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A MICMAC and ISM for Correlation Analysis of Supply Chain Intricacy Drivers

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Abstract

Abstract: The Intricacy in present day supply chain is numerous and constantly evolving due to globalization, customization, innovation, flexibility, sustainability and uncertainties. The growing supply chain intricacy results in negative consequences on cost, customer service and reputation. Supply chain Intricacy management is significant to gain competitive advantage. Managing the supply chain Intricacy involves identifying, prioritizing, measuring, analysing, controlling/eliminating the drivers of Intricacy. A supply chain Intricacy driver includes number and variety of suppliers, customers, products, processes and uncertainties. The Intricacy drivers are highly interdependent and the interdependence of the drivers needs to be studied before prioritizing the drivers. In this research, an Interpretive Structural Modelling (ISM) and Impact matrix cross-reference multiplication (MICMAC) are used to establish the interdependence of supply chain Intricacy drivers. A case study of a typical mining and construction equipment manufacturer located in India is presented to illustrate the proposed approach. From the results the significant supply chain Intricacy drives are identified with their interdependence.

Key words: Supply chain Intricacy, ISM, MICMAC.

1 Introduction

A supply chain is a complex network of facilities designed to procure, produce and distribute goods to customers at right quantities, to the right locations and at the right time. The Intricacy in the present day supply chain is numerous and is constantly evolving due to globalization, customization, innovation, flexibility, sustainability and disruptions (Hashemi et al., 2013). The growing supply chain Intricacy (SCC) results in negative consequences on cost, customer service and reputation. A survey conducted by PricewaterhouseCoopers (PwC, 2012) highlights that Intricacy management in supply chain is significant to gain competitive advantage. SCC management is a long-term decision that involves identifying, prioritizing, measuring, analysing, controlling/eliminating the drivers of SCC (Kaluza et al., 2006). The

Intricacy drivers are highly interdependent and the interdependency of the drivers is to be studied before prioritizing the Intricacy drivers (Hashemi et al., 2013). Models and methods for studying the interdependency of SCC drivers are limited in literature. In this research, an ISM and MICMAC are used to establish the interdependence of SCC drivers. A SCC driver includes number of suppliers, customers, products, processes, interactions and uncertainties (Serdarashan, 2013). In the literature, the supply chain Intricacy drivers are classified as upstream, internal manufacturing and downstream drivers (Bozarth et al., 2009), internal and external drivers (Isik, 2011), internal, supply/demand interface and external drivers (Blecker et al., 2005; Serdarsan, 2013). To proactively manage the supply chain Intricacy the Intricacy drivers are to be prioritized considering the interdependence. Models and methods for studying the interdependency of SCC drivers need attention. Interpretive structural modelling (ISM) developed by Warfield (1973) helps individuals or groups to provide order to an uncertain, interdependent complex system by a distinguishable hierarchical model based on the interdependency between the variables (Warfield,1973; Gorane and Kant ,2012). Researchers have used ISM for establishing the interdependency between the variables (Deviamma et al, 2014; Mitamura & Ohuchi 1997; Xiong, Li, & Hao 2010). In this research, ISM is used, for studying the dependency between the SCC drivers. MICMAC analysis is used for classifying the variables in to four clusters namely: independent, linkage, autonomous and dependent (Gorane and Kant, 2012; Khan and Haleem, 2012).

2. Proposed decision making model

2.1 Proposed ISM and MICMAC

Fourteen Intricacy drivers are identified and are categorized as supply base, internal manufacturing, and customer base and external as shown in Table 1.

Table 1 Identified SCC drivers from literatures.

Categories	Supply chain complexity drivers
Supply base complexity: Complexity originating from the supply base of a manufacturing facility	Number of suppliers [A_{S1}]
	Unreliability of suppliers [A_{S2}]
Internal manufacturing complexity: Complexity that originates within the manufacturing facility's products, processes, planning and control systems.	Number of parts [A_{M1}]
	Number/variety of products [A_{M2}]
	Number/variety of process [A_{M3}]
	Forecast inaccuracy [A_{M4}]
	Lack of visibility/information sharing [A_{M5}]
Customer base complexity: Complexity originating from the downstream markets of a manufacturing facility.	Number and variety of customers [A_{C1}]
	Changing needs of customers [A_{C2}]
	Shorten product life-cycle resulting in increase in spare-parts [A_{C3}]
External complexity: Complexity that originates from sources external to the supply chain.	Market uncertainty and risks[A_{E1}]
	Technological Innovation [A_{E2}]
	Actions of competitors [A_{E3}]
	Laws and regulations imposed by the government [A_{E4}]

A Pair wise comparison between the drivers is carried out and the contextual relationship between the drivers is established in structural self interaction matrix (SSIM). For constructing initial reachability matrix (K) the following rules are used:

[redacted]

become 1and (j,i) becomes 0.

[redacted]

become 1and (j,i) becomes 0.

[redacted]try in SSIM is C then (i,j) in K

become 1and (j,i) becomes 1.

[redacted]

become 0 and (j,i) becomes 0.

The contextual relation between SCC drivers is considered for creating initial reachability matrix. The final reachability matrix (H) is obtained by adding the initial reachability matrix (K) with unit matrix I and raising it to its power until the condition in the equation $H = ((K+I)^x) = ((K+I)^{x+1}) = \cdots x > 1$ is satisfied. The hierarchical levels of the drivers and the ISM model are constructed from the final reachability matrix (H).In MICMAC, the drivers are grouped in to four clusters based on their driving power and dependency power obtained from the final reachability matrix of ISM. The steps of ISM are given in appendix A.

3. Case study

The applicability of the proposed decision making model is demonstrated for a typical mining and

Table 2 Structural self interaction matrix (SSIM)

		Contextual relation 'leads to' is used in the study											
	A_{34}	A_{33}	A_{32}	A_{31}	A_{23}	A_{22}	A_{21}	A_{13}	A_{12}	A_{11}	A_{02}	A_{01}	A_{00}
A_{01}	B	B	B	A	D	C	B	A	C	B	B	B	B
A_{02}	D	B	D	B	D	D	D	B	B	B	B	D	
A_{11}	D	B	C	D	D	B	B	A	D	A	B		
A_{12}	D	B	B	D	C	B	C	A	A	C			
A_{13}	D	B	B	D	B	B	D	C	D				
A_{23}	B	B	B	B	D	B	D	C					
A_{31}	D	B	B	B	C	C	D						
A_{21}	D	B	B	A	D	C							
A_{22}	C	C	B	B	A								
A_{32}	B	B	C	B									
A_{33}	B	B	B										
A_{34}	C	C											
A_{00}	C												

construction equipment manufacturer located in Karnataka - India. The company manufactures and supplies mining and construction equipments like bull dozers, excavators, dumpers, shovels, loaders, pipe layers, tyre handlers, water sprinklers and motor graders to various user segments. At present 200 product variants are produced from over 2, 00,000 parts procured from around 1500 suppliers both locally and globally. The domestic suppliers' delivers about 80% of the raw materials and remaining 20% of raw materials are from global suppliers. The company has a wide customer base in the domestic and the global markets with an annual turnover of around 10,000 crores (INR).Increased competition from the multinational companies, global economic slowdown, market uncertainties and delay in resolving the mining issues by the Indian government have affected the company's growth, profitability and customer service. To retain the existing customers and to increase he market share the company has decided to simplify the supply chain operations by prioritizing the Intricacy drivers considering the interdependency. A decision making team

consisting of three senior managers, D1, D2, D3, from planning and purchasing departments is formed. The team members have more than ten years of experience in the company. Based on the interactions with the decision making team, the SSIM constructed is given in Table 2.

Table 3 Final reachability matrix

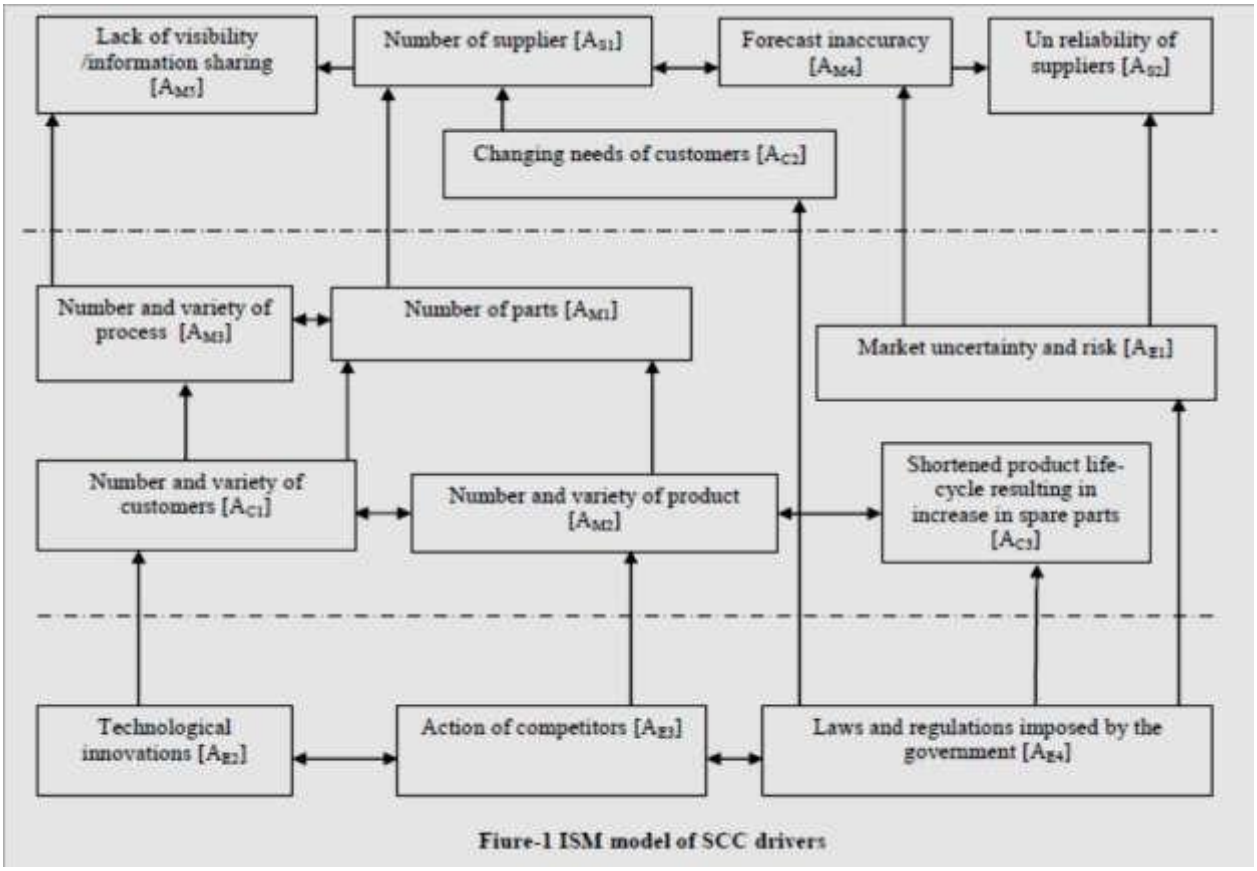
Drivers	A_{S1}	A_{S2}	A_{M1}	A_{M2}	A_{M3}	A_{M4}	A_{M5}	A_{C1}	A_{C2}	A_{C3}	A_{E1}	A_{E2}	A_{E3}	A_{E4}	Driving power
A_{S1}	1	1	1	1	1	1	1	1	1	1	1	0	1	1	13
A_{S2}	1	1	0	0	0	1	1	0	1	0	1	0	0	0	6
A_{M1}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{M2}	1	1	1	1	1	1	1	1	1	1	1	1	0	0	12
A_{M3}	1	1	1	1	1	1	1	1	1	1	1	0	0	0	11
A_{M4}	1	1	0	0	1	1	1	0	1	1	1	0	0	0	8
A_{M5}	1	1	1	1	1	1	1	1	1	1	0	1	1	1	13
A_{C1}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{C2}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{C3}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{E1}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{E2}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{E3}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
A_{E4}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Dependency power	14	14	12	12	13	14	14	12	14	13	13	10	10	10	

Table 4 Levels of SCC drivers

Driver	Reachability set	Antecedent set	Intersection set	Level
A_{S1}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E3}, A_{E4}$	1
A_{S2}	$A_{M4}, A_{M5}, A_{C2}, A_{E1}, A_{E2}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{M4}, A_{M5}, A_{C2}, A_{E1}, A_{E2}$	1
A_{M1}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, , A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, , A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	2
A_{M2}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}$	2
A_{M3}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}$	2
A_{M4}	$A_{S1}, A_{S2}, A_{M3}, A_{M4}, A_{M5}, A_{C2}, A_{C3}, A_{E1}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}, A_{M3}, A_{M4}, A_{M5}, A_{C2}, A_{C3}, A_{E1}$	1
A_{M5}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E2}, A_{E3}, A_{E4}$	1
A_{C1}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	2
A_{C2}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	1
A_{C3}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	2
A_{E1}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	2
A_{E2}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	3
A_{E3}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	3
A_{E4}	$A_{S1}, A_{S2}\ A_{M1}, A_{M2}, A_{M3}, A_{M4}, A_{M5}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	$A_{S1}, A_{M1}, A_{M2}, A_{M3}, A_{M5}, A_{C1}, A_{C2}, A_{C3}, A_{E1}, A_{E2}, A_{E3}, A_{E4}$	3

4. Results and Discussions

ISM: From the proposed ISM values of initial reachability matrix obtained are given in appendix B. The values of final reachability matrix (H) are given in Table 3. The level partition of each drivers and the corresponding ISM model are shown in Table 4 and Figure 1 respectively. A three level hierarchical model is developed from fuzzy ISM and the Intricacy drivers namely technological innovations [AE2], action of competitors [AE3] and laws and regulations imposed by the government [AE4] occupies the bottom level in the fuzzy ISM model and are decisive drivers of SCC. Lack of visibility/ sharing [AM5], number of suppliers [AS1], forecast inaccuracy [AM4], un reliability of suppliers [AS2] and changing needs of customers [AC2] occupies at the top levels in ISM model and are highly depended drivers. The ISM model developed is useful for supply chain managers to study the interdependence between the SCC drivers. Further a MICMAC analysis is conducted to analyze the driving power and dependency power of each driver. MICMAC: The driving power and dependency power of the SCC drivers obtained are given in Table Dependence-driving power diagram shown in Figure.2. is constructed for visualising the driving and dependency powers of each drivers. The drivers are clustered into four namely autonomous, dependent, linkage and independent drivers. Autonomous drivers: The drivers which are having weak driving power and weak dependency power is called autonomous drivers, these drivers are disconnected from the system but if this drivers



Fiure-1 ISM model of SCC drivers

contains strong link it will be considered for the analysis. In this study Intricacy driver number and variety of product [AM2] lies in this category, but its significance in the system cannot be omitted since it is almost nearer to the regulator. Dependent drivers: The drivers having high dependency power and weak driving power is called dependent drivers. Unreliability of suppliers [AS2], number and variety of process [AM3] and forecast inaccuracy [AM4], are found to be dependent drivers. Fiure-1 ISM model of SCC drivers Market uncertainty and risk [AE1] Changing needs of customers [AC2] Number and variety of customers [AC1] Technological innovations [AE2] Action of competitors [AE3] Laws and regulations imposed by the government [AE4] Number of parts [AM1] Number and variety of product [AM2] Number and variety of process [AM3] Number Lack of visibility of supplier [AS1] /information sharing [AM5] Shortened product lifecycle resulting in increase in spare parts [AC3] Forecast naccuracy [AM4] Un reliability of suppliers [AS2] Linkage drivers: These drivers are having strong driving power and strong dependency power and are unstable since any action on this will have an effect on other. Number of suppliers [AS1], changing needs of the customer [AC2] ,shorten product life-cycle resulting in increase in spare-parts[AC3], lack of visibility / information sharing [AM5] and market uncertainty and risk [AE1] lies in this category. Independent drivers: The drivers which are having strong driving power and weak dependency power is called independent drivers. Number of parts [AM1], number and variety of customers [AC1], technological innovations [AE2], action of competitors [AE3] and laws and regulations imposed by the government [AE4] are found to have high driving power and are the key drivers of SCC Intricacy. From the MICMAC analysis it is found that all the drivers considered for the study are having a significant role in creating SCC.

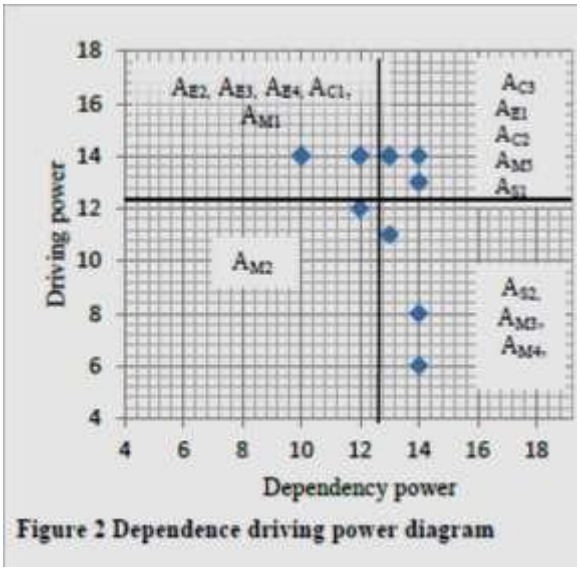


Figure 2 Dependence driving power diagram

Technological innovations [AE2], fore cast inaccuracy [AM4], action of competitors [AE3] and laws and regulations imposed by the government [AE4] are the significant drivers and belong to external complexities. From fuzzy MICMAC analysis it is observed that these drivers are highly dependent drivers. The proposed decision making model helps the firm to develop appropriate mitigation strategies considering the significant interdependence among drivers.

5. Conclusion and future scope

Managing the SCC is a long term decision that involves identifying, prioritizing, measuring, analysing, controlling / eliminating the drivers of SCC. Models and methods to prioritize the Intricacy drivers considering their interdependence need attention. In this study an integrated ISM and MICMAC is used for

establishing the interdependency among SCC drivers. This enables the firm to align the decisions that impact Intricacy with their supply chain strategies in order to gain competitive advantage. A case example of typical mining and construction equipment manufacturer is presented to demonstrate the proposed model. The future scope of this work is to identify the industry specific Intricacy drivers and to develop the proposed approach for a specific industry sector.

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APPENDIX

Appendix A. Steps involved in ISM.

Step 1: Identification of the Variables affecting the system.
Step 2: Establish contextual relationship among the variables by constructing the structured self interaction matrix (SSIM).
Step 3: Develop an initial reachability matrix from SSIM.
Step 4: Construct the final reachability matrix (H) by adding the initial reachability matrix (K) with unit matrix I and raising it to its power until the condition in the equation 1 is satisfied.

$$H = ((K + I)^x) = ((K + I)^{x+1}) = \cdots x > 1 \qquad (A.1.1)$$

Step 5: Establish the hierarchical structure of the variables from the final reachability matrix and develop the diagraph considering the transitivity links. Obtain the ISM model from the diagraph by removing the transitivity links and replacing the nodes in the diagraph by the corresponding variables.
Step 6: Construct the dependency – driving power diagram from dependency power and driving power of variables obtained from final reachability matrix (H).

Appendix B. Initial reachability matrix

	A_{S1}	A_{S2}	A_{M1}	A_{M2}	A_{M3}	A_{M4}	A_{M5}	A_{C1}	A_{C2}	A_{C3}	A_{E1}	A_{E2}	A_{E3}	A_{E4}
A_{S1}	1	0	0	0	0	1	1	0	1	0	1	0	0	0
A_{S2}	1	1	0	0	0	0	0	0	0	0	0	0	0	0
A_{M1}	1	0	1	0	1	0	1	0	0	0	0	1	0	0
A_{M2}	1	1	1	1	1	1	1	1	0	1	0	0	0	0
A_{M3}	1	1	0	1	1	0	1	0	0	0	0	0	0	0
A_{M4}	1	1	0	0	0	1	1	0	0	0	0	0	0	0
A_{M5}	0	1	0	0	1	1	1	0	1	1	0	0	0	0
A_{C1}	1	0	1	1	0	0	0	1	1	0	1	0	0	0
A_{C2}	1	0	1	1	1	1	1	1	1	1	0	0	1	1
A_{C3}	0	0	0	1	1	0	1	0	0	1	0	1	0	0
A_{E1}	0	1	0	0	0	1	1	0	1	1	1	0	0	0
A_{E2}	1	0	1	1	1	1	1	1	1	1	1	1	1	1
A_{E3}	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A_{E4}	1	0	0	0	0	1	0	0	1	1	1	1	1	1