# Analysis of Supply Chain Riskdrivers in Automotive Industries Using ISM

Sreejith B J[1], Kavilal E G[2]
[1,2]*Sree Chitra Thirunal Colleeg of Engineering, Kerala, India*

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

***Index TermsSupply Chain, Automotive Industry, ISM*.**

## I. INTRODUCTION

The management of the flow of products and services, or supply chain management (SCM), includes the transportation and storage of raw materials, inventories of goods still being manufactured, and finished goods, as well as the complete order fulfilment process from the point of production to the point of consumption [4]. In reality, risk refers to the reasons behind risk and uncertainty, such as market risk and political risk. However, the word risk is also used to refer to prospective result indications, or the incidence of risk [8]. The location or origins where risks are formed are referred to as the sources of supply chain risk. Risks can originate internally or externally to the supply chain and refer to any occurrence that influences the movement of materials, funds, or information in the supply chain [1]. Chain of Supply risk sources are unforeseen environmental, organisational, or supply chain-related factors that have an impact on the results of the supply chain. At the simplest level of supply chain, five sources of risk are: supply risk sources, demand risk sources, process risk sources, control risk sources and environmental risk sources. Supply chain risk drivers increase the risk implications (frequency of risk occurrence and negative impact). This impact would escalate depending upon the interdependencies of the risk drivers. So there is a need to mange the risk drivers considering their intendencies in order to attain competitive advantage. Researchers used multi criteria approaches such as ANP, ISM and DEMATEL to study the risk interdependency. Among this methods ISM is generally used to study the interdependency. Interpretive structural modeling (ISM) is an interactive learning process. In this technique, a set of different directly and indirectly related elements are structured into a comprehensive systematic model. The model so formed portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words. Interpretive structural modeling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. For any complex problem under consideration, a number of factors may be related to an issue or problem. However, the direct and indirect relationships between the factors describe the situation far more accurately than the individual factor taken into isolation. Therefore, ISM develops insights into collective understandings of these relationships. This methodology is interpretive as the judgment of the group decides whether and how the different elements are related. It is structural on the basis of mutual relationship; an overall structure is extracted from the complex set of elements. It is a modeling technique, as the specific relationships and overall structure are portrayed in a digraph model. It helps to impose order and direction on the complexity of relationships among various elements of a system. It is primarily intended as a group learning process, but individuals can also use it. In this research we use ISM to study the interdependency between the risk drivers.

## 2. LITERATURE REVIEW

### 2.1 Interpretive structural modelling (ISM)

Interpretive structural modelling (ISM) is a well-established methodology for identifying relationships among specific items which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue [6]. ISM approach starts with an identification of variables, which are relevant to the problem or issue. Then a contextually relevant subordinate relation is chosen. Having decided the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. After this, SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived. In this paper, key concept of ISM approach is discussed in detail [6]. From the review it is identified that ISM is used in a variety of situations, and from these experiences, some conclusions regarding the nature and efficacy of the ISM process and are drawn in the review. It was discovered that ISM offers its users a complete and systematic way for incorporating group judgements in the creation of "first-cut" structural models [5]. However, the method was also discovered to be rather rigid and may, in some cases, impede group procedures. So in this research we use ISM to study the interdependencies of risk drivers.

### 2.2 Supply chain and risk management.

The global supply chain and risk management survey study of the supply chain operations and risk management approaches of 209 companies with a global footprint conducted by PWC reveals that. As globally operating organizations, are exposed to high risk scenarios ranging from controllable risks, such as raw material price fluctuation, currency fluctuation, market changes or fuel price volatility, to uncontrollable ones such as natural disasters. The findings validate five key principles that companies can learn from to better manage today's risk challenges to their supply chains and prepare for future opportunities [2]. 1. Supply chain disruptions have significant impact on company business and financial performance. 2. Companies with mature supply chain and risk management capabilities are more resilient to supply chain disruptions. They are impacted less and they recover faster than companies with immature capabilities. 3. Mature companies that invest in supply chain flexibility are more resilient to disruptions than mature companies that don't. 4. Mature companies investing in risk segmentation are more resilient to disruptions than mature companies that do not invest in risk segmentation. 5. Companies with mature capabilities in supply chain and risk management do better along all surveyed dimensions of operational and financial performance than immature companies. The above five principles were determined using the supply chain and risk management capability maturity framework. This framework assesses the degree to which companies are applying the most effective enablers of supply chain risk reduction (e.g., flexibility, risk governance, alignment, integration, information sharing, data, models and analytics, and rationalization) and their associated processes. The model depicts where a company stands in relation to its competition and the rest of the industry. According to the survey results, as many as 60% of the companies pay only marginal attention to risk reduction processes. These companies are categorized as having immature risk processes. They mitigate risk by either increasing capacity or strategically positioning additional inventory. This is not a surprise as the survey also shows that most of these companies are focused either on maximizing profit, minimizing costs or maintaining service levels. The remaining 40% do invest in developing advanced risk reduction enabler capability and are classified as having mature processes. The research validated that companies with mature risk processes perform operationally and financially better – something for CEOs and CFOs to note. Indeed, managing supply chain risk is good for all parts of the business—product design, development, operations and sales. The companies can benchmark their ability to respond to risks, and then increase their capability maturity to gain competitive advantage. Sharma and Bhat (2012) conducted empirical research on supply chain risk factors.

Analysis of comments from 102 executives in the Indian automotive industry provides insight into the relationship between supply chain threats and major risk drivers, including supply chain complexity, efficiency focus, reliance on a small number of members, and node criticality. The competitive considerations that require the company to adapt and be competitive in the market are known as supply chain risk drivers. These factors also raise the firm's exposure to risk at the same time. According [3], there are five main explanations for why risk in supply chains has grown recently: 1, a stronger focus on efficiency rather than on effectiveness 2, supply chain globalization 3, focused factories and centralized distribution 4, increased outsourcing and 5 supply base reduction. The lack of effective mechanisms to recognize and effectively manage escalating supply-chain vulnerabilities as the globe becomes more linked is at the core of these crises. Cyber-ransom attacks and other new vulnerabilities are rising alongside more established and well-known supplier risks, like supplier insolvency.

Identification Of Risk drivers: Risk drivers are collected from various sources such as literatures, articles, newspapers, etc. Initially we have shortlisted 50 risk drivers from the listed sources. The risk drivers shortlisted after reviewing the literatures, articles, newspapers and shortlisted 50 risk drivers based on the inclusion criteria's are classified into social, operational, environmental risk drivers is listed and highlighted in Table 1. In order to validate we circulated a questionnaire among the academicians, experts and among the managers in automotive industry. Based on their response we have shortlisted 10 risk drivers and used for the further analysis. The various risk drivers short listed are listed into major 3 categories as social risk drivers, operational risk drivers and environmental risk drivers. The majority of risk drivers are pertaining to automotive industries so the study mainly focuses on automotive industry. The shortlisted risk drivers used for the study are shown in in table 2.

Table 1

Shortlisted risk drivers for the study

| SL No | Risk drivers shortlisted for the study |
|---|---|
| 1 | Directing regulations and standard requirements-A1 |
| 2 | Increased external demand for sustainability-A2 |
| 3 | Uncertainty in the market.-A3 |
| 4 | Laws and regulations imposed by government.-A4 |
| 5 | Dependency on a single source of supply as well as the capacity and responsiveness of alternative suppliers.-A5 |
| 6 | Poor quality of yield at supply source-A6 |
| 7 | Excessive handling due to border crossing or to change in transportation mode.-A7 |
| 8 | Forecast inaccuracy.-A8 |
| 9 | Resource scarcity & Natural disasters-A9 |
| 10 | Cultural diversity.-A10 |

## 3. METHODOLOGY

It is generally felt that individuals or groups encounter difficulties in dealing with complex issues or systems. The complexity of the issues or systems is due to the presence of a large number of elements and interactions among these elements. The presence of directly or indirectly related elements complicates the structure of the system which may or may not be articulated in a clear fashion. It becomes difficult to deal with such a system in which structure is not clearly defined. Hence, it necessitates the development of a methodology which aids in identifying a structure within a system. Interpretive structural modelling (ISM) is such a methodology1. ISM is defined as a process aimed at assisting the human being to better understand what he/she believes and to recognize clearly what he/she does not know. Its most essential function is organisational. The information added (by the process) is zero.. The ISM process transforms unclear, poorly articulated mental models of systems into visible and well-defined models. In this, the methodology includes the identification of various risk drivers in and around the automotive industry. It is a major task to find the main risk drivers that are relevant in automotive industry. Collection of risk drivers found in various industries is a major task. Collection can be done from various literatures, surveys, articles and newspapers. After the collection of various risk drivers they are to be shortlisted and find out major risk drivers that affect the industry. This is to be done with experts and experienced persons so that the main and most affected risk drivers in the industries can be found out and can be classified. After the shortlisting of these drivers, based on a questionnaire the pairwise comparison of the variables are identified. In the next step, the SSIM is converted into Reachability Matrix and its transitivity is checked. Once transitivity embedding is complete, an initial reachability matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived (See Figure 1).

The different steps involved while developing the ISM model are as follow:

**Step 1.**List all the research variable of system under the study; it can be factors, criteria and dimensions which can be objective, actions and individual etc.

**Step 2.**Establish a contextual relationship among the variables with respect to which pair of variable would be examined.

**Step 3.**Develop the Structural Self-Interaction Matrix (SSIM) for the variables which can indicate pair wise relationships among the variable of the system under consideration.

**Step 4.**Develop the Binary Initial Reachability Matrix (IRM) from SSIM and the matrix is checked for transitivity, leading to development of "Final Reachability Matrix ". The transitivity of the contextual relations is basic assumptions made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

**Step 5.**The final reachability matrix obtained in step 4 is partitioned into different levels.

**Step 6.**Based on the relationship given in the reachability matrix and the determined levels for each variable a directed graph is drawn and the transitive links are removed.

**Step 7.**The resultant diagraph is converted into ISM by replacing variable nodes with statements.

**Step 8.**The ISM model developed in step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

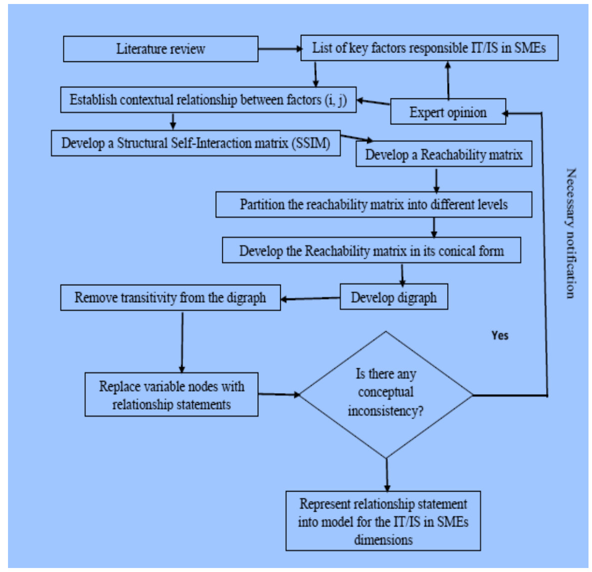


Figure 1: Flow chart of ISM process

**3.1 Structural Self-Interaction Matrix (SSIM)**

ISM methodology suggest the use of expert opinions based on various management techniques such as brain storming, nominal group technique etc. in developing contextual relationship among the variables. Based on this contextual relationship and associated direction between any two parameters (i and j) all relationship between the two parameters in associated direction are questioned from the experts, following four symbols are used to denote the direction of the relationship between the research variables. The SSIM developed from the expert opinion are highlighted in Table 3

1. '**A**' represents 'i' is related to 'j' but 'j' is not related to 'i'.
2. '**B**' represents 'i' is not related to 'j' but 'j' is related to 'i'.
3. '**C**' represents both 'i' and 'j' are interrelated.
4. '**D**' represents that there is no relation between 'i' and 'j'.

Based on the opinion of experts and academia people table on SSIM is developed.

Table 2

SSIM for supply chain risk drivers

| | A10 | A9 | A8 | A7 | A6 | A5 | A4 | A3 | A2 |
|---|---|---|---|---|---|---|---|---|---|
| A1 | B | B | D | D | B | B | B | D | D |
| A2 | D | C | C | A | D | B | D | D | |
| A3 | D | C | A | D | D | D | B | | |
| A4 | C | D | D | A | D | D | | | |
| A5 | D | B | D | D | C | | | | |
| A6 | D | D | A | D | | | | | |
| A7 | D | D | D | | | | | | |
| A8 | D | B | | | | | | | |
| A9 | D | | | | | | | | |

### 3.2 Initial Reachability Matrix (IRM)

SSIM is now transformed into binary matrix called the initial reachability matrix(see table 4) by substituting A, B, C and D by 1 and 0 according to the following rules.

1. If (i, j) entry in the SSIM is A, then the (i, j) entry in the Initial Reachability Matrix (IRM) becomes 1 and (j, i) entry becomes 0.
2. If (i, j) entry in the SSIM is B, then the (i, j) entry in the Initial Reachability Matrix (IRM) become 0 and the (j, i) entry becomes 1.
3. If (i, j) entry in the SSIM is C, then the (i, j) entry in the Initial Reachability Matrix (IRM) becomes 1 and the (j, i) also becomes 1.
4. If (i, j) entry in the SSIM is D, then the (i, j) entry in the Initial Reachability Matrix (IRM) becomes 0 and the (j, i) also becomes 0.

Table 3
Initial Reachability Matrix

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A2 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| A3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| A4 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| A5 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| A6 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| A7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| A8 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| A9 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| A10 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

### 3.3 Final Reachability Matrix (FRM)

The final reachability matrix (FRM) is obtained after checking for transitivity and removing transitivity if there is any, transitivity effects in IRM should be considered and it is to be removed (see table 4). To remove the transitivity in table, we need to follow these steps.

1. Look for the entry 0 in IRM.
2. Check for the transitivity e.g., if **A** leads to **B** is 1 and **B** leads to **C** is 1 this implies **A** leads to **C** is 1.
3. If there is any transitivity replace the 0 with 1.

After completing all the entries the final reachability matrix (FRM) will come into existence.

Table 4
Final Reachability Matrix

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | Driving power |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| A2 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 7 |
| A3 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 6 |
| A4 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| A5 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 5 |
| A6 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 5 |
| A7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| A8 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 4 |
| A9 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 7 |
| A10 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 5 |
| Dependence | 8 | 6 | 5 | 2 | 5 | 3 | 5 | 7 | 5 | 2 | |

### 3.4 Level Partition

From the final reachability matrix reachability and antecedent set for each factor are found. The reachability set contains the element itself and other elements which it can have impact on other elements. The antecedent set consist of the element itself and other factors that may impact it, therefore intersection of the set obtained in reachability set and antecedent set are derived. The factors for which the reachability set and intersection set are same occupy the top level of hierarchy in ISM model. The top level factors in the hierarchy will not lead to any other parameter above its own levels, once a level is identified its parameters are removed from the further consideration of other levels. Same process is repeated till the level of each and every parameter is identified, these levels help in building the diagraph and the ISM model as highlighted in table 4.

Table 5
Levels of Risk Drivers

| Drivers | Reachability Set | Antecedent Set | Intersection Set | Levels |
|---|---|---|---|---|
| A1 | A1 | A1,A2,A3,A4,A5,A6,A9,A10 | A1 | I |
| A2 | A1,A2,A3,A5,A7,A8,A9 | A2,A3,A5,A6,A8,A9 | A2,A3,A5,A8,A9 | II |
| A3 | A1,A2,A3,A5,A8,A9 | A2,A3,A4,A9,A10 | A2,A3,A9 | III |
| A4 | A1,A3,A4,A7,A8,A9,A10 | A4,A10 | A4,A,10 | III |
| A5 | A1,A2,A5,A6,A8 | A2,A3,A5,A6,A9 | A2,A5,A6 | III |
| A6 | A1,A2,A5,A6,A8 | A5,A6,A9 | A5,A6 | III |
| A7 | A7 | A2,A4,A7,A8,A10 | A7 | I |
| A8 | A2,A7,A8,A9 | A2,A3,A4,A5,A6,A8,A9 | A2,A8,A9 | II |
| A9 | A1,A2,A3,A5,A6,A8,A9 | A2,A3,A4,A6,A8,A9 | A2,A3,A8,A9 | III |
| A10 | A1,A3,A4,A7,A10 | A4,A10 | A4,A10 | III |

## 4 RESULT AND DISCUSSION

ISM is one of the important tool for the modeling and it need to be interpreted correctly and hence the successful implementation can be done by relevant authority. Relationships among various factors were identified from the Final Reachability Matrix, the model will show how the required objective is achieved at various levels and the arrow at various factors indicating relevance at different levels, the levels that were identified were used in building the final model of ISM. After partition of levels, 3 different levels come into existence. The three-level hierarchical model is developed from fuzzy ISM and the Risk drivers namely

1. Uncertainty in the market[A3],
2. Laws and regulations imposed by government[A4],
3. Dependency on a single source of supply as well as the capacity and responsiveness of alternative suppliers[A5],
4. Poor quality of yield at supply source[A6],
5. Resource scarcity & Natural disasters[A9],
6. Cultural diversity[A10]

occupies the bottom level in the fuzzy ISM model and are decisive drivers. The final ISM model is shown in figure 2.

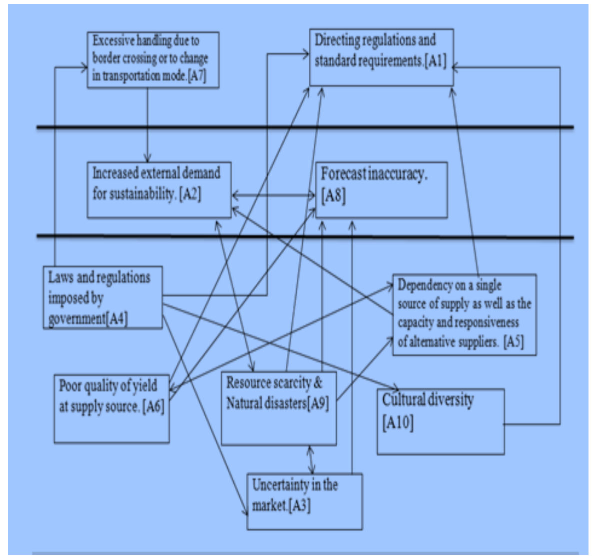


Figure 2: ISM Model

## 5 CONCLUSIONS AND MANAGERIAL IMPLICATIONS

Managing Supply Chain risk drivers involves identifying, prioritizing, measuring, analyzing, controlling/eliminating the drivers. Models and methods to prioritize the risk drivers considering their interdependence need attention. In this study an integrated ISM is used for establishing the interdependency among Risk drivers. This enables the firm to align the decisions that impact risk with their supply chain strategies in order to gain competitive advantage. A case example of typical automobile industry is presented to demonstrate the proposed model. The decisive drivers of the risk for automotive industries are identified and with the MICMAC analysis the SC risk drivers are grouped based on their driving and dependency power. The future scope of this work is to identify the industry specific complexity drivers and to develop the proposed approach for a specific industry sector.

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