Analysis of Barriers on Integrated Flood Risk Management in Metro Manila, Philippines, by Interpretive Structural Modeling Approach

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ABSTRACT

The adaptation of integrated flood risk management (IFRM) approach in the Philippines is a challenging task due to heavy reliance of traditional structural measures in the past. And so, there are critical issues or "barriers" that hamper the adaptation of IFRM. This study presents for the first time a framework in identifying the barriers on IFRM in a case-specific approach focusing on a megacity of a developing country such as Metro Manila, Philippines. Moreover, this framework presents a systematic approach in analyzing the barriers on IFRM by interpretive structural modelling. This study was able to identify a total of 12 barriers that encompasses governance, social, and technological resources aspects in Metro Manila, Philippines. The results show that barriers on the governance aspect are the most influential barriers while barriers on the social aspect have the least influence to other barriers.

INTRODUCTION

Flooding has been the most frequent natural disaster in Metro Manila (MM), Philippines. The perennial flood occurrences affect MM wherein housing and other infrastructure are inundated, traffic congestion are heavily and frequently aggravated, and urban dwellers' daily routines and business functions are unfavorably affected. There are about 3 to 4 incidences of significant flooding that besets MM annually caused by typhoons, monsoon rains and even torrential rains (DPWH, 2004). Inundation depths in MM can range from a gutter-height inundation, usually due to torrential rains which can cause traffic congestion, to more than 5 meter inundation brought by storms or typhoons, which can cause extensive property damages and hundreds of fatalities. In the last decade, there were at least three disastrous flood events that devastated MM such as, typhoon Ondoy (international name Ketsana) in 2009 and two monsoon rains locally known as "Habagat" in 2012 and 2016. Typhoon Ondoy incurred losses and damages estimated to be more than one billion dollars, 747 fatalities, and 7-meter flood depths submerging even the luxurious and exclusive residential areas within MM. Such flood events gravely and consistently distressed MM economically, socially, and environmentally, despite numerous structural mitigation measures that has been established since the early part of the 20th century.

Before the Typhoon Ondoy event, there were no comprehensive implementation program for flood control projects in MM. The onslaught brought by the Typhoon Ondoy has prompted the Philippine government to start taking a proactive approach in disaster risk management and one of its first strategies was the development of an IFRM plan for MM in 2013. This plan was initiated by the Department of Public Works and Highways (DPWH) to provide an integrated and strategic approach to flood management that will guide the government's decisions and investments over the next 25 years (DPWH, 2013). However, the shift to an integrated approach for flood management is an immensely laborious task for MM and there is an absolute existence of barriers that would impede the unerring materialization of the IFRM plan since MM have heavily depended on traditional structural measures in the past. There is an extreme need to identify first the barriers on IFRM but there are no researches on this, despite some notable researches conducted which focused on the nature of flooding in MM at the last decade. These researches focused on the hydrological process on local street flood (Lagmay et al., 2017) and the assessment on the environmental impacts of structural flood mitigation measures in MM (Gilbuena et al., 2013b, 2013c).

Apart from identifying the barriers on IFRM, these barriers need to be translated in a systematic manner to provide coherent interpretation and in depth understanding for the decision makers and practitioners since barriers, in general, are obstacles that can be overcome with concerted effort, creative management, shift of thinking, prioritization, and provision for financial and human resources (dos Muchangos et al., 2015). Moreover, it is very likely that when decision makers undertake crucial decisions on complex issues and problems, such as overcoming barriers on IFRM, they usually make an intuitive judgment based on prior experience rather than a rational assessment. To date, there are no single accepted framework wherein barriers on complex issues and problems are either categorized or assessed presumably because if its complexity and difficulty in analyzing abstract concepts.

One systematic method that can be used in this study is the Interpretive Structural Modelling (ISM) since this approach can overcome inherent limitations on complex issue adaptability i.e., interrelation of criteria and practical applicability on actual situation, in which other methods such as the Analytic Hierarchy Process (Saaty, 1987) and Analytic Network Process (Saaty, 2004) fail to overcome (Thakkar et al., 2008). Barriers on supply chains management (Agi and Nishant, 2017; Mudgal et al., 2010; Ravi et al., 2005), knowledge management (Singh et al., 2003), and landfill development (Chandramowli et al., 2011) were analyzed using ISM. No studies related to natural hazards and disaster risk reduction management, such as the IFRM, are known to apply ISM method hitherto. Hence, this study applies ISM for the analysis of barriers on IFRM.

This study identifies the barriers on IFRM and analyzes the interrelationships of this barriers for the first time by applying the interpretive structural modelling (ISM) method.

FRAMEWORK FOR BARRIER ON IFRM ANALYSIS

Barrier identification: There are no standard method or any acceptable framework to which barriers on IFRM are identified hitherto. Some of the possible approaches that can be utilized are the review of literature, data gathering from experts and practitioners, and conducting survey or interviews. In this study, we utilized comprehensive review of literature to identify and scrutinize the barriers on IFRM in MM. The collection of literature gathered are comprised of project reports from DPWH, local publications, international journal publications, and a book that features a case study in MM.

Interpretive Structural Modeling: The ISM approach, which was developed by Warfield (1973), is an effective method for analyzing complex and interrelated issues. ISM is used to assess fundamental understanding of complex situations and allows portrayal of different and related elements to be structured in a comprehensive systematic model (Agi and Nishant, 2017).

ISM utilizes some application of some elementary graph theory such that theoretical, conceptual, and computational leverage are efficiently exploited to construct a structural model. This model guides decision makers and practitioners to interpret and understand the complexity of the interrelated issues in order for them to put a course of action for solving problem (Farris and Sage, 1975; Warfield, 1976; Watson, 1978). Fundamentally, ISM method has six major steps (Attri et al., 2013) as shown in Figure 1.

The succeeding paragraphs discuss in detail the methodology in each step, the modification of the symbols, and the simplified method on constructing the matrices and the modified ISM model schematic:

Step 1: Establish the relationship between barriers and develop a Structural Self-Interaction Matrix (SSIM).

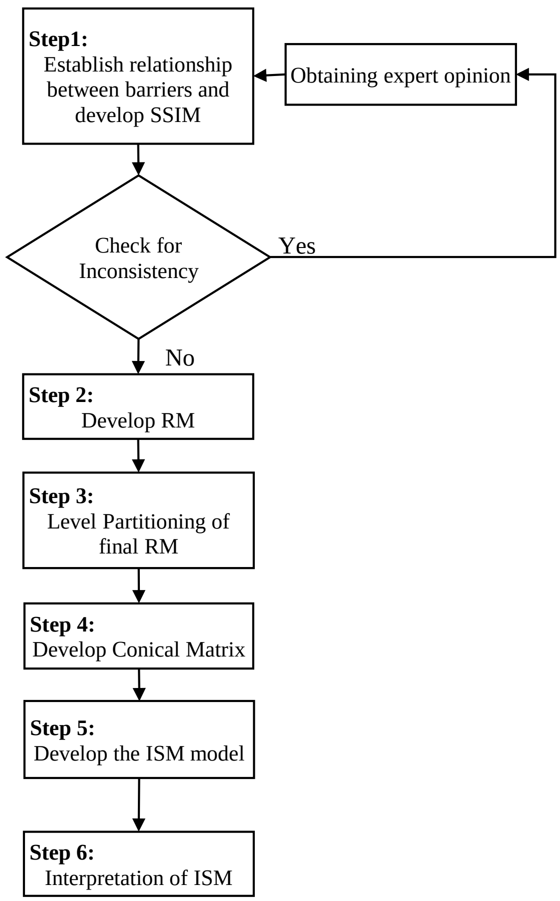

Figure 1. Flowchart for ISM.

SSIM is developed by evaluating a pairwise relationship among the barriers. Four types of relationships that can be derived in each variable, wherein in this study these variables are the barriers on IFRM. This can be done by individually or consulting key actors concerned by conducting a group discussions, interviews or surveys. In this study, selected experts and practitioners were engaged to develop first a preliminary SSIM. The preliminary SSIM is the individual assessment of each expert and practitioner then their responses are summarized by considering the majority answer to produce the SSIM. Applied on this study is a contextual relationship of the IFRM barriers based on "influencing factors" type of relation. This type of relation identifies if one variable influences another variable. The symbolism used in the SSIM was modified in this study in order to provide a more meaningful representation of the results without memorizing the conventional symbolism in the SSIM. Four symbols were used to denote the pairwise relationship between barrier i and barrier j. The following shows the conventional and the modified symbolism for the SSIM:

a. Letter "V" is changed to symbol "+" denotes that barrier i influences barrier j
b. Letter "A" is changed to symbol "-" denotes barrier i is influenced by barrier j
c. Letter "X" is changed to symbol "±" means that barrier i and barrier j influence each other
d. Letter "O" is changed to symbol "0" means that barrier i and barrier j are independent of each other.

In the modified approach, all cells of the matrix, except the diagonal, are filled with the modified symbolism which is in contrast to the conventional methodology wherein only half of the table is filled up. Apart from the meaningful representation, these modifications simplified the construction of the matrix in the next step.

Step 2: Develop Reachability Matrix (RM).

From the SSIM, an initial RM (RM_{init}) is to be derived by transforming each cell of SSIM into binary digit, 0 or 1. The rules for the transformation of conventional methodology are as follows:

a. If V is in the SSIM(i, j), then $RM_{init}(i, j)$ is 1 while the $RM_{init}(j, i)$ is 0.
b. If A is in the SSIM(i, j) then $RM_{init}(i, j)$ is 0 while the $RM_{init}((j, i)$ is 1.
c. If X is in the SSIM(i, j) then $RM_{init}(i, j)$ is 1 while the $RM_{init}(j, i)$ is 1.
d. If O is in the SSIM(i, j) then $RM_{init}(i, j)$ is 0 while the $RM_{init}(j, i)$ is 0.

As mentioned in Step 1, the modifications made in this study allows simpler guidelines for deriving the RMi. Modification of the above rules are as follows:

a. If "+"is in the SSIM(i, j) then $RM_{init}(i, j)$ is 1.
b. If "-"is in the SSIM(i, j) then $RM_{init}(i, j)$ is 0.
c. If "±" is in the SSIM(i, j) then $RM_{init}(i, j)$ is 1.
d. If "0" is in the SSIM(i, j),then $RM_{init}(i, j)$ is 0.

The RM_{init} is further transformed to a final RM (RM_{fin}). The RM_{fin} is derived by incorporating transitivity to the RM_{init}. The rule for transitivity is as follows: if the input in $RM_{init}(i, j)$ is equal to 1 and $RM_{init}(j, k)$ is equal to 1, then $RM_{fin}(i, k)$ should be equal to 1.

Step 3: Level partitioning using RM_{fin}.

The level partitioning is basically assigning levels for each barriers. This is done by first identifying the reachability set, antecedent set, and the intersection set for each barriers using the RM_{fin}. The elements of the reachability set of each barrier i, are those barriers j that have an entry "1" within its row, while the antecedent set of each barrier j consist of barriers i that have an entry "1" within its column in the RM_{fin}. Meanwhile, barriers that are identified to belong to both the reachability set and the antecedent set are identified as elements of the intersection set.

Thereafter, the barriers to be assigned in level I are those barriers whose reachability and intersection set are exactly the same. Then to identify the barriers that belong to the next level, barriers in level I are eliminated from the reachability, antecedent and intersection sets and new sets of reachability, antecedent and intersection sets are produced. Again, barriers whose reachability and intersection set are exactly the same will be assigned as level II. Likewise, barriers on level II are eliminated from all the sets and new sets of reachability, antecedent and intersection sets are produced. This process is recursively done until the last level partition is determined.

Step 4: Develop conical matrix (CM).

Once barriers are assigned to its respective level, RM_{init} is transform to a conical matrix (CM) by simply rearranging barriers *i* and *j* and its binary value, 0 or 1, in the sequence of ascending level, level I up to the last level, across the rows and columns.

Step 5: Develop to ISM model.

The ISM model is a kind of a directed graph (or digraph) which shows a set of variables that are interconnected together representing association wherein in this study, this association represents influencing power. The major attribute that sets apart ISM model to a digraph is the incorporation of the hierarchy among the set of variables apart from interconnection. To develop the ISM model, the CM is used which shows the association and levels on each barriers. In the CM, if there is 1 on barrier i and barrier j and arrow is drawn in the direction of barrier *i* to barrier *j*.

Step 6: Interpretation of the ISM model.

Finally, the produced ISM model is interpreted. The model produced allows interpretation to which barriers influences them which is directed by the arrows in the model. The model also shows the hierarchy which manifests which barriers are the most and least influencing.

Table 1. Barriers on IFRM in Metro Manila, Philippines.

Aspect	Barrier		References
Governance	1	Lack of sole organizing body	Bankoff, 2003; Zoleta-Nantes, 2000; DPWH, 2004
	2	Lack of communication	DPWH, 2013, 2004
	3	Lack of funding	DPWH, 2004; Zoleta-Nantes, 2000
	4	Lack of flood control measures	Gilbuena et al., 2013b; Porio, 2011; Zoleta-Nantes, 2000
Social	5	Illegal settlers	Ballesteros, 2010; Bankoff, 2003; Shatkin, 2004; Zoleta-Nantes, 2000
	6	Poor solid waste management	Ballesteros, 2010; Zoleta-Nantes, 2000
	7	Poor social planning	Bankoff, 2007; Shatkin, 2004; Zoleta-Nantes, 2000
Technological Resources	8	Lack of technological capabilities	Gilbuena et al., 2013a; Zoleta-Nantes, 2000
	9	Sparse data and limited access	DPWH, 2013, 2004; Gilbuena et al., 2013a
	10	Lack of experts	Albert et al., 2016; DPWH, 2004; Shatkin, 2004
	11	Lack of data processing systems	Albert et al., 2016; DPWH, 2013; Gilbuena et al., 2013a
	12	Deterioration of flood control structures	DPWH, 2013, 2004; Gilbuena et al., 2013a

Table 2. Structural Self-Interaction Matrix

Barrier		*j*											
		1	2	3	4	5	6	7	8	9	10	11	12
i	1		+	+	+	0	0	0	+	+	+	+	+
	2	-		+	0	+	+	+	0	+	0	0	0
	3	-	-		+	0	0	0	+	+	+	+	+
	4	-	0	-		0	0	+	+	+	±	±	+
	5	0	-	0	0		+	-	0	0	0	0	0
	6	0	-	0	0	-		-	0	0	0	0	0
	7	0	-	0	-	+	+		0	0	-	0	0
	8	-	0	-	-	0	0	0		+	-	±	+
	9	-	-	-	-	0	0	0	-		-	-	0
	10	-	0	-	±	0	0	+	+	+		+	+
	11	-	0	-	±	0	0	0	±	+	-		+
	12	-	0	-	-	0	0	0	-	0	-	-	

Table 3. Final Reachability Matrix.

Barrier		*j*											
		1	2	3	4	5	6	7	8	9	10	11	12
i	1	1	1	1	1	1*	1*	1*	1	1	1	1	1
	2	0	1	1	1*	1	1	1	1*	1	1*	1*	1*
	3	0	0	1	1	1*	1*	1*	1	1	1	1	1
	4	0	0	0	1	1*	1*	1	1	1	1	1	1
	5	0	0	0	0	1	1	0	0	0	0	0	0
	6	0	0	0	0	0	1	0	0	0	0	0	0
	7	0	0	0	0	1	1	1	0	0	0	0	0
	8	0	0	0	1*	1*	1*	1*	1	1	1*	1	1
	9	0	0	0	0	0	0	0	0	1	0	0	0
	10	0	0	0	1	1*	1*	1	1	1	1	1	1
	11	0	0	0	1	1*	1*	1*	1	1	1*	1	1
	12	0	0	0	0	0	0	0	0	0	0	0	1

RESULTS AND DISCUSSIONS

Barriers on IFRM in MM: As mentioned in the methodology, the barriers on IFRM in Metro Manila, Philippines were identified by conducting a comprehensive review of literature. Table 1 shows the 12 barriers that belong to three aspects: governance, social, and technological aspects. Out of the 12 barriers, 4, 3, and 5 barriers belong to the governance, social, and technological aspect, respectively. Barriers on IFRM related to governance aspect pertains to those structural context in which the Philippine government develop policies and implement projects for flood control. In the case of the barriers on social aspect, these are barriers related to urban development and society's values, attitudes and morals towards its environmental. The technological resources aspect, on one hand, are those that support decision making based from scientific insights and evidences.

ISM Model: As mentioned in the methodology, there are 6 steps for the ISM approach. The result in Step 1, the SSIM, which was derived by consulting 5 expert and practitioners in the Philippines presented in Table 2 which represents the majority response in the pairwise assessment. SSIM inherently captures the heuristic knowledge of the respondents (the experts and practitioners) at the problem on hand. Then, using Table 2, the second step is derived and presented in Table 3, in which this shows RM_{fin} wherein the 1* suggests that it was initially 0 before applying transitivity on the RM_{init}. It can be seen on the table that Barrier 1 (Lack of sole organizing body) influences almost all the other barriers on IFRM. Then, using Table 3 (using RM_{fin}) Step 3 is done in accordance to the procedure discussed in the Methodology. The summary of the reachability, antecedent, intersection sets and the corresponding level of each barrier set is presented in Table 4. In study, the barriers on IFRM are assigned to a total of 7 levels as can be seen in Table 4. Table 5 shows the derived CM from the RM_{init} which is used to develop the ISM model.

The final outcome of this study is the ISM model shown in Figure 2. This study reveals that the most influential barrier on IFRM for MM is Barrier 1 (Lack of sole organizing body) implying that establishment or at least assigning a lead agency in IFRM that supports planning, implementation, and operations and maintenance has to be carried out. Currently, there are too many key players on flood risk management in MM (DPWH) such as, DPWH, MMDA, National Disaster Risk Reduction and Management Council and the Office of Civil Defense, among others, but the lack of a governing body hinders sound, consistent and integrated management. The second most influential barriers is Barrier 2 (Lack of coordination among agencies and stakeholders) which directly influences Barrier 3 (Lack of prioritization) and the social aspect barriers Barrier 7 (Poor social planning), Barrier 5 (Poor solid waste management) and Barrier 6. The ISM model also reveals that Barrier 4 (Lack of flood control measures) and 10 (Lack of experts), and Barrier 11 (Lack of data processing systems) and 8 (Lack of technological capabilities) are directly influencing each other. The improvement of these barriers are actually triggered and influenced by experts. Barrier 10 (Lack of Experts) triggers the improvement of most of the scientific resources barriers including Barrier 4 (Lack of flood control measures). Lastly, the least influential barriers are Barrier 6 (Poor Solid Waste Management), Barrier 9 (Sparse data and limited access), and Barrier 12 (Modernization of flood control structures).

Table 4. Level partition summary.

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,5,6,7,8,9,10,11, 12	1	1	VII
2	2,3,4,5,6,7,8,9,10,11,12	1,2	2	VI
3	3,4,5,6,7,8,9,10,11,12	1,2,3	3	V
4	4,5,6,7,8,9,10,11,12	1,2,3,4,8,10,11	4,8,10,11	IV
5	5,6	1,2,3,4,5,7,8,10,11	5	II
6	6	1,2,3,4,5,6,7,8,10,11	6	I
7	5,6,7	1,2,3,4,7,8,10,11	7	III
8	4,5,6,7,8,9,10,11,12	1,2,3,4,8,10,11	4,8,10,11	IV
9	9	1,2,3,4,8,9,10,11	9	I
10	4,5,6,7,8,9,10,11,12	1,2,3,4,8,10,11	4,8,10,11	IV
11	4,5,6,7,8,9,10,11,12	1,2,3,4,8,10,11	4,8,10,11	IV
12	12	1,2,3,4,8,10,11,12	12	I

Table 5. Conical Matrix.

Level	I	I	I	II	III	IV	IV	IV	IV	V	VI	VII	Level
Barrier	12	9	6	5	7	11	10	8	4	3	2	1	
12	1	0	0	0	0	0	0	0	0	0	0	0	I
9	0	1	0	0	0	0	0	0	0	0	0	0	I
6	0	0	1	0	0	0	0	0	0	0	0	0	I
5	0	0	1	1	0	0	0	0	0	0	0	0	II
7	0	0	1	1	1	0	0	0	0	0	0	0	III
11	1	1	1*	1*	1*	1	1*	1	1	0	0	0	IV
10	1	1	1*	1*	1	1	1	1	1	0	0	0	IV
8	1	1	1*	1*	1*	1	1*	1	1*	0	0	0	IV
4	1	1	1*	1*	1	1	1	1	1	0	0	0	IV
3	1	1	1*	1*	1*	1	1	1	1	1	0	0	V
2	1*	1	1	1	1	1*	1*	1*	1*	1	1	0	VI
1	1	1	1*	1*	1*	1	1	1	1	1	1	1	VII

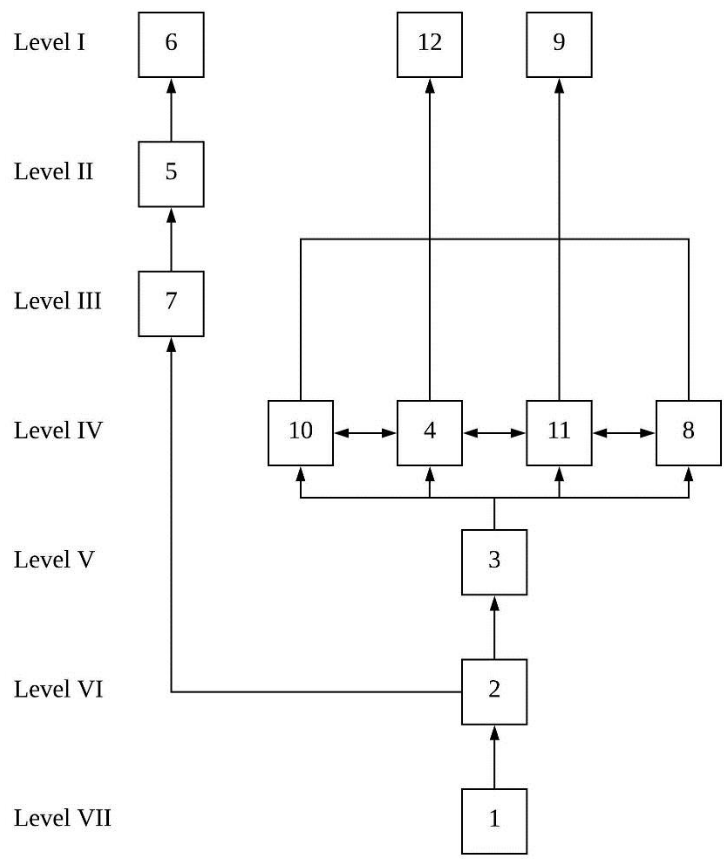

Figure 2. ISM model for the barriers on IFRM in Metro Manila, Philippines.

CONCLUSIONS

The main objective of this study is to identify barriers on IFRM through an extensive review of literature and analyze its interrelationships by ISM method. This study was able to identify 12 barriers to an IFRM which reflects megacities of a developing countries. Of the 12 barriers, 4, 3, and 5 barriers encompasses the governance, social and scientific resources aspects, respectively.

Interrelationships among these barriers were successfully analyzed using ISM method. The produced ISM model shows that the lack of sole organizing body that manages flooding is the most influential and important barrier in to an IFRM. Resolving this barrier is presumably to positively affect all other depending barriers especially those in the governance and scientific resources aspect. The poor solid waste management, lack of data access and sparse data, and modernization of flood control structures barriers showed to be the least influential barrier but depended with all other barriers in the IFRM. Categorically, the governance related barriers have a strong driving influence among other barriers. This was followed by the scientific resources-based barriers. The social barriers are found to be the least influential barriers.

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