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# Identifying and Assessing Supply Chain Risks Depending on Product Variety

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A R T I C L E I N F O

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A B S T R A C T

Companies always trying to increase market share and profits by increasing customer satisfaction through the variety in the products they offer. However, at the same time, the Product variety brought many challenges to manufacturing systems and supply chains. Product variety could make a supply chain more exposed to various types of disruptions. There are always associated opportunity risks when variety products. Risk can be defined as the uncertainty of an event occurring that could have an impact on the achievement of the objectives. A natural extension of supply chain management is supply chain risk management. Risk management can't be done without define the risks then prioritize them to mitigate the most important risks. This paper helps in identifying and assessing the potential risks that are likely to disrupt a supply chain when variety products. All product variety risks gathered based on the previous researches of the effect of product variety on the supply chain from 1985 until 2014. The risks grouped under five basic dimensions of supply chain (Marketing, Logistic, Manufacturing, Engineering, and purchasing). Then the risks prioritized using Fuzzy Analytical Hierarchy process (FAHP).

## 1. Introduction

Recently to gain more market share, companies are increasing variety in their products where customers' preferences to products change rapidly and customers would like to buy just what they need. By increasing product variety (PV) in style, function, package, size, and so on, it may be possible to satisfy customers more, resulting in enhanced competitiveness and more market share in the market. Even though increasing product variety might increase sales, it has drawbacks so that it might not be profitable. Thus, a challenge faced by companies today is to offer variety in order to satisfy customer's needs while managing the product variety risks.

Increasing product variety might have strong effect on the supply chain (SC). However, more product variety may increase the manufacturing costs and complexity. Increasing product variety causes higher complexity of demand forecasting and matching of supply with demand in the supply chain (Whang and Lee, 1998; Randall and Ulrich, 2001; Desai, K. and Trivedi, M., 2014). Therefore, companies increasing variety in their product lines should also understand the effect of product variety on all relevant costs and the various functions performed by the supply chain.

All the previous changes increase the importance of supply chain risk management (SCRM). Hopkin (2014) defines Risk management as "Actions taken to reduce the likelihood and/or magnitude of a risk". Risk management provides a framework for organizations to deal with and to react to uncertainty. While the Institute of Internal Auditors (IIA) defines risk as the uncertainty of an event occurring that could have an impact on the achievement of objectives.

Effective management of risks is becoming the focal concern of the firms to survive and thrive in a competitive business environment. Thus the supply chain risk management (SCRM) has emerged as a natural extension of supply chain management with the prime objective of identifying the potential sources of risks and suggesting suitable action plans to mitigate them (Singhal, P. et al, 2011). A typical process of risk management contains three basic steps (Manuj and Mentzer, 2009 and Mody, A., 2012): (i) Risk identification, (ii) Risk Assessment, (iii) Risk Mitigation.

Risk identification is the first stage of risk management. It develops the basis for the next steps: assessment and mitigation of risk management (Tchankova, L., 2002). Correct risk identification ensures risk management effectiveness. The second step is the risk assessment which refers to assign weights to risks and determine the priority of these risks that defined in the first step to be mitigated in the third step. It is difficult to response to all risks in the same time, so prioritize risks is a basic procedure in risk management.

The previous background provides the motivation to investigate and assess the product variety risks in the supply chain. The objective of this research is to define and assess the important risks of product variety in the supply chain. The procedures of the research are shown in "Figure 1".

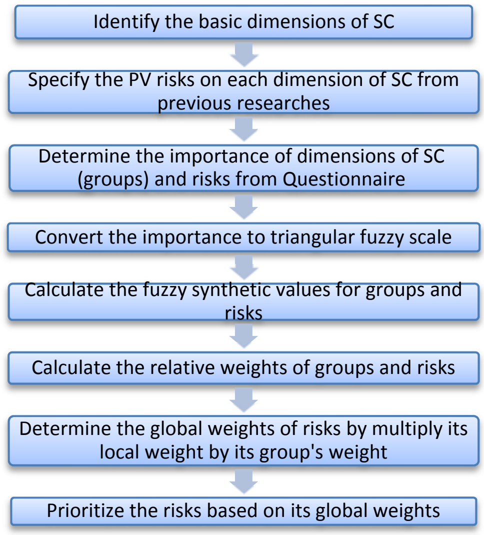


Fig. 1. The research's procedures

## 2. Literature Review

Thönemann and Bradley (2002) assert that high product variety impairs supply chain performance. Several functions in the supply chain have directly related to product variety, as illustrated in "Figure 2" (Park, T. et al., 2004). Marketing department in a firm plays a main role to determine the customer's needs. However, percentage of publications of the effect of product variety on each dimension of the supply chain is indicated in "Figure 3".

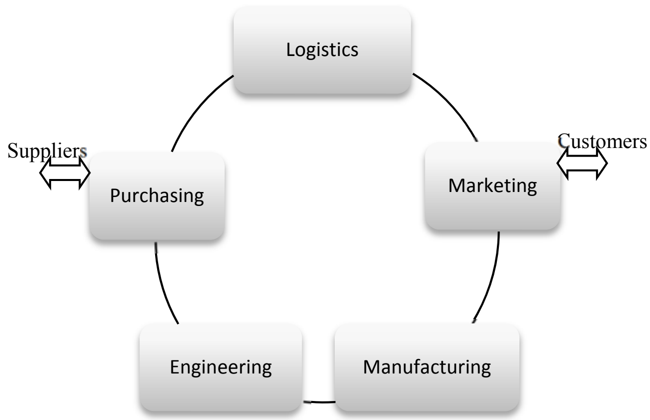


Fig. 2. Supply chain functions affected by product variety

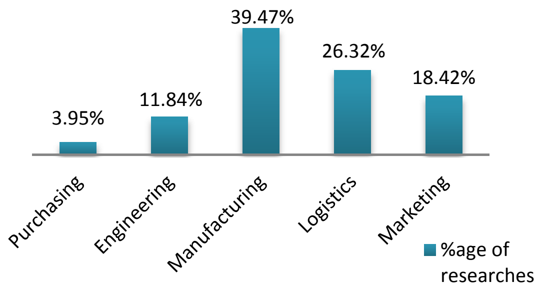


Fig.3. Percentage of publication of PV in each dimension of SC

Product variety has long been used to increase firm performance (Wan, X., 2011). However, greater product variety does not always lead to higher sales. For example, when Procter & Gamble Co. reduced the number of versions of its Head and Shoulders shampoo from 26 to 15, sales actually increased ten percent (Wan, X., 2011).

Offering products, which do not satisfy the customer needs, might not increase the market share, but might adversely affect the costs. Marketers have to be careful in assessing the customers' needs, since, increasing product variety increases the costs and complexity in manufacturing (Alford et al., 2000; Hu, S.J. et al., 2008; ElMaraghy, H. et al., 2013). Higher product variety also evokes the complexity of demand forecasting and matching of supply with demand in the supply chain.

Increasing variety has effect on various logistics operations and costs. Variety incurs many indirect costs, such as raw material costs, work-in-process (WIP), finished goods, and post-sales service inventories, and logistics costs that are difficult to capture, and are often neglected when making the decision about introducing variety (Martin and Ishii, 1996). Due to the uncertainty in forecasting demands, a firm offering more variants usually tends to carry more finished goods inventory than a firm with less variants.

Increase in variety increases the inventory levels and inventory costs (Fisher and Ittner, 1999; Thonemann and Bradley, 2002; Ton, Z. and Raman, A., 2010). Increasing variety also increases the inventories of purchased and semi-finished parts (Forza and Salvador, 2001). Benjaafar, et al. (2002) examined the effect of product variety on inventory-related costs, and showed that total cost increases linearly with the number of products. De Groote, X. and Yücesan, E.(2011) show that keeping the total demand constant, the expected cost of inventories and backorders increases linearly with the number of products. Er and MacCarthy (2006) asserted that increasing variety alone does not have a significant impact on the average of total inventory. They stated that the average of total inventory is affected highly by the uncertainty in supply delivery time.

Increasing variety increases the inventories of purchased and semi-finished parts (Forza and Salvador, 2002). As the product variety increases the variety in purchased parts and materials also increases (Fisher et al., 1999; Forza and Salvador, 2002). Increase in part/ material variety may lead to uncertainty in delivery times (Fisher and Ittner, 1999).

Increase in variety increases the purchasing costs (Randall and Ulrich, 2001. Also, Increasing variety increases the design workload connected to the development of numerous product variants (Forza and Salvador, 2002; Desai, K. and Trivedi, M., 2014. Also, increasing product variety increases the costs and complexity in manufacturing (Alford et al., 2000; Hu, S.J. et al., 2008; Desai, K. and Trivedi, M., 2014). As product variety increases, the performance of the firm's internal operations decreases due to higher direct manufacturing costs, manufacturing overhead, delivery times, and inventory levels (Forza and Salvador, 2002).

Increasing the variety level also generates a range of difficulties in ensuring operational efficiency (McCutcheon et al., 1994; Åhlström, P. and Westbrook, R., 1999). A broader product line with corresponding low volumes for each item in the line can result in higher unit costs, mainly because of increases in overhead expenses (Park, T. et al., 2004; Hayes and Wheelright, 1984), and higher direct labor and material costs (Park, T. et al., 2004; Abbegglen and Stalk, 1985).Especially, if setup times are significant, the effect of product variety on cost is substantially greater than that suggested by the risk-pooling literature for perfectly flexible manufacturing processes (Thonemann and Bradley, 2002).

Banker et al. (1990) studied an auto component manufacturer and observed that product complexity had a significant impact on the cost of supervision, quality control, and tool maintenance. Increasing product variety within a supply chain increases both production costs (Park, T. et al., 2004; Stalk and Hout, 1990; Cooper and Kaplan, 1990) and market mediation costs (Fisher et al., 1999).

Although product variants risks have a major impact in the supply chain, no one of the surveyed researches is interested in managing the product variety risks (Thun, J.H. and Hoenig, D., 2011). Or, at least, gather all the product variety risks and determine the most important risks to be able to mitigate them. So, this study helps in filling the gap in the literature. In this paper all product variety risks will be identified in section 3, and then assessed in section 4.

## 3. Risk Identification

The most significant risks of product variety are gathered from precedent product variety researches. Then the risks are grouped under the five basic dimensions of supply chain (Purchasing, Engineering, Manufacturing, Logistic, and Marketing) suggested by (Park, T. et al., 2004). The total number of risks at first was 38 but it was reduced to 11 main risks after a depth interview with supply chain managers of sixty industries to eliminate excess risks that depend on main risks. The product variety risks in each dimension of the supply chain, the definition of each risk, and the researchers studied the effect of these risks on the supply chain, are shown in "Table 1".

Table 1. Product variety risks

| Risks | Definition | Researches |
|---|---|---|
| Purchasing | | |
| Increasing purchasing costs | Product variety exacerbates purchasing costs when volume is divided into multiple products such that quantity discounts in purchasing are impossible. | Ulrich and Randall, 2001 |
| Increasing the lead time | The length of time required by a supplier to deliver the material to the manufacturer, and it subject to uncertainty. | Er, M. (2004) |
| Engineering | | |
| Increasing the complexity in design | Product families with high product variety level and low production volume tend to be more complex than product families with low product variety level and high production volume. | Zhenxin Yu (2006); Forza and Salvador, 2002; Kalpesh and Minakshi, 2014; S.J. Hu et al., 2008; Xiaowei Zhu, 2009; Hui Wang, 2010 |
| Manufacturing | | |
| Quality ( increasing control costs or reworks) | Greater parts variety implies lower volume per part, so, statistical process control becomes harder to perform when demand for parts is low and episodic, which increasing quality problems. | G. Scott Webb (2011); Hesna Muge Yayla-Kullu (2009) , Zhenxin Yu (2006), Banker et al., 1990 |
| Increasing set-up time | Setup time is the period required to prepare a device, machine, process, or system to be ready to function or accept a job. | Er, M., 2004, Yeh and Chu, 1991, Fisher and Ittner,1999; Susan, 2006 |
| Increasing manufacturing complexity | A complex system is one, which has many numbers of parts, which their relationships are not simple. | Alford et al., 2000; Yeh and Chu, 1991 |

Table 1(continue). Product variety risks

| Risks | Definition | Researches |
|---|---|---|
| Logistics | | |
| Increasing the WIP | Work in process inventory means partially completed goods, parts, or sub-assemblies. | Yeh and Chu, 1991; Trivikarm H Rao (2008) |
| Increasing the inventory level | The current amount of a product that a company has in stock. | Anderson, 1995; Fisher and Ittner, 1999; Forza and Salvador, 2002;Miller and Vollmann, 1985; Fisher et al., 1995; Xavier de Groote and Enver Yücesan 2011; Zeynep and Ananth, 2010 |
| Increasing the market mediation cost | Includes the variety-related inventory holding costs and shortage costs. | Fisher et al., 1996 |
| Increasing the material handling cost | The movements of materials to, through, and from productive processes in warehouses and storage, and in receiving and shipping areas. | Yeh and Chu 1991; Fisher et al., 1995; Abegglen and Stalk, 1985 |
| Marketing | | |
| Increasing the Demand uncertainty | There is a difficulty accurately forecast customer demand in the future. | Kalpesh and Minakshi, 2014; Zhenxin Yu 2006; Er, M. (2004); Ulrich and Randall, 2001; Er and MacCarthy, 2003; Fisher et al., 1995 |

## 4. Risk Assessment

It is difficult to respond to all risks in the same time. So, prioritize risks is a basic procedure in risk management to define which risks should be mitigated. In this study, Fuzzy Analytic Hierarchy Process (FAHP) which is considered as one of the most popular decision making techniques is used to estimate the weights of the risks in a supply chain to prioritize them. The analytic hierarchy process (AHP) is a multi-criteria decision-making tool that can handle unstructured or semi-structured decisions with multi-person and multi-criteria inputs. AHP includes the basics of decomposition, pair-wise comparisons, and priority vector generation and synthesis.

Although AHP is based on expert's opinion; traditional approach of the method can not reflect the human mind in a realistic way (Faisal, 2010). In the traditional AHP technique, it is suspicious to use integer values while the alternatives are compared to each other. Besides, judgment scale in this method is criticized for not being capable of understanding the uncertainties and negligence in the comparison process (Sofyalıoğlu and Kartal, 2012). In order to eliminate these shortcomings, FAHP method will be used.

FAHP can be seen as a synthetic extension of the traditional AHP method by taking into account the fuzziness of decision maker. In order to show how calculations are made, the basic steps of this method are described as follows (Sofyalıoğlu and Kartal, 2012):

1. A hierarchical structure is created by defining multi-criteria decision problem. The structure consists of an overall objective, alternatives to reach to the objective and criteria that relate the alternatives to the objective.

2. Expert's opinion is very critical in the solving of this decision problem. So, a questionnaire is constructed containing pair-wise comparisons of criteria or alternatives and answered by the experts of the subject. These pair-wise comparisons are diverted to a comparison matrix through a preference scale developed by Wind and Saaty (1980). Because of the fact that uncertainty should be considered in some or all of the pair-wise comparison values, the pair-wise comparison under traditional AHP, in which discrete values are selected in the process, may not be acceptable (Yu, 2002). Therefore, the preference scale is converted into linguistic fuzzy scale as proposed by Angnostopoulos et al., (2007). The preference scale of AHP and linguistic fuzzy scale are shown in "Table 2" and represented in "Figure 4".

Table 2. Triangular Fuzzy linguistic scale

| Definition | Intensity of importa-nce | Triangular fuzzy scale | Triangular fuzzy reciprocal scale |
|---|---|---|---|
| Equal Importance | 1 | (1,1,1) | (1,1,1) |
| Equal to moderate importance | 2 | (1,2,3) | (1/3,1/2,1) |
| Moderate Importance | 3 | (2,3,4) | (1/4,1/3,1/2) |
| Moderate to strong importance | 4 | (3,4,5) | (1/5,1/4,1/3) |
| Strong Importance | 5 | (4,5,6) | (1/6,1/5,1/4) |
| Strong to very strong importance | 6 | (5,6,7) | (1/7,1/6,1/5) |
| Very strong Importance | 7 | (6,7,8) | (1/8,1/7,1/6) |
| Very strong to demonstrated importance | 8 | (7,8,9) | (1/9,1/8,1/7) |
| Demonstrated Importance | 9 | (8,9,9) | (1/9,1/9,1/8) |

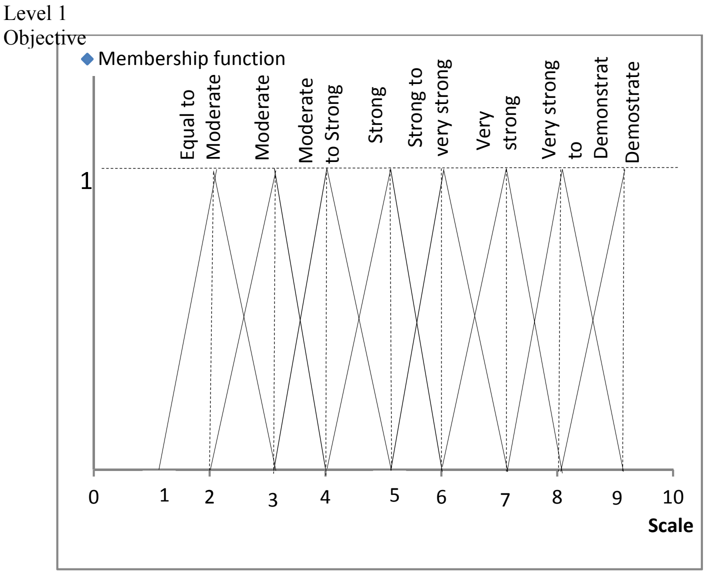


Fig. 4. Triangular Fuzzy Linguistic Scale

3. Chang, 1996, extent analysis method is used to calculate fuzzy synthetic values. This calculations are explained following:

   - The triangular fuzzy number can be denoted as: $M = (l, m, u)$. Where, $(l < m < u)$ $l$, $m$, and $u$ stands for the lower value, mind-value, and upper value of the support of $M$, respectively. When $(l = m = u)$, it is a non fuzzy number.

   - Chang's analysis method is applied for each criteria and alternative. Therefore, for each criteria or alternative $(i)$, $k$ extent analysis values is obtained, as following:

     $M_i^1, M_i^2, \ldots\ldots, M_i^k,\ \ (i = 1,2,\ldots.,n)$, $and\ k = number\ of\ criteria\ or\ alternatives.$

   - Each value of $M_i^j, (i = 1,2,\ldots,n\ \ and\ j = 1,2,\ldots,k)$ is a triangle fuzzy number. According to criteria or alternative $i$, the fuzzy synthetic value (fuzzification process) is defined as:

$$S_i = \sum_{j=1}^{k} M_i^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{k} M_i^j\right]^{-1} \quad (1)$$

Where;

$$\sum_{j=1}^{k} M_i^j = \left(\sum_j^k l_j, \sum_j^k m_j, \sum_j^k u_j\right) \quad (2)$$

And;

$$\sum_{i=1}^{n}\sum_{j=1}^{k} M_i^j = \left(\sum_i^n l_i, \sum_i^n m_i, \sum_i^n u_i\right) \quad (3)$$

Hence;

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{k} M_i^j\right]^{-1} = \left(\frac{1}{\sum_i^n u_i}, \frac{1}{\sum_i^n m_i}, \frac{1}{\sum_i^n l_i}\right) \quad (4)$$

4. Using Wang's method, Wang et al. (2008), to estimate the relative weights of each criterion or alternative (defuzzification process). The Chang's extent analysis method estimates the final weights from the fuzzy comparison misapplications. From that, in this study, after calculating the synthetic values by Chang's method, the final weights are calculated from weighted index values of integral values according to Wang's method. The total integral value for the triangular fuzzy number is defined as following;

$$I_i^{\alpha}(M) = \frac{1}{2}\alpha(m+u) + \frac{1}{2}(1-\alpha)(1+m) = \frac{1}{2}[\alpha u + m + (1-\alpha)l] \quad (5)$$

Where, α is an index of optimism which represents the degree of optimism of the decision-maker, and $0 \leq \alpha \leq 1$. A bigger value of α denotes a higher degree of optimism. $l$, $m$, and $u$ stands for the lower value, mind-value and upper value of the Synthetic value, and $(l < m < u)$. Then, the weight of every criterion is calculated by normalizing the index of optimism using the formula of:

$$W_i = \frac{I_i}{\sum_{i=1}^{n} I_i} \quad (6)$$

According to the first step of the previous method, figure 5 indicates the prioritization problem. Where, the overall objective is prioritization the product variety risks. On the other hand, the departments of the supply chain can be considered as the alternative groups to reaching the objective. Moreover, criteria are the risks related to each alternative.

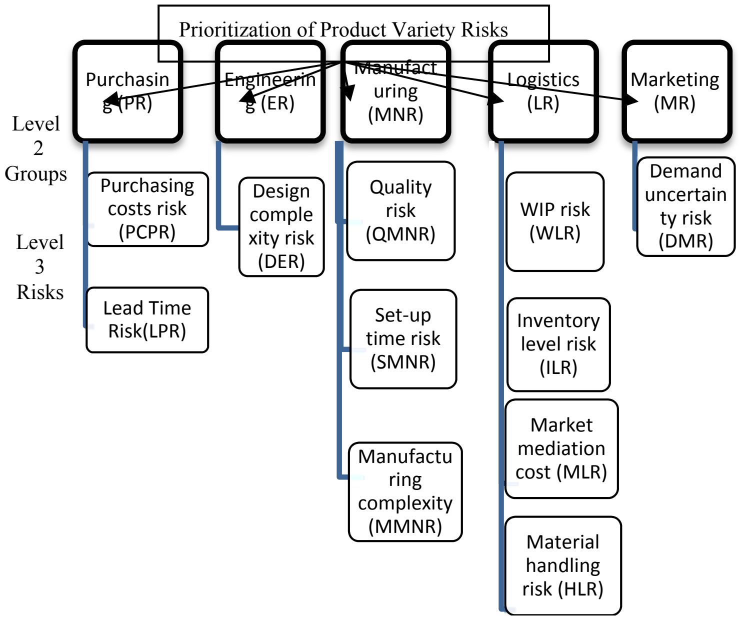

Fig. 5. A hierarchy based model of product variety risks

The second step is the pair wise comparisons that made by a questionnaire. Section 4.1 introduces the design and analysis of the questionnaire. While, Sections 4.2 describes the third and fourth steps which, calculating the weights of alternative groups (departments of the supply chain) using the methodology explained before. The same calculations are made for criteria (risks). In section 4.3 calculating the final or global weights of the risks by multiplying risk's weight by its group's weight, and priority of the risks.

### *4.1. Questionnaire*

The expert's opinions are collected by distributing a designed pair wise questionnaire on sixty companies which located in 10th of Ramadan city in Egypt. This sample size was considered enough to achieve the goal of the research by getting a casual trend of the importance of the risks. Filling the questionnaire was done through direct discussion (interviews) with the supply chain manager of each company. The role of the participants is to express the degree of importance (equal importance to demonstrate importance) for each pair of groups and each pair of risks in the same group. Table 3 illustrates the pair wise comparisons between each pair of SC groups. The importance degree of each pair wise comparison is computed by taking the geometric mean of individual evaluations. Table 4 introduces the results of the questionnaire's analysis for alternative's groups after transferred it into linguistic scale.

Table 3. Pair wise comparisons of SC groups

| Questions | SC Groups | Demonstrated importance | Very Strong | Strong | Moderate | Equal importance | Moderate | Strong | Very Strong | Demonstrated | SC Groups |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Marketing | | | | | | | | | | Logistics |
| 2 | Marketing | | | | | | | | | | Purchasing |
| 3 | Marketing | | | | | | | | | | Manufacturing |
| 4 | Marketing | | | | | | | | | | Engineering |
| 5 | Logistics | | | | | | | | | | Purchasing |
| 6 | Logistics | | | | | | | | | | Manufacturing |
| 7 | Logistics | | | | | | | | | | Engineering |
| 8 | Purchasing | | | | | | | | | | Manufacturing |
| 9 | Purchasing | | | | | | | | | | Engineering |
| 10 | Manufacturing | | | | | | | | | | Engineering |

Table 4. Importance of Risk Groups

| Risks | Importance | Risks |
|---|---|---|
| **Marketing** | Equal to Moderate Importance | **Logistics** |
| **Marketing** | Strong to Very Strong Importance | **Purchasing** |
| **Marketing** | Very Strong to Demonstrated Importance | **Engineering** |
| **Marketing** | Moderate to Strong Importance | **Manufacturing** |
| **Logistics** | Moderate to Strong Importance | **Purchasing** |
| **Logistics** | Very Strong to Demonstrated Importance | **Engineering** |
| **Logistics** | Strong to Very Strong Importance | **Manufacturing** |
| **Purchasing** | Strong to Very Strong Importance | **Engineering** |
| **Manufacturing** | Moderate to Strong Importance | **Purchasing** |
| **Manufacturing** | Strong to Very Strong Importance | **Engineering** |

### *4.2. Group's weights*

The data from "Table 4" is transferred into the fuzzy comparison matrix using the triangular fuzzy scale in "Table 2" as shown in "Table 5".

Table 5. Fuzzy comparison matrix of product variety risk groups

| | Marketing (MR) | Logistics (LR) | Purchasing (PR) | Engineering (ER) | Manufacturing (MR) |
|---|---|---|---|---|---|
| Marketing (MR) | 1 1 1 | 1 2 3 | 5 6 7 | 7 8 9 | 3 4 5 |
| Logistics (LR) | 1/3 0.5 1 | 1 1 1 | 3 4 5 | 7 8 9 | 5 6 7 |
| Purchasing (PR) | 1/7 1/6 1/5 | 1/5 1/4 1/3 | 1 1 1 | 5 6 7 | 1/5 1/4 1/3 |
| Engineering (ER) | 1/9 1/8 1/7 | 1/9 1/8 1/7 | 1/7 1/6 1/5 | 1 1 1 | 1/7 1/6 1/5 |
| Manufacturing (MR) | 1/5 1/4 1/3 | 1/7 1/6 1/5 | 3 4 5 | 5 6 7 | 1 1 1 |

From "Table 5" the weights of the product variety risk groups are calculated using fuzzy as shown in the following;

*The Fuzzy synthetic values ($s_i$) of the risk groups from equation (1)are:*

$$S_i = \sum_{j=1}^{k} M_i^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{k} M_i^j\right]^{-1}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{k} M_i^j = (50.72698, 61.16667, 72.08571)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{k} M_i^j\right]^{-1} = \left(\frac{1}{72.08571}, \frac{1}{61.16667}, \frac{1}{50.72698}\right)$$

So;

$$S_{MR} = (0.2358308, 0.3433248, 0.492835)$$
$$S_{LR} = (0.2265825, 0.3188016, 0.4534082)$$
$$S_{PR} = (0.090765, 0.1253408, 0.1747921)$$
$$S_{ER} = (0.0209187, 0.0258856, 0.0332312)$$
$$S_{MNR} = (0.1296078, 0.1866488, 0.266788)$$

*Total integral value for triangular fuzzy number, $I_i$, (The defuzzification process) from equation (5) are:*

$$I_i^{\alpha}(M) = \frac{1}{2}\alpha(m+u) + \frac{1}{2}(1-\alpha)(1+m) = \frac{1}{2}[\alpha u + m + (1-\alpha)l]$$

Using α = 0.5 (Sofyalıoğlu and Kartal, 2012), then;

$I_{MR} = 0.354$ $I_{LR} = 0.329$ $I_{PR} = 0.129$
$I_{ER} = 0.026$ $I_{MNR} = 0.192$

*Finally the relative weights ($W_i$) of the product variety risks are calculated by normalizing the indexes of optimism from equation (6);*

$$W_i = \frac{I_i}{\sum_{i=1}^{n} I_i}$$

$W_{MR} = \frac{0.354}{1.026} = 0.345 \qquad W_{LR} = \frac{0.329}{1.026} = 0.32$

$W_{PR} = \frac{0.129}{1.026} = 0.125 \qquad W_{ER} = \frac{0.026}{1.026} = 0.025$

$$W_{MNR} = \frac{0.192}{1.026} = 0.185$$

*4.3. Prioritization of product variety risks*

Similar calculations are made for product variety risks (criteria). The findings of all the analyses are in "Table 6". Specifically, it shows (1) the weight (importance) of each supply chain risk group, (2) the weight (importance) of each product variety risk type in each group, (3) the global weight (importance) of each product variety risk, (4) and the priority of each risk which largest weight has the first priority.

Table 6. Product variety risks' global weight.

| Group's weight | Product variety sub-risks | Local weights | Global weights $local\ weight * group's\ weig$ | Priority |
|---|---|---|---|---|
| Purchasing (0.125) | Purchasing costs | 0.2 | 0.025 | 9 |
| | Lead time | 0.8 | 0.1 | 3 |
| Engineering (0.025) | Design Complexity | 1 | 0.025 | 9 |
| Manufacturing (0.185) | Quality costs | 0.2 | 0.037 | 7 |
| | Set up time | 0.5 | 0.0925 | 5 |
| | Manufacturing complexity | 0.3 | 0.0555 | 6 |
| Logistics (0.32) | WIP | 0.3 | 0.096 | 4 |
| | Inventory level | 0.5 | 0.16 | 2 |
| | Market mediation cost | 0.1 | 0.032 | 8 |
| | Material handling | 0.1 | 0.032 | 8 |
| Marketing (0.345) | Demand uncertainty | 1 | 0.345 | 1 |

## 5. Conclusion

This paper helps in identifying and assessing the potential product variety risks that are likely to disrupt a supply chain. All product variety risks gathered based on the previous researches of the effect of product variety on the supply chain from 1985 until 2014. The risks grouped under the five basic dimensions of supply chain (Marketing, Logistic, Manufacturing, Engineering, and purchasing). Then the risks prioritized using Fuzzy Analytical Hierarchy process (FAHP).

The findings of this paper are important insights for managers of supply chain regarding product variety risks. First of all, marketing and logistics seem to be highly important as a risk group, followed by manufacturing then purchasing. On the other hand, the weight of engineering is minimal.

Demand uncertainty and inventory level have the highest priority to be mitigated. Also lead time, set up time, and WIP have high priority. The rest of risks have low weights so, mitigate them will be costly than profitably.

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