

FLOOD DAMAGE ANALYSIS FOR URBAN AREA IN KOREA

HungSoo Kim¹, KeonHaeng Lee²

(1) Dept. of Civil Engineering, Inha University, #253, Yonghyun-Dong, Nam-Gu, Incheon, Korea, email: sookim@inha.ac.kr

(2) Dept. of Civil Engineering, Inha University, #253, Yonghyun-Dong, Nam-Gu, Incheon, Korea, email: ggun@inha.ac.kr

ABSTRACT

In 2004, the Multi-Dimensional Flood Damage Analysis(MD-FDA) was developed for the economic analysis of a flood control project and now it is widely used in Korea. However, the MD-FDA was developed for general damage assessment and analysis without consideration of a specific regional characteristic such as urban or rural area. So, we modify the MD-FDA for the application in urban area.

The MD-FDA considers damages for the residential, agricultural, and industrial areas as damage components and these are direct flood damages. Also the public facility is considered as a damage component and its damage is estimated by the damage rate of total damage for three areas. And here we modify the original damage components of the MD-FDA for more accurate estimation of direct flood damage in urban area and consider one more damage component for a damage which can be reduced by pumping station. The pumping station for flood damage estimation was not considered in the MD-FDA. So we will explain the MD-FDA and how we modify the MD-FDA method which is being used in Korea.

We compare the results by the modified MD-FDA for the urban area with those by original MD-FDA. As a result the B/C ratio showed 6.75 and 5.51 respectively for the modified and original MD-FDA. This difference might be largely affected by the damage rate of the public facilities.

Key words: MD-FDA, flood control project, direct damage, damage rate of the public facility

1. INTRODUCTION

We can reduce flood damage through the systematic flood prevention projects. These projects may need their economic validity by the economic analysis of the projects. For this, the Multi-Dimensional Flood Damage Analysis(MD-FDA) was developed and widely used in Korea. However, the MD-FDA was developed for general damage assessment and analysis without consideration of a specific regional characteristic such as urban or rural area. Here we modify the MD-FDA for the application in urban area.

There are three damage components of the residential, agricultural, and industrial areas in the original MD-FDA and there are also sub-items in three components. We modify a part of damage components in the original MD-FDA and suggest a component by pumping station which can affect damage estimation for the application of urban area. The pumping station was not considered in the original MD-FDA for the damage estimation. The component we suggest is for the consideration of the pump capacities of stormwater pump stations in the study area. When flood is occurred in the urban area, the damage potential is larger than the rural area because of the concentration of human lives and properties. So, many stormwater pump stations are located in the urban area and the inundation depth is estimated by considering the pump capacities of pump stations. We also modify the damage components in sub-items of the original MD-FDA such as the damages of human life, industrial area, residential structure and contents, and public facilities for the flood damage estimation of the urban area.

The flood damage in industrial area is divided into tangible and stock properties. By the way, the MD-FDA method includes the land value in the tangible property but the land value should not be considered in the flood damage estimation. So we do not consider the land value for the damage estimation of the tangible property. The damage for the contents of the residential structure is estimated by using Expenditure on Gross Regional Domestic Product(EGRDP). The damage rate of public facilities to the damage of general properties is re-estimated by using damage data obtained from the disaster annual report published every year in Korea.

2. MULTI-DIMENSIONAL FLOOD DAMAGE ANALYSIS

The Multi-Dimensional Flood Damage Analysis(MD-FDA) is the concept that evaluates the direct flood damage as shown in Fig. 1 and there are damage items or components for direct flood damage estimation as shown in table 1.

The MD-FDA divides direct damage(or benefit) components into residential area, agricultural area, industrial area, and public facility damage (reduction). Each damage is estimated by the properties using statistical data except for the public facility. And total amount of damages is estimated through the inundation ratio of damage components.

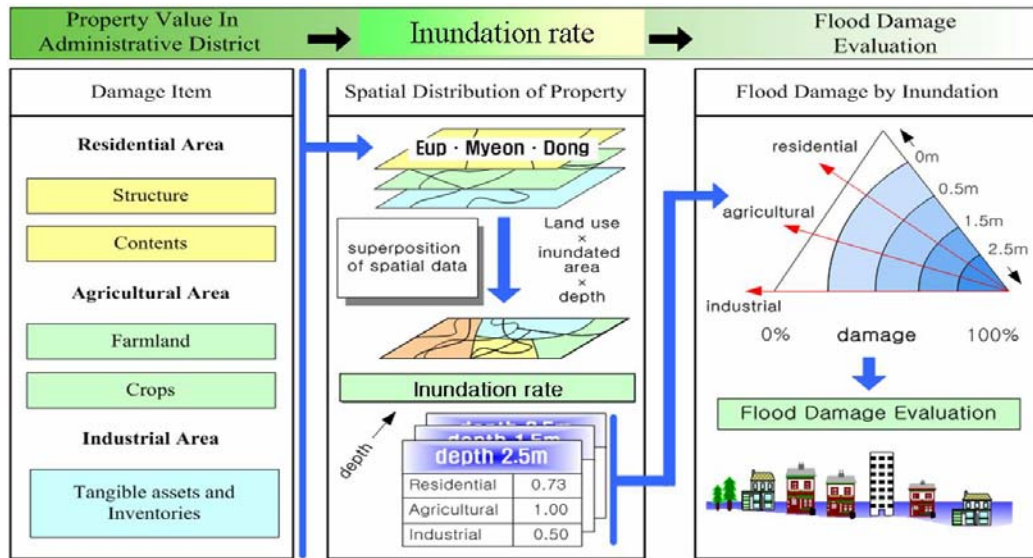


Fig. 1 Concept of Multi-Dimensional Flood Damage Analysis (MD-FDA)

Table 1 Damage items for direct flood damage estimation

Regional damage component	Damage sub-item
Residential area	① structure : residential structure ② content of structure : goods of household
Agricultural area	③ farmland : paddies and dry fields ④ crops : representative crops at flood season
Industrial area	⑤ tangible · stock property : facilities for production or stock property except for land among company property

2.1 Inundation rate

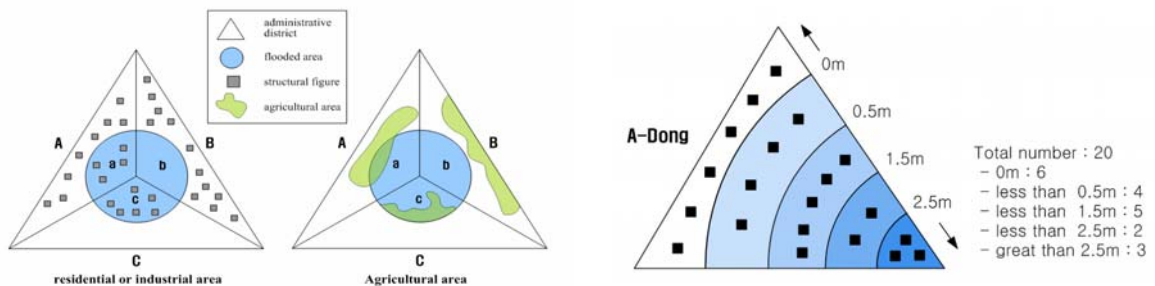


Fig. 2 Conceptual scheme to compute the inundation rate

A certain district has residential, industrial, and agricultural areas for the estimation of direct flood damage. However, those three areas may show different inundation areas in each inundation depth

and the ratio of each district area to total inundation area is called the inundation rate. For calculating inundation rate, we need to use spatial information such as inundated district map, administrative district map, land cover map(land use map), and digital topographical map. Fig. 2 shows the conceptual scheme to compute the inundation rate.

2.2 Total direct flood damage

The damages of general properties are evaluated by Eq. (1).

$$\begin{aligned}
 & \text{Inundation Damage (₩)} \\
 & = \text{Value of Property (or each item) (₩)} \times \text{Inundation Rate} \times \text{Damage Rate in Depth} \quad (1)
 \end{aligned}$$

Total direct flood damage is calculated considering damage rate of public facility of Eq. (2)

$$\begin{aligned}
 & \text{Total Direct Flood Damage (₩)} = (1 + \alpha) \times \text{Inundation Damage (₩)} \\
 & \text{Here, } \alpha \text{ is the damage rate of public facility to the damage of general property} \quad (2)
 \end{aligned}$$

3. DAMAGE ESTIMATION OF URBAN AREA

The accuracy of the MD-FDA depends on the estimation of properties of each damage component. This study investigates and analyzes the damage components of residential area, industrial area, and public facility for the estimation of flood damages in urban area by the MD-FDA. In first, we consider the benefit by the use of pumping station for draining water in urban area which is not considered in the MD-FDA. Secondly, we reconsider the property in the industrial area which includes the land price. Because the land price do not affect the flood damage estimation, we remove the land price in flood damage estimation for the property of industrial area. Finally, we also reconsider the damage rate of public facility to the damage of general property for the estimation of the damage of public facility.

3.1 Flood damage estimation considering pumping station

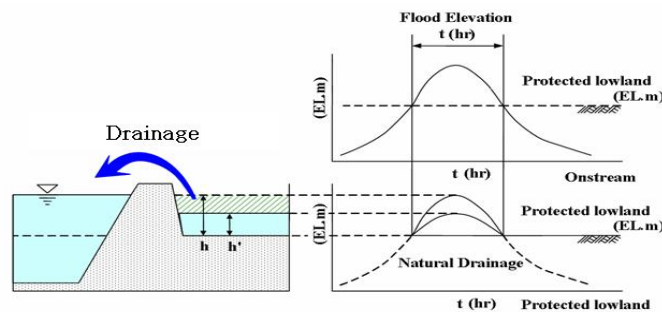


Fig. 3 Drainage by pumping station

When we construct the inundated district map and estimate the flooding area, we might consider the pumping station. The flood damage is related to the flooded area, flooding depth, and the flooding ratio of damage components according to the flooded water level. Therefore, if we do not consider the pumping station, we can estimate more large flooding area and flood damage. That is, we may overestimate flood damage. So, it may be reasonable to consider the pumping station in the inundation simulation for the estimation of flood damage.

3.2 Flood damage in industrial area

If we estimate the property in industrial area such as building property including the land price, the flood damage will be overestimated. So, we reconsider the estimation of property in industrial area(National Statistical Office, Korea, 1999) by removing the land price for the flood damage estimation. The publicly assessed value of the land in Korea(Korea Association of Property Appraisers, 2004) is provided in the internet in the level in each county and town and we reconsider the value. The value of industrial damage components in each district and city are estimated in table 2. The industrial damage components are classified in D, E, F, G, and so on. Also the districts and cities are represented such as Gang-won, Kyung-gi, Gwangju, and so on.

$$\begin{aligned} & \text{Values of Industrial Damage Components in Each District and City (₩)} \\ & = \text{value per 1 employee classified by Industrial classification(money/man)} \\ & \quad \times \text{number of employee} \times \text{consumer price index} \end{aligned} \quad (3)$$

Table 2 Value per 1 employee by Industrial classification for each district and city (unit : one thousand ₩)

Industrial classification	Gang-won	Kyung-gi	Gyeong-nam	Gyeong-buk	Gwang-ju	Daegu	Daejeon	Busan	Seoul	Ulsan	Incheon	Jeon-nam	Jeon-buk	Chung-nam	Chung-buk
D	405,968	325,311	166,910	405,276	123,451	98,546	85,789	108,840	52,610	371,108	152,923	490,785	223,331	477,404	441,549
E	966,077	913,783	1954,019	5,023,149	3141,316	981,942	1156,676	1446,642	790,375	648,999	1,663,252	2,497,601	1,253,274	2,568,889	771,687
F	77,395	29,028	43,207	40,748	77,510	39,054	165,880	144,027	111,321	13,626	71,737	28,929	42,487	17,901	73,189
G	29,531	12,169	7,346	9,596	13,822	12,121	14,485	16,832	16,886	15,032	13,607	8,345	5,387	9,896	6,861
H	35,853	0	690	5,964	1,263	762	3,654	9,578	8,353	2,289	0	1,467	1,185	1,488	1,753
I	109,096	66,270	54,206	85,427	134,398	44,370	99,830	311,922	436,062	160,021	75,810	73,038	42,564	65,285	68,008
J	53,376	45,575	57,674	47,683	40,786	153,971	48,233	36,671	158,867	50,355	29,131	44,646	40,242	55,490	55,943
K	19,379	52,371	36,551	19,049	15,071	6,887	72,634	4,415	23,588	3,154	13,561	86,429	10,614	11,060	14,404
M	39,356	116,701	44,736	156,585	119,618	74,602	107,536	90,109	155,428	49,486	53,872	41,261	106,339	116,370	36,588
N	37,958	30,799	24,652	35,114	11,713	28,955	74,074	26,539	19,168	26,647	23,763	58,422	44,656	26,148	254,629
O	18,362	25,058	23,814	5,316	9,310	8,906	8,722	1,475	5,712	11,894	0	17,232	44,656	1,406	23,476

3.3 Flood damage of public facility

We have a difficulty to estimate flood damage of the public facilities, because the public facilities have various size and many species. So, we estimate damage of public facilities using the damage rate of public facilities to the damage of general properties, instead of we do not estimate directly property of public facility.

Table 3 Damage rate of public facilities to the damage of general properties in seven main cities in Korea

Classification	Seoul	Busan	Incheon	Daejeon	Daegu	Gwangju	Ulsan
Damage rate	4.436	32.826	2.471	12.054	0.797	1.882	8.357

Table 4 Damage rate of public facilities to the damage of general properties in urban area

Road/Bridge	River	Stream	water supply and drainage	Habor	Fishing port	School
31.7%	40.5%	24.2%	4.3%	11.6%	1.9%	1.4%
Railroad	Water use	Sediment detention	Military installations	Small Scale Facility	Others	Total
1.2%	10.5%	13.3%	12.8%	21.0%	29.2%	203.50%

MD-FDA had calculated damage rate of 600% by Annual Disaster Report for just 1 year, now, we are using the rate of 1.694 that was suggested in Japan. In this study, we calculate the average of public facility damage rate for general damage using damage data in annual disaster reports for 7 years (1997~2003) on 7 cities.

4. COMPARISON BETWEEN ORIGINAL MD-FDA AND MODIFIED MD-FDA

4.1 Study area

We choose Dorim stream in An Yang River basin, Korea as the study area. Dorim stream's watershed area is 41.93 km², stream length is 14.20 km. The big underground channel in this stream was planned for the flood control(Watershed Based Integrated Flood Control Plan of An Yang River, 2005). The Dorim stream basin is shown in Fig. 4.

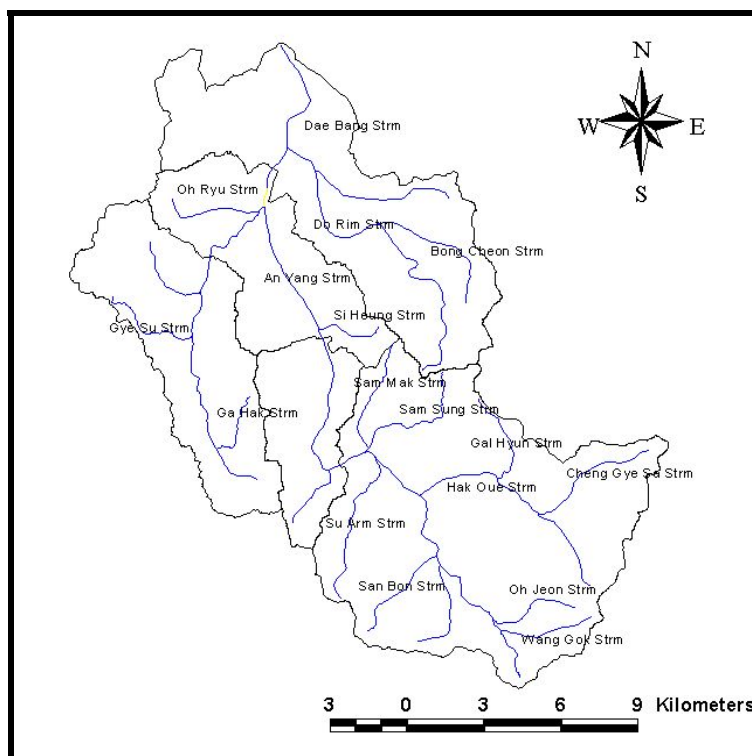


Fig. 4 Dorim stream in An Yang River Basin, Korea

4.2 Damage estimation by flood frequency

There is no item related to agricultural characteristic in watershed of Dorim stream. Therefore, the damage items are consisted of residential district, industrial district and public facilities. The damages for the frequencies of 50, 80, 100, 150 and 200yrs are estimated by multiplying inundation rate and damage rate.

After we estimated damages for the flood frequency of 50, 80, 100, 150, and 200 yrs, the expected annual damage reduction was estimated the averaged damage in each interval by multiplying interval occurrence probability. These works in cases with flood control project and without flood control project were carried out.

Table. 5 Expected annual damage reduction by MD-FDA

Frequency	Exceedance probability	Before project	After project	Damage reduction	Damage reduction in each interval	Probability In each interval	damage reduction In each interval	Expected annual damage reduction
50	0.0200	2,772,766	1,705,396	1,067,369				
80	0.0125	3,660,596	2,346,794	1,313,802	1,190,586	0.0075	8,929	8,929
100	0.0100	4,190,335	2,723,885	1,466,450	1,390,126	0.0025	3,475	12,405
150	0.0067	4,738,70	3,527,102	1,211,598	1,339,024	0.0033	4,463	16,868
200	0.0050	4,999,216	4,009,845	989,371	1,100,485	0.0017	1,834	18,702 (USD 18mil)

Table. 6 Expected annual damage reduction by modified MD-FDA

Frequency	Exceedance probability	Before Project	After project	Damage reduction	Damage reduction in each interval	Probability In each interval	damage reduction In each interval	Expected annual damage reduction
50	0.0200	2,658,970	1,593,808	1,065,162				
80	0.0125	3,822,854	2,235,114	1,587,741	1,326,451	0.0075	9,948	9,948
100	0.0100	4,513,311	2,610,409	1,902,903	1,745,322	0.0025	4,363	14,312
150	0.0067	5,104,447	3,395,141	1,709,306	1,806,104	0.0033	6,020	20,332
200	0.0050	5,330,804	3,859,881	1,470,924	1,590,115	0.0017	2,650	22,982 (USD 22mil)

4.3 Estimation of benefit

We suppose that the benefit is created for 50 years after the project(see the report of 'A Study on standard policy for Preliminary feasibility research to water resources projects(Dam)' (3rd edition), Korea Development Institute, 2003)

Table 7 benefit changed to present value

year	MD-FDA	Modified	year	MD-FDA	Modified	year	MD-FDA	Modified
2004	0	0	:	:	:	:	:	:
2005	0	0	2031	10,857	13,313	2051	8,085	9,914
2006	0	0	2032	10,623	13,026	2052	8,023	9,839
2007	0	0	2033	10,393	12,745	2053	7,962	9,764
2008	0	0	2034	10,169	12,469	2054	7,902	9,689
2009	0	0	2035	9,949	12,200	2055	7,841	9,615
2010	0	0	2036	9,734	11,937	2056	7,782	9,542
2011	0	0	2037	9,524	11,679	2057	7,722	9,469
2012	17,744	21,759	2038	9,318	11,427	2058	7,664	9,397
2013	17,378	21,310	2039	9,117	11,180	2059	7,605	9,326
2014	16,987	20,830	2040	8,920	10,938	2060	7,547	9,255
2015	16,573	20,323	2041	8,728	10,702	2061	7,490	9,184
2016	16,139	19,790	2042	8,661	10,621			
:	:	:	:	:	:	Total	536,144	657,444

The expected annual damage reduction is corrected by the rate of GDP(2003/2004) growth, 104.6%. And we consider a rate of economic growth will be 5.2%/year from 2004 to 2012, will decrease 0.1%/year for 10 years after 2013, and maintain 4.2%/year after 2022.

Also, we use that the analysis base year is 2004, the analysis period is 50 years, and the discount rate is 6.5% for the economic analysis for 30 years in operating, 5% after that(see the report of 'A Study on revise and repletion of general policy for preliminary feasibility research' (4th edition), Korea Development Institute, 2004).

Table 7 shows benefits to be estimated respectively for the modified and original MD-FDA. As a result, the modified method estimated larger benefit than original MD-FDA.

4.4 Estimation of cost

Table 8 Distribution plan of working expense by year

	Period for planning		Period for construction				Total
	1	2	3	4	5	6	
Working expenses by year	1,628	2,762	18,155	27,261	26,742	17,933	94,481
1. The cost of construction	-	-	16,016	24,024	24,024	16,016	80,081
The cost of construction	-	-	8,898	13,347	13,347	8,898	44,489
others	-	-	7,118	10,677	10,677	7,118	35,592
2. Incidental expenses	1,480	2,511	286	286	286	286	5,136
Basic design	1,039	-	-	-	-	-	1,039
Operation design	-	2,070	-	-	-	-	2,070
supervision	-	-	286	286	286	286	1,145
Examination and measurement	440	440	-	-	-	-	881
3. The reserve fund	148	251	1,650	2,478	2,431	1,630	8,589
4. cost of reservation compensation	-	-	203	473	-	-	675
Reservation	-	-	203	473	-	-	675

Source: Korea Development Institute(2005). The preliminary feasibility research report on project of channel in Mokgam stream-underground channel in Dorim stream.

Table 9 Cost changed to present value

Year	Cost	Year	Cost	Year	Cost	Year	Cost
2004	0	2019	1,203	2034	468	2049	204
2005	0	2020	1,130	2035	439	2050	194
2006	1,435	2021	1,061	2036	413	2051	185
2007	2,286	2022	996	2037	387	2052	176
2008	14,113	2023	935	2038	364	2053	168
2009	19,898	2024	878	2039	342	2054	160
2010	18,327	2025	825	2040	321	2055	152
2011	11,540	2026	774	2041	301	2056	145
2012	1,870	2027	727	2042	287	2057	138
2013	1,756	2028	683	2043	273	2058	131
2014	1,649	2029	641	2044	260	2059	125
2015	1,548	2030	602	2045	248	2060	119
2016	1,454	2031	565	2046	236	2061	113
2017	1,365	2032	531	2047	225		
2018	1,282	2033	498	2048	214		
						Total	97,359

Estimation of cost that is needed for calculation of B/C is referred to the report (Korea Development Institute, 2005), and work expenses was distributed to each year as shown in Table 8.

4.5 Economic evaluation of flood control project

We use the indices such as Net Present Value(NPV), Benefit Cost ratio (B/C), and Internal Rate of Return (IRR) for the economic evaluation of two methods and Table 4 shows the results for the indices.

Table 10 Results of index calculated for economic evaluation

	MD-FDA	Modified MD-FDA
NPV	438,784	560,084
B/C	5.51	6.75
IRR(%)	23.26	26.77

5. CONCLUSION

This study has modified the MD-FDA for more accurate estimation of flood damage for urban area and we have used the modified MD-FDA for the application to Dorim stream, Seoul, Korea.

Finally, we have conclusions as follows :

- 1) We have compared the results by the modified MD-FDA with those by original MD-FDA for the urban area application.
- 2) As a result, the B/C ratio showed 6.75 and 5.51 respectively for the modified and original MD-FDA.
- 3) This difference might be largely affected by the damage rate of the public facility. It is thought that the result of this study can be useful for urban flood damage estimation in Korea.

REFERENCES

- Korea Association of Property Appraisers(2004): Officially Assessed Individual Land Price.
- Korea Development Institute(2003): A Study on standard policy for Preliminary feasibility research to water resources projects(Dam)(3rd edition).
- Korea Development Institute(2004): A Study on revise and repletion of general policy for preliminary feasibility research(4th edition)
- Korea Development Institute(2005): The preliminary feasibility research report on project of channel in Mokgam stream-underground channel in Dorim stream.
- Ministry of Construction and Transportation, Korea(2001): Improvement Study on the Economic Analysis in Flood Control Projects.
- Ministry of Construction and Transportation, Korea(2004): A Study on the Economic Analysis in Flood Control Projects.
- Ministry of Construction and Transportation, Korea(2005): Watershed Based Integrated Flood Control Plan of An Yang River
- Ministry of Government Administration and Home Affairs, Korea(1997~2003): Annual Disaster Report.
- National Statistical Office, Korea(1999): National Wealth Survey.