# INTERPRETIVE STRUCTURAL MODELS IN ASSESSMENT OF SUPPLY CHAIN AGILITY INDEX

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## ABSTRACT

*In the contemporary manufacturing scenario, agility is seen as the fundamental weapon for competitiveness and long term survival. Responsiveness towards the ever changing environment has continuously evolved from the concept of agility. Agility in its simplest form can be defined as the capability to respond quickly and effectively to the ever changing market conditions. Past literature exhibits that imminent agility problem in inflexible and fragile supply chains eventually arise from the unidentified enablers which are the pivot point in this research attempt. In this paper, prominent agile supply chain enablers have been traced from times of yore and Interpretive Structural Models (ISM) have been deployed to develop Structural Self-Interaction Matrix (SSIM) in order to identify the relationships between the enablers, followed by Graph Theoretic Approach (GTA) for classification of enablers. A digraph has been developed to establish the interdependencies among ISM identified driver enablers followed by development of the permanent function for Agility Index (AI) tabulations in order to categorize the constraints in supply chain agility transformation.*

***Keywords:*** *Interpretive Structural Models, Structural Self-Interaction Matrix, Graph Theoretic Approach, digraph, Supply Chain agility, Agility Index*

## INTRODUCTION

In the modern business environment, supply chain often is the part of a firm that is severely affected by changes [1,22]. In any supply chain, agility is all about being market sensitive and developing the ability to respond to actual real time changes in demand [16]. In achieving agility, it is very essential to understand the mutual relationship among the supply chain enablers [6,8]. There are few enablers which would help to transform a rigid supply chain into an agile entity. The understanding of those enablers is important as they not only impact the agility in the supply chain, but also influence each other. The identification of such enablers would be helpful for the management contemplating to transform their existing supply chain into a truly agile entity [11, 13]. ISM is often used for identifying and summarizing relationships among specific variables, which define a problem [3,5,10]. It provides a means by which prioritization can be imposed on the complexity of such variables. ISM as a process is intended for use when it is desired to utilize systematic and logical thinking to approach a complex issue and then communicate the results to others [1, 9,19]. It uses experts' practical experience and knowledge to integrate a complicated system into several subsystems and construct a multilevel structural model [17,21,22]. Further, classification of the enablers shall be performed using MICMAC (Matriced' Impacts croises-multiplication applique' and classment) analysis through which the key enablers are deduced [4, 7]. ISM integrated with GTA to explore the AI, forms a unique area in improvising manufacturing through agile practices [6,20].

**STEPS:**

1. Study the problem with respect to the gaps in supply chain.
2. List the enablers related to agility in the supply chain.
3. Establish contextual relationship among variables.
4. Develop the Structural Self Interaction Matrix (SSIM).
5. Develop the Reachability Matrix (RM).
6. Partition the RM into different levels.
7. Structure the ISM hierarchy.
8. Perform MICMAC analysis for enabler classification.
9. Develop digraph using driver enablers.
10. Convert digraph into matrix and matrix into its permanent function.

Based on literature surveys, eminent supply chain enablers have been listed as inputs and contextual relationships have been established using the following syntax in SSIM (Table 1).

V: enabler *i* will augment enabler *j*;
A: enabler *i* will be augmented by the enabler *j*;
X: enabler *i* and *j* will augment each other;
O: enabler *i* and *j* are unrelated

Table 1 Structural Self – Interaction Matrix ( SSIM )

| S.No. | Enablers | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Continuous Improvement [4,15,18,22] | V | V | V | V | X | V | V | V | V |
| 2 | Technological Opportunities [4] | O | V | V | V | A | A | V | V | |
| 3 | Enhanced Collaboration [21] | A | A | A | A | A | A | A | | |
| 4 | Better Decision Making [21] | O | O | A | A | A | A | | | |
| 5 | Quality [18,22] | V | V | V | V | A | | | | |
| 6 | Co-operation with Customers [15] | V | V | O | O | | | | | |
| 7 | Information Sharing [1,4] | O | X | V | | | | | | |
| 8 | Product Variety [12] | X | O | | | | | | | |
| 9 | Long term Strategic Goals [4,27] | O | | | | | | | | |
| 10 | Flexibility [1,18] | | | | | | | | | |

From the deduced SSIM, the RM can be drawn from alpha variables tabulated with the binary numbers. This renders a way to calculate the driver and dependence values by summing up rows and columns respectively. The driver and dependence power may be used for classification of variables as autonomous, dependent, linkage and driver enablers [15,23].The SSIM is subsequently transformed into RM (Table 2) by substituting V, A, X, O by 1 and 0 based on the following rules (Table 2).

- If (i,j) entry in the SSIM is V, the( i,j) entry in the RM becomes 1 and (j,i) entry becomes 0.
- If (i,j) entry in the SSIM is A, the (i,j) entry in the RM becomes 0 and (j,i) entry becomes 1.

- If (i,j) entry in SSIM is X, the (i,j) entry in the RM becomes 1 and (j,i) entry becomes 1.
- If (i,j) entry in the SSIM is O, the (i,j) entry in the RM becomes 0 and (j,i) entry becomes 0.

Table 2 Reachability matrix

| S.No | Enablers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Driver Power |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Continuous Improvement | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **10** |
| 2 | Technological Opportunities | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1* | 7 |
| 3 | Enhanced Collaboration | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| 4 | Better Decision Making | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **2** |
| 5 | Quality | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | **8** |
| 6 | Co-operation with Customers | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1* | 1 | 1 | **10** |
| 7 | Information Sharing | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1* | **6** |
| 8 | Product Variety | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | **4** |
| 9 | Long term Strategic Goals | 0 | 0 | 1 | 1* | 0 | 0 | 1 | 1* | 1 | 0 | **5** |
| 10 | Flexibility | 0 | 0 | 1 | 1* | 0 | 0 | 0 | 1 | 0 | 1 | **4** |
| **Dependence power** | | **2** | **4** | **1** | **9** | **3** | **2** | **6** | **8** | **6** | **7** | |

**1*→ means transtivity**

The reachability set and antecedent set can be deduced from the summation of rows and columns respectively. Intersection set is considered by the similarity achieved between the reachability and antecedent sets. The levels are obtained by the similarity of reachability and intersection sets and it is further iterated by eliminating the repeated real numbers in the set (Table 3). In this case, the iteration procedure extends till the seventh level until all enablers find a level in the ISM hierarchy (Figure 1).

Table 3 Level partitions

| Enablers | Reachability set | Antecedent set | Intersection | Level |
|---|---|---|---|---|
| 1 | 1,6 | 1,6 | 1,6 | VII |
| 2 | 2 | 1,2,5,6 | 2 | V |
| 3 | 3 | 1,2,3,4,5,6,7,8,9,10 | 3 | I |
| 4 | 4 | 1,2,4,5,6,7,8,9,10 | 4 | II |
| 5 | 5 | 1,5,6 | 5 | VI |
| 6 | 1,6 | 1,6 | 1,6 | VII |
| 7 | 7,9 | 1,2,5,6,7,9 | 7,9 | IV |
| 8 | 8,10 | 1,2.5,6,7,8,9,10 | 8,10 | III |
| 9 | 7,9 | 1,2,5,6,7,9 | 7,9 | IV |
| 10 | 8,10 | 1,2,5,6,7,8,10 | 8,10 | III |


Figure 1 ISM Model

From the findings of driver and dependence power, a graph is drawn subsequently to classify the four quadrants for the ease of viewing and analyzing [12,14]. Based on driver dependence powers, the enablers were further classified using MICMAC Analysis [2,4,18], which surface the following four quadrants of enablers and the quadrants which enabler would fit in (Figure2).

1. Autonomous enablers (weak drive power and weak dependence) {NIL}.
2. Dependent enablers(weak drive power and strong dependence) {3,4,8,9,10}.
3. Linkage enablers(strong drive power and strong dependence) {7}.

4. Driver enablers (strong drive power and weak dependence) {1, 2, 5, 6}.

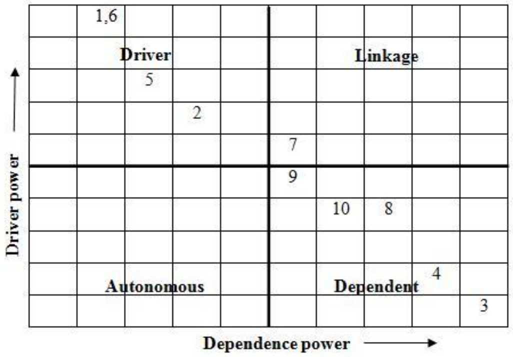


Fig.2 Classification of enablers using MICMAC Analysis

The driver enablers form the basis for driving the other enablers and their impact is maximum in achieving the agility. Thus, the selected driver enablers are extracted from ISM results and represented in the form of digraph. Digraph models the abstract structure of a system that facilitates the understanding of independencies among them [6]. A node in the graph represents the contribution of the enabler itself, while a directed edge from one node to other node represents the interaction or interdependencies between the two enablers [20]. In this case, diagraph is represented by considering the driver enablers {1,2,5,6} and the number of nodes is equal to the number of attributes (Figure 3).

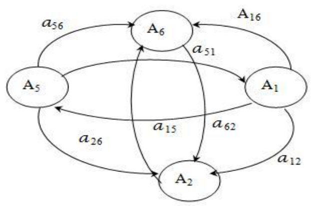

Figure 3 Diagraph for the four driver enablers

The developed digraph is converted into a matrix form. In the matrix, the diagonal element represents the inheritances, in the sense, the impact of the individual enablers and off the diagonal elements represents the interdependencies. With four enablers considered in the digraph (Figure 3), its corresponding 4x4 matrix resembles,

A* = | | (1)

Void of negative signs, will finally transform the 4x4 matrix into its permanent function [6] as

( ) (2)

## CONCLUSION

To reach the goal of satisfying the customers in modern manufacturing era, it becomes vital to improve agility by being fast, responsive and proactive to the rigorous market demands. In this attempt, ISM has been deployed to develop relationships among the various agile enablers. The output of ISM has been used effectively as an input for MICMAC Analysis for identifying the driver- dependence power of the agile enablers. This paper has integrated GTA with ISM for quantification of the interdependencies among various enablers and has resulted in tabulation of AI of the subcomponents involved in submersible pump manufacturing. The issue is growing pivotal as the relationships among variables contribute to overall agility of the supply chain. The integrated tool will also aid the current supply chain managers to match supply and demand inorder to meet the rapid change in the market and simultaneously meet the end user requirements.

## REFERENCES

[1] Akhilesh Barve, International Conference on E-business, Management and Economics, 3 (2010) 325-329.

[2] Aravind Jayant & Mohd Azhar, Analysis of the barriers for implementing green supply chain management(GSCM) Practices: An Interpretive Structural Modeling (ISM) Approach, Procedia Engineering, 97 (2014) 2157-2166.

[3] B. Atul Borade & Satish Bansod, Interpretive structural modeling-based framework for VMI adoption in Indian industries', International Journal of Advanced ManufacturingTechnology,

58 (2012) 1227-1242.

[4] Devendra Kumar Dewangan, Rajat Agrawal, & Vinay Sharma , Enablers for Competitiveness of Indian Manufacturing Sector: An ISM-Fuzzy MICMAC Analysis, Procedia Social and Behavioral Sciences,189 (2015), 416-432.

[5] A. K. Digalwar & Ganneri Girdhar, Interpretive Structural Modeling Approach for Development of Electric Vehicle Market in India, Procedia CIRP, 26 (2015) 40-45.

[6] M.N. Faisal, D.K. Banwet & R. Shankar, Supply chain agility: analyzing the enablers, International Journal of Agile Systems and Management, 2 (2007) 76-91.

[7] Fatemeh Kahrarian, An ISM Access for Modeling the enablers in the performing of Total Productive Maintenence(TPM), International Journal of Research in Social Sciences, 3 (2014) 41-59.

[8] P. Jacob George, & V.R. Pramod, ISM for analysing the safety of SRRMs, International Journal of Scientific and Research publication, 3 (2013) 1-9.

[9] B. Jayalakshmi & V.R Pramod, Interpretive Structural Modeling of the Prospects of Ict Enabled Process Control in the Industry, IOSR Journal of Computer Engineering, 11 (2013) 57-63.

[10] Li Yanmei & ZI Chen, Analysis of Load Factors Based on Interpretive Structural Model, Journal of Computers, 7, (2012) 1704-1711.

[11] V.B. Mahajan, J.R Jadhav, V.R. Kalamkar & B.E. Narkhede, 'Interpretive Structural Modelling for Challenging Issues in JIT Supply Chain: Product Variety Perspective, International Journal of Supply Chain Management,2 (2013) 50-63.

[12] K. Mathiyazhagan, Kannan Govindan, A. Noorul Haq, & Yong Geng , An ISM approach for the barrier analysis in implementing green supply chain management, Journal of Cleaner Production, 47 (2013) 283-297.

[13] Paulina Golinska, Environmental Issues in Logistics and Supply Chain Management, Berlin Heidelberg, Germany (2012).

[14] Peral Toktas-Palut, Ecem Baylav, Seyhan Teoma, & Mustafa Altunbey , The impact of barriers and benefits of e-procurement on its adoption decision: An empirical analysis, International Journal of Production Economics,158 (2014) 77-90.

[15] Rajesh Attri, Nikhil Dev, & Vivek Sharma, Interpretive Structural Modeling (ISM) approach: An Overview, Research Journal of Management Sciences, 2 (2013) 3-8.

[16] Rajesh. P. Mishra, Ram Babu Kodali, Gajanand Gupta & Nidhi Mundra, Development of a framework for implementation of World-Class Maintenance Systems using Interpretive Structural Modelling approach, Procedia CIRP, 26 (2015) 424-429.

[17] Ravi Kalra, Sunil Kumar, & Kamal Jangra, Application of Graph Theory: A Review, Proceeding of the National Conference on Trends and Advances in Mechanical Engineering, (2012) 782-786.

[18] Reza Sigari Tabrizi, Yeap Peik Foong, & Nazli Ebrahimi, Using Interpretive Structural Modeling to determine the Relationship among Knowledge Management Criteria inside Malaysian Organizations, World Academy of Science, Engineering and Technology, 48 (2010) 727-732.

[19] P.G. Saleeshya, Karthik Suresh Thampi, & P. Raghuram, P, A combined AHP and ISM-based model to access the agility of supply chain- a case study, International Journal of Integrated Supply Management, 7 (2012) 167-191.

[20] Sanjay Kumar, Sunil Luthra & Abid Haleem, Customer involvement in greening the supply chain: an interpretive structural modeling methodology, Journal of Industrial Engineering International, 9 (2013) 1-13.

[21] P. Shahabadkar, S. Hebbal, & S. Prashant ,Deployment of Interpretive Structural Modeling Methodology in Supply Chain Management-An Overview, International Journal of Industrial Engineering & Production Research, 23 (2012) 195-205.

[22] S. K. Sharma, B.N. Panda, S.S.Mahapatra & S. Sahu, Analysis of Barriers for Reverse Logistics: An Indian Perspective, International Journal of Modeling and Optimization, 1 (2011) 101-106.

[23] Sudarshan Kumar, & Ravi Kant, Supplier Selection Process Enablers: An Interpretive Structural Modeling Approach, International Journal of Mechanical and Industrial Engineering, 3 (2013) 89-95.