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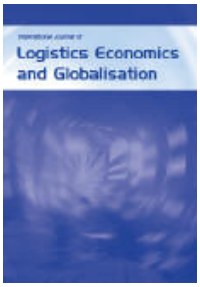

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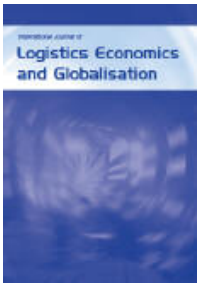

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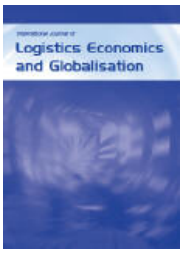

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Special Issue on Research Trends in Global Logistics

***Guest Editors*: Dr. K. Ganesh, Dr. Matti Muhos and Dr. M.N. Qureshi**

Decision support framework for risk assessment of sustainable supply chain

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Abstract: Decision support systems can play a role in improving the ability of decision-makers to assess and decide as good as. We introduced new paradigm in sustainable assessment in supply chain operations. Conceptual thinking is conducted by analysing two types of thinking namely general framework of supply chain risk management and assessment of sustainable supply chain. The content of the two types of the conceptual thinking will be analysed by observing diverse perspectives such as the constituent components, structuring the components and process of adoption. We found that there are three aspects in risks of sustainable supply chain namely economics, environment and social politics aspects. Product, processes and information flow are elements that interact with each aspect as a whole system. We proposed a conceptual model of decision support for risk assessment of sustainable supply chain. It has provided functional capabilities: modelling, data management, and knowledge management to support all decision-making processes. All risk indicators are arranged in the structure hierarchical. The proposed decision support is applying non-numeric under multi decision-maker's assessment. We presented a decision support framework that applicable in principle. The proposed system provided for eligibility proof to be implemented.

Keywords: decision support; sustainable; supply chain; SC; risk assessment; indicators.

Reference to this paper should be made as follows: Hadiguna, R.A. (2012) 'Decision support framework for risk assessment of sustainable supply chain', *Int. J. Logistics Economics and Globalisation*, Vol. 4, Nos. 1/2, pp.35–54.

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1 Introduction

Recently, sustainability issues in context of economics, environment and social have received growing attention so that topic of sustainable supply chain management (SCM)

has become an increasingly popular research area (Carter and Easton, 2011). The pressure from various stakeholders has encouraged supply chain (SC) managers face the challenge to integrate sustainable practices in managing their SC. Practices like green packaging, return of end-of-life and used products to the producer as well as the green handling of these returns, recycling, remanufacturing and adequate waste disposal have assumed importance (Faisal, 2010). In term of sustainability, total cost must calculate costs that have incurred from the effects of resource depletion and the generation of by-products. Resources that used have transformed into pollution and waste. Research into the operational implications of various policies and how business can integrate sustainability issues is critical and urgent to be performed, since current legal trends will force many of these changes whether or not academe and practice is prepared (Linton et al., 2007).

Many organisations need to establish suitable measures for effective green SC. Because there have failed in SCM due to their inability to develop the key measures that required for complete SC operations effectively (Olugu et al., 2010). A sustainable SCM is intended to manage all processes of using environmentally friendly inputs and transforming these inputs through change agents whose by products can improve or be recycled within the existing environment. This process develops outputs that can be reclaimed and re-used at the end of their life-cycle thus, creating sustainable SC (Kushwaha, 2010). SCM has developed inseparable from the success of industrialisation in a country. The process of industrialisation created the amazing human social wealth by opportunities in economics sector. Obviously, this has continued to encourage the resources exploration along with the increase of population, shortage of resources, environmental pollution and ecological negative impact.

To this end, many companies have also pro-actively acted in favour of a more sustainable development. It has derived SC to participate in cross-regional, inter-countries, and multi-link feature. Their assertive approach toward the environment has helped them to reap the benefits of an environment-friendly image, e.g., to gain or retain environment-conscious consumers, to comply with the sometimes cumbersome and blurry current legislation, and to anticipate necessary changes to cope with future legal environmental standards (Neto et al., 2008). In recent years, most scholars focus on the research, production and operation of sustainable SC model, corporate relations and performance evaluation, only a small amount of research on sustainable SCM and related issues discussed. It is vulnerable to the external environment and internal entities adverse factors to form the SC risk.

Tang (2006a) has been reviewed various quantitative models for managing SC risks and related various supply chain risk management (SCRM) strategies examined in the research literature with actual practices. Risk management of a SC has a great influence on the stability of dynamic cooperation among SC partners and hence very important for the performance of the SC operations as a whole (Khan and Burnes, 2007). Various factors contribute to the complexity of an SC risk system. Too many suppliers may make it very difficult to maintain a stable relationship. Cross-production processes increase complexity and uncertainty. A long chain can trigger the obsolescence risk. Expanded product catalogues make service supporting system more complex a cycle affects availability and increases the risk of inventory. According to Trkman and McCormack (2009), several different classifications of risks and methodologies have focused only on the prediction of disruptive events instead of the root causes of uncertainties. Disruptive events such as bankruptcy, natural disaster or the possibility of a terrorist attack are

considered, whereas continuous changes due to a turbulent environment such as a change in customer tastes, technology shifts or supplier priorities are ignored. In this context, we are believed that sustainable risks should consider economics, environment and social politics aspects.

This paper suggests a decision support framework for the risk assessment of sustainable based on economics, environment and social politics as interdependent aspects. The framework that developed consists of structure, performance and attributes as modified by previous relevance studies. The approach is grounded within concept of SCRM and green SC. This framework is needed to assess the sustainability level of SC to support the collaboration strategy. Managing uncertainties and risks in SC is difficult organised only with single factor such as green or revenue.

The organisation of the paper is as follows: first, describe briefly and concisely about substance and importance of sustainable SC issues in automotive industry. Second, review the concepts that consist of sustainable SCM, performance measurement in SC and automotive SC overview. Third, develop model that consist of critical control functions, performance indicators and integrating concepts as a proposed system. Finally, paper culminates with conclusions and recommendations for further studies in this area.

The paper is organised as follows. Literature reviews consist of sustainable SC, SCRM and risk assessment approaches are presented in Section 2. Section 3 addresses the framework design, and Section 4, the discussion of the framework evaluation, novelty and reusability are presented. Finally, conclusions and directions for further research are presented in the last section.

2 Literature review

2.1 Sustainable SC

Sustainable development undertakes to improve economy, society and environment for the current generation, without ignoring the destiny of future generations to meet their needs (Blengini and Shields, 2010). Sustainability refers to an integration of economic, social, and environmental issues are simple and flexible enough to allow for multiple interpretations, as well as application in a variety of circumstances and across sectors of the economy (Carter and Rogers, 2008). That is, sustainability paradigm is a philosophy that balances between economic development, environmental security, and social equity (Sikdar, 2003).

According to Bloemhof (2005), the area of sustainable SCM was divide the area in two fields: firstly, the triple-P concept, optimising profit (economic aspect), people (social aspect) and environmental performance of a traditional forward SC, and secondly, the closed-loop supply chain management (CLSC) concept, combining forward and reverse SCs by closing material flows to limit emissions and residual waste. It is similarly related with terms of reverse logistics (Pokharel and Mutha, 2009), CLSC (Guide and van Wassenhove, 2009), green SCM (Shang et al., 2010), green marketing (Papadopoulos et al., 2010), etc.

According to Linton et al. (2007), focus on SCs management is an approach towards the broader adoption and development of sustainability, since the SC considers the product from initial processing of raw materials to delivery to the customer. In an effort to explore sustainability in a SC context, greater consideration needs to be given to the

connection between first-, second-, and n-order SCs and the components and interfaces thereof. Accordingly, the SC should be seen as not ending at the point of consumption, but at another (or a new) point of origin (Svensson, 2007).

Multifaceted models have been discussed many researchers and it will increase as the running time. A few models have developed to obtain the ways of solving sustainable SCs problems such as Widodo (2010) proposed scenarios to optimise trade-off between palm oil and furniture industries in Indonesia case study by simulated using the system dynamic model. Solvang and Hakam (2010) proposed conceptual model about on challenges to economic and environmental sustainability of logistics networks in sparsely populated areas in Norway. Chung and Wee (2006) developed mathematical model to investigate an optimal pricing and replenishment policy for a multi-echelon inventory system with remanufacturing by considering the integration of the supplier, the manufacturer, the retailer and the third party of the used product collection. In addition, many literature reviews have been conducted to explain future direction of research in sustainable SCM.

Seuring and Müller (2008) have been taken a broad look at sustainable SCM and the issues emerging in this field with point of view in environmental perspective. Pokharel and Mutha (2009) have been reviewed many papers with reverse logistic perspective. Sarkis et al. (2011) have been reviewed the literature on green SCM with a focus on identifying applicable and explanatory organisational theories that have been utilised to expand understanding and knowledge of this research field. Carter and Easton (2011) have been provided a systematic review of the evolution of sustainable SCM over the past 20 years. They have been argued that the sustainable SCM research has become more theoretically rich and methodologically rigorous; there are numerous opportunities for further advancing theory, methodology, and the managerial relevance of future inquiries.

Benefits of sustainable SCM can be interpreted and summarised from Seuring and Müller (2008), Solvang and Hakam (2010), Sikdar (2003), Shang et al. (2010), and Searcy et al. (2008) that is decrease cost and add the value to operations, increase utilisation of key assets, mitigate risks (environmental, social, and market), be a catalyst for supplier innovation, product differentiation, standardise operations and allow for improve customer service, continuous improvement, and enhance company reputation. Many benefits will obtained by companies when sustainable SCM has implemented.

2.2 Supply chain risk management

SCRM can be viewed as a strategic decision and analysis that it can affect SC operations. Consequently, it will give affect toward operational, market and financial performance of firms that involved in SC network system. In this connection, we must understand and define two terms: SCM, and risk management. The main goal of SCM is aimed to produce and deliver products or services for the consumers to satisfy the elements of customer satisfaction. According to Gunasekaran (2004), SCM has been considered as a competitive strategy for integrating suppliers and customers with the objective of improving responsiveness and flexibility of manufacturing organisations. Generally, SCM can be seen as the management process of material, information and financial flows intra and inter organisations including suppliers, manufacturers, logistics providers, wholesalers, distributors, retailers, and customer's customer. Risk management in SCM is managing the SC risks through a broad partnership which focused on coordination or

collaboration to ensure profitability and continuity (Tang and Musa, 2011). Many different functions are involved in a SC consisting of marketing, manufacturing, product design, procurement, transportation, storing, warehousing, finance, and information technology within the network of organisations.

Tang (2006b) has explained that one can address the issue of SCRM along two dimensions: SC risk and mitigation approach. A SC risk is including operational risk and disruption risk that appear from material flow. On the other hand, mitigation of risks needs an approach to reduce or to eliminate risks that appear from uncertainty. Mitigation is including supply management, demand management, product management, or information management. Uncertainties can occur due to information that inaccurate, incorrect and less rapidly. Uncertain in customer demand, supply, and cost is types of operational risks. Types of disruption risks can cause by natural disaster such as earthquakes, floods, hurricanes, and man-made disasters such as terrorist attacks. In most cases, the disruption risks will be impact greater toward the business continuity than operational risk. Bullwhip effect is one case of the complicated problems in SCRM.

Various definition of risk has been summarised in some literatures (Khan and Burnes, 2007; Tang and Musa, 2011). In particular, term of risk and uncertainty in SC operations is still ambiguous. It should clear to distinguish. According to Tang and Musa (2011), risk is interpreted as unreliable and uncertain resources creating SC interruption; whereas uncertainty can be explained as matching risk between supply and demand in SC processes. We believe that uncertainty can trigger the risk occurrence. The outcome of risk impact and expectation of risk sources are two dimensions that are important in discussing risk. Specifically, risk issue is associated with negative consequences of impact (Christopher and Lee, 2004; Wagner and Bode, 2006). Uncertainty issue is difficult to define but it is have specific characteristic such as unpredictable, ill-defined and complex. A quality deficiency is an example of risk but it can be categorised as certainty because of predictable and well-defined. Otherwise, wars, strikes or terrorist attacks are examples as the real risk. Furthermore, a fundamental question is how to determine the level of risk because the expectation is described as probability or possibility. These questions has been became the reasons for having vague definitions of risk. These have been debated for centuries by many researchers. A broad discussion about risk assessment will describe below.

Tang and Tomlin (2008) have been identified the disruption risks that occur regularly. There are six major types of SC risks:

1 Supply risks. Number of suppliers will increase level of risk so that managing a small number of suppliers is more efficient. Risk mitigation can be done by reducing the cost of managing multiple suppliers and fostering better supplier relationships.

2 Process risks. Process is internal operations that consist of in-bound and out-bound logistics. These risks can be caused by fluctuations in effective capacity and quality. Many firms have invested famous concept such as total quality management (TQM), Six Sigma, lean and agile manufacturing to improve internal quality and capabilities.

3 Demand risks. Many firms have been selected a strategy to sell their products in multiple countries with expectation to increase revenue. A risk source of demand is not only the demand volume unpredictable but the demand mix too. Demand risk therefore encompasses uncertainties in both volume and mix.

4 Intellectual property (IP) risks. Sometimes a firm have made policy to develop their system by out sourcing or off-shoring. They have believed that it can result in lower manufacturing costs. It is difficult to protect IP and to eliminate the risk of counterfeits when a multinational firm out-sourced their manufacturing operations to their suppliers under certain licensing or contractual agreements.

5 Behavioural risks. A global SC network is always involving the large number of partners. The level of visibility and control can be reduced significantly the confidence of each SC partner. Kind of behavioural risk can be triggered regarding the following information: the replenishment lead time/order status quoted by upstream partners, and demand forecasts provided by downstream partners, etc. Corrective actions such as SC visibility, timely communication, and coordinated are needed to restore the confidence level of each SC partner.

6 Political and social risks. A global SC is subjected to social/political risks when multiple countries are involved. A different of policy or social situation in particular country where firms have been involved in global SC system is more contribute toward the risk occurrence. When a country is not stable then it will affect against the firms in the other countries.

Globalisation, improved infrastructure and information technology have led SCs to become longer and more complex, resulting in higher SC vulnerability (Tang, 2006a, 2006b). SCRM has become very important aspect for many firms. In context of globalisation, a financial crisis as political risk type is different from single suppliers defaulting in a SC network, as the entire supply network, including the focal firm, may be distressed. Furthermore, one could argue that the financial crisis may not only negatively affect the focal firm; there can also be positive repercussions (Blome and Schoenherr, 2011)

2.3 Risk assessment for SC

Risk assessment is one of steps in risk management process. Basically, the risk management process has the same phases in various environments. These steps are applicable to risk management in SC processes as well. A typical process of risk management consists of four steps (Tuncel and Alpan, 2010; Hallikasa et al., 2004) namely:

1 Risk identification is first step which recognise the uncertainties to be able to manage proactively. This step helps to develop a common understanding of the future uncertainties surrounding the SC. Risk sources are not easy to identify. Sources of SC risk are usually derived from material flow and information flow.

2 The second step is the risk assessment and prioritisation that are needed to be able to choose suitable management actions according to the situation of SC. It is important to assess the risk probabilities in the system and to identify the consequences of these risk events. Risk probabilities assessment is not an easy task and requires fidelity and accuracy the entire SC.

3 The third step is risk management actions. After risk identification and assessment, it gives a more specific indication and where we shall focus the actions. Generally, there are types of action as strategies for risk management, i.e., risk transfer, risk

taking, risk elimination, and risk reduction. The aim of management action is to reduce either the occurrence probability or the degree of severity of its consequences. These actions could be called reactive actions and proactive actions.

4 Risk monitoring is final process where the system is supervised to anticipate the risks occurrence. The company and its environment are dynamic, and this will stimulate the consequences that changed status of each event. The defined risk sources can be monitored to discover the potential increasing trends of risk probability or consequences.

A SC system involves numerous suppliers, service providers, and ends consumers that cause risks and vulnerability for everyone. Oke and Gopalakrishnan (2009) have argued that SC risks may be categorised into two fairly distinct categories inherent and frequent risks, i.e., high-likelihood or low-impact risks and disruption and infrequent risks, i.e., low-likelihood or high-impact risks. Analysis is not sufficient performed regard to one particular company, but potential domino effects upon all SC units and relations have to be reviewed (Pfohl et al., 2010). Role of SCRM is to investigate risks sources and make appropriate decision to reduce or eliminate the risk. Reducing the vulnerability of the entire SC can be achieved through the collaboration between players of the SC. Everyone must identify and manage internal and external risks of the SC. SC risks that failed to be anticipated have been proven disrupt companies to continue their operations. The magnitude impact is decrease market share significantly. That is causes a great loss and endanger the survival and development of enterprises. Therefore, risk preventive programme is very important for the companies. The success of managing risk will be able to make an expeditious response in the dynamic business environment (Yang and Li, 2010). Thus, risk management is not only preventing risks, but also increase the endurance to escalate market opportunities and enhance the overall competitiveness.

Table 1 A summary of the various models (selected for last five years)

Approaches	*Authors*	*Focuses*
Mathematical formulation	Goh et al. (2007), Scheller-Wolf and Tayur (2009), Yu et al. (2009), Ben-Tal et al. (2011), Schmitt (2011), Hahn and Kuhn (2011)	Supply chain network including inventory, profit, and total cost
Simulation	Dabbene et al. (2008), Jacxsens et al. (2010), Finke et al. (2010), Vilko and Hallikas (2011), Olson and Wu (2011)	Product quality and quantity
Analytic hierarchy process (AHP)	Schoenherra et al. (2008), Zhang et al. (2009), Faisal (2009), Yang and Li (2010), Xia and Chen (2011), Wang et al. (2011)	Evaluation of risk factors
Statistical testing	Tapiero (2007), Thun and Hoenig (2009), Pujawan and Geraldin (2009), Laeequddin et al. (2009), Foerst et al. (2010)	Risk factors analysis

Development of risk assessment models has attracted the attention of many researchers. In this section, we only focus on the discussion of risk assessment models of the SC alone. Basically, risk assessment model aims to quantify the probability of occurrence and risk impact. A summary of the various models that have been developed can be seen in Table 1. Previous studies have been showed that risk assessments have needed the perceptual decision-makers and data availability. Mathematical models will greatly

depend on the data availability while multi criteria decision-making (MCDM) methods can overcome the unavailability of data through the experience of experts for assessments. Meaning, models of risk assessment should consider historical data and experts perceptions so that events that may occur can be assessed by carefully

3 The proposed framework

3.1 Conceptualisation

Several of the published work in the framework of risk SC assessment is based on various perspectives and approaches. The initial steps must be performed before the framework development process is to examine some of the previous framework. Term of framework in this paper is a mechanism to assess the risk of SC that assembled from a collection of risk indicators and equipped with the principles of computational. As stated previously, framework that developed is intended to assess the risk of sustainable SC. Sustainable is becoming a keyword that distinguishes with framework previously developed by others. Many researchers have developed different framework/concept for managing SC risks. Unfortunately, framework that elevated the sustainable issues in a comprehensive have yet encountered. However, the previous study will be used in the development process of a risk assessment framework for sustainable SC.

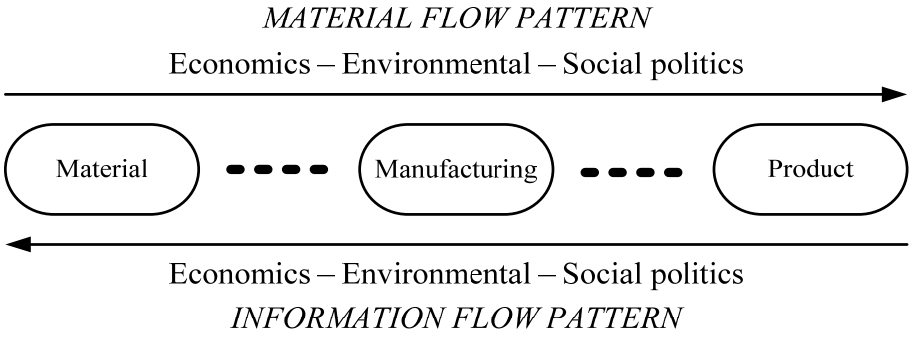
In general, several papers in majority must consider the economic aspects and environmental aspects of sustainable assessment. For example, some paper are Nicolliera et al. (2011), Büyüközkan and Berkol (2011), Winkler (2011), Gunasekaran and Spalanzani (2011), Giannakis and Louis (2011), Tang and Musa (2011), Paju et al. (2010), Fernandes et al. (2010), Ghadge et al. (2010), Chan (2010), Trkman and McCormack (2009), Chen and Sheu (2009), Hu and Bidanda (2009), Kim et al. (2009), Chung and Wee (2008), Seuring and Müller (2008), Tang and Tomlin (2008), Chung et al. (2008), and Svensson (2007). In contrast, most studies have ignored the social and politics aspects excluding Büyüközkan and Berkol (2011), and Paju et al. (2010). We are conclude clearly that green is not similar with sustainability term but a part of sustainability. Rather, sustainability is an extension of meaning of the green which coupled with social and political pressures such as law.

In addition, most papers discussed sustainable assessment in context of system among others Nicolliera et al. (2011), Büyüközkan and Berkol (2011), Winkler (2011), Gunasekaran and Spalanzani (2011), Giannakis and Louis (2011), Tang and Musa (2011), Fernandes et al. (2010), Ghadge et al. (2010), Chan (2010), Trkman and McCormack (2009), Chung and Wee (2008), Seuring and Müller (2008), Tang and Tomlin (2008), and Svensson (2007). Papers that discussed the process and products are a few, of which Paju et al. (2010) and Chung et al. (2008) for process and Chen and Sheu (2009), Hu and Bidanda (2009), and Kim et al. (2009) for product.

Conceptual thinking is conducted by analysing two types of thinking namely general framework of SCRM and assessment of sustainable SC. The content of two types the conceptual thinking will be analysed by observing diverse perspectives such as the constituent components, structuring the components and process of adoption. We studied some papers for last five years. We found that there are three aspects in risks of sustainable SC namely economics, environment and social politics aspects. Risks that related to SC operations to increase revenue and reduce operational costs. Risks related to

SC operations that cause negative influence or impact on the surrounding environmental conditions physically. Risks associated with SC operations that could potentially trigger social unrest and political decision. In addition, we classify the focus of risk assessment into product, process and a whole system. It is called as types of sustainable implementation. The proposed paradigm can be seen in Figure 1.

Figure 1 Conceptual in risk assessment of sustainable SC



In principle, the economics orientation is remains a major fundamental in the SC operations. All activities are managed by considering the several of environment and socio-political constraints. However, the final decision relating to production volumes, the types of materials used and other things have considered environmental and social politics issues. Material flow decided based on economic considerations that can be seen based on flow pattern from left to right. In contrast, the planning decisions triggered by socio-political issues as seen the information flow from left to right.

3.2 Structuring risk indicators

The next step is to identify and formulate risk indicators for each aspect. These indicators are identified by considering the product, processes, and information flow. Previous studies were show that assessment process should concern SC operations as a whole system. Product, processes and information flow are elements that interact with each other are called as a system. Three aspects of concern are economics, environmental and social politics. Economics aspect is a paradigm for managing the SC to maximise profit. Income is required the company to maintain its business viability. Through profits, a company can increase its competitiveness even it can expand its business. In this context, SC operations will use the resources such as material, energy and the other to produce products. The role of environment becomes an important aspect in this regard. Environmental aspect is an attempt by companies to make tradeoffs between economic benefits and environmental concern through natural resources utilisation and saving energy policies. Socio-political aspect is implementation policies by government such as laws or other regulations which constitute threat potential to continuity of company's operations.

The proposed framework has identified many indicators for each aspect. First, indicators of economic aspect are demand volume, product price, quality of finished product, production flow, timelines of delivery, product stock out, inventory cost uncertainty, manufacturing cost uncertainty, and bullwhip effect. Demand volume is number of demand in market. Demand volume is number of demand in market which fluctuating so that it is trigger uncertainty potentially. Product price is a product value that set by company to compete in the market. Quality of finished product is specification the product accordance with customer requirement. Production flow is number of stages in production processes by company to meet demand. Timelines of delivery is an ability to meet schedule which has be negotiated with customers. Product stock out is an event where demand cannot be fulfilled due to stock not exist or less in warehouse. Inventory cost uncertainty is fluctuation of inventory costs that cannot be estimated accurately. Uncertainty in manufacturing cost is determining production cost without certainty policy. Bullwhip effect is distortion in information flow of entire SC.

Second aspect is environmental concern with indicators are energy consumption fluctuation, waste unmanageable, reuse and recycle material failure, natural disaster, remanufacturing failure, environment violation, and technology shift. Energy consumption is usage various sources of energy and for different types of activity including manufacturing, transportation, lighting, etc. Waste unmanageable is unintended output that is be produced by manufacturing activities but not managed properly due to various things. Reuse and recycle material failure is activity that fail to produce product by using second-hand goods for material as well as remanufacturing. Natural disasters are natural events that become threat against the smooth operation of production and transportation. Remanufacturing failure is conducting correction operation to manufacture product with minor reject in accordance quality control. Environment demolition is various actions that damage the physical environment directly. Technology shift is a decision to replace technology that has risk of wasting energy and raw material usage.

Finally, the social politics aspects is an equally important to be considered in risk assessment of SC sustainability. Labour strike is not conducting production activities and other operational triggered by pretension for salary increasing. Mass demonstration is activity of massive community to reform policy issues related to politics. Environment act and others regulations is government policies that designed to regulate business activities. Local custom is belief and attitude of local communities in responding to various situations that considered bringing hazard. Facilities location is site to be denied its existence by public because of various considerations subjectively. Crime/terrorist attack is potential threats of terrorist that disrupt economics and business operations.

Various indicators that have been identified can be described in hierarchical structure as seen in Table 2. Level 0 is main level which reflects the overall risk level. The next level is first level as aspects of economic, environmental and social politics. Furthermore, level 2 is a collection of various risk indicators for each aspect. This hierarchical structure is needed to describe the relationship of each indicator as a whole.

Table 2 Hierarchical structure of risk indicators

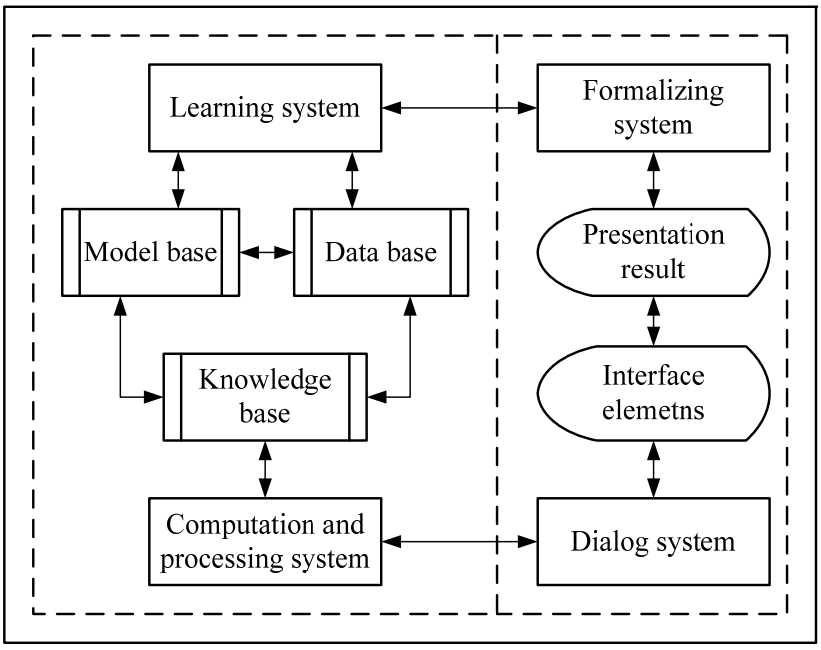
Aspects	*Indicators*
Economics	Demand volume uncertainty
	Product price uncertainty
	Quality of finished product
	Production flow
	Timelines of delivery
	Product stock out
	Inventory cost uncertainty
	Manufacturing cost uncertainty
	Bullwhip effect
Environmental	Energy consumption fluctuation
	Waste unmanageable
	Reuse and recycle material failure
	Natural disaster
	Remanufacturing failure
	Environment demolition
	Technology shift
Socio-politics	Labour strike
	Mass demonstrations
	Environment act and policy
	Local custom
	Facilities site
	Crime/terrorist attack

3.3 Operating system

From the risk indicators presented above, we built a framework as platform in designing decision support system of risk assessment for sustainable SC. The architecture of the proposed framework is consisting of model base and knowledge base that connected with user interface. Model base is a framework that serves as processor of decisions which has been given by decision-makers. Generally, content of model base is algorithms, methods, formulations, or others mathematical manner that used to process a set of inputs either numeric or non-numeric. This framework applied a method that developed by Yager (1993). We built a comprehensive procedure by to calculate a set of assessment from group decision-making process. The selected method that applied in a decision support

system will be advantage as well as drawback of the model. We believe that the selected method is appropriate because this method has been widely applied in decision-making groups. Base model will propose a compromise judgements based on different assessment of decision-makers. The procedure that built in model base will serve to process the aggregation of assessment results that has been made decision-makers for each indicator. Furthermore, aggregation results are further processed for each indicator to obtain aggregation level for all aspect. The process is operated by connecting between risk and severity.

Figure 2 A framework of operating system



Moreover, there are at least two kinds of knowledge that needed to make decision for problem solving: knowledge on risk mitigation, and knowledge on sustainability. The first aspect is taken care of in the knowledge base. The system requirements indicate that should provide facilities to support decision-maker with relevant data, information, and knowledge. Knowledge base is a very essential part of risk assessment in this framework. It stores information that had counted namely as specific performance indicators. Knowledge base also contains information about risk occurrence and risk severity problem for easy reference by later users. User interface and knowledge base are being linked so indicate that users can both obtain information from knowledge base and extend the knowledge base with their expert knowledge. Such information contributes to fulfilling the functional requirement of recognition and expression the proposed framework.

As mentioned previously, this framework requires the user interface that is useful for communication between users and system. User interface is consisting of input and

output that can use easier. With the help of various features, the user interface supports and guides users in executing each step in assessment steps. The user interface is designed at least incorporate the functionalities namely risk occurrence assessment, risk severity assessment, and results. The designed system is provide outcome namely an overall risk level, risk for each aspect, risk for each indicators, and advice for risk mitigation. The operating system can be seen in Figure 2.

Operation of decision support is arranged logically with the procedure that use input the non-numeric. The system is using a decision-making group that consist of three to seven people. This number is considered adequate to conduct risk assessments for operational, tactical and strategic. The proposed framework of assessment process that performed by people as well as model is specified in some steps namely:

Step 0 Top management determine number of decision-maker that involved in assessment process.

Step 1 Decision-makers who selected perform assessment of each indicators risk as well as severity for each decision-maker.

Step 2 System performs aggregation process of decision-makers assessment for each indicator of risk as well as severity

Step 3 System performs aggregation process of risk indicators to obtain the risk level of each aspect.

Step 4 System performs aggregation process of risk aspects to obtain the whole risk.

Step 5 System displays the advice of risk mitigation.

Step 6 Top management implement the recommendation.

Decision support framework that proposed can play a crucial role in the crisis decision-making process by allowing the top management to navigate large amounts of information quickly and compromising differences of opinion between the various parties who involved in the SC system. In addition, it is explore interrelationships between factors which may influence the decision.

4 Discussion

After the proposed decision support framework was built, we conducted a pilot test in a number of settings. Basically, this phase is primarily aimed in reviewing the requirement. We want to ensure that the requirements are clearly defined, consistent, and complete. The review focuses on the intended use, configuration management, and fidelity to be developed. The purpose of this test was primarily to identify potential drawbacks in the prototype and process descriptions. There are two types of processes that have been done: create a questionnaire and perform a computer programme. The questionnaire contains a set of risk indicators and scale of assessment. The questionnaire was sent to seven persons to fill out it. If there have felt less, they will provide comments. These seven

people are practitioners and academics in field of SC and logistics. Computer programmes testing carried out by filling out the values of where questionnaires filled out by the respondents. Then, running the programme is checked to ensure that programme has been working in accordance with the built assumptions and logic earlier.

The proposed model applies group decision-making approach. Consequently, application of this model involves some decision-makers. We recommend that number of decision-makers involved in risk assessment is three to seven persons. They are persons who are believed to have the capability and good understanding toward discussed issue. For example, the involved persons in decision-making group for this assessment include general manager, production manager, procurement manager, purchasing manager, marketing manager, research and development manager, and other relevant. Group decision-making approach that applied in this framework is to accommodate the culture in many companies often conduct a meeting to discuss and make decisions in problem solving. Certainly, everyone has own tendencies to solve the problem. These tendencies will compose the conflicts of opinion. The decision support framework can facilitate to obtain the compromise through the aggregation process. Decision support framework is not intended to replace the role of humans to the computer but as a tool to maintain consistency of decision-makers.

Model provides the structural technique that is applicable to recognise the processes and the dynamics of SC system. We selected the judgement method for the decision process. In this model, we assume that the decision-makers usually make the work plan collectively, face to face, and share the information. Risk assessment of sustainable SC is a process of information processing and assessment failure is due to insufficient or wrong information. This model is a kind of knowledge formulated in a set of rules that called as organisational decision knowledge. Languages, words or linguistics variable are decision knowledge manner that be articulated in decision assessment. For example, when facing complex situation in the logistics, a logistics manager can make decision rapidly. Manager who has made decision cannot articulate how he made the decision whereas his decision is correct. It is prove that decision knowledge consists of one's experiences, wisdom, intuition, etc. It is usually called as tacit knowledge. Zhong (2008) described characteristic of organisational decision knowledge namely:

- purpose is serve the decision-making (especially semi- and unstructured decision-making)
- carrier is tacit decision knowledge that stored in one's brain
- types is know-how knowledge that takes a large proportion
- focuses is reducing or removing cognitive biases, improve mental models, supporting and improving decision-making.

Overall, it helps firms to:

a satisfy the stakeholder expectation (customers, government, non-government organisation) by designing and developing sustainable SC

b ensure business growth and profitability

c increase customers' loyalty by formulating proper SC strategies.

Firms can easily evaluate different SC strategies using the assessment result. The risk assessment model will help them to anticipate failure in the long-term return on investment of tentative business strategies. In addition, it recommends risk mitigation so that losses potential can be eliminated and reduced.

Information and computer technology has been applied in many areas including SCM. Application artificial intelligence and the internet for decision support can greatly increased the flexibility and expansion ability to assess risk of sustainable SC. This is also the main development mode of the framework when implemented for particular SC. The decision support framework based on natural language has become an interactive human-machine system that has a strong learning ability and adaptation.

5 Conclusions and further work

We have proposed a conceptual model of decision support for risk assessment of sustainable SC in this paper. It has provided functional capabilities: modelling, data management, and knowledge management to support all decision-making processes. Implementation of the proposed framework should provide personalised support, integrity, and other important capabilities for the support of increasingly complex problems in SCRM and sustainable SC. Until recently, stakeholder needs change paradigm that focused on economic expectations such as reduced total cost of SC become maximising sustainability.

We have introduced new paradigm in sustainable assessment in SC operations. We have believed that environmental factors need to be divided into two aspects: the physical environment and socio-politics aspects. Material flow pattern is managed refer to economics considerations and on contrary, socio-politic is become the main driving to produce the product volume, types of materials, and energy consumption. The intersection of material flow and information flow is production volume and variety of products. It has proved that the paradigm is feasible and reliable to be applied in the risk assessment of sustainability in a SC system.

In accordance with system approach, we have designed interrelationship between data base, model base and knowledge base in the proposed framework. It is important manner in designing a decision support system. All risk indicators are arranged in the structure hierarchical. Risk indicators have been verified by experts to ensure eligibility. The proposed decision support is applying non-numeric under multi decision-maker's assessment.

We have presented a decision support framework that applicable in principle. The proposed system provided for eligibility proof to be implemented, but still needs to be extended in knowledge base content. In addition, user interfaces and presentation display need to be polished in order to user friendly. However, the decision support framework does not need to be changed relating to functionality. Additional development is needed for practical use in reality.

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