure the actual number of people in the flooded part of a catchment of a proposed drain. To overcome the problem, the population density of a Municipality's Ward as per Community Series of Bangladesh Bureau of Statistics (BBS, 2001) has been used to estimate the number of people in the flooded area. The area subject to flood is multiplied by population density of a Ward to get the number of the population exposed to flood. The magnitude of these criteria has been standardized by dividing by the largest value among all drain catchments.

This criterion has been calculated by the following equation.

$$PS_i = (NP_i / NP_{max}) * 20 \quad \dots\dots\dots \blacktriangleright (3)$$

Where,  $PS_i$  = Value of population suffering criterion for the catchment of i-th drain.

$NP_i$  = Number of population exposed to flooding or runoff way in hills in the catchment of i-th drain.

$NP_{max}$  = Maximum value of  $NP_i$  among all drain catchments.

#### 9.4 Damage Characteristics Criterion

Flood damage depends on the land use distribution in the flooded area. So the land use distribution in the flooded area has been taken as the indicator of flood damage characteristics. Land use has been grouped into three categories: commercial, residential and agricultural/forest. Storm flood damage data is not available for Bandarban Municipality. Weighting factors for different land use categories have been estimated based on observed damage cost per unit land area for land use categories in Dhaka City (JICA, 1991). The estimated weighting coefficients are 0.60, 0.33 and 0.07 for commercial, residential and agricultural / forestry land use respectively. The magnitude of the damage characteristic criterion has been standardized by dividing by the largest value among all drain catchments. This criterion has been calculated by the following equation.

$$DC_i = (DM_i / DM_{max}) * 20 \quad \dots\dots\dots \rightarrow (4a)$$

$$DM_i = A_{c-i} * 0.60 + A_{r-i} * 0.33 + A_{a-i} * 0.07 \quad \dots\dots\dots \rightarrow (4b)$$

Where,

$DC_i$  = Value of damage characteristics criterion in the catchment of the i-th drain.

$DM_i$  = Value of damage for flooding in the catchment of i-th drain.

$A_{c-i}$  = Area in hectare of the Commercial Land in the flooded catchment or runoff way in hills of the i-th drain.

$A_{r-i}$  = Area in hectare of the Residential Land in the flooded catchment or runoff way in hills of the i-th drain.

$A_{a-i}$  = Area in hectare of the Agricultural / Forest Land in the flooded catchment or runoff way in hills of the i-th drain.

$DM_{max}$  = Maximum value of  $DM_i$  among all drain catchments.

#### 9.5 Social Vulnerability Criteria

The poor people, particularly the slum dwellers, are most vulnerable to flood hazards. It takes quite a long time for them to recover from the disruption due to flood hazards. The equity principle emphasizes attention to vulnerable sections of the society because of their inability to withstand the adverse impacts of hazards. So the slum area needs special attention in flood hazard management. The Poverty Reduction Strategy Paper (Planning Commission, 2005) also emphasized access to physical infrastructure facilities for poor women, slum-dwellers and poor neighborhoods.

The total population of slum areas in Bandarban Municipality is 2,380 and the total number of households is 567 as discussed in section 2.3.3. There are 29 slums in Bandarban Municipality which are characterized by a severe lack of basic amenities like roads, drainage, street light, dustbins, water supply, tubewell, sanitary latrines and others (LGED, 2005a). The slum dwellers suffer from different types of diseases. To improve the environment of the slum area, storm drainage facilities need to be implemented on a priority basis. The number of slum households in the catchment of a drain has been collected from Poverty Reduction Action Plan (LGED, 2005a).

Social vulnerability criterion has been calculated along with standardization by the following equation.

$$SV_i = (NS_i / NS_{max}) * 20 \quad \dots\dots\dots \rightarrow (5)$$

Where,  $SV_i$  = Value of the social vulnerability criterion for the catchment of the i-th drain.

$NS_i$  = Number of slum households in the catchment of i-th drain.

$NS_{max}$  = Maximum value of  $NS_i$  among all drain catchments.

Table 2 : Criteria and Indicators for Flood Hazard Assessment

Criteria	Indicator
Drain Deficiency	Shortage of drain in percent of total requirement
Flood Magnitude	(a) Area subject to runoff way in hill slope area
	(b) Area subject to at least 0.3m of flood depth
Population Suffering	(a) Number of population in the runoff way in hill slope area
	(b) Number of population in the flooded area
Damage Characteristics	(a) Landuse distribution in the runoff way in hill slope area
	(b) Landuse distribution in the flooded area.
Social Vulnerability	Number of slum household in the catchment of proposed drain.

## 10. Procedure of Multi-Criteria Prioritization of Drain Works

The storm drain network in Bandarban Municipality consists of individual drain system. There is no branching in the network. Every individual drain discharges directly to the canal or river. Every proposed drain ranked separately based on the following equation.

$$S_i = DD_k + FM_i + PS_i + DC_i + SV_i \quad \dots\dots\dots \rightarrow (6)$$

Where  $S_i$  is the score of the  $i$ -th drain. Values of the five indicators in the right hand side of the equation have been calculated based on equation (1) to (5). Values of  $DD_k$  are equal for all drains in the  $k$ -th Ward. The scale of  $S_i$  is 0 to 100.

## 11. Priority Ranking of Drain Construction

The steps of calculation are shown shortly in Figure 3.

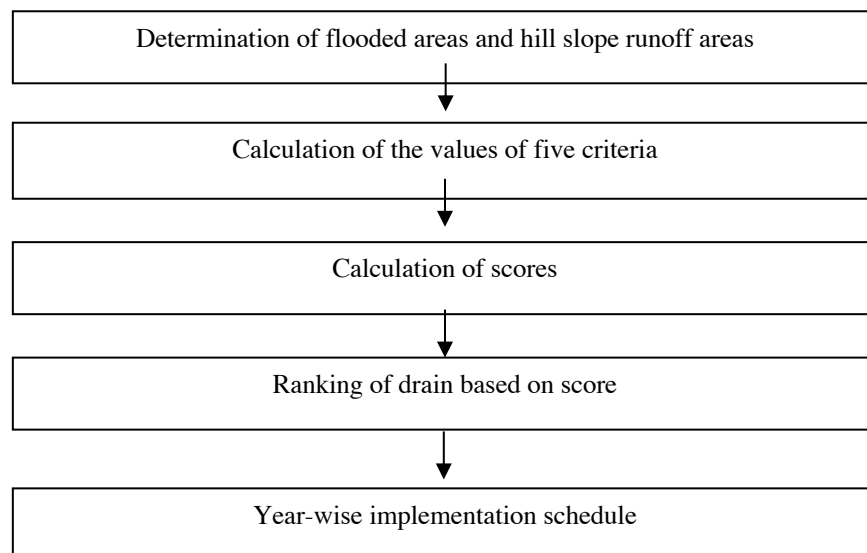


Figure 3 : Main Steps of Multi Criteria Prioritization

## 12. Year-wise Implementation Schedule

How many drains can be constructed in a year is dependent on the available budget for that year. So the year-wise implementation schedule of drain construction over the planning period is to be determined based on year-wise budget. The ranked series of drains are to be divided into segments, and the number of segment is equal to the



number of year in the planning period. The segmentation is to be made such that the total drain length in a segment can be implemented using the budget available for the year.

Table 3 : Storm Drain Implementation Schedule

Implementation Year	Drain to be constructed in different Wards									
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	Total Length (m)
1 <sup>st</sup>						60				2.70
2 <sup>nd</sup>	17		25		50, 44	54	64			1.93
3 <sup>rd</sup>	1				49	55		66	75, 72	1.62
4 <sup>th</sup>	3		24		43, 41, 51, 40					1.71
5 <sup>th</sup>	20, 12, 18		26, 29, 27		45, 42			67, 68		1.90
6 <sup>th</sup>	14, 10, 16, 19, 15, 8	21			52		65		78, 77, 73	1.78
7 <sup>th</sup>	11, 7, 9				39		61, 63	69		1.52
8 <sup>th</sup>	2, 4, 6		32, 31	35, 36			62		71	1.72
9 <sup>th</sup>	13, 5	22	33, 30, 28		46, 47, 48	58, 57		70		1.75
10 <sup>th</sup>		23		38, 37, 34		53, 56, 59			78, 74	1.16
Total Length (m)	4.40	0.54	1.70	0.61	3.48	3.31	1.40	1.07	1.28	17.79

### 13. Conclusion

Storm water flood hazard during monsoon is a major concern in Bandarban Municipality. Responses received from 190 households during a questionnaire survey, reveal that 33 out of 67 paras get flooded during monsoon. The main causes of floods are the absence of drain and lack of proper operation and maintenance of drain. The major consequences are an inconvenience to movement, damage due to intrusion of floodwater into home/market and environmental sufferings.

To overcome the problem of the non-availability of the data on flooded areas, the prediction of the flooded area has been made based on the contour map. Prediction for a rainfall of 123 mm shows that 5.32% areas of the topographic zones get flooded. Major portion of non-flooded area is hill area. The high slope areas also suffer from damage because of heavy runoff flow.

Main outcome of this study is the development of a multi-criteria decision aid to determine the priority order of the storm drain to be constructed in the future. Five criteria have been selected to represent storm flood hazards that serve as the basis for prioritization. The criteria are drain deficiency, flood magnitude, population suffering, damage characteristics, and social vulnerability. The 78 new drains that are to be constructed over 10 years in Bandarban Municipality, has been ranked in priority order by applying the method. The ranked series is to be divided into 10 segments such that the total length of drains in a segment can be implemented using the budget available for the year corresponding to that segment.

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