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Development of A Real Time Flood Damage Assessment Model

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1. INTRODUCTION

Real-time flood damage assessment is very important for flood disaster mitigation. Estimation of damage for possible future flood events can help in preparedness against flood disaster, in reduction of possible damage with both structural and non-structural measures. In the past, several researchers worked on development of flood damage methodologies (*Tang et al., 1992* etc.). However, the methodology presented in this paper for estimation of various kinds of flood damages in real-time by integrating it with flood forecasting model is a new approach. The paper presents an example of the model application in one Japanese basin.

2. MODEL DEVELOPMENT

2.1 BACKGROUND: Damages from flooding are recognized as belonging to several categories. There are two major categories i.e. tangible and intangible damages. Tangible damages are those which can be evaluated in terms of monetary value. But, intangible damages are difficult to express in monetary values such as anxiety, inconvenience and disruption of social activities.

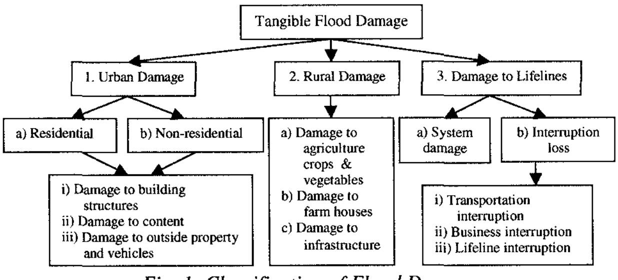

Fig. 1: Classification of Flood Damage

In this study, tangible damages are considered for analysis. Development of methodologies for assessment of intangible damages needs long term study and it is considered as out of the scope of this study. For the formulation of the model, tangible damages are classified into three broad categories as shown in the Fig. 1.

2.2 FORMULATION OF MATHEMATICAL MODEL: The damage assessment model (DAM) has three subroutines for three different categories of damage and it is developed such as way that it can read the temporal data of inundation depth from the flood plain model directly (*Dutta et al., 1997*). For each category of damage, mathematical formulae are developed to estimate flood damage. In formulation of mathematical models, stage-damage functions are the essential building blocks upon which flood damage assessments are based (*Smith, 1994*). They state the relationship between flood damage and depth and duration of floodwater for different categories of damage. In this study, stage-damage functions are developed based on historical records. Some examples of models developed for different categories of damage are described below;

1. Urban Damage

a) Residential Damage

i) Structural damage: Structural damage to a residential building unit can be estimated as;

$$\mathbf{Ds(i,j) = FA(i,j)*Ns*ECs(i,j)*Cs(i,j,t,d)}$$

Where, for any grid (i,j), Ds = total damage to structure, Ns = total number of building units, FA = Average floor area per building unit (in sq. m), ECs = Estimated cost per sq.m and Cs = structure stage-damage function (%). Cs is calculated as;

$$\mathbf{Cs = \beta_0*(1-e^{\beta 1*x1}*e^{\beta 2*x2})}$$

Where, β_0, β_1 and β_2 are constants to be fixed based on statistical analysis of survey parameters for particular type of structure. X_1 is depth of floodwater relative to the first floor (in m) and X_2 is the binary variable (= 0, if no basement present, = 1, if basement present).

2. Rural Damage

a) Damage to agriculture crops & vegetables: Average damage to agriculture crops & vegetables in any grid (i,j) can be estimated as,

$$\mathbf{AD\ (i,j) = \{{}^{n}\Sigma_{i=1}\, D_m\ (i,j)*CRP_a*mn\}}$$

$$\mathbf{D_m = CP_i*Y_i*C_i*d\{1+t(B_i+I_i*d)\}}$$

Where, in any grid (i,j) for any type of crop i, AD = total agriculture damage; D_m = damage to crop per unit area; CRP_a= total area of cultivation of crop type i; CP_i = estimated cost per unit weight of crop type i; Y_i = yield of crop type i per unit area; C_i and B_i are rates of increase in damage for unit increases in d and t respectively. I_i expresses the interaction between d and t. mn = loss factor, which varies for different time period in the year for different types of crops and vegetables, and n = types of crops.

3. Damage to Lifelines

b) Interruption loss

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KEYWORDS: Flood Damage Assessment, Stage-damage function, Ichinomiya River Basin

i) Transportation Interruption loss (Lifeline Damage): The methodology to estimate traffic disruption loss is as follows;

$$\mathbf{TDR} = {}^{tnm}\sum_{m=1}[{}^{rn}\sum_{r=1}\{C(m,r)*T(m,r)*t_{dur}(m,r)\}]$$

Where, TDR = total traffic disruption loss, tnm = total number of mode of transportation, rn = total number of roads within the flood affected areas. For any road r and transportation mode m, C = cost per trip (in terms of income); T = average trip per day and t_{dur} *= duration of flood (unit: day).*

$$\mathbf{T = K/C^a}$$

Where, K is a constant, which can be determined from average usage and cost data for any facility and a is the negative of demand elasticity

3. APPLICATION OF THE MODEL

3.1 STUDY AREA: Ichinomiya river basin, a moderate size basin with an area of 220 sq. Km, located in the Chiba prefecture, Japan between longitude 35°18' N to 35°30' N and latitude 140°10' E to 140°25' E is selected for this study. The topography of the basin varies from hilly areas in the western part with maximum elevation of about 155 m to lowland flat areas in the eastern part with minimum average elevation of about 1-2m from mean sea level. The mean annual rainfall is approximately 1,700 mm and rainfall distribution is uniform in the entire basin. During September 21- 26, 1996, the basin suffered from a big flood disaster due to heavy rainfall. In this study, the flood damage assessment model was used to estimate the different categories of damage caused by the flood. Surveyed flood plain was used as input flood data for the model. Spatial distribution of detailed landuse classes was obtained from the Mitsui Private consultant group.

3.2 RESULTS: Some of the simulated results from the model are shown in the Figs. 2 & 3. Fig. 2 shows the damage to structure of residential buildings in the basin. The distribution of structure damage to non-residential buildings is shown in Fig. 3. The simulated results were compared in the Table 1 with the surveyed data obtained from the Ministry of Construction. From the table, it can be seen that the simulated results are closed to the surveyed estimation of damage.

Table 1: Comparison of Estimated and Surveyed Damage

Type of Damage	Categories of Damage	Amount of Damage(1000 Yen)	
		Simulated by DAM	From Report of Ministry of Construction
Damage to Residential buildings	Structure Damage	18,809,600	9,023,299
Damage to Non-residential buildings	Structure Damage	11,009,400	9,050,364 (estimated only for two wards)

4. CONCLUSIONS

The damage assessment model developed in this study is a new and important approach for real-time flood damage assessment. The simulated results show that the model can be used for estimation of damage with very high accuracy. If the input spatial data are prepared beforehand, the model can be used effectively due to less simulation time. However, the model is not yet a complete one. Verification of the model has to be carried out comparing with actual damage occurred instead of average values obtained from the report of Ministry of Construction. A detailed questionnaire survey is being carried out for this purpose. Also, research work is being continued to integrate the model with flood plain model.

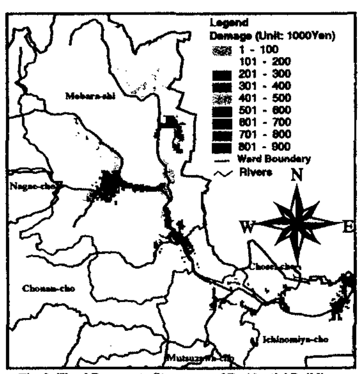

Fig. 2: Flood Damage to Structures of Residential Buildings

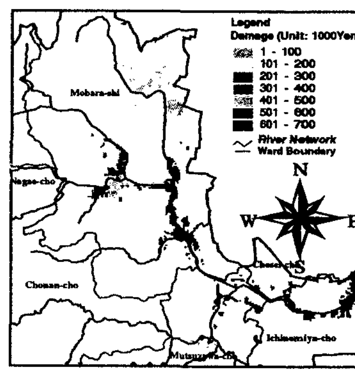

Fig. 3: Flood Damage to Structures of Non-residential Buildings

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