M. A. Ali, S. M. Seraj and S. Ahmad (eds): ISBN 984-823-002-5

Delineation of Flood Damaged Zones of Dhaka City Based on the 1998 Flood by Using GIS

Mohammad A. Mohit and Shakil Akther
Department of Urban and Regional Planning
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

Abstract

The 1998 flood in Bangladesh was an unprecedented event of its kind in terms of duration, inundation of areas and damages. In Dhaka City alone, more than 70% of the city area was inundated and about 60% city population was under inundation for about 10 weeks – the longest time in memory. The city experienced colossal loses in housing, infrastructure, industry, commerce and education sectors. The total damage was estimated at Taka 2.0 billion or US$ 41.0 million. The experience of the 1998 flood suggests that the city has to be saved from recurrent floods by adopting both structural and non-structural measures for flood mitigation. Since structural measures are very expensive and time-consuming, non-structural measures such as flood damage zoning may provide a basis for planning disaster mitigation in the city. Considering this, the present study has attempted to delineate the 1998 flood affected city wards into three flood damage zones based on composite damage value derived from five sectors of the city. These flood damage zones are: low, moderate and high. The planning implications of this zoning exercise are – direct development at safer places of the city, and formulation of land use policies and planning standards to guide development in low and moderate flood damage zones so that the city suffers minimum damages from future floods.

INTRODUCTION

Although Bangladesh is predominantly a rural country with 75 per cent people living in rural area compared to 25 per cent of urban population, flooding

problems are serious in city areas because of high population densities and inadequate drainage facilities. Along with concentration of population, cities of Bangladesh have concentration of large-scale investments relating to housing, infrastructure, industry and commerce. Dhaka, the capital city, as well as the largest administrative, commercial and industrial centre, alone has a population of over 8.0 million which accounts for about 33.0 per cent of the national urban population (World Bank, 1999) Of the total manufacturing establishments, 44.6 per cent are concentrated in Dhaka region which accounts for 50 per cent of the manufacturing sector employment (BBS, 1998). The metropolitan district of Dhaka accounted for 32.1 per cent of GDP in the manufacturing sector including 36.8 per cent of GDP generated by the large-scale industry sector in 1996-97. In total, 16.7 per cent of GDP of the country are generated by the Dhaka metropolitan city (BBS, 1998). Therefore, the potential of loss of GDP due to flood is very high in Dhaka City compared to other areas of Bangladesh.

FLOOD IN DHAKA CITY

The occurrence of floods in and around Dhaka City can be traced back to as early in 1787-88 when terrible inundation occurred and the streets of Dhaka were submerged to a depth sufficient to admit boats sailing along them (Hunter, 1877). Again in 1833-34, 1870 devastation due to floods were reported (Hunter, 1877). Major floods also occurred in 1954, 1955, 1962 and 1966, which severely affected the city of Dhaka (Rizvi, 1969). Floods that occurred during 1970, 1974, 1987, 1988 and 1998 also affected the city. Among these the floods of 1988 and 1998 were catastrophic. It was estimated that about 77 per cent of city area were submerged to depths ranging between 0.3 to over 4.5 metres and that about 60 per cent of city population were directly affected in the 1988 flood (FAP, 1991). The return period for a 1988 flood was estimated at 70 years but in just 10 years another flood occurred in 1998.

The 1998 flood of Bangladesh was an unprecedented event of its kind in terms of duration, inundation of areas and damages (DMB, 1998). It was estimated that 79 per cent of Dhaka City area were inundated ranging between 0.3 to over 3.0 metres and that about 60 per cent city population were under inundation for about 10 weeks – the longest time in memory. The city experienced colossal loses in housing, infrastructure, industry and commerce sectors. According to DCC estimates, two-thirds of the city roads and 75% of *kutcha* and semi-*pucca* houses were affected in the flood. It was reported that 1000 km of city streets, 400 km of drains, 40 km of foot paths, 400 switch points and 1 lock gate were affected and these were estimated at Taka 4.0 billion or US$

89 million (DCC, 1998). The total damage in housing sector was estimated at Taka 2310.9 million or US$ 48.2 million (Islam, 1998).

Poor drainage has been identified as the principal cause of flooding in the metropolitan areas of Bangladesh. Flooding in Dhaka City is mainly caused by heavy rainfall, drainage congestion, high surrounding water and overflow of rivers. In whatever way flood occurs, it disrupts city life and inflicts major damages. Local flooding due to poor drainage affects 65 per cent of slums and squatter dwellers and 22 per cent of city dwellers are regularly flooded during minor rainfall (FAP, 1991).

FLOOD DISASTER MANAGEMENT IN DHAKA CITY

Flood disaster management (FDM) in Dhaka City has been attempted through the construction of embankments along the rivers. The Buckland Bund was the earliest attempt to protect the city from the overflows of river Buriganga. The unprecedented flood of 1988 in the country in general and in Dhaka City in particular, led to the adoption of several structural measures to mitigate future flood disaster in the city. Immediately after the flood, the then Government undertook a plan to protect Dhaka from the intrusion of flood water from surrounding areas and drain out internal storm water run off due to local rainfall. Thirteen projects constituting eight types of flood control facilities including embankment (34 km), flood-wall (37 km), sluice (10 nos), pump house (2 nos), canal cleaning (13 nos), road construction (2.2 km), road raising (8.5 km) and restoration of sewerage, at a cost of US$ 142.6 million.

The effectiveness of these measures became evident during the flood of 1998. While the western part of the city remained flood free, the eastern part of Dhaka suffered the severe devastation due to lack of an embankment. Several studies have been done to examine the prospect of constructing an embankment-cum road by-pass at the eastern side of Dhaka. It will be a huge project in terms of monetary involvement and technical feasibility needs to be reassessed.

Flood plain zoning is basically a non-structural approach used to mitigate flood damages as a precautionary measure. Its necessity as a flood mitigation measure was assessed in the French Consortium Study undertaken after the 1988 flood. Nevertheless, none of the FAP study seriously considered it. Flood zoning is an established disaster mitigation measure widely used in countries such as USA and Japan. In Bangladesh, very few studies have been conducted to apply flood zoning as a policy making tool (BUET/JICA, 1987). These studies are mostly confined to national level analysis. In a few cyclone studies, zoning concept has been used to indicate risk and policy formulations (UNDP/WB/GoB, 1993). Urban flood zoning has not been attempted in Bangladesh. However, the

potential of urban flood zoning remains as a non-structural measure for the mitigation of flood disaster in urban/city areas of Bangladesh.

OBJECTIVES

The main purpose of the study was to delineate flood damage zones, which will provide a basis for flood disaster management of Dhaka City, and hence the following objectives were set for the study:

a. To collect data on the flood damages that occurred in different sectors of the city;
b. To identify the city areas where these flood damages have occurred; and
c. To delineate city areas vulnerable to flood disaster and damages.

METHODOLOGY

Methodology of the study was developed with due consideration to achieve the objectives of the research. As such the following methodological procedures were adopted.

Identification of Flood Affected Areas/Wards

The Dhaka City Corporation office was visited just after the flood to collect information about areas inundated during 1998 flood. A reconnaissance survey was made to gather preliminary information about the flood-affected areas of the city. Ward commissioners were contacted and details of flooding and extent of damages were recorded. These communications enabled identification of 64 wards (out of 90) which were variously affected during the flood of 1998.

Assessment of Sectoral Damages

For assessing sectoral damages of the city, following approaches were adopted:

(i) Collection of Official Records: From the zonal offices of DCC, ward-specific damage data were collected on roads and other infrastructures, persons affected, evacuated and sheltered. Despite this, it became necessary to get flood-specific damage data through field survey.

(ii) Questionnaire Survey: A questionnaire was prepared for collecting ward-wise damage data covering five sectors – housing, educational institutions, commerce, industry and roads. In the housing sector, the sub-sectors were *pucca*, semi-*pucca* and *kutcha* houses. In the education

sector, the sub-sectors were primary and secondary schools and colleges. The sub-sector covered in the commerce sector included shops only. Industry sector included both large and small and the roads sector included all local, arterial and collector roads. Ward commissioners were the respondents for the questionnaire survey and so they were interviewed very thoroughly. In addition to questionnaire survey, discussions were held with local leaders in order to crosscheck information and also to record their suggestions about flood mitigation measures.

(iii) Imputation of Damages: Both ratio method i.e., percentage of units damaged and its monetary value in local currency were used to measure extent of damage. Thus, imputation rather than physical unit was used to record sectoral damages for the study.

Data Analysis

Simple statistical tools such as mean, median, mode, min/max values, were utilised to make the data meaningful. Spreadsheet method such as Excel was used for this purpose. PC version SPSS has been used to calculate correlation matrix among the variables.

Digitizing of City Map

A copy of the Dhaka City Corporation map showing 90 wards (Fig. 1a) was collected from DCC. This map was digitised at three covers (layers) – (a) a cover (layer) with ward boundaries, (b) a cover (layer) with water bodies, and (c) a cover (layer) with embankment.

Preparation of Sectoral Damage Maps

Based on the percentage of units, sectoral damage maps were prepared. These maps show the extent of damages in different sectors and their spatial distribution by wards of DCC. Such an exercise provided the inputs for the zoning exercise.

Preparation of Composite Damage Map and Zoning Exercise

A composite damage map was prepared based on the total value of damages of all the sectors combined. This map shows the extent of total damages and their spatial distribution by wards of DCC. Such an exercise has profound planning and policy-making implications. Nevertheless, the present flood damage zoning exercise has been based on the 1998 damage data only; longitudinal data of damages resulting from floods which occurred at different time periods could provide a better data base for flood zoning exercise.

ANALYSIS OF SECTORAL DAMAGES

The water of 1998 flood entered Dhaka City area on 15 July 1998 and continued to rise and the total duration of the flood was 3 months or 90 days. Sixty-four Wards out of 90 were inundated to different extent during the flood. Whereas 24 Wards experienced normal flooding with upto 20 per cent area inundated, 9 Wards experienced high-to-severe flooding and 31 Wards suffered catastrophic flooding. In 11 Wards, 100 per cent area was inundated. The extent of flood inundation presented in Fig. 1(b) shows that the city wards lying in the eastern periphery and those in the western periphery but outside the embankment faced severe inundation from the 1998 flood. The minimum depth of flood was recorded at 13cm while average depth was 1 metre and the highest depth was 3.66 metres. Apart from depth, the duration of 1998 flood was exceptional. The minimum duration of 10 days was recorded in only one Ward, but maximum duration was 90 days and average duration was 56 days. Thirty-seven Wards experienced flood duration above the average. The correlation coefficient of depth-duration relationship has been estimated at 0.56. Both depth and duration of flooding inflicted sectoral damage, which has been the concern of subsequent discussion of the study.

Housing Sector Damage And Its Spatial Distribution

The housing sector of Dhaka City covers three types of houses – *pucca*, semi-*pucca*, and *kutcha*. 43 per cent of *pucca*, 53 per cent of semi-*pucca* and 71 per cent of *kutcha* houses of the city suffered damages during the 1998 flood. Average damage value of a *pucca* house was Tk. 8,001, of a semi-*pucca* house was Tk. 4,838 and of a *kutcha* house was Tk. 3,156. The city experienced housing damages in different degrees in its 64 Wards. Sixty-three Wards out of 64 experienced damages in *pucca*, semi-*pucca* and *kutcha* houses. While 1 per cent damage of *pucca* house occurred in Ward-5, 10 Wards experienced 100 per cent damages of *pucca* houses and 11 Wards experienced damages of *pucca* houses above the average of 43%. Similarly, there was a 1 per cent damage of semi-*pucca* house in Ward-68, but 11 Wards had 100 per cent damages of semi-*pucca* houses and 15 Wards experienced damages in semi-*pucca* houses above the average of 53%. Again, there was a minimum of 6 per cent damage of *kutcha* house in Ward-5, but 28 Wards had 100 per cent damage of their *kutcha* houses and 7 Wards experienced damages in *kutcha* houses above the average of 72%. It thus appears that *kutcha* houses and semi-*pucca* houses were vulnerable during the 1998 flood.

Damage value data presented in Table 1 shows that while 50% of flood affected wards suffered low housing damages and 19% faced moderate damages, 30% of wards faced severe damages of more than Taka 10 million each. The

spatial distribution of affected wards that experienced housing damages [Fig.1(c)] shows that the wards located at the eastern periphery and those outside the embankment at the western and southern periphery faced severe housing damages compared to the wards located at the centre of the city.

Table 1: Distribution of city wards by housing, education, road, industry and shopping sector damages during 1998 flood.

Damage (Million Taka)	Sector				
	Housing No. of wards	Education No. of wards	Road No. of wards	Industry No. of wards	Shopping No. of wards
No damage	1(1.6)	2(3.1)	5(7.8)	12(18.7)	12(18.7)
Upto 2.5ml	17(26.6)	34(53.0)	25(39.0)	34(53.0)	20(31.2)
2.6-5.0	15(23.4)	10(15.7)	7(11.0)	10(15.7)	10(15.7)
5.1-7.5	8(12.5)	10(15.7)	5(7.8)	3(4.7)	12(18.7)
7.6-10.0	4(6.2)	2(3.1)	11(17.2)	1(1.6)	2(3.1)
10.1-above	19(29.7)	6(9.4)	11(17.2)	4(6.2)	8(12.5)
Total:	64(100.0)	64(100.0)	64(100.0)	64(100.0)	64(100.0)

Note: Figures within bracket indicate percentage.

Damages in Education Sector And Its Spatial Distribution

The education sector of Dhaka City consists of primary schools, secondary schools, and colleges. These sub-sectors suffered damages both due to floodwater and for being used as flood shelters during flood time. Forty-six percent of primary schools, 62 percent of secondary schools and 36 percent of colleges of the affected Wards of the city suffered damages worth Taka 19.0, 8.0 and 3.5 millions, respectively. Average damage values estimated for a primary school, a secondary school and a college were Taka 70,500/-, 82,500/- and 111,300/-, respectively. Ward-wise damages suffered by different sub-sectors were varied. Whereas four wards did not experience damage in primary schools, Ward-6 suffered a minimum of 4% damage, 24 Wards had 100% of their primary schools damaged and an additional 15 Wards had primary schools damaged above the average. In the secondary school sub-sector, 15 Wards did not experience any damage and Ward-6 experienced the minimum damage of 17%, but 29 Wards experienced 100 percent damages each and an additional 6 Wards experienced damages above the average of 62%. In the college sub-sector, 22 Wards experienced damages. Ward-48 suffered a minimum of 13% damage and 16 Wards faced 100% damage; 4 wards suffered damages above average. It thus appears that damages in the college sub-sector were concentrated to 22 (34.4%) wards.

The loses which occurred in the education sector due to 1998 flood (Table 1) shows that whereas 69% wards experienced lower level of damages and 19% wards suffered medium level of damages, 9% of wards suffered high level of damages whose value exceeded Tk 10.0 million each. The spatial distribution of damages in the education sector [Fig. 1(d)] shows that the wards at the eastern periphery and those lying outside the embankment at the southern periphery including some centrally located wards suffered severe flood damages in their education sectors. One reason for centrally located wards being suffered was their involvement in the flood shelter programme.

Infrastructure Damages And Its Spatial Distribution

Infrastructure under the control of Dhaka City Corporation consists of roads, drains and footpaths. The 64 Wards, which were inundated during 1998 flood, had 932 km of roads, of which 303 km or (33%) suffered damages (DCC, 1998). The total value of damaged roads has been estimated at Taka 410 million. However, the extent of road damage by wards was quite varied. The minimum road damage of 2% occurred in Ward-78 and the maximum of 100% damages were experienced in 10 wards. 18 wards experienced road damages above the average of 33%. Average damage value of road has been estimated at Taka 1.62 per kilometer. Minimum road damage of Tk. 37,500/km occurred in Ward-37, but highest per kilometer damage of Tk. 8.0 million was reported in Ward-34. 18 Wards experienced road damages above the average of Tk. 6.96 million. 51 kilometers of drains were damaged during the flood and 27 Wards suffered the damage. The highest damage of 12 km was experienced by Ward-19 and the minimum of 0.21 occurred in Ward-20. Average drain damage was estimated at 1.87 km and 8 Wards suffered drain damages above the average. 11 Wards of Dhaka City Corporation suffered damages of their footpaths. The minimum of 0.26 km damage of footpath occurred in Ward-30 and maximum footpath damage of 5 km occurred in Ward-73. Average footpath damage was estimated at 1.8 km and 5 Wards experienced damages in footpaths above the average.

The distribution of total loss resulting from road damages presented in Table 1 shows that a significant number of wards did not experience any damage in this sector. Whereas 32 (50%) wards suffered low damages and 16 (25%) wards suffered medium level of damages, 17% (11) Wards suffered severe damages in this sector. The spatial damage distribution of roads presented in Fig. 2(a) shows that the wards at the eastern periphery and those lying outside the embankment at the southern periphery including a few centrally located wards suffered severe flood damages in the road sector

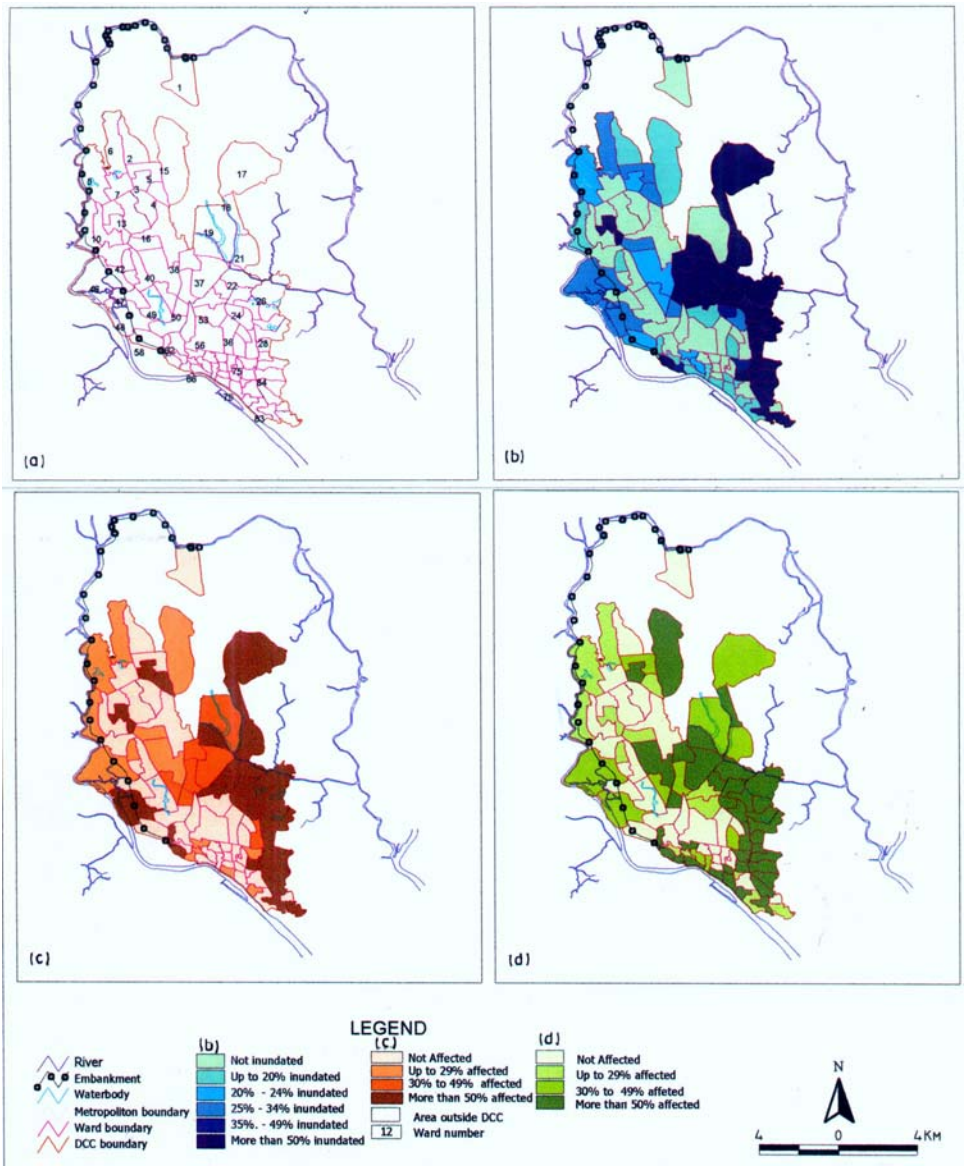

Figure 1: (a) 1998 Ward map of DCC, (b) Inundation of Dhaka City during 1998 Flood, (c) Housing damages in Dhaka City, (d) Education sector damages in Dhaka City

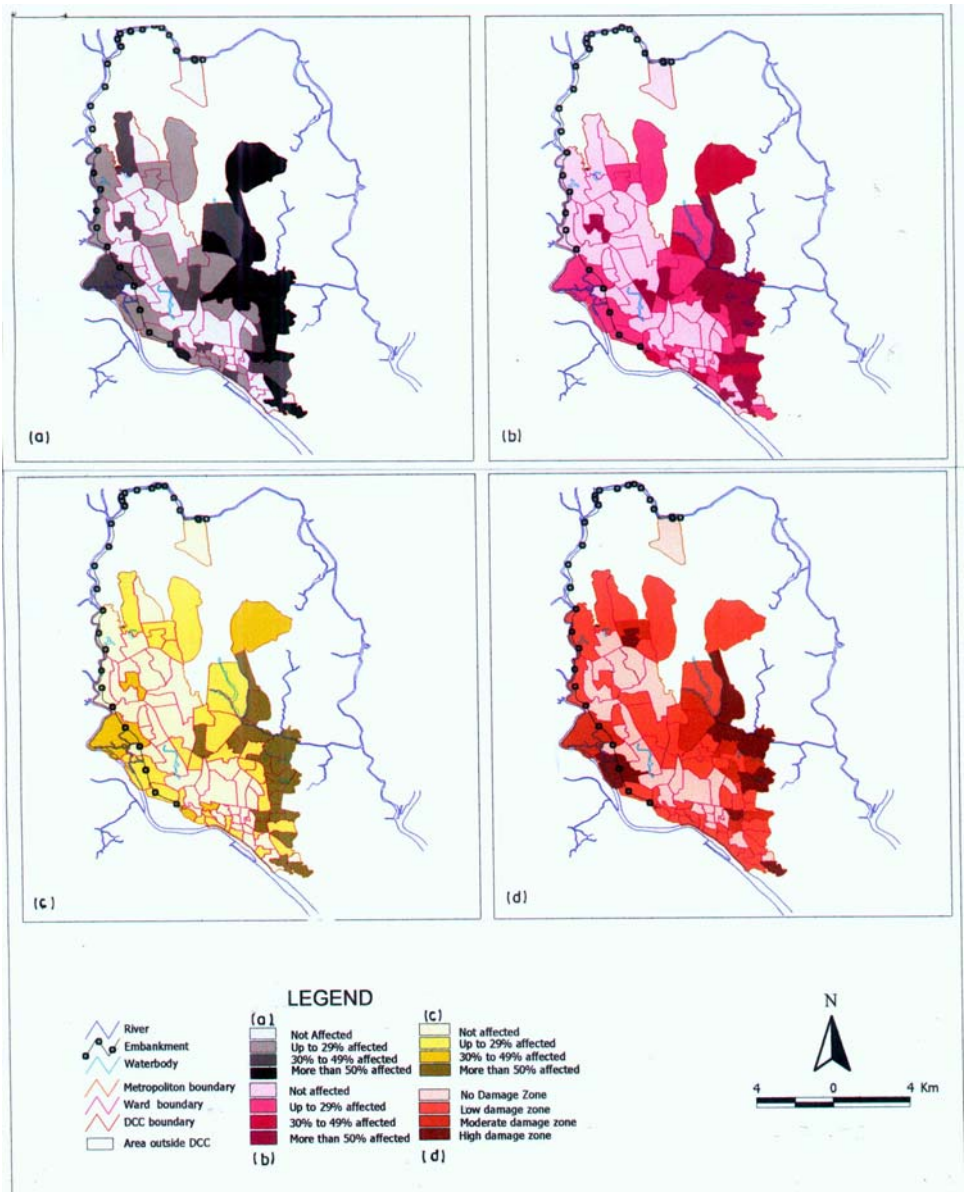

Figure 2: (a) Road sector damage in Dhaka City during 1998 flood, (b) Industrial sector damage in Dhaka City, (c) Shopping sector damage in Dhaka City, (d) Flood 1998 damage zones of Dhaka city

Industry Sector Damages And Its Spatial Distribution

Different types and sizes of industries within the Dhaka City Corporation area suffered damages during the 1998 flood. Industrial damages occurred from the loss of capital value – depreciation that has to be compensated through repair and from loss of production due to closure or production loss. Although the former type of loses can be calculated, it is difficult to impute loses arising due to closure of an industrial unit. Thus, an indicative measure has been adopted to reveal the second type of damages. Of the 64 wards that faced flood inundation, 51 wards were reported to have damages in their industrial sector. A total of 11,718 industrial units were reported to exist in the flood-damaged 51 wards, of which 1954 units or 17% suffered damages from flood. Whereas Ward-34, faced the minimum of 1% of its industries suffered, 7 wards experienced 100% of their industries damaged by the flood. On an average, 43% industries were damaged and 21 wards faced damages above the average. The total loss of the industrial sector was estimated at Taka 18.56 million. While Ward-23 suffered only Tk. 5,000/- damage to its industries, Ward-82 faced the highest damage of Tk. 8.0 million in the industrial sector. Average damage value in the industrial sector was Tk. 0.14 million and 7 wards suffered loses in the sector above the average. In addition to capital loses, industries also suffered production loses due to closure. Due to flood, a minimum of 10 days of closure was faced by the industries of Wards 31, 65 and 78, but the industries of Wards 27 and 30 faced the highest 90 days of closure. Average day of closure faced by the industries was 49 days and 24 wards suffered loss above the average due to closure.

The distribution of total loss from industrial damage presented in Table 1 shows that a significant number of wards did not suffer any damage. While 44 (69%) wards suffered loss of upto Tk. 5.0 million and 4 (6)% wards faced moderate loss, 4 wards (6%) suffered large-scale damages of more than Tk.10.0 million each in their industrial sector. The spatial distribution of damages in the industry sector [Fig. 2(b)] shows that the wards lying at the eastern and southwestern periphery including 4 from the central area of the city suffered severe flood damages in their industrial sector.

Damages in Commerce Sector and Its Spatial Distribution

The commercial sector of the city experienced flood damages from both loss of capital assets which have to be repaired and also of profit due to closure, i.e., remaining out of business. 51 wards out of 64 suffered lose in the commerce sector consisting of local/ neighbourhood and corner shops. A total of 1,52,550 shops were reported to be in operation in the affected wards, of which 39,760 or 26% suffered loss due to flooding. Total loses suffered were Taka 391 million. Shops affected by flood were a minimum of 1% in Ward-3 but a maximum of

100% damages were experienced in 8 Wards. A total of 21 wards suffered loses in the shopping sector which was above the average of 26%. The monetary loses suffered by the shopping sector varied significantly by wards. Whereas average loss was as low as Tk. 200 in Ward-30, the maximum loss of Taka 40,000 was suffered by Ward-21. A total of 19 wards suffered shopping loses whose amount exceeded the average of Tk.8,811.

The distribution of total loses arising from damages of the shopping sector (Table 1) shows that a significant number of wards did not suffer damages. Whereas 30 (47%) wards suffered damages of upto Tk. 5.0 million, 14 (24%) wards faced moderate damages, 10 (13%) wards suffered large loses of more than Tk.10.0 million each. The spatial distribution of wards which suffered damages in the shopping sector [Fig.2(c)] shows that the wards located at the eastern periphery and those outside the embankment at the western periphery including 1 in the central area suffered severe damages in this sector.

Composite Flood Damage And Its Spatial Distribution

The total damages of Dhaka City within the city corporation area during the 1998 flood have been estimated at slightly more than Taka 2.0 billion. Sector-wise distribution of damages presented in Fig. 3 shows that while the housing sector suffered bulk of the damage of 51% followed by roads (20%) and shops (19%), industry accounted for 9% and education only 1%. Ward-wise distribution of composite damage value (Table 2) shows that whereas 45 wards (50%) suffered low damage of upto Taka 25.0 million, 9 wards or 14% suffered moderate level of damage ranging between Taka 25.1 to 50.0 million, 10 wards or 16% suffered severe damage exceeding Taka 50.0 million each.

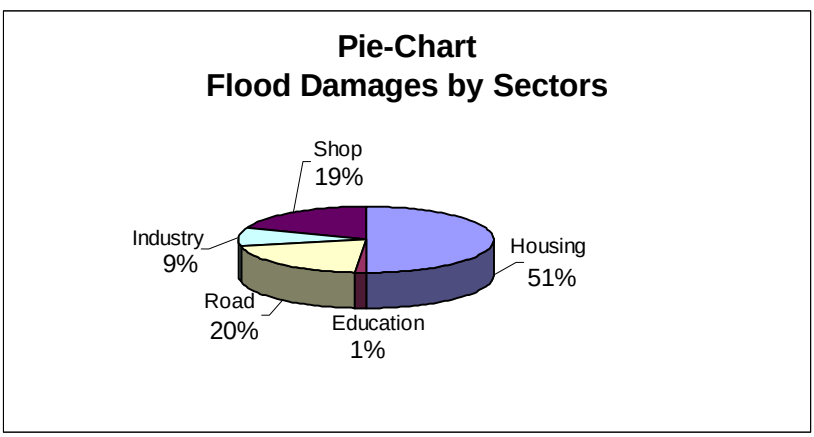

Figure 3: Flood damages by sector

Table 2: Distribution of total damages suffered by the Wards of Dhaka City during 1998 flood

Damages (Taka mil.)	Number of Wards	Percentage
Upto 10ml	25	39.1
10.1-25.0	20	31.2
25.1-50.0	9	14.1
50.1-100.0	3	4.7
100.1-above	7	10.9
TOTAL:	64	100.0

In order to provide explanations to the damage factors, correlation coefficients have been calculated with inundation, depth, duration and the sectoral variables. The results presented in Table 3 shows that although flood damages to different sectors of the city are the outcome of inundation, depth and duration of flooding, their contributions to total loss are different. Among the three factors, the contribution of inundation to flood damage is wide and profound compared to depth and duration. While area of inundation has a significantly high positive correlation with road, housing, shopping, industry and education sector damages, flood duration has a significantly positive correlation with housing, road, shopping and industry sector damages, and depth of flooding has significant correlation with housing, road and shopping sector damages. It is evident from Table 3 that whereas housing sector damages were mostly contributed by inundation, duration and depth, education sector damages were contributed by inundation alone. Again, while road and shopping sector damages were contributed by inundation, duration and depth, industrial damages were caused by inundation and duration. Therefore, it appears that area inundation is a prime factor that, if controlled, can significantly contribute towards reduction of flood damages of Dhaka City.

FLOOD DAMAGE ZONING OF DHAKA CITY AND ITS PLANNING IMPLICATIONS

Zoning is primarily a grouping exercise adopted to develop typology, which provide a scientific basis for planning or policy decisions. The zoning exercise undertaken to group city wards which suffered devastation during 1998 flood is based on the aggregate or composite value of damages that occurred in the five sectors of the city. Three damage zones – low, moderate and high, could be identified and their distribution is presented in Table 4.

Table 3: Correlation matrix of sectoral damages with area inundation, depth and duration.

Sectoral Damage	Inundated area (%)	Depth (Av)	Duration (Days)
Inundation(%)	1.000	.449**	.561**
Depth (Av)	0.449**	1.000	.290*
Duration (Av)	0.561**	.290*	1.000
Percent of houses damaged	0.870**	.422**	.539**
Percent of Pucca houses Damaged	0.902**	.304*	.496**
Percent of Semi-pucca H.D.	0.899**	.381*	.515**
Percent of Kutcha H.D.	0.550**	.260*	.379**
Percent of Education Sector Damaged	0.508**	.127	.120
Percent of Primary School Damaged	0.441**	.134	.086
Percent of Secondary School Damaged	0.370**	.076	.111
Percent of College Damaged	0.117	-0.034	.166
Percent of Industry Damaged	0.703**	0.286	.409**
Percent of Shops Damaged	0.797**	0.330**	.440**
Percent of Roads Damaged	0.895**	0.356**	.505**
Total loss(Taka)	0.514**	0.248*	0.382**

Note: **Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4: Distribution of Dhaka City Wards by flood damage zones

Flood Zones	Ward Numbers	Total of Wards	Percentage
No-Damage Zone	1,7,10,12,13,14,16,33,36,43,44,45,47,49,52,56,57,62,69,79,71,72,74,77,81,88	26	28.9
Low Damage Zone	2,4,6,8,9,11,15,17,19,24,29,30,31,32,35,38,39,40,41,42,50,51,53,54,55,58,59,60,61,63,64,65,66,67,68,73,78,79,80,82,83,84,86,87,90	45	50.0
Moderate Damage Zone	5,85,46,76,20,37,25,34,23	9	10.0
High Damage Zone	3,18,21,22,26,27,28,48,75,89	10	11.1
TOTAL:	90	90	100.0

Table 4 shows that 26 (29%) wards of the city are flood-free and hence constitute the no-damage zone in the city. The table also shows that while 45 (50%) wards have low flood damage risk and 9 (10%) wards have moderate sectoral damage risks from flood, 10 (11%) wards are high-risk areas liable to

severe sectoral damages occurring from flood in the city. The spatial distribution of flood damage zones presented in Fig. 2(d) shows that the wards located at the eastern periphery including one in the north and those outside the embankment at the western periphery of the city suffered severe damages. Wards located at the central part of the city along north-south strip are safe from flood damages. It is thus evident that peripheral wards, if not protected by embankment, are more vulnerable to flood damages than inner city wards.

Damage zoning of Dhaka City based on 1998 flood has the following planning implications: (a) Encourage development in the wards belonging to flood free zone; (b) Improve drainage of centrally located wards of the city; (c) Restrict development in the wards belonging to severe flood damage zone of the city; (d) Formulate policies and standards in order to protect development in low flood damage zone; (e) Adopt land use planning and development control measures in moderate flood damage zone; (f) Protection of the eastern part of the city area is essential in order to protect development from future flooding.

CONCLUSIONS

This research has endeavoured to delineate flood damage zones of Dhaka City based on damages which occurred in five sectors – housing, education, industry, road and shopping, during the flood of 1998. The composite damage analysis led to the identification of three damage zones – low, moderate and high and a no-damage zone of 26 wards of the city. The identification of damage zones has several planning implications, the most important of which is to protect through embankment the wards lying at the eastern periphery of the city from flooding. In the absence of such an embankment, flooding will remain a regular phenomenon in the city. A no-embankment situation will require considerations for non-structural measures to mitigate flood damages. In such a situation, this zoning exercise will provide a basis to direct development to safer wards of the city and formulate land use policies and planning standards in order to guide development in low and moderate flood zones so that the city suffers minimum damages from future floods.

REFERENCES

BBS (1998), Statistical Year Book of Bangladesh 1997, Dhaka: Bangladesh Secretariat, p.224.

BUET/JICA (1997) Japan Bangladesh Joint Study, 1997, Flood Plain Zoning Based on Analysis of Flood Damage to Agriculture, Dhaka, BUET-JICA joint study.

DCC (1998) Dhaka City Corporation (DCC), 1998, Dhaka City Corporation's Post-Flood Recovery/Reconstruction and Development Programme, Dhaka: DCC, p.1-3.

DMB (1998) Disaster Management Bureau (DMB), 1998, Report on Bangladesh Flood 1998, Dhaka

FAP-8B (1991), Dhaka Integrated Flood Protection Project, Final Report, p.1.

Hunter, W.W. (1877), A Statistical Account of Bengal, Vol.V, (Districts of Dacca, Bakerganj, Faridpur and Maimansingh, London: Trubner & Co. (Reprinted in India by D.K. Publishing House, Delhi), p.103.

Islam, N. (1998), "Flood '98 and the future of urban settlements in Bangladesh", CUS BULLETIN 35, July-December, 1998, p.3.

Rizvi, S. N. H. (1969), East Pakistan District Gazetteers – Dacca, Dacca: East Pakistan Govt. Press, pp.33-34.

UNDP/WB/GOB (1993) Planning Commission, 1993, Multipurpose Cyclone Shelter Programme, UNDP/WORLD BANK/GOB PROJECT/BGD/91/025, Dhaka, BUET-BIDS.

World Bank (1999), Towards an Urban Strategy for Bangladesh, Dhaka: World Bank, p.3.