Middle-East Journal of Scientific Research 22 (1): 05-17, 2014
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2014.22.01.21793

Supply Chain Information Risk Management Model

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Abstract: In this paper we will discuss about the development of Supply Chain Information Risk Management Model based on the Supply Chain Operations Reference (SCOR) Model. The development of this model begins with identifying the categories of information sharing, the risk factors that affect the information flow and also mitigation activities which could reduce information risk factors in a supply chain. The model which provides an overview of information risks in a supply chain is validated via the Delphi technique. This model could assist a manager to make the t decisions in solving and mitigating problems involved.

Key words: SCOR Model · Information Sharing · Risk Factors · Mitigation Activities

INTRODUCTION

Managing supply chains is a complex undertaking because of the number of organizations involved and also because of the conflicting goals of each organization. The complexity is increased when we take risk into account. Risks, whether internal or external, are always present in any supply chain. This presents a form of uncertainty that has to be dealt with. Therefore supply chain risk management is required. The supply chain risk management processes start with the risk factors identification and identifying the mitigation activities to reduce the risk factors. Risk management action plans can then be developed to preferably avoid the identified risks, or if not possible, at least mitigate, contain and control them [1].

Information is the driver that serves as the glue to create a coordinated supply chain. Information must have the following characteristics to be useful: accurate, accessible in a timely manner and information must be of the right kind. Information provides the basis for supply chain management decisions on inventory, transportation and facility. A successful supply chain is one that shares important information between all the players. Information sharing means that supply chain partners share information and act together based on the knowledge. Information sharing is the key factor and also can be a problematic one for supply chain management. For this reason, information sharing and coordination between members of chain has gained a lot of interest among supply chain researchers [2].

To date a lot of research on supply chain risk management has concentrated on material flow risks. A review of literature reveals that so far not much work has been done to investigate the issue of supply chain information risk. Realizing the importance of information sharing for supply chains and also the ubiquity of risks and uncertainties, it is thus important to investigate the possibility of a supply chain information risk model.

As stated above, information sharing is one of the keys to a successful integrated supply chain. Therefore, identifying the categories of information sharing and the involved risk factors are very important. The aim is to reduce information risk factors with some mitigation activities and in this way the performance of the supply chain will increase. Some of researches have used SCOR model to reduce supply chain risk susceptibility [3,4,5,6] so in this research, SCOR model will becomes the benchmark model to develop Supply Chain Information Risk Management Model. The proposed model could assist the practitioners in identifying information risks, mitigation activities and make the right decisions in solving the problem in production system.

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This paper is organized as follows: Section II provides the literature that provides the motivation and forms the basis of the research. Section III describes the methodology. This is followed by section IV that presents the proposed supply chain information risk management model and section V gives an account of the validation results that were acquired by the Delphi method. Section VI concludes the paper.

Literature Review: Literature review is aims to understand the background of relevant issues and also to obtain the state of research so that it can eventually be developed into supply chain information risk management model. The literature review is divided into four sections as follows:

Role of Information in a Supply Chain: The objective of supply chain management is to provide a high velocity flow of high quality, relevant information that will enable suppliers to provide an uninterrupted and precisely timed flow of materials to customers [7]. Information flow in a supply chain system also serves as the bonding agent between material flow and financial flow. The information flow is used to keep all supply chain elements updated and hence provides resources for decision making. Implementing a successful supply chain, there must be a proper and continuous flow of information [8] As such, information sharing has an important role in supply chain management. It is to ensure the availability of data in a timely manner, ensuring the owned data can be shared along the supply chain, helping companies to improve efficiency and effectiveness of the supply chain and to be able to respond to changing consumer needs and desires more quickly.

Zhiling *et al*. also tried to answer on what information could and should be shared and information are shared effectively [9]. According to their research, the new information system should focus on forecasting element at an appropriate aggregation level. In other research, Grean and Shaw [10] explained that the important strategy for managing an integrated supply chain is to share information among supply-chain partners. One of the main benefits of sharing information is the reduction of inventory. As a result, the supply chain achieves better performance in terms of financial returns, service level and turn-around times. With information shared among the manufacturer and the retailer, the manufacturer can use the information on the inventory level of the retailer to manage the frequency, quantity and timing of the shipments, instead of waiting for the retailer to place orders.

Value adding activities in a supply chain are often triggered by information flows such as demand, inventory status, order fulfilment, product and process design changes and capacity status [5]. The key ingredient for success in managing a supply chain is fast, accurate data from a wide range of information including inventory level, sales data and forecasting, order status for tracking/tracing, production/delivery schedule, performance metrics and purchasing/ procurement [11].

Information Risks: Supply chain risks can be categorized into disruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory and capacity [12]. Supply chain risk management is not just about identifying and mitigating against natural disasters and other "big" events but there are countless other risks associated, some include: daily fluctuations in demand and supply, rapid growth, changes to the supplier base, changes to IT systems and counterfeit and contaminated products. Information risk can be viewed as a factor that contributes to supply chain risks [13]

Information risk can be defined as the probability of loss arising because of incorrect, incomplete, or illegal access to information [3]. Under this definition, the "bullwhip effect", that is the distortion and amplification of demand information as it moves up the supply chain can be categorized as one of the factors in information risk. The Bullwhip Effect arises because of the incorrect amplification of the demand (or order) variance up the supply chain, from customer to factory, as demand information passes back through the supply chain. The bullwhip effect in the supply chain occurs when changes in consumer demand causes the companies in a supply chain to order more goods to meet the new demand. There are four major causes of the bullwhip effect: demand forecast updating, order batching, price fluctuation and rationing and shortage gaming [14].

The risk information accuracy maybe caused by information accessibility, information efficiency and data accuracy. Accurate in information should further affect decision making in supply chain. The threats of information system security and disruption could be internally due to ill-manage system, or externally by hackers and nature disaster [3]. The information system risk can also be considered at application, organizational and inter-organizational levels [15]. Passing on risk information between the companies is however necessary in order to effectively implement Supply Chain Risk Management.

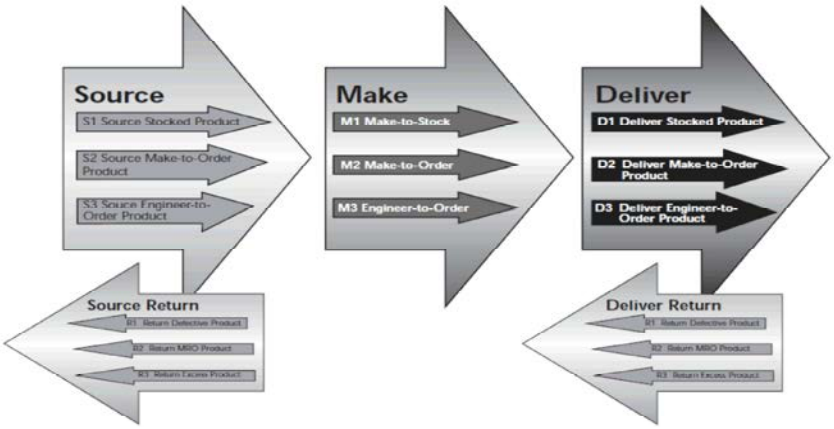

Fig. 1: Supply Chain Operations Reference (SCOR) Model (SCC, supply-chain.org 2010)

Supply Chain Operations Reference (SCOR) Model: The supply chain operations reference (SCOR) model, proposed by the supply chain council (SCC) is a standard supply chain performance evaluation model, which has been widely embraced by many modern organizations [16]. SCOR is a cross-industry model designed to analyse a supply c hain and identify improvement opportunities in both Material flow and Work & Information flow. The SCOR model defines supply chain as "The integrated processes of Plan, Source, Make, Deliver and Return, spanning your supplier's supplier to your customer's customer, aligned with Operational Strategy, Material, Work & Information Flows" [17].

The implementation of a methodology that not only provides accurate guidelines about how to deal with risk, but also builds on widely used tools stimulates companies to acquire an adequate knowledge about causes and effects of supply chain uncertainty. The developed framework is also extremely flexible because it may be applied to various levels of organizational complexity, in order to analyse just one supply chain process or to understand risks affecting all the main processes of a company, according to the amount of information that is available. Moreover, different breakdowns of supply chain processes may be used as an alternative to the one suggested by the SCOR-Model [18].

SCOR was developed and continues to evolve with the direct input of industry leaders who manage global supply chains and use it daily to analyse and improve the performance of their organizations. It features an intentionally broad scope and definitions that can be adapted to the specific supply chain requirements of any industry or application [19]. Figure 1 illustrates the SCOR Model.

Supply Chain Risk Models: The supply chain consists of many stages, all of which work in tandem to fulfil customer requests. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses and all other [20]. The supply chain should strive toward the same goals and they must have an open line of communication with each other [21]. Many companies achieve significant competitive advantage based on how they configure and manage their supply chain operations. The idea is to apply a total systems approach to manage the entire flow of information, materials and services from raw materials suppliers through factories and warehouses to end customer.

Some efforts have been made to integrate material and cash flows by adapting financial option theory, but there is a lack of models in analysing the risk associated with information flows. In this aspect, the SCOR model has been used by researchers to be the basis in analysing material flows and risks in a supply chain [4]. Tang and Musa [5] identified that the flow in the forms of material, financial, information and also the analysis of the system process of source (supply), make (production) and deliver (demand) can be done using SCOR Model.

Development of supply chain risk model refers to the system analysis process described by Tang and Musa [5] only focused on three processes out of five SCOR processes (Plan, Source, Make, Deliver and Return). Tang and Musa [5] have used the SCOR model to reduce supply chain risk susceptibility but focused in material flow (production network) and financial flow. Therefore, this research fulfil the gap with investigates Supply Chain Information Risk Management using the SCOR Model as the based model, focuses on three basic processes which is Source, Make and Deliver.

In this paper, SCOR model which focuses on three processes (Source, Make and Deliver) is selected as a general model to develop the supply chain information risk management model. These three processes were selected because it contains strategy production (Make to Stock, Make to Order and Engineering to Order) that is essential for a supply chain. The result of this research will be expected to provide an overview of information risk in a supply chain that could assist manager to make the right decision in solving the problem in production system.

Another case study combined an analytic network process approach with the SCOR model to define a model of supply chain risk susceptibility [3] and developed a SCOR oriented model to manage risks in production networks [6]. Several risk management methods are applied in the supply chain context and integrated as a comprehensive model.

Risk mitigation should commensurate with the level of the risk. It will not necessarily need to remove all the risk. Risk mitigation should be simple so it is manageable and can be communicated readily to all staff. Monitoring and reviewing entails not only evaluating the effects of risk treatment but also maintaining the plan and responding to changes in suppliers, processes and regulation affecting elements of the supply chain [22].

Improve visibility with technology and make data backup are example of the risk mitigation activities. Technology will play a greater role in providing real-time visibility of sales and stocks to support the agility required in the current environment. Adoption of technology-led solutions will accelerate. Backup refers to the copying of data then it can be restored when the data are loss or damage. Information technology is expected to assist companies to reduce and manage the risks faced daily. Handling the corruption of the goods or stealing of the goods during the logistics process and missing data during the supply process, replicas are needed for backup to manage incomplete and uncertain data [23].

MATERIALS AND METHODS

This section explains all the steps to develop and validate supply chain information risk management model. As Figure 2 depicts, the methodology of this research consist of three phases which are explained in subsequent sections:

The literature reviews will become the main reference in determining the important issues of supply chain risk management that can be applied to develop Supply Chain Information Risk Management Model. As literature review reveals, a lot of researches have used the SCOR model to reduce supply chain risk susceptibility but most focused in material flow (production network) and financial flow. Therefore, in this paper, SCOR model based on three issues of Source, Make, Deliver is selected as a general model. SCOR model is selected because it is a cross-industry model designed to analyse supply chain and can identify improvement opportunities in both Material flow & Information flow. The system process of source (supply/supplier), make (production) and deliver (demand/customer) will represent material flow and information flow in a supply chain, especially on production system. This is because material flow is a physical movement of products from suppliers to customers and information flow is used to keep all supply chain elements from customers to suppliers updated and hence provides resources for decision making [5].

Based on the literature review, the categories of information sharing, the list of information risk factors and also the list of mitigation activities can be identified. Furthermore, this identification will be combined with SCOR model that has been selected as a general model of supply chain information risk management model. This combination will eventually be developed into the initial model of supply chain information risk management.

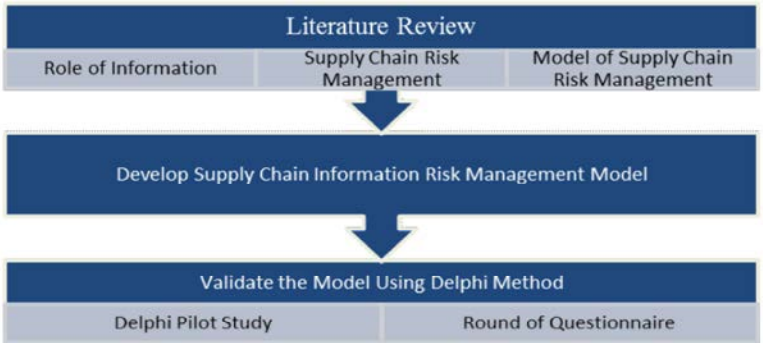

Fig. 2: Research Phases

Model validation is carried out using the Delphi method which is an iterative process to collect and distil the judgments of experts using a series of questionnaires interspersed with feedback [23]. The formation of questionnaire consists of three main phases which is Delphi pilot study, the first round Delphi process and the second round Delphi process. Delphi Pilot Study will be held first before a questionnaire was sent to the Delphi panellist. A pilot study is sometimes conducted with the goals of testing and adjusting the Delphi questionnaire to improve comprehension.

Selecting research participants is a critical component of Delphi process as their expert opinions determined the final outputs of the Delphi analysis [23]. There are four requirements for "expertise": i) knowledge and experience with the issues under investigation; ii) capacity and willingness to participate; iii) sufficient time to participate in the Delphi; and, iv) effective communication skills [24].

There are a lot of literature review that explained about the number of panellist for Delphi method. The Delphi group size does not depend on statistical power, but rather on the group dynamics for arriving at consensus among experts. Based on Adler and Ziglio [23], the lowest number of samples for Delphi method is three panellists with two rounds and the largest is 171 panellists with two rounds. Only using three Delphi participants formed the homogeneous sample to develop rules for ceramic casting process, presumably because such expertise is limited [25]. Summarizing the various characteristics and size panellists of the publications reviewed, it was found that the lowest number of samples is 7 panellists with two rounds and the largest is 26 panellists [26]. Based on this works [25, 26], six Delphi panellists are chosen and agree to participate in this study.

Supply Chain Information Risk Management Model: There are 8 main types of information that can be shared, which are: Inventory Level; Sales Data; Order Status; Transportation/Shipment Sizes; Delivery Schedule; Sales Forecasting; Machine Capacity; and Production Schedules [27, 28, 29, 30, 31, 32]. Information sharing in the supply chain can provide facts that can be used by managers to make decision and also to provide managers supply chain visibility.

Risk is something that might yield loss. Therefore, with regards to information sharing, risk factors can be defined as condition, element, or activity in information sharing that may adversely affect the supply chain performance. In this paper the risk factors in information sharing include: Uncertainties in demand; Inaccuracies of demand data; Changes in ordering contract; Natural disasters; Late payment; Uncertainties in supply; Inaccuracies of the past demand data; Machine problem; Inaccuracies of supplier data; Price fluctuation; Shipment and delivery accuracy; and Networking system problem [3, 12, 13, 33-38].

Information Risk Mitigation is the collection of processes that collectively ensure that information risks are adequately reduced to an acceptable level. In this paper, six mitigation activities are generated by considering the information risk factors in supply chain [13, 22, 30 39, 40]. The identified mitigation activities in information sharing are: Good practice standards; Plan, Do, Check, Act (PDCA); Monitor and review protection failures; Make data backup; and Focus on information technology. To identify the categories of information sharing, the information risks and the mitigation activities are then moulded into the initial supply chain information risk model by using the SCOR model as the basis. The relationships between the components are depicted in Figure 3.

The presented model focuses on three basic processes, that is Source, Make and Deliver and captures and explain the issues of information risk and its effect. There are six modules in the model, namely Deliver Stocked Product (DSP) to Make-to-Stock (MTS), Deliver Make-to-Order Product (DMTOP) to Make-to-Order (MTO), Deliver Engineer-to-Order Product (DETOP) to Engineer-to-Order (ETO), Make-to-Stock (MTS) to Source Stocked Product (SSP), Make-to-Order (MTO) to Source Make-to-Order Product (SMTOP) and Engineer-to-Order (ETO) to Source Engineer-to-Order Product (SETOP). From the initial model, there are 5 main types of information (shown by dashed arrow) that can be shared from Deliver to Make, that is inventory level, sales data, order status, transportation/shipment sizes and delivery schedule and also 5 main types of information that can be shared from Make to Source, which is inventory level, sales data, sales forecasting, machine capacity and production schedules.

Model Validation: The validation of the supply chain information risk management model is done by using the Delphi method. The first step is Delphi Pilot Study. The implementation of Delphi pilot study in this paper involves 2 participants who have the capacity, experience and knowledge about supply chain risk management. Overall, the participants agree with the questionnaire design which needs a little improvement in terms of formatting and layout of the questions. They also suggested some modifications to the initial model of

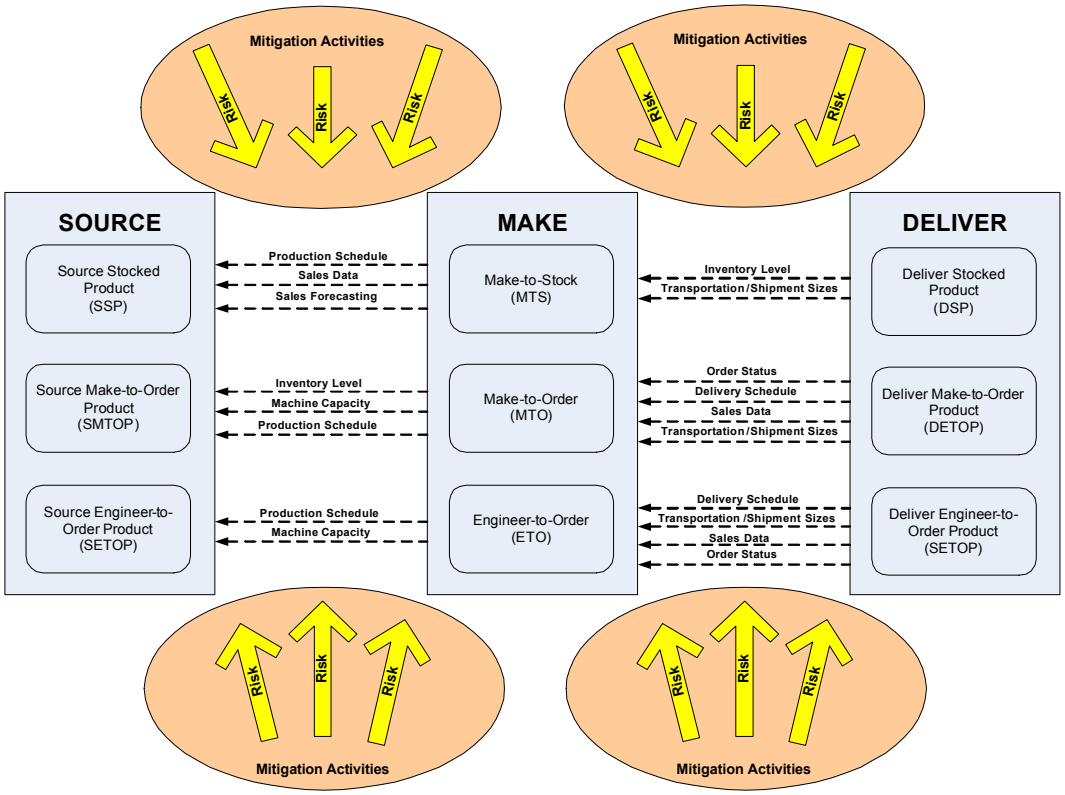

Fig. 3: The Initial Supply Chain Information Risk Management Model

supply chain information risk management (Figure 3). In the initial model, the categories of information sharing are subdivided according to the different modules. For example from DSP to MTS module, the categories of information sharing are inventory level and transportation/shipment sizes. The participants in Delphi Pilot study suggested that all 5 categories of information sharing should be depicted for each of the modules. This means that all 5 categories are present for example from DSP to MTS instead of just two as illustrated in Figure 3. Therefore, improvements to the questionnaire design and the initial model are required. Ultimately, the respondents agreed with the new initial model that have been improved and developed. Their comments and suggestions are then combined into the new questionnaire, which were sent to the Delphi panellists.

The first round Delphi questionnaire consisted of six parts based on the six different modules in the model (refer to Figure 3). For each part panellists are asked to identify the categories of information, the risk factors that affect the information flow in supply chain and mitigation activities to reduce that risk. The responses are then analysed based on frequency. Responses that received less than 50% frequency are rejected whilst those that receive frequencies of equal to or more than 50% were accepted. This method of analysis is in accordance with Raja [41]. This process is carried out iteratively until all of the panellists are in agreement with the items in the questionnaire. The result of the first round questionnaire, the six panellists responded agreeing that the five variables are the categories of information sharing from Deliver to Make and also from Make to Source. The results also have found that every model has different risk factors and mitigation activities based on each module and each variable of information sharing.

In the second Delphi round, panellists' answers from the first round are refined and reduced based on the 50% acceptance and rejection criteria defined earlier. This resulted in the final supply chain information risk management model, which is shown in Figure 4. In this final model, consensus via Delphi indicated that all 5 categories of information sharing which are inventory level, sales data, order status, transportation/shipment sizes and delivery schedule, from the deliver to make components should be in the model. Similarly all five categories of information sharing which are inventory level, sales data, sales forecasting, machine capacity and production schedules should be present from the make to

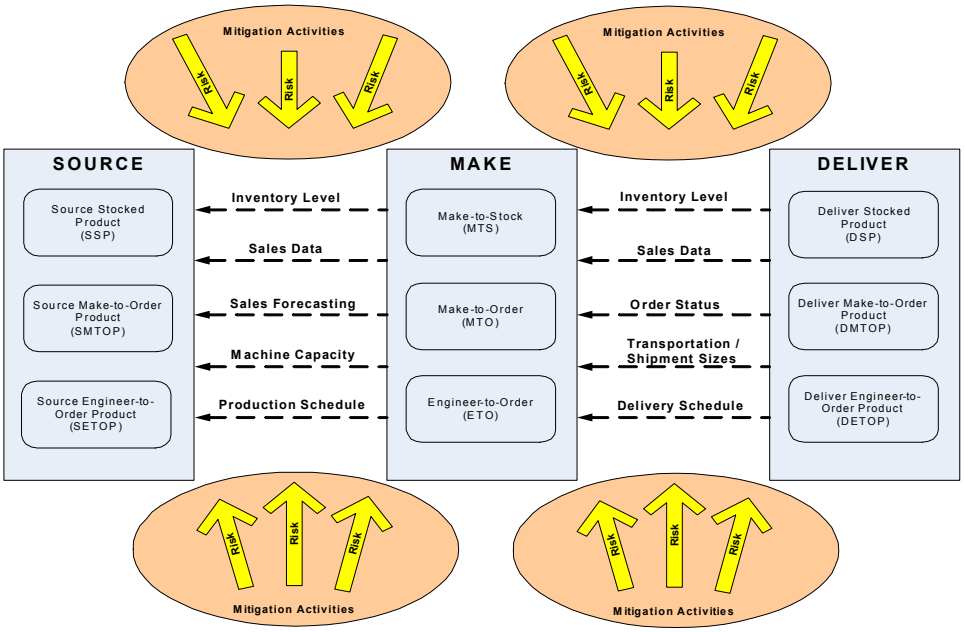

Fig. 4: The Supply Chain Information Risk Management Model

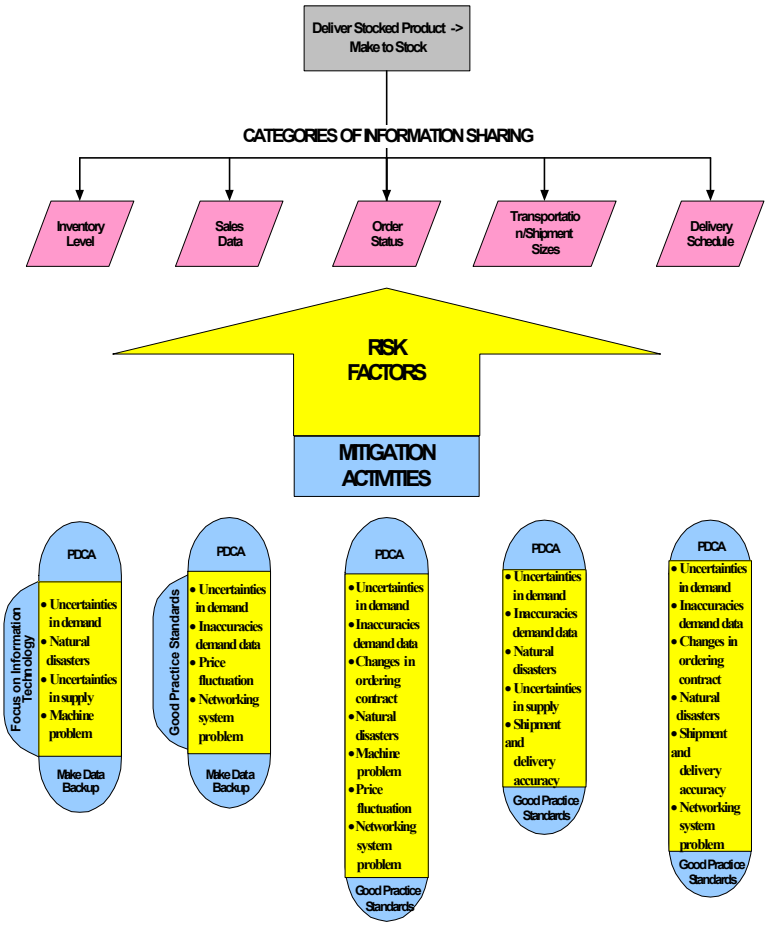

Fig. 5: The Supply Chain Information Risk Management Model from DSP to MTS

source components. In Figure 4 these are indicated by the dashed arrows. The whole analysis of the risk factors associated with each category of information sharing and their mitigation activities resulted in six separate Information-Risk-Mitigation models. Figure 5 to 10 show the risk factors and mitigation activities for the information flows from each module.

For example, in Figure 5 the risks are the yellow bulleted items whilst the mitigation activities, which are plan, do, check, act (PDCA), make data backup, good practice standards and focus on information technology are indicated in the blue oval shaped graphics, each corresponding to the type of information sharing category. For example, in sharing inventory level information between the DSP to MTS, risks involved are uncertainties in demand, natural disasters, uncertainty in supply and machine problem. To determine the mitigation activities, the model suggests backing up the data, focuses on information technology and undertakes the PDCA.

In sharing sales data information, the risks involved are uncertainties in demand, inaccuracies of demand data, price fluctuation and networking system problem. To determine the mitigation activities, the model suggests backing up the data, applies good practice standards and undertakes the PDCA. In sharing order status information, the risks involved are uncertainties in demand, inaccuracies of demand data, changes in ordering contract, natural disasters, machine problem, price fluctuation and networking system problem. To determine the mitigation activities, the model suggests applies good practice standards and undertakes PDCA.

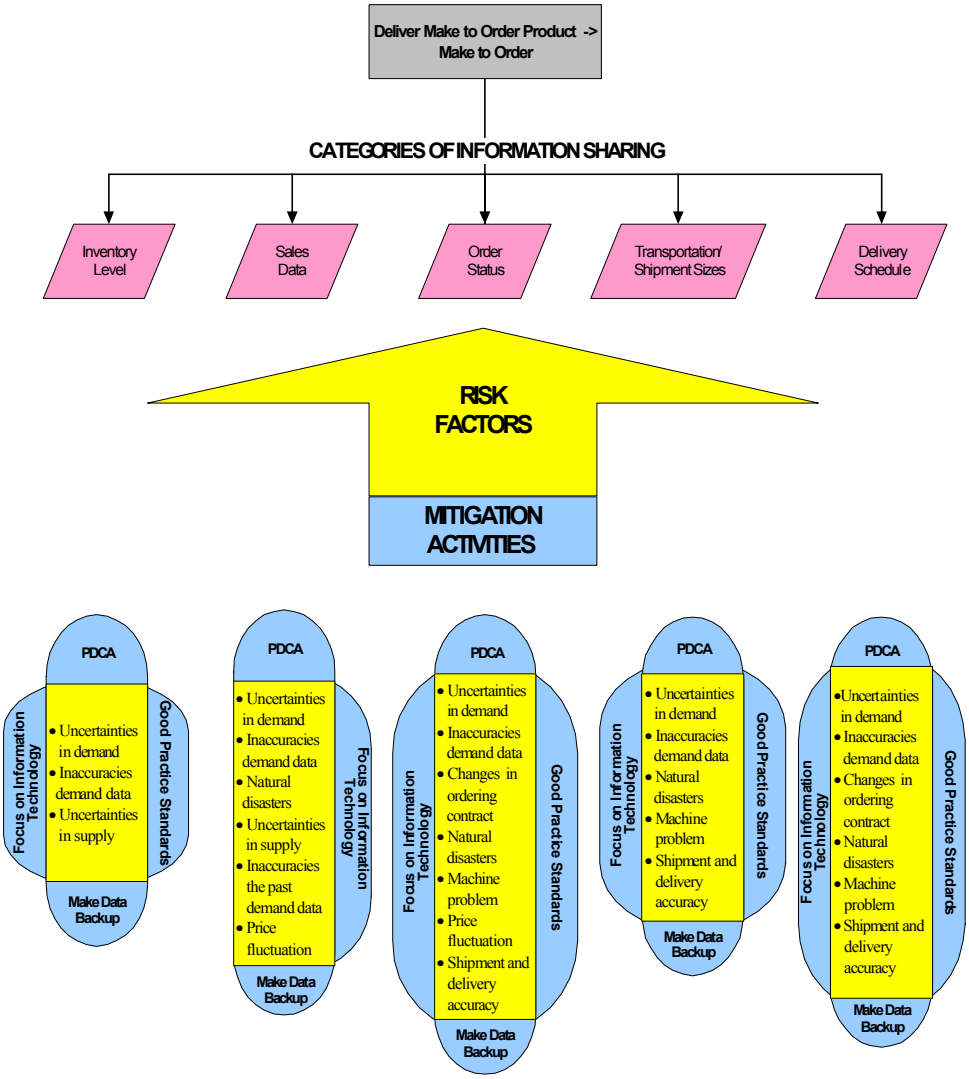

Fig. 6: The Supply Chain Information Risk Management Model from DMTOP to MTO

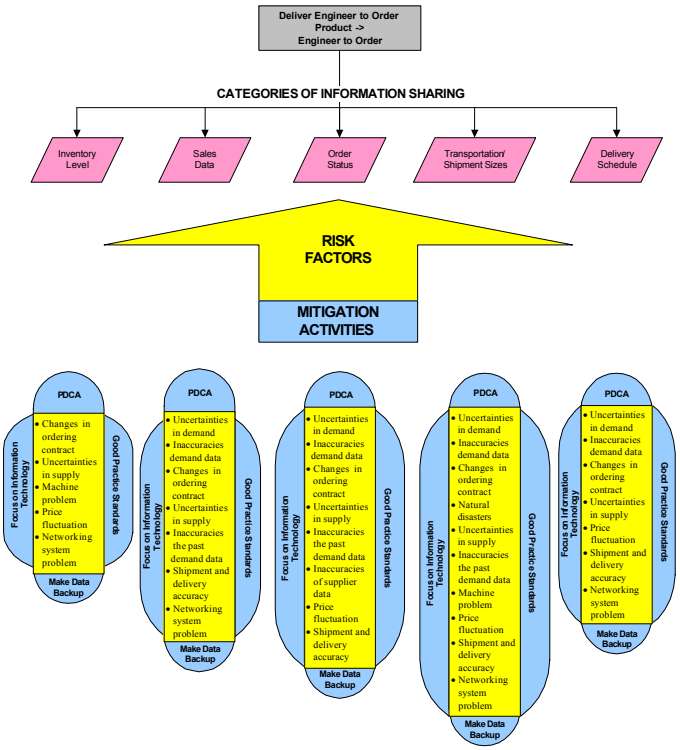

Fig. 7: The Supply Chain Information Risk Management Model from DETOP to ETO

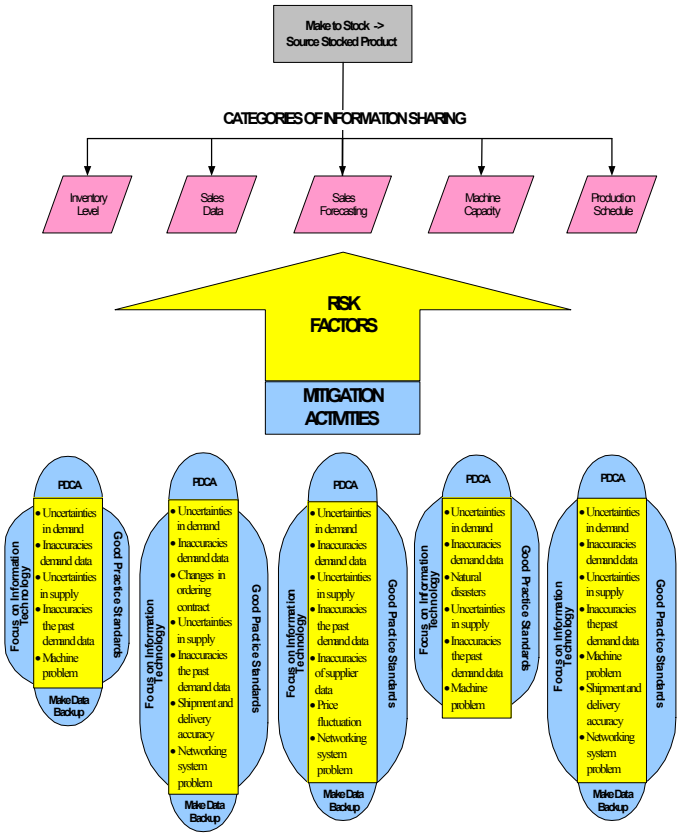

Fig. 8: The Supply Chain Information Risk Management Model from MTS to SSP

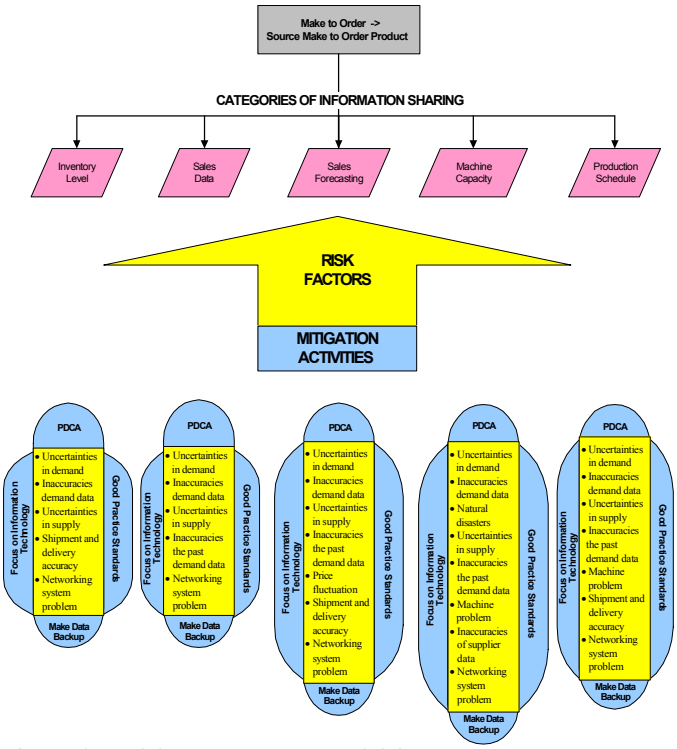

Fig. 9: The Supply Chain Information Risk Management Model from MTO to SMTOP

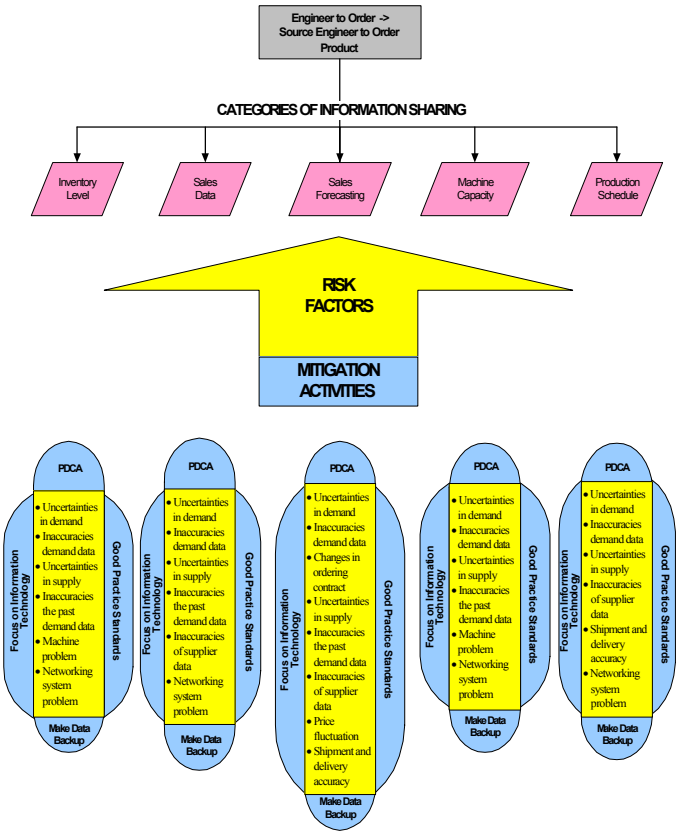

Fig. 10: The Supply Chain Information Risk Management Model from ETO to SETOP

CONCLUSION

Although research into the categories of information that can be shared by supply chain members has been done by many researchers, they have not related them to information risks and mitigation activities. This research is expected to be the initial work that can be refined further by future research.

To implement a successful supply chain, there must be proper and continuous flow of information. However there are risks associated with information and information sharing in a supply chain. Mitigating information risk will help companies in: decision making, problem solving and enlightenment of the supply chain [8]. In this paper, we have identified the categories of information and the risk factors that affect the information flow in a supply chain. We also suggested mitigation activities which could reduce information risk factors. Supply chain information risk management model was developed by combining all the factors using the SCOR model as the basis. The model is then validated using the Delphi techniques.

The proposed Supply Chain Information Risk Management Model can be used as a tool for helping practitioners in identifying information risks and mitigation activities depending on the type of manufacturing or distribution strategy that they adopt. The proposed model gives details of the risks and mitigation activities via its six separate elements or modules. Scientific contribution of this paper is to enrich the theoretical framework to be used as reference in assessing risk factor information in the supply chain. It will generate more in-depth findings in supply chain information risk management.

Future research can be done by concentrating in each production strategy (make to stock, make to order and engineering to order) and refining the details of the risks and mitigation activities. Multiple case studies from different industries will provide a rich set of information from which comparisons can be made and knowledge can be inferred. This will lead to a further refinement of the proposed model and will subsequently enhance its applicability. The proposed mitigation activities of this model were very general and did not describe each risk factor that is involved in the information flow of the supply chain. Therefore, further research can be conducted to refine the mitigation activities for each risk factor. We believe that the model will provide a valuable tool to supply chain managers in identifying information risks and subsequently mitigate those risks.

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