DESIGNING SUPPLY CHAIN RISK MITIGATION STRATEGY IN THE CABLE SUPPORT SYSTEM INDUSTRY OF PT. X

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ABSTRACT

Every company needs to be aware of the importance of product and service quality to improve the competitiveness. To realize the quality of those products and services, each company needs to rely on the quality throughout the supply chain focusing on speed, quality, and flexibility as a way to respond to customer's needs to create superior customer value. In every activity of the supply chain system, the firms having extensive supply chain systems was usually confronted with the complexity of products or services that result in risk. The disruption of the supply chain process resulted in the inhibition of the company's production process which affected the delays in the delivery of goods or products to the consumers. The approach to manage the risk is known as risk management. However, current risk management is increasingly complex due to the emergence of various issues that not only increase the various risks, but also gives domino's effect in which there is a correlation relationship between the risks and the relationship between the causes of risks. This study analyzes the correlation relationship by combining two methods, namely Analytic Network Process (ANP) method and House of Risk (HOR). The final result of both methods found that there were 30 causes or sources of risk and 13 critical risk that had 28 risks management strategies with 15 priority strategies that can be carried out by the company.

Keywords: Risk Management, House of Risk, Analytic Network Process (ANP), Supply Chain Management.

Introduction

In the midst of the more competitive manufacturing industry, supply chain disruptions have been currently experienced by PT X over the past few years that had resulted in some cases of supply chain disruptions that can cause the delay of goods delivery to customers. The disruption in the supply chain caused a domino effect on the next process that can be threaten the sustainability of the company's business. PT X is a plate manufacturer which is based in Indonesia and is holding the manufacturing office equipment, warehouse equipment, building and building materials, hospital equipment, and security equipment.

Over the last few years, PT X often experienced the delays in the delivery of goods to the consumers. Therefore, the consumers were dissatisfied with the provided services. After conducting the interviews to obtain preliminary data, it was found that in conducting its business process, PT X experienced various risks as well as the causes of risks that affected its business processes, for example, running out of raw materials, queuing in the finishing process, loss of goods on the delivery process, and the other unexpected things. Disruptions or risks in the supply chain had a long-term negative impact on the company and many companies were unable to quickly recover from these negative impacts (Hendricks and Singhal, 2003).

The company needs a great framework to analyze the potential risk of a supply chain system in order to deliver the goods to the consumers on time. Therefore, this study will combine the 2 methods of ANP (Analytical Network Process) which is the development of AHP method that was firstly introduced by (Saaty, 1975) in order to analyze the relationship between risk and the cause of risk as well as House of Risks (HOR) method developed by (Nyoman Pujawan and Geraldin, 2009).

Methodology

The first step in this study was to mapping the company's supply chain activity based on SCOR model. This mapping was done to know the process activity in supply chain at PT X. The activity of supply chain process based on SCOR model was divided into five processes ie plan, source, make, deliver, and return. Therefore, the process identification of this business process can help researchers to analyze the risk events and possible causes of risks in the production department's business processes observed. Risk identification in this study was done by holding focus group discussion to company management along with experienced respondents.

The second step was analysis risk of supply chain that using 2 methods that were HOR and ANP. This study will carry ANP concept which was included in the HOR model to calculate correlation among each risk agent, causes of risk. The output on HOR 1 will be used for the next step.

In the next step, strategic planning was performed using the second phase of the House of Risk (HOR) matrix to develop mitigation actions in handling potential risks.

Thus this study focuses on supply chain management to designing supply chain management risk strategy. Meanwhile, framework about supply chain risk is illustrated.

Table 1. Summary of Results from Selected Previous Studies

Author	Title	Method	Research Subject	Result
Mangla & Kumar (2016)	An integrated methodology of FTA and fuzzy AHP for risk assessment in green supply chain	Fault-tree analysis and the fuzzy analytical hierarchy process (AHP)	A plastic manufacturer	The study findings depict that eight risk criteria and 30 sub-criteria were analyzed for risk assessment
Yousefi, Alizadeh, Hayati, Baghery (2018)	HSE risk prioritization using robust DEA-FMEA approach with undesirable outputs: A study of automotive parts industry in Iran	Robust data envelopment analysis (RDEA)-FMEA	Automotive parts industry	The study findings that 10 critical risks can be done with 19 corrective actions.
Aqlan & Lam (2015)	A fuzzy-based integrated framework for supply chain risk assessment	Fuzzy Logic and Bow Tie Analysis	A high-end server manufacturing environment	Numerical results for the company considered in this study showed that the risk scores for the two main product categories are 22% and 19%. This means that product 1 risk values needs further mitigation to reduce the risk.
Lam (2014)	Designing a sustainable maritime supply chain: A hybrid QFD–ANP approach	Quality Function Deployment (QFD) and Analytical Network Process (ANP)	The maritime industry	There are four main customer, which is the Use of Green Design Ships, Engines and Machinery is found to be the most important design requirement.
Wahyudin & Santoso (2016)	Modelling of Risk Management for Product Development of Yogurt Drink Using House of Risk (HOR) Method	House of Risk (HOR)	A Yogurt Drink Manufacturer	The research results have examined 20 risks with 27 identified risk agents and provides a strategic guideline as how to mitigate the top-three identified risk agents.

A Hybrid HOR-ANP Methodology

A method that is aimed to analyze the factors causing the risk of production process by combining 2 methods of HOR and ANP. Where in this study will carry ANP concept included in HOR model aims to calculate correlation among each risk agent, cause of risk. Data processing by ANP method was done by using Super Decision software version 2.8.0. Here were the steps of A Hybrid HOR-ANP methodology:

1. Identifying risk events occurred in each business process. In the figure of HOR1 Model, risk events were symbolized as Ei.
2. Identifying the risk agents and assess the probability of occurrence of each risk of the agent that was symbolized as Aj.
3. Developing a Decision Model Structure
   The first stage in the ANP process was the preparation of the problem and the conceptual model that should be created. The important components must be initially identified. The top element (cluster) was decomposed into sub-components and attributes (nodes). Each variable at each level must be defined along with its relationship with other elements in the system. In this study, risk events and risk agents were the clusters that had several nodes that will produce the value of severity (Si) and occurance (Oj).
4. Creating a pairwise comparison matrix that describes the contribution or influence of each element (cluster) and each criterion (node). The correlation matrix was arranged with the scale of 1 to 9.
5. After the pairwise comparisons and the input of the reverse values were completed, then each criterion was searched, the consistency was tested, and the priority vector was obtained. The priority value was found by normalizing this vector. The consistency ratio should be 10% or less. If the calculated ratio was less than 0.1 or 10%, then the consistency was considered satisfying.
   The stable value was obtained at this stage if all of the columns in the supermatrix were associated to each node having the same value. The steps of ANP method in this research were done in Super Decisions software in which it is a software package developed for ANP application where in ANP process the matrix will produce severity and

occurrence value using eigenvector value. The symbols of severity and occurrence obtained from eigenvector values were Si and Oj.

6. Developing a correlation matrix between each of the delay factor agents with each delay. Rij (relationship) {0, 1, 3, 9} with value 0 indicates no correlation and values 1, 3, and 9 showed low, moderate, and high correlation as seen in Table 3.2.
7. Calculating Aggregate Risk Potential Agent (ARPj) in which it is the result of the possible risk occurrence of j (Ej) and the cause of the risk (Aj).

$$ARP_j = O_j \sum_i S_i R_{ij} \quad (1)$$

8. Making an ARP weight rating (ARPj). This ARPj value was determined by all pairwise pairs presented in the HOR model that were sorted starting from the highest value to the lowest value. The results of this ARP value calculation will be used to determine the priority of risk agents in order to give precautions to reduce or prevent the occurrence of risk.

Table 2. A Hybrid HOR1-ANP Methodology

Source: Pujawan (2009).

		Risk Agents (Aj)							
Business Processes	***Risk Event (Ei)***	***A1***	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***	***Severity of Risk Event (Si) - ANP***
Plan	E1	R11	R12	R13	…	…	…	…	S1
	E2	R21	R22	…	…	…	…	…	S2
Source	E3	R31	…	…	…	…	…	…	S3
	E4	R41	…	…	…	…	…	…	S4
Make	E5	…	…	…	…	…	…	…	S5
	E6	…	…	…	…	…	…	…	S6
Deliver	E7	…	…	…	…	…	…	…	S7
	E8	…	…	…	…	…	…	…	S8
Return	E9	…	…	…	…	…	…	…	S9
	E10	…	…	…	…	…	…	…	S10
Occurrence of Risk Agent (Aj) - ANP		**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	
Weight ARP j		**ARP1**	**ARP2**	**ARP3**	**ARP4**	**ARP5**	**ARP6**	**ARP7**	
Priority Rank of Agent j									

House Of Risk 2 (HOR2)

The strategy design process was conducted using the second phase of the House of Risk matrix (HOR2) to develop the mitigation actions in handling the potential risks in the supply chain. HOR2 described the steps in the priority rank stage that were obtained from the ANP calculation values in the above-mentioned steps of HOR1-ANP.

1. Identifying strategy that were considered effective and relevant to the risk agent. A risk agent can be handled by more than one strategy and one strategy can simultaneously reduce the probability of occurrence of more than one risk agent. This prevention strategy was symbolized as PAk.
2. Determining the relationship between each strategy and each risk agent using the scale of 0, 1, 3, 9, where 0 represents no correlation, 1 denotes low correlation, 3 means mean, and 9 means high correlation between action k and agent j. This relationship was symbolized as Ejk and can be considered as the level of effectiveness of action k in reducing the probability of the occurrence of agent risk j.
3. Calculating the total value of the effectiveness of each strategy. This value may state how the action can definitely overcome the probabilities of the risk agent. The formula of total effectiveness was as follows:

$$TE_k = \sum_j ARP_j E_{jk} \; vk \quad (2)$$

4. Assessing the level of difficulty in performing any strategy. The difficulty level of this prevention strategy should accommodate and reflect the budget and other resources needed in conducting the prevention. The difficulty level was symbolized as Dk. Calculating the total effectiveness of the difficulty ratio (ETDk) with the following formula:

$$\mathrm{ETD_k} = {TEk}/{Dk} \quad (3)$$

5. Prioritizing priority ranking for each precautionary action (Rk). The priority for each precautionary strategy was stated based on the value of the of the difficulty ratio effectiveness (ETDk) in which order 1 was given in the precautionary action with the total effectiveness of the highest difficulty value The highest precautionary action represents the most cost-effective strategy.

Table 3. House Of Risk 2 (HOR2)

	Preventive Action (PAK)					
To be treated Risk Agent *(Aj)*	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**ARPj**
A1	E11	E12	E13	…	…	**ARP1**
A2	E21	E22	…	…	…	**ARP2**
A3	E31	…	…	…	…	**ARP3**
A4	…	…	…	…	…	**ARP4**
A5	…	…	…	…	Ejk	**ARP5**
Total efectiveness of action *k*	**TE1**	**TE2**	**TE3**	**TE4**	**TE5**	
Degree of difficulty performing action *k*	**D1**	**D2**	**D3**	**D4**	**D5**	
Effectiveness to difficulty ratio	**ETD1**	**ETD2**	**ETD3**	**ETD4**	**ETD5**	
Rank of priority	**R1**	**R2**	**R3**	**R4**	**R5**	

Source: Pujawan (2009).

Result and Discussion

Table 4. Identify of Risk Events and Risk Agents Based on SCOR Model

Business Process	Sub-Proses	Ei	Risk Event	Aj	Risk Agent
Plan	Order Recieving	E1	Production schedule is not in accordance with the condition	A1	Short Order of Settlement Time
				A2	Production Schedule is empty
				A3	Difference between Time of Purchase Order and the past Works Order
				A4	Production Administration Error
Source	Incoming Material Quality Inspection Material	E2	Late Raw Material Supply	A5	The scarcity of raw Materials in the Market / Raw Materials are Not Available
				A6	The significant increase of material price
				A7	The delay of Material delivery from the supplier
				A8	Waiting Leader's approval for the availability of goods
				A9	The raw material does not meet the specification.
				A10	Error Making of Periodic Stock Material Data (1 Month) In the form of Raw Material Report
Make	Inspection Guilotine Share Roll Forming Process Power Press Process Bending Process	E3	Employee Performance Decreases	A11	The boredom of the work
				A12	Dissatisfaction with the Corporates' Policies
				A13	There is friction between the subordinates and the boss
		E4	Troubled Production Process	A14	Damaged Dieset
				A15	Damaged Production Machine
				A16	Human Error
				A17	There is a Discontinue Spare Part So It Needs Time To Look For Substitution
				A18	Engine Technicians Must Be Imported From Jakarta (Head Office)
		E5	Production Schedule Delayed	A19	Late payment
				A20	Late Invoice

	Welding Section WIP (Material Type 2) Finishing Section Final Inspection Finish Good Grinding Process Galvanis Process Material Handling (Sub-Vendor)		During Repeat Order	A21	Late Payment Document Distribution
				A22	Incompatibility Between Sent Material And Ordered material
		E6	Working accident	A23	Human Error
				A24	Operator does not use security tool
				A25	The condition of Working tools that need to be repaired
		E7	Material return to Sub-Vendor	A26	Material quality does not meet the specifications
Deliver	Packing Section Delivery Section	E8	Late Delivery	A27	Unfinished Material Production
				A28	The delay of Delivery schedule, Truck is damaged
				A29	Customers' Unpreparedness To Receive Materials
				A30	Error Preparation Packing List To Section Delivery As A Base Making Way

A Hybrid HOR1-ANP Methodolgy

Using the ANP method, table 3 shows the result of pairwise comparison output between risk event. On the output, it shows that the value of inconsistency below 0.1 or 10%. This e-vector value will be used to determine the severity of the risk event

Table 5. Output Pairwise Comparisons of Risk Event

Inconsistency	0.05444	
Name	**Normalized**	**Idealized**
E1	0.1250577	0.3778907
E2	0.1059703	0.3202137
E3	0.0411424	0.1243213
E4	0.0822862	0.2486469
E5	0.0585305	0.1768635
E6	0.2355468	0.7117592
E7	0.0205299	0.0620357
E8	0.3309361	1.0000000

The occurrence of causes, risk represents the probability level of occurrence of a risk source resulting in the occurrence of one or more risks that may cause disruption to a business process with a certain degree of impact. Similarly, the determination of the severity value, the determination of the occurance value was also determined using the ANP method of generating an inconsistency value of 0.0691500 < 0.1 or 10% (shown in Table 4). The results of a normalized e-vector calculation will be used to determine the probability level (occurance) of the source or causes of the risk.

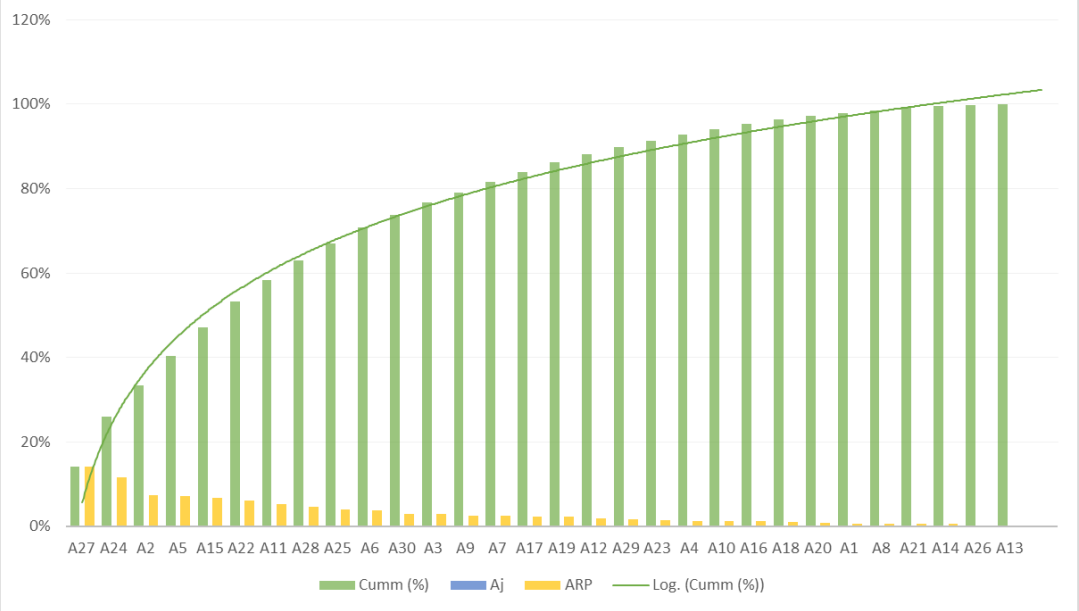
Table 6. Output Pairwise Comparisons of Risk Agent

Inconsistency	0.0691500				
Name	**Normalized**	**Idealized**	**Name**	**Normalized**	**Idealized**
A1	0.0082911	0.0669085	A16	0.0117560	0.0948698
A2	0.0807758	0.6518539	A17	0.0238065	0.1921165
A3	0.0311571	0.2514355	A18	0.0110967	0.0895496
A4	0.0136930	0.1105015	A19	0.0220561	0.1779907
A5	0.0685203	0.5529531	A20	0.0093102	0.0751323
A6	0.0410044	0.3309025	A21	0.0068504	0.0552818

A7	0.0241209	0.1946534	A22	0.0604684	0.4879752
A8	0.0074599	0.0602006	A23	0.0150245	0.1212464
A9	0.0271457	0.2190636	A24	0.1070656	0.8640105
A10	0.0125945	0.1016367	A25	0.0417814	0.3371723
A11	0.0530263	0.4279180	A26	0.0065262	0.0526661
A12	0.0181026	0.1460864	A27	0.1239170	1.0000000
A13	0.0054707	0.0441483	A28	0.0465096	0.3753286
A14	0.0069450	0.0560459	A29	0.0171540	0.1384313
A15	0.0660382	0.5329224	A30	0.0323318	0.2609151

After finding the occurance value and severity, the next step was to calculate the ARP value and sorted. Based on the sorted ARP value, this study will take the cumulative percentage by using the pareto diagram where the cumulative value of more than 80% will be eliminated and the one below 80% will be used as the HOR phase 2 inputs. The picture of the pareto diagram for risk taking with value The highest ARP shown in Figure 1 follows.

Figure 1. Pareto Diagram of ARP Ranked Value



House Of Risk 2 (HOR2)

The results from the pareto diagram were used for the phase 2 HOR that was used to identify and prioritize the proactive strategy that the firm will undertake to follow up the cause or source of risk by maximizing effective efforts by utilizing available resources to reduce potential emerging from the cause of the risk.

Study at this step was done with focus group discussion with the experienced respondents who had responsibility in the production department of cable support system PT X. In Table 7 below was the result of identification of mitigation strategies on 13 main causes or sources of risk with the number of 28 risk mitigation strategies.

Table 7. Identify Risk Mitigation Strategy

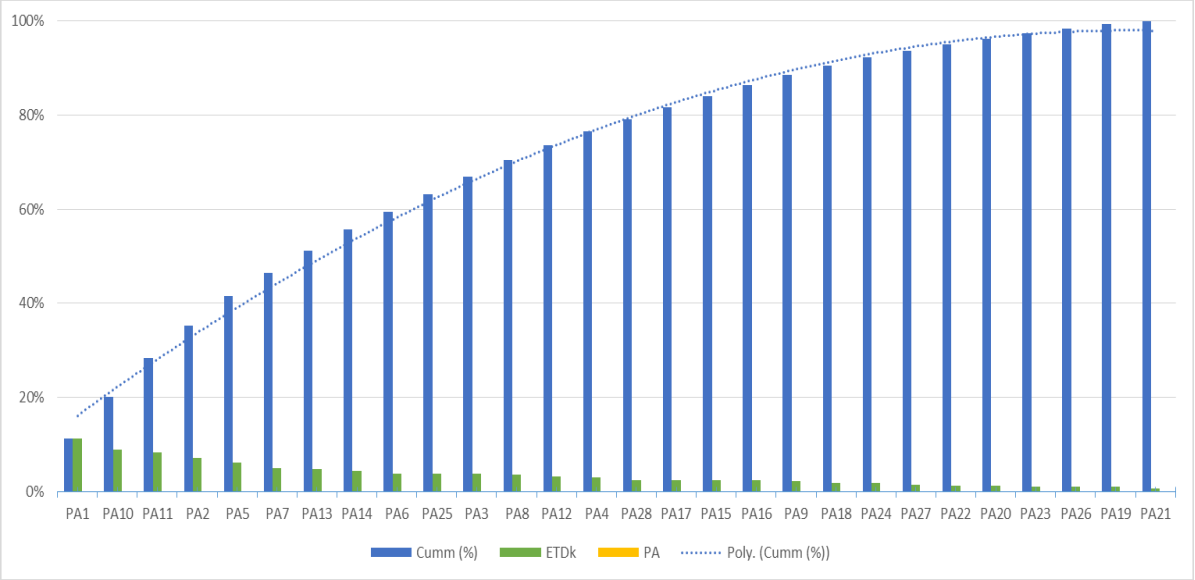
Aj	Risk Agent	PAk	Strategy
A27	There were Unfinished Production Materials	PA1	Provide working deadlines to sub-vendors
		PA2	Make work contact with sub-vendor
		PA3	Make selective sub-vendor selection

		PA4	Had an alternate sub-vendor
A24	Operator does Not Use Security Tool	PA5	K3 policy
		PA6	Provision of incentives and sanctions against workers
		PA7	Monitoring and Control of Non-Safeguard Measures at work.
		PA8	Make the selection of workers more stringent
A2	Empty Schedule Production	PA9	The use of part-time employees
		PA10	doing production process to increase inventory during low demand period
		PA11	Establish good communication to all parties both customers and suppliers
A5	Scarcity of raw Materials In The Market / Raw Materials are Not Available	PA12	Subcontracting suppliers during periods of high demand.
		PA13	The addition of stock material (strategy stock)
		PA14	Make SOP of purchase - control of procurement of raw materials and auxiliary materials
A15	Damaged Production Machine	PA15	Periodic Maintenance.
		PA16	Had Spare Part (Spare Part) backup or Component
A22	Incompatibility Between Sent Material And Ordered material	PA17	Selection of suppliers with more selective
		PA18	Review of contracts to suppliers
A11	Boredom At Work	PA19	Offers career development programs
		PA20	Hold a regular family gathering
A28	Late Delivery Schedule, Damaged Truck	PA21	Rent truck fleet at a time of high demand
A25	Condition of Work Tool needs to be Fixed	PA22	Recruit technicians
A6	Significant Price Increase	PA23	Adjust the current price
		PA24	Review and re-analyze the offer before it was given to potential customers
		PA25	Had an alternative material supplier
A30	Error Preparation in Packing List To Section Delivery As A Base Making Way	PA26	Double checking by delivery department
A3	Difference between Time of Purchase Order and past Works Order	PA27	Inden Number Sales Order-Works Order
A9	Raw Materials do Not Match Specifications	PA28	Conduct periodic audits of suppliers

The strategy design process was carried out using the second phase of the House of Risk (HOR) matrix to prepare mitigation actions in handling potential risks. After the correlation between the mitigation strategy and the risk factors that had been included in the Phase 2 HOR matrix in the previous stage, the following was the stage of determining the difficulty level in performing each action (Dk). The second phase HOR calculation results and sequences based on ETDk values can be seen in the following table. The ranked strategy on the Appendix 1, in this study will be taken cumulative percentage by using a

pareto diagram where strategy chosen was a strategy which had a cumulative value below 80%. The picture of pareto diagram for taking a risk mitigation strategy with the highest ETDk value shown in the following Figure 2 below.

Figure 2. Pareto Diagram of ETDk Ranked Value



So from the pareto diagram above, obtained the result that the selection of priority risk mitigation strategy amounted to 15 strategy with the cumulative value in the following table.

Table 8. Priority Risk of Mitigation Strategy

PAk	Strategy	PAk	Strategy
PA1	Provide working deadlines to sub-vendors	**PA6**	Provision of incentives and sanctions against workers
PA10	Perform production process to increase inventory during low demand period	**PA25**	Had an alternative material supplier
PA11	Establish good communication to all parties both customers and suppliers	**PA3**	Make selective sub-vendor selection
PA2	Make work contact with sub-vendor	**PA8**	Make the selection of workers more stringent
PA5	K3 policy	**PA12**	Subcontracting suppliers during periods of high demand.
PA7	Monitoring and Control of Non-Safeguard Measures at work.	**PA4**	Had an alternate sub-vendor
PA13	The addition of stock material (strategy stock)	**PA28**	Conduct periodic audits of suppliers
PA14	Make SOP of purchase - control of procurement of raw materials and auxiliary materials		

Conclusions and Avenues for Future Research

This study concludes, that the method of using ANP (Analytical Network Process) and HOR (House of Risk) is proved to be the right solution to identify and influence strategy. The main causes of the results of this study yielded 13 risk causes that should be noticed. There were 15 mitigation strategies priority that can be used by the company to assessment supply chain risks.

Not only in the supply chain of the production process, this research can be done throughout the company process, not only in the production department, variable variables of observers, and factors that can be changed in more detail to all supply chain parts of the company. As a committee of only less than 10 expert judgements or respondents were formed while exploring firm production of cable support system, future research might increase the number of expert judgement.

Therefore, future work may be conducted by using any of other risk analysis techniques, such as, FMEA, QFD, FTA method, etc.

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Appendix 1. *House Of Risk 2 (HOR2)*

	Preventive Action (PAK)																												
To be Treated Risk Agent (Aj)	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**PA7**	**PA8**	**PA9**	**PA10**	**PA11**	**PA12**	**PA13**	**PA14**	**PA15**	**PA16**	**PA17**	**PA18**	**PA19**	**PA20**	**PA21**	**PA22**	**PA23**	**PA24**	**PA25**	**PA26**	**PA27**	**PA28**	**(A**
A27	9	9	9	9	0	0	0	0	3	3	9	1	1	0	0	0	0	0	0	0	1	0	1	0	9	0	0	3	0.8
A24	0	0	0	0	9	9	9	9	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0.6
A2	3	9	1	3	0	0	3	1	9	9	9	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0.4
A5	1	3	3	3	0	0	0	0	1	1	9	9	9	9	0	0	9	9	0	0	0	0	0	9	9	0	0	1	0.4
A15	0	0	0	0	3	0	9	9	1	0	0	0	0	0	9	9	0	0	0	0	0	9	0	0	0	0	0	0	0.3
A22	9	9	9	9	0	0	0	0	0	1	3	9	9	9	0	0	9	9	0	0	0	0	3	1	9	0	0	3	0.3
A11	0	0	0	0	0	9	1	9	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0	0	0	3	0	0	0.2
A28	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	9	0	0	0	0	0	1	0	0.2
A25	0	0	0	0	0	0	3	0	0	0	0	0	0	9	9	9	0	0	0	0	0	9	0	0	0	0	0	0	0.2
A6	1	1	1	1	0	0	0	0	9	9	9	9	9	0	0	0	3	3	0	0	0	0	9	9	9	0	0	3	0.2
A30	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	9	0	0	0.1
A3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0.1
A9	1	1	1	1	0	0	0	0	9	9	9	9	1	9	0	0	9	9	0	0	0	0	1	1	9	0	0	9	0.1
Ejk	12.902	16.225	12.864	13.704	7.104	8.773	11.606	12.431	10.210	10.180	18.928	10.782	10.846	10.049	5.441	5.441	8.668	8.668	3.468	2.637	3.117	7.430	5.214	6.063	17.236	2.395	1.716	5.788	
Dk	1	2	3	4	1	2	2	3	4	1	2	3	2	2	2	2	3	4	3	2	4	5	4	3	4	2	1	2	
Tek	12.902	8.112	4.288	3.426	7.104	4.387	5.803	4.144	2.553	10.180	9.464	3.594	5.423	5.025	2.721	2.721	2.889	2.167	1.156	1.318	0.779	1.486	1.304	2.021	4.309	1.197	1.716	2.894	
Rank	1	4	11	14	5	9	6	12	19	2	3	13	7	8	17	18	16	20	27	24	28	23	25	21	10	26	22	15	