MODULE 4

Interpretive Structural Modeling (ISM)

Atila Ertas
Utku Gulbulak

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ATLAS Publishing

Transdisciplinary modules are dedicated to Dr. Raymond T. Yeh and Mr. Bob Block, for their continued support of ATLAS, enthusiasm, dedication, and passion!

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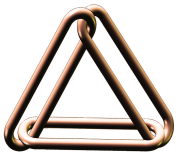

MODULE 4

Interpretive Structural Modeling (ISM)

We live in a highly complex, technological world – and it's not entirely obvious what's right and what is wrong in any given situation unless you can parse the situation, and deconstruct it. People just don't have the insight to be able to do that very effectively.

Christopher Langan

4.1 Introduction

A *structural model* is a collection of components (elements) showing their relationship in a diagram that consists of nodes and the links that connect them. Using structural modeling we can gain a broad understanding of the system as a whole by studying a structural model of the components within the system. Warfield defines the structural modeling as:[1]

> "Structural modeling is a methodology which employs graphics and words in carefully defined pattern to portray the structure of a complex issue, a system, or a field of study."

Interpretive Structural Modeling (**ISM**) is an effective methodology used to cope with the novel, ill-defined problems in complex, real-world settings. It is a transdisciplinary tool used to understand complex situations that occur in diverse knowledge domains such as: when developing plans, managing organizations, designing large-scale systems, and used in many other kinds of human endeavors.

ISM is a well-established systematic and comprehensive method for dealing with complex issues. It was proposed by Warfield in 1973. ISM identifies relationships among specific factors, which are relevant to the problem or issue. This helps researchers to structure a set of different and directly related factors (parameters) affecting the system into a comprehensive hierarchical model so that unclear and poorly expressed conceptual system models will be well-defined.

[1] J. Warfield, "Structuring Complex Systems," Battelle Memorial Institute, Columbus, OH, Battelle Monograph, No. 3, 1974.

The fundamental approach of the ISM process is to use experts from diverse knowledge domains (academic and non-academic) with practical experience and knowledge to decompose a complex issue into smaller sub-issues and build an easily understandable multilevel structural model.

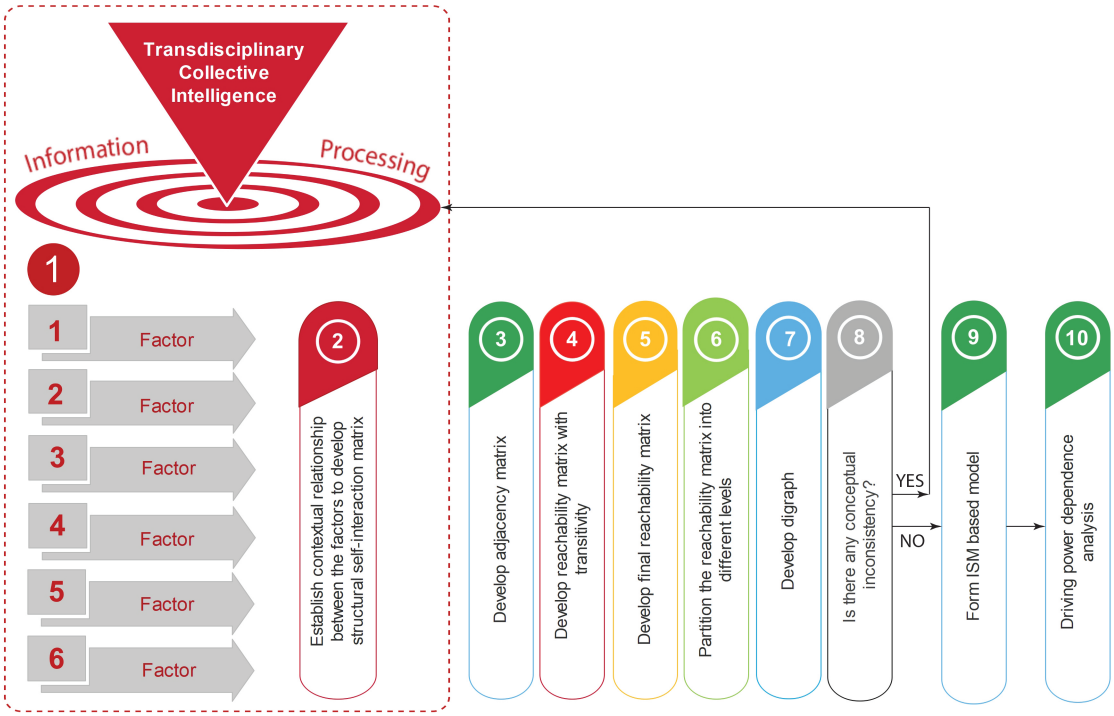

Figure 4.1: ISM process.

4.2 ISM Process

As shown in Figure 4.1, the following steps are followed to developed the ISM process.

Step 1 Development of TD collective intelligence: ISM approach starts with the development of transdisciplinary (TD) collective intelligence which includes identifying the main factors affecting complexity and establishing contextual relationships between the factors (Step-1) to develop the Structural Self-Interaction Matrix (SSIM) (Step-2). This will be accomplished by exercising the Interactive Collective Intelligence Management workshop which was covered in Module 1.

Step 2 Structural Self-Interaction Matrix: The next step is to establish a contextual relationship between the factors to develop a Structural Self-Interaction Matrix (SSIM) shown in Figure 4.2. During this phase, the transdisciplinary collective intelligence workshop participants

must decide upon the pairwise relationship between the factors (element). The contextual relationship for each factor, the relationship between any two factors (i and j), and the associated direction of the relation will be decided through the workshop participants' debate. The four symbols used to indicate the direction of the relationship between the factors i and j are given below:

- V = for the relation from i to j but not in both directions;
- A = for the relation from j to i but not in both directions;
- X = for both-direction relations: from i to j and j to i; and
- O= if the relation between the elements does not appear to be valid

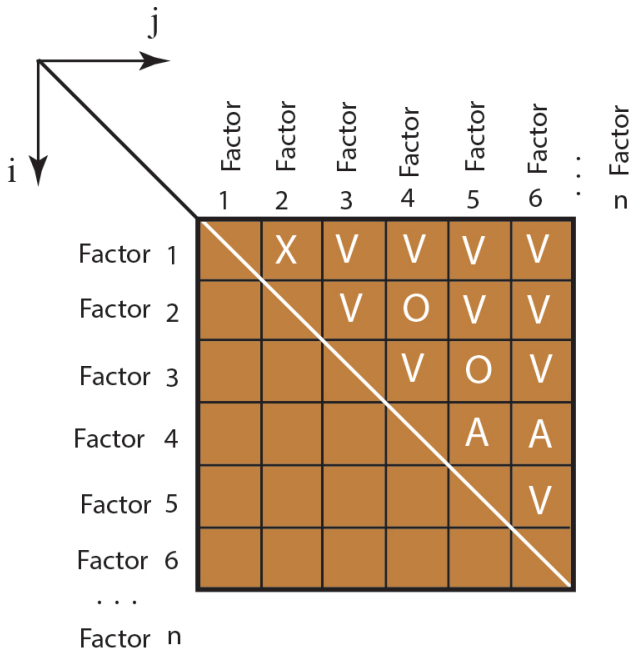

Figure 4.2: Structural self-interaction matrix (SSIM).

STEP 3 Develop Adjacency Matrix: As shown in Figure 4.3, replace the entries V, A, X, and O of the SSIM into 1 and 0, following the below rules:

- When the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- When the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.

- when the (i, j) entry in the SSIM is X, then both the (i, j) and (j, i) entries of the reachability matrix become 1.
- when the (i, j) entry of the SSIM is O, then both the (i, j) and (j, i) entries of the reachability matrix become 0.

$R_a =$

	1	2	3	4	5	6
Factor 1	1	1	1	1	1	1
Factor 2	1	1	1	0	1	1
Factor 3	0	0	1	1	0	1
Factor 4	0	0	0	1	0	0
Factor 5	0	0	0	1	1	1
Factor 6	0	0	0	1	0	1

Figure 4.3: Adjacency matrix.

STEP 4 Reachability Matrix with Transitivity: Figure 4.4 shows the reachability matrix with transitivity. Reachability matrix is tested for the transitivity rule and is updated until transitivity is confirmed. Transitive rule is "if **A** has relationship to **B** and **B** has relationship to **C**, then **A** has relationship to **C**". Following transitivity rule a reachability matrix shown in Figure 4.4 is developed.

$R_t =$

	1	2	3	4	5	6
Factor 1	1	1	1	1	1	1
Factor 2	1	1	1	1	1	1
Factor 3	0	0	1	1	0	1
Factor 4	0	0	0	1	0	0
Factor 5	0	0	0	1	1	1
Factor 6	0	0	0	1	0	1

Figure 4.4: Reachability matrix with transivity.

STEP 5 Final Reachability Matrix: *Final reachability matrix* in Figure 4.5 shows *Driving power* and *dependence* of factors. The summation of ones in the corresponding rows gives the driving power and the summation of ones in the corresponding columns gives the dependence. Figure 4.5 is the final form of the relationships of all the factors involved with the problem under

consideration. Calculated driving power and dependence in Figure 4.5 will be used for MICMAC analysis.

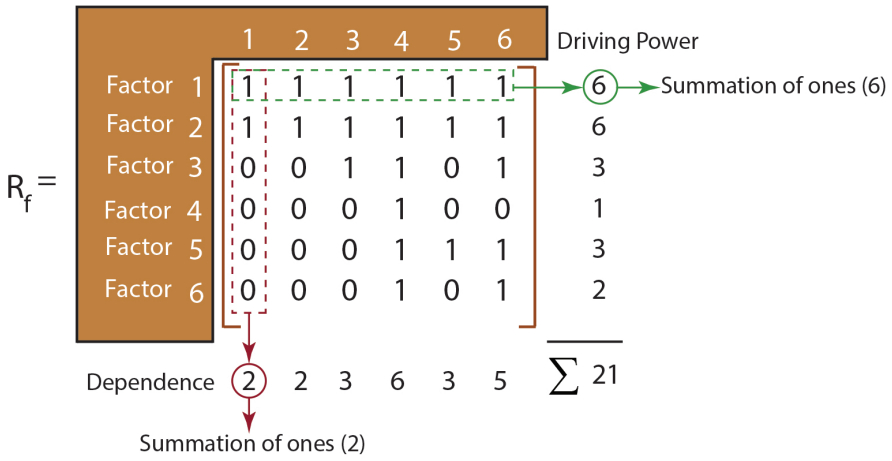

Figure 4.5: Final reachability matrix.

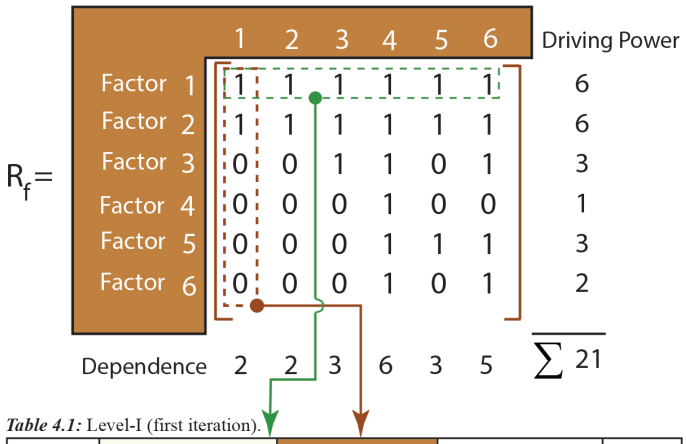

Table 4.1: Level-I (first iteration).

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2, 3, 4, 5, 6	1, 2	1, 2	
2	1, 2, 3, 4, 5, 6	1, 2	1, 2	
3	3, 4, 6	1, 2, 3	3	
4	4	1, 2, 3, 4, 5, 6	4	I
5	4, 5, 6	1, 2, 5	5	
6	4, 6	1, 2, 3, 5, 6	6	

Since factor 4 has the same reachability and intersection set, it is the level-I.

Figure 4.6: Identifying level 1.

STEP 6 Level Partition: The driving force and dependence obtained from the final reachability matrix will help us to classify the factors into groups. As shown in Figure 4.6, the intersection of antecedent and reachability sets will provide an intersection set. In other words, the factors common in the reachability set and the antecedent set are included in the intersection set. These three sets will help us to identify the levels of the factors. When the factors of the intersection and reachability sets are the same, then that factor will be identified as the top-level group (level I group) in the ISM hierarchy. Once the top-level factors are identified, they are deleted from the set to identify the next level. As seen from Tables 1 through 4, this iteration process is repeated until all the levels are identified. These levels will be used to build the digraph and ISM model.

Table 1: Level-I (first iteration).

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2, 3, 4, 5, 6	1, 2	1, 2	
2	1, 2, 3, 4 ,5, 6	1, 2	1, 2	
3	3, 4, 6	1, 2, 3	3	
4	4	1, 2, 3, 4, 5, 6	4	I
5	4, 5, 6	1, 2, 5	5	
6	4, 6	1, 2, 3, 5, 6	6	

Delete factor 4 and level-I from the table for the next iteration.

Table 2: Level-II (second iteration).

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2, 3, 5, 6	1, 2	1, 2	
2	1, 2, 3, 5, 6	1, 2	1, 2	
3	3, 6	1, 2, 3	3	
5	5, 6	1, 2, 5	5	
6	6	1, 2, 3, 5, 6	6	II

Delete factor 6 and level-II from the table for the next iteration.

Table 3: Level-III (third iteration).

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2, 3,5	1, 2	1, 2	
2	1, 2, 3, 5	1, 2	1, 2	
3	3	1, 2, 3	3	III
5	5	1, 2, 5	5	III

Delete factors 3 and 5 and levels-II and III from the table for the next iteration.

Table 4: Level-IV (fourth iteration).

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2	1,2	1, 2	IV
2	1, 2	1, 2	1, 2	IV

STEP 7 Formation of Digraph: The digraph is a diagram that shows the connections of the direct and indirect relationships between the factors. As shown in Figure 4.7, the relationship of factors and binary associations through matrices can now be translated into graphical form by using the theory of digraphs (directed graphs).[2] For example, consider factor 1. Factor 1 is reaching factor 3 (see red circle on final reachability matrix). But factor 3 is not reaching factor 1 (see the line without arrow from 3 to 1). Another example is relationships between factors 4

[2]F. Harary, R. V. Norman and D. Cartwright, Structural Models: An Introduction to the Theory of Directed Graphs, Willey, New York, 1965.

and 6. While factor 6 is reaching factor 4, factor 4 is not reaching factor 6. In this analysis "0" means there is no relationships among the factors whereas "1" means there is a relationship.

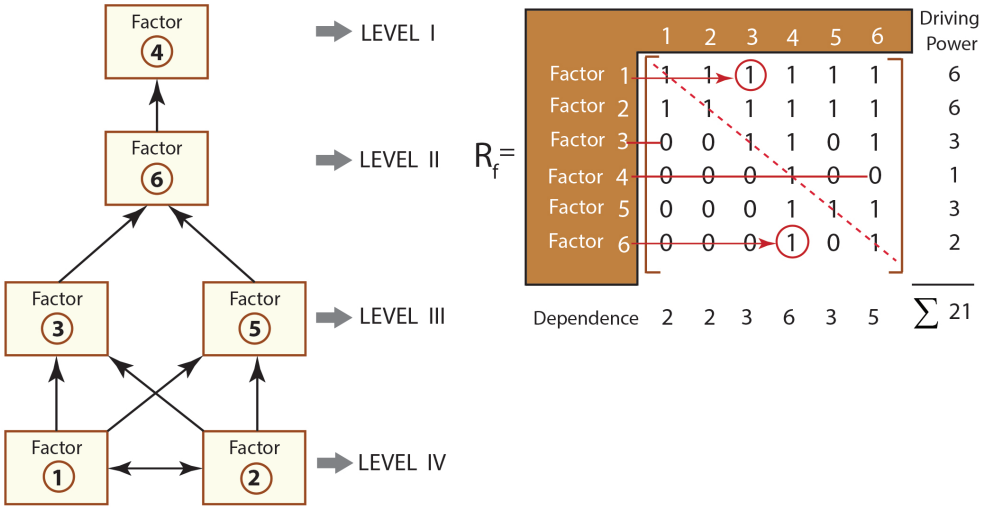

Figure 4.7: Digraph.

STEP 8 Conceptual Inconsistency: If there is any conceptual inconsistency, go back to Steps 1 and 2 to re-iterate the problem – carefully check the relationships among the factors.

STEP 9-10 MICMAC Analysis: The MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée á un Classement) (cross-impact matrix multiplication applied to classification) analysis was developed by Duperrin and Godet in 1973 to analyze the driving power and the dependence of the factors affecting the issue in hand.[3] As shown in Figure 4.8, factors are placed with respect to their driving power and dependence in four clusters:[4] (1) autonomous, (2) dependent, (3) linkage, and (4) independent factors. The driving power and dependence of each of the factors are imported from Figure 4.5. For example, coordinates of factor 4 are Dependence = 6 and Driving power = 1, thus factor 4 is placed at the very bottom right corner of the MICMAC diagram.

[3]J. C. Duperrin and M. Godet, Methode De Hierar Chization des Elements D'um System, Rapport Economique de CEA, 1973, pp.45–51.

[4]A. Mandal and S. G. Deshmukh, Vendor Selection Using Interpretive Structural Modelling (ISM), International Journal of Operations & Production Management, 14(6), 1994, pp.

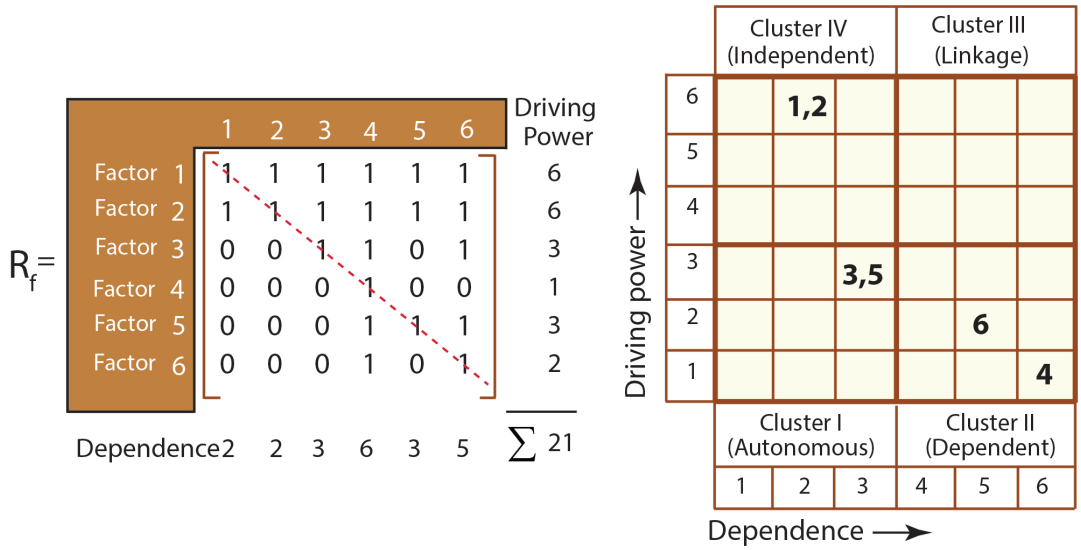

Figure 4.8: MICMAC analysis.

EXAMPLE 4.1

Figure 4.9 shows the relationships of five elements of a system. Develop:

(a) the adjecency matrix;
(c) the final reachability matrix;
(d) the level partition;
(e) the digraph.

SOLUTION

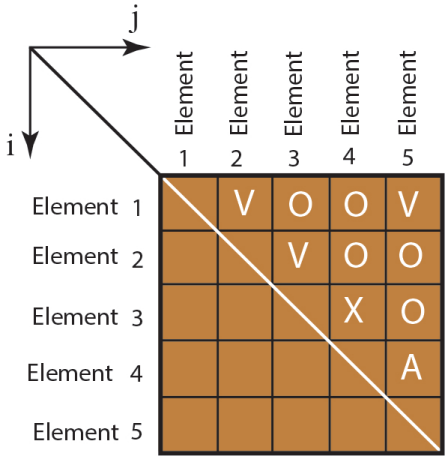

Figure 4.9: Structural self-interaction matrix.

EXAMPLE 4.1 (continued)

(a) The adjacency matrix shown in Figure 4.10 is obtained by transforming SSIM into a binary matrix by substituting V, A, X, and O by 1 and 0.;

$R_a =$

	1	2	3	4	5
Factor 1	1	1	0	0	1
Factor 2	0	1	1	0	0
Factor 3	0	0	1	1	0
Factor 4	0	0	1	1	0
Factor 5	0	0	0	1	1

Figure 4.10: Adjacency matrix.

(b) Final Reachability matrix with transitivity is shown in Figure 4.11. As shown in this figure, summation of ones in the corresponding rows gives the driving power of 15 and the summation of ones in the corresponding columns gives the dependence of 15.;

$R_f =$

	1	2	3	4	5	Driving power
Factor 1	1	1	1	1	1	5
Factor 2	0	1	1	1	0	3
Factor 3	0	0	1	1	0	2
Factor 4	0	0	1	1	0	2
Factor 5	0	0	1	1	1	3
Dependence	1	2	5	5	2	$\sum$ 15

Figure 4.11: Reachability matrix with transitivity.

EXAMPLE 4.1 (continued)

(c) The final reachability matrix, R_f is used to develop the level partition. If the intersection and reachability sets of any individual factor are the same, then that factor is identified as the top-level group (level I group) in the ISM hierarchy. As shown in Table 4.5, once the top-level factors are known, they are removed from the set to identify the next level. This iteration process is repeated until all the levels are recognized.

Table 4.5: Reachability set, antecedent set, iteration levels.

Factor Numbers	Reachability Set	Antecedent Set	IntersectionSet	Factor Levels
1	1, 2, 3, 4, 5	1	1	
2	2, 3, 4	1, 2	2	
3	3, 4	1, 2, 3, 4, 5	3, 4	I
4	3, 4	1, 2, 3, 4, 5	3, 4	I
5	3, 4, 5	1, 5	5	
1	1, 2, 5	1	1	
2	2	1, 2	2	II
5	5	1, 5	5	II
1	1	1	6	III

(d) As shown in Figure 4.12, initial digraph can be developed by using adjacency matrix. As seen from the adjacency matrix, element 1 is reaching to elements 2 and 5 (first row of the matrix). Element 2 is reaching element 3 (second row of the matrix). Element 3 is reaching element 4 (third row of the matrix). Element 4 is reaching element 3 (fourth row of the matrix). And finally, element 5 is reaching to element 4 (fifth row of the matrix).

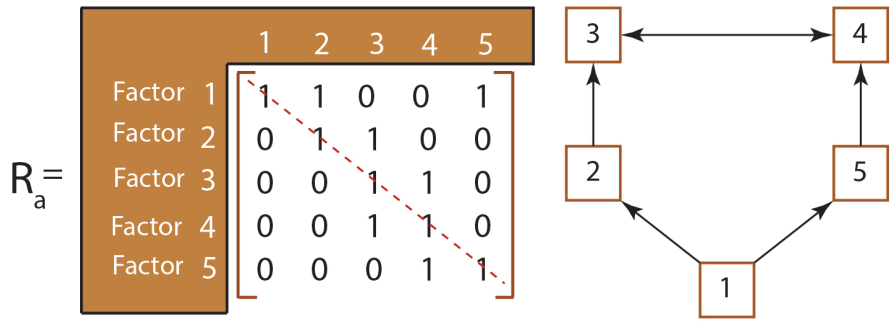

Figure 4.12: Digraph through adjacency matrix.

EXAMPLE 4.1 (continued)

The final digraph which takes transitivity into account can be developed by using the final reachability matrix as follows (see figure 4.13):

- Element 1 reaches to Element 2 (arrow should go from 1 to 2) and reaches to component 5 (arrow should go from 1 to 5). Note that, element 1 also reaches to elements 3 and 4 through elements 2 and 5.
- Element 2 reaches to Element 3 (arrow should go from 2 to 3)
- Element 3 reaches to Element 4 (arrow should go from 3 to 4)
- Element 4 reaches to Element 3 (arrow should go from 4 to 3)
- Element 5 reaches to Element 4 (arrow should go from 5 to 4)

$R_f =$

	1	2	3	4	5
Factor 1	1	1	1	1	1
Factor 2	0	1	1	1	0
Factor 3	0	0	1	1	0
Factor 4	0	0	1	1	0
Factor 5	0	0	1	1	1

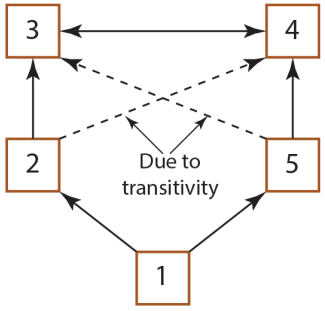

Figure 4.13: Digraph through adjacency matrix.

EXAMPLE 4.2

Figure 4.14 shows the relationships of eight elements of a system. Develop:

(a) the adjecency matrix;

(c) the final reachability matrix;

(e) the digraph.

SOLUTION

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Factor 1		V	O	O	O	O	O	O
Factor 2			V	O	O	O	O	O
Factor 3				O	O	V	V	O
Factor 4					X	O	O	O
Factor 5						O	O	O
Factor 6							O	O
Factor 7								O
Factor 8								

Figure 4.14: Structural self-interaction matrix.

(a) The adjacency matrix shown in Figure 4.15 is obtained by transforming SSIM into a binary matrix by substituting V, A, X, and O by 1 and 0.;

$R_a =$

	1	2	3	4	5	6	7	8
Factor 1	1	1	0	0	0	0	0	0
Factor 2	0	1	1	0	0	0	0	0
Factor 3	0	0	1	0	0	1	1	0
Factor 4	0	0	0	1	1	0	0	0
Factor 5	0	0	0	1	1	0	0	0
Factor 6	0	0	0	0	0	1	0	0
Factor 7	0	0	0	0	0	0	1	0
Factor 8	0	0	0	0	0	0	0	1

Figure 4.15: Adjacency matrix.

EXAMPLE 4.2 (Continued)

(b) Final Reachability matrix with transitivity is shown in Figure 4.16.

$R_f =$

	1	2	3	4	5	6	7	8	Driving power
Factor 1	1	1	1	0	0	0	0	0	3
Factor 2	0	1	1	0	0	1	1	0	4
Factor 3	0	0	1	0	0	1	1	0	3
Factor 4	0	0	0	1	1	0	0	0	2
Factor 5	0	0	0	1	1	0	0	0	2
Factor 6	0	0	0	0	0	1	0	0	1
Factor 7	0	0	0	0	0	0	1	0	1
Factor 8	0	0	0	0	0	0	0	1	1
Dependence	1	2	3	2	2	3	3	1	Σ 17

Figure 4.16: Final reachability matrix with transitivity.

(c) Digraph is shown in Figure 4.17.

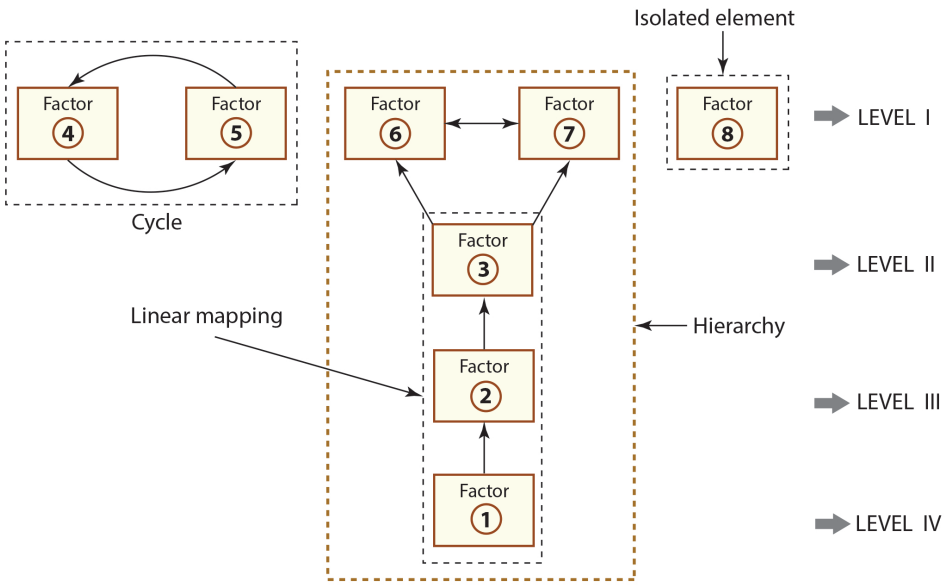

Figure 4.17: Digraph.

EXAMPLE 4.2 (continued)

As shown in Figure 4.17, factor 8 is isolated since it is not adjacent to any factor – this factor does not influence system performance. Factors 1, 2, and 3 represent the linear mapping of the system. The system contains one cycle between factors 4 and 5. Factor 1 is the source element since it has only outgoing paths. As shown in this figure system also contain a hierarchy.

4.2.1 Structural Types

Figure 4.18 shows different kinds of structural types that can occur in the analysis of a complex issue. Any combination of those types will make the system of hybrid structure. The previous example showed some of the structural types in one system description.

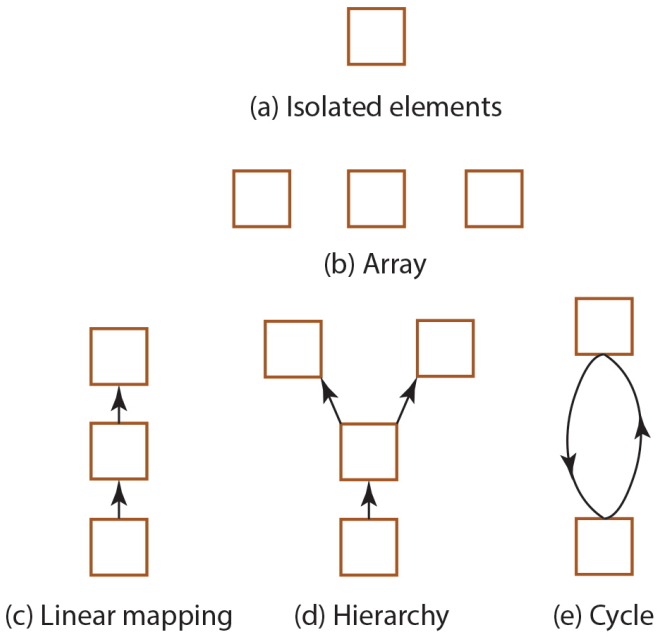

Figure 4.18: Structural types.

CASE STUDY 4.1

Complexity of Global Refugee Crisis: Needs for Global Transdisciplinary Collaboration

People are on the move for many reasons such as war and civil war, human rights, violation, economic, social, climate, environmental, political, and individual reasons that create these changing aspects. In such complex situations, the need to flee (***forcibly displaced***) versus the choice to leave (***migration***) can be difficult to determine. The issue of refugee resettlement is complex and includes many factors to consider. Factors being considered for their impact on resettlement include budget and cost issues, federal law and policies, administration challenges, security screening process, education and training, health and housing, crime rate, socioeconomic issues, and many others. The objective of this case study is to discuss how the aforementioned factors relate and interact with one another using Interpretive Structural Modeling (ISM).[a]

ANALYSIS

The worldwide population of *forcibly displaced* rose by 2.3 million people in 2018 reaching 70.8 million – 20 people are displaced every minute in a day. The worldwide population of forcibly dislocated people grew considerably from 43.3 million in 2009 to 70.8 million in 2018, reaching a record high. This increase took place between 2014 and 2015, cause to move mainly by the Syrian conflict along with other conflicts in the region such as in Iraq, Yemen, and Sudan as well as other poor countries. The complexity of the issue makes it difficult to understand global refugee problems.

The issue of refugee resettlement is complex and includes many other factors to consider. Factors being considered for their impact on resettlement include budget and cost issues, federal law and policies, administration challenges, security screening process, education and training, health and housing, crime rate, socioeconomic issues, and many others.

The objective of this case study is to discuss how the aforementioned factors relate and interact with one another using Interpretive Structural Modeling (ISM).

[a] From (Moran, D., Gulbulak, U., Ertas, A., and students from senior design class of ME-TTU, (2020). Complexity of Global Refugee Crisis: Needs for Global Transdisciplinary Collaboration. *Transdisciplinary Journal of Engineering & Science*, Vol. 11, pp. 115-131).

CASE STUDY 4.1 (continued)

Context

Transdisciplinary Collective Intelligence: ISM methodology implementation against this problem consisted of a group of 25 undergraduate students in senior design class, all pursuing Mechanical Engineering degree at Texas Tech University, two PhD students, one faculty member in design, four research engineers from different companies. This group recognized significant difficulties and challenges in carrying out successful refugee resettlement and sought to identify the main factors affecting the problem and how they were interrelated, with the goal of improving the rate of success for these displaced individuals.

Process

Effectiveness in accepting and integrating immigrants into a new home country requires transdisciplinary collaboration among, and within, institutional sectors in the receiving countries. Partnering and joining must occur between organizations such as social services; education; government; community-based organizations, and others.

The working group developed transdisciplinary collective intelligence using the Interactive Collective Intelligent Management (ICIM) workshop to investigate the issue. (1) The Nominal Group Technique (NGT) was used to develop and clarify a list of factors affecting the complex issue, (2) Interpretive Structural Modeling (ISM) process was used to develop:

(a) Structural self-interaction matrix

(b) Final reachability matrix

(c) Digraph

(d) MICMAC Analysis

The working group identified nine factors for how to handle complex issues of refugee settlement. The factors were grouped into six levels. Through MICMAC analysis, it was shown that how these factors are interrelated to support the successful refugee settlement.

Content

The working group developed a set of factors affecting the complex issues of refugee settlement showing how selected factors of the problem they identified were related to each other. One of the PhD students who is familiar with the ICIM facilitated the workshop.

Identifying Factors

During the first stage of the workshop, potential factors which affect the successful refugee settlement were identified. One of the methodologies that have been found useful was the NGT structured method for group brainstorming that encourages contributions from group members and enables quick agreement on the relative importance of issues, problems, or solutions.

CASE STUDY 4.1 (continued)

NGT was used to obtain and specify potential factors. The working group developed twenty factors affecting the issue at hand.

Structuring Factors

Following the development of factors, a part of the NGT process was used to determine which of the factors were most important. From the set of twenty factors, the following subset of nine was structured using the methodology of ISM. Those were the ones receiving the highest scores in the voting on the most important main factors.

Budget (Cost)

There are various costs that the Office of Refugee Resettlement (ORR) takes into account in the budget for funding refugee resettlement. The first and most obvious being the monetary costs: funding for transitional and medical services, social services, preventive health, shelter, utilities, supplies, training, and education, etc. To determine the most feasible investment, depending on factors such as federal law and policies, the budget request is formulated based on the number of people in need.

Policies and Rules

Federal (Nation-State) laws and policies are significant when dealing with a wave of refugees trying to enter a new country. They dictate how effectively a refugee crisis can be handled by a host country. Furthermore, the laws and policies set up how the country is going to respond to the situation. Whether it could be a temporary or permanent solution, the host country is responsible for accommodating the refugees and creating the laws that will govern them. The host country creates these laws and policies in order to offer protection, shelter, and life to the refugees – facilitating the process of resettlement. Nation-State policies and rules can also, on the contrary, limit the number of refugees entering the country and hinder the resettlement processes

Screening Process

Refugees seeking resettlement must pass through a series of steps planed at ensuring they will not pose a security risk to the hosting country – security is among the top priorities of a nation. In the last couple of years, nations have come a long way in finding ways to intercept threats and stopping them before they can happen. This is in part because of new technologies that can pick up encrypted communication and a certain pattern of messages being transmitted around the globe paired with the work of the various intelligence communities for host countries.

CASE STUDY 4.1 (continued)

Administration Challenges

Administration challenges regarding the logistics and bureaucracy in the execution of decisions for resettling refugees will delay resettlement. Obtaining information about the refugees and how they are faring is the only way to know if current administration policies are achieving their desired goals. One key metric for successful resettlement is measuring the time between the influx of refugees and successful resettlement.

Health and Shelter

During the resettlement phase, health care needs to be provided to the refugees. In doing so, this factor will affect the cost and the crime rate of the shelter. Although health care is a large expense, it will ensure a high survival rate. The more services physicians provide, the higher the cost will be to maintain that standard of care. As a result of having healthier patients both physically and mentally, the crime rate decreases. The opposite will occur if no health care is provided.

The health care set by the host government is completely structured by the federal policies of said government. The benefits that refugees receive are based on federal administrative regulations. Adversely, health care is dependent on federal policy, and not the other way around. In terms of economics, a government-subsidized health care program can create an entirely new market of jobs, specifically ones set up to support the refugees as they are taken in. Economics slowly transforms from micro to macro level depending on the length of government-funded care, and the number of refugees supported.

Education and Training Programs

Education and training programs are crucial for refugees to adapt and make a life for themselves in society. Without these programs, refugees are left to fend for themselves and survive in a culture they are most likely very unfamiliar with.

Self Sufficiency

In order to help refugees become self-sufficient, there must be help from the country where they are settling in. In the United States, the Refugee Career Pathways program helps refugees to achieve self-sufficiency by providing different types of training. The training consists of, assistance in creating personalized career development plans, classroom and work-based learning opportunities, career coaching and mentoring, connections with educational opportunities, apprenticeships, on-the-job training, re-credentialing and credential recognition, and vocational English language training.[a]

[a]Refugee Career Pathways. ACF, www.acf.hhs.gov/orr/programs/refugee-career-pathways, accessed February 26, 2020)

CASE STUDY 4.1 (continued)

Safety and Security

"Protecting the physical security of refugees entails securing their areas of residence, or taking steps to prevent their safety from being jeopardized. It also requires that the living environment of refugees should be peaceful, humanitarian and civilian, free of violence and criminal activity, and conducive to the realization of human dignity...".[b]

Social Issues and Economic Impact

Economic issues that affect the countries where refugees reside are mainly in the cost of their well-being. The governments of those countries are responsible for food, housing, and education to name a few. Large-scale refugee populations can have a serious impact on the social, economic, and political life of host countries (in particular developing countries) and create strain on the local administration. Refugees will compete with the host country citizens for resources of host countries. Gradually, their presence will cause considerable demands on natural resources, education and health facilities, energy, transportation, social services, and finally employment.[c]

Interpretive Structural Modelling (ISM)

Structural Self-Interaction Matrix (SSIM)

Structural Self-Interaction Matrix (SSIM)

The above factors are assumed to be interrelated, rather than independent, where it is noted that some factors may increase the effects of other factors. The next step was to determine the contextual relationships to develop a structural self-interaction matrix shown in Figure 4.19. Using expert opinions along with working members the SSIM was developed.

Adjacency matrix

Then the adjacency matrix, R_a, shown in Figure 4.20 is developed via transforming SSIM into a binary matrix, by substituting V, A, X, and O by 1 and 0 per the schema described previously in STEP 3:

[b] Protection Guidelines Relating to Refugee Security. https://www.refworld.org/pdfid/4124bee54.pdf. Accessed March 13, 2020.

[c] Social and economic impact of large refugee populations on host developing countries, EC/47/SC/CRP.7, UNHCR Standing Committee (1997). https://www.unhcr.org/en-us/excom/standcom/3ae68d0e10/social-economic-impact-large-refugee-populations-host-developing-countries.html. Accessed March 12, 2020.

CASE STUDY 4.1 (continued)

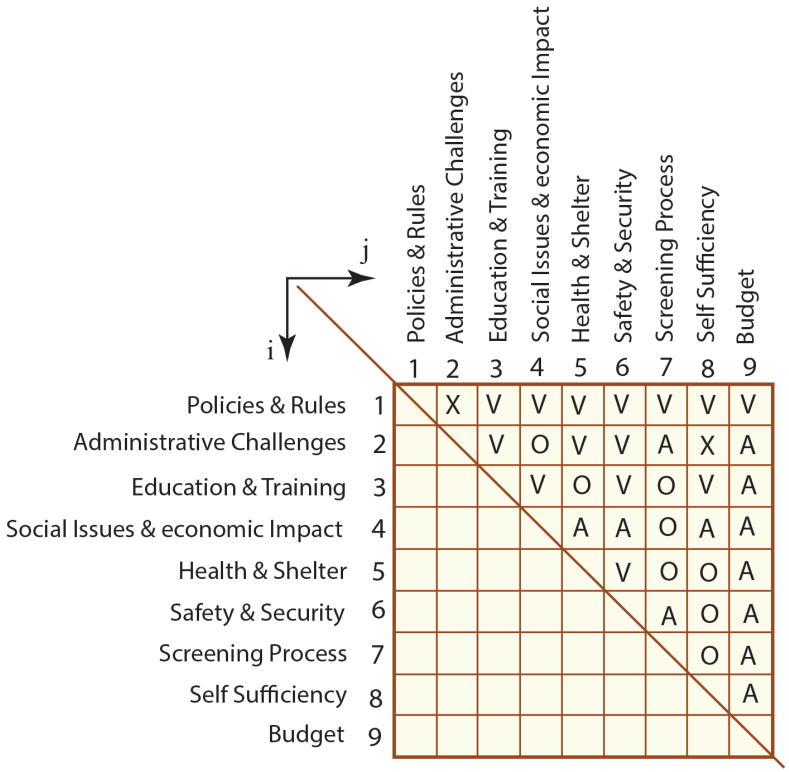

Figure 4.19: Structural Self-Interaction Matrix (SSIM).

$R_a =$

	1	2	3	4	5	6	7	8	9
Policies & Rules 1	1	1	1	1	1	1	1	1	1
Administrative Challenges 2	1	1	1	0	1	1	0	1	0
Education & Training 3	0	0	1	1	0	1	0	1	0
Social Issues & economic Impact 4	0	0	0	1	0	0	0	0	0
Health & Shelter 5	0	0	0	1	1	1	0	0	0
Safety & Security 6	0	0	0	1	0	1	0	0	0
Screening Process 7	0	1	0	0	0	1	1	0	0
Self Sufficiency 8	0	1	0	1	0	0	0	1	0
Budget 9	0	1	1	1	1	1	1	1	1

Figure 4.20: Adjacency matrix.

CASE STUDY 4.1 (continued)

Reachability Matrix with Transitivity

Using the transitivity rule, a reachability matrix, R_t, shown in Figure 4.21 was obtained. The transitivity rule states that, if a factor 'A' is related to factor 'B' and if factor 'B' is related to factor 'C', then factor 'A' is related to factor 'C'. This matrix was updated until transitivity is established.

$R_t =$

		1	2	3	4	5	6	7	8	9
Policies & Rules	1	1	1	1	1	1	1	1	1	1
Administrative Challenges	2	1	1	1	1	1	1	1	1	1
Education & Training	3	0	1	1	1	0	1	0	1	0
Social Issues & economic Impact	4	0	0	0	1	0	0	0	0	0
Health & Shelter	5	0	0	0	1	1	1	0	0	0
Safety & Security	6	0	0	0	1	0	1	0	0	0
Screening Process	7	1	1	1	1	1	1	1	1	0
Self Sufficiency	8	1	1	1	1	1	1	0	1	0
Budget	9	1	1	1	1	1	1	1	1	1

Figure 4.21: Reachability matrix with transitivity.

Final Reachability Matrix

The final reachability matrix as shown in Figure 4.22 was established by including driving power and dependence of factors. The summation of ones in the corresponding rows gives the driving power and the summation of ones in the corresponding columns gives the dependence.

$R_f =$

		1	2	3	4	5	6	7	8	9	Driving power
Policies & Rules	1	1	1	1	1	1	1	1	1	1	9
Administrative Challenges	2	1	1	1	1	1	1	1	1	1	9
Education & Training	3	0	1	1	1	0	1	0	1	0	5
Social Issues & economic Impact	4	0	0	0	1	0	0	0	0	0	1
Health & Shelter	5	0	0	0	1	1	1	0	0	0	3
Safety & Security	6	0	0	0	1	0	1	0	0	0	2
Screening Process	7	1	1	1	1	1	1	1	1	0	8
Self Sufficiency	8	1	1	1	1	1	1	0	1	0	7
Budget	9	1	1	1	1	1	1	1	1	1	9
Dependence		5	6	6	9	6	8	4	6	3	$\Sigma = 53$

Summation of ones (9)

Summation of ones (5)

Figure 4.22: Final reachability matrix.

CASE STUDY 4.1 (continued)

Level Partition

As shown in Table 4.6, The reachability and antecedent set for each variable are obtained from the final reachability matrix.

Table 4.6: Reachability set, antecedent set, iteration levels.

Factor Numbers	Reachability Set	Antecedent Set	IntersectionSet	Factor Levels
1	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8	
2	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 2, 3, 7, 8, 9	
3	2, 3, 4, 6, 8	1, 2, 3, 4, 5, 6, 7, 8, 9	2, 3, 8	
4	4	1, 2, 3, 4, 5, 6, 7, 8, 9	4	I
5	4, 5, 6	1, 2, 5, 7, 8, 9	5	
6	4, 6	1, 2, 3, 5, 6, 7, 8, 9	6	
7	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 3, 4, 5, 6, 8	1, 2, 3, 7, 8, 9	1, 2, 3, 8	
9	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 9	1, 2, 9	
1	1, 2, 3, 5, 6, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	
2	1, 2, 3, 5, 6, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 2, 3, 7, 8, 9	
3	2, 3, 6, 8	1, 2, 3, 7, 8, 9	2, 3, 8	
5	5, 6	1, 2, 5, 7, 8, 9	5	
6	6	1, 2, 3, 5, 6, 7, 8, 9	6	II
7	1, 2, 3, 5, 6, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 3, 5, 6, 8	1, 2, 3, 7, 8, 9	1, 2, 3, 8	
9	1, 2, 3, 5, 6, 7, 8, 9	1, 2, 9	1, 2, 9	
1	1, 2, 3, 5, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	
2	1, 2, 3, 5, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 2, 3, 7, 8, 9	
3	2, 3, 8	1, 2, 3, 5, 7, 8, 9	2, 3, 8	III
5	5	1, 2, 5, 7, 8, 9	5	III
7	1, 2, 3, 5, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 3, 5, 8	1, 2, 3, 7, 8, 9	1, 2, 3, 8	
9	1, 2, 3, 5, 7, 8, 9	1, 2, 9	1, 2, 9	
1	1, 2, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	IV
2	1, 2, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	IV
7	1, 2, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 8	1, 2, 7, 8, 9	1, 2, 8	IV
9	1, 2, 7, 8, 9	1, 2, 9	1, 2, 9	
7	7	7, 9	7	V
9	7, 9	9	9	
9	9	9	9	VI

CASE STUDY 4.1 (continued)

Formation of Digraph

The digraph is an illustration that shows the existence of the direct and indirect relationships between the factors. After removing transitivity, as shown in Figure 4.23, the relationship of sets and binary associations through matrices can now be translated into graphical form by using the theory of digraphs.

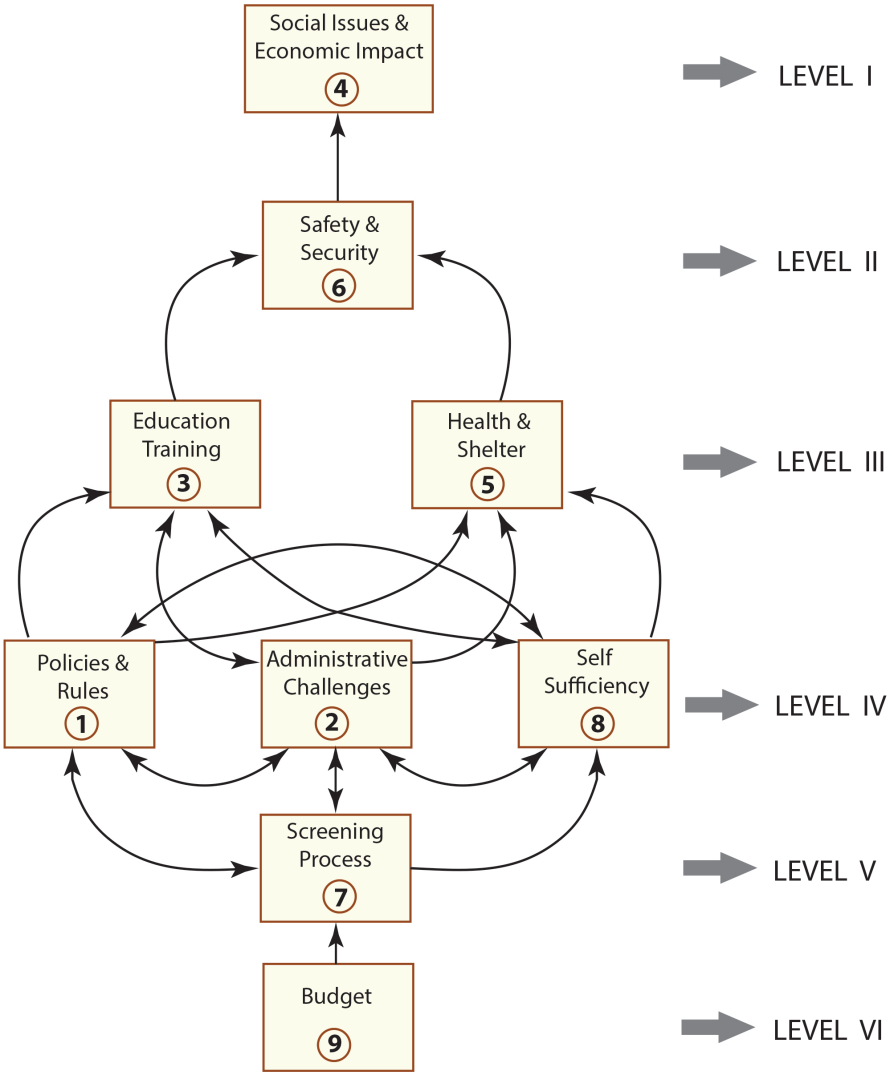

Figure 4.23: Digraph.

CASE STUDY 4.1 (continued)

MICMAC Analysis – Classification of Performance Measures

Through MICMAC analysis, factors are arranged with respect to their driving power and dependence in four clusters: (1) autonomous, (2) dependent, (3) linkage, and (4) independent factors. The driving power and dependence of each of the factors are imported from Figure 4.22. Figure 4.24 shows the driving power-dependence map for refugee resettlement success factors.

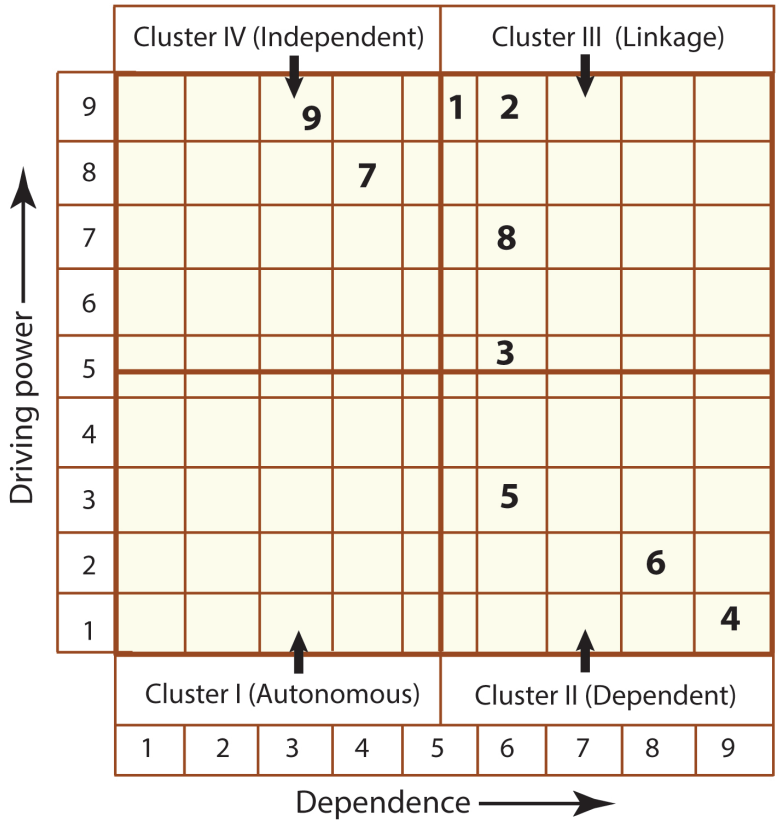

Figure 4.24: MICMAC Analysis.

Discussions

The factors affecting successful refugee settlement in a multi-project environment presented in Figure 4.23 show complex interactions among them. This complexity can be described using Cyclomatic complexity through digraph as:

$$M = E - N + 2P \tag{4.1}$$

CASE STUDY 4.1 (continued)

where
E = the number of edges of the graph
N = the number of nodes of the graph
P = the number of connected components

The number of edges (depicted as arrows) shown in Figure 4.23 is 16, the number of nodes (depicted as rectangles) is 9, and the number of connected components, P is equal to 1. Then, the Cyclomatic complexity M of the digraph given in Figure 4.23 is

$$M = 16 - 9 + 2 \times 1 = 9$$

A higher number of Cyclomatic complexity means that the complexity of an issue will be complicated to understand. The acceptable upper bound that has been used for Cyclomatic complexity is 10. Since digraph gives close to the complexity of 10, the issue of refugee settlement is too complex to understand. As seen from Figure 4.23, the issue of refugee settlement consist of multiple levels of combinations, and functional behaviors can arise at many of the levels. It is usually difficult in dealing with complex issues such as this one. The existence of directly or indirectly related factors complicates the solution of the issue which may or may not be articulated in a clear fashion.

The issue of refugees is complex and includes many factors. As shown in Figure 4.23, Level IV is the most complex one because of many interactions with the other levels. Administration plays an important role in the success of the refugee settlement to implement policies and rules in order to help refugees become self-sufficient. Level IV effort should support education and training programs as well as health care needs which are crucial for refugees to adapt and make a life for themselves in society. A source factor of establishing a realistic budget should be allocated to separated families, detained children, threatened immigrants, and also all the required activities of secure and successful resettlement of refugees. However, this effort should not be at the cost of crucial education, housing, and nutritional assistance programs that promote public safety and improve poverty in hosting countries.

Figure 4.24 shows that there are no autonomous factors. The absence of these factors shows that all the considered factors influence successful refugee resettlement. Health & shelter, safety and security, and social issues, and economic impact are in the category of the dependent quadrant. This means that these issues have little driving power but strong dependence (called driven factors).

The linkage cluster consists of four factors, including the policies and rules (factor 1), administrative challenges (factor 2), Self-sufficiency (factor 8), and education and training (factor 3). These factors have strong driving power, as well as strong dependence power, therefore they are considered as key factors for the success of the refugee settlement. These factors are critical, meaning that any action on these factors may influence the other factors and an effect on themselves by the other factors.

CASE STUDY 4.1 (continued)

The fourth quadrant includes independent barriers that have a low dependence but strong driving power. In this research, budget & cost (factor 9) and screening process (factor 7) are in this quadrant. It can be assumed that these factors may be considered as the important key parameters, as well as the root cause of problematic issues. Management should give the greatest attention to these factors in order to meet the terms of the success of the goal of the refugee settlement.

As shown in Figure 4.23, factors safety and security (factor 6), social issues, and economic impact (factor 4) are positioned at the top of the hierarchy. They are also very significant measures for the successful development of a refugee settlement as they are being affected by the other factors: living environment of refugees should be peaceful, humanitarian and civilian, free of violence and criminal activity, and conducive to the realization of human dignity.

Concluding Remarks

It has been shown that the issue of refugee settlement consist of multiple levels of combinations and functional behaviors can arise at many of the levels – the problem of refugee settlement is too complex to understand. In this research, budget & cost (factor 9) and screening process (factor 7) are considered as the important key parameters, as well as the root cause of problematic issues. Management should give the greatest attention to these factors in order to meet the terms of the success of the goal of the refugee settlement.

It is important to note that ISM is a tool to identify the order and directions of the complexity of relationships among the factors affecting certain issues. It does not provide any relative weight associated with the factors. Complex systems such as this one, require communications and the exchange of information among responsible organizations. Information flow between organizations can be created using a Design Structure Matrix (DSM) in order to better map organizational responsibilities and their interactions to address the problems associated with refugee resettlement. Clustering (integration) of organizations can provide new understandings into organizational decomposition and integration.