Available online at www.sciencedirect.com
ScienceDirect
Procedia Manufacturing 4 (2015) 282 – 290
Procedia MANUFACTURING

Industrial Engineering and Service Science 2015, IESS 2015

Development of integrated model for managing risk in lean manufacturing implementation: a case study in an Indonesian manufacturing company

Wiwin Widiasih[a*], Putu Dana Karningsih[b], Udisubakti Ciptomulyono[c]

[a*,b,c] Department Industrial Engineering, Sepuluh Nopember Institute of Technology, 60111 Indonesia

Abstract

Managing risk is not an easy task for every company. Top management needs decision making tools to support them in indentifying, analysing, and evaluating potential risks. The objective of this research is to develop a model of risk management by integrating several tools. This integration is intended to improve decision making by providing quantitative analysis at each step of risk management. Delphi Method is utilized to identify potential risks, while House of Risk is used to categorize risks into risk events and risk agents and also to rank risk agent. To map relationships between risk events, Interpretive Structural Modeling is used. Then, Analytical Network Process is utilized to determine weights of risk events and risk agents for calculating adjusted Risk Potential Number. This proposed model is applied to assist risk management departement in an Indonesian manufacturing company that has just started to implement Lean Manufacturing in the last couple of years. Nineteen potential risks have been identified and categorized into ten risk events and nine risk agents. After mapping interrelationships among these risks and calculating adjusted Risk Priority Number, there are top three risk events that should be prioritized to be mitigated, namely: (1) Unable to achieve Key Performance Index target based on SQCDP parameter, (2) Unable to finalize action plan on schedule, (3) Unable to deliver lean manufacturing training material/knowledge to employees. This integrated model brings Company X to manage their risks better, not only for Lean Manufacturing implementation project but also for all of their projects.

Peer review under responsibility of the organizing committee of the Industrial Engineering and Service Science 2015 (IESS 2015)

Keywords: Risk management; lean manufacturing implementation: integrated model

1. Introduction

In the beginning, Lean Manufacturing (LM) concept is implemented in automotive industry such as Toyota.

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000
E-mail address: wiwinwidiasih126@gmail.com

Peer review under responsibility of the organizing committee of the Industrial Engineering and Service Science 2015 (IESS 2015)
doi:10.1016/j.promfg.2015.11.042

Then, LM concept is widely adopted by other types or industries including aerospace [1]. However, there are many assumptions that should be taken into account when LM concept implement in different kind of industries. Crute et al. [1] suggest that there are several key strategic factors when the LM concept is implemented in an aerospace company, namely: change strategies, effects of company culture, product focus, senior management commitment and consistency, time and space for performance improvement.

LM concept is utilized to identify and eliminate waste in value stream mapping (VSM) of production process that considered not only about organization aspect but also company's supply chain [2]. When companies start implementing LM concept, they are aiming to maintain product quality with lower cost of production and shorter lead time. Rathje et al. [2] said that there are many lessons to be learned when a company implement LM concept in their first time. For example, lack of management commitment, lack of autonomy's team, lack of transparancy from management to share objective's LM implementation, unavailability of mechanism for LM implementation, lack of communication, and discontinuation of improvement plan.

Company X is an aerospace manufacturing company in Indonesia. This company produces aircraft, aerostructure as well as provides aircraft and engineering services. Company X has started to implement Lean Manufacturing (LM) concept in 2013. It has special department that is responsible for implementing LM under Production Directorate, which is named as Lean and Development Department. In implementing LM, company X focuses to achieve five aspects, that are safety, quality, cost, delivery, and people (SQCDP). According to Nugraha [3], delivery and people are the most critical aspect in implementing LM concept in Company X. Delay in product delivery is always happened because there were many waste in product development phase. Another problem such as difficulty to change company's culture is also occured. Another study identifies that there are several problems in implementation of LM concept in this company, namely: lack of LM and SQCDP knowledge among the worker, improper SQCDP meeting activity, complaint of LM implementation has no been addressed properly, and delay in product delivery [4]. These problems impede company X to achieve objectives and gain benefits from LM implementation. Any event that may prevent any project/activities to achieve its objective is considered as a risk. Risk can be defined as a disadvantage or loss of project's profit [5]. In relation to LM implementation, several risks has been identified by [6], they are: demotivation of employees after a few years of LM implementation, lack of LM knowledge, lack of communication, etc. Therefore, to ensure successfulness of LM implementation, any potential risk should be manage properly since risk management seeks to understand and control the risk that may affect a project with a view to increase the chances of positive results [7].

At this moment, Company X has a department which is responsible to manage their enterprise risk, that is Risk Management Department. Risk Management Department in this company adopts generic model to manage its risk by following ISO 31000:2009 standard. This model consists of several stages such as context determination, risk assessment, risk mitigation, communication and consultation, also monitoring and review [8]. Risk assessment stage is divided into several steps, they are: risk identification, risk analysis, risk evaluation, and risk mitigation. Susilo [8] suggests that ISO 31000:2009 adopts quality management concept (Plan, Do, Check, Action) with additional stages which accommodate feedbacks and continuous improvement.

Risk Management Departement and Lean and Development Departement of company X, work together to identify risks during LM implementation in company X based on their experiences and subjectivity without following a particular approach. Therefore, there is a need to manage risk in LM implementation in a more structured manner and thoroughly, not only limited on identifying risk but also analyzing, evaluating, and mitigating risk. Thus, the objectives of this research are two folds. Firstly, to develop a proposed model that integrated several approaches which aiming a better way for managing risk. Delphi method is used to identify potential risk of LM implementation quantitatively. Next, to classify risk events and risk agents of potential risks, House of Risk (HOR) is utilized. HOR is also utilized to rank the risk agent by calculating Aggregate Risk Potential (ARP). Interpretive Structural Modeling (ISM) is then used to determine interrelationships between risks. Analytical Network Process (ANP) is used for determine weight of risk events and risk agents who has been considered in the interrelationship model. The weight of risk events and risk agents is utilized to calculate adjusted Risk Potential Number (RPN). Finally, risk mitigation is prioritized on risk that has highest adjusted RPN. Secondly, to assist Company X in managing risk in LM implementation by using the proposed integrated model.

2. Development of integrated model for risk management

Risk Assessment is one of important stage in Risk Management. In this research, several approaches (i.e. Delphi, HOR, ISM, ANP) are incorporated and is particularly supported this stages (Fig. 1).

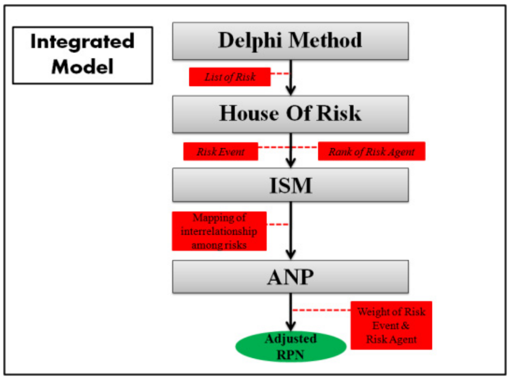

Fig. 1 Integrated Model

2.1. Risk identification step with delphi method, house of risk and interpretive structural method

The first step in risk assessment is to identify potential risks. There are many methods available to identify risks. Risk identification can be conducted by in-depth interview, brainstorming, questionnaire, historical document, judgment based on experience and direct observation. It is necessary to have expert opinion in identifying risks. Hence, Delphi method is utilized to gather information about potential risk from expert. Delphi method is a way to obtain collective view from individuals about issues when there is no or little definite evidence and when opinion is important. It is an iterative questionnaire exercise with controlled feedback to a group of panel who are anynomous [9]. Panel also allow to control and manage the round of Delphi questionnaire. Each round needs approximately two to three times to get feedback from panel, and each round is taken place on average for two weeks. The round is stopped when answer of the panel has reached a consensus. The consensus is occured when statistic parameters such as mean, median, deviation standard, and inter quartile range has achieved Delphi's objectives. The Delphi method has been utilized in many areas such as forecasting, criteria prioritization, and concept development [10]. The used of Delphi method provides better result than traditional survey [10], since it affirm brainstorming and in-depth interview method.

In identifying risk, it is also needed to classify between risk agent or risk event. House of Risk (HOR) is a method that combines two approaches: failure mode and effect analysis (FMEA) and house of quality (HOQ) [11]. The HOR is divided into HOR 1 and HOR 2. The role of HOR 1 is to rank risk agent based on their Aggregate Risk Potential (ARP). ARP of risk agent in HOR 1 is calculated using equation 1. The role of HOR 2 is to prioritize proactive actions that a company should pursue to maximize the cost-effectiveness of an effort in dealing with selected risk agents in HOR 1. Since this step is only for identifying risk event and risk agent thus only HOR 1 is utilized.

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

O_j is probability of occurance risk agent j, S_i is severity of impact if risk event occured, and R_{ij} is e correlation between risk agent j and risk event i (which is interpreted as how likely risk agent j would induce risk event i) [11]. Correlation magnitude between risk event and risk agent are 0, 1, 3, and 9 which means in sequentially order as do not have any correlation, low correlation, medium correlation, and high correlation [11].

In risk identification step, it is also necessary to know interrelationship among risks, not only classify risk event and risk agent [12]. By considering relationship between risks, proper magnitude of risk and its mitigation can be determined more accurately. ISM is utilized to map risk interrelationship. Hence, in this research, HOR and ISM are integrated to gain understanding of interrelationship between risk events and causal relation between risk agent and risk event. ISM is an interactive learning process. In this technique, a set of directly and indirectly related elements are structured into comprehensive systematic model which is called as directed graph (digraph) [13]. ISM has been applied in many areas such as design process, carrier planning, strategy planning, engineering problem, product design, re-engineering process, financial decision making, human resources development, competitive analysis, e-commerce [14] [15] [16]. ISM method consists of six main steps, they are: (a) construction of structural self-interaction matrix (SSIM), (b) developing a reachabilty matrix from the SSIM and checking for transitivity, (c) level partitioning of reachability matrix, (d) developing conanical matrix, (e) drawing digraph, and (f) construction of ISM model [17].

2.2. Risk analysis step with analytical netwok process and risk priority number

This step is aiming to determine risk factors influence on the system as a whole [5]. Risk analysis is also utilized to calculate Risk Priority Number (RPN). Risk can be measured by two parameters that are likelihood and consequences. Likelihood is considered as probability of risk that is happened. Consequences is considered as impact of risk. Company X has develop their own standard to measure these two parameters which can be seen in Table 1.

Table 1. Score of likelihood and consequences of company x

Likelihood		**Consequences**	
Score	**Description**	**Score**	**Description**
1	rare, < 1% Probability	**1**	insignificant, low impact, be able to ignore
2	unlikely, 1-5 % Probability	**2**	minor, low impact, be able to repair
3	possible, 15-50 % Probability	**3**	moderate, effect goal to achieved
4	likely, 50-70% Probability	**4**	major, loss of production capability
5	almost certain, > 70% Probability	**5**	catastrophic, big impact, loss of profit

Risk is generally measured by their individual likelihood and consequences. However, by utilizing ISM, it can be determined that some of risks may trigger to or are triggered by other risk(s) [18]. A risk event can be triggered by one or more risk event(s) or a risk event may be triggered by one or more risk agent(s). Hence, when measuring a risk, it should considers those interactions by applying certain weigthages on any risk that has relation to other risk. ANP is utilized to calculate weightage by expert evaluation. Integration between ISM and ANP has been utilized to select third party logistics (3PL) for an Indian organic food organization [19]. The weightage from ANP is used to calculate new likelihood that is considered interrelationship among risks. The formula to calculate new likelihood (L_{new}) is represented in equation 2 considering likelihood of risk event (L_{basic}) and multiplication of likelihood of trigger risk event-n ($L_{trigger\text{-}n}$) and weightage trigger risk event which is resulted from ANP. Hence, the adjusted RPN can be calculated by equation 3.

$$L_{new} = L_{basic} + (L_{trigger1} * W_{trigger1}) + ... (L_{trigger\ n} * W_{trigger\ n}) \quad (2)$$

$$RPN_{adjusted} = L_{new} * \text{Consequences} \quad (3)$$

2.3. Risk evaluation step

In their study, Ahmed et.al [5] present many technique for risk evaluation (e.g. decision tree analysis. portfolio management, multiple criteria decision-making method, etc.). In this research, the highest rank of risks are selected based on calculated adjusted RPN. Thus, there is a difference of prioritized risk to be mitigated when calculated using RPN and adjusted RPN since risks interrelationship is considered.

3. Case study of managing risk in Company X

In this research, integrated model (Fig. 1) is applied in a case study of Company X. It is started by identifying potential risk which may happened during implementation of Lean Manufacturing approach by company X using Delphi Method. First round of Delphi method was conducted using open questionnaire that is distributed to ten respondents who are managers and head of division that have implemented LM concept in their division/production area. In the first round, these respondents are not only questionned about how deep is their understanding on LM implementation concept but also suggest potential risk occur during LM implementation. Result from this round is collected, summarized and used for the second round questionnaire. Next, respondents are asked to confirm all potential risk that has been indentified from the first round. Score is given based on likert scale from 1 to 5 which refers from “not agree” until “very agree” consecutively. Similarly, in the third round, summary of result from second round are presented and potential risks are re-evaluated. Finally, based on these round, total of 19 risks are identified and reached its consensus. Consensus is occured when value of standars deviation has decrease from the previous round (i.e. the second round to third round). Furthermore, value of Inter Quartille Range and value of range have been performed the same [20].

HOR is utilized to categorize 19 identified risks into 10 risk events and 9 risk agents as can be seen at Table 2. Then, by calculating Aggregate Risk Potential (ARP) using equation 1, the top fifth rank risk agent code A4, A3, A5, A1, and A9 that refers to lack of communication, lack of knowledge in LM implementation, unqualified human resources, lack of top management commitment, and difficult to change work culture [21].

Table 2. List of Risk Events and Risk Agents

Code	Risk Events	Code	Risk Agents
E1	Unable to finalize action plan on schedule	A1	Lack of top management commitment
E2	Demotivated employee	A2	Lack of supporting facilities
E3	Lack of employee’s commitment implementing lean manufacturing approach	A3	Lack of knowledge in LM implementation
E4	Undiscipline employee in SQCDP meeting	A4	Lack of communication
E5	Employee can not feel the benefit directly of implementing LM	A5	Unqualified human resources
E6	Employee did not get reward	A6	Collecting data manually
E7	Inappropriate mapping for improvement plan	A7	Lack of data due to create VSM
E8	Unable to achieve Key Performance Index target based on SQCDP parameter	A8	Lack of budget
E9	Inappropriate of implementation of Tactical Improvement Plan by employee	A9	Difficult to change work culture
E10	Unable to deliver lean manufacturing training material/knowledge to employees		

Integration between HOR 1 and ISM illustrated in Fig. 2. The top fifth rank of risk agent which resulted from HOR 1 are connected to one or more risk event(s). For example, risk agent A9 (Difficult to change work culture) may cause risk event E1 (Unable to finalize action plan on schedule). Fig. 2 also shows interrelationship between risk events. Risk event E1 is triggered by risk event E3 (Lack of employee’s commitment implementing lean manufacturing approach) which is located in level II. Similar things is also applied to other risk events. After knowing interrelationship between risk events or between risk event and risk agent, then it is necessary to calculate weightage of risk event and risk agent. ANP method is utilized for this purpose by considering interrelationship model of integration HOR 1 and ISM (Fig. 2). Fig. 3 shows model of ANP interface in Super Decision software. In addition, an expert from company X is selected to fill out pairwise comparison quistionnaire and then input into the software. Result of weightage from ANP model for each risk event and risk agent can be seen in Fig. 3.

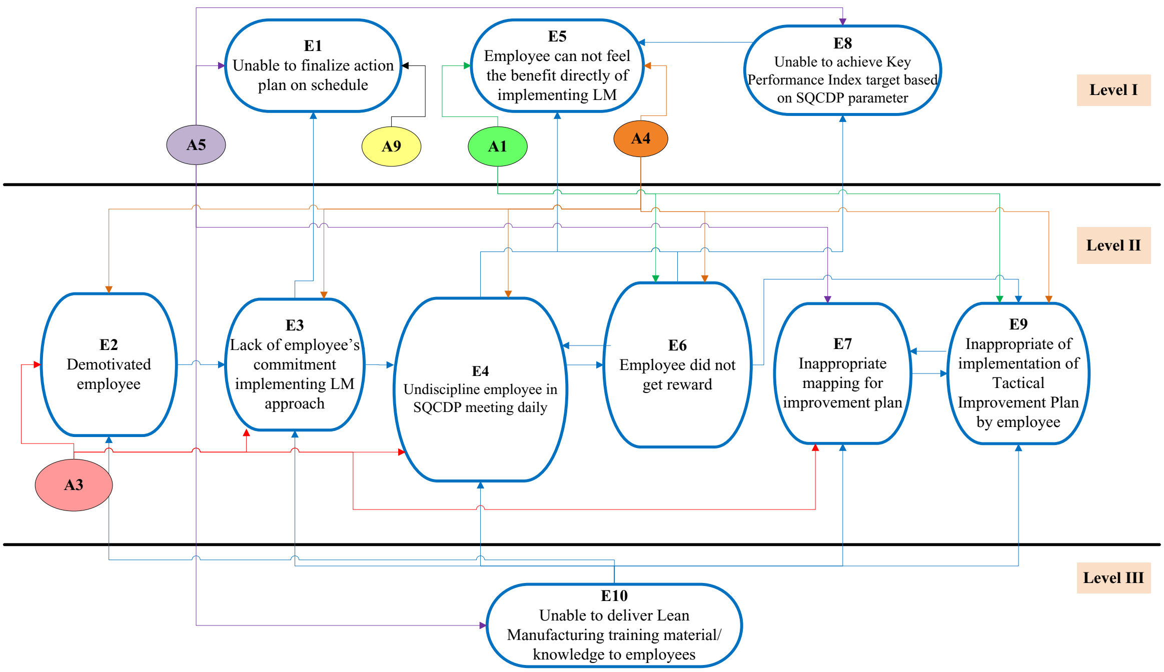

Fig. 2 HOR 1- ISM model integration

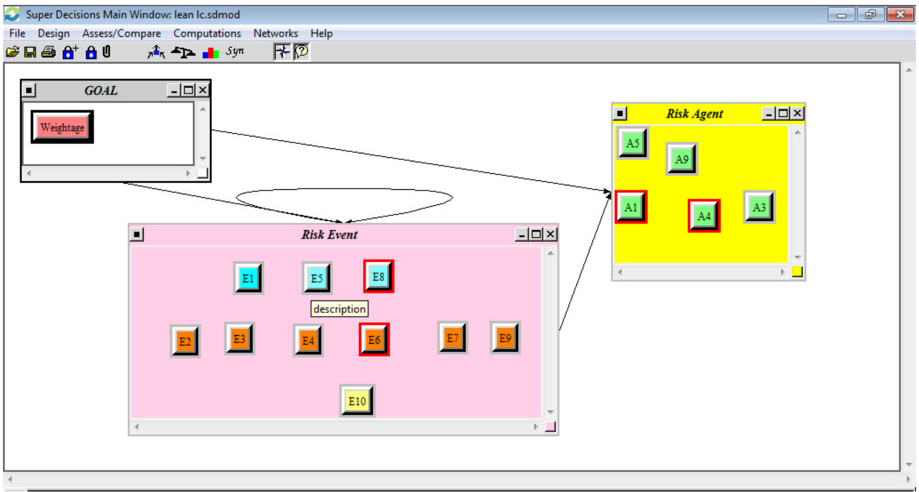

Fig. 3. Interface ANP model in software super decision

Table 3. Result of Weightage from ANP Model

Risk Event	**Weightage**	**Risk Agent**	**Weightage**
E1	0.122719	A1	0.01374
E2	0.003599	A2	0.05731
E3	0.010893	A3	0.06934
E4	0.015616	A4	0.71866
E5	0.613595	A5	0.14096
E6	0.005402		
E7	0.000691		
E8	0.122719		
E9	0.002459		
E10	0.102307		

Table 4. Result of RPN Considering Interrelationship among Risks

Risk Event	**Likelihood**	**Consequences**	**Basic RPN**	**Risk Enabler(s)**	**New Likelihood**	**Adjusted RPN**
E1	5	3	15	E3, A5, A9	9	27
E2	4	3	12	E6, E8, A1, A4	5	15
E3	4	3	12	E4, A5	7	21
E4	4	4	16	E10, A3, A4	5	20
E5	4	4	16	E10, E2, A3, A4	5	20
E6	4	4	16	E10, E3, E6, A3, A4	5	20
E7	4	2	8	E4, A4, A1	5	10
E8	5	4	20	E10, E9, A3, A5	9	36
E9	4	3	12	E6, E10, E7, A4, A1	5	15
E10	4	3	12	A5	7	21

Table 4 shows calculation result of adjusted RPN. New likelihood and adjusted RPN was calculated by using equation 2 and 3 which has been explained in previous sub section . From Table 4, risk event code E1 refers to unable to finalize action plan on schedule has likelihood value 5. Because risk event code E1 has enablers (is caused by) E3, A5, and A9 then likelihood value must be re-calculated by considering weightage of interrelationship model using ANP. After re-calulate new likelihood, the risk magnitude becomes 9. As a result, RPN is also changed. Previously, RPN basic value of Risk event E1 is 15, but in adjusted RPN it becomes 27. The complete calculation result of adjusted RPN can be seen in Fig. 4.

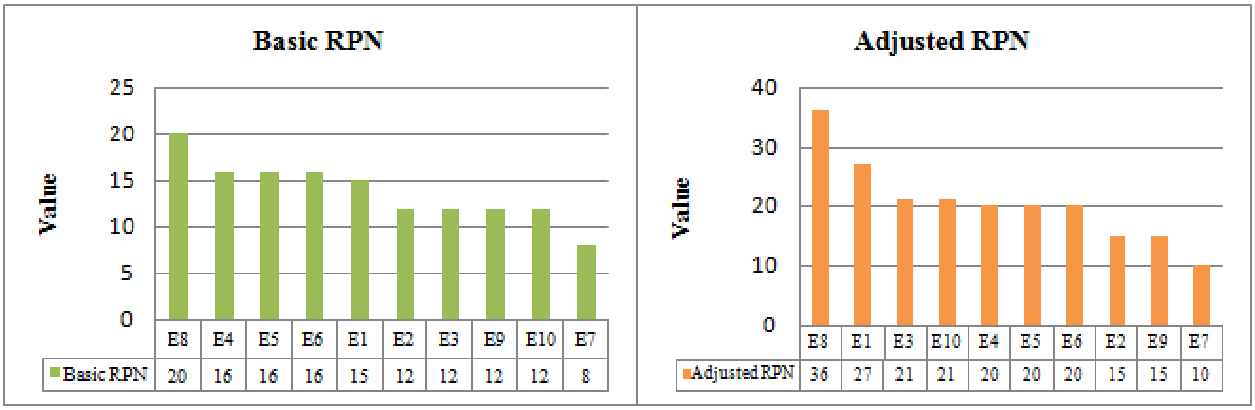

Fig. 4. Basic vs Adjusted RPN

4. Research finding

In this research, development of risk management model by utilizing integrated method to support company X for identifying, analysing, and evaluating risks of lean manufacturing implementation is conducted. Based on the result, it shows several interesting facts. The first is that there were changing in risk magnitude when interrelationships of risk are considered. The difference can be shown clearly in the calculation of basic and adjusted RPN. Risk event 8 (Unable to achieve Key Performance Index target based on SQCDP parameter) are the first priority both in basic and adjusted RPN. Risk event E1 (Unable to finalize action plan on schedule) become the second priority in adjusted RPN while in basic RPN is the third priority. Then, risk event E10 (Unable to deliver lean manufacturing training material/knowledge to employees) is the third priority, which is also changed from basic RPN. By knowing the priority of the risks, then several recommendation can be structured to mitigate those risk. Secondly, by understanding corelation between risk agent and risk event, recommendation for mitigation strategy can be started by considering how to reduce or avoid this risk agent to be occured. In this research, risk agent A5 (Unqualified human resources) can lead to the first, second and third priority of risk event. Therefore, proper mitigation strategy should be formulate for this risk agent.

Eventhough, in this research integration of Delphi Method, HOR, ISM and ANP lead to a better way for managing risk, there are several issues that should be taken into consideration for future research. First, there is a need to incorporate other quantitative methods for checking consistency of transitivity rule in ISM method. While, in this research, checking of transitivity rule is conducted manually. It will be difficult to do in the case of large size of matrix . Thus, ISM method should be integrated with another method such as Structural Equation Modeling for validation purpose. Second, ISM may also combined with application software for simplying ISM modelling. Third, another quantitative method (e.q. Decision Making Trial and Error Laboratory method) can also be utilized to measure interaction degree of risk interrelationships.

References

[1] V. Crute, Y. Ward., S. Brown, A. Graves, A., “Implementing Lean in aerospace-challenging the assumptions and understanding the challenges”, *Journal of Technovation* (23), 2003, *pp* 917-928.

[2] M.S. Rathje, T.A. Boyle, P. Deflorin, “Lean, take two! Reflections From The Second Attempt At Lean Implementation”, *Journal of Business Horizons* (52), 2009, *pp* 79-88.

[3] R.C. Nugraha, “*Analysing New Product Development Process in Company X Using Lean Product Development Approach*”, *Final Project: ITS Surabaya*, 2014.

[4] S.V. Oey, R. Sanjaya, W. Indrawam, “Analisis SQCDP *Tools* dalam Implementasi Konsep *Lean Manufacturing* di PT. DI”, *Daily Report Universitas Kristen Maranatha: Bandung*, 2015.

[5] A. Ahmed, B. Kayis, S. Amornsawadwatama, “A Review of Techniques for Risk Management in Projects”, *Benchmarking: An International Journal*, *Volume14 Number* 1, 2007, *pp* 22-36.

[6] G. A. Marodin, T.A. Saurin, “Classification and Relationships Between Risks That Affect Lean Production Implementation: A Study In Southern Brazil”, *Journal of Manufacturing Technology Management*, *Volume* 25 *Number* 1, 2014, *pp* 57-79.
[7] B. Ritchie, C. Brindley, “Supply Chain Risk Management and Performance: A guiding framework for future development”, *International Journal of Operations and Production Management* 27, 2007, *pp* 303-322.
[8] L. J. Susilo, “Manajemen Risiko Berbasis ISO 31000 untuk Industri Nonperbankan”, PPM: Jakarta Pusat, 2015.
[9] S. Thanaratinam, WE Charler Redman, “The Delphi Technique”, *Education The Obstetrician & Gynaecologist*, 2005, *pp* 120-125.
[10] C. Okoli, S.D. Pawlowski, “The Deplhi Method as a Research Tool: An Example, Design Considerations and Applications”, *Information and Management Journal* (42), 2004, *pp* 15-29.
[11] N. Pujawan, L.H. Geraldin, “House of Risk: A Model for Proactive Supply Chain Risk Management*”, Business Process Management Journal*, *Volume* 15 *Number* 6, 2009, *pp* 953-967.
[12] B. Kayis, P.D. Karningsih, “SCRIS: A knowledge based system tool for assisting organization in managing supply chain risks”, *Journal of Manufacturing Technology Management*, *Volume* 23 *Number* 7, 2010, *pp* 834-852.
[13] R. Attri, N. Dev, V. Sharma, “Interpretive Structural Modelling (ISM) approach: An Overview*”, Research Journal of Management Sciences*, *Volume* 2, 2013, *pp* 3-8.
[14] S. Chidambaranathan, C. Muralidharan, S.G. Deshmukh, “Analyzing the Interaction of Critical Factors of Supplier Development using Interpretive Structural Modeling-an empirical study”, *International Journal of Advance Manufacturing Technology*, 2009, *pp* 1081-1093.
[15] W.L. Li, P. Humphreys, L.Y. Chan, M. Kumaraswamy, “Predicting purchasing performance: the role of supplier development programs”, *Journal of Material Processing Technology*, 2003, *pp* 243-249.
[16] D.K. Banwet, R. Arora, “Enablers and inhibitors of e-commerce implementation in India-an Interpretive Structural Modeling (ISM) approach”, *Operations Management for Global Economy Challenges and Prospects*, *Phoenix*, *New Delhi*, 1999, *pp* 332-341.
[17] R. Attri, N. Dev, V. Sharma, “Interpretive Structural Modelling (ISM) approach: An Overview*”, Research Journal of Management Sciences*, *Volume* 2, 2013, *pp* 3-8.
[18] P.D. Karningsih, W. Widiasih, Wiwin., I. Hisyam, B. Arifin, “Modelling and Mnaaging Supply Chain Risks: A Case Study in An Indonesian Mnaufacturing Company”, *6th International Conference on Operations and Supply Chain Management*, Bali, 2014.
[19] J. Thakkar, S.G. Deshmukh, A.D. Gupta, R. Shankar, “Selection of Third-Party Logistics (3PL): A Hyrbrid Approach Using Interpretive Structural Modeling (ISM) and Analytical Network Process (ANP)*”, An International Journal of Supply Chain*, *Volume* 6, 2005, *pp* 32-46.
[20] W. Widiasih, P.D. Karningsih, U. Ciptomulyono,“Identifikasi Risiko pada saat Implementasi Lean Manufacturing dengan Metode Delphi”, Seminar Nasional MMT 23, 2015.
[21] W. Widiasih, P.D. Karningsih, U. Ciptomulyono, “Managing Risk of Lean Manufacturing Concept Implementation Approaching by Delphi and HOR”, The First International Seminar on Science and Technology, 2015.