DESIGN MITIGATION OF BLOOD SUPPLY CHAIN USING SUPPLY CHAIN RISK MANAGEMENT APPROACH

Roy Enggar Achmadi
Department of Industrial Engineering
Universitas Islam Indonesia
Yogyakarta, Indonesia
royenggara@gmail.com

Agus Mansur
Department of Industrial Engineering
Universitas Islam Indonesia
Yogyakarta, Indonesia
agusmansur@uii.ac.id

Abstract

Indonesian Red Cross is one of the appointed organizations by the Indonesian government to circulate and manage blood distribution. Blood is a perishable product due to its short lifetime. Therefore good management is crucial in achieving optimal blood supply. Reaching the optimal balance point of supply and demand has been a major challenge and risk that often occurs in the supply chain. The purpose of this research is designing a strategy mitigation action to risk agents in blood supply chain. It is aimed to minimize the level of risk that affects blood supply. The approach taken to achieve these objectives is an observation of risk agents that occur in each supply chain. The method used in this research is House of Risk. Application of the method will result in an Effectiveness to Difficulty Ratio value on Preventive Action. Preventive Action is designed and customized based on the risk agents occurrence. The results of this study indicate that there are eleven risk agents which are needed to be treated in prioritization by seven possible mitigation actions. It is expected that the mitigation action could be a help in suppressing risk agents of blood supply chain flow.

Keywords
Supply Chain Risk Management, Blood Supply Chain, House of Risk.

1. INTRODUCTION

Supply Chain Management activities is a crucial part of an organization's business process since it involves all stakeholders, starting from suppliers, manufacturing companies, to its customers (Kusnindah, et al., 2014). Nowadays, the focus on an organization starts to shift. It is not only focused on the products created, but rather on the whole process, from procurement to on-time delivery, which is also valued by the customer. Indonesian Red Cross (Palang Merah Indonesia/PMI), as a non-profit organization, is working toward that goal. PMI starts to focused on the whole process of blood management, including blood supply chain management.

Blood itself is body fluid that delivers necessary substance in human body, thus plays a critical role for human life, especially in near-death experience such as accident or emergency situation. Blood is categorized as a perishable product due to its relatively short lifespan. Depended on blood product type, it has varied lifespan. Whole Blood and Packed Red Cells are expired in ± 30 days, platelets is expired in ± 5 days), Frozen Plasma is expired in ± 6 months, while Wash Red Cells is expired in ± 4 days. Therefore, it is crucial to have a good management in achieving optimum blood supply (Stanger, et al., 2012). Achieving balance point between blood supply and demand is a challenge that is needed to overcome and remains as the main risk that often occurs in blood supply chain. During this past 6 years, the number of blood donors in PMI at Kabupaten Sleman has increased in each year, from

20% to 50% (PMI Kabupaten Sleman, 2017). These improvements have both positive and negative impacts to PMI Sleman. One of the negative impacts is the abundant number of blood bags that become waste due to its short lifetime. Based on the data during these 6 years, 124 to 1877 blood bags have become waste due to uncertain blood demand (PMI Kabupaten Sleman, 2017). Fluctuating blood demand which is stochastic and erratic in nature for years has demanded PMI Sleman attention to regulate effective and efficient production process to meet blood demand in timely delivery. There are several obstacle in blood supply chain activities, such as a limited stock of blood per day which up to 200 bags, under assumption that the demand will be able to be covered by PMI Sleman unless there is an emergency situation, such as natural disaster. During certain emergency, as in dengue fever endemics or natural disasters, there will be sudden spike in blood demand. PMI Sleman will make an emergency order to other nearby PMI and suppliers. Yet, despite these actions taken, there will be no guarantee that the demand will eventually be fulfilled. In result, the late supply will have a bullwhip effect toward continuity of the next production cycle. This will certainly harm PMI's resource management, both in terms of time and cost. Thus, it is necessary to establish a risk mitigation precaution to overcome this problem and develop effective supply chain system. The effectiveness of supply chain management is the key measurement for organization's competitive advantage (Pujawan, 2005; Millaty, et al., 2014). There will be always a chance of risk emergence in supply chain activities (Kristanto & Hariastuti, 2014). Currently, PMI Sleman does not have any supply chain risk management yet. Risk management is needed to minimize resources, whether it is cost, time, or working effort (Millaty, et al., 2014). A study by Finch (2004) suggests that inter-organizational networks can increase risk factors in companies, especially when dealing with small and medium business partners. Hanafi (2006) said that risk management is necessary in order to minimize the level and impact of risk. One of the method that can be used in risk management is House of Risk (HOR). HOR could identify risks and risk agents, while also design a mitigation strategy, reducing the probability of risk agents occurrence by providing precautions in blood supply chain flow. HOR focused on the analysis of risk cause and effectiveness of a mitigation strategy that has been designed to suppress the underlying risk cause. This research is aiming to solve blood supply chain problem by identifying the risk agents and possible causes of problem.

2. METHOD

2.1 Research Structure

This study is descriptive in nature, which relates to exploratory, confirmatory, and interpretation of a phenomenon based on the ongoing reality through the data collected (Mardais, 1999). This study uses the House of Risk method, developed by I. Nyoman Pujawan and Laudine H. Geraldin, based on the idea that proactive supply chain risk management should focus on preventive action, such as reducing the likelihood of risk agent emergence (Millaty et al., 2014). House of Risk aims to identify risks and design a coping strategy to reduce the probability of risk agent occurrence by providing a precautionary measure to risk agents. This research is conducted through several stages of preliminary research, data collecting, data processing, data processing result analysis, the design of mitigation strategies, and finally concluded the results of research.

2.2 House of Risk phase 1

The first phase is identifying potential risks and risk agents. The output of phase 1 is risk agents grouping into several tiers of risk agents priority in accordance with Aggregate Risk Potential (ARP) value. The steps in calculating Aggregate Risk Potential of HOR phase 1 are as follows:

1. Mapping of the Organization's Supply Chain activities based on SCOR model (Supply Chain Operation Reference).

		Risk Agents (A_j)					
Business Process	***Risk Event (E_i)***	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	***Severity of risk event i (S_i)***
Plan	E_1	R_{11}	R_{12}	R_{13}			S_1
Source	E_2	R_{21}	R_{22}				S_2
Make	E_3	R_{31}					S_3
Deliver	E_4	R_{41}					S_4
Return	E_5						S_5
Occurance of agent j		O_1	O_2	O_3	O_4	O_5	
Aggregate risk potential j		ARP_1			ARP_4	ARP_5	
Priority rank of agent							

Figure 1. *Framework House of Risk* phase 1 (Sumber: Pujawan, 2005)

2. Identify Risk Event (E_i) on each business process activity by referring to SCOR model element (Plan, Source, Make, Deliver, and Return).
3. Measuring Severity (S_i) value of risk events in business process activities
   The severity value was determined based on the questionnaire and experts/stakeholders interview result in reference to Table 1.

Table 1. Value of Severity Scale (Sumber: Shahin, 2004)

Scale	Information	Scale	Information
1	No	6	Significant
2	Very Slight	7	Major
3	Slight	8	Extreme
4	Minor	9	Serious
5	Moderate	10	Hazardous

4. Identify of Risk Agent (Aj) related to factors causing the risk events occurred that have been previously identified in step 2.
5. Measuring risk agent occurrence
   The determination of this occurrence value is based on the questionnaire and the result of interviews with the expert concerned with reference to Table 2.

Table 2. Value of Occurrence Scale (Sumber: Shahin, 2004)

Scale	Information	Scale	Information
1	Almost Never	6	Medium
2	Remote	7	Moderately High
3	Very Slight	8	High
4	Slight	9	Very High
5	Low	10	Almost Certain

6. Measuring correlation value between risk occurrence to the causative agent of risk.
   This correlation value is determined based on questionnaires and interviews with experts concerned with reference to Table 3.

Table 3. Value of Correlation Scale (Sumber: Pujawan & Geraldin, 2009)

Scale	Information
0	No correlation
1	Low level of correlation
3	Mid-level of correlation
9	High level of correlation

7. Calculating Aggregate Risk Potential.
   Aggregate Risk Potential could be calculated using the following formula:

$$ARP_j = O_j \sum S_i R_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

   Where:
   ARP : Aggregate Risk Potential
   O_j : Occurance
   S_i : Severity
   R_{ij} : Correlation value

2.3 House of Risk phase 2

The second phase is designing the mitigation strategies for categorization of risk agents priority. The output of phase 1 will be processed further as input to phase 2 in calculating the total effectiveness value and effectiveness to difficulty ratio (ETD) value. Here are the steps to calculate Aggregate Risk Potential in phase 2:

1. Risk agents selection based on highest to lowest ARP using Pareto analysis.
2. Identify relevant Preventive Actions (PA_k) using risk agents priority.
3. Measuring correlation values between risk agents and risk management.
4. Calculating Total Effectiveness (TE_k) value
   Total Effectiveness could be calculated using this following formula:

$$TE_k = \sum ARP_j E_{jk} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where;
TE_k : Total of Effectiveness
ARP_j : Aggregate Risk Potential
E_{jk} : Correlation value

5. Measuring difficulty level to apply mitigation action (D_k) for risk agents emergences reduction (referred to Table 4).

Table 4. Difficulty Level of performing action scale (Kristanto & Hariastuti, 2014)

Scale	Information
3	Mitigation actions are **easy** to implement
4	Mitigation actions are **somewhat difficult** to implement
5	Mitigation actions are **difficult** to implement

6. Measuring *Effectiveness to Difficulty* ratio (ETD).
   Effectiveness to Difficulty ratio could be calculated using the following formula:

$$ETD_k = TE_k \,/\, D_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where;
ETD : Effectiveness to difficulty ratio
TE_k : Total Effectiveness of Action
D_k : Degree of Difficulty performing action (Table 4)

7. Determining the ETD priority scale from highest to lowest.
   The main priority value will be given to the mitigation action that has the highest ETD value.

	Preventive Action (PA_k)					
To be treated risk agent (A_j)	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	***Aggregate Risk Potentials (ARP)***
A_1						ARP_1
A_2						ARP_2
A_3						ARP_3
Total Effectiveness of Action	TE_1	TE_2	TE_3	TE_4	TE_5	
Degree of difficulty preforming action	D_1	D_2	D_3	D_4	D_5	
Effectiveness to difficulty ratio	ETD_1	ETD_2	ETD_3	ETD_4	ETD_5	
Rank of priority	R_1	R_2	R_3	R_4	R_5	

Figure 2. Framework House of Risk phase 2 (Sumber: Pujawan, 2005)

3. RESULT AND DISCUSSION

The identification of supply chain risk in PMI Sleman is analyzed based on existing data sources and used as inputs for HOR phase 1. The results of identification of possible risk events occurring in the supply chain flow are listed in table 5.

Table 5. Risk Event Identification

Code	Risk Event	SCOR Stage	Severity
E1	The sudden blood demand change	Plan	5
E2	Discrepancy of minimum bloodstock	Plan	5
E3	Donor activity is not affordable	Plan	3
E4	Cancellation of blood delivery	Plan	5
E5	Changes in the blood delivery amount to the hospital	Plan	4
E6	Negotiation failure for equipment and disposable material	Plan	5
E7	Errors in equipment and disposable material planning	Plan	3
E8	Non-conformance in tools and materials specifications	Source	6
E9	Defective items from suppliers	Source	6

Code	Risk Event	SCOR Stage	Severity
E10	Delayed delivery from supplier	Source	7
E11	Error in blood type and rhesus diagnosis	Make	6
E12	Failure in blood-taking process	Make	8
E13	The stalled screening process	Make	8
E14	Tool-reading mistakes	Make	9
E15	Blood does not pass the screening	Make	9
E16	Error in reading crossmatch results interpretation	Make	9
E17	Failed production of Whole Blood or Packed Red Cell	Make	7
E18	The presence of bacteria	Make	9
E19	Damaged blood	Make	7
E20	Stacked up finished blood inventory	Make	8
E21	Blood mixed blood has been tested with damaged blood to be retested	Make	5
E22	Delay in blood delivery	Deliver	6
E23	Error in blood delivery	Deliver	5
E24	Accidents in delivery of goods	Deliver	5
E25	Blood damage during delivery process	Deliver	7
E26	Late in filing complaints to suppliers	Return	7
E27	Late return of equipment and materials to supplier	Return	8
E28	Returned blood by the hospital	Return	6

After the risk events are identified, the risk agent was later identified as the cause of the risk event. The result of risk agent identification that causes the occurrence of risk event could be seen in Table 6.

Table 6. Risk Agent Identification

Code	Risk Agent	Occurrence
A1	Inaccurate forecast	3
A2	A natural disaster occurs in an area	7
A3	Uncertain number of blood safety stock	6
A4	Uncertainty of donor health	3
A5	Uncertainty of HR planning in activities	2
A6	Simultaneous donor activities request	7
A7	Lack of field personnel	5
A8	Blood demand has been met by the hospital	2
A9	Uncertain blood demand from hospital or other PMI	7
A10	Lack of market price references	2
A11	Human error in tools and materials planning	2
A12	The number of donors uncertainty	6
A13	There is no recommendation from the public health ministry or the PMI headquarter	2
A14	Driver's negligence in the delivery process	2
A15	The occurrence of natural disasters on the route traversed	7
A16	Disturbance or damage to the transportation mode	6

Code	Risk Agent	Occurrence
A17	Employees fatigue	2
A18	Unqualified donor health	8
A19	Difficulty in detecting blood vessels (veins)	3
A20	The fainted donor	2
A21	The incidence of hematoma	2
A22	Nervous patients during the donor process	2
A23	Tools damage	2
A24	Employees inaccuracy in reading results	1
A25	Blood volume which is taken less than 350 ml	3
A26	Damage to Refrigerated Centrifuge (RC)	5
A27	The retrieval process is unsterile	2
A28	Storage time exceeded the expired date of blood	3
A29	The hospital does not want the Hospital Blood Bank	4
A30	Human error in blood selection	5
A31	Unreachable delivery	4
A32	Bad weather conditions	4
A33	Number of delivery locations	6
A34	The temperature instability of blood storage	3
A35	Delays in tools and materials receipt	4
A36	Weaknesses in memorandum of agreement	4
A37	Incompatibility with required blood criteria	1

The result of Risk Event and Risk Agent identification will proceed into Aggregate Risk Potential calculation phase. ARP calculation is conducted to measure risk level of risk agent by considering the priority level. Recapitulation result of Aggregate Risk Potential is shown as in Figure 3.

	RISK EVENT	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	A34	A35	A36	A37	SEV
		RISK AGENT																																					
PLAN	E1	1	9							9						9																							5
	E2	3		9	1					3									1																				5
	E3		9			1	3	3		3																													3
	E4								3																							1							5
	E5		9	3						9																				1									4
	E6										1			1																									5
	E7			3						9		1	3	1																									3
SOURCE	E8										3			1																									6
	E9														1																	1							6
	E10															9	3																1	1					7
MAKE	E11																								9														6
	E12																		9	3	1	1	1			1													8
	E13																							9															8
	E14																							1	3														9
	E15																											3											9
	E16																							1	3														9
	E17																		3					1		1	3												7
	E18				1																							1	3										9
	E19				3																								9						1				7
	E20	1								9			9																	9									8
	E21																														9								5
DELIVER	E22															9	9															1	3	1					6
	E23														3																3			3					5
	E24														3		3	1														1	3						5
	E25														1																				3				7
RETURN	E26																																			3	3		7
	E27																3															1	3			1	3		8
	E28																																					3	6
	OCC	3	7	6	3	2	7	5	2	7	2	2	6	2	2	7	6	2	8	3	2	2	2	2	1	3	5	2	3	4	5	4	4	6	3	4	4	1	
	ARP	84	756	396	105	6	63	45	30	1428	46	6	486	28	86	1134	684	10	784	72	16	16	16	194	108	45	105	72	270	304	300	120	256	168	84	116	180	18	
	RANK	21	4	7	18	36	25	27	29	1	26	36	6	30	20	2	5	35	3	23	32	32	32	12	17	27	18	23	10	8	9	15	11	14	21	16	13	31	

Figure 3. House of Risk phase 1 of the case company

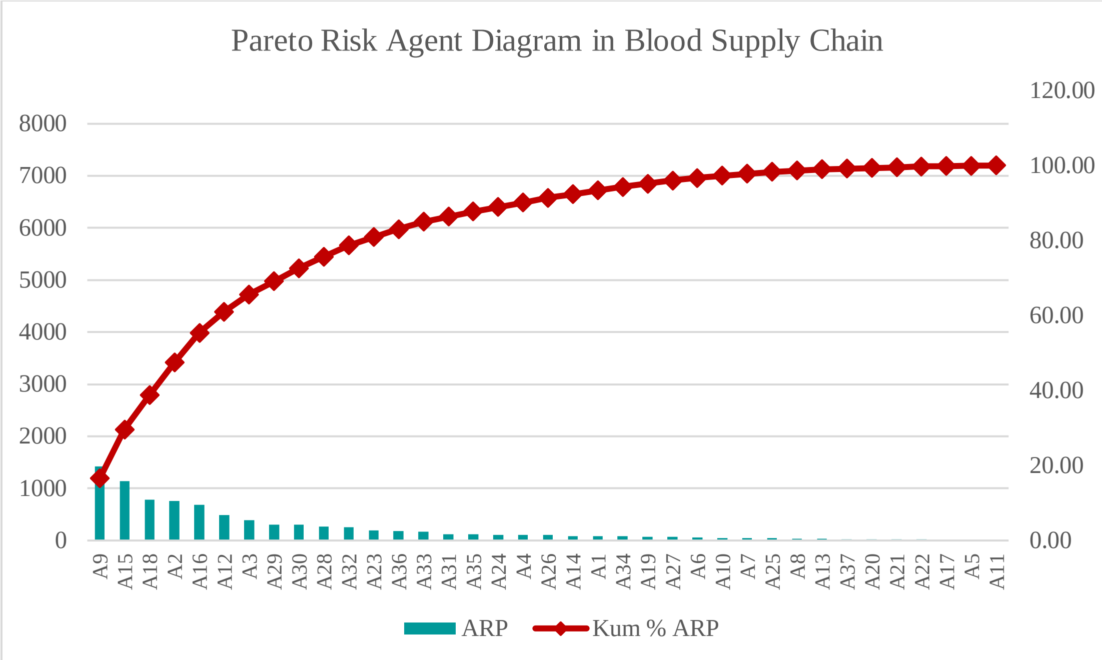

Figure 4. Pareto diagram of Aggregate Risk Potentials of all risk agents

Before the ARP value is obtained, the researcher has determined the correlation value in accordance with the value of the provision (referred to table 3). The correlation value is determined based on the subjectivity of the experts whose results are listed in Figure 3, section correlation. After the correlation value is determined, the next step is the calculation of Aggregate Risk Potential (ARP) value shown in Figure 3. ARP value was meant to measure risk level of risk agent by considering the priority level of risk agent handling. The final step in the HOR phase 1 is determining the priority level of risk agent using Pareto diagram. The results obtained from the priority level of risk agent in Figure 4. From the ARP value, in reference to the priority level of risk agent that has been obtained, researcher select eleven risk agent. Those risk agents are found in: (a) Uncertain blood demand from hospitals or other PMI (1428); (b) The occurrence of natural disasters on the route taken (1134); (c) Unqualified donor health (784); (d) A natural disaster occurs in an area (756). (e) Transport disturbances (684); (f) Uncertainty number of donors (486); (g) Uncertain number of blood safety stock (396), (h) Hospital does not want Hospital Blood Bank (304); (i) Human Error in blood selection (300); (j) Storage time exceeded blood expired date (270); (k) Bad weather conditions (256). Thus, after knowing the risk agent that becomes a priority to handle, then researcher design mitigation action strategy in HOR phase 2 as in Table 7, and calculate the Effectiveness to Difficulty ratio (ETD) value.

Table 7. Preventive action

Code	Preventive Action
PA1	Collaborate with other PMI
PA2	Improve communication with RS
PA3	Improve service standards
PA4	Managing mass donor activities and socialization
PA5	Improve communication with suppliers
PA6	The addition of blood storage
PA7	Maximize the use of SIMUDDA

ETD calculation is conducted to know the effectiveness level of a mitigation action strategy in handling a risk agent. The first step is to calculate Total Effectiveness of Action (TE_k) value. The calculation of TE_k scores aims to measure the effectiveness of mitigation action strategies. Mitigation strategies have been designed without any regard to the difficulty level of applying mitigation action. The next step is determining the Degree of Difficulty in performing the action (D_k). Determination of value (D_k) is based on the subjectivity of experts whose results are listed in Figure 5. The final step of HOR phase 2 is the calculation of ETD value. The result of ETD calculation recapitulation is shown in Figure 5.

	Preventive Action							
Risk Agent	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**PA7**	**ARP**
A9	3		3	3	1		3	1428
A15	3	9					3	1134
A18			3	1				784
A2	9			9	9			756
A16	1				3			684
A12	9	9		3			9	486
A3	9	3					9	396
A29	3							304
A30						9	3	300
A28			9	9				270
A32	3				3			256
Total Effectiveness of Action (TEk)	24792	15768	9066	15760	11052	2700	16524	
Degree of Difficulty preforming action (Dk)	3	3	4	4	3	4	3	
Effectiveness to Difficulty Ratio (ETD)	74376	47304	36264	63040	33156	10800	49572	
Rank	1	4	5	2	6	7	3	

Figure 5. House of Risk phase 2 of the case company

After HOR model is calculated, the next step was to provide accessibility for PMI by performing risk recording. This record will help PMI to make decisions in the future. Thus, the researcher has designed a program to record risk database system which refers to HOR model extraction result (Figure 6 & Figure 7).

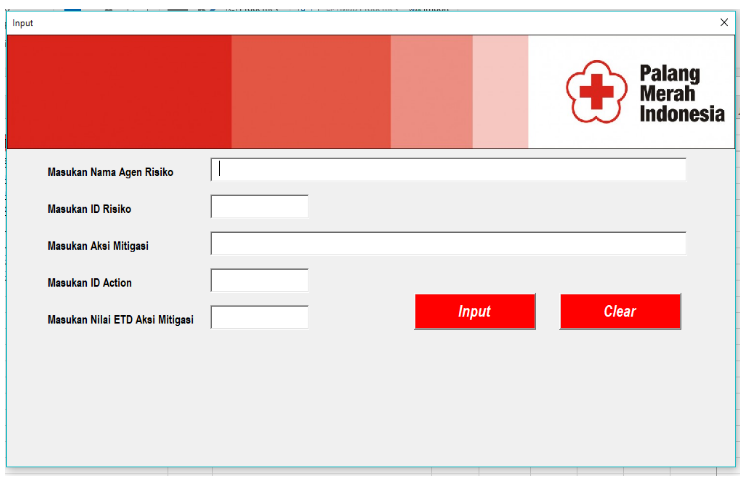

Figure 6. Design input data interface

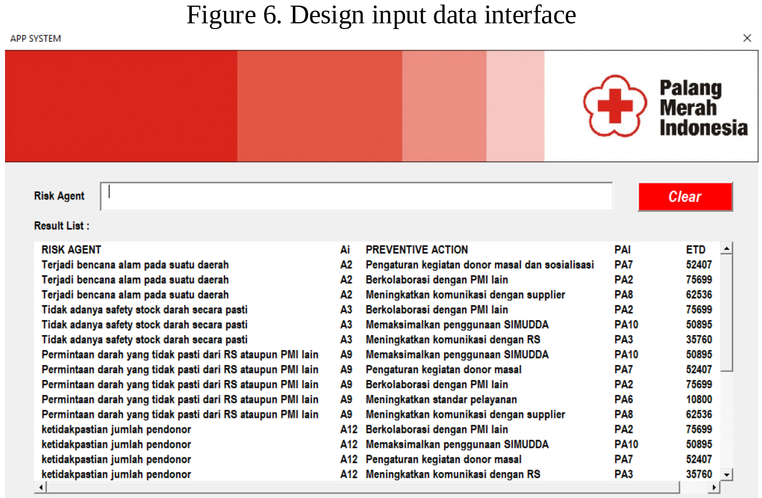

Figure 7. Design search engine interface

4. CONCLUSIONS

This paper result is aimed to solve supply chain risk of PMI. Here is the conclusion that could be drawn based on the HOR model process for problem illustrated previously:

1. There are 28 Risk Events and 37 Risk Agents that have been identified. Based on the calculation of House of Risk phase 1, there are 11 risk agents that counted in the priority category, ranked by the highest value for handling. Those 11 risk agents are; uncertain blood demand from hospital or other PMI (1428), occurrence of natural disasters on the route traversed (1134), donor health donor (784), natural disaster occurred in a region (756), transport disturbance (684), uncertainty donor (486), absence of definite blood safety stock (396), RS did not want any BDRS (304), employee inaccuracy in blood selection (300), storage takes too long to exceed the expired blood limit (270), bad weather conditions (256).
2. In House of Risk phase 2, preventive action that is needed to be carried out based on the risk agents handling priority are; collaborating with other PMI (74376), managing mass donor activities (63040), adding blood storage (49572), maximizing SIMUDDA usage (47304), improving communication with suppliers (36264), improving communication with RS (33156), and improving service standards (10800).

References

Finch, P., Supply Chain Risk Management, *Supply Chain Management: An International Journal,* vol. 9, no. 2, pp. 183-186, 2004.

Hanafi, M., *Manajemen Risiko,* Yogyakarta: STIE YKPN, 2006.

Kristanto, B, R., & Hariastuti, N, L., Aplikasi Model House of Risk (HOR) Untuk Mitigasi Risiko Pada Supply Chain Bahan Baku Kulit, *Jurnal Ilmiah Teknik Industri,* vol. 13, no.2, pp. 149-157, 2014.

Kusnindah, C., Sumantri, Y., & Yuniarti, R., Pengelolaan Risiko Pada Supply Chain dengan Menggunakan Metode House of Risk, *Jurnal Rekayasa dan Manajemen Industri,* vol. 2, no. 3, pp. 661-671, 2014.

Mardais, *Metode Penelitian Suatu Pendekatan Proposal,* Jakarta: Bumi Aksara, 1999.

Millaty, S, D., Rahman., A., & Yuniarti., R, Analisis Risiko Pada Supply Chain Pembuatan Filter Rokok (Studi Kasus: PT. Filtrona Indonesia, Surabaya), *Jurnal Rekayasa dan Manajemen Sistem Industri,* vol. 2, no. 1, pp. 151-162, 2014.

PMI Kabupaten Sleman., *Darah Rusak 2011-2016,* Sleman: PMI Kabupaten Sleman, 2017.

PMI Kabupaten Sleman., *Permintaan Darah Masuk (Donasi Darah) tahun 2011-2016,* Sleman: PMI Kabupaten Sleman, 2017.

Pujawan, I, N., *Supply Chain Management.* Surabaya: Gunawidya, 2005.

Pujawan, I, N., & Geraldin, L, H., House Of Risk: A Model for Proactive Supply Chain Risk Management, *Business Process Management Journal,* vol. 15, no. 6, pp. 953-967, 2009.

Shahin, A., Integration of FMEA and The Kano Model An Exploratory examination, *International Journal of Quality and Reliability Management,* vol. 21, no. 7, pp. 731-746, 2004.

Stanger, S, H., Wilding, R., Yates, N., & Cotton, S., What Drives Perishable Inventory Management: Lesson Learn from The UK Blood Supply Chain, *Supply Chain Management: An International Journal,* vol. 17, no. 2, pp. 107-123, 2012.