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Interpretive Structural Modeling and House of Risk Implementation for Risk Relationship Analysis and Risk Mitigation Strategy

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Abstract. *The increasingly fierce industry competition causes each company to have strong supply chain activities as part of the company to survive in an environment full of competition. In carrying out supply chain activities, it is certainly inseparable from supply chain risks that can disrupt supply chain activities. Therefore, it is essential to know the key risks as the risks that trigger the other risks in the supply chain. This study aims to identify the relationship of risk and to determine risk mitigation strategies to reduce the causes of the risk by implementing Interpretive structural modeling (ISM), and the house of risk (HOR) approaches. The ISM approach is applied to identify relationships among specifics risks, which define as key risks, which are risks that most influence the occurrence of other risks. These key risks obtained are then processed using the HOR method to determine the priority of risk mitigation actions. From the ISM approach, four key risks have been obtained, such as the risk element of inputting data error when entering the number of goods and specifications, product specification errors desired by the customer, frequent changes in customer design requests, and revisions to the design drawings. Then HOR method gave four recommended priority mitigation actions: updating information on a scheduled basis, conducting briefings every day before work, coordinating and reconfirming requests for product specifications, and implementing more stringent worker selection procedures. The linkage of the causes of risk, the validation of the ISM model statistically, and the weighting of the triggered criteria are several aspects that further research is needed.*

Keywords: *risk mitigation, interpretive structural modeling, house of risk, risk relationship analysis, supply chain management*

I. INTRODUCTION

The rapid development of the industry has led to increased business competition between companies in manufacturing and service companies. Supply chain management is a series of production processes and activities that are ranging from purchasing raw materials from suppliers, processing raw materials into finished goods, storage, inventory, and shipping finished products to retail and final customers (Pujawan & Mahendrawathi, 2010). The implementation of supply chain management will assist the company in forming a secure network to survive in a competitive industrial environment.

A reliable supply chain network and the application of proper supply chain management does not guarantee a supply chain network despite the risk. This is due to the scope and complexity of the supply chain network itself. The risks contained in the supply chain are different between one supply chain of a company with another company's supply chain, depending on the supply chain activities owned by the company itself. Potential risk arises from several causes including increasingly complex supply chain network, increasingly dynamic environmental situations, the life cycle of product, interaction between different organizations in the supply chain network and high dependence on suppliers (Punniyamoorthy et al., 2013)

Risk drivers are arising from the external environment, from within an industry, from within a specific supply chain, from specific partner relationships, or specific activities within

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the organization (Olson & Dash, 2010). According to Pujawan and Geraldine (2009), the risk occurs due to several risk factors, and the cause of risk is events that can encourage risk.

Risks that occur have an impact on the company's performance in the long term and short term. Moreover, the company can stop operating or go bankrupt if the risk is not appropriately managed (Tang, 2006). For example, a company experiences delays in delivering products to the consumer, which causes the company to need to negotiate their delivery date as requested by customers. Most companies and SMEs have faced dealing with risk, especially those who produce deteriorate products such as fresh fruits. For example, SMEs that produce Salak Fruit have faced risk events such as damage or deterioration in quality, damage during storage, decrease production, run out of supplies, changes in the number of orders, product returns, delays in processing, damage in handling, and contamination during processing (Risqiyah & Santoso, 2017). Likewise, large industries have to deal with risk events such as those occurring in the shipyard industry (Cahyani et al., 2016)

Therefore, currently, industry players need to be aware of the importance of implementing supply chain risk management to survive in a risky environment. Ulfah et al. (2016) argue that supply chain risk management is important in keeping the supply chain system uninterrupted because it never knows what will happen in the future. Supply chain risk management is a proactive approach to identify, analyze, and manage risks that are faced company. In general, supply chain risk management stages are identification risk, analyze risk, evaluation risk, and risk mitigation (Hallikas et al., 2004; Norman & Liondorth, 2004; Karningsih et al., 2010). To manage risks and mitigate risks in supply chain risk management are not an easy task for the company's stakeholders (Widiasih et al., 2015) and needs to understand the relationship between risk agents and among risk.

Supply chain management does not only lie in the amount of risk in the supply chain but also needs to pay attention to the relationship between one risk and another risk. Pujawan and Geraldin (2009) stated it is essential to investigate the relationship between one risk and another risk because the occurrence of risk could be triggered by another threat. An understanding of the relationship between one risk and another chance will significantly assist in making the most effective decisions to reduce supply chain risk (Chopra & Sodhi, 2004). Preventive actions are the final step of supply chain risk management to minimize risks and increase company performance productivity.

In recent decades, a lot of research has been discussed regarding supply chain risk and has become a hot topic for industry players. Pujawan and Geraldin (2009) combined the FMEA and QFD methods to create *House of Risk* (HOR), a method to design preventive action that reduces the causes of risks arising from fertilizer companies. This research has successfully identified 22 risk events. Ulfah et al. (2016) applied the HOR method to identify risks in the refined sugar industry and mitigation actions needed to reduce the causes of risk in which the study's result was defined as many as 47 risk events. Similar research was conducted by (Ratnasari et al., 2018) using the HOR method to identify risks in newspaper company and mitigation actions needed to reduce the causes of risk, where the results of the study were identified 24 risk events.

Research that uses the HOR method in company supply chain risks has only identified supply chain risks and mitigation action needed to reduce the causes of risk without regard to the relationship between one risk and other risks in the company's supply chain. Inderawati (2013) uses the *Interpretive Structural Modeling* (ISM) method in companies located in East Java to identify risks in the supply chain, from which this research successfully identified 32 risk events. This research did not design mitigation actions to reduce the cause of risk but looked in terms of the relationship between one risk and another. (Linstone et al., 1979) argue that ISM is a method to identify the relationship among the considered elements, which further leads to perceiving the system's structure better (Jena et al., 2017).

(Deshmukh & Mohan, 2017)—define this ISM method needs classification of the variables according to their position on driving and dependence power, and this is done by using Matrices Impacts Cruises Multiplication Applique a un Classement (MICMAC) and fuzzy logic is applied to get a precise approximation in the analysis. In the context of supply chain risk management, ISM method has been used in previous studies such as research by (Pfohl et al., 2011) that using ISM method to the structural analysis of potential supply chain risks; and Inderawati study (2013) that successfully identified 32 risk events in her research in companies located in East Java by implementing ISM method. This research did not design mitigation actions to reduce the cause of risk but looked in terms of the relationship between one risk. Thus, the ISM method can map the relationship between risks and produce key risks that most trigger other risks.

Very little research has addressed the risk problem in the company's supply chain to examine the relationship between the risks in the supply chain and provide mitigation action accordingly. It is deemed essential to find out the relationships among risk events to mitigate risk agents. Therefore, the ISM and HOR methods are integrated into this research to identify risks that occur in the company's supply chain, modeling the relationship between the risks and define proactive actions to mitigate risk agents. Hence, it is expected that this study will contribute to a deeper understanding of supply chain risk, specifically on the ISM and HOR methods.

II. RESEARCH METHOD

This research conducted at PT. XYZ is engaged in the printing industry and produces molds such as 600 ml bottle molds and 55 ml anti-sealed bottles. This study suggested the integration of ISM and HOR methods. The ISM method used to obtain critical risks, the risks that most trigger other risks in the company's supply chain, whereas the HOR method is used to identify the causes of risk and to determine mitigation actions. The HOR method is divided into 2 phases: HOR phase 1 and HOR phase 2. HOR phase 1 is used to identify the causes of risk from critical risks, which we obtained from the ISM method. Then priority risk-causes are chosen to mitigate further actions needed to reduce the causes of risk in HOR phase 2 and determine the priority of mitigation actions that recommended to the company.

In this section, we proposed a framework for the integration of ISM and HOR methods. It can be seen in Figure 1.

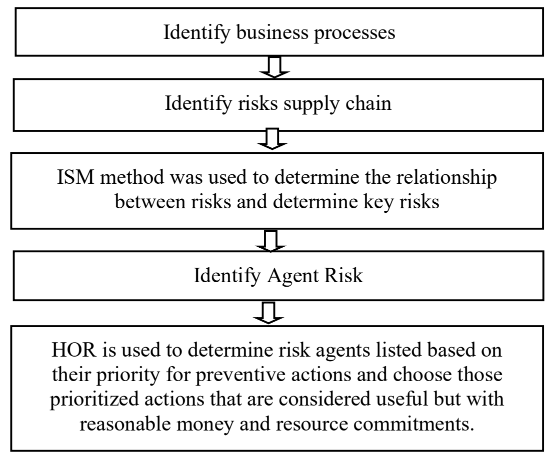

Figure 1. Flowchart Research

There are five main stages carried out in this study. Firstly, identify supply chain activities or business processes based on five core supply chain processes (SCOR), namely plan, source, make, deliver, dan return. Secondly, identify risks that occur in the supply chain activities or business processes (Supply Chain Operation Reference - SCOR). These two stages have been done by using participatory observation during 6 (six) months from October 2019 until March 2019 and is accompanied by an interview with the production manager.

The third stage is the interpretive structural modeling method to model the relationship between the risks in the supply chain and identify the causes of threats to critical risks in the supply chain. The result of this ISM method is used as an input for the next two stages, which is the implementation of the HOR method.

According to (Pfohl et al., 2011), ISM is a method that helps managers in identifying and understanding the relationship between the elements of supply chain risk at different levels. Steps of ISM method are as follows:

1. Build a *structural self – interaction matrix* (SSIM). SSIM is a paired comparison matrix between two elements that are filled out by respondents in the form of questionnaires. The filling is done using 4 symbols that describe the direction of the relationship between the elements of risk, i.e. :
   - Symbol V states the relation of risk element *i* to risk element *j,* in the same direction, where risk element *i* will trigger risk element *j*.
   - Symbol A, which states the relation of risk element *j* to risk element *i,* in the same direction, where the risk element *j* will trigger the risk element *i.*
   - Symbol X, which states the relation of risk element *i* with a relationship of risk element *j,* two ways, where the risk element *i* and risk element *j* trigger each other.
   - Symbol O which states there is no correlation between risk element *i* and risk element *j* so that they do not affect each other
2. Creating *a reachability matrix* (RM) and checking *transitivity*. *Reachability Matrix* is a step to change SSIM into a binary matrix. The thing to do is convert the symbols V, A, X, and O with the number 0 and 1. The conversion rules are :
   - If enter (i,j) in SSIM is denoted by V notation, then in RM enter (i,j) becomes 1 and (j,i) becomes 0.
   - If enter (i,j) in SSIM is denoted by notation A, then in RM enter (i,j) becomes 0 and (j,i) becomes 1.
   - If enter (i,j) in SSIM is denoted by X notation, then in RM enter (i,j) becomes 1 and (j,i) becomes 1.
   - If enter (i,j) in SSIM is denoted by O notation, then in RM enter (i,j) becomes 0 and (j,i) becomes 0.

   Transitivity checks are carried out to reach the *final reachability matrix* (FRM). Checking transitivity is done to check the statement if risk A has a relationship with risk B and risk B has a relationship with risk C, it can be concluded that risk A has a relationship with risk C. *Transivity* is only performed on reachability matrix cells with a value of 0 to find out whether or not they have met the transivity rules. This stage not only checks the result of transivity but also obtains the dependence value and drives the power value of each risk. The value of drive power and dependence, these risks will be categorized into 4 risk elements. According to (Pfohl et al., 2011), risk elements can be classified into 4 categories:
   a. *Autonomous* is a risk element that has weak drive power (trigger ability) and soft dependence power.
   b. *Linkage* is a risk element that has reliable drive power (trigger ability) and durable dependence power.
   c. *Independent* is a risk element that has reliable drive power (trigger ability) and weak dependence power.
   d. *Dependent* is a risk element that has weak drive power and durable dependence power.
3. The determination of partition level aims to build a diagram of the reachability matrix. In determining the partition level, there are *reachability set, antecedent set,* and *intersection set*. *Reachability set* describes what elements of risk *j* are related to risk elements i_n and antecedent set describes what elements of risk i are similar to elements of risk j_n. While the *intersection set* describes the elements that appear together in the *reachability set* and *antecedent set* columns. Level partition is done by paying attention to *the reachability set* and *intersection set*. If the *reachability* and *intersection set* column has the same number, then the risk elements are categorized at the same level. Iteration will continue until you find all levels at each risk.
4. Making a conical matrix where in this conical matrix, the level of the elements of risk will be sorted so that the sequence of risk will be obtained from the lowest to the top. Conical matrix forms will be the basis for building the ISM model. In the ISM model, there are elements of risk that have been sorted from the risks that are at the top, middle to bottom levels.
5. Building the ISM model developed based on

the results of the conical matrix form in which the model was built, the risk elements have been sorted from the risk elements at the top, middle level to the lowest level. In the ISM model, some arrows connect a risk with other risks that have a relationship with other risks. Risks that begin with a line states that the risk is a trigger risk, while the risk that ends with an arrow indicates that the risk is triggered.

The output of the ISM method will be obtained key risks, those risks that most trigger other risks in the company's supply chain. Then the data will be processed using the *house of risk* (HOR) method after obtaining the data of the causes of risk from each critical risk that has been successfully identified through the ISM method.

Pujawan and Geraldine (2009) developed a model known as the *House Of Risk* (HOR), which is a model that combines the FMEA dan HOQ methods. The HOR method is divided into 2 stages HOR phase 1 to determine the priority causes of risk for mitigation actions and HOR phase 2 to determine priority mitigation actions to be recommended to the company. The stages in this study for the HOR phase 1 and HOR phase 2 methods are as follows :

For the stages of HOR, phase 1 are as follow:

1. Risk impact assessment (*severity)* is the stage where the key risks obtained from the ISM method will be assessed. Impact assessments are carried out by respondents using a scale of 1-10 where scale 1 shows no impact, and scale 10 shows the impact of the hazard (Shahin,2004).
2. An assessment of the emergence rate of causes of risk where the causes of risk from key risks will be assessed by the respondent's rate of emergence. The level of occurrence of a risk event is expressed as the magnitude of the frequency of occurrence of risk events. The rate of occurrence assessment uses a 1-10 scale risk (Shahin, 2004).
3. The assessment of the correlation of risks and risk events is the stage in which the assessment of the correlation between the risk and risk events is conducted by the respondent. Correlation assessment is done to find out how much risk events can lead to a risk. The magnitude of the correlation is measured using a scale of 0, 1, 3, 9, where scale 0 represents no correlation, scale 1 represents a weak correlation, scale 3 represents a moderate correlation, scale 9 represents a high correlation (Pujawan & Geraldine, 2009).
4. Determination of the aggregate risk potential (ARP) value, in which the ARP value is used as a basis in determining the priority risk events, must be taken as a mitigation action.
5. Pareto diagrams are tools used to determine the priority of risk events to be carried out mitigation actions.

The output of HOR phase 1 is the priority of risk events to be taken mitigation action. The priority of risk events will be input in HOR phase 2. The stages of HOR phase 2 are as follows :

1. The design of mitigation actions is the stages carried out by designing mitigation actions against risk events obtained from the HOR phase 1 method.
2. Correlation assessment of risk events and mitigation actions is the stage of evaluating the correlation between risk events and mitigation action by the respondent. The correlation measure using the scale 0, 1, 3, 9, where scale 0 states there is no correlation, scale 1 indicates a weak correlation, scale 3 indicates a moderate correlation, scale 9 indicates a high correlation (Pujawan and Geraldine, 2009).
3. Assess the level of difficulty of mitigation action using a weighting scale of 3,4,5. Scale 3 states mitigation is easy to implement, scale 4 states mitigation is rather challenging to implement, scale 5 states mitigation is difficult to apply (Pujawan and Geraldine, 2009)
4. Determination of the value of the *effectiveness to difficulty ratio* (ETD) is used as a basis in determining the priority of mitigation action to be recommended to the company.
5. Pareto diagrams are tools used to determine the priority of mitigation actions to be recommended.

The output from the HOR phase 2 is the priority of mitigation actions that will be recommended to the company.

III. RESULT AND DISCUSSION

Identification risk and activities of supply chain

The identification of supply chain activities becomes an important stage in supply chain risk. This activity not only to identify risk events but also to trace the relationship between risk events. This activity starts with mapping a business process divided into a plan, source, make, delivery, and return. Each company has a different business process flow. Therefore, it is necessary to interview with company stakeholders to discuss the business process in detail. The results of this activity obtained 47 risk events that can be seen in Table 1. Next, 47 risk events will be processed using the ISM method.

Interpretive Structural Modeling (ISM)

Based on the research (Deshmukh & Mohan, 2017), classification of the variables according to their position on driving and dependence power is done using (MICMAC). The purpose of MICMAC analysis is to analyze the driver power and dependence power. It is done by determining the key factors that drive the system in various categories, as shown in Figure 2. Based on their driver power and dependence power, these factors have been classified into four categories, i.e., autonomous, linkage, dependent, and independent (Attri et al., 2013).

Autonomous factors in group 1 are these factors have weak driver power and weak dependence power. There are 37 risk events (E4, E6, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E21, E22, E24, E26, E27, E28, E29, E30, E32, E35, E36, E37, E38, E39, E40, E41, E42, E43, E44, E45, E46, E47) as elements that is categorized as a autonomous factors in this research. Group II are dependent factors where these factors have weak driver power but strong dependence power. There are 5 risk events E7, E8, E23, E31, dan E33. Group III are linkage factors where these factors have strong driver power as well as strong dependence power called the key factors.

However, in this research, no element risk event is included in the linkage factor. Group IV are independent factors where these factors have strong driver power, but weak dependence power called key factors. There are 4 risk events E1, E2, E23, and E5. It can be seen in Figure 3.

The partition level determination aims to build the ISM model from the *reachability matrix.* The process of determining the partition level is done through several iterations until the results obtained degrees for the risk element. In the

Table 1. Identification Risk Events

Major Process	***Sub-Process***	**Risk Events**	**Code**
Plan	Acceptance of product design requests	Error inputting data when entering item quantities and specifications	E1
		Incorrect product specifications desired by the customer.	E2
	Making product design drawings and price quote estimates	Frequent changes in the image of the customer	E3
		Difficulty in estimating price quotes	E4
	Providing detailed pictures and estimated price quotes	There was a revision of the design drawings	E5
	Price negotiation process	Negotiations are not going well	E6
	Financial planning of supply chain activities	Incompatibility of supply chain activities with financial planning	E7
	Issuance of the purchase order	Delay in issuing purchase orders	E8
	Issuance of work orders	A mismatch between purchase orders and issued work orders	E9
	Production Planning	The production plan underwent a sudden change	E10
	Material planning and control	Discrepancies between recorded stocks and those used and available	E11
	Capacity planning	Capacity is not as planned	E12

Table 1. Identification Risk Events (continued)

Major Process	***Sub-Process***	**Risk Events**	**Code**
Source	Making a list of material requirements	Error in determining the material needed.	E13
		The estimated amount of material requirements is inaccurate.	E14
	Checking raw materials in the warehouse	Raw materials are not available/used	E15
	The process of procuring raw materials	Purchasing does not accept documents for requests for purchase of materials	E16
		Purchase orders for late delivery of materials	E17
		An evaluation of the material request document was made late.	E18
		The quality of raw materials from suppliers decreases	E19
	Scheduling delivery of raw materials	Delay in receipt of material from the supplier	E20
		Raw material supply has been disrupted.	E21
	Recording material reports received	Material that came not recorded in full	E22
	Payment of purchase orders to suppliers	Late payment of the purchase order to the supplier	E23
Make	Provision of product design drawings and production planning documents	Production planning documents not updated	E24
	Production scheduling	The production schedule has been delayed	E25
		A mechanical problem occurred.	E26
	Production process and production control	Error in understanding product design drawings	E27
		An inefficient process has occurred.	E28
		The machine is experiencing downtime.	E29
		An error occurred in setting the machine.	E30
	Product checking	There was a revision of the production results	E31
		There was a decrease in dimension and visual quality during the process.	E32
	Scheduling the delivery of the finished product	Late delivery schedule for finished products	E33
Deliver	Selection of transportation services	Inaccuracy in determining shipping transportation	E34
	Issuance of travel permit	Delay in the issuance of travel documents	E35
	Delivery process	Interference occurred in shipping the finished product	E36
		Product delivery error	E37
		The product has been damaged during travel.	E38
		The packaging has been contaminated during the trip.	E39
	Shipping bills to customers	A late bill payment occurred	E40
	Record of shipping goods and paying bills	The difference between recording and physical delivery of goods	E41
Return	Acceptance of product complaints	Product complaint response is too long	E42
	Estimated product repair time	Inaccuracies in product repair time estimates	E43
	Handling repairs of repellent products	Delay in the process of returning the product from the customer	E44
		The handling of repairs to the reject product takes too long.	E45
		Material deficiencies in the process of repairs of refined products	E46
	Handling shipments of repairs of refined products to industrial users	Late delivery of new products to the user industry	E47

reachability matrix, the *reachability set* and the *antecedent set* will be obtained. Based on the results, it is element risks divided into 17 levels. Making a conical matrix where in this conical matrix, the level of the elements of risk will be sorted so that the sequence of risk will be obtained from the lowest level to the top level. Conical matrix forms will be the basis for building the ISM model. In the ISM model, there are elements of risk that have been sorted from the risks that are at the top, middle to bottom levels. The ISM model was built; the elements of risk have been sorted from the risks that are arrows connecting one chance with another risk that has

Elemen	*Reachability Matrix*																																															*Drive Power*	*Rank*
	Risiko Ej																																																
Risiko Ei	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	E26	E27	E28	E29	E30	E31	E32	E33	E34	E35	E36	E37	E38	E39	E40	E41	E42	E43	E44	E45	E46	E47		
E1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	1
E2	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	2
E3	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	3
E4	0	0	1	1	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	4
E5	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	3
E6	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11
E7	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12
E8	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	9
E9	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8
E10	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	5
E11	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	6
E12	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	13
E13	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	11	5
E14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	10
E15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	5	11
E16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	12
E17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	11
E18	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	6
E19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8
E20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	10
E21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	10
E22	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10
E23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14
E24	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11
E25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	13
E26	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8
E27	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7
E28	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8
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E30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8
E31	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10
E32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11
E33	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	13
E34	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0	1	7	9
E35	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	13
E36	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	1	0	0	0	0	0	0	1	8	8
E37	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	13
E38	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	1	9	7
E39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	7	9
E40	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	13
E41	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	13
E42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	5	11
E43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	3	13
E44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	4	12
E45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	4	12
E46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	4	12
E47	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	3	13
Dependence	1	2	5	5	5	6	32	18	10	6	3	8	6	11	16	3	11	3	1	3	3	1	1	1	31	1	1	14	6	2	20	12	31	1	1	2	1	3	4	7	1	1	5	2	5	9	10		
Rank	18	17	14	14	14	13	1	4	9	13	16	11	13	8	5	16	8	16	18	16	16	18	18	18	2	18	18	6	13	17	3	7	2	18	18	17	18	16	15	12	18	18	14	17	14	10	9		

Figure 2. MICMAC analysis

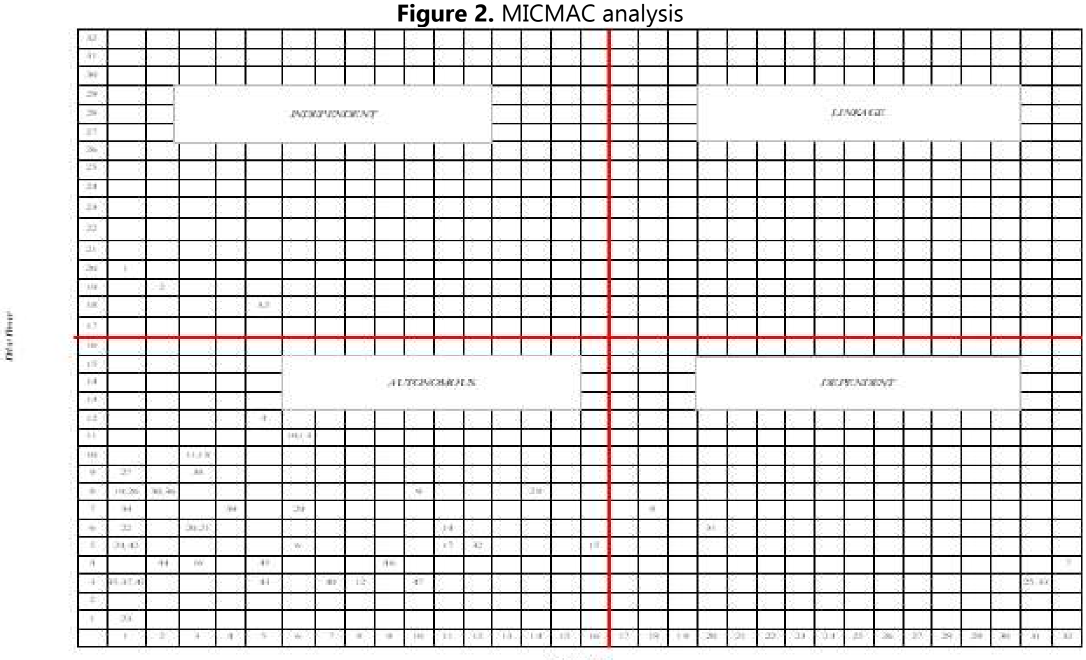

Figure 3. Driver Power-Dependence

a relationship. The risk element that starts with a line states that the risk element is a trigger risk, while the risk element ends with an arrow indicating that the risk element is triggered.

House of Risk (HOR)

The HOR method is divided into 2 stages. HOR phase 1 is to determine the priority causes of risk for mitigation actions, and HOR phase 2 is

Table 2. Identify Risk Agent

Major Process	*Sub-Process*	Risk Events	Risk Agent
Plan	Acceptance of product design requests	Error inputting data when entering item quantities and specifications (E1)	Lack of understanding in-unit fields (A1) Inaccuracy in inputting data when entering the number of items specifications (A2) Lack of data validation between marketing and customers (A3) Lack of understanding in unit fields (A3)
		Incorrect product specifications desired by the customer (E2)	Specification product requests from customers are unclear (A4)
	Making product design drawings and price quote estimates	Frequent changes in the image of the customer (E3)	There are no valid product data or desire customer. (A5) Periodic information that causes many design changes (A6)
	Providing detailed pictures and estimated price quotes	There was a revision of the design drawings (E5)	The product changes that have been fixed (A7)

to identify priority mitigation actions to be recommended to the company. The output from the ISM method in the form of key factors is used for HOR phase 1 data processing. In phase 1, the selected key risks are identified as risk agents, and seven risk agents are identified, as shown in Table 2.

Next, there is an assessment based on the severity of each risk event, the occurrence of risk agents, a correlation between risk agents and risk events. These factors are used to calculate the aggregate risk potentials of each risk agents (ARP). The result of this can be seen in Table 3. As an illustration, risk agent number 1 (A1). The likelihood of this agent occurring is 6 on the 1-10 scale. The risk agent has four risk events, each with a degree of severity 7, 5, 3, 3. Then, risk agent A1 has a moderate correlation with one risk event (E1) and does not correlate with three risk events. Hence, the ARP of a risk agent is accounted as follows:

$$ARP1 = 6x [3 (7)+ 0(5) + 3(0) +3(0)] = 126$$

As can be seen from Table 3, the calculated value ranges from 40 – 441. The Pareto diagram of the aggregate risk potentials for all risk agent A6, A3, A4, A1, A7, A5, and A2 is shown in Figure 4. Further analysis shows that four risk agents contribute to 80% percent of the total ARP A6, A3, A4, and A1.

The HOR phase 2 framework can be used to identify and prioritize proactive action to purpose maximize the effectiveness of effort based on resource and financial commitments. The HOR2, which presents the four risk agents with eight proposed measures, is depicted in Table 4. The priority for each action is obtained based on the values of the effectiveness to difficulty ratio of action k (ETD)k. The higher the ratio is, the proposed action. A higher rate reflects the money and other resources needed to perform the corresponding action. There four mitigation action priorities updating information on a scheduled basis (PA1), carrying out briefings every day before work (PA3), coordinating and reconfirming related to product specification requests (PA4), and implementing stricter worker selection procedures (PA7).

IV. CONCLUSION

There is a relationship between one risk and another risk in the company's supply chain modeled by the ISM. There are 4 key risks have been obtained, namely data input when entering the number of goods and specifications (E1), product specifications desired by the customer (E2), frequent changes in customer design requests (E3), and revisions to the design drawings (E5) is categorized independently.

Table 3. Calculate Aggregate Risk Potential (ARP)

Core Proses	Risk Events (E_i)	Agents Risk (A_j)							*Severity* (S_i)
		A1	A2	A3	A4	A5	A6	A7	
Plan	E1	3	1	9		1			7
	E2	0			3		9	1	5
	E3	0			3	1	3	1	3
	E5	0			1		3	1	3
Occurrence (O_j)		6	4	3	5	4	7	5	
Aggregate risk potential (ARP)		126	28	189	135	40	441	55	
Rank		4	7	2	3	6	1	5	

Table 4. House of Risk Phase 2

Risk Agents (A_j)	Risk Agent Actions (A_j)								ARP
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	
A6	9								441
A3	0	1	3						189
A4	0			3					135
A1	0	1	3		3	3	3	3	126
Total Effectiveness of Action (TE_k)	TE_1 = 3969	315	945	405	378	378	378	378	
Degree of difficulty performing an action (D_k)	D_1 = 3	3	3	3	4	4	3	3	
Effectiveness to difficulty ratio (ETD_k)	ETD_1 = 1323	105	315	135	95	95	126	126	
Rank	1	5	2	3	6	6	4	4	

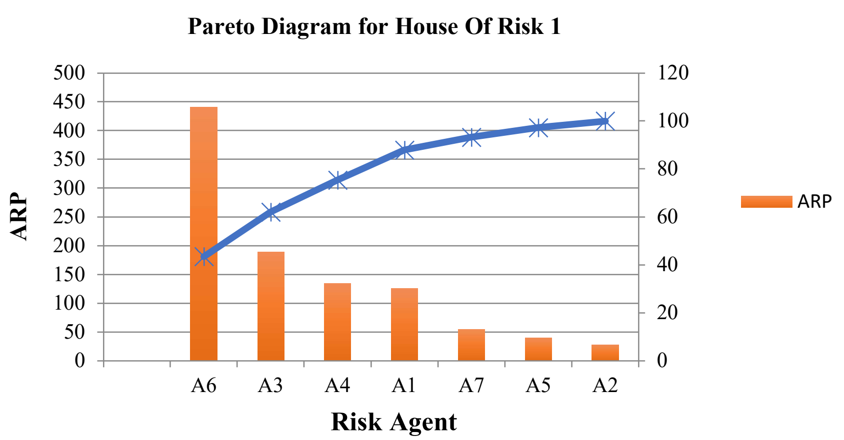

Figure 4. Pareto Diagram

The house of risk phase 1 stage (HOR1) has obtained seven risk agents. Furthermore, these risk agents have been assessed and calculated their aggregate risk potential (ARP) values. Based on Pareto diagram is obtained four risk agents have contributed to 80% of total ARP value namely periodic information that causes design changes (A6), lack of understanding in the unit field (A3), request for product specifications from customers are unclear (A4), inaccuracy in inputting data when entering the number of items and specifications (A1). For the house of risk phase 2, the risk agents have eight proposed actions. The priority for each step is obtained based on the values of the effectiveness to difficulty ratio of action k (ETD)k. The higher the ratio is, the proposed action. There are eight recommended mitigation action and four mitigation action priorities are obtained namely updating information on a scheduled basis (PA1), carrying out briefings every day before work (PA3), coordinating and reconfirming related to product specification requests (PA4), and implementing stricter worker selection procedures (PA7).

Pujawan and Geraldin (2009) stated that the House Of Risk (HOR) method could be easily implemented because the procedure would still be the same. However, this previous method work ignored the dependence on risk events. Suggest Pujawan and Geraldin (2009) need to dependencies could happen in reality. ISM methods can be used to vendor selection (Mandal & Deshmukh, 1994); (Oktavia et al., 2019) (Maheshwari et al., 2018) argue the ISM method for analyzing advertisement effectiveness in the Indian Mobile Phone. (Raj et al., 2012) ISM method for analyzing the mutual relationship between factors affecting the flexibility in FMS.

It is recommended for future research that focus group discussion (FGD) with supply chain parties is needed, considering the dependence relationship among risk agents action. In reality, these dependencies could happen; thus, the ANP method is suggested to reduce it.

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