Supply chains risks: an interpretative structural modelling approach

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Abstract: As plastic manufacturing companies operate in a global environment, supply chain risks (SCR) become more unpredictable. Therefore, one of the pressing issues in the plastic manufacturing sector is identifying and prioritising the numerous risks for operating in a competitive business environment. Using interpretative structural modelling (ISM), the research illustrates, how managers in the plastic manufacturing industry can establish and apprehend interdependencies among the possible SCR. Interdependencies among the risks are attained and structured hierarchically in order to attain subsystems of interdependent elements that have representative driving power and dependency power. Next, the research assesses the mitigation strategies for addressing the numerous SCR. The ISM model established provides extensive insight for assisting managers to deal with the SCR while categorisation proves to be a relevant tool for differentiating between independent and dependent elements that can enable the managers to focus on key elements for minimising risk within the supply chain networks.

Keywords: interpretative structural modelling; ISM; decision-making; supply chain risks; SCR; modelling; mitigation.

Reference to this paper should be made as follows: Mwanza, B.G. and Telukdaire, A. (2022) 'Supply chains risks: an interpretative structural modelling approach', *Int. J. Supply Chain and Operations Resilience*, Vol. 5, No. 2, pp.217–234.

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1 Introduction

The high interdependencies between the nodes of supply chains structures is high and complex, enabling the risks generated in one section of the chain to transfer rapidly to other sections thus disrupting the whole supply chain (Wang et al., 2017). The disruptions end up striking the operation and sustainability of the entire supply chain. SCR are evitable for any organisation and it is necessary for organisations to understand the different types of risks they can encounter. Many scholars categorise SCR into disruption and operational risks (Fahimnia et al., 2018; Xu et al., 2020). Disruption risks focus on events with high impacts and low frequency while operational risks are associated with common disturbances such as demand fluctuations, lead-time, etc. Identification of these SCR has become inevitable for plastic manufacturing companies as the growing global competition demands companies to broaden concentration on core competencies, resulting in new supply chain networks. These supply chain networks are so complex because of the number of participants (suppliers, manufacturers, distributors, retailers and customers).

Management and identification of SCR in the networks is complex but a very important subject in the plastic manufacturing industry. Therefore, companies are exposed to range of risks as the demand to supply plastic materials intensifies alongside customer changing preferences. Consequently, the index of plastic products supplied internationally is broad, including construction materials; electrical and electronic goods; plastic packaging; automobile parts, household products, etc. These products are manufactured in infinite numbers through horizontally and vertically integrated companies and partners across the globe, where SCR are inevitable. Thus, in risk management processes of supply chains, identification of the risks is the first step but the visibility of the potential risk across the supply chain may not be the only precondition for an effective risk management. With completion of a successful structural assessment of the risks, establishment of suitable mitigation strategies follows while establishing the impact areas of the many risks (Chopra and Shodi, 2004). Despite the existence of empirical literature on SCR and mitigation tactics (Deng et al., 2019; Prompatanapak and Lopetcharat, 2020; Jianying et al., 2021; El Baz and Ruel, 2021; Auer and Rauch, 2021) and supply chain risk management (SCRM) (Faizal and Palaniappan, 2014), there are few studies that have focused attention on interconnectedness of SCR in the plastic manufacturing industry.

Interpretative structural modelling (ISM) can be utilised to summary and pinpoint connections among specific elements that describe a problem (Sage, 1977). The procedure by which sequence is imposed on complex elements is provided via ISM (Ravi and Shankar, 2005). Using the ISM approach, a set of directly related and different elements affecting a system can be structured into an extensive systematic model. Thus, the paper aims to structurally analyse the potential SCR using ISM. The research illustrates how ISM can enable risk managers to comprehend and pinpoint interdependences among SCR along the network. While the research focuses on SCR in the plastic manufacturing industries, interdependences among the risks are extracted and arranged using a hierarchy basis for the purpose of extracting subsystems of independent elements with matching dependency and driving power. The ISM methodology started by identifying the relevant elements in the case study (i.e., plastic manufacturing industries).

The specific objectives are:

- to establish and rank the risks in supply chain networks
- to develop the interaction among the identified risks using ISM
- to suggest mitigation strategies for addressing the risks.

The rest of the paper is structured as follows. The paper begins by providing a literature review on SCR and risk mitigation tactics (Section 2) in which the key elements for modelling are identified. In Section 3, the methodology is presented while findings of ISM and mitigation strategies are presented in Section 4. Further, Section 5 presents detailed discussion of the research findings and implication. Lastly, Section 6 presents the conclusion and provides an orientation for future research.

2 Literature review

2.1 Supply-chain risks identification

Many definitions of SCR exist and hence, no clear definition. Jianying et al. (2021) suggests that SCR attributes to many factors affecting the final focus of supply chain that consists of risk results, risk factors and risk accidents. Gouda and Saranga (2018) augments that, SCR is the feasibility of the real supply chain operation deviating from its intended aim. Several scholars define it differently and some contemplate that, SCR is loss caused through accidents within the supply chain (Iqbal and Shalij, 2019; Shan et al., 2020).

The definition of SCR is not only difficult but its classification is difficult too. In literature, there are many ways in which potential risks within the supply chain networks are classified (Gotze and Mikus, 2007; Spekman and Davis, 2004). The different definitions of supply chain risks (SCR) have contributed to many studies that have been conducted on SCR within different manufacturing industries.

Faizal and Palaniappan (2014) analysed the effective management of SCR. The study identified risks associated with supply chains in the casting industry. Prompatanapak and Lopetcharat (2020) conducted a study on change management and risks within the seafood supply chain. The study revealed that critical changes such as external and internal issues affect the industry. Jianying et al. (2021) evaluated SCR in the fresh grape industry by using neutral network. Deng et al. (2019) suggested feasible measures for improving the sustainable management of perishable products supply chains by exploring risk propagation mechanisms through a case study approach of a yogurt supply chain. The reviewed studies identified, the SCR in different sectors of the manufacturing industry but not in the plastic manufacturing industry. Thus, this presents an opportunity to establish the existing SCR in the plastic manufacturing industry.

In other studies, many approaches of studying these SCR have been used. For example; Manuj and Mentzer (2008) integrated insights, concepts and frameworks from various disciplines for the purpose of developing and proposing a detailed mitigation and risk management in global supply chains. Gomes Filho et al. (2021) conducted a structured review of literature to ascertain how supply chain's stocks and flows are entry points for cyber risks. El Baz and Ruel (2021) investigated the function of SCRM in lessening the consequences of disturbance impacts on supply chain robustness and resilience in the COVID-19 era in survey approach. Auer and Rauch (2012) used qualitative and quantitative data analysis methods to present the systematically reviewed risks affecting wood supply security and risk mitigation tactics. In the reviewed studies, SCR and mitigation tactics have not only been demonstrated but different approaches in which the studies were conducted have been shown. None of the reviewed studies used ISM approach to show the relationship among the identified risks.

Table 1 Summary of SCR

SCR	*References*
Failure by supplier to deliver	Deng et al. (2019), Auer and Rauch (2021), Prompatanapak and Lopetcharat (2020) and Faizal and Palaniappan (2014)
Failure by supplier to meet quality standards	Faizal and Palaniappan (2014), Prompatanapak and Lopetcharat (2020), Deng et al. (2019) and Auer and Rauch (2021)
Commodity and raw material prices	Prompatanapak and Lopetcharat (2020), Faizal and Palaniappan (2014) and Deng et al. (2019)
Logistic delays	Faizal and Palaniappan (2014), Jianying et al. (2021), Deng et al. (2019) and Auer and Rauch (2021)
Logistic damages	Deng et al. (2019), Jianying et al. (2021), Prompatanapak and Lopetcharat (2020) and Faizal and Palaniappan (2014)
Information loss	Deng et al. (2019) and Prompatanapak and Lopetcharat (2020)
Business interruption (theft, vandalism, conflicts)	Deng et al. (2019), Auer and Rauch (2021), Jianying et al. (2021) and Faizal and Palaniappan (2014)
Fluctuating demand	Faizal and Palaniappan (2014) and Manuj and Mentzer (2008)
Fluctuation in fuel/oil/energy/transportation prices	Jianying et al. (2021), Deng et al. (2019) and Prompatanapak and Lopetcharat (2020)
Production downtimes	Faizal and Palaniappan (2014) and Jianying et al. (2021)
Lagging technology	Deng et al. (2019), Prompatanapak and Lopetcharat (2020) and Manuj and Mentzer (2008)

In every business, risks exist and they are inevitable. Table 1 shows the summary of the SCR as identified in the reviewed studies. The application of lean manufacturing, just-in-time and other concepts suggests a definite vulnerability in the supply chains (Peck, 2006). To reduce the prospective cynical effects of SCR, a comprehensive and methodical risk management procedure is essential. A SCRM approach for identifying, assessing, treating and monitoring SCR has gained relevance over the years (Franck, 2007; Faisal et al., 2007; El Baz and Ruel, 2021) and its focus is broader than the typical 'risk management'. Its unit of analysis portrays a dyadic relationship of a supply chain with three or more companies. As a result of the high interconnectedness of supply chains, SCR can be numerous, difficult to spot and may consist of tough to evaluate cause-effect connections. A detailed and organised collection of every single one of the potential risks including their interdependencies is critical for the successive phases in the plastic manufacturing supply chains.

2.2 Supply chain risk mitigation strategies

Identification of SCR demands mitigation strategies and the subject of SCR mitigation strategies in the manufacturing industry is important. Many studies have looked at SCR and have established appropriate strategies to manage these risks. In the context of developed and developing economies, different approaches to identify these mitigation strategies have been used.

Faizal and Palaniappan (2014) conducted a study in the casting industry and SCR mitigation strategies were identified as having; good supplier relationships, actualising collaborative relationships, redundant suppliers, product postponement strategy, collaborative forecast planning, decentralised inventory resources, implementation of optimum inventory level, creation of training and skill development programs, development of quality management systems and creation of human safety management. In another study by Manuj and Mentzer (2008), SCR mitigation strategies were established as having; flexibility, information systems, performance metrics and organisational learning, postponement, hedging, avoidance, speculation, control and transfer. Prompatanapak and Lopetcharat (2020) established SCR mitigation strategies as; development of innovative manufacturing systems, improve research on ecology, simulate various scenarios for change management, improvement of public relations, use of media to win consumers trust, supply chain actors to conform to local and international regulations, seafood industry to attend to sustainability and local communities' views and readiness to change should be adopted by every actor in the supply chain. Jianying et al. (2021) established SCR mitigation strategies to be; effective collaboration among links, development of grape production insurance, and subsidise grape owners. In another study by Deng et al. (2019), SCR mitigation strategies were identified to be; control dependency among nodes in the supply chain, control risk propagation modes and restructure supply chain into fractal supply chain. Lastly, Auer and Rauch (2021) identified SCR mitigation strategies as; product shelf life, supply chain integration; long-term contracts, supplier integration; feedback and resource diversification, and increase process resilience.

The studies revealed above focused on identifying SCR mitigation strategies in the different sectors of the manufacturing industries. The approaches for identifying these strategies took a different approach but it is also important to show the similarities in the mitigation strategies established in these studies. Faizal and Palaniappan (2014) recommended good supplier relationship, development of quality management systems and actualising collaborative relationships. Jianying et al. (2021) recommended effective collaboration among links. The recommendations by Faizal and Palaniappan (2014) and Jianying et al. (2021) are aligned to good supplier relationship and this is also recommended by Deng et al. (2019). Supply chain actors to conform to local and international regulations is recommended by Prompatanapak and Lopetcharat (2020) and Auer and Rauch (2021). Further analysis of the studies shows that; the recommended strategies can be applied to any of the reviewed industries but it depends on the prevailing SCR at that particular time. The analysis of these SCR mitigation strategies is necessary for the assessment of the mitigation strategies that should cut across many manufacturing industries despite the difference in the sector of manufacturing. Table 2 presents a summary of SCR mitigation strategies as reviewed from the above studies.

Table 2 Summary of the SCR mitigation strategies

Authors	*Mitigation tactics*
Faizal and Palaniappan (2014)	Good supplier relationships, actualising collaborative relationships, redundant suppliers. Product postponement strategy, collaborative forecast planning, decentralised inventory resources, implementation of optimum inventory level, creation of training and skill development programmes, development of quality management systems, creation of human safety management.
Manuj and Mentzer (2008)	Flexibility, information systems, performance metrics and organisational learning, postponement, hedging, avoidance, speculation, control, transfer.
Prompatanapak and Lopetcharat (2020)	Develop innovative manufacturing systems; improve research on ecology; simulate various scenarios for change management; improvement of public relations; use of media to win consumers trust; supply chain actors to conform to local and international regulations; seafood industry to attend to sustainability and local communities' views; readiness to change should be adopted by every actor in the supply chain.
Jianying et al. (2021)	Effective collaboration among links; develop grape production insurance, subsidise grape owners.
Deng et al. (2019)	Control dependency among nodes in the supply chain; control risk propagation modes; restructure supply chain into fractal supply chain.
Auer and Rauch (2021)	Product shelf life; supply chain integration; long-term contracts, supplier integration; feedback and resource diversification; increase process resilience.

3 Methodology

The interdependencies in supply chains are complex and solving the challenges is not limited to single factors. The need to probe interdependencies is essential. As an interpretive and qualitative technique, ISM produces answers to complicated problems through discussions founded on structural mapping of complicated relationships of elements (Watson, 1978). As a process, ISM translates unclear, inadequately articulated reasoning shapes of systems into well-defined, visible functional models for several purposes (Sage, 1977). This method supports the identification and sequence of complicated relations among systems' elements in order to analyse the influence that exists between elements. For complicated problems, such as the one under examination, several risks may be affecting SCRM. Nevertheless, the indirect and direct interconnections between the risks explain the situation accurately than individually isolating the factors. Thus, it has been applied to many problems (Faisal et al., 2006, 2007; Jain et al., 2018; Kumar et al., 2021; Raut et al., 2021) in order to establish a clear understanding of systems being analysed.

On the basis of interconnection, ISM is structural; an entire structure is extricated from the complicated set of elements. As a modelling technique, certain relationship of elements and the entire systems' structure under examination are depicted as a digraph model (Agarwal et al., 2007). It is purposefully a set of learning procedure but also applicable individually. Hence, this methodology is suitable for utilisation by experts in the problem being addressed. It draws insights by collectively comprehending the relationships.

3.1 Stages of ISM methodology

The ISM technique involves the following steps:

1. Selection of elements appropriate to the problem: Elements identification should be the starting point and for this study, structured literature review was performed to identify the elements. These elements were confirmed through a brainstorming online workshop with experts in the selected plastic manufacturing companies.
2. Contextual relation type establishment: using the elements established in stage one, a contextual relationship is generated among the elements with regards to which sets of elements would be assessed. The relations can be of many types such as neutral, comparative, temporal or influence relations (Warfield, 1994).
3. Building of a structural self-interaction matrix (SSIM) using pairwise comparison. Stage 3 is the most tiring and demanding. In the course of this stage, participants should determine the pairwise relationship among the elements of the system being examined.
4. Using the SSIM, the reachability matric is constructed and it is validated for transitivity. This stage focuses on developing the reachability matrix. The reachability matrix is binary because the entry V, A, X and O of SSIM are changed into 1 and 0 in accordance with the rules below:

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

   If (i, j) entry is A in the SSIM, the (i, j) entry becomes 0 in the reachability matrix and (j, i) becomes 1.

   If the (i, j) entry is X in the SSIM, then both the reachability entries (i, j) and (j, i) become 1.

   If the (i, j) entry is of the SSIM, then both the reachability entries (i, j) and (j, i) become 0.
5. The reachability matrix developed in stage 4 is divided into different levels.
6. Using the relationships developed in the reachability matrix, a directed graph is sketched and transitive links are taken out.
7. By substituting element nodes with statements, the resultant digraph is changed into an ISM.
8. To inspect for conceptual inconsistency, the ISM model constructed in stage 7 is reviewed and the necessary adjustments are made.

3.2 Data collection

The fact that ISM adopts an interpretive and qualitative approach, and plastic manufacturing companies were engaged in the data collection process. The process of data collection from the companies consisted of three phases.

Phase 1 A search for plastic manufacturing companies was conducted and the selection criterion was based on:

1. the company being located in the capital city, Lusaka
2. the company being in existence for more than ten years
3. the company being registered with the Zambia Manufacturing Association.

Based on the selection criterion, 12 companies were identified.

Phase 2 The second phase of the data collection was a formal request to the organisations to nominate a representative for an online workshop. All the 12 selected companies nominated a representative from the supply-chain; procurement or any other department in charge of supply-chain management. The telephone numbers to enable the collection of email addresses from the experts were shared with the data collection team.

Phase 3 Prior to the online workshop, the agenda for discussion was emailed to the participants. The information that was shared also consisted of the SCR and mitigation strategies as identified from the reviewed literature as well as additional literature on SCRM. Table 1 shows the SCR that were emailed for discussion while the mitigation strategies emailed consisted of only those that were dominant in the studies that were reviewed. An online workshop was held in June of 2021 in which 8 out of the 12 experts brainstormed the SCR and mitigation strategies within the plastic manufacturing companies. Further, the experts identified mutual relationships among the SCR (elements). A ranking approach was used to assess the mitigation strategies for the SCR.

With an agreement on the 11 elements among the experts, an ISM-based model was developed using these elements. The selected elements are as follows:

1. failure by supplier to deliver
2. failure by supplier to meet quality standards
3. commodity and raw material prices
4. logistic delays
5. logistic damages
6. information loss
7. business interruption (theft, vandalism, conflicts)
8. fluctuating demand
9. fluctuation in fuel/oil/energy/transportation prices

10 machine breakdowns

11 lagging technology.

4 Research findings

4.1 Formation of SSIM

ISM methodology recommends the use of experts' judgements based on many management techniques such as brain storming, nominal technique, etc. in constructing the contextual relationships between the elements. To identify the contextual connections between risks in the supply chains for this research, an online workshop that was structured in form a focus group discussion (FGD) was held with the experts. Although the area of SCR is comparatively new, the experts involved in this research are conversant in risk identification and mitigation practices for plastic manufacturing companies as well as the whole supply chains. To analyse the risks within the supply chains, a contextual connection of 'leads to' kind is selected. This shows that, one element contributes to the enhancement of another element and on this foundation, a contextual connection between the elements is constructed.

Taking into account how all the elements of the system interact, any pair of elements may be investigated to determine the nature of relationships of the elements. To show the direction of relationship between the risks (i and j), four symbols are used; and Table 3 illustrates the pairwise relationship prevailing between two sub-elements.

V risk i will enhance risk j

A risk j will be enhanced by risk i

X risk i and j will enhance each other

O risk i and j are unrelated.

Table 3 Structural self-interaction matrix

	Elements	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	Failure by supplier to deliver	A	V	X	V	V	A	O	V	V	X
2	Failure by supplier to meet quality standards	O	A	A	O	A	A	A	O	A	
3	Commodity and raw material prices	A	A	A	X	A	O	O	V		
4	Logistic delays	A	A	A	O	A	A	X			
5	Logistic damages	A	O	O	O	A	O				
6	Information loss	A	V	O	O	A					
7	Business interruption (theft, vandalism, conflicts)	O	V	V	A						
8	Fluctuating demand	O	O	X							
9	Fluctuation in fuel/oil/energy/transportation prices	O	V								
10	Production downtimes	O									
11	Lagging technology										

4.2 Reachability matrix

By exchanging V, A, X, O by 1 and 0, SSIM is changed into a binary matrix known as the reachability matrix. The guidelines for changing 1's and 0's are as follows:

- if 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
- if 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
- if the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1
- if the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Based on these guidelines and after integrating the transitivities, the final reachability matrix is depicted in Table 4.

Table 4 Final reachability matrix

	Elements	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*Driver*
1	Failure by supplier to deliver	1	1	1	1	0	0	1	1	1	1	0	8
2	Failure by supplier to meet quality standards	1	1	0	0	0	0	0	0	0	0	0	2
3	Commodity and raw material prices	0	1	1	1	0	0	0	1	1	0	0	4
4	Logistic delays	0	0	0	1	1	0	0	0	0	0	0	2
5	Logistic damages	0	0	0	1	1	0	0	0	0	0	0	2
6	Information loss	1	1	0	1	0	1	0	0	0	1	0	5
7	Business interruption (theft, vandalism, conflicts)	0	1	1	1	1	1	1	0	1	1	0	8
8	Fluctuating demand	0	0	1	0	0	0	1	1	1	0	0	4
9	Fluctuation in fuel/oil/energy/transportation prices	1	1	1	1	0	0	0	1	1	1	0	7
10	Production downtimes	0	1	1	1	0	0	0	0	0	1	0	4
11	Lagging technology	1	0	1	1	1	1	0	0	0	0	1	6
	Dependence	5	7	7	9	4	3	3	4	4	5	1	

4.3 Level partitions

Using the final reachability matrix, the antecedent set and reachability for each risk are determined. The antecedent set comprises the element itself and separate elements that may affect it, whereas the reachability set comprises the element itself and separate elements that it may affect. Subsequently, the convergence of the sets is obtained for all risks. Elements having the same reachability and intersection sets occupy the highest level in the ISM hierarchy. The element at the highest level does not assist any element above its own level. Once the element at the highest level is established, it is segregated from the other elements. To determine the element in the next level, the same process is repeated and this process continues until each element's level is determined (Tables 5 and 6). This process facilitates the construction of the digraph and the final model.

Table 5 Iteration 1

Elements	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
1	1, 2, 3, 4, 7, 8, 9, 10	1, 2, 6, 9, 11	1, 2, 9	
2	1, 2	1, 2, 3, 4, 6, 7, 9, 10	1, 2	1
3	2, 3, 4, 8, 9	1, 3, 7, 8, 9, 10, 11	3, 8, 9	
4	4, 5	1, 3, 4, 5, 6, 7, 9, 10, 11	4, 5	1
5	4, 5	4, 5, 7, 11	4, 5	1
6	1, 2, 4, 6, 10	6, 7, 11	6	
7	2, 3, 4, 5, 6, 7, 9, 10	1, 7, 8	7	
8	3, 7, 8, 9	1, 3, 8, 9	3, 8, 9	
9	1, 2, 3, 4, 8, 9, 10	1, 3, 7, 8, 9	1, 3, 8, 9	
10	2, 3, 4, 10	1, 6, 7, 9, 10	10	
11	1, 3, 4, 5, 6, 11	11	11	

Table 6 Iterations 2-7

Iteration	*Elements*	*Reachability set*	*Antecedent set*	*Intersection set*	*Level*
2	3	3, 8, 9	1, 3, 7, 8, 9, 10, 11	3, 8, 9	2
3	10	10	1, 6, 7, 9, 10	10	3
6	6	6	6, 7, 11	6	4
6	9	1, 3, 8, 9	1, 3, 7, 8, 9	1, 3, 8, 9	4
	11	11	11	11	5
5	7	7	1, 7, 8	7	5
6	1	1, 2, 9	1, 2, 6, 9, 11	1, 2, 9	6
6	8	3, 8, 9	1, 3, 8, 9	3, 8, 9	6

4.4 Digraph development and establishment of ISM

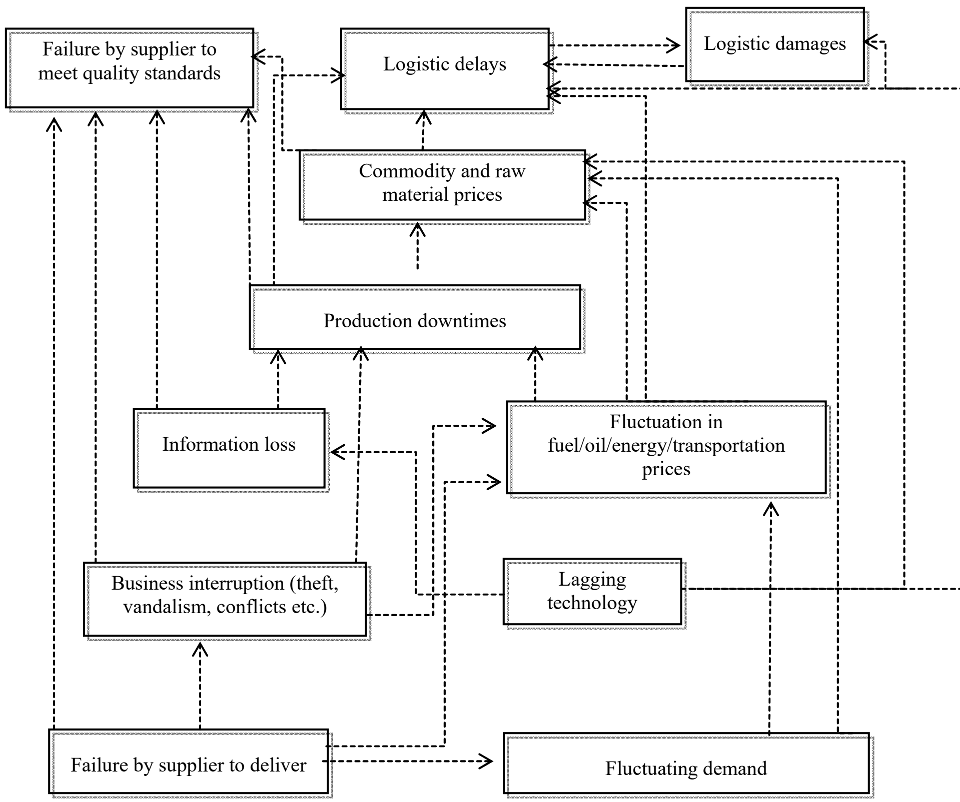
By reorganising the elements (Table 4) based on their levels in the reachability matrix, a cone-shaped matrix is developed. Using the cone-shaped matrix, the inceptive digraph that includes transitive links is obtained. The final digraph is developed after detaching indirect links. Next, to call the digraph an ISM, the elements narration is written in the digraph (Figure 1). In the established ISM, there are no cycles and the elements are connected in a pure hierarchical pattern.

For the elements established in this research, the ISM model designed illustrates that plastic manufacturing industries encounter SCR that have the ability to enhance each other. Failure by supplier to deliver (risk 1) enhances fluctuating demand (risk 8) and business interruption (theft, vandalism, conflicts) (risk7). Lagging technology (risk 11) enhances information loss (risk 6) and fluctuation fuel, oil, energy/ transportation prices (risk 9). Therefore, it is necessary that supply-chain expert's s understand that there exists interconnectedness among the risks in the ISM model because risks (6, 9) further enhances production downtimes (risk 10) which can also be enhanced by risks 1, 6, 7 and

9. Risk 10 further enhances commodity and raw material prices (risk 3) which enhances failure by supplier to meet quality standards (risk 2) and logistics delays (risk 4). As the result of the existing interconnectedness among the risks, risk 5 is enhanced by risks 4 and 11.

Even though the ISM has provided much information on the dependencies that exist among the SCR, it cannot be used to establish an analytic link between two risks, to show if the elimination will not have any effect. Further, the ISM has not shown the impact of the risk on another risk. Rather it has only shown the connections.

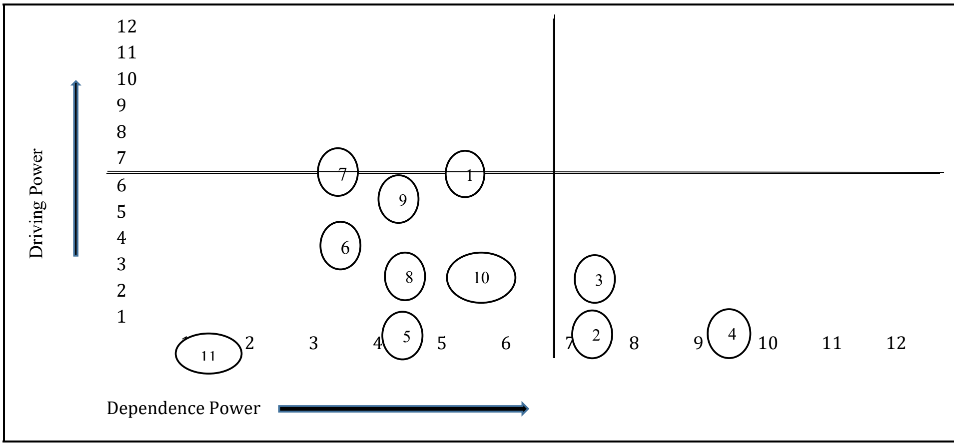
Figure 1 ISM-based model



4.5 MICMAC analysis

Establishment and categorisation of the several SCR is necessary for the establishment of the ISM under study. Contrasting the ranking of risks in the several categorisations (direct, potential, indirect) results in wealthy source of knowledge. As an indirect categorisation method, MICMAC critically analyses the span of an individual element. The purpose is to evaluate the dependence and driving power of SCR (Mandal and Deshmukh, 1994; Saxena and Sushil, 1990). In Table 4, the sum down the columns and across the rows indicates the dependence and driving power. The elements are separated into four clusters of risks (independent, autonomous, linkage and dependent). Cluster 1 consists of autonomous elements; these have weak dependence power and weak driver power. Cluster 2 is made up of dependent elements that have weak driver power and strong dependence. Linkage elements have strong driver and strong dependence power and are in Cluster 3. Finally, Cluster 4 consists of all independent elements having weak dependence but strong driver power. Figure 2 depicts the categorisation of the examined risks founded on their dependence and driving power.

Figure 2 Driving power and dependence diagram (see online version for colours)

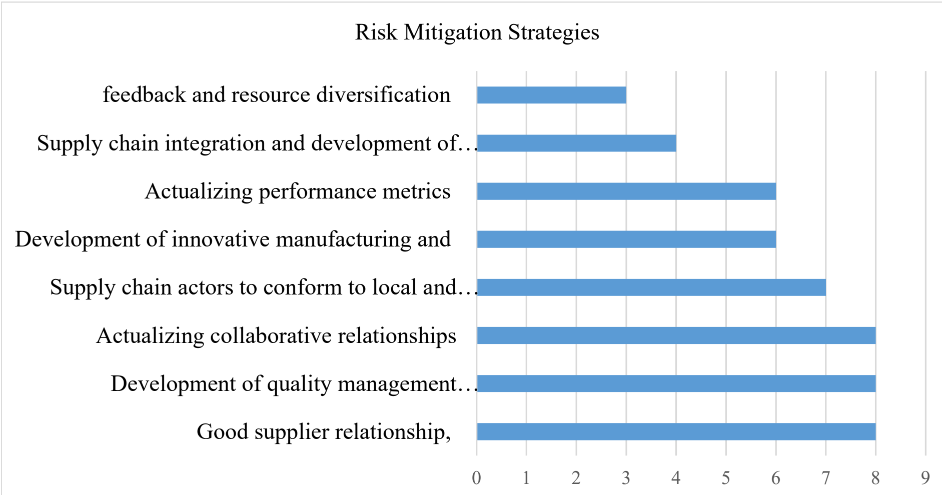


For this case, there are no elements in the linkage Cluster 3. Cluster 1 consists of elements 5, 6, 8, 9, 10, 11 and these have weak drivers and weak dependence. Cluster 2 is made up of elements with strong dependence and weak drivers and these are 2, 3, 4. The elements with the maximum driving power are 1 and 7. These elements are; failure by supplier to deliver and business interruptions (theft, vandalism, conflicts). The elements in Cluster 4 are the most cardinal elements that control the impact of the other elements at the peak of the ISM hierarchy in the entire SCR process. This shows that, the management of the plastic companies should address these elements diligently within the supply chains.

4.6 Mitigation strategies

Using the identified key SCR mitigation strategies from the reviewed studies (Jianying et al., 2021; Auer and Rauch, 2021; Prompatanapak and Lopetcharat, 2020; Deng et al., 2019; Faizal and Palaniappan, 2014), an online workshop was conducted with the selected experts in order to rank the mitigation strategies as well as align the SCR to the mitigation strategies. Figure 3 shows the mitigation strategies for addressing SCR within the plastic manufacturing industry. Figure 3 shows that: good supplier relationship; development of quality management systems; and actualising collaborative relationships were ranked highest at 1. Supply chain actors to conform to local and international regulations were ranked at 2 while development of innovative manufacturing and actualising performance metrics was ranked at 3. Supply chain integration and development of contracts with penalties was ranked at 4. Lastly feedback and resource diversification was ranked at 5.

Figure 3 Risk mitigation strategies (see online version for colours)



The ranking of the key SCR mitigation strategies by the experts does not imply that these are the only existing mitigation strategies but it is an indication that, certain mitigation strategies cuts across different supply-chains. For example, development of quality management systems; actualising performance metrics; feedback and resource diversification; and supply chain integration and development can result in good supplier relationship; actualising collaborative relationships and actors within the supply-chains conforming to local and regional regulations.

Further analysis of the findings shows that, the MICMAC analysis confirms that, to manage SCR, it is imperative to control; failure by supplier to deliver that would assist to control business interruption among the supply chain networks. Failure by supplier to deliver and business interruptions are the dominant elements (with the highest driving power) that can be mitigated by implementing the most ranked strategies; good supplier relationship, development of quality management systems and actualising collaborative relationships. If quality management systems are well developed, this reduces production rejects and goods returned leading to reduced failure by supplier to deliver. Further, collaborative relationships and good supplier relationships enable good information sharing within the supply chain network thus reducing business interruptions.

5 Discussion and implications

The aim of this research was to structural analyse the potential SCR using ISM in order to demonstrate how ISM can support risk managers to establish and understand interdependencies among SCR. The elements (risks) established are important because plastic manufacturing companies are operating in a global environment and competition is increasing among the supply chains. It is not individual plastic manufacturing companies that are facing risks but all the entities within the supply chain and suppliers can manage the risks when they understand the interdependencies and this can serve as a way of managing the risks. The aspect of establishing the risk mitigation strategies as well as understanding the interdependencies among the risks presents more opportunities for risk managers to compete in a global environment.

The driver dependence diagram assists in classifying the several elements of risk within the supply chain. Cluster 1 consists of elements such as logistic damages, information loss, fluctuating demand and fluctuation in fuel/ oil/energy/transportation prices. These elements have weak dependence and weak driving power. These elements are disconnected from other elements in the system and have few links.

In Cluster 2, the elements include; failure by supplier to meet quality standards, commodity and raw material prices; and logistic delays. These elements are dependent with strong dependence but weak driving. This means that, their enhancement depends on the other risks in the supply chain. However, managers should understand them because they denote those elements that are resultant efforts for successful risk management in the supply chain networks. The strong dependence depicts that; all the other elements should be controlled for them to be controlled. However, they are still cardinal risks to watch out for in the supply chain because they should be controlled to achieve an effective supply chain.

There is no element in Cluster 3 (linkage), this shows that, there are no elements that are unstable such that, any action on them will affect the other elements and themselves. Therefore, management has to focus attention on the identified elements in the other clusters. The driving and dependence powers for the elements in this cluster are strong but Figure 2 shows there are no elements to have a strong driving and dependence power on other elements.

In Cluster 4, the elements are; failure by supplier to deliver and business interruptions (theft, vandalism, conflicts). These elements have weak dependence but strong driving power. These elements are also referred to key/dominant elements and they fit into the linkage or independent cluster. However, for this case, there are no elements in the linkage cluster and this means, risk managers should focus on suppler failure to deliver and business interruptions. Generally, failure by supplier to deliver and business interruptions have a high driving power but little dependence in the supply chain networks (Faizal and Palaniappan, 2014; Prompatanapak and Lopetcharat, 2020; Deng et al., 2019; Auer and Rauch, 2021). These risks perform a central role in managing risks in the supply chain networks. Basically risk assessment in plastic manufacturing companies can take a single organisation view but information about risks expands if the entire supply chain is reviewed because new associates and markets come with new types of risks formerly never examined by the plastic manufacturing companies but can be cardinal for the entire risk assessment strategy.

The mitigation strategies assessed by the experts in this research were extracted from these studies (Faizal and Palaniappan, 2014; Manuj and Mentzer, 2008; Prompatanapak and Lopetcharat, 2020; Jianying et al., 2021; Deng et al., 2019; Auer and Rauch, 2021). The analysis of the mitigation strategies shows that; plastic manufacturing companies affirm to the strategies that were identified in the manufacturing companies of the reviewed studies. Further, the study has shown how the dominant risks depicted in the ISM model can be mitigated. The mitigation strategies demonstrated for the dominant risks align with strategies in Faizal and Palaniappan (2014), Prompatanapak and Lopetcharat (2020) and Jianying et al. (2021).

The presentation of inter-relationships by the ISM model is relevant for informing supply chain managers as they evaluate and learn on the impact of these risks on each other. The model also presents an opportunity for communicating and explaining the dependencies within the entire supply chain of the companies. By understanding the dependencies in the model, it enables companies to effectively manage their supply chains by focusing on relevant risks in the entire supply chain. Despite using few plastic manufacturing companies in developing the ISM model, the business environment under which these companies operate is fairly the same with the other uninvestigated plastic manufacturing companies. However, the model may demand modifications as experts from uninvestigated plastic manufacturing companies may state different opinions concerning the contextual relationships among the elements. For this research, the contribution is on the ability of the model to show the existing interdependencies among the risks as well as establishing risk mitigation strategies that would assist management in decision making that pertains to risk management. Further, the ISM generates controls for logical decision making where complex problems are structured. The brainstorming of risks by experts from the plastic manufacturing companies inspires practical contributions on the subject of discussion but it leaves out items related to the entire risk management process. Hence the current research provides more information for decision making on the subject and great understanding on the influence among the risks within the supply chain. Considerate discussion on the established risks among the experts has resulted in notable learning over the inter-relationship and the exposure of SCR within plastic manufacturing industry. In addition, the research contributes strategically by providing a comprehensive framework that integrates diversified issues associated risk management in the supply chain networks. The proposed framework integrates graph theory and ISM that enables managers to quantify the influence of several elements of SCR in the final result but also leads to a logical result.

6 Conclusions

The paper has demonstrated an argument that to manage SCR, there is a requirement to comprehend the interrelationships among the risks. Nevertheless, research in the field of SCRM is complex as supply chain networks continue to expand. Thus, this motivated the authors to establish and design taxonomy of SCR that can effect a supply chain. To this regard, the study objectives were to; establish and rank the risks in supply chain networks; develop the interaction among the identified risks using ISM; and suggest mitigation strategies for addressing the risks. The SCR in the plastic manufacturing companies have been established and ranked. Using the ISM model, the iteration among the SCR was identified. Finally, the mitigation strategies for addressing SCR are demonstrated.

Risk management is still a complex management procedure because of its dependency on many elements that are strenuous to quantify in precise terms. In this paper, eleven elements are identified which can affect supply chain networks of plastic manufacturing companies as well as the mitigation strategies. The suggested methodology aids as a recommendation to the supply chain managers to manage SCR effectively.

The established ISM model has not been validated statistically and structural equation modelling (SEM) has the ability of checking the validity of this hypothetical model. Thus, SEM can be applied in future studies to check the validity of the model. In as much as SEM has the ability to check the validity of a designed model statistically, it cannot design a model and test it. However, ISM has the ability of developing a model through managerial techniques and this makes ISM an analytic tool. In this regard, future research work should focus on developing a model using ISM and testing using SEM. Further, a quantitative approach would have been used to statistically show the magnitude of the mitigation strategies but rather a qualitative approach was used.

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