Design of a Risk-Based Vendor Selection Model in The Implementation of VMI in Retail Company

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Abstract

There is a varied way for a company to compete in the market, creating an effective supply chain could be the choice by building a new way of a partnership with vendors. Eliminating non-added value through the supply chain such as lead time uncertainty can be done by implementing Vendor Managed Inventory (VMI). Information exchange between roles related to point of sales which cause vendors to have control over the inventory owned by retailers is a characteristic of VMI. A large number of actors had a positive impact from VMI, mainly it can control the bullwhip effect in the supply chain. With all the benefits derived from this concept, it comes with some risks involved. Most people pay more attention to what suppliers faced by implementing this concept instead of what's on the retailer side. Selecting the right vendor to implement this concept by knowing the risk have to be a concern since retailer needs to rely on the vendor's decision of their inventory. The objective of this research is to identify the risks faced by retailers and design the appropriate vendor selection model to apply the concept of VMI. Integrating method for identifying the risk (FMEA) and a method for solving multi-criteria decision making (FAHP) is believed to be able to obtain a robust result and reduce bias by considering the combination of assessment. Collecting data at retail company that already applied the concept of VMI was carried out as a case study in this study.

Keywords
Vendor Managed Inventory (VMI), Risk Management, FMEA, Fuzzy AHP

1. Introduction
The smooth flow of material and information in the operating system from upstream to downstream is one of the necessary things in the supply chain. Choosing the wrong supplier to support operational activity could impact the service level of the whole process. This role encourages companies to take various ways to selecting reliable vendors and establish good relationships with vendors or suppliers. This strategy is one way to produce a competitive advantage in the market.

The term lean in the supply chain has become popular since the introduction of the Toyota Production System, continuously to be developed and applied in various fields including supplier selection management. The implementation of the lean concept in supplier selection is related to Just in Time where suppliers can provide the right product at the right time (Wu, 2003). Based on this concept, it can be seen that the supplier's ability is needed in responding to changes in meeting customer demands, and determining supplier selection strategies is the key. Kumar et al. also said that the reliability of several suppliers in supplying the business can keep operational activities lean (Kumar, Routroy, & Mishra, 2018).

Lots of companies have been implemented Vendor Managed Inventory (VMI) to create a productive supply chain. In 2015 in a survey conducted by E2Open of 1,000 companies, 70% of them have implemented VMI (Yalcin, Özpolat, & Schniederjans, 2018). With VMI retailers give their trust to suppliers so that they have the power to manage their product inventory at retailers (Zachariassen, Haas, & Bürkland , 2014). According to Waller et al., this system brings various advantages such as the productivity of the sales space, increased sales for retailers, as well as providing goods control over the bullwhip effect (Zachariassen, Haas, & Bürkland , 2014). Retailers and manufacturers also obtain a benefit when there is a raise in holding costs (Ru, Ruixia, & Zhang, 2017). Neutral profit gain between suppliers and retailers can be achieved with incentives in the form of profit or loss sharing as has

been done by Birim and Sofyalioglu (2017). Several studies shown the implementation of VMI, most of the studies highlighted that retailer gain more benefit than supplier. Transfer of control related to inventory to suppliers poses risks for suppliers because the supplier needs to prepare goods by bearing shipping costs, storage costs, and losses when implementing VMI (Sheng–shi, Li–hong, & Yong–qiang, 2011). Most of the studies focus to designed a models or contracts in VMI based on the risks faced by the supplier side, there are still limited sources that discuss risks from the retailer side.

There are several potential risks faced by retailers while implementing VMI. Sheng-shi et al. (2011) stated that several risks need to be considered, such as evaluating the price index, quality complaints and service levels, as well as transportation and delivery (Sheng–shi, Li–hong, & Yong–qiang, 2011). In addition, there is also the possibility of failure while making a decision due to lack of trust between the actors who play a role (Zhi-song, Hui-min, & Jun-fei, 2007). Yalcin et al. (2018) suggested that distributors need to set limits on the level of dependence on manufacturers to avoid the possibility of loss of trust due to one-sided dependence (Yalcin, Özpolat, & Schniederjans, 2018). Huynh (2015) explained that in implementing the VMI system, retailers also have a risk of overstock due to the high number of goods sent by manufacturers due to high price offers by retailers (Huynh, 2015). Based on this potential, it is necessary to know the risks faced by retailers by implementing VMI. Despite the various benefits, there are still many supply chain actors who are not completely convinced to apply the concept (Borade & Bansod, 2012). Retailers need to select suppliers based on the risks to be faced. The risk-based vendor selection modeling is carried out in research to identify the risks faced by retail companies as well as selecting the right vendor in the application of the VMI concept, which so far there are limited studies that discuss further risks on the retailer side of the entire supply chain.

2. Literature Review

2.1 Risk of Vendor Managed Inventory

The concept of VMI is very similar to a consignment relationship because before the customer receives the goods produced by the supplier, all the goods belong to the supplier and during the process, the supplier is faced with all inventory risks (Sheng–shi, Li–hong, & Yong–qiang, 2011). The exchange of information related to the point of sales is felt in the practice of this concept and makes it a distinctive feature. There are many previous studies that discuss the implementation of VMI and most of them focus on the risks faced by suppliers and the preparation of strategies to obtain neutral profits as shown in Table 1 below.

Table 1. Previous study related to the implementation of VMI

Author	Year	Title	Description
Sheng–shi, Z., Li–hong, Y., and Yong–qiang, H	2011	Risk Analysis and Control of Vendor Managed Inventory Model Implementation for Manufacturers	Proposed strategy in risk control through the establishment of performance indicators, inventory forecasting, coordination between the two parties and vendor supplier agreements
Huynh, C. H.	2015	Operational Strategies for Supplier and Retailer with Risk Preference under VMI Contract.	The characteristics of the demand conditions and the selling price of the products involved in the VMI contract to achieve a neutral or balanced risk.
Sainathan, A., and Groenevelt, H.	2018	Vendor Managed Inventory Contracts – Coordinating the Supply Chain while looking from the Vendor's Perspective.	Comparison of contractual capabilities between VMI and RMI in supply chain coordination.
Yalcin, M. G., Özpolat, K., and Schniederjans, D.	2018	Post-implementation analysis: dependence and trust in VMI context. International Journal of	The relationship between 2 dimensions, namely Dependence and Trust after applying the VMI concept.

G.		Physical Distribution and Logistics Management	
Birim, S., and Sofyalioglu, C.	2017	Evaluating Vendor Managed Inventory Systems: How incentives can benefit supply chain partners	The design of the VMI model with incentives in obtaining a balanced profit between vendors and buyers.

In applying the concept of VMI there are many considerations, as done by Borade et al. (2013) who ranked the issues encountered when implementing VMI (Borade, Kannan, & Bansod, 2013). Appart from suppliers who experience some risks by implementing VMI, retailers also experience the same thing. Borade and Bansod states that success in VMI can be achieved by a supplier's outstanding ability in demand forecast, inventory management and retail management (Borade & Bansod, 2012).

vendor selection is a problem that can be solved using an MCDM approach such as AHP. This approach is commonly used because of its practical convenience. The data source used in this approach is in the form of weighting of several criteria based on the following Satty scale shown in Figure 1.

Scale	Ranking	Explanation
1	Equally important	Both criteria or alternatives contribute to the objective equally
3	Moderately Important	Based on experience and estimation, moderate preference is given to one criteria or alternative over the other
5	Strictly more important	Based on experience and estimation, strict preference is given to one criteria or alternative over the other
7	Very strict, proven importance	One criteria or alternative is strictly preferred over the other; its dominance has been proven in practice
9	Extreme importance	The evidence based on which one criteria or alternative is preferred over the other has been confirmed to the highest confidence
2,4,6	Mid-values	

Source: (Parvez, Rakib, & Islam, 2016)

Figure 1. Satty Scale

The concept of fuzzy can be applied in this approach to be able to represent the subjective judgment of humans. The change from crisp numbers to fuzzy numbers can be seen in Figure 2 below.

Linguistic Variables	Triangular Fuzzy Value Corresponding	Triangular Fuzzy Value Corresponding Reverse
Equal	(1, 1, 1)	(1, 1, 1)
Not very strong	(2, 3, 4)	(1/4, 1/3, 1/2)
Strong	(4, 5, 6)	(1/6, 1/5, 1/4)
Very strong	(6, 7, 8)	(1/8, 1/7, 1/6)
Extremely strong	(9, 9, 9)	(1/9, 1/9, 1/9)

Source: (Fagundes, Hellingrath, & Freires, 2021)

Figure 2. Tringular Fuzzy Number

3. Methods

The competition that occurs today is not only between companies but also competition between supply chains. This causes many companies to compete in implementing more efficient supply chain management. Many companies, especially retail companies apply the concept of Vendor Managed Inventory (VMI) with this condition. The application of this concept requires good collaboration between suppliers and retailers. In addition to increasing competitiveness in the entire supply chain, establishing long-term relationships with the most reliable suppliers is

the key to success (Chen & Wu, 2013). The implementation of this system transfers the uncertainty of demand and inventory decisions to the supplier. Suppliers will face various challenges in managing inventory and replenishment decisions from retailers. With this condition, retailers depend on the supplier's ability to make decisions. The trust given by retailers to suppliers to manage the inventory makes supplier selection an aspect that needs to be concerned. Retailers need to assess the ability of suppliers before they will take over the retailer's inventory. The level of trust and reliability is a mandatory factor in choosing the best supplier in VMI. One way to assess the level of reliability of suppliers is to consider the level of risk obtained from each supplier.

The supplier selection process is part of the decision-making process by considering several criteria from the alternatives offered. This decision-making is part of the Multi-Criteria Decision Making (MCDM), one of the approaches used in supplier selection is the Analytical Hierarchy Process (AHP) (Fagundes, Hellingrath, & Freires, 2021). Human judgment carried out on AHP often does not represent actual judgments using crisp numbers, the application of fuzzy concepts in AHP can overcome these obstacles (Fagundes, Hellingrath, & Freires, 2021). The decision-making process needs to consider risks, but this cannot be handled properly using AHP (Parvez, Rakib, & Islam, 2016). This limitation can be well handled using Failure Mode Effect Analysis (FMEA). Along with the development of technology, this method is not only used in risk analysis to mitigate risks in the production process, currently FMEA is also starting to be developed in the selection of suppliers with the lowest risk by considering 3 dimensions, namely Likelihood, Severity and Control as well as providing a supplier order for each risk (Li & Zeng, 2016). This approach has limitations when dealing with identical values in priority number (Parvez, Rakib, & Islam, 2016). The integration of the two approaches can complement the shortcomings of each method by considering the weight of each risk and the priority level of risk obtained by each supplier.

4. Data Collections

4.1 Risk Identification

The decision-making process in selecting a suitable vendor to implement VMI involves various risk considerations. In this study, direct observations were made on the retail industry through experts with more than 7 years of experience working in the health and beauty field. Experts think that there are several things to be a concern to retailers in implementing VMI namely, retailers have low control over the selling price of the products because the supplier determines the selling price and they often decide the highest retail price. This causes retailers unable to do pricing strategies and obtain lower margins.

The ability of suppliers to display the products they have in stores is one of the necessary things that need to be considered in choosing a supplier. Almost all suppliers that implement VMI have personal assistants who manage all operational activities unfortunately, they often arrange products which causes poor space productivity. Not only the inventory that will be taken over by suppliers, product display, product arrangement in stores, and also product variety to be offered are part of the supplier's responsibility. Things that cause losses for retailers are often done by suppliers, such as too many facing of a product on the shelf, too much distance between products due to the number of SKUs that do not match with the available space, low number of products due to fears of losing goods and product placement that makes it difficult for customers to find a product.

The performance of suppliers is also an indicator for suppliers to apply the concept of VMI. Related to the following criteria, retailers are often faced with an inaccurate forecast that affects the number of goods shipped to the store and the condition of the retailer's inventory. unsuccessful promotions running in store were also found due to insufficient stock. The performance of this supplier can also be illustrated by the ability or performance of SPG, the low understanding of product knowledge often makes customers lose interest in buying a product.

Reliability is an important factor in the VMI concept because retailers will depend on suppliers to control their inventory. Reliable delivery of goods is also important in VMI because only the supplier has the authority regarding shipping and replenishment decisions. Wrong Decision-making regarding replenishment can directly result in lost sales in stores. The low response to change is also often felt by retailers so that the product is not available which has an impact on sales. Retailers are not able to monitor shipments and this is a risk for retailers due to delivery uncertainty. This is different from the traditional concept that applies the PO system with certain delivery date provisions. Based on the explanation above Table 2 shows the summary of the risk that is considered in a supplier selection in VMI.

Table 2. Summary of risk criteria in the selection of VMI suppliers

Criteria	Risk	Cause	Effect
Price	Low price control	The selling price is determined by the supplier	Can't do price selection strategy
	Low margins	Terms of the highest retail selling price	Can't gain a big margin
Display	Unproductive product arrangement	Too many facing for a product	Sales per square meter are not productive
	Poor shelf fulfillment	The number of SKUs is smaller than the available space	Reduce customer buying interest
	Low product availability	Worry about the risk of losing	Increasing the potential for out of stock
	Poor product positioning	Does not make it easy for customers to find products	Low productivity and sales are not optimal
Performance	Forecast is not accurate	Lack of monitoring of stock conditions	There may be over stock or under stock
	Bad performance for personal assistance	Lack of product knowledge	Loss of customer interest
	Low promotion performance	Insufficient stock	The promo given cannot run effectively
Delivery	Lack of monitoring on delivery	Not using the PO system with a certain delivery date	delivery uncertainty
	Unreliable delivery	Unable to respond any changes and there is no penalty fee for goods that are not delivered	Product unavailable

4.2Weighted Risk Criteria

Risk criteria obtained based on the opinion of experts, the next step in the data collection process is the weighting of the criteria based on the Satty scale. This stage aims to determine the level of importance of each criterion. This weighting is done through pairwise comparisons between criteria and sub-criteria. The assessment is carried out completely based on the opinion of experts, therefore it is necessary to consider the value of the consistency index to determine whether the weighting is reliable or not. If the consistency ratio value is less than 0,1, it can be said that the assessment between criteria is consistent (Chen & Wu, 2013). Table 3 – Table 7 shown the result for weighted criteria and sub-criteria.

Table 3. Weighted main criteria for supplier selection

Criteria	Price	Display	Performance	Delivery
Price	1	1/3	5	1/2
Display	3	1	9	3
Performance	1/5	1/9	1	1/5
Delivery	2	1/3	5	1

λ_{maks}: 4,12 CI: 0,04 RI: 0,9 CR: 0,04 < 0,1

Table 4. Weighted sub-criteria for price

Price	Prince Control	Low Margin
Prince Control	1	3
Low Margin	1/3	1

Table 5. Weighted sub-criteria for display

Display	Product Arrangement	Shelf Fulfilment	Product Availability	Product Positioning
Product Arrangement	1	1/5	1/5	1/5
Shelf Fulfilment	5	1	1	1/3
Product Availability	5	1	1	1/3
Product Positioning	5	3	3	1

λ_{maks}: 4,20 CI: 0,06 RI: 0,9 CR: 0,07 < 0,1

Table 6. Weighted sub-criteria for performance

Performance	Forecast Accuracy	SPG Perfomance	Promotion Performance
Forecast Accuracy	1	1/7	1/3
SPG Perfomance	7	1	5
Promotion Performance	3	1/5	1

λ_{maks}: 3,11 CI: 0,05 RI: 0,58 CR: 0,09 < 0,1

Table 7. Weighted sub-criteria for delivery

Delivery	Delivery Monitoring	Delivery Reliability
Delivery Monitoring	1	1/3
Delivery Reliability	3	1

There have been many studies that apply AHP in solving MCDM problems. Apart from the ease of application, this method can also translate qualitative assessments into quantitative numerical calculations (Fagundes, Hellingrath, & Freires, 2021). The application of the fuzzy concept in this approach can help reduce the level of ambiguity in the crisp number. Therefore, changing the crisp value into a tringular fuzzy number is applied at this stage. An example of changing a crisp number to a fuzzy number is attached in the table 8.

Table 8. Transformation crisp number into fuzzy number for main criteria

Criteria	Price			Display			Performance			Delivery		
Price	1	1	1	0,250	0,333	0,500	4	5	6	0,333	0,500	1,000
Display	2	3	4	1	1	1	9	9	9	2	3	4
Performance	0,167	0,200	0,250	0,111	0,111	0,111	1	1	1	0,167	0,200	0,250
Delivery	1	2	3	0,250	0,333	0,500	4	5	6	1	1	1

After making these changes, the geometric mean value is calculated to determine the reverse vector of each column. The value of this reverse vector will be used to determine the fuzzy weight by multiplying the reverse vector value with the result of each geometric mean. The results from this calculation are still fuzzy numbers, therefore a de-fuzzified process is carried out to create a priority vector by calculating the average of the value of each row. if viewed carefully, the total of the de-fuzzified calculations is not equal to one, which means that a normalization process is needed to determine the level of importance or priority of each criterion. The same process is necessary for the calculation of the priority vector of each sub-criteria. An example of the results of the priority vector for the main criteria can be seen in table 9.

Table 9. Risk priority for each main criteria

Criteria	Fuzzy Weight			De-fuzzified	Priority Vector
Price	0,11172573	0,17169271	0,2960778	0,19316541	0,182025687
Display	0,36017133	0,53909888	0,77932059	0,55953027	0,527262511
Performance	0,0346575	0,04639824	0,06494338	0,04866638	0,045859817
Delivery	0,14703933	0,24281016	0,3896603	0,2598366	0,244851985
Total				1,06119865	1,0000000

4.3 Risk Assesment

In selecting a suitable vendor to apply the concept of VMI based on the risk faced by a retailer, a data collection process is done by calculating 3 dimensions of FMEA, namely Occurrence, Severity, and Detection for each supplier. The aim of this assessment is to determine the level of risk that needs to be considered which can be seen from the final result in the form of a risk priority number. After gain the values for the three dimensions, the RPN is calculated to find out which risks need to be considered the most in the selection of suppliers. Furthermore, the results of this RPN will be multiplied again with the weights obtained previously using the AHP approach to produce a weighted RPN which is the final result of the process of designing a risk-based vendor selection model. An example of the calculation for the weighted RPN results from one of the supplier options can be seen in table 10.

Table 10. Calculation of severity, occurrence and detection

Criteria	Weight of Criteria (1)	Sub-criteria	Weight of Sub-criteria (2)	Supplier A			RPN (3)	Weighted RPN (1)*(2)*(3)
				S	O	D		
Price	0,182025687	Prince Control	0,742385592	7	7	1	49	6,621529111
		Low Margin	0,257614408	5	5	1	25	1,17231099
Display	0,182025687	Product Arrangement	0,05861022	2	2	2	8	0,247223773
		Shelf Fulfilment	0,221106648	1	1	2	2	0,233162493
		Product Availability	0,221106648	1	2	2	4	0,466324985
		Product Positioning	0,499176485	1	1	2	2	0,526394094
Performance	0,045859817	Forecast Accuracy	0,083143937	2	2	3	12	0,045755589
		SPG Performance	0,727297296	1	1	2	2	0,066707442
		Promotion Performance	0,189558767	2	2	3	12	0,104317565
Delivery	0,24485198	Delivery Monitoring	0,257614408	1	1	2	2	0,126154798
		Delivery Reliability	0,742385592	1	1	2	2	0,363549171
Total								9,973
Average								0,90667546

5. Result and Discussion

Table 11. Comparison of weighted RPN for each supplier

Criteria	Sub-criteria	Weighted RPN

		Supplier A	Supplier B
Price	Prince Control	6,621529111	0,270266494
	Low Margin	1,17231099	1,17231099
Display	Product Arrangement	0,247223773	0,494447546
	Shelf Fulfilment	0,233162493	4,663249854
	Product Availability	0,466324985	1,398974956
	Product Positioning	0,526394094	2,105576376
Performance	Forecast Accuracy	0,045755589	0,183022357
	SPG Performance	0,066707442	0,60036698
	Promotion Performance	0,104317565	0,156476348
Delivery	Delivery Monitoring	0,126154798	9,083145478
	Delivery Reliability	0,363549171	9,088729271
Total		9,973	29,217
Average		0,90667546	2,65605151

The results based on the calculation of the criteria's weight show that the display is the most important thing that needs to be considered compared to other criteria. This thing happened because the appearance of the product is the thing that greatly affects the productivity of sales in the store. Besides, the appearance of the product is also something that greatly influences customer interest to buy a product. the more variants or product options offered, the greater opportunity for customers to buy products in large quantities. After the display, the second place as a criterion that should be considered is delivery. the system of implementing VMI is the handover of all inventory decisions to suppliers, so retailers cannot monitor deliveries made by suppliers. This causes retailers to rely heavily on the level of reliability of deliveries made by suppliers. products that are not available can increase the chance of lost sales which can be a big loss for retailers. these two criteria are criteria that need to be considered as well as possible in the selection of VMI vendors.

The risk generated from each alternative shown in Table 11 has a significant difference, because there are significant differences in risk assessment in almost all criteria. Supplier A has a much lower level of risk than supplier B for criteria with a high level of importance such as display and delivery. However, there are conditions that indicate that supplier B has a lower level of risk than supplier A, as in the example of the price criteria assessment. Supplier B has a low risk on price control because the price offered by the supplier is not too high so that the price can compete in the market.

6. Conclusion

From the comparison of these two suppliers, it can be seen that supplier A is the most decent supplier to apply the concept of VMI by conducting the lowest level of risk. In other words, supplier A can be called a reliable supplier to manage inventory from retailers. There are some things that need to be developed in this research, such as adding more alternatives for comparison from a wider scope. This assessment has different characteristics depending on the type of business being run, therefore it would be better if this model could be implemented in other fields with a different perspective.

References

Wu, Y. C. , Lean Manufacturing: a Perspective of Lean Suppliers. *International Journal of Operations and Production Management*, 1349-3577, 2003.

Kumar, C. S., Routroy, S., and Mishra, R. , Lean Supplier Management for Better Cost Structures. *Materials Today: Proceedings 5 , 2018.*

Yalcin, M. G., Özpolat, K., and Schniederjans, D. G., Post-implementation analysis: dependence and trust in VMI context. *International Journal of Physical Distribution and Logistics Management*, 724-740, 2018.

Zachariassen, F., Haas, H. d., and Bürkland , S. , Vendor Managed Inventory: Why You Need to Talk to Your Supplier. *Journal of Industrial Engineering and Management*, 831-856, 2014.

Sheng–shi, Z., Li–hong, Y., and Yong–qiang, H. ,. Risk Analysis and Control of Vendor Managed Inventory Model Implementation for Manufacturers. *IEEE*, 2011.

Ru, J., Ruixia, S., and Zhang, J. ,When Does A Supply Chain Member Benefit from Vendor-Managed Inventory? *Production and Operations Management Society*, 2017.

Zhi-song, C., Hui-min, W., and Jun-fei, C., Research on the Contract in Jointly Managed Inventory. *IEEE*, 2007.

Huynh, C. H., Operational Strategies for Supplier and Retailer with Risk Preference under VMI Contract. *International Journals of Production Economics* , 2015.

Chen, P.-S., and Wu, M.-T., A modified failure mode and effects analysis method for supplier selection problems in the supply chain risk environment: A case study. *Computers and Industrial Engineering*, 634-642, 2013.

Fagundes, M. V., Hellingrath, B., and Freires, F. G. , Supplier Selection Risk: A New Computer-Based Decision-Making System with Fuzzy Extended AHP. *Journal of Logistics*, 2021.

Parvez, N., Rakib, M. G., and Islam, S. R. , Integrated FMEA Approach for Supplier Selection Problem: The Case on Steel Manufacturing Company. *Proceedings of 14th Asian Business Research Conference.* Bangladesh, 2016.

Li, S., and Zeng, W. , Risk analysis for the supplier selection problem using failure modes and effects analysis (FMEA). *Journal of Intelligent Manufacturing*, 2016.

Borade, A. B., Kannan, G., and Bansod, S. V. , Analytical hierarchy process-based framework for VMI adoption. *International Journal of Production Research*,2013.

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