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Urban Infrastructure Suitable for Flood Hazard Mitigation[1]

Tae Jung Kwon, Assistant Professor
Dong-A Univ. in Busan, Korea
edankwon@dau.ac.kr
+82-51-200-7664

I. Introduction

A dramatic increase in natural disasters attributed to climate change and the resulting damage is a global phenomenon, and is no exception in the Republic of Korea. For example, Seoul, its capital, received an enormously large amount of rain, 259.5 mm, on September 21, 2010, which led to the flooding of the Sejong-no district. This incidence was an opportunity to draw public attention to the seriousness of climate change and for the authorities concerned to take action against those kinds of disasters. The damage from the flooding largely on the roads tarnished the Country's reputation because it suggested an inability to cope with extreme flooding events. Nevertheless, the district suffered very little damage. The flooding on the roads might have prevented the areas around the roads from being inundated and protected the Government's important public tasks and private commercial functions.

Based on this supposition, this study aims to explore a more comprehensive list of general urban infrastructure candidates, which can be used as a space to mitigate extreme flooding in urban areas, based on the concept of the integrated flood management (IFM). It also aims at assessing them for their appropriateness, using the analytic hierarchy process (AHP) analysis method. Different professional groups, including urban planners, civil engineers, and environmentalists, have systemically evaluated the candidates with respect to their appropriateness.

Figure 1 Flooding of the Sejong-no District in Seoul on Sep. 21, 2010

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II. The role of general urban infrastructure in IFM

The Global Water Partnership (GWP), an international institute dedicated to water resources, emphasized the necessity of applying an integrated water resources management (IWRM) to efficiently manage and develop water resources, land and other related resources as IWRM helps achieving economic growth and social welfare, without damaging the ecosystem. The IWRM also stresses on the importance of IFM, an integrated countermeasure-like linkages between land use and water resource management to cope effectively with extreme flood events caused by climate change (WMO, 2009). In addition, recent emphasis has also been placed on the importance of a non-structural measures, such as land use management. A range of efforts have been made to recognize and overcome the problems caused by a sudden increase in impermeable layers derived from urban development (APFM, 2008), which impermeable layers have been found to not only increase the flood-peak discharge but also decrease the time for reaching the flood-peak discharge, which places a considerable burden on flood control facilities, such as the urban drainage system (USGS, 2003). Accordingly, emphasis has been placed on efforts to reduce the burden placed on the flood control facilities by expanding permeable layers and a variety of spaces for the rainwater detention within a system of integrated flood management (Sim, 2010; Zandaryaa, 2011).

On the other hand, such countermeasures for improving related flooding control facilities and securing spaces for the detention of out-flown rainwater include a range of problems in overpopulated and extremely urbanized areas like a national capital (e.g. Seoul, South Korea). The construction expense to increase the capacity of existing urban drainage facilities is high. Moreover, it is doubtful that the facilities will be of great use. For example, it was estimated that 4 to 5 trillion won (about 3 to 4 billion U.S. dollars) would be required to increase the capacity of urban drainage facilities in Seoul to cope with extreme flood events (NEMA, 2008). On the other hand, the urban drainage facilities with high capacity are economically inefficient in that much of their storage volume is barely used at normal times when there is no heavy rain. Therefore, it is not an easy decision in cost-benefit terms to spend money on drastically improving the drainage facilities, considering the other priority in the budget agendas, such as education, welfare and economy, as well as the financial conditions of each local government. Securing open spaces for the rainwater detention, which is known as sharply decreasing flood-peak discharge, in a highly urbanized area would also be difficult because of the huge expenses purchasing land. The construction of huge underground facilities for the detention of rainwater has also been discussed as an alternative to this problem, but has come up with no consensus because of high construction costs (SDI, 2011). Therefore, the most rational and desirable approach is to find public urban facilities and spaces for multi-purpose uses to detain rainwater in highly urbanized areas. The approach through the multi-purpose use of public urban facilities and spaces is judged to meet the demands of the times, i.e. the 'Integrated Flood Management'.

Although urban parks and school playgrounds are frequently suggested as feasible candidates of the multi-purpose uses among varying types of urban infrastructure, they won't complete a full list of the candidates, and they have not been assessed for appropriateness, either. This study is, therefore, to make a comprehensive list of possible public urban infrastructure candidates for flood mitigation use, and then to assess them for their appropriateness using the analytic hierarchy process (AHP) method.

III. A list of feasible multi-purpose urban infrastructure

As the first step toward making the list, the most fundamental Korean law, *Act on Planning and Use of National Territory*, on spatial and urban planning has been reviewed. Per the Act, public urban infrastructure are divided into seven major categories, including (1) transportation, (2) spatial, (3) distribution and supply, (4) public, culture and sport/recreation, (5) hazard mitigation, (6) public health, and (7) environmental pollution categories. The transportation category represents transportation-related urban infrastructure, such as roads, railroads, ports and harbors, airports, bus terminals, etc. The spatial category consists of public squares or plazas, urban parks, and other urban open spaces. The majority of detailed types of urban infrastructure in the distribution and supply category are related to drinking water, gas, electricity, or oil supply and distribution as broadcasting and telecommunication facilities fall into the same category. The representative detailed facilities in the hazard mitigation category are rainwater retention (or detention), fire protection facilities, etc. The public health category consists of medical centers, slaughter houses, cemeteries, etc. while the environmental pollution category includes sewer system, waste disposal/treatment facilities, etc. In sum, 53 detailed types of public urban infrastructure have been identified in the seven major categories.

Major category	Transportation (3)	Spatial (3)	Distribution and supply (2)	Public and education (3)	Culture and sport/recreation (2)	Public health (3)
Detailed types	-Local streets -Parking spaces -Bus terminals	-Squares or plazas -Urban parks -Amusement parks	-Distribution centers -Markets	-Schools -Universities -Government offices	-Sport facilities -Cultural facilities	-Cemetery -Crematories -Medical centers

Table 1 Urban infrastructure candidates for multi-purpose flooding mitigation

However, all 53 detailed urban infrastructure types are not to be introduced to their appropriateness assessment for some reasons. For instance, regional scale transportation facilities such as arterial roads, highways, airports, railroads, and ports has been ruled out in order to secure their functionality in emergency situations. Broadcasting and telecommunication facilities are also removed for the same reason. All detailed types under the environmental pollution category have not been introduced in consideration of rainwater contamination risk. Pipe network facilities such as gas and oil pipelines have not been considered because there is no enough room for multiple uses. Finally, every detailed type under the hazard mitigation category has been removed in consideration of the purpose of this study to find general, not hazard mitigation-related, urban infrastructure suitable for flooding hazard mitigation. After these five elimination process 16 detailed types in six categories have survived for the appropriateness test. Table 1 shows the list of the 16 feasible urban facilities for multi-purpose flooding mitigation.

IV. Appropriateness assessment of the candidates

Based on the six major categories and the 16 detailed types, the analytic hierarchy process (AHP) method has been used to assess their appropriateness as being used as counter measure against extreme urban flooding. 87 researchers or professionals in different fields participated in the AHP survey during the period from Jan. 11 to 18, 2013. The various fields include urban planning, architecture, landscape architecture, civil engineering, and environmental planning and science. The analytical results of the survey reveals that (1) transportation, spatial, and public/ education categories are expected to be more appropriate for the flooding mitigation multi-purpose use while the distribution and supply category is the least appropriate, and (2) local streets and schools (including their playing grounds) are to be the most appropriate ones in the transportation and public/education categories, respectively. Table 2 shows the results of the AHP appropriateness assessment.

Categories	Ranking	%	Detailed Types	Ranking	%
Transportation	1	20	Local streets	1	40
			Parking spaces	2	34
			Bus terminals	3	26
Public/ education	1	20	Schools	1	45
			Universities	2	29
			Government offices	3	26
Spatial	3	19	Urban parks	1	40
			Squares/Plazas	2	33
			Amusement parks	3	27
Culture and sport/recreation	4	14	Sport facilities	1	54
			Cultural facilities	2	46
Public Health	4	14	Medical centers	1	42
			Cemeteries	2	30
			Crematories	3	28
Distribution and supply	6	12	Distribution Centers	1	53
			Markets	2	47

Table 2 The results of appropriateness assessment for the flood mitigation multi-purpose use

Additionally, when the responses are divided into six (based on their professional groups) and compared to each other, it is found that respondents from civil engineering and environmental planning/science consider the spatial category less appropriate for the multi-purpose use, being compared with urban planners or architects. That is why the spatial category that has been expected to be the most appropriated is ranked third overall. Table 3 shows the different responses from various professional groups.

Categories	Ranking			
	Architecture	Urban Planning	Civil Engineering	Environmental Science and Planning
Transportation	3	1	2	2
Public and education	2	3	1	1
Spatial	1	2	4	3
Culture and sport/recreation	4	4	5	4
Public Health	5	5	6	5
Distribution and supply	6	6	3	6

Table 3 The comparison of the responses from different professional groups

V. Conclusion

Analytical results show that (1) there is a consensus on using transportation and public/education infrastructure as a counter measure against extreme flooding; (2) local streets and schools, more specifically, are believed to be suitable for flood-related hazard mitigation; (3) some professional groups seem to be more or less reluctant to use spatial infrastructure including urban parks and squares (plazas) as storm water detention basins. Given that roads tend to take up a significant portion of urban surface, they have great potential to detain rainwater temporarily as related construction technique develops further. Of course, some roads for people's escape and emergency access for cars should be secured in advance.

It is suspected that people's expectation for spatial infrastructure is too much high already, on the other hand. Considerable existing burden on parks, for instance, might make respondents from environmental science and planning worry about deteriorating the original quality or function of parks. Further research that aims to find environmental impacts of flood mitigation multi-use would be necessary before its more regular multiple-use.

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