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Hierarchical Structure of the Barriers to Integrated Flood Risk Management in Metro Manila, Philippines by Interpretive Structural Modelling Approach

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The adaptation of integrated flood risk management (IFRM) plan in Metro Manila, Philippines is a challenging task due to heavy reliance on traditional structural measures in the past. Moreover, there are critical issues or “barriers” that hamper the adaptation of IFRM. These barriers are interrelated with each other, hence, they should be translated in a systematic model showing the interrelationships as well as the hierarchy. This study presents for the first time the application of the Interpretive Structural Modelling (ISM) method to barrier analysis related to IFRM. This method is a systematic approach that analyses complex and interrelated issues that is structured in a comprehensive model. The results show that, among the 12 barriers identified, the lack of sole organizing body is the most influential barrier while the poor solid waste management, sparse data and limited access, and deterioration of flood control structure barriers are the least influential barrier. The ISM model clearly showed that the barriers on the governance aspect are the most influential barriers that may dictate the movement of all other barriers. The ISM model produced in this study shows the interconnections of each barrier that can aid the decision makers and practitioners in Metro Manila, Philippines.

Key Words : *barriers, integrated flood risk management, interpretive structural modelling, Metro Manila*

1. INTRODUCTION

The disaster brought by Typhoon Ondoy (international name: Ketsana) in Metro Manila (MM), Philippines, back in 2009, has prompted the Philippine government to start taking a proactive approach in disaster risk management. One of its first strategies was to develop an Integrated Flood Risk Management (IFRM) plan for MM. This plan was initiated and completed by the Department of Public Works and Highways (DPWH) in 2013 which provides an integrated and strategic approach to flood management that will guide the government’s decisions and investments for the next 25 years[1)]. However, the shift to an integrated approach for flood management is an immensely laborious task for MM. There are certain issues or “barriers” that can impede the unerring materialization of the IFRM plan since MM have heavily depended on traditional structural measures.

The IFRM is an approach that is a combination of both structural measures, which are the traditional hard engineering measures, and non-structural measures to mitigate flood risks in flood-vulnerable areas[2)]. In this approach, there is a growing recognition towards the shift of promotion of non-structural measures than the traditional structural measures, which basically adopts the concept of “keeping people away” rather than “keeping water away”[3)]. The increased promotion of non-structural measures takes into account of the effects of climate change wherein flood impacts and frequencies are expected to intensify in the future[2),3)].

The present authors have already conducted various studies on flood management in the Philippines that focus on MM[5), 6), 7), 8)] and we have identified the gaps in flood disaster risk reduction even before shifting to an IFRM approach. Moreover, we have identified various barriers to IFRM that encompasses the governance, social, and technological resources aspects in our previous study(9). We conducted a questionnaire-based survey to determine which barrier is influential by consulting experts and practitioners. The results of this study showed varying views on the interrelationship of the barriers(9). Nonetheless, a systematic analysis of these barriers to IFRM in MM has not yet been carried out. A systematic assessment is needed that provides coherent interpretation and in depth understanding of barrier interrelationships 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(10). Moreover, it is very likely that when decision makers undertake crucial decisions on complex issues and problems, such as overcoming barriers to 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 of 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 that is, interrelation of criteria and practical applicability on actual situation, in which other methods such as the Analytic Hierarchy Process(11) and Analytic Network Process(12) fail to overcome(13). Barriers on supply chains management(14), 15), 16), knowledge management(17), and landfill development(18) 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. The objective of this study is to model the hierarchical structure of the barriers to IFRM in MM in a systematic manner using the ISM model. The ISM permits a rational and logical interpretation to them and at the same time, captures the experts' heuristic knowledge on flood control and management. We have also modified the symbology used in the conventional ISM in order to present more meaningful results and at the same time to simplify some of its steps.

2. MODELING THE HIERARCHY OF THE BARRIERS TO IFRM

(1) Identifying barriers to IFRM

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 our previous study(9), we utilized a comprehensive review of literature to identify the barriers to IFRM in MM. A collection of literature, which comprised of project reports from DPWH, local publications, international journal publications, and a book that features a case study in MM, were gathered in this study.

(2) Interpretive Structural Modelling (ISM)

The ISM approach, which was developed by Warfield(19) (1973), is an effective method for analyzing complex and interrelated issues. 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(20), 21), 22). Fundamentally, ISM method has six major steps(23) 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.

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

SSIM is developed by evaluating a pairwise relationship among the barriers. This can be done individually or by consulting key actors concerned by conducting group discussions, interviews or surveys. In this study, selected experts and practitioners were engaged to develop an original SSIM at first. Then, the individual assessment of each expert and practitioner was refined by conducting a consistency check. The SSIM after the consistency check is now called a refined SSIM. The refined SSIM was further summarized by considering the majority answer to produce the final SSIM. Applied in this study is a contextual relationship of the IFRM barriers based on "influencing factors" type of relation. There are four types of relationships can be derived in each variable and this identifies whether one variable influences another variable or not. The conventional symbolism used in the SSIM was modified in this study in order

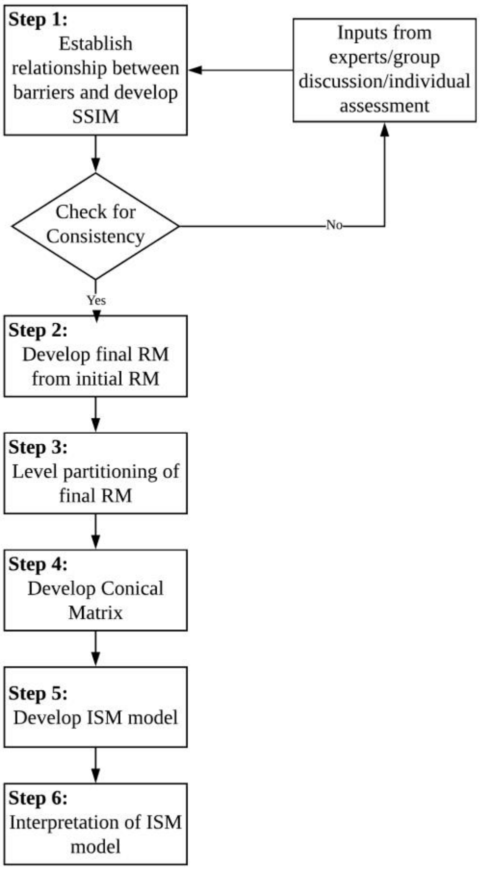

Fig.1 Flowchart of ISM.

to provide a more meaningful representation of the results. 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" was changed to symbol "+" denotes that barrier i influences barrier j
b. Letter "A" was changed to symbol "-" denotes barrier i is influenced by barrier j
c. Letter "X" was changed to symbol "±" means that barrier i and barrier j influence each other
d. Letter "O" was 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 ($\mathrm{RM}_{\mathrm{init}}$) 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 $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 1 while the $\mathrm{RM}_{\mathrm{init}}(j, i)$ is 0; this was modified to, if "+"is in the SSIM(i, j) then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 1.
b. If A is in the SSIM(i, j) then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 0 while the RMinit(j, i) is 1; this was modified to if "-"is in the SSIM(i, j) then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 0.
c. If X is in the SSIM(i, j) then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 1 while the RMinit(j, i) is 1; this was modified to if "±" is in the SSIM(i, j) then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 1.
d. If O is in the SSIM(i, j) then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 0 while the $\mathrm{RM}_{\mathrm{init}}(j, i)$ is 0; this was modified to if "0" is in the SSIM(i, j),then $\mathrm{RM}_{\mathrm{init}}(i, j)$ is 0.

In addition to these rules, $\mathrm{RM}_{\mathrm{init}}(i, i)$ was changed to 1 for both conventional and modified approach. As mentioned in Step 1, the modifications made in this study allows simpler guidelines for deriving the $\mathrm{RM}_{\mathrm{init}}$.

Then, $\mathrm{RM}_{\mathrm{init}}$ is further transformed to a final RM ($\mathrm{RM}_{\mathrm{fin}}$). The $\mathrm{RM}_{\mathrm{fin}}$ is derived by incorporating transitivity to the $\mathrm{RM}_{\mathrm{init}}$. The rule for transitivity for both conventional and modified methodology is as follows: if the input in $\mathrm{RM}_{\mathrm{init}}(i, j)$ is equal to 1 and $\mathrm{RM}_{\mathrm{init}}(j, k)$ is equal to 1, then $\mathrm{RM}_{\mathrm{init}}(i, k)$ should also be equal to 1. The $\mathrm{RM}_{\mathrm{init}}$ is checked multiple times for transitivity until all variables are completely transitive[23)].

Step 3: Level partitioning using $\mathrm{RM}_{\mathrm{fin}}$.

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 $\mathrm{RM}_{\mathrm{fin}}$[23)]. 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 $\mathrm{RM}_{\mathrm{fin}}$. 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.

3. RESULTS AND DISCUSSIONS

(1) Barriers to IFRM in MM.

The barriers to IFRM in Metro Manila, Philippines were identified by conducting a comprehensive review of literature in our previous study[9)]. **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 to 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. For in-depth discussion on the barriers to IFRM in MM, we elucidated the background of each barrier and this can be found in our previous study[9)].

Table 1 Barriers to IFRM in Metro Manila, Philippines[9)].

Aspect	**Barrier**	
Governance (A_1)	B_{11}	Lack of sole organizing body
	B_{12}	Lack of communication
	B_{13}	Lack of funding
	B_{14}	Lack of flood control measures
Social (A_2)	B_{21}	Illegal settlers
	B_{22}	Poor solid waste management
	B_{23}	Poor social planning
Technological Resources (A_3)	B_{31}	Lack of technological capabilities
	B_{32}	Sparse data and limited access
	B_{33}	Lack of experts
	B_{34}	Lack of data processing systems
	B_{35}	Deterioration of flood control structures

(2) ISM model.

As mentioned in the **Section 2**, there are 6 steps for the ISM approach. In Step 1, the SSIM was derived by consulting five expert and practitioners in the Philippines who have overarching knowledge on the flood condition in MM. These experts are the foremost authority at the Unified Project Management Office – Flood Control Management Cluster (UPMO-FMC), which is the department in DPWH that specializes in flood management.

The actual process for drawing out expert input for the SSIM was done by conducting a questionnaire – based survey. The experts answered the questionnaires individually, then we tallied their answers. These tallies had undergone consistency check wherein, a consistency in this study is considered as a tally that have three or more common answer. For any inconsistent tally, we requested the experts to reevaluate again that specific pairwise assessment and this was iterated until we get consistent results. For this process, it took us only one iteration of consistency check in order to obtain at least three consistent results from the experts.

The output of Step 1 was comprised of the original SSIM, refined SSIM, and final SSIM. The original SSIM, which is the original results before consistency check, is found in previous study[9)] where we carefully discussed the differences and similarities of expert assessment.

Table 2 Refined SSIM.

	j		1	2	3	4	5	6	7	8	9	10	11	12
i	Aspect		A_1				A_2			A_3				
		Barrier	B_{11}	B_{12}	B_{13}	B_{14}	B_{21}	B_{22}	B_{23}	B_{31}	B_{32}	B_{33}	B_{34}	B_{35}
1	A_1	B_{11}		+++ +-	+++ ++	+++ +0	+00 00	++0 00	++0 00	+++ 00	+++ ++	+++ +0	+++ +±	+++ +±
2		B_{12}	- - - -+		+++ +±	++0 00	+++ +0	++0 0+	+++ 0±	+00 0±	+++ ±±	-00 00	-00 00	+00 00
3		B_{13}	- - - - -	--- -±		+++ -±	-00 0±	000 ±±	+00 0±	+++ -±	+++ 0±	+++ 0±	+++ ± ±	+++ ±±
4		B_{14}	- - - -0	--0 00	--- +±		+00 0±	+00 00	+++ 00	+++ +±	+++ +±	++± ±±	+0± ±±	+++ ++
5	A_2	B_{21}	-00 00	--- -0	+00 0±	-00 0±		+++ +±	+-- -±	000 00	000 00	000 00	000 00	000 0±
6		B_{22}	--0 00	--0 0-	000 ±±	-00 00	--- -±		--- 00	-00 00	000 00	-00 00	000 00	000 0±
7		B_{23}	--0 00	--- 0±	-00 0±	--- 00	-++ +±	+++ 00		-00 00	-00 0±	--- 00	000 ±±	000 0±
8	A_3	B_{31}	--- 00	-00 0±	--- +±	--- -±	000 00	+00 00	+00 00		+++ +±	++- --	+±± ±±	+++ 0±
9		B_{32}	--- --	--- ±±	--- 0±	--- -±	000 00	000 00	+00 0±	--- -±		+-- --	+-- -±	+00 0±
10		B_{33}	--- -0	+00 00	--- 0±	--± ±±	000 00	+00 00	+++ 00	--+ ++	-++ ++		+++ 00	+++ 00
11		B_{34}	--- -±	+00 00	--- ±±	-0± ±±	000 00	000 00	000 ± ±	-±± ± ±	-++ +±	--- 00		0+0 ++
12		B_{35}	--- -±	-00 00	--- ±±	--- --	000 0±	000 0±	000 0±	--- 0±	-00 0±	--- ±±	0-0 --	

Table 3 Final SSIM.

	j		1	2	3	4	5	6	7	8	9	10	11	12
i	Aspect		A_1				A_2			A_3				
		Barrier	B_{11}	B_{12}	B_{13}	B_{14}	B_{21}	B_{22}	B_{23}	B_{31}	B_{32}	B_{33}	B_{34}	B_{35}
1	A_1	B_{11}		+	+	+	0	0	0	+	+	+	+	+
2		B_{12}	-		+	0	+	+	+	0	+	0	0	0
3		B_{13}	-	-		+	0	0	0	+	+	+	+	+
4		B_{14}	-	0	-		0	0	+	+	+	±	±	+
5	A_2	B_{21}	0	-	0	0		+	-	0	0	0	0	0
6		B_{22}	0	-	0	0	-		-	0	0	0	0	0
7		B_{23}	0	-	0	-	+	+		0	0	-	0	0
8	A_3	B_{31}	-	0	-	-	0	0	0		+	-	±	+
9		B_{32}	-	-	-	-	0	0	0	-		-	-	0
10		B_{33}	-	0	-	±	0	0	+	+	+		+	+
11		B_{34}	-	0	-	±	0	0	0	±	+	-		+
12		B_{35}	-	0	-	-	0	0	0	-	0	-	-	

Table 2 presents the refined SSIM that have undergone consistency checks so that a firm relationship between two barriers were established. Meanwhile, **Table 3** showed the majority assessment which represents the final SSIM. As an example, the pairwise relationship between B_{11} and B_{12} was evaluated as "+" (barrier *i* influences barrier *j*) as shown in **Table 3**, because majority (4 out of 5) of the responses from the experts and practitioners in **Table 2** evaluated that the former influences the latter. Then, using **Table 3** for Step 2 the reachability matrix (RM) was derived, in which there are two forms of RM: the initial RM (RM_{init}), and the final RM (RM_{fin}). The RM_{init} had undergone three iterations of transitivity check to obtain the RM_{fin} shown in **Table 4**. Note that those with 1^* in **Table 4** indicates that these were initially 0 representing the RM_{init}. It can be seen on the table that B_{11} (Lack of

sole organizing body) influences almost all the other barriers to IFRM. Then, from **Table 4** (using RM_{fin} values) Step 3 is done in accordance to the procedure discussed in **Section 2(2)**. The summary of the reachability, antecedent, intersection sets and the corresponding level of each barrier set is presented in **Table 5**. In this study, the barriers to IFRM are assigned to a 7 levels as can be seen in **Table 5.** Then for Step 4, **Table 4** (using the RM_{init}) is rearranged according to its level in ascending order. The outcome of the Step 4 is presented in **Table 6** which is the Conical Matrix (CM). For Step 5, the ISM model is drawn based on the CM shown in **Table 6** wherein, an arrow is drawn from barrier *i* to barrier *j* if there is 1 in the matrix.

The outcome of Step 5 is the ISM model for the barriers to IFRM shown in **Figure 2**. The barriers were arranged in ascending order from top to bottom which shows the hierarchy of the barriers. The least influential barriers were placed at the top of the ISM model while the most influential barriers were placed at the bottom. The direction of the arrow also shows influence from barrier *i* to barrier *j*. For example, an arrow is drawn from B_{11} to B_{12} which means that B_{11} influences B_{12}.

For Step 6, this study reveals that the most influential barrier on IFRM for MM is B_{11} (Lack of sole organizing body) implying that establishment or

Table 4 Final Reachability Matrix (RM_{fin}).

	j		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
i	Aspect		A_1				A_2			A_3				
		Barrier	B_{11}	B_{12}	B_{13}	B_{14}	B_{21}	B_{22}	B_{23}	B_{31}	B_{32}	B_{33}	B_{34}	B_{35}
1	A_1	B_{11}	1	1	1	1	1^*	1^*	1^*	1	1	1	1	1
2		B_{12}	0	1	1	1^*	1	1	1	1^*	1	1^*	1^*	1^*
3		B_{13}	0	0	1	1	1^*	1^*	1^*	1	1	1	1	1
4		B_{14}	0	0	0	1	1^*	1^*	1	1	1	1	1	1
5	A_2	B_{21}	0	0	0	0	1	1	0	0	0	0	0	0
6		B_{22}	0	0	0	0	0	1	0	0	0	0	0	0
7		B_{23}	0	0	0	0	1	1	1	0	0	0	0	0
8	A_3	B_{31}	0	0	0	1^*	1^*	1^*	1^*	1	1	1^*	1	1
9		B_{32}	0	0	0	0	0	0	0	0	1	0	0	0
10		B_{33}	0	0	0	1	1^*	1^*	1	1	1	1	1	1
11		B_{34}	0	0	0	1	1^*	1^*	1^*	1	1	1^*	1	1
12		B_{35}	0	0	0	0	0	0	0	0	0	0	0	1

(Those with 1^* are originally 0 which indicates the initial Reachability Matrix)

Table 5 Level partition summary.

Barrier	**Reachability Set**	**Antecedent Set**	**Intersection Set**	**Level**
B_{11}	B_{11}, B_{12}, B_{13}, B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}	B_{11}	VII
B_{12}	B_{12}, B_{13}, B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}, B_{12}	B_{12}	VI
B_{13}	B_{13}, B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}, B_{12}, B_{13}	B_{13}	V
B_{14}	B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}, B_{12}, B_{13}, B_{14} , B_{31}, B_{33}, B_{34}	B_{14}, B_{14}, B_{33}, B_{34}	IV
B_{21}	B_{21}, B_{22}	B_{11}, B_{12}, B_{13}, B_{14} , B_{21}, B_{23}, B_{31}, B_{33}, B_{34}	B_{21}	II
B_{22}	B_{22}	B_{11}, B_{12}, B_{13}, B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{33}, B_{34}	B_{22}	I
B_{23}	B_{22}, B_{23}, B_{31}	B_{11}, B_{12}, B_{13}, B_{14} , B_{21}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}	B_{23}	III
B_{31}	B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}, B_{12}, B_{13}, B_{14}, B_{31}, B_{33}, B_{34}	B_{14}, B_{14}, B_{33}, B_{34}	IV
B_{32}	B_{32}	B_{11}, B_{12}, B_{13}, B_{14}, B_{31}, B_{32}, B_{33}, B_{34}	B_{32}	I
B_{33}	B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}, B_{12}, B_{13}, B_{14}, B_{31}, B_{33}, B_{34}	B_{14}, B_{14}, B_{33}, B_{34}	IV
B_{34}	B_{14} , B_{21}, B_{22}, B_{23}, B_{31}, B_{32}, B_{33}, B_{34}, B_{35}	B_{11}, B_{12}, B_{13}, B_{14}, B_{31}, B_{33}, B_{34}	B_{14}, B_{14}, B_{33}, B_{34}	IV
B_{35}	B_{35}	B_{11}, B_{12}, B_{13}, B_{14}, B_{31}, B_{33}, B_{34}, B_{35}	B_{35}	I

Table 6 Conical Matrix.

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

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 B_{12} (Lack of coordination among agencies and stakeholders) which directly influences B_{13} (Lack of prioritization) and the social aspect barriers B_{23} (Poor social planning), B_{22} (Poor solid waste management) and B_{21}. The ISM model also reveals that B_{14} (Lack of flood control measures) and B_{33} (Lack of experts), and B_{34} (Lack of data processing systems) and B_{31} (Lack of technological capabilities) are directly influencing each other. The improvement of these barriers are actually triggered and influenced by experts. B_{33} triggers the improvement of most of the scientific resources barriers including B_{14} (Lack of flood control measures). Lastly, the least influential barriers are B_{22}, B_{32} (Sparse data and limited access), and B_{35} (Modernization of flood control structures).

The produced ISM for the barriers to IFRM in MM now clearly shows the hierarchy of from the most influential barrier to the least influential barrier. As can be seen in the model, barriers on the governance aspect, A_1, have the most influence to all other barriers especially B_{11}. This manifests that barriers on A_1 can drive change to barriers on the other aspect. The ISM model also provides information on which barriers trigger the refinement or impediment to a sound IFRM approach.

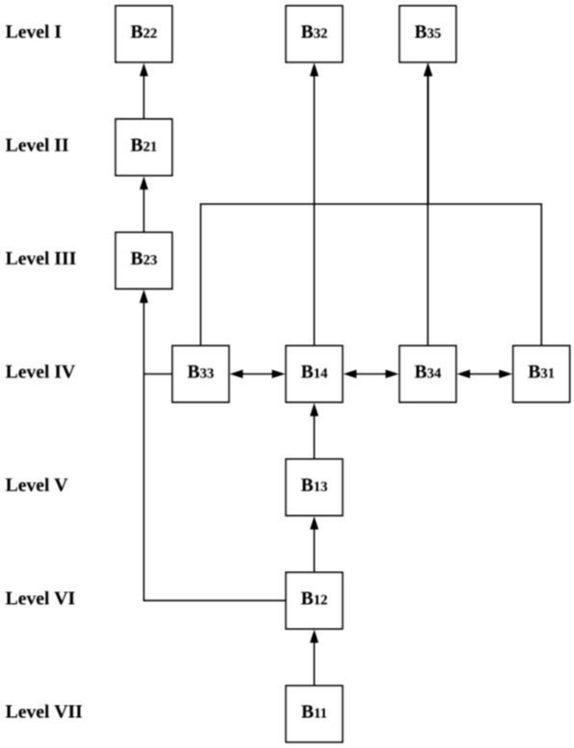

Fig. 2 ISM model for the barriers to IFRM in Metro Manila, Philippines**.**

4. CONCLUSIONS

The main objective of this study is to model the hierarchical structure of the barriers to IFRM in MM in a systematic manner using the ISM model. The ISM permits a rational interpretation to them and at the same time, captures the experts' heuristic knowledge on flood control and management.

Interrelationships among these barriers and the hierarchy were successfully determined 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 will presumably affect positively 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 then the social aspect barriers.

The produced ISM model allows interpretations and offered a coherent assessment on the barriers to IFRM. This study will greatly aid and provide insights to decision-makers of the Philippines or any other country that have similar flood problems.

Cross validation and interpretation of results using other methods such as MICMAC analysis, etc. can also be done for future works to further elucidate the interrelationships barrier to IFRM.

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