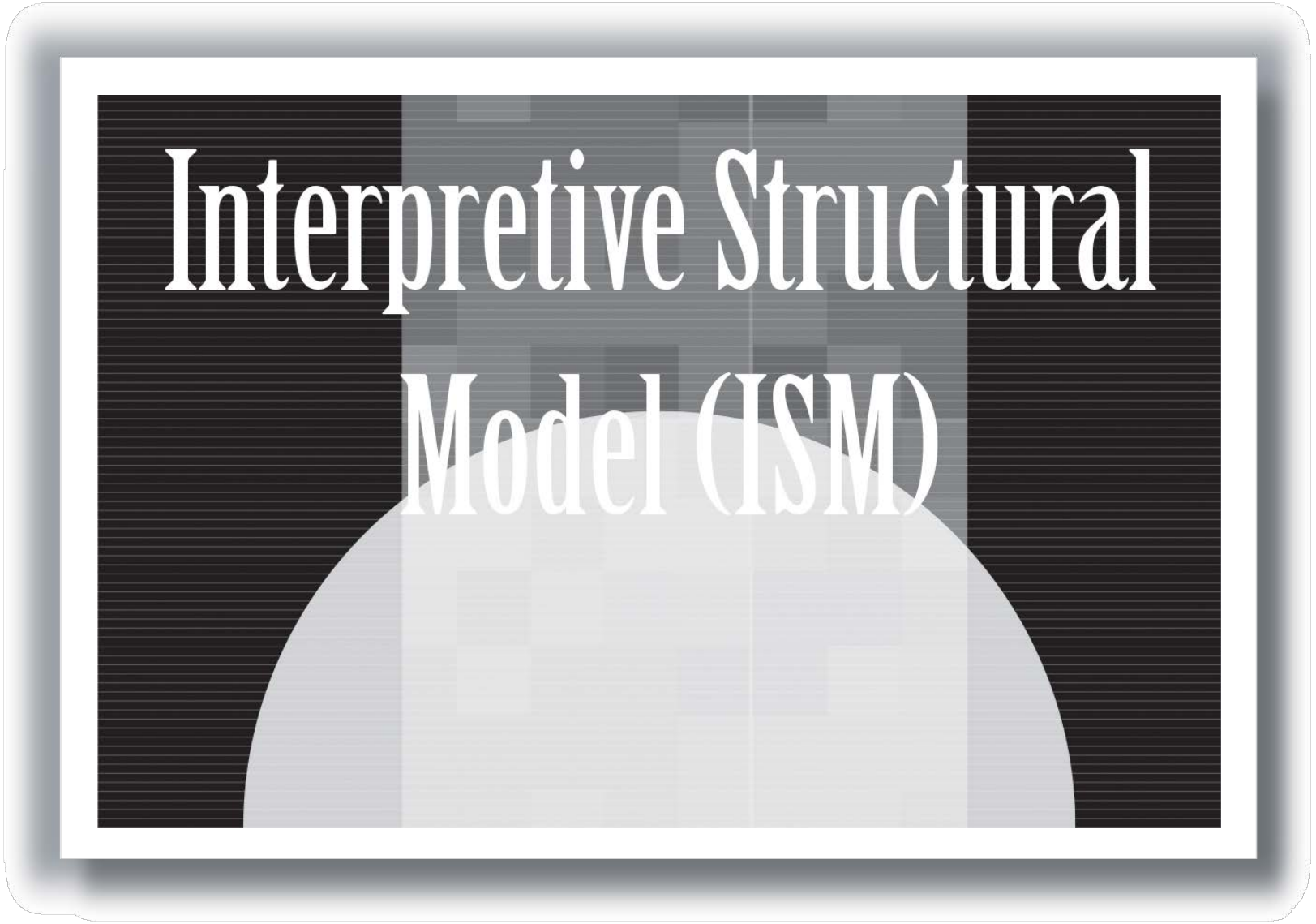
Instructor’s
Title & Name

Course Title….



Transdisciplinarity

Transdisciplinarity is a method of acquiring new knowledge through rethinking current methods and processes, rearranging our fundamental science and engineering knowledge to create innovative technological products and services to confront society's complex issues. The practical focus of transdisciplinarity is a collaborative process to improve our understanding of complex issues by using collective intelligence through collective experts and multiple resources for designing and implementing solutions to challenging problems by considering the public good.

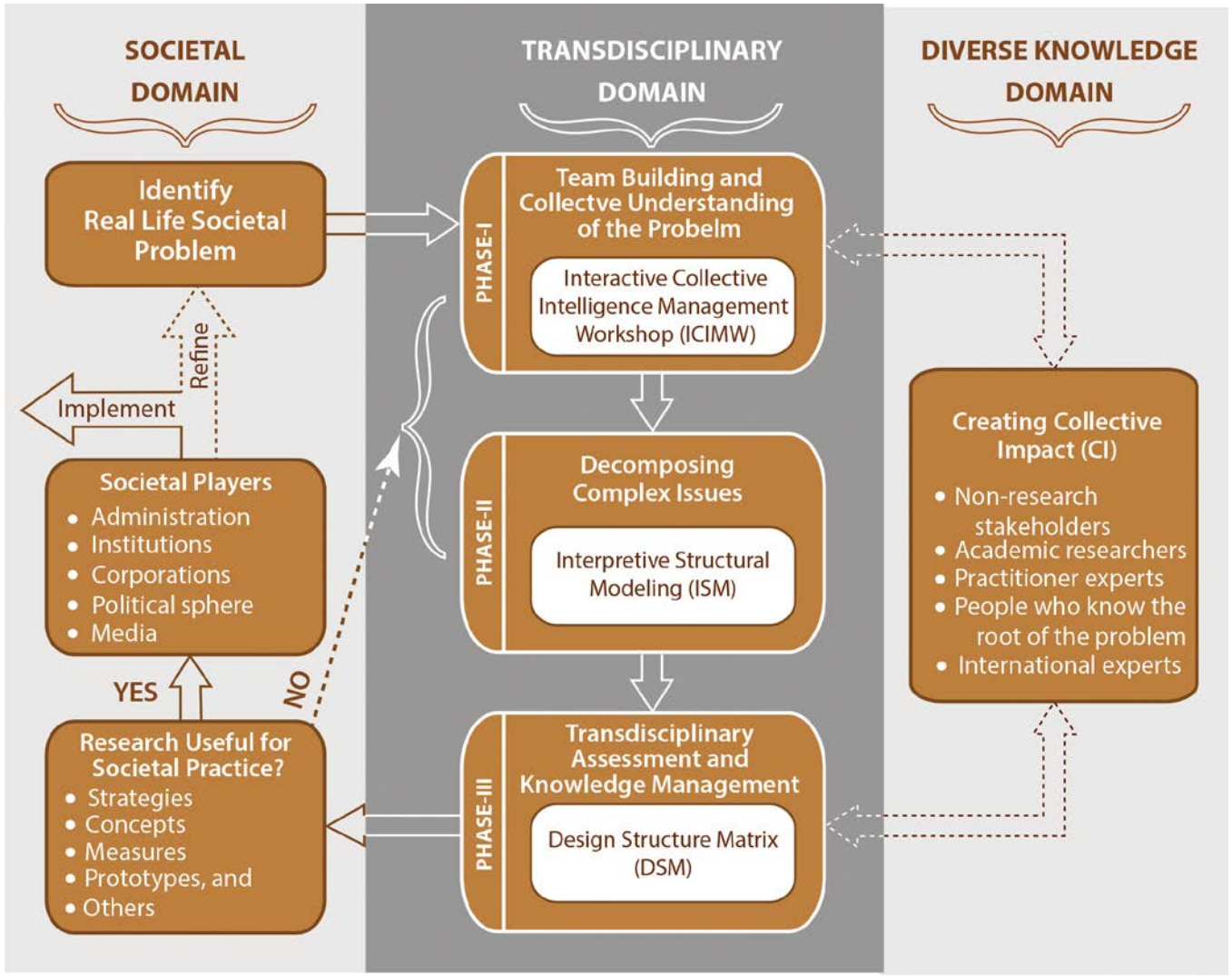


Figure 4.1: Transdisciplinary Research Process

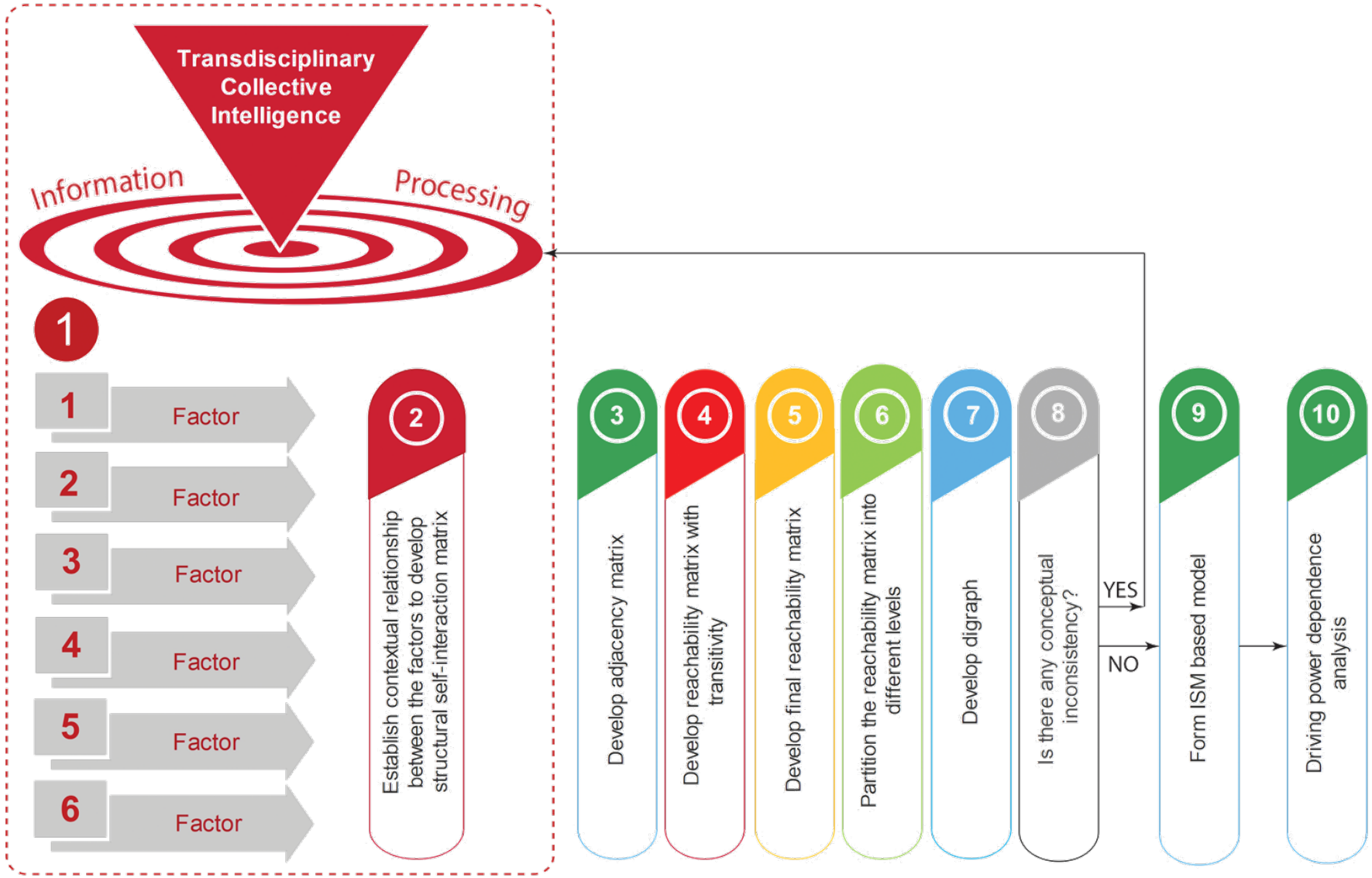


Figure 4.2: ISM process.

Step 1: Development of TD collective intelligence

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

Step 2: Develop Structural Self-Interaction Matrix

- 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

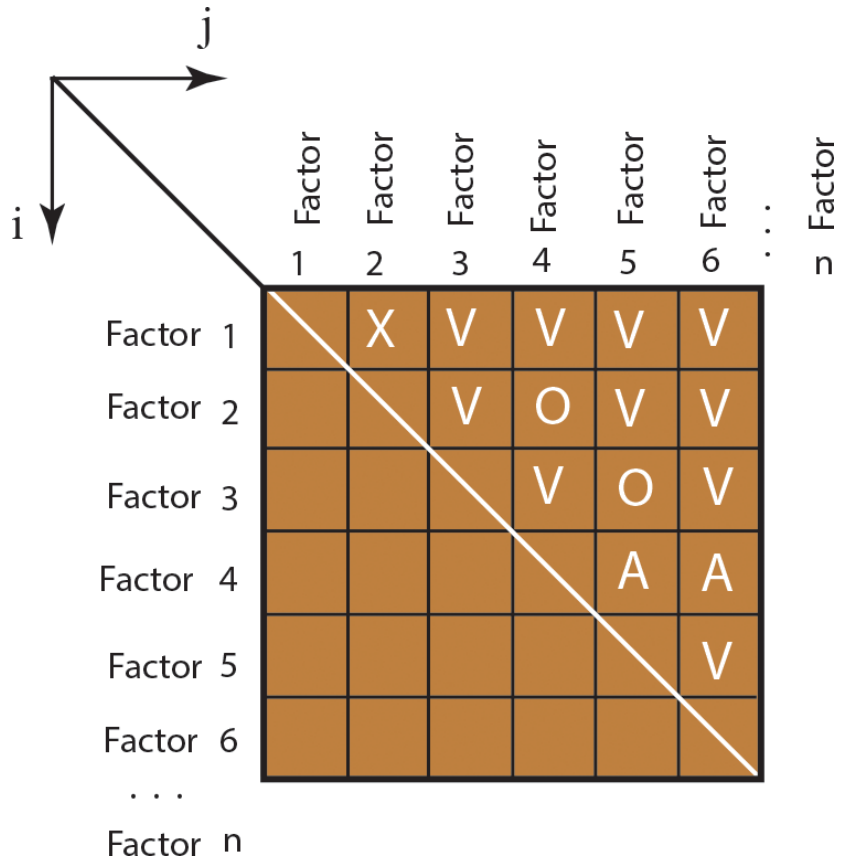


Figure 4.3: Structural self-interaction matrix (SSIM).

STEP 3: Develop Adjacency Matrix

As shown in Figure 4.4, replace the entries V, A, X, and O of the SSIM into 1 and 0 (binary matrix).

$R_a =$

	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 4.4: Adjacency matrix.

STEP 4: Reachability Matrix with Transitivity

Figure 4.5 shows the reachability matrix with transitivity. The reachability matrix is tested for the transitivity rule and is updated until transitivity is confirmed. The transitive rule is “if A has a relationship to B and B has a relationship to C, then A has relationship to C”. Following the transitivity rule reachability matrix, Rt shown in Figure 4.5 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 4.5: Reachability matrix with transitivity.

STEP 5: Final Reachability Matrix

The final reachability matrix in Figure 4.6 shows the *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 4.6 is the final form of the relationships of all the factors involved with the problem under consideration. Calculated driving power and dependence in Figure 4.6 will be used for MICMAC analysis.

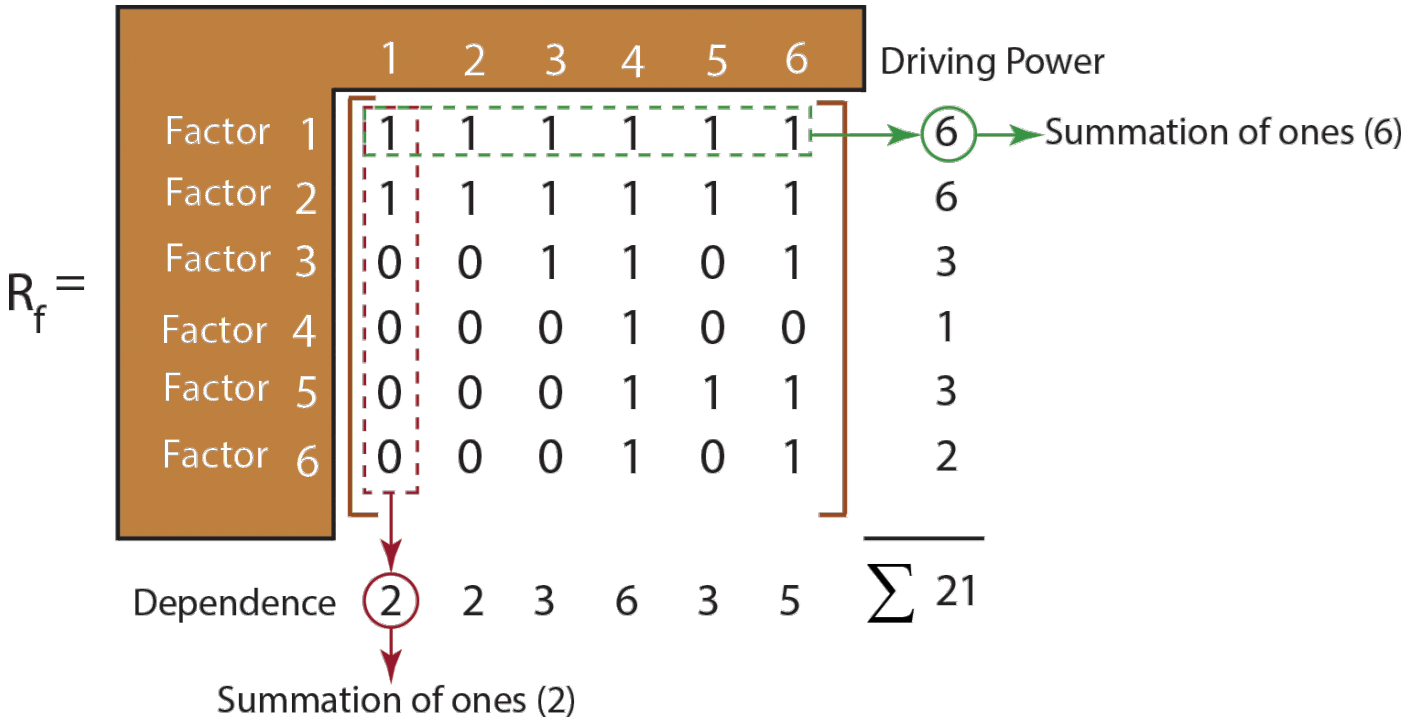


Figure 4.6: Final reachability matrix.

STEP 6: Level Partition

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 4.1 through 4. 4, this iteration process is repeated until all the levels are identified. These levels will be used to build the digraph and ISM model.

$R_f =$

	1	2	3	4	5	6	Driving Power
Factor 1	1	1	1	1	1	1	6
Factor 2	1	1	1	1	1	1	6
Factor 3	0	0	1	1	0	1	3
Factor 4	0	0	0	1	0	0	1
Factor 5	0	0	0	1	1	1	3
Factor 6	0	0	0	1	0	1	2
Dependence	2	2	3	6	3	5	$\sum$ 21

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 4.7: Identifying level 1

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

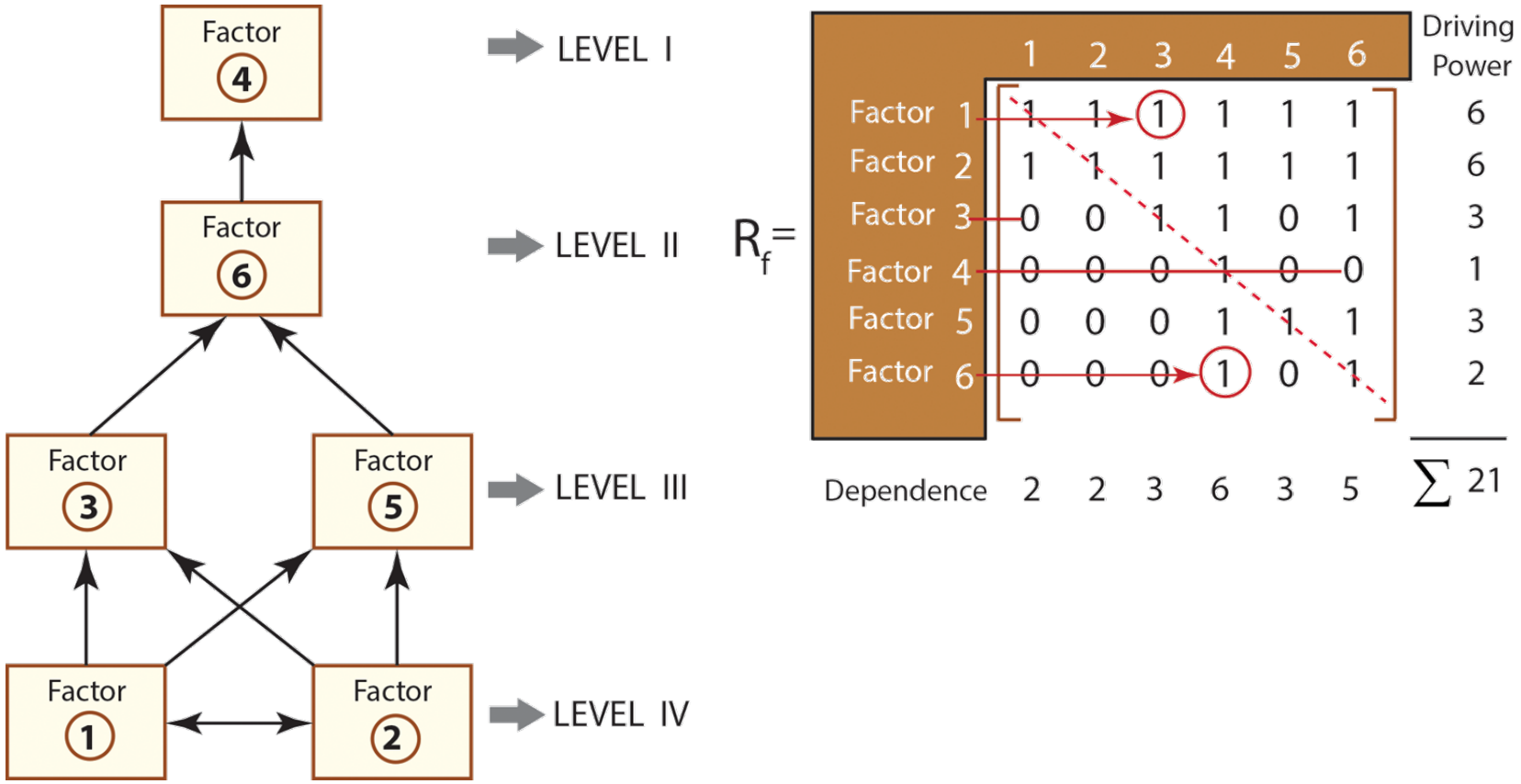


Figure 4.8: Digraph.

STEP 8: 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

$R_f =$

	1	2	3	4	5	6	Driving Power
Factor 1	1	1	1	1	1	1	6
Factor 2	1	1	1	1	1	1	6
Factor 3	0	0	1	1	0	1	3
Factor 4	0	0	0	1	0	0	1
Factor 5	0	0	0	1	1	1	3
Factor 6	0	0	0	1	0	1	2
Dependence	2	2	3	6	3	5	∑ 21

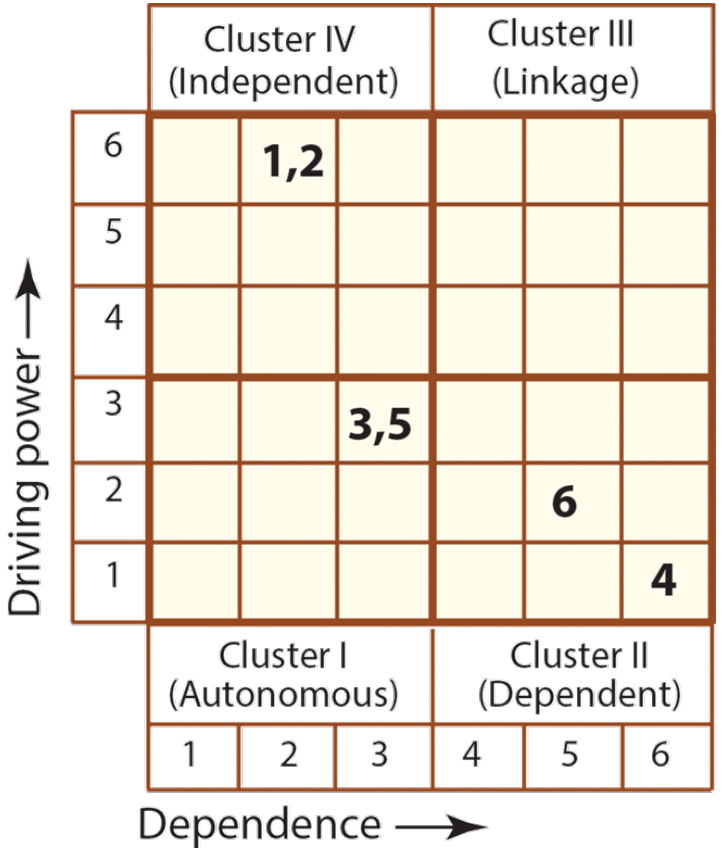


Figure 4.9: MICMAC analysis.

Example 4.1

Figure 4.10 shows the relationships of five elements of a system. Develop:

(a) the adjacency matrix;

(b) the final reachability matrix;

(c) the level partition;

(d) the digraph.

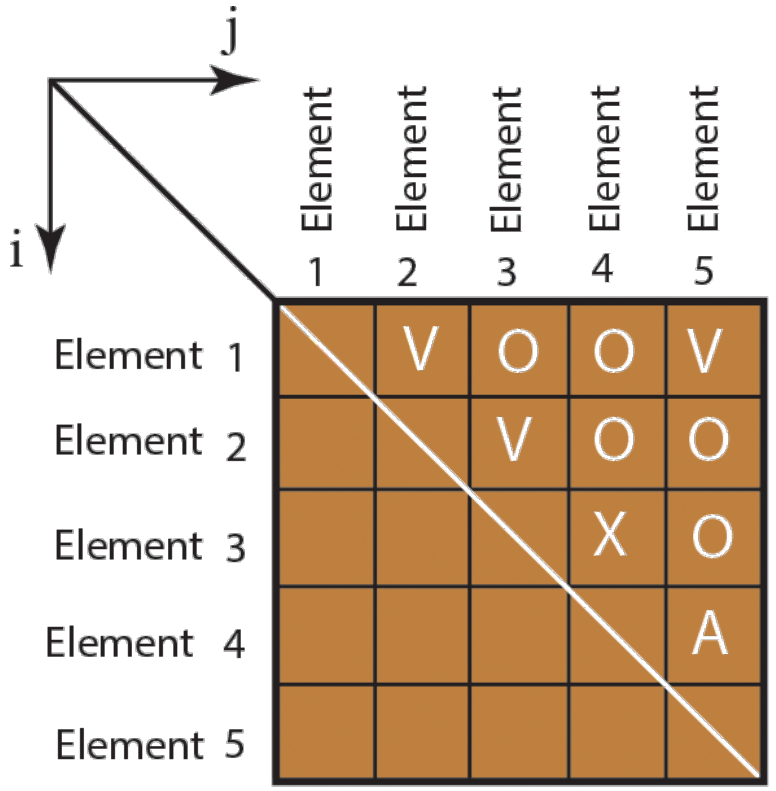


Figure 4.10: Structural self-interaction matrix.

(a) The adjacency matrix shown in Figure 4.11 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 4.11: Adjacency matrix.

(b) Final Reachability matrix with transitivity is shown in Figure 4.12. As shown in this figure, the 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 4.12: Final reachability matrix with transitivity.

(c) The final reachability matrix is used to develop the level partition.

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 4.13, the initial digraph can be developed by using an adjacency matrix.

$R_a =$

	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

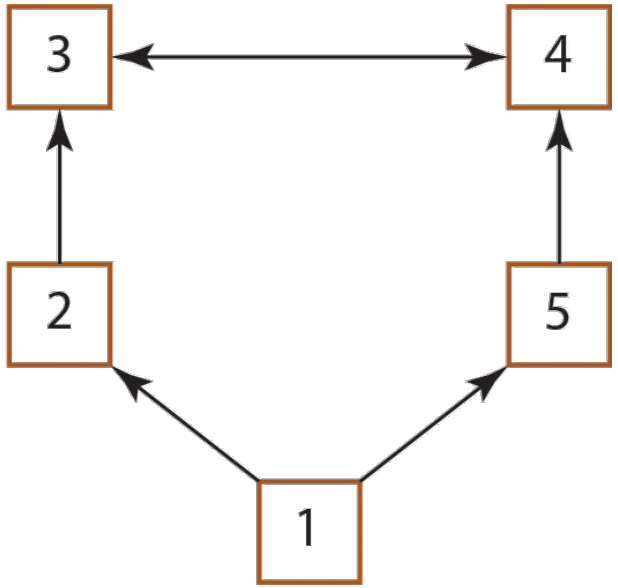


Figure 4.13: Digraph through adjacency matrix.

EXAMPLE 4.2

Figure 4.14 shows the relationships of eight elements of a system. Develop:
(a) the adjacency matrix;
(b) the final reachability matrix;
(c) the digraph.

	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.

(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.

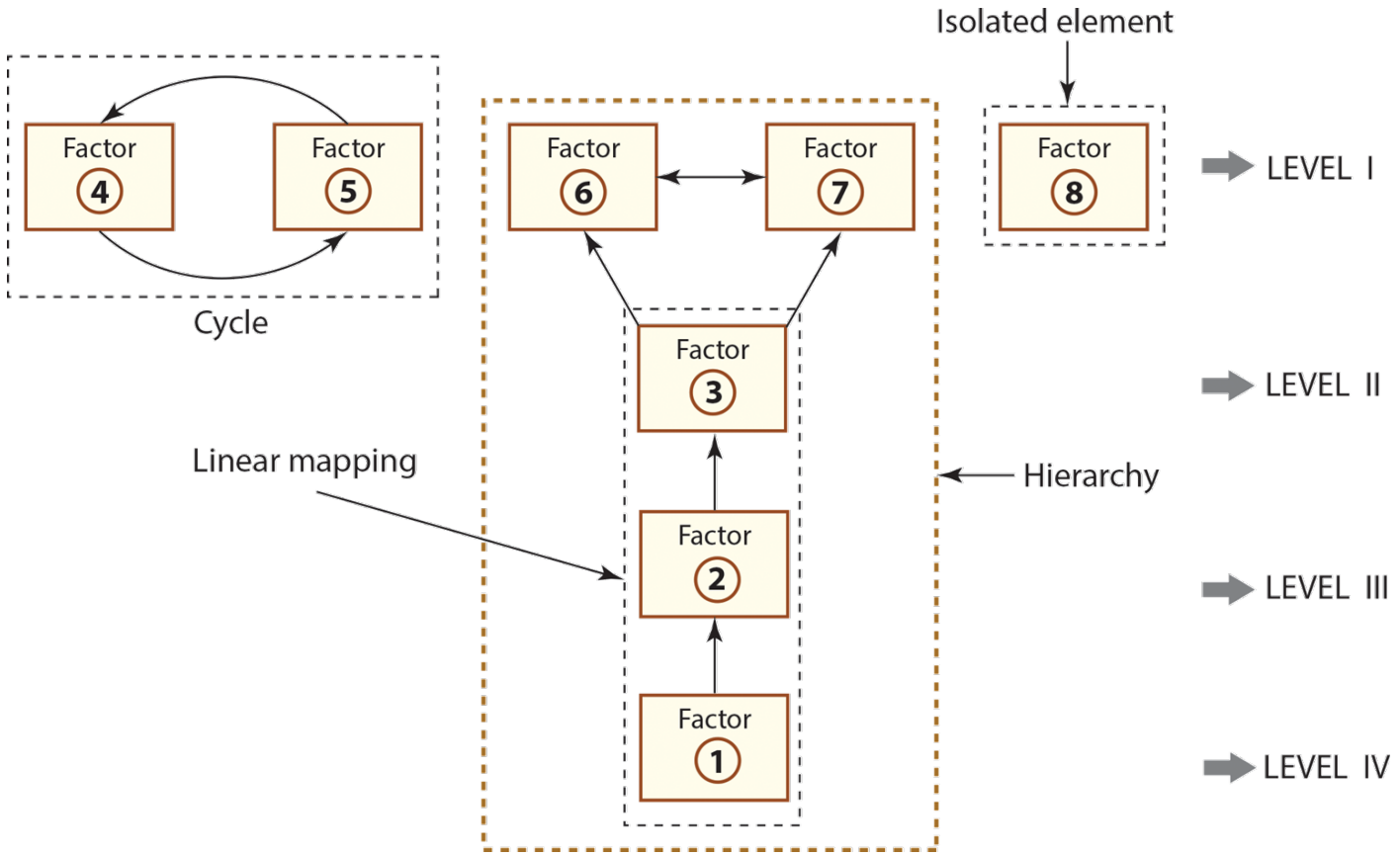


Figure 4.17: Digraph.

CASE STUDY 4.1

The complexity of Global Refugee Crisis: Needs for Global Transdisciplinary Collaboration.

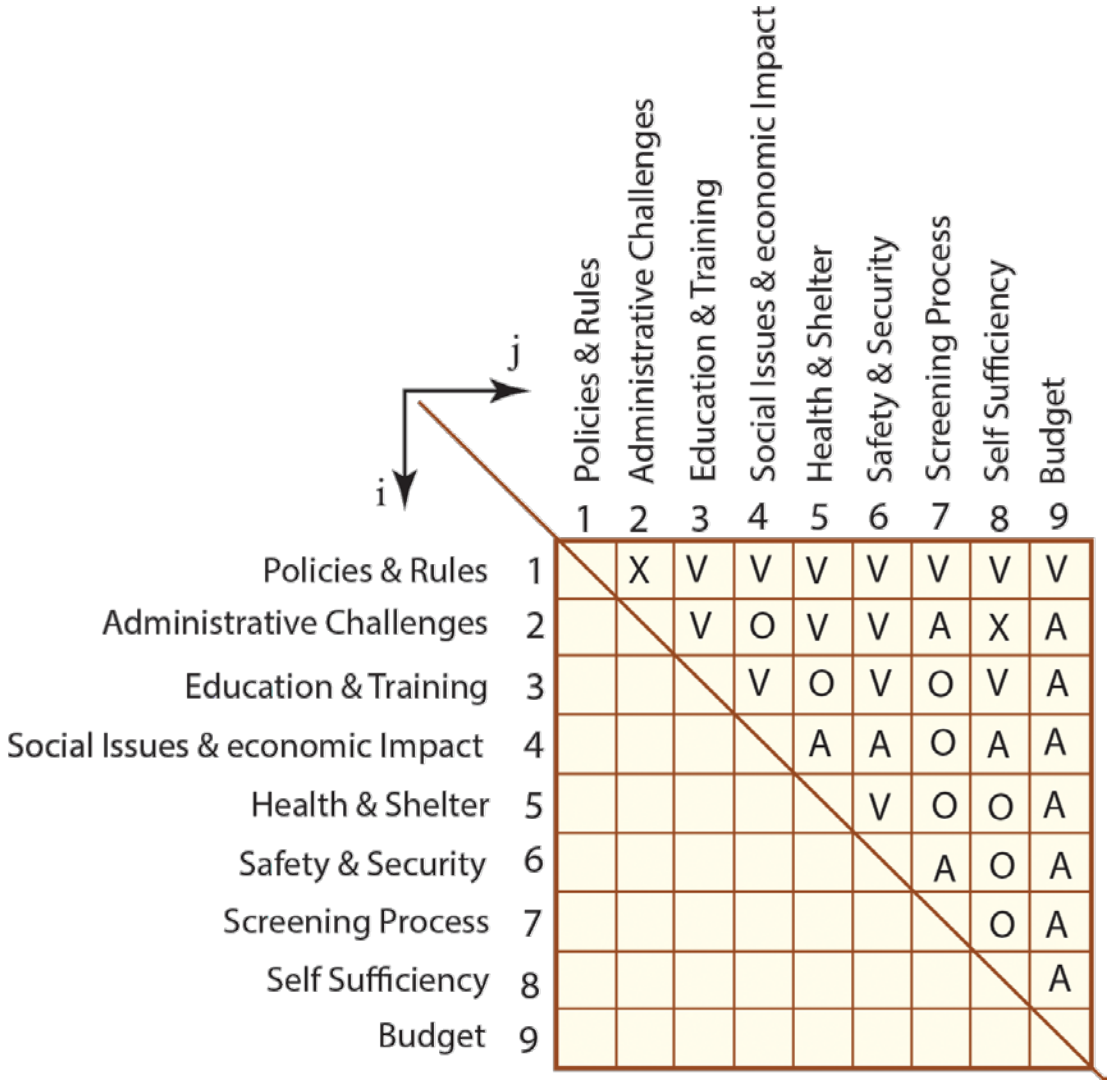


Figure 4.18: Structural Self-Interaction Matrix (SSIM).

$R_a =$

		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 4.19: Adjacency matrix.

$R_t =$

		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 4.20: Reachability matrix with transitivity.

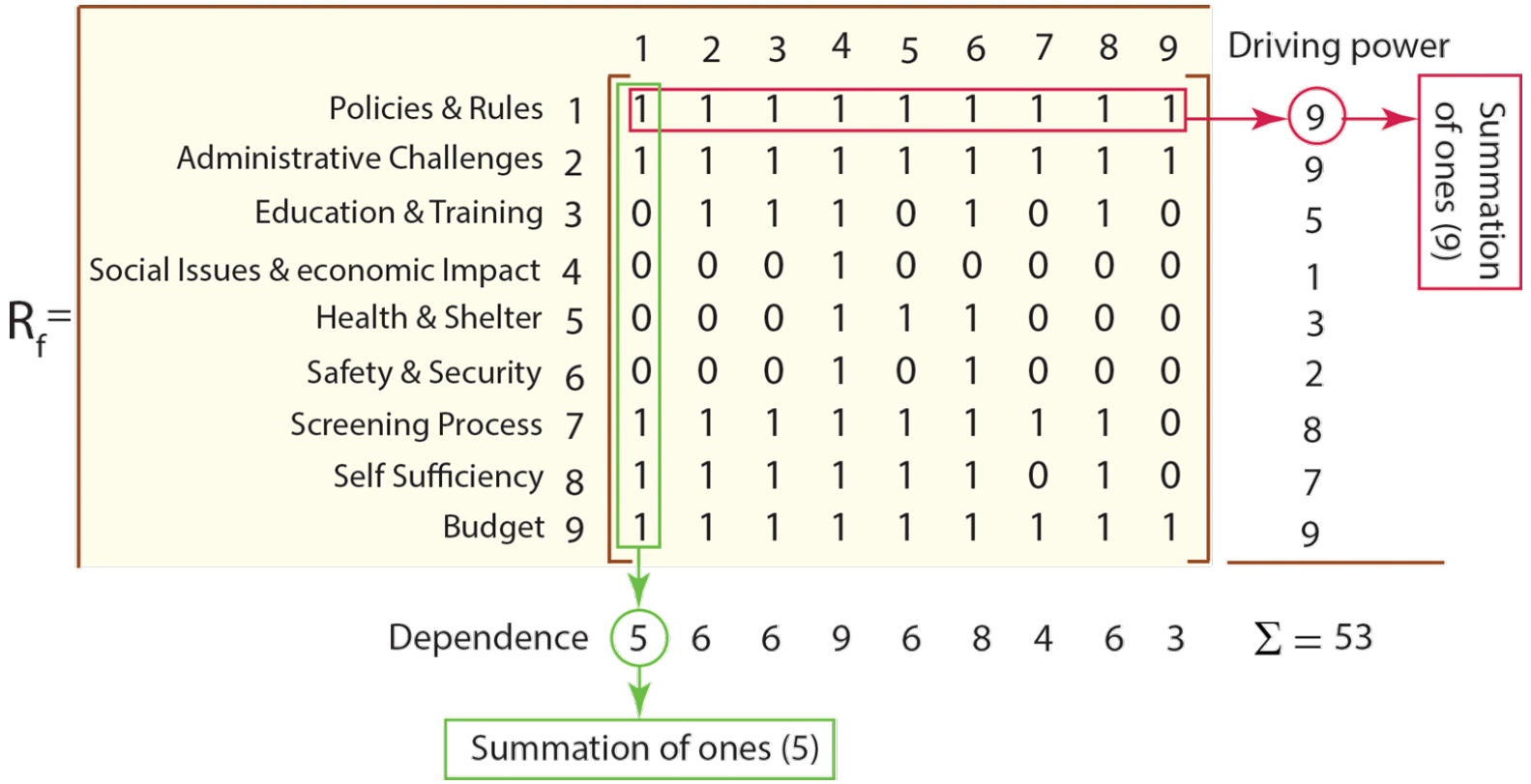


Figure 4.21: Final reachability matrix.

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

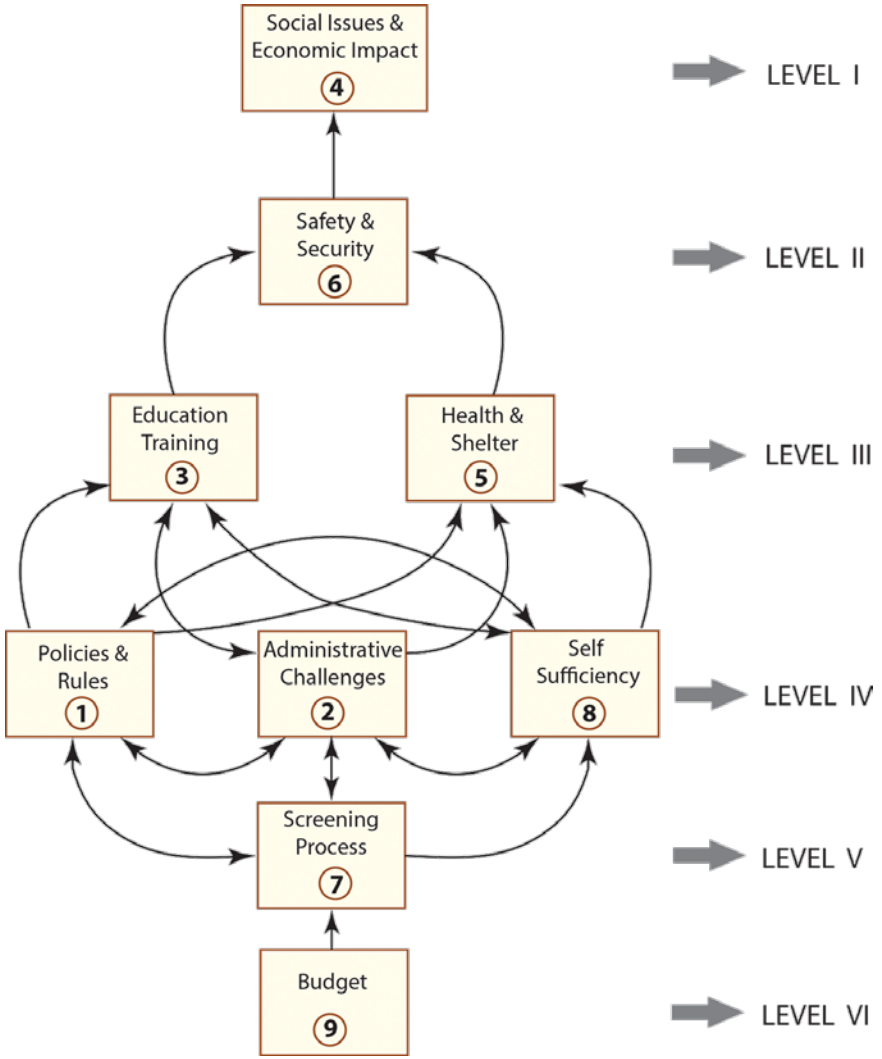


Figure 4.22: Digraph.

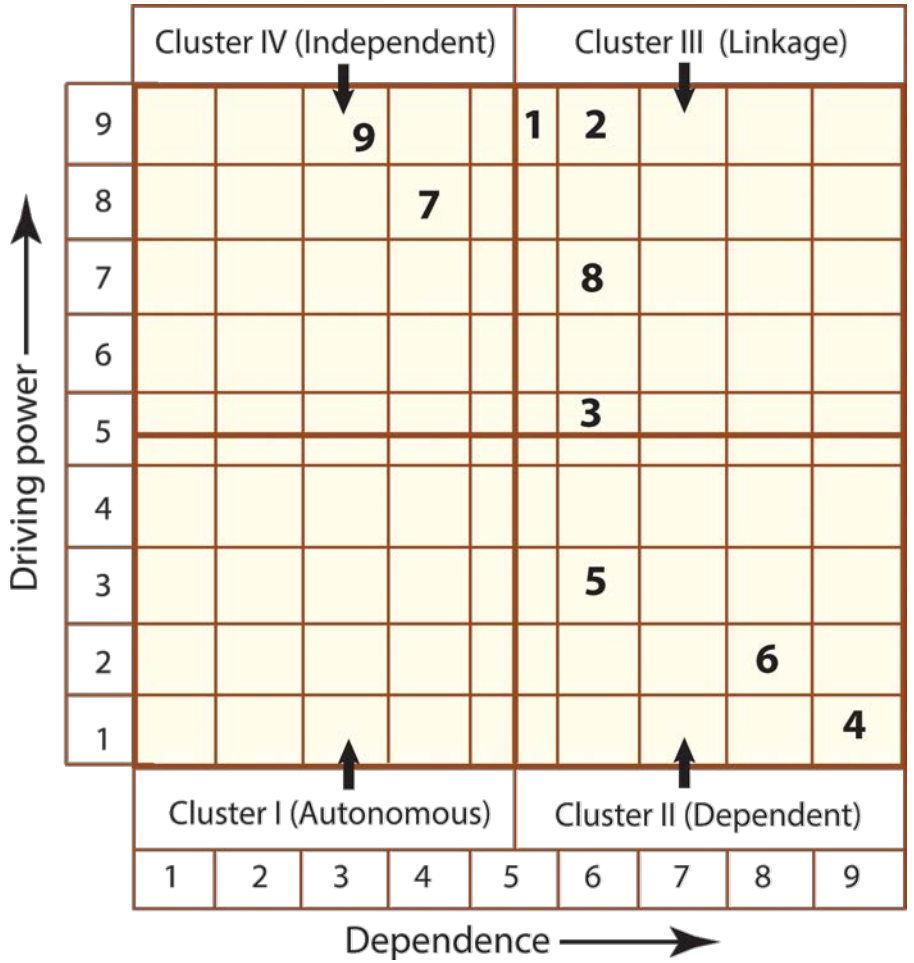


Figure 4.23: MICMAC Analysis.