Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering), Vol. 68, No. 4, I_109-I_114, 2012.

MULTI-CRITERIA GAP ANALYSIS OF FLOOD DISASTER RISK REDUCTION MANAGEMENT IN METRO MANILA, PHILIPPINES

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Identification of priority areas for flood disaster risk reduction (FDRR) management is critical and often tedious to both planners and decision-makers. Requests for additional resources, infrastructures and capability enhancement may require a quantifiable basis for budget allocation. In Metro Manila, Philippines, flooding is a perennial problem, thus requires a regular assessment of FDRR management. This study provides a simple approach to address this requirement using a multi-criteria gap analysis method. This is demonstrated using the results of the assessment made by the local government units (LGUs) in Metro Manila at the aftermath of an extreme flood event in 26 September 2009. Results show that gaps ranging from very small to medium-scale exist in the management system of the LGUs. Serious attention must be given to land use planning and flood mitigation measures. Flood hazard mapping should also be a priority in most local government units. Efforts must also be made to improve flood warning dissemination.

Key Words : *gap analysis, multi-criteria decision analysis, flood disaster risk reduction management, Metro Manila*

1. INTRODUCTION

The flood disaster risk reduction (FDRR) management system of Metro Manila, Philippines was challenged when a rare meteorological event, locally known as typhoon Ondoy, occurred on 26 September 2009. The storm largely inundated more than one-third of Metro Manila, putting a large number of urban and flood control structures under water. The disaster affected a population of more than 4.5 million, caused the death of almost 500 people, and incurred an accumulated loss amounting to almost USD 240 million[1).

During Ondoy's aftermath, a post-disaster needs assessment[2)] (PDNA) was conducted to estimate the damage, losses and economic and social impacts of the typhoon. The PDNA also identified and qualitatively assessed the constraints in the FDRR management system of Metro Manila, particularly those found in land use planning, housing, water management and disaster mitigation[2)]. Quantitative gap analysis, which was not performed in the PDNA, however, can help identify priority FDRR management tasks and priority flood prone areas, which are valuable in the formulation of a strategic FDRR management improvement plan.

In a management perspective, constraints or *gaps* represent the "space between where we are and where we want to be"[3)]. Liedtka[4)] described gap analysis as a time-based intent-driven strategic planning technique that uses historical information and desired outcomes as bases for improvement. Thus, gap analysis is both fact-based and goal-oriented, which makes it a powerful technique in the development and improvement of management systems.

The process of quantitatively evaluating gaps has recently been adopted in various areas of studies, such as in biodiversity conservation[5)], public transport systems[6)] and information technology research[7)]. This is perhaps due to the increasing demand for effective management strategies to cope with the rapidly changing environment and society. Despite its wide applicability, quantitative gap analysis has never been used in the evaluation of FDRR management systems. Most of the FDRR studies mainly concentrate on the effects of hydrological processes (e.g. Chen and Yu[8)]). This paper however focuses on the implementation of the FDRR management system and the evaluation of its constraints to identify priority tasks and priority areas in aid of developing an effective FDRR management plan, using Metro Manila as a case study.

The FDRR management systems of Metro Manila consist of several FDRR measures that require simultaneous gap evaluation. To cope with this, gap analysis, combined with a multicriteria decision analysis (MCDA) approach, was employed. MCDA is widely regarded for its robust applicability in various fields of studies[9),10),11)], particularly those that require comparison of benefits and importance. The use of gap analysis combined with MCDA approach, however, is still not well explored in the literatures.

From these reasons mentioned above, we intend to perform a gap analysis of the FDRR management system of Metro Manila using MCDA approach. MCDA was used to identify, organize and quantify the desired state of the FDRR measures. **Fig. 1** shows the conceptual framework of the multicriteria gap analysis of the FDRR management system. The criteria (FDRR phases) and sub-criteria (FDRR measures) were enumerated and were given weighting factors based on priority rankings. The gaps were quantified using the equivalent weight values and the performance scores (translated from the questionnaire-based assessments of the LGUs) of the FDRR measures. Priority tasks and priority areas in the FDRR management system have been identified, using the relationship: *bigger gaps means higher priority*. The multicriteria gap analysis method produced clear results that can be used to propose strategic improvements in the FDRR management plan of Metro Manila.

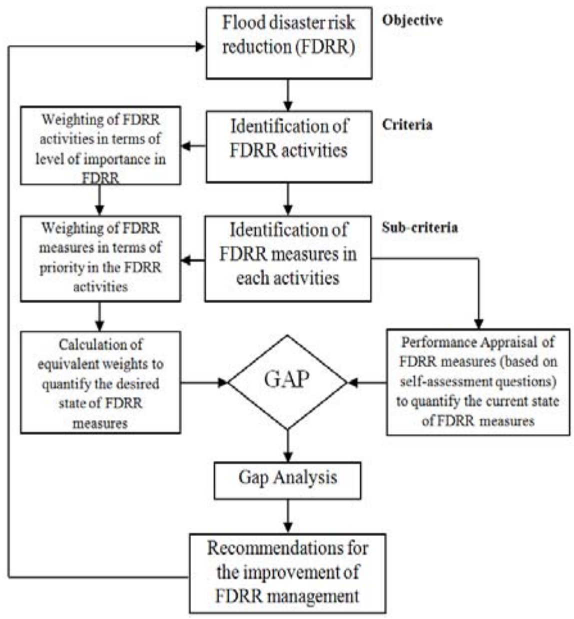

Fig. 1 Conceptual framework of multi-criteria gap analysis

2. THE STUDY AREA AND FDRR MANAGEMENT SYSTEM SURVEY

Metro Manila is situated on a semi-alluvial fan that opens to Manila Bay on the west and Laguna de Bay Lake on the southeast[12)]. **Fig. 2** shows the administrative boundary of Metro Manila including its 17 municipal LGUs. Metro Manila is the most populated region in the Philippines with a density of around 18,000people/km^2. It is also the country's political and economic capital with annual contribution of around 33% of the country's gross domestic product (GDP)[13)]. Despite its progress, floods have persistently slowed down the region's economic growth. The floods in Metro Manila regularly caused heavy inundation and traffic, which often result in the suspension of office and school works[14)]. Floods in Metro Manila can also be devastating, causing the loss of lives and damages to properties and public infrastructures.

On 26 September 2009, Metro Manila was hit by typhoon Ondoy. It brought a huge amount of rainfall measuring at 450 mm within a span of 12 hours, an amount almost equivalent to 2 months of rainfall in the same area. This resulted in unmitigated floods that devastated millions of lives and caused the loss of hundreds of millions of dollars in terms of agriculture and property damages[1)].

In October 2009, the authors conducted a comprehensive field survey as part of a PDNA study to investigate the extent of the typhoon's impact in Metro Manila and its suburbs. A questionnaire survey instrument was developed to aid in the assessment of FDRR management system. The management systems were assessed based on different time frames, i.e. before, during and after the disaster caused by typhoon Ondoy. The inquiries were made based on disaster preparedness; flood

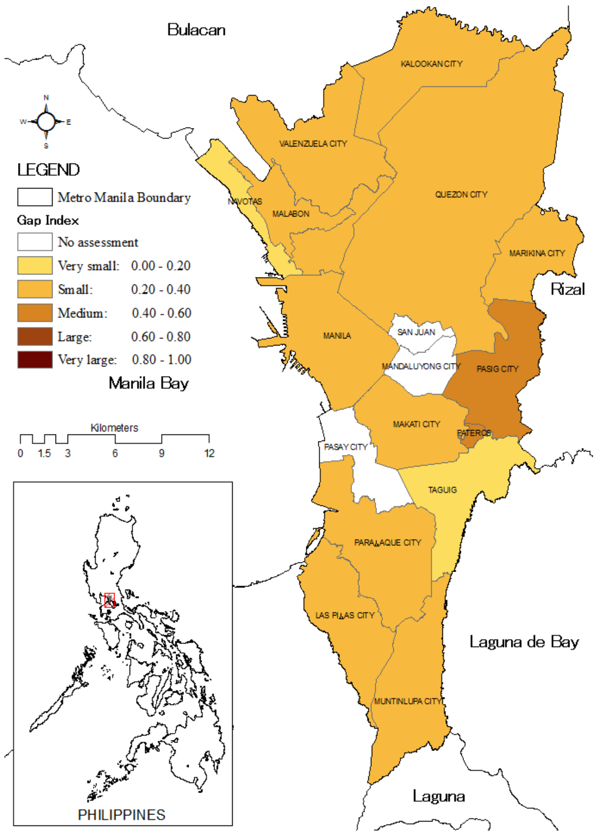

Fig. 2 Location of Metro Manila and its 17 city and municipal local government units.

mitigation measures; early warning and evacuation system; emergency response system; flood risk prevention planning and hazard mapping.

3. MULTI-CRITERIA GAP ANALYSIS

People are often faced with problems having multiple objectives and conflicting requirements. To simplify the route of decision-making, critical aspects is usually used as basis for prioritization. Thus, in order to identify the critical aspects and to compare and assess which decision is most appropriate a multicriteria gap analysis method was used.

The conduct of multicriteria gap analysis method in this study follows three stages, the first stage consists of enumerating the criteria or *FDRR activities*, and sub-criteria or *FDRR measures* (**Fig. 1**). In this paper, the FDRR activities include: Prevention, Preparedness, Response and Recovery. The enumerated FDRR activities and FDRR measures are shown in **Table 1.** Weighted scores are assigned, usually in a subjective manner[7),15)], to each FDRR activity and FDRR measure. In this paper, the authors propose a weighted score assignment method based on priority ranks. Priority ranking is done by arranging the criteria based on relative importance. The ranks are given as positive integer values from 1 to p, where p, is the number of criteria (or sub-criteria) within the same group. The criterion that has a rank of 1 has the highest importance within that group. The relative importance of each criterion was subjectively determined based on 1) order of need prior to the occurrence of disaster, i.e. Prevention criterion is expected to have the highest risk reduction compared to Recovery criterion, where the disaster has already occurred; and 2) when the criterion is most likely a prerequisite of the succeeding criterion. For example, in the Preparedness criterion, Institutional Framework (Serial Code D) ranks higher than Vulnerability Assessment (Serial Code E), since organizational structure for disaster management and appropriate policies must be established prior to conducting any vulnerability assessment to provide a guiding committee for the assessors. The weighted scores are then determined based on the rank, at which the sum of the weighted scores in a group of criteria is equal to 1.0. The weighted scores, W_i and $W_{i,j}$, of the i^{th} FDRR activities and j^{th} FDRR measures, respectively, were determined using the following expressions:

$$W_i = (n - R_i + 1) / \sum_{i=1}^{n} R_i \qquad (1)$$

$$W_{i,j} = (n_i - R_{i,j} + 1) / \sum_{j=1}^{n_i} R_{i,j} \qquad (2)$$

where, n is the total number of FDRR activities and n_i is the total number of FDRR measures. R_i and $R_{i,j}$ are priority ranks of the i^{th} FDRR activity and j^{th} FDRR measure. In this study, n = 4, n_1 = 3, n_2 = 6, n_3 = 3 and n_4 = 1. The equivalent weight, $W_{eq,i,j}$, was calculated for each FDRR measure based on the product of the weighted scores of the FDRR activities and FDRR measures, as shown in Eq. 3:

$$W_{eq,i,j} = W_i * W_{i,j} \qquad (3)$$

Table 1 shows the priority ranks and weighted scores of each FDRR activity and FDRR measure, with computed equivalent weights corresponding to each FDRR measure.

The second stage consists of performance appraisal of each FDRR measure based on the FDRR management system assessment done by the LGUs. Prior to appraisal, the evaluation measure was first defined[7)], in this study, 3 categories were used:

$$E = (1.0 \quad 0.5 \quad 0.0) \qquad (4)$$

A value of 1.0 or *achieved goal* means that the desired state of FDRR measure is in place and there is no known constraint that will contribute in the poor performance of the FDRR management. A value of 0.5 or *inadequately achieved goal* means that the desired state of FDRR measure is in place,

Table 1 Weighted scores, performance appraisal and gap values of Metro Manila FDRR management systems.

FDRR Activities (i)	Priority Rank (R_i)	Weight Level 1 (W_i)	Serial Code	FDRR Measures (j)	Priority Rank ($R_{i,j}$)	Weight Level 2 ($W_{i,j}$)	Equiv. Weight ($W_{eq,i,j}$)	Performance Appraisal ($P_{i,j,k}$)			Gap Index ($\Delta_{i,j,k}$)		
								Malabon City	Navotas City	Pateros	Malabon City	Navotas City	Pateros
Prevention	1	0.4	A	Avoidance of settlement in flood hazard zones	1	0.500	0.200	0.5	0.5	0.5	0.100	0.100	0.100
			B	Flood mitigation measures (structural and/or non-structural)	2	0.333	0.133	0.5	1.0	0.5	0.067	0.000	0.067
			C	Early flood warning	3	0.167	0.067	1.0	1.0	1.0	0.000	0.000	0.000
Preparedness	2	0.3	D	Institutional framework	1	0.286	0.086	1.0	1.0	0.0	0.000	0.000	0.086
			E	Vulnerability assessment (hazard mapping)	2	0.238	0.071	1.0	0.5	0.5	0.000	0.036	0.036
			F	Response mechanisms (evacuation and rescue procedures)	3	0.190	0.057	1.0	1.0	1.0	0.000	0.000	0.000
			G	Information systems	4	0.143	0.043	1.0	1.0	1.0	0.000	0.000	0.000
			H	Public education and flood hazard awareness	5	0.095	0.029	0.5	1.0	1.0	0.014	0.000	0.000
			I	Emergency response capability (e.g. rescue and communcation equipment, training,	6	0.048	0.014	0.5	1.0	0.0	0.007	0.000	0.014
Response	3	0.2	J	Warning Dissemination	1	0.500	0.100	0.5	1.0	0.0	0.050	0.000	0.100
			K	Evacuation response	2	0.333	0.067	0.5	1.0	0.0	0.033	0.000	0.067
			L	Emergency response (e.g. rescue operations)	3	0.167	0.033	0.0	1.0	0.0	0.033	0.000	0.033
Recovery	4	0.1	M	Rehabilitation	1	1.000	0.100	0.5	1.0	0.5	0.050	0.000	0.050

but there is at least one observed constraint that may contribute to the poor performance of the FDRR management system. Lastly, a value score of 0.0 or *no achievement* means that the desired FDRR measure is not yet in place thus, may result in unmitigated disaster when flood occurs. During the FDRR management survey in Metro Manila, 14 (including the lone municipality of Pateros) out of the 17 municipal LGUs were assessed, and the assessment results were translated to performance scores. **Table 1** show 3 of the 14 LGUs, as examples, with scores based on the self-assessment done by the LGUs.

To further explain this, in Malabon City, the emergency response was performed when floods occurred during typhoon Ondoy. However, several constraints were observed such as lack of rescue vehicles and lack of rescuers' training that resulted in the poor performance of the overall emergency response mechanism. The performance score (**Table 1**) of the Emergency Response Capability measure (Serial Code I) of Malabon City is 0.5.

The third stage is the calculation of gap indices. The product of the equivalent weight, $W_{eq,i,j}$, of each FDRR measure, and the performance appraisal, $P_{i,j,k}$, of the k^{th} municipal LGU, represents the estimated actual performance of the FDRR measures. The gap index, $\Delta_{i,j,k}$, is computed by taking the difference of the equivalent weight, $W_{eq,i,j}$, and the estimated actual performance of a FDRR measure ($W_{eq,i,j}$ * $P_{i,j,k}$). This is expressed by the formula:

$$\Delta_{i,j,k} = W_{eq,i,j} - W_{eq,i,j} * P_{i,j,k} \tag{5}$$

Table 1 shows the gap indices, $\Delta_{i,j,k}$, of 3 of the 14 LGUs, as examples, computed using Eq.(5).

The FDRR management gap index, Δ_k of the k^{th} LGU, is determined using the following expression:

$$\Delta_k = \sum_{i=1}^{n} \sum_{j=1}^{n_i} \Delta_{i,j,k} \tag{6}$$

The FDRR management gap indices of Metro Manila by FDRR measure, $\Delta_{MM,i,j}$ are calculated using the following formula:

$$\Delta_{MM,i,j} = \sum_{k=1}^{N} \Delta_{i,j,k} / N \tag{7}$$

where N is the total number of municipal LGUs that performed the FDRR management assessment, in this case $N = 14$.

4. RESULTS AND DISCUSSION

Graphs are very useful in evaluating quantified constraints. These provide simple and convenient means to visually compare the gap indices of the FDRR measures, and gap indices of the flood prone municipal LGUs. **Fig. 3** shows the gap index values, Δ_k, computed using Eq.(6), of all FDRR-assessed municipal LGUs in Metro Manila. Pateros and Pasig City have gap index values higher than 0.40, while Navotas City and Taguig City have gap index values lower than 0.20. The relatively large difference between the gap index values of these municipalities roughly indicates the inconsistencies in the implementation of the FDRR systems within the administrative region. Pateros, the smallest municipality in Metro Manila (2.1 km^2), has the highest gap index value ($\Delta_k = 0.55$). This municipality has a population of more than 62,000[16] people, making it the second most densely

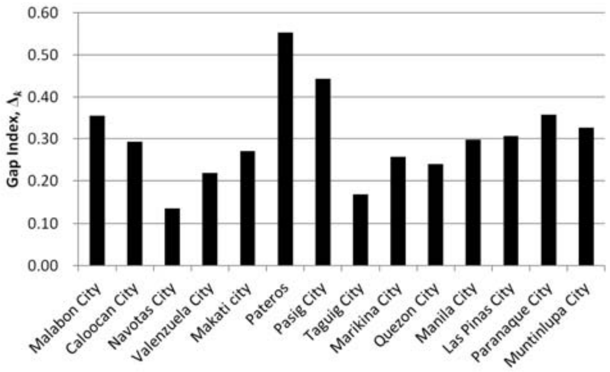

Fig. 3 Gap value chart of 14 municipalities in Metro Manila.

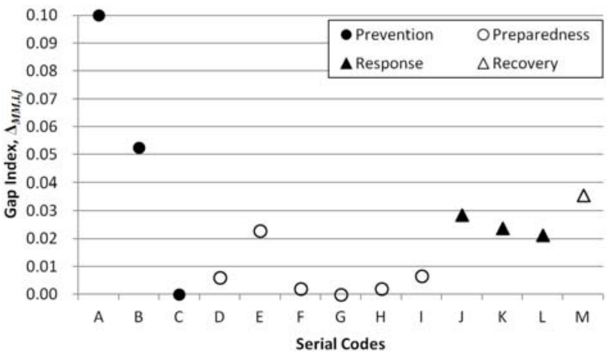

Fig. 4 Gap value chart of the sub-criteria based on the assessment of 14 LGUs.

populated municipality (next to Manila City) in the Philippines. Around 60% of Pateros is prone to 10 years return flood, however during typhoon Ondoy, almost 100% of its area was inundated (1 to 2m). Based on the assessment of the FDRR management assessment system of Pateros, it has many settlement areas vulnerable to flood (Serial Code A), has no clear FDRR management institutional framework (Serial Code D), has no systematic procedures for flood warning dissemination (Serial Code J), not efficient in the conduct of evacuation procedures (Serial Code K), and it is not capable of performing effective rescue and emergency operations (Serial Code L). Thus, Pateros requires serious and immediate attention to improve its FDRR management system.

On the other hand, the relatively smaller gaps (**Fig. 3)** of Navotas City (Δ_k = 0.14) and Taguig City (Δ_k = 0.17) indicates that these LGUs have more established FDRR management systems compared to the other municipalities. The FDRR constraints in Navotas City and Taguig City are mainly due to the presence of settlements in flood hazard areas (Serial Code A in **Table 1**). This land use-related problem is a common situation in Metro Manila. To address this issue, it will basically require land use conversion in the flood hazard areas, which may result in the resettlement of affected population. The local policy requires the government to compensate (i.e. in terms of housing, utilities, livelihood, etc.) any of those who will be displaced by a government initiated programs. Such activities will require space and entail substantial resettlement budget allocation. Relocation of the affected population may also have impact in the local political situations. The absence of comprehensive flood hazard maps (Serial Code E in **Table 1**) is also a common issue, which is primarily due to the unavailability of information necessary in the preparation of a flood hazard map (e.g. topographic map, geologic map, hydrological data, etc.). From a general perspective, the gaps in the FDRR management system of each LGU, as shown in **Fig. 2**, are fairly small (except Pateros), which indicates that most LGUs are still pro-active in reducing the effects of flood disasters despite the existence of various constraints.

Looking at the overall FDRR management system of Metro Manila, to identify the priority FDRR measures on the basis of constraints, the gap indices of each measure, $\Delta_{MM,i,j}$, were evaluated. **Fig. 4** shows the gap index values of each FDRR measure as computed using Eq.(7). The shapes (●, ○, ▲, and △) represent the FDRR activities (or first level criteria) of the FDRR management system. The meaning of the alphabets (Serial Codes) A to M, are shown in **Table 1**. In **Fig. 4**, Serial Code A ($\Delta_{MM,i,j}$ = 0.100) has the largest gap in the FDRR management system. As explained above, land use and resettlement issues are common in Metro Manila due to the lack of space and insufficiency of budget for relocation. The constraints in Serial Code B ($\Delta_{MM,i,j}$ = 0.052) is perhaps due to the lack of effective flood mitigation measures (structural on non-structural measures) in several flood prone areas (e.g. Las Piňas City). With regards to Serial Code C ($\Delta_{MM,i,j}$ = 0), there was no constraint identified since all the assessed LGUs claimed that they have community-based early flood warning systems, which is perhaps due to their experiences with recurring floods. The gap index value concerning the effectiveness of the early flood warning systems (**Fig. 4**, Serial Code J), however, was high ($\Delta_{MM,i,j}$ = 0.029). In terms of Preparedness (○), Metro Manila clearly has gaps in the preparation of flood hazard maps (Serial Code E, $\Delta_{MM,i,j}$ = 0.023). This is attributed to the lack of updated physical maps (topographical maps, geologic maps, etc.) and meteorological and hydrological data (rainfall, river discharge, etc.). All LGUs have information systems (Serial Code G) and most have response mechanisms (Serial Code F) for flood emergencies, however, execution of these measures were found ineffective in several LGUs. In general, Metro Manila, is weak in the

Response (▲) criterion, (Serial Codes J, K and L), as evidenced by the unreliable flood forecasting and warning systems, lack of rescue teams and lack of evacuation vehicles during typhoon Ondoy. The gaps in the Recovery (△) criterion (Serial Code M) are mostly attributed to the lack of funds of most LGUs to engage in immediate flood disaster rehabilitation.

5. CONCLUSION

This study describes a method of gap analysis combined with MCDA to systematically and quantitatively evaluate the FDRR management systems in Metro Manila. The conclusions were drawn as follows:

(1) The gaps existing in the LGU-based FDRR management systems in Metro Manila can be quantified and evaluated using multi-criteria gap analysis method;

(2) The use of priority ranking in MCDA provided a systematic approach in assigning acceptable weighted values in each of the FDRR measure;

(3) The overall gaps in the FDRR management systems in Metro Manila are relatively low, except for the gaps present in the Prevention (●) criterion. Relocation of human settlement from known flood hazard zones will still significantly reduce the potential losses and damages. The establishment of new and enhancement of existing structural and non-structural flood mitigation measures were found to be still valuable in the FDRR;

(4) Finally, it was found that all assessed LGUs have management gaps that require attention in order to realistically achieve the desired FDRR management systems and that some LGUs (e.g. Pateros) may require more immediate solutions than others.

The multi-criteria gap analysis method is simple and very useful in providing insights to researchers and decision-makers, however, it requires a comprehensive and clear assessment of the FDRR management system (by the stakeholders) to generate acceptable results.

ACKNOWLEDGEMENT

This study was carried out as part of the research program of the Asian Human Resource Fund under the research project, "Solutions for the water-related problems in Asian Metropolitan areas" (with A. Kawamura as representative) supported by the Tokyo Metropolitan Government, Japan. We thank Woodfields Consultants, Inc. for providing the field data necessary for the accomplishment of this study.

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(Received September 30, 2011)