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**A Multi-Attribute Value Theory to assess the benefits of Vendor Managed Inventory**

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**Abstract**

This paper aims to show the effect of the qualitative decision factors on the implementation of VMI solution in the grocery industry. The methodology used in the study is a combination of an analytical approach and empirical analysis. A multi-attribute value theory called Simple Multi-Attribute Rating Theory was selected as a tool of analysis. This model was combined with the Analytical Hierarchical Process to obtain a hybrid model to express subjective and objective decision-maker evaluations. Then, the empirical analysis was conducted to validate the research paradigm and to test the model generated. As a result, qualitative factors are considered essential elements for a supply chain collaboration project's success. For the literature, it is the first attempt to assess an analytical model combining both qualitative and quantitative factors for such a solution. For practitioners, the model may be used as a supporting tool for decision-making about VMI solution.

**Keywords:** VMI, supply chain collaboration, grocery supply chain, Multi-Objective decision models
**Paper type:** Research paper

## 1. Introduction

Supply chain collaboration has gained much attention in supply chain management, and it is considered an important research topic (Ivanov *et al.*, 2018; Soosay and Hyland, 2015). The most diffused programme is the Vendor-Managed Inventory (VMI) (Ryu, 2020), which has been extensively studied in the literature (Lee and Cho, 2018; Parsa *et al.*, 2017; Lee *et al.*, 2016; Chen, 2013; Mangiaracina *et al.*, 2012). Most of the papers pay attention to the tangible aspects of the VMI. They mainly discuss the impact of the VMI solutions on order processing costs, inventory costs, and transportation costs (Choudhary and Shankar, 2015; Li, Yu and Dong, 2015; Mateen and Chatterjee, 2015). Although the expected cost savings from a VMI adoption are usually considered the principal drivers of adoption for organisations, firms do not enter into a strategic relationship such as VMI just because of cost factors (Parsa *et al.*, 2017). They consider other variables that sometimes outweigh the cost savings of a VMI relationship (Lyu *et al.*, 2010). These are qualitative factors and could have a strong influence during the decision-making process (Niranjan *et al.*, 2012; Ivanov, 2010). Trust, cooperation, and implementation capability are qualitative attributes relevant to be considered in VMI analyses (Ivanov *et al.*, 2019).

This study is motivated by the considerable impact qualitative decision factors have on VMI implementation decisions. The sample of reference is the Italian grocery industry, one of the most advanced sectors in adopting supply chain collaboration projects (Seghezzi and Mangiaracina, 2020;

Digital B2b Observatory, 2017). As suggested by several scholars, the methodology adopted to fill the existing gap in the literature is the multi-objective decision model that can integrate the quantitative and qualitative decision factors in the implementation of the VMI (Ivanov, 2020; Dolgui *et al.*, 2020; Parsa *et al.*, 2017). Furthermore, since there is an increasing awareness of companies' managers that the outcome is affected by a mixed set of factors (Niranjan *et al.*, 2012), the study can also help the enterprises identify the crucial factors related to the implementation of such solution.
The paper is structured as follows: in the second section the review of the extant literature body is presented; the research questions that this study will try to address are formulated; in the third section, along with the description of the methodology adopted. In the fourth section, the model is proposed, while in the fifth part, the main insights and findings of this research are presented and discussed. Finally, implications for both academics and practitioners and main areas for future research are identified.

## 2. Literature review

Vendor-Managed Inventory is one of the strategies for supply chain collaboration. In this collaborative project, the vendor controls the buyer side's inventory, and the buyer provides information on inventory and sales (Ivanov et al., 2019). The partners need to have Warehouse Management Systems (WMS) and Electronic Data Interchange (EDI), thus technological capabilities to share accurate demand and inventory information on a daily basis (Angulo et al., 2004). The diffusion of VMI between firms leads many academic researchers to study this particular collaboration programme (Park and Shim, 2008).
Many contributions cover the benefits of a VMI implementation, relying on different methodologies (such as analytical, simulation, and case studies approach). Chen (2013) shows that the communication channel between the supply chain actors is more efficient by adopting such a solution. Through technology, they can share specific information, profits increase for both the retailer and the supplier, and consumers have lowered retail prices. Thron et al. (2006) consider the costs associated to lost sales by assessing the increase in service level, which may be achieved through VMI for the whole supply chain while maintaining inventory levels at the same values as before VMI adoption. Lee and Ren (2011) assess the benefits of VMI in a global environment. The study demonstrates that VMI provides the supplier with an opportunity to achieve economies of scale in production and delivery. Choudhary *et al.* (2014) compare the VMI with information sharing and emphasise the importance VMI entails in transportation savings. Mateen and Chatterjee (2015) discuss the impact of transportation, modelling the savings with an efficiency factor. Additionally, Mangiaracina *et al.*

(2012) create a model to quantify the benefits stemming from VMI in terms of cost reduction, and to assess the "critical mass" effect on the success of this project, even if there is no clarity about the effect of non-tangible benefits on the implementation of such solution (Parsa *et al.*, 2017). Lyu *et al.* (2010), studying the VMI, focus on the store-level retailer's replenishment problems and provide some implications to coordinate their replenishment mechanisms with the suppliers, focusing on the importance of the cost-saving benefits as leverage to implement the solution.

Figure 1 graphically shows the focus areas and methodologies of VMI-based papers on different dimensions. As shown, the authors focused mainly on the tangible aspects of the VMI. Nevertheless, the industrial viewpoint is chiefly focused on the intangible factors of VMI (Marques *et al.*, 2010). It emerges an existing gap in the extant literature on the intangible benefits of VMI that can also contribute to the practitioners in their decision-making process.

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## 3. Research questions and methodology

This paper attempts to contribute to the extant literature by proposing a multi-objective decision model that can integrate the quantitative and qualitative decision factors in the implementation process of VMI solution.

To reach this objective, the following research questions were identified:

RQ1. How do qualitative and quantitative decision factors impact the VMI implementation decision of the grocery industry stakeholders and how they change after the implementation?

RQ2. How do stakeholders make the VMI implementation decision in case of conflicting variation of cost and value factors?

### 3.1 *Model development methodology*

The work is based on the Multi-Criteria Decision Model (MCDM), which considers the main objectives of the stakeholders involved in a VMI project (Malczewski, 1999). Each objective is measured to assess the impact of the collaborative solution implemented. The phases of the model development methodology are shown in Figure 2.

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Specifically, Simple Multi-Attribute Rating Theory (SMART) is a comprehensive multi-criteria decision-making model of decision-makers to account for qualitative and quantitative factors (Arh and Blažič, 2007). The model is applied by giving weight values to each criterion that illustrates how important they are if compared to the other ones (Risawandi, 2016).

The general process is identified as follows:

1. *Define the stakeholders*. This step is needed to identify the actors involved in the decision process. The model takes into account both manufacturers' and retailers' perspectives. Therefore, each Business-to-business (B2b) relationship manufacturer-retailer consist of a case study for the model development (see Figure 3).

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2. *Determine the main objectives and sub-objectives*. This phase depicts the main objectives and the related sub-objectives that stakeholders try to achieve.
3. *Construct the value tree.* Given the different factors affected by VMI implementation (qualitative and quantitative), two value trees are created.
4. *Determine the value measures*. In this step, value measures, that can be evaluated quantitatively, have from each value tree. Natural and constructed scales are used.
5. *Determine the value functions*. Each value measure, basically for qualitative factors, have a different scale with different units. Value functions are fundamental to compute value measures with candidate solutions. In this phase, interaction with experts is conducted.
6. *Weights*. To consistently determine weight, the Analytical Hierarchical Process (AHP) is integrated with the MCDM. AHP is a model developed by Saaty (1980). It is based on the research of attribute trade-offs weights using the technique of pairwise comparison. The sum of the weights at each level of the hierarchy is 1, and each weight has a value between 0 and 1.
7. *Quantitative value model.* In this last phase, an additive value model is used to merge different factors and to numerically calculate the global value.

### *3.2 Empirical analysis methodology*

Once the model has been defined, interviews with stakeholders have been structured and conducted to identify the objectives (and build the value trees) and feed the model.

A pool of 60 target companies was identified from *Digital B2b Observatory of the Politecnico di Milano* network, which studies the enterprises' collaborative solutions in Italy. The selected target companies were contacted and invited to have either face-to-face or online interviews. 19 firms replied to the invitation, and 15 accepted to take part in the interview. Furthermore, companies have been allowed to provide off-line additional information and data (generally via a survey questionnaire) that could not be covered during the interview, either due to lack of time or ready-by-hand data. Thus, the data have been elaborated through the AHP and SMART techniques, and the results discussed.

## 4. The Model

### *4.1 Values measures*

After the interviews with experts in the sector, two distinct value trees with the main companies' objectives have been constructed. At the top of the value trees, the main objectives have been set, followed by their sub-objectives. Figures 4 and 5 show the value threes for both quantitative and qualitative factors.

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From the value tree, it is possible to notice that the speculative purchasing and penalties represent a cost for the vendor (manufacturer) and revenue for the buyer (retailer). Therefore, since the value tree describes factors for both types of stakeholders, in the first case, the number of penalties and speculative purchasing should be minimised and in the second case maximised.

The scales of the different value measures have been determined through the interviews. Qualitative value measures have a constructed scale, which should approximate decision-makers' opinion, whereas quantitative value measures have a natural scale. For a non-disclosure request of the interviewed companies, the cost items have been measured as the percentage of impact over the total turnover volume generated in the business relationship. Value measures for all the defined variables are listed in Tables 1 and 2.

Please Take in Table 1

Please Take in Table 2

Information obtained through the surveys and the interviews have been processed with the hybrid model mentioned above – the AHP used to compute weights and the SMART to transform scores into ratings. To understand the impact that variables have on the VMI implementation decision-making process, two situations have been assessed: the non-VMI and VMI.

### *4.2 Model implementation*

The model implementation is made up of four parts, as described in Figure 6.

Please Take in Figure 6

Linkages between input data models used and output results are shown in Figure 7.

Please Take in Figure 7

#### *4.2.1. Input data*

Input data have been collected through surveys sent to different respondents and interviews. All the interviewees were asked to assess qualitative variables with a discrete score, ranging from 1 to 5, and quantitative variables with a percentage, expressing the cost variable impact on the transaction

volume between manufacturer and retailer. For non-disclosure reasons, company names have been substituted with $M_n$ for manufacturers and $R_n$ for retailers. The manufacturers' data gathered through this method is shown in Table 3 for what concerns a condition in which VMI is not implemented. Table 4 for the same condition with VMI implemented. In the Tables, scores are shown both for qualitative and quantitative factors.

Please Take in Table 3

Please Take in Table 4

$M_1$, $M_2$, $M_3$, $M_7$, $M_8$, and $M_9$ are the manufacturers that are adopting VMI while estimations of the manufacturer himself give the other scores.
Similarly, data gathered for the retailers' side are shown in Tables 5 and 6.

Please Take in Table 5

Please Take in Table 6

Since data are collected for a specific manufacturer-retailer collaboration, all the respondents have been welcomed to provide answers for all the ongoing VMI relations. The only respondent that provided feedbacks on two distinct collaborations has been $R_2$, and the second data collection for this company has been named $R_2$'.
Regarding the qualitative variables, each interviewee has been asked to mutually compare all the variables. Thus, a nomenclature must be introduced to associate each qualitative variable with the corresponding preference $p$, followed by the relative index $j$. In Appendix A, qualitative variables are described.

The set of collected data are showed in Appendix B for manufacturers and in Appendix C for retailers. In the latter one, in particular, only a single column is shown for $R_2$ since being the decision-maker the same, the preferences about factors remain constant.

An important consideration has to be done for the collection of these data. Given that very close values have been given by decision-makers in the pairwise comparison matrixes, the decision does not respect the Saaty (1980) scale with an integer value between 1 and 9, and the value has a small fluctuation around the value 1. Nevertheless, Saaty (1980) recommends using decimal numbers between 1 and 2 when the decision-makers evaluate two criteria/alternatives with a very close impact on the main objective. Given that the numbers' reciprocal is distributed in an interval [1; 2] falls in an interval [0.5; 1], these numbers can also be accepted.

#### *4.2.2 AHP*

For what concerns the quantitative variables, they have been constructed to collect cost-related information as a percentage to compare one to the other ones. In addition to that, all costs (to which those percentages refer) are expressed with the same unit of measure (i.e., €), to facilitate the comparison. For this reason, since all the cost-related variables can be perfectly compensated with each other, they have been considered to have the same weight, which is found as follows:

$$z_c = \frac{1}{C} \cong 0.14$$

Where $C$ is the number of cost-related variables with $C = 7$ and $c = 1, \dots, 7$.

On the other hand, a completely different approach has to be used with qualitative variables since they all express different concepts that cannot be easily measured. Each decision-maker could have a different perception of their regard.

The SMART model uses normalised weights according to the following formula:

$$w_j = \frac{p_j}{\sum_{j=1}^{m} p_j}$$

where $p_j$ is the preference score assigned by the decision-maker to each criterion, and $w_j$ values are included between 0 and 1. In particular, $\sum_{j=1}^{m} w_j = 1$.

Since this method did not allow manufacturers and retailers to have a good sensitivity in expressing their preferences for what concerns qualitative factors, the AHP has been proposed.

## 5. Findings

As described in Figure 7, this analysis exploits input data directly derived from the surveys and the weights computed through the AHP. The scores are then converted through the value functions in a

value score and then multiplied by the relative weight. Thanks to the computation of these value scores, it is possible first to understand the impact each variable has on the decision-making process and then to understand which is the most suitable option for each stakeholder. The general value generated by the value functions for both qualitative and quantitative variables will be called rating hereafter.

### *5.1 Variable's value impact*

**Manufacturers**

Following the SMART model, the first computation to be performed is the transformation in the rating scale of the manufacturer's scores both for qualitative and quantitative variables. Applying the equations identified in the Value Modelling, where $x$ is represented by the scores listed in Tables 3 and 4, the rating of each variable has been computed as in the next examples:

*Trust rating for $M_1$ in the Pre-VMI situation*

As the first step, $v_{qmij}$ has to be defined, representing the rating expressed for a qualitative variable $i$ (with $i = 1, \dots, 10$) of a manufacturer $j$ (with $j = 1, \dots, 9$).

The following equation represents the value function for the Trust qualitative variable:

$$y = -0.0679x^2 + 0.6421x - 0.54$$

Given that $M_1$ in the Pre-VMI situation has given for the Trust variable a score equal to 1, we have:

$$v_{qm11} = -0.0679 * 1^2 + 0.6421 * 1 - 0.54 = 0.03$$

Where $v_{qm11}$ is the rating expressed for the qualitative variable 1 (i.e. Trust) by the manufacturer 1.

*Inventory costs rating for $M_1$ in the Pre-VMI situation*

As in the previous example, the first step is to define $v_{cmkj}$, which represents the rating expressed for a quantitative variable $k$ (with $k = 1, \dots, 7$) of a manufacturer $j$.

The following equation represents the value function for the Inventory Costs:

$$y = -5.00x + 1.00$$

Given that $M_1$ in the Pre-VMI assessed that the Inventory Costs impact on the transaction volume for a percentage that is equal to 3%, the corresponding rating is:

$$v_{cm11} = -5.00 * 0.03 + 1.00 = 0.85$$

Where $v_{c11}$ is the rating for the quantitative variable 1 (i.e. Inventory Costs) expressed by the manufacturer 1.

The value function equations derive from an interpolation. As a result, extreme scores (i.e., 1 and 5) of certain variables do not give extreme ratings (i.e., 0 and 1). Thus, the interpolation tool introduces a sort of error in the extreme scores' rating caused by transforming a discrete function into a continuous one. Nonetheless, given the importance of expressing the trend of rating variation, a tolerance of +/-5% for the general rating computation has been adopted. After the computation, each rating has been multiplied by the relative preferences expressed and elaborated through AHP. The weighting methods for qualitative and quantitative factors are illustrated in the two following examples: Trust and Inventory costs.

*Trust's weighted rating for $M_1$ in the Pre-VMI situation*

Defining $w_{qij}$ as the weight of a qualitative variable $i$ for a manufacturer $j$, the result is that Trust's weighted rating for the manufacturer $M_1$ can be computed as follow:

$$wv_{qm11} = v_{qm11*} w_{q11} * 100$$

That is

$$wv_{qm11} = 0.03 * 0.10 * 100 = 0.36$$

*Inventory costs' weighted rating for M1 in the Pre-VMI situation*

Similarly, defining $p_{ckj}$ as the weight of a quantitative variable k for a manufacturer $j$, the Inventory Costs' weighted rating for the manufacturer M1 can be computed as follow:

$$wv_{cm11} = v_{cm11*} w_{c11} * 100$$

That is

$$wv_{cm11} = 0.85 * 0.14 * 100 = 12.14$$

As in the previous case, the result of the formula is scaled in cents (0 to 100), and the provided result is computed without approximations.

At this point, having all the weighted ratings for each variable and each manufacturer, it is possible to compute the market average for the specific stakeholder to verify which of the variables have the highest impact on the decision-making process. Each qualitative variable requires the following computation:

$$\overline{wv}_{qmi} = \frac{\sum_{j=1}^{J} wv_{qmij}}{J}$$

where $J = 9$.

Similarly, for quantitative variables:

$$\overline{wv}_{cmk} = \frac{\sum_{j=1}^{J} wv_{cmkj}}{J}$$

Considering Trust and Inventory Costs again, using results from Tables 13 and 14, the following computations can be made:

*Manufacturers' average Trust weighted rating in the Pre-VMI situation:*

$$\overline{wv}_{qm1} = \frac{0.36 + 9.08 + 0.38 + 6.24 + 10.15 + 4.76 + 10.73 + 7.99 + 5.56}{9} = 6.14$$

*Manufacturers' average Inventory Costs weighted rating in the Pre-VMI situation:*

$$\overline{wv}_{cm1} = \frac{12.14 + 12.14 + 12.14 + 11.43 + 12.86 + 5.71 + 10 + 12.14 + 11.43}{9} = 11.11$$

The final results are shown in Figure 8 and Figure 9.

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Please Take in Figure 8

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Enhanced Supply Chain Visibility (+5.87), Customer Satisfaction (+5.37), and Orders Flexibility (+5.32) are those variables that impact the most on manufacturers' rating of the implemented collaboration, since they directly perceive these as the main objectives of a successful supply chain management.

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Please Take in Figure 9

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For the quantitative variables, instead, the difference is much more relevant. What emerges is that Transportation Costs (+2.13) and Stock-Out Costs (+1.19) are the main quantitative decision variables taken into account this stakeholders' category in the decision-making process. These two variables account for more than 50% of the total rating increase provided by quantitative variables.

**Retailers**

As previously described, the same approach to manufacturers' input data has also been used for retailers. The first step is to transform the input score given by retailers into ratings. The variables $v_{qriz}$ and $v_{crkz}$ have to be computed, with $z$ representing the retailers such that $z = 1, \dots, 7$ (R2 has to be counted twice). The final results are shown in Figures 10 and 11.

Please Take in Figure 10

Starting from qualitative variables, if compared with manufacturers' results, Supply Chain Visibility loses its role as the most impacting variable. The visibility is gained mainly by the manufacturer, which can see what is happening downstream, while retailers perceive very few changes. Orders flexibility has moved downstream, losing its influence on VMI implementation. This shift can be explained by the fact that while manufacturers are free to set orders and vary them as they are willing to do, retailers are not placing orders anymore, so the flexibility of the orders is no more a relevant topic to them. On the other hand, Trust shifted toward the graph's left side, given its increased rating variation. Indeed, as proved in the literature, retailers experience lower cost gains than manufacturers in adopting VMI. Thus, to keep alive the collaboration, they need higher scores for enabling conditions such as Trust. Moreover, since manufacturers are in charge of a higher number of activities in a VMI relationship, they are asked a greater degree of reliance.

Please Take in Figure 11

Considering the quantitative variables, Forward Buying Gain, and Penalty Related Gain negatively impacted retailers' rating due to the missed economic opportunity that the retailer has in a VMI relationship. As a matter of fact, since they cannot place orders, they cannot exploit discount periods to buy more products than needed and keep them stocked for the future. Moreover, since VMI allows manufacturers to be better organised in advance on orders' delivery, they must be more respectful of agreed conditions. Therefore, fewer penalties are inflicted on them. As a consequence, there is a reduction of the economic flow on the retailers' side. For what concerns positive values, it is clear how Transportation Costs lose their relevance in terms of additional rating generated by the collaboration since transportation management is in charge of manufacturers. Stock-Out Costs and Inventory Costs become the most relevant variables. In addition to this, it is interesting to notice that losses in Forward Buying Gain entirely cancel improvements in the value of Inventory Costs. The qualitative benefits of VMI have been identified in Supply Chain Visibility, Customer Satisfaction, and Orders Flexibility for manufacturers and Customer Satisfaction, Communication Level, and Strategic Alignment for Retailers. This information could be used as an additional tool for the

traditional quantitative variables by manufacturers to convince retailers of VMI's importance in managing the supply chain.

### *5.2 Global Value and Global Costs*

At this point, the SMART model's last step can be applied, calculating the sum of the weighted rating of each variable to compute the global value of the two alternatives (i.e., non-VMI and VMI).

**Manufacturers**

The following formulas have been applied to obtain the manufacturers' rating for the two dimensions (Cost and Value):

- For the Value dimension:

$$V_{ma} = \sum_{i=1}^{I} \overline{wv}_{qmi}$$

- For the Cost dimension:

$$C_{ma} = \sum_{k=1}^{K} \overline{wv}_{cmk}$$

Where $a$ is the index of the alternatives (non-VMI, VMI; $a = 1, 2$), $I$ is the number of qualitative variables ($I = 10$), and $K$ is the number of quantitative variables ($K = 7$). Examples of non-VMI values are provided.

*Manufacturers' Global Value Non-VMI:*

$$V_{m1} = 6.14 + 4.43 + 6.34 + 3.05 + 1.74 + 2.06 + 5.53 + 4.09 + 1.80 + 2.44 = 37.62$$

*Manufacturers' Global Cost Non-VMI:*

$$C_{m1} = 11.11 + 11.90 + 10.40 + 8.25 + 11.59 + 13.25 + 12.38 = 78.89$$

Results for the VMI situation are shown in Table 7.

For both the Value and Cost dimensions, the VMI implementation provides benefits to the manufacturer on average. Finally, in Figures 12 and 13, it is possible to see how each variable affects the Global Value and the Global Cost respectively and how they vary with the adoption of the VMI.

Please Take in Figure 12

Please Take in Figure 13

**Retailers**

As for manufacturers, Global Value and Global Cost can be obtained for retailers with the following formulas:

$$V_{ra} = \sum_{i=1}^{I} \overline{wv}_{qri}$$

and

$$C_{ra} = \sum_{k=1}^{K} \overline{wv}_{crk}$$

for the Value and Cost dimensions, respectively, and results are shown in Table 8.

Please Take in Table 8

The first comparison with manufacturers' results clearly displays how the upstream player benefits the most from the collaboration, having an increase in rating that is double than the one obtained by retailers. Nevertheless, on average, also for retailers the adoption of a VMI collaboration generates benefits on both dimensions, and so its implementation should be pursued by both parties.
Figures 14 and 15 describe how each variable affects the final results, clearly describing the negative impact given by lost gains in the VMI collaboration for retailers.

Please Take in Figure 14

Please Take in Figure 15

*5.3 Implementation decision*

Once analysed the situation as market average and assessed the collaboration implementation's convenience for the two types of stakeholders, a case-specific analysis has been conducted to identify cases of conflicting decision-making situations. A matrix has been designed to understand the situation of each stakeholder.

As visible in Figure 16, the matrix comprises four areas according to the variation in rating that each company is expected to have as a consequence of the VMI adoption. In particular, a positive variation in Global Value for the As-Was situation generates a "Yes" answer on the vertical axes to the following question (a negative variation while providing a "No" answer):

- *Has VMI to be implemented according to the Value dimension?*

Similarly, a positive variation in Global Cost concerning the As-Was situation generates a "Yes" answer on the horizontal axes to the following question:

- *Has VMI to be implemented according to the Cost dimension?*

The matrix is intended to be used for the evaluation of a VMI collaboration toward a specific partner. As previously proved with the retailer $R_2$ and $R_2$', different partners can lead to different VMI situation.

Please Take in Figure 16

In particular, the point in the centre of the matrix represents the decision-maker's situation before the adoption of the collaboration. After the implementation, the situation is expected to change. A new point (As-Is if the company implemented the collaboration or To-Be otherwise) will be placed in the

matrix defining the improvement direction. In those cases, in which the As-Is point is located in the Yes-Yes or No-No quadrants, the decision-making process is straightforward. If the improvement is positive for both Value and Cost (Yes-Yes quadrant) the decision-maker can implement the collaboration without going deeper into the analysis; otherwise, the project should be discarded (No-No quadrant).

On the other hand, the situation is trickier when the two dimensions are discordant. In this case, the decision-maker must evaluate a trade-off between Global Cost and Global Value. A preference for the two dimensions can be expressed through two weights, and such that. A straight line through the As-Was point can be traced on the matrix, with the following equation:

$$V(C) = \begin{cases} -\dfrac{c}{v} & for\ c, v \in\ (0; 100); \\ V = 0 & for\ c = 0;\ v = 100; \\ C = 0 & for\ c = 100;\ v = 0; \end{cases}$$

Where $V$ represents the Global Value axis and $C$ the Global Cost axis.

This additional information allows the decision-maker to solve the trade-off problem, eliminating the two quadrants affected by uncertainty. In Appendices D, E, and F, three explicative cases are provided. The reduction of the weight $c$, and the consequent increase of the weight $v$, generates a counter-clockwise rotation of the straight line.

Once theoretically defined the so-called Yes/No Matrix, decision-makers can use it to solve tricky decision-making process while considering both qualitative and quantitative variables in the VMI adoption.

### *5.3 Model implementation and validation*

The model was built to analyse the decision-making drivers of VMI implementation and to understand the overall benefits coming from both cost and value dimensions. Based on these premises, a decision matrix has been used to test each possible scenario. The data set of 9 manufacturers and 6 retailers have been used to position companies on this matrix. The two axes of the matrix have been defined wth respect to the variation of the As-Is situation from the As-Was situation. The four starting quadrants are still easily identifiable since the positive variations correspond to “Yes” answers. With this transformation, the As-Was point results to be always in the $(0; 0)$ coordinates so that different companies can be easily compared on the same graph having the same starting point. The first two Figures 17 and 18 represent the As-Is position on the matrix of manufacturers and retailers interviewed.

Please Take in Figure 17

Please Take in Figure 18

In the two figures, companies that adopted VMI are identified with the grey colour while those that did not implement VMI are identified in orange. From a direct comparison between manufacturers and retailers, it is graphically visible in the previous part of the study: manufacturers have higher benefits than retailers for Global Value and Global Cost.

All the interviewed companies gain benefits for at least one of the two dimensions, and almost all of them find a place in the "Yes-Yes" quadrant, even those that did not implement VMI. Three outliers can be identified: two manufacturers ($M_3$ and $M_4$) and a retailer ($R_6$). Two of them ($M_4$ and $R_6$) are on the vertical axis – between the “Yes-Yes” and the “No-Yes” quadrants – while one is on the “No-Yes” quadrant.

Nevertheless, Cost and Value are probably not enough to describe the overall complexity of the decision process that is case-specific and varies from company to company. For this reason, the case-specific analysis of the outliers is needed and performed through the bi-dimensional decision matrix. The first company analysed is $M_3$. This company is the only one that is in an actual trade-off situation. The matrix can be performed straight forward with the result shown in Figure 19.

Please Take in Figure 19

The trade-off line results to be horizontal, since the weights given by $M_3$ for Value and Cost are 98 and 2 respectively; thus, its preference structure is strongly shifted towards the Value dimension. The As-Is point is in the "Yes-Yes" area at a distance from the straight line equal to 68.31. Thus, the benefits accrued from the perspective of $M_3$. Different considerations need to be highlighted for $M_4$ and $R_6$. These two companies are both on the vertical axes and did not implement VMI, even though they are positioned in an area of convenience in the matrix, following the two dimensions’ change

(see Figures 20 and 21) and the weights assigned by them on cost and value sides – $M_4$ (60;40), $R_6$ (60;40).

Please Take in Figure 20

Please Take in Figure 21

Nonetheless, what can be noted is that the two points are much closer to the straight line than for the $M_3$'s case. In particular, the distance of the As-Is point for $M_4$ is equal to 5.17, and the distance of the $R_6$'s point is 12.69. These two values are much smaller than the distance of the $M_3$'s As-Is point (68.31) and, as a consequence, the missed implementation can be associated with low benefits. Other variables not considered in this model, such as investment costs or predictable difficulties in scalability with a critical mass of partners, are needed to spread the investment cost and make the collaboration profitable.

Finally, it is important to highlight that stakeholders $M_5$, $M_6$, $R_1$, and $R_3$, as shown in Figures 20 and 21, are well-positioned in the "Yes-Yes" area, but they did not implement the VMI collaboration. During the interviews, all of them appeared to be highly interested in this kind of process as well as aware of the potential advantages; accordingly, given the assessed benefits, they declared the project would be probably implemented in the future.

## 6. Conclusion

The purpose of this study is to provide new insights and knowledge to both the scientific community and companies' managers. From the academic point of view, it represents the first attempt to analytically assess the two categories of qualitative and quantitative factors jointly affected by the VMI implementation, as suggested by different authors (Parsa *et al.*, 2017). In fact, despite the extensive studies regarding the benefits of VMI in terms of cost-savings (Singh *et al.*, 2018), the literature lacks studies concerning the qualitative factors, considered essential elements for the success of a supply chain collaboration (Lyu *et al.*, 2010). An important insight from the study confirms this consideration: retailer companies are usually reluctant to share strategic data with their suppliers, due to some conflicts of interests, for instance forward buying and unbalanced monetary

benefits. Thus, forward buying and unbalanced monetary benefits represent a barrier for VMI implementation and a reason for failure for performed projects. As suggested by several authors in the literature, the methodology adopted to fill the existing gap is the multi-objective decision model that can integrate the quantitative and qualitative decision factors in VMI implementation (Ivanov, 2020; Dolgui *et al.*, 2020; Parsa *et al.*, 2017). The study reveals the importance of qualitative factors: almost all the companies demonstrated a high degree of interest towards the *quality* of the collaboration, most of the times more than the *cost* of it. For the manufacturer Customer Satisfaction, Supply Chain Visibility, and Orders Flexibility impact the most on the decision of implementing VMI, since the enterprises directly perceive these factors as the main objectives of a successful supply chain management project. Indeed, greater information exchange from the Point of Sales allows better visibility of downstream demand, leading to a reduction of the bullwhip effect. Therefore, there is an improvement in the service level, thanks to higher products' availability, leading to greater customer satisfaction. Customer Satisfaction (i.e., the self-evaluation of the own satisfaction as a client) and Communication Level show the most significant improvement on the retailer side. This information could be used as an additional tool to the traditional quantitative variables by manufacturers to convince retailers of VMI's importance in managing the supply chain.

From the managerial side, the analysis helps enterprises consider the crucial intangible factors related to implementing such a solution. Furthermore, it provides guidance for the implementation of such a solution with a specific partner of the business. A decision matrix is reported, according to the Global Value and Cost rating variation. If the variation is positive, it means that the VMI implementation is recommended, if the variation is negative, the firm should consider not implementing the collaboration practice.

The research presents some limitations. The model considers only two levels of the supply chain (i.e., manufacturer and retailer). No further distinctions have been made (i.e., supplier, manufacturer, distribution centres, point of sales). The model does not take into account case-specific factors such as:

- scalability, the VMI investment is not justified if it is implemented just with one business partner. Thus, some companies probably do not implement it because they still do not reach “critical mass”.
- lack of technological capability and know-how. Since this represents a prerequisite for implementing the VMI (Angulo et al., 2004), it is a crucial barrier most of all if the manufacturer/retailer does not have these skills.

Further developments could solve these issues, considering the scalability and lack of technological skills in the model. Future research could also analyse the additional factors working as enablers of

the VMI implementation decision, providing a better understanding of the reasons at the bottom side affecting the implementation of supply chain collaboration.

**References**


Angulo, A., Nachtmann, H. and Waller, M. (2004) 'Supply Chain Information Sharing in a Vendor Managed Inventory Partnership', *Journal of Business Logistics*, 25, pp. 101–120. doi: 10.1002/j.2158-1592.2004.tb00171.x.

Arh, T. and Blažič, B. J. (2007) 'Application of multi-attribute decision making approach to learning management systems evaluation', *Journal of Computers*, 2(10), pp. 28–37. doi: 10.4304/jcp.2.10.28-37.

Chen, L.-T. (2013) 'Dynamic supply chain coordination under consignment and vendor-managed inventory in retailer-centric B2B electronic markets', *Industrial Marketing Management*, 42, pp. 518–531. doi: 10.1016/j.indmarman.2013.03.004.

Choudhary, D. *et al.* (2014) 'Benefits of retailer-supplier partnership initiatives under time-varying demand: A comparative analytical study', *International Journal of Production Research*. Taylor & Francis, 52(14), pp. 4279–4298. doi: 10.1080/00207543.2013.879615.

Choudhary, D. and Shankar, R. (2015) 'The value of VMI beyond information sharing under time-varying stochastic demand', *International Journal of Production Research*. Taylor & Francis, 53(5), pp. 1472–1486. doi: 10.1080/00207543.2014.951093.

Digital B2b Observatory (2017) *Digital B2b: le fondamenta dell'Italia digitale*. Available at: https://www.osservatori.net/it/prodotti/formato/report/digital-b2b-le-fondamenta-dell-italia-digitale-1.

Dolgui, A., Ivanov, D. and Sokolov, B. (2020) 'Reconfigurable supply chain: the X-network', *International Journal of Production Research*. Taylor & Francis, 58(13), pp. 4138–4163. doi: 10.1080/00207543.2020.1774679.

Ivanov, D. (2010) 'An adaptive framework for aligning (re)planning decisions on supply chain strategy, design, tactics, and operations', *International Journal of Production Research*, 48(13), pp. 3999–4017. doi: 10.1080/00207540902893417.

Ivanov, D. (2020) '"A blessing in disguise" or "as if it wasn't hard enough already": reciprocal and aggravate vulnerabilities in the supply chain', *International Journal of Production Research*, 58(11), pp. 3252–3262. doi: 10.1080/00207543.2019.1634850.

Ivanov, D., Das, A. and Choi, T. M. (2018) 'New flexibility drivers for manufacturing, supply chain and service operations', *International Journal of Production Research*, 56(10), pp. 3359–3368. doi: 10.1080/00207543.2018.1457813.

Ivanov, D., Tsipoulanidis, A. and Schönberger, J. (2019) *Global supply chain and operations*

*management: A Decision-Oriented Introduction to the Creation of Value*. 2nd Ed., *A decision-oriented introduction to the creation of value*. 2nd Ed. Cham: Springer Nature.

Lee, J. Y. and Ren, L. (2011) 'Vendor-managed inventory in a global environment with exchange rate uncertainty', *International Journal of Production Economics*. Elsevier, 130(2), pp. 169–174. doi: 10.1016/j.ijpe.2010.12.006.

Li, S., Yu, Z. and Dong, M. (2015) 'Construct the stable vendor managed inventory partnership through a profit-sharing approach', *International Journal of Systems Science*, 46(2), pp. 271–283. doi: 10.1080/00207721.2013.777982.

Lyu, J., Ding, J.-H. and Chen, P.-S. (2010) 'Coordinating replenishment mechanisms in supply chain: From the collaborative supplier and store-level retailer perspective', *International Journal of Production Economics*, 123, pp. 221–234. doi: 10.1016/j.ijpe.2009.07.017.

Malczewski, J. (1999) *GIS and multi-criteria decision analysis*. John Wiley & Sons.

Mangiaracina, R., Melacini, M. and Perego, A. (2012) 'A critical analysis of vendor managed inventory in the grocery supply chain', *International Journal of Integrated Supply Management*, 7(1–3), pp. 138–166. doi: 10.1504/IJISM.2012.051052.

Marques, G. *et al.* (2010) 'A review of vendor managed inventory (VMI): From concept to processes', *Production Planning and Control*, 21(6), pp. 547–561. doi: 10.1080/09537287.2010.488937.

Mateen, A. and Chatterjee, A. K. (2015) 'Vendor managed inventory for single-vendor multi-retailer supply chains', *Decision Support Systems*. Elsevier B.V., 70, pp. 31–41. doi: 10.1016/j.dss.2014.12.002.

Niranjan, T., Wagner, S. and Nguyen, S. (2012) 'Prerequisites to vendor-managed inventory', *International Journal of Production Research*, 50, pp. 939–951. doi: 10.1080/00207543.2011.556153.

Park, Y.-B. and Shim, K.-T. (2008) 'Development of the Decision Support System for Vendor-managed Inventory in the Retail Supply Chain', *IE interfaces*, 21.

Parsa, P. *et al.* (2017) 'Quantifying the Benefits of Continuous Replenishment Program for Partner Evaluation', *International Journal of Production Economics*, 187. doi: 10.1016/j.ijpe.2017.02.017.

Risawandi, R. R. (2016) 'Study of the simple multi-attribute rating technique for decision support', *Decision-making*, 4, p. C4.

Ryu, C. (2020) 'Investigation on how VMI affects ongoing performance of supply chain system', *Journal of Distribution Science*, 18(1), pp. 85–94. doi: 10.15722/jds.18.01.20201.85.

Saaty, T. L. (1980) 'The Analytic Hierarchy Process Mcgraw Hill, New York', *Agricultural*

*Economics Review*, 70.

Seghezzi, A. and Mangiaracina, R. (2020) 'On-demand food delivery: investigating the economic performances', *International Journal of Retail and Distribution Management*. doi: 10.1108/IJRDM-02-2020-0043.

Singh, H., Garg, R. K. and Sachdeva, A. (2018) 'Supply chain collaboration: A state-of-the-art literature review', *Uncertain Supply Chain Management*, 6(2), pp. 149–180. doi: 10.5267/j.uscm.2017.8.002.

Soosay, C. A. and Hyland, P. (2015) 'A decade of supply chain collaboration and directions for future research', *Supply Chain Management*, 20(6), pp. 613–630. doi: 10.1108/SCM-06-2015-0217.

Wang, S. *et al.* (2008) 'A literature review of electronic marketplace research: Themes, theories and an integrative framework', *Information Systems Frontiers*, 10(5), pp. 555–571. doi: 10.1007/s10796-008-9115-2.

**Tables and Figures**

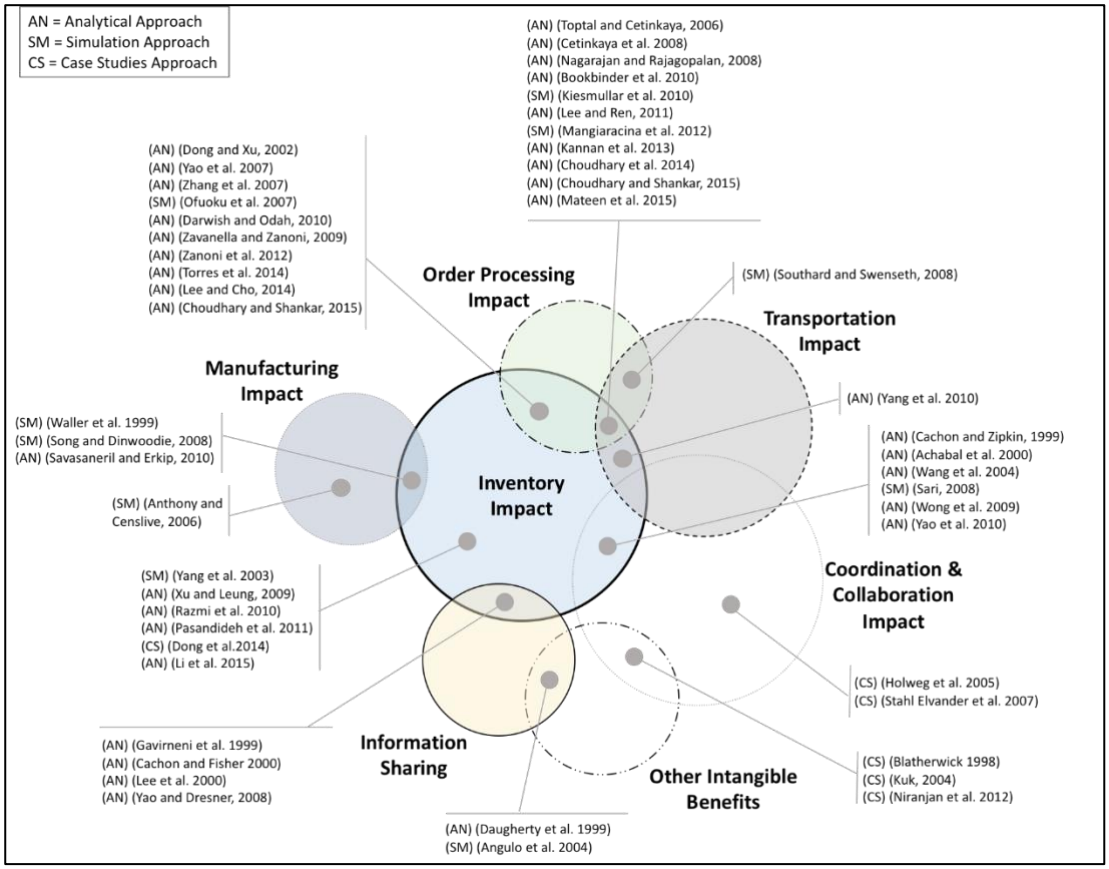


*Figure 1. Graphical representation of VMI studies, based on the area of focus and research methodologies used (Source: Parsa et al., 2017).*

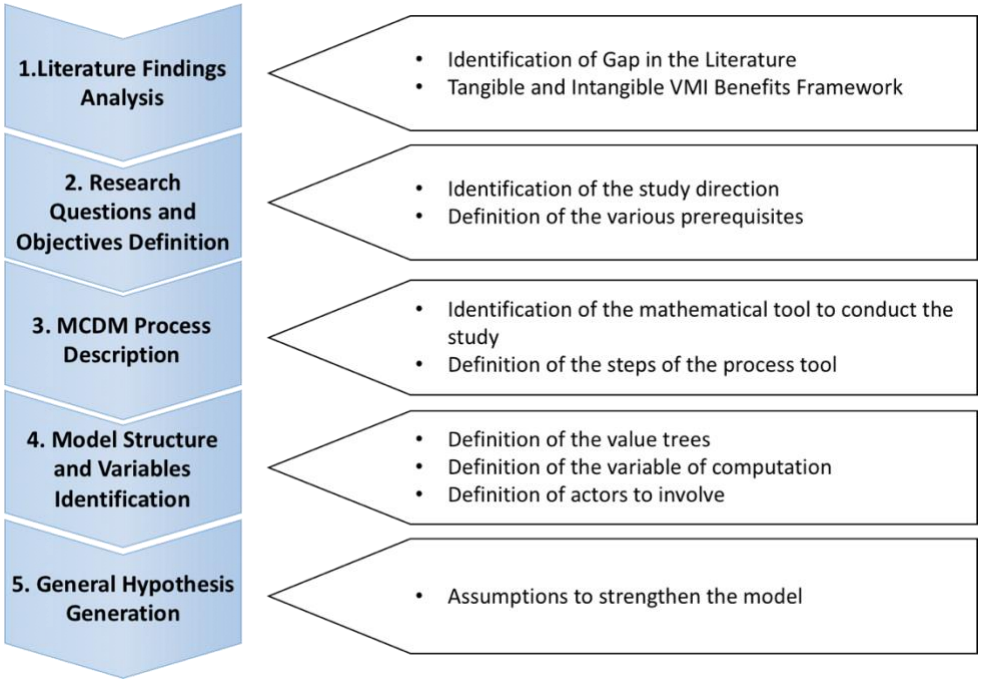



*Figure 2: Phases of the Model Development and related activities.*

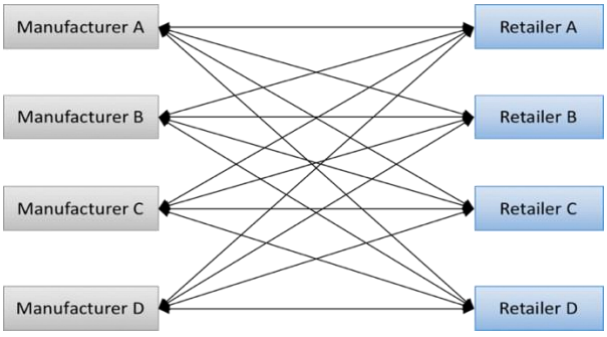



*Figure 3: Supply Chain typology and number of possible relationships considered for the model analysis (relationship 1 vendor – 1 buyer).*

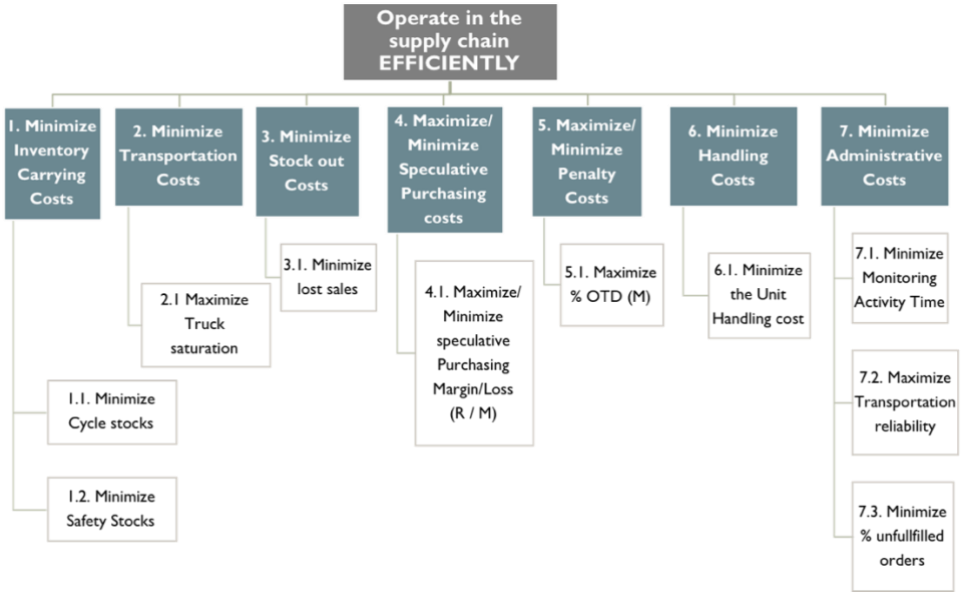



*Figure* 4*: Value tree of quantitative (tangible) factors.*

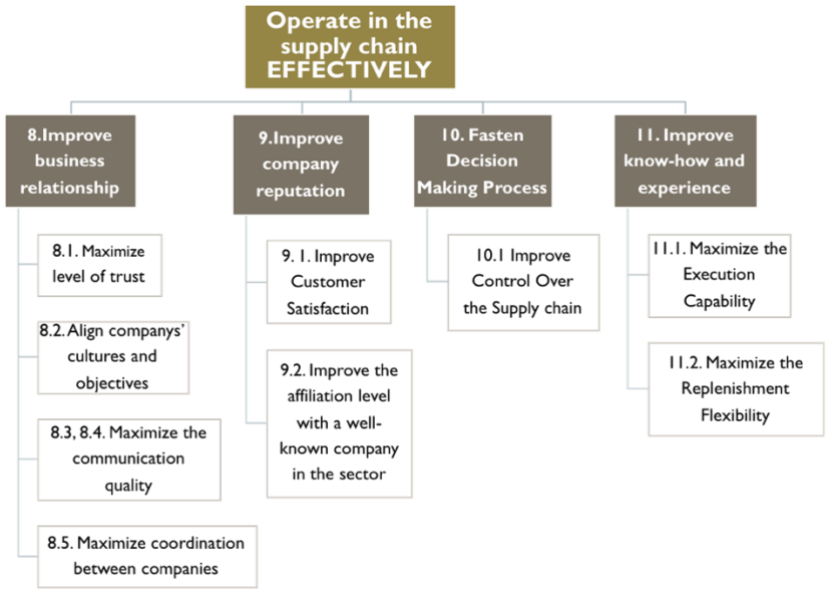



*Figure* 5*: Value tree of qualitative (intangible) factors.*

| **Value Measures** | **Type** | **Scale (% of impact of the cost item over the total volume of the transaction)** |
|---|---|---|
| Inventory carrying costs | Natural | [0, 20%] |
| Transportation costs | Natural | [0, 20%] |
| Stock-Out costs | Natural | [0, 20%] |
| Forward Buying costs | Natural | [0, 20%] |
| Penalty costs | Natural | [0, 20%] |
| Handling costs | Natural | [0, 20%] |
| Administrative costs | Natural | [0, 20%] |

*Table 1: Quantitative Value Measures*

| **Value Measures** | **Type** | **Scale** |
|---|---|---|
| Trust | Constructed | 5 levels |
| Strategic Alignment | Constructed | 5 levels |
| Communication Level | Constructed | 5 levels |
| Communication Frequency | Constructed | 5 levels |
| Coordination level | Constructed | 5 levels |
| Customer Satisfaction (downstream) | Constructed | 5 levels |
| Degree of Partnership | Constructed | 5 levels |
| Supply Chain Visibility | Constructed | 5 levels |
| Execution Capability | Constructed | 5 levels |
| Replenishment Flexibility | Constructed | 5 levels |

*Table 2: Qualitative Value Measures*

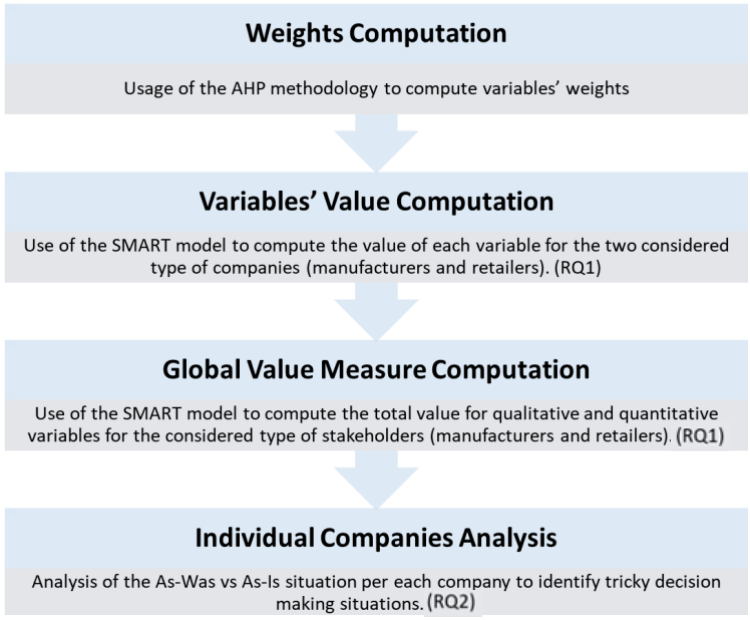



*Figure 6: Model Implementation Process.*

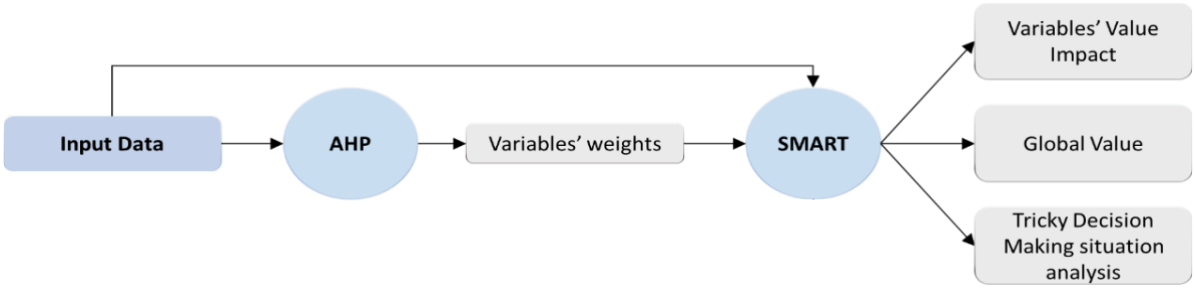



*Figure 7: I/O and models' linkages.*

| | **Manufacturers Data Set Pre-VMI** | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** | **$M_7$** | **$M_8$** | **$M_9$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Qualitative Variables | Trust | 1 | 4 | 1 | 3 | 4 | 2 | 4 | 3 | 2 |
| | Strategic Alignment | 1 | 3 | 1 | 4 | 4 | 1 | 3 | 2 | 1 |
| | Communication Level | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 |
| | Communication Frequency | 1 | 3 | 3 | 4 | 5 | 4 | 3 | 3 | 3 |
| | Partnership Level | 1 | 3 | 2 | 2 | 4 | 1 | 2 | 2 | 2 |
| | Strategic Coordination | 1 | 3 | 1 | 3 | 2 | 1 | 3 | 3 | 1 |
| | Execution Capability | 3 | 4 | 1 | 3 | 2 | 2 | 4 | 3 | 2 |
| | Customer Satisfaction | 2 | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 2 |
| | Supply Chain Visibility | 2 | 2 | 1 | 3 | 3 | 1 | 2 | 2 | 1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Order Flexibility | 1 | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 4 |
| Quantitative Variables | Inventory Costs | 3 | 3 | 3 | 4 | 2 | 12 | 6 | 3 | 4 |
| | Handling Costs | 3 | 3 | 3 | 1 | 5 | 6 | 3 | 4 | 2 |
| | Stock-Out Costs | 5 | 5 | 5 | 0 | 10 | 14 | 10 | 9 | 7 |
| | Transportation Costs | 8 | 7 | 6 | 5 | 10 | 14 | 10 | 9 | 7 |
| | Administrative Costs | 5 | 5 | 5 | 5 | 1 | 4 | 2 | 2 | 5 |
| | Penalty-Related Cost/Gain | 2 | 2 | 2 | 0 | 1 | 2 | 1.5 | 1.5 | 1 |
| | Forward Buying Cost/Gain | 4 | 4 | 4 | 0 | 2 | 4 | 3 | 2 | 1 |

*Table 3: Manufacturers' data for a Manufacturer-Retailer partnership before the implementation of a VMI collaboration.*

| | **Manufacturers Data Set Post-VMI** | **$M_1$** | **$M_2$** | **$M_3$** | **$M_4$** | **$M_5$** | **$M_6$** | **$M_7$** | **$M_8$** | **$M_9$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Qualitative Variables | Trust | 4 | 5 | 3 | 3 | 4 | 3 | 5 | 4 | 4 |
| | Strategic Alignment | 4 | 5 | 3 | 4 | 4 | 3 | 4 | 3 | 4 |
| | Communication Level | 5 | 5 | 5 | 4 | 3 | 5 | 4 | 4 | 5 |
| | Communication Frequency | 3 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 5 |
| | Partnership Level | 2 | 5 | 4 | 4 | 5 | 2 | 4 | 4 | 4 |
| | Strategic Coordination | 3 | 4 | 3 | 4 | 5 | 3 | 4 | 4 | 4 |
| | Execution Capability | 5 | 4 | 3 | 4 | 5 | 3 | 5 | 5 | 4 |
| | Customer Satisfaction | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 |
| | Supply Chain Visibility | 5 | 5 | 3 | 4 | 5 | 4 | 5 | 5 | 4 |
| | Order Flexibility | 5 | 4 | 4 | 2 | 5 | 2 | 3 | 4 | 4 |
| Quantitative Variables | Inventory Costs | 2 | 1.5 | 3 | 4 | 2 | 11 | 3 | 2 | 3.5 |
| | Handling Costs | 1 | 3 | 3.3 | 1 | 2 | 3 | 2 | 3 | 2 |
| | Stock-Out Costs | 3 | 1.5 | 5 | 0 | 8 | 4.5 | 3.5 | 4 | 4.5 |
| | Transportation Costs | 3 | 3.5 | 6.7 | 5 | 4 | 8 | 6 | 6 | 7 |
| | Administrative Costs | 5 | 5 | 5.1 | 5 | 0.8 | 3 | 2 | 1.5 | 4 |
| | Penalty-Related Cost/Gain | 2 | 1 | 2 | 0 | 0.5 | 1.5 | 0.8 | 1 | 1 |
| | Forward Buying Cost/Gain | 4 | 0 | 4 | 0 | 1.5 | 2 | 1 | 1 | 0.98 |

*Table 4: Manufacturers' data for a Manufacturer-Retailer partnership after the implementation of a VMI collaboration.*

| | **Retailers Data Set Pre-VMI** | **$R_1$** | **$R_2$** | **$R_2$'** | **$R_3$** | **$R_4$** | **$R_5$** | **$R_6$** |
|---|---|---|---|---|---|---|---|---|
| Qualitative Variables | Trust | 3 | 3 | 4 | 2 | 2 | 4 | 2 |
| | Strategic Alignment | 3 | 2 | 3 | 1 | 2 | 4 | 1 |
| | Communication Level | 1 | 2 | 2 | 3 | 3 | 2 | 1 |
| | Communication Frequency | 2 | 1 | 1 | 3 | 2 | 2 | 1 |
| | Partnership Level | 4 | 1 | 3 | 3 | 2 | 3 | 1 |
| | Strategic Coordination | 2 | 2 | 3 | 2 | 1 | 1 | 2 |
| | Execution Capability | 5 | 3 | 5 | 3 | 3 | 4 | 2 |
| | Customer Satisfaction | 4 | 2 | 3 | 3 | 3 | 2 | 2 |
| | Supply Chain Visibility | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| | Order Flexibility | 4 | 1 | 2 | 2 | 2 | 3 | 1 |
| Quantitative Variables | Inventory Costs | 1 | 10 | 10 | 8 | 8 | 9 | 8 |
| | Handling Costs | 3.5 | 3.5 | 3 | 3 | 3 | 3 | 3.5 |
| | Stock-Out Costs | 2 | 5 | 6 | 5 | 4 | 6 | 7 |
| | Transportation Costs | 4 | 1.5 | 1 | 2 | 3 | 4 | 2.5 |
| | Administrative Costs | 0.5 | 5 | 5 | 4 | 3 | 3 | 2.5 |
| | Penalty-Related Cost/Gain | 0.2 | 2 | 2 | 2 | 0.7 | 2 | 2 |
| | Forward Buying Cost/Gain | 0 | 4 | 3 | 5 | 3 | 3 | 2 |

*Table 5: Retailers' data for a Manufacturer-Retailer partnership before the implementation of a VMI collaboration.*

| | **Retailers Data Set Post-VMI** | **$R_1$** | **$R_2$** | **$R_2$'** | **$R_3$** | **$R_4$** | **$R_5$** | **$R_6$** |
|---|---|---|---|---|---|---|---|---|
| Qualitative Variables | Trust | 4 | 4 | 5 | 3 | 4 | 5 | 3 |
| | Strategic Alignment | 4 | 3 | 4 | 2 | 3 | 4 | 2 |
| | Communication Level | 3 | 3 | 3 | 3 | 5 | 4 | 1 |
| | Communication Frequency | 2 | 1 | 1 | 3 | 3 | 3 | 2 |
| | Partnership Level | 4 | 4 | 4 | 4 | 3 | 4 | 2 |
| | Strategic Coordination | 2 | 3 | 4 | 2 | 2 | 3 | 2 |
| | Execution Capability | 5 | 3 | 5 | 4 | 4 | 5 | 3 |
| | Customer Satisfaction | 5 | 3 | 4 | 4 | 4 | 4 | 3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Supply Chain Visibility | 4 | 3 | 2 | 3 | 3 | 4 | 3 |
| | Order Flexibility | 4 | 1 | 2 | 2 | 2 | 3 | 2 |
| Quantitative Variables | Inventory Costs | 1 | 7 | 6 | 4 | 7 | 5 | 9 |
| | Handling Costs | 2.5 | 3.5 | 3 | 2.5 | 3 | 2 | 3.5 |
| | Stock-Out Costs | 1 | 3 | 2 | 2 | 2.5 | 3.5 | 5.5 |
| | Transportation Costs | 2 | 1.5 | 1 | 2 | 3 | 2.5 | 2.5 |
| | Administrative Costs | 0.2 | 5 | 5 | 1 | 3 | 2 | 3 |
| | Penalty-Related Cost/Gain | 0 | 2 | 1 | 0 | 0.5 | 1.5 | 2 |
| | Forward Buying Cost/Gain | 0 | 1 | 0 | 0 | 2 | 0 | 2 |

*Table 6: Retailers' data for a Manufacturer-Retailer partnership after the implementation of a VMI collaboration.*

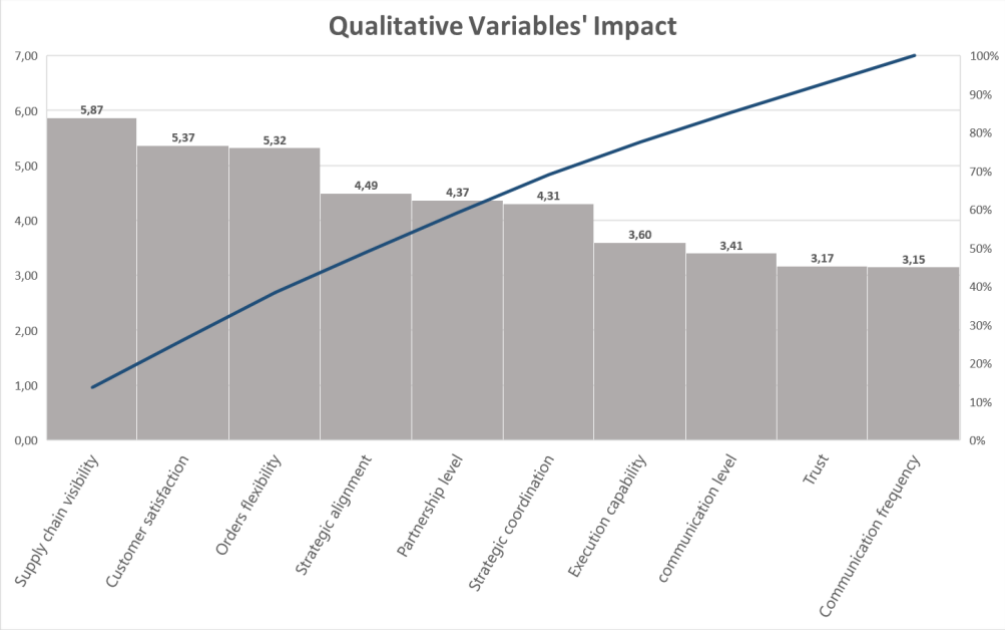



*Figure 8: Impact of Qualitative Variables on manufacturers' rating due to VMI implementation.*

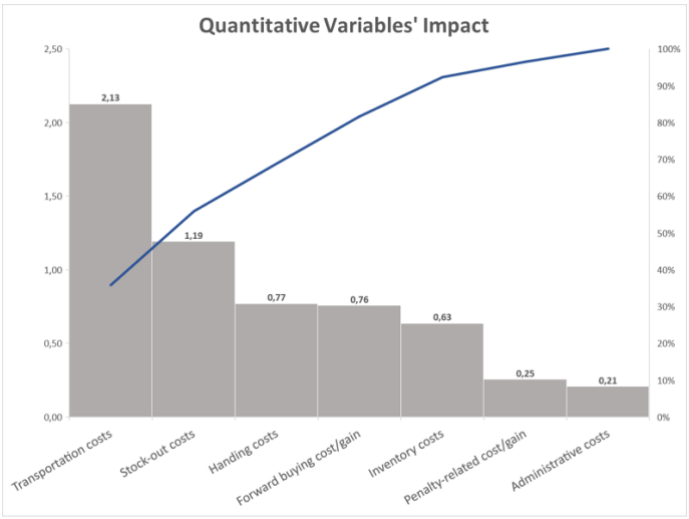



*Figure 9: Impact of Quantitative Variables on manufacturers' rating due to VMI implementation.*

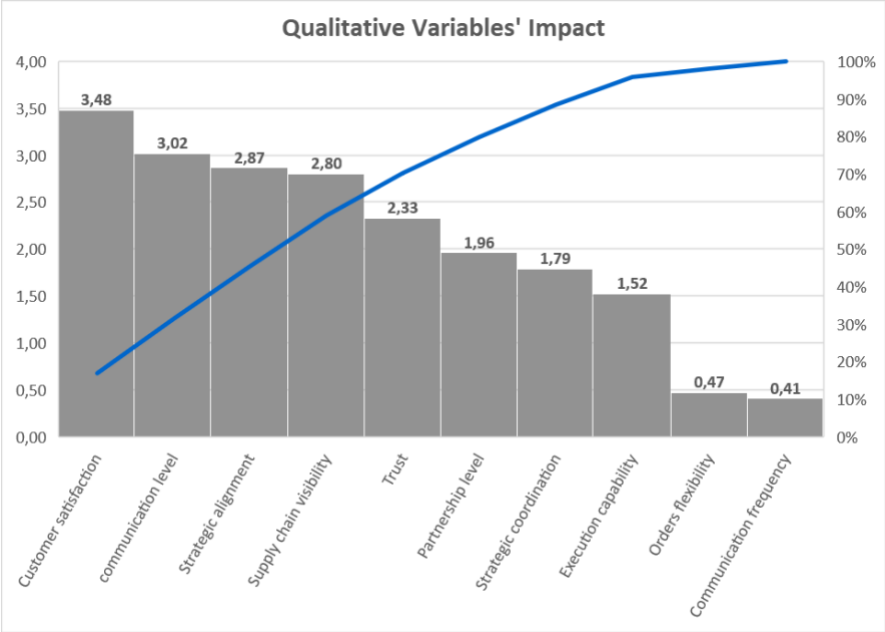



*Figure 10: Impact of Qualitative Variables on retailers' rating due to VMI implementation.*

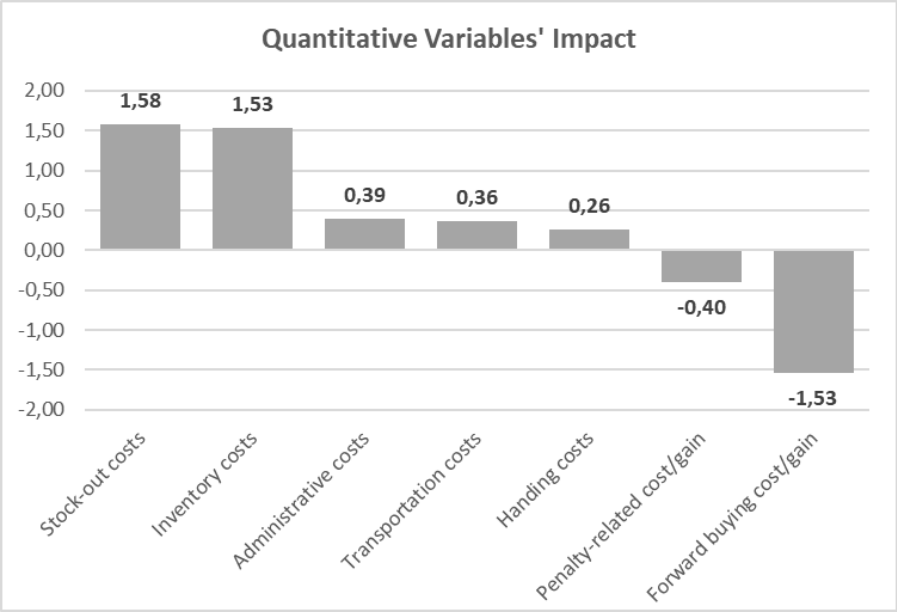



*Figure 11: Impact of Quantitative Variables on retailers' rating due to VMI implementation.*

| **Market average Manufacturer** | **Alternatives** | | **Non-VMI vs VMI** | |
|---|---|---|---|---|
| | **Non-VMI** | **VMI** | **Δ Value** | **Δ % Value** |
| Global Value | 37.62 | 80.67 | 43.05 | 114% |
| Global Cost | 78.89 | 84.83 | 5.94 | 8% |

Table 7*: Manufacturers' market average Global Value and Global Cost.*

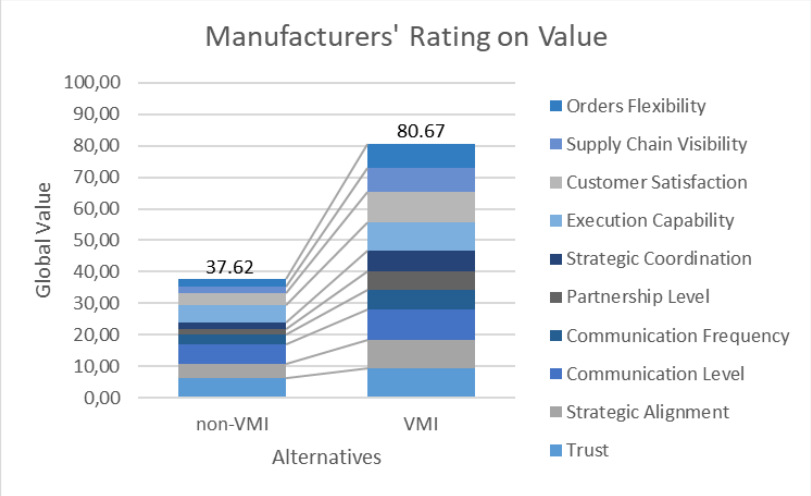



*Figure 12: Manufacturers' Global Value composition.*

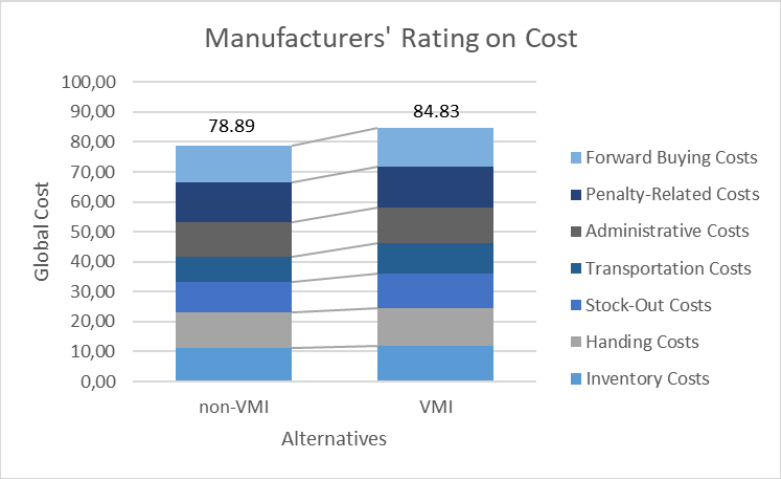



*Figure 13: Manufacturers' Global Cost composition.*

| **Market average Retailer** | **Alternatives** | | **Non-VMI vs VMI** | |
|---|---|---|---|---|
| | **Non-VMI** | **VMI** | **Δ Value** | **Δ % Value** |
| Global Value | 39.57 | 60.21 | 20.65 | 52% |
| Global Cost | 59.02 | 61.20 | 2.18 | 4% |

*Table 8: Retailers' market average Global Value and Global Cost.*

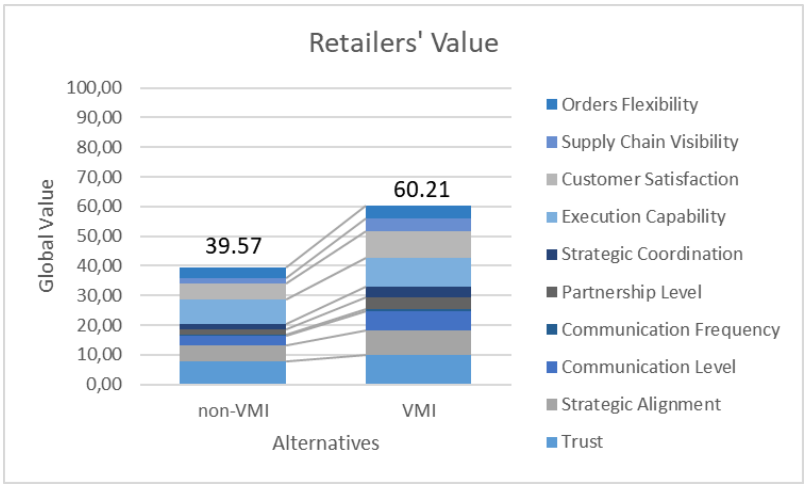



*Figure 14: Retailers' Global Value composition.*

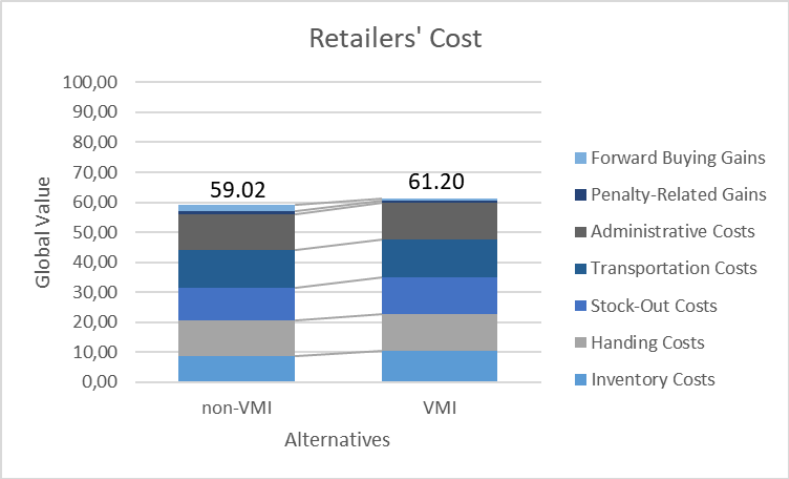



*Figure 15: Retailers' Global Cost composition.*

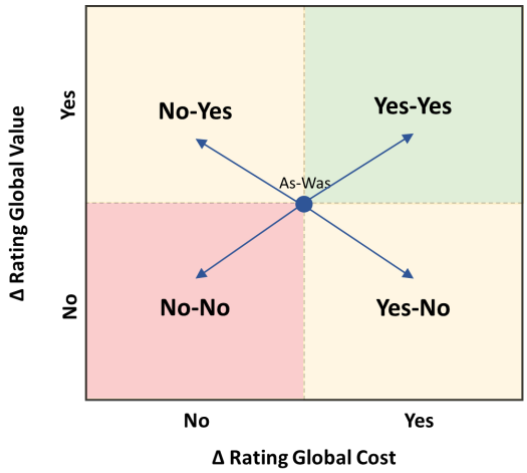



*Figure 16: Bi-Dimensional Decision Matrix.*

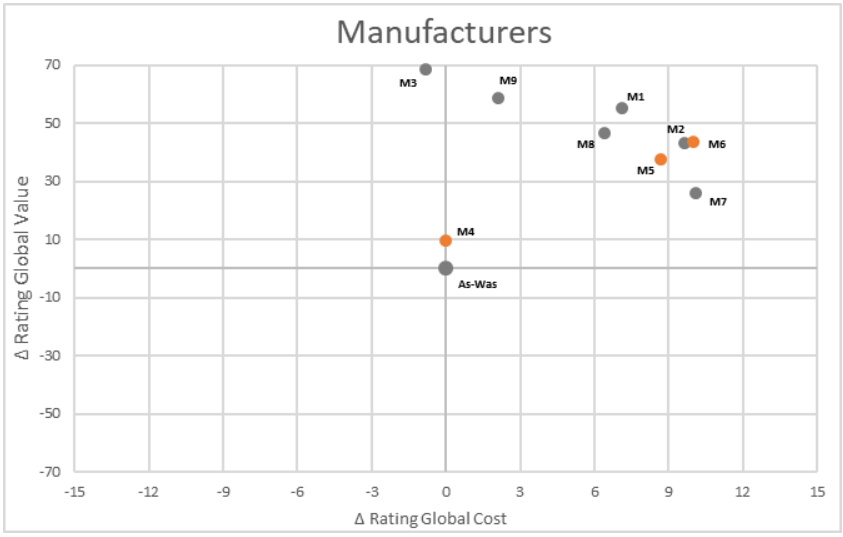



*Figure 17: Manufacturers' distribution on the Bi-Dimensional Decision Matrix.*

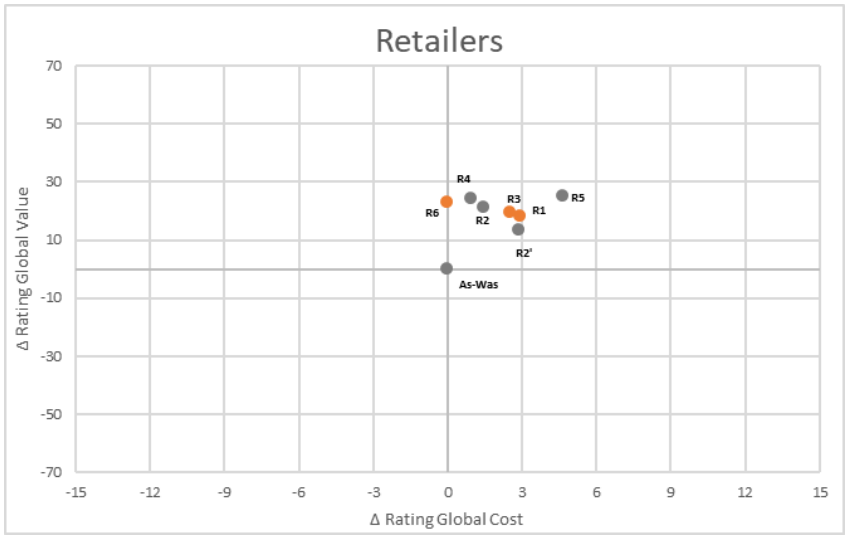



*Figure 18: Retailers' distribution on the Bi-Dimensional Decision Matrix.*

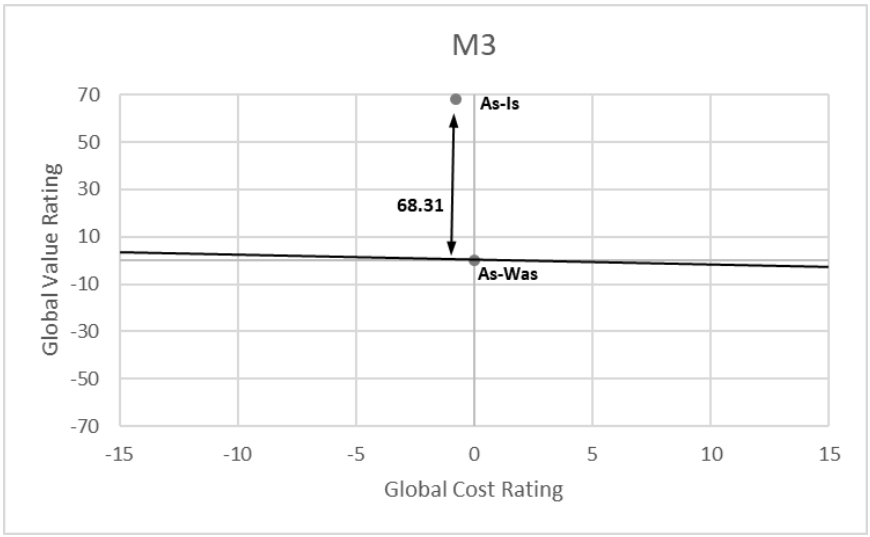



*Figure 19: M3's Bi-Dimensional Decision Matrix.*

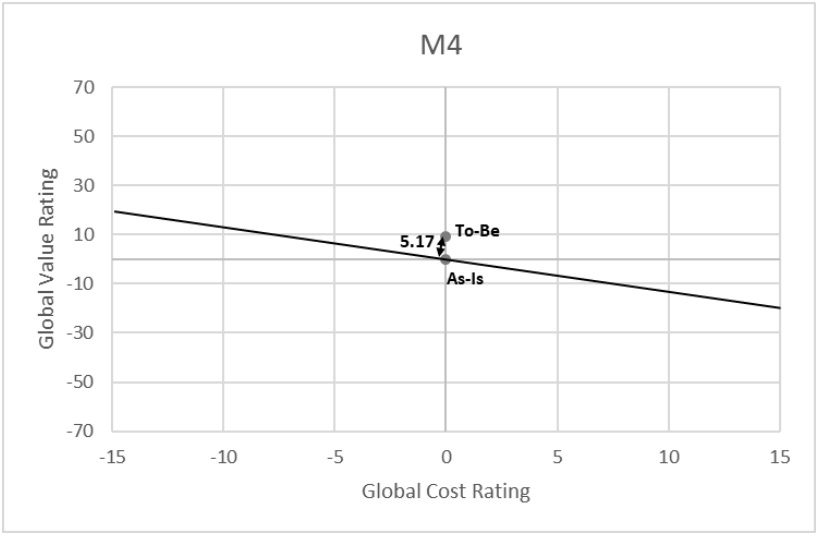



*Figure 20: M4's Bi-Dimensional Decision Matrix.*

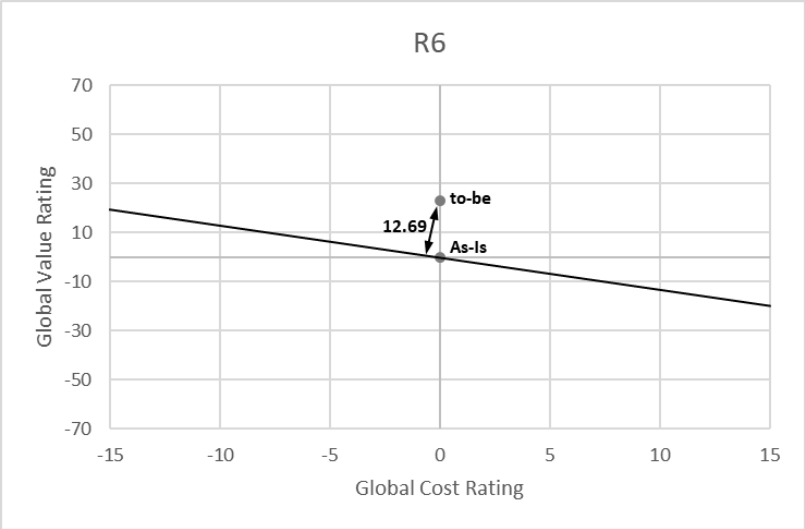



*Figure 21: R6's Bi-Dimensional Decision Matrix.*

## Appendices

| Qualitative variable | Index j |
|---|---|
| Trust | p1 |
| Strategic Alignment | p2 |
| Communication Level | p3 |
| Communication Frequency | p4 |
| Partnership Level | p5 |
| Strategic Coordination | p6 |
| Execution Capability | p7 |
| Customer Satisfaction | p8 |
| Supply Chain Visibility | p9 |
| Order Flexibility | p10 |

*Appendix A: Definition of the qualitative variables as $p_j$.*

| Manufacturers preferences | $M_1$ | $M_2$ | $M_3$ | $M_4$ | $M_5$ | $M_6$ | $M_7$ | $M_8$ | $M_9$ |
|---|---|---|---|---|---|---|---|---|---|
| p1/p2 | 1.31 | 0.89 | 1.13 | 0.88 | 1.29 | 1 | 1 | 1.06 | 1.13 |
| p1/p3 | 0.98 | 0.8 | 0.9 | 0.7 | 1.06 | 1.14 | 1.29 | 1.13 | 1.13 |
| p1/p4 | 0.98 | 1.33 | 1.5 | 0.7 | 1.13 | 1.33 | 1.8 | 1.21 | 1.13 |

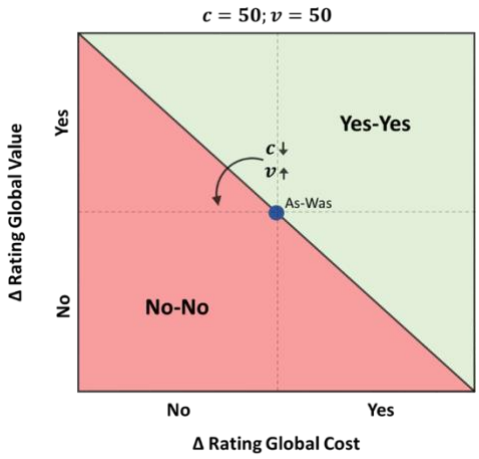
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| p1/p5 | 1.09 | 0.8 | 0.9 | 0.88 | 0.9 | 1.07 | 1.2 | 1.06 | 1.5 |
| p1/p6 | 1.09 | 1.14 | 1.29 | 0.88 | 1.13 | 0.94 | 1.06 | 0.94 | 1.2 |
| p1/p7 | 0.98 | 1 | 1.29 | 0.7 | 1 | 0.89 | 1 | 0.94 | 1.29 |
| p1/p8 | 1.09 | 0.8 | 1 | 0.88 | 1 | 0.94 | 1.06 | 0.89 | 1.13 |
| p1/p9 | 0.98 | 1.33 | 1.13 | 0.88 | 1.13 | 1 | 1.29 | 1.42 | 1.13 |
| p1/p10 | 0.98 | 0.89 | 1.13 | 0.7 | 1.29 | 0.89 | 1.06 | 0.85 | 1.29 |
| p2/p3 | 0.75 | 0.9 | 0.8 | 0.8 | 0.82 | 1.14 | 1.29 | 1.07 | 1 |
| p2/p4 | 0.75 | 1.5 | 1.33 | 0.8 | 0.88 | 1.33 | 1.8 | 1.14 | 1 |
| p2/p5 | 0.83 | 0.9 | 0.8 | 1 | 0.7 | 1.07 | 1.2 | 1 | 1.33 |
| p2/p6 | 0.83 | 1.29 | 1.14 | 1 | 0.88 | 0.94 | 1.06 | 0.89 | 1.07 |
| p2/p7 | 0.75 | 1.13 | 1.14 | 0.8 | 0.78 | 0.89 | 1 | 0.89 | 1.14 |
| p2/p8 | 0.83 | 0.9 | 0.89 | 1 | 0.78 | 0.94 | 1.06 | 0.84 | 1 |
| p2/p9 | 0.75 | 1.5 | 1 | 1 | 0.88 | 1 | 1.29 | 1.33 | 1 |
| p2/p10 | 0.75 | 1 | 1 | 0.8 | 1 | 0.89 | 1.06 | 0.8 | 1.14 |
| p3/p4 | 1 | 1.67 | 1.67 | 1 | 1.06 | 1.17 | 1.4 | 1.07 | 1 |
| p3/p5 | 1.11 | 1 | 1 | 1.25 | 0.85 | 0.93 | 0.93 | 0.94 | 1.33 |
| p3/p6 | 1.11 | 1.43 | 1.43 | 1.25 | 1.06 | 0.82 | 0.82 | 0.83 | 1.07 |
| p3/p7 | 1 | 1.25 | 1.43 | 1 | 0.94 | 0.78 | 0.78 | 0.83 | 1.14 |
| p3/p8 | 1.11 | 1 | 1.11 | 1.25 | 0.94 | 0.82 | 0.82 | 0.79 | 1 |
| p3/p9 | 1 | 1.67 | 1.25 | 1.25 | 1.06 | 0.88 | 1 | 1.25 | 1 |
| p3/p10 | 1 | 1.11 | 1.25 | 1 | 1.21 | 0.78 | 0.82 | 0.75 | 1.14 |
| p4/p5 | 1.11 | 0.6 | 0.6 | 1.25 | 0.8 | 0.8 | 0.67 | 0.88 | 1.33 |
| p4/p6 | 1.11 | 0.86 | 0.86 | 1.25 | 1 | 0.71 | 0.59 | 0.78 | 1.07 |
| p4/p7 | 1 | 0.75 | 0.86 | 1 | 0.89 | 0.67 | 0.56 | 0.78 | 1.14 |
| p4/p8 | 1.11 | 0.6 | 0.67 | 1.25 | 0.89 | 0.71 | 0.59 | 0.74 | 1 |
| p4/p9 | 1 | 1 | 0.75 | 1.25 | 1 | 0.75 | 0.71 | 1.17 | 1 |
| p4/p10 | 1 | 0.67 | 0.75 | 1 | 1.14 | 0.67 | 0.59 | 0.7 | 1.14 |
| p5/p6 | 1 | 1.43 | 1.43 | 1 | 1.25 | 0.88 | 0.88 | 0.89 | 0.8 |
| p5/p7 | 0.9 | 1.25 | 1.43 | 0.8 | 1.11 | 0.83 | 0.83 | 0.89 | 0.86 |
| p5/p8 | 1 | 1 | 1.11 | 1 | 1.11 | 0.88 | 0.88 | 0.84 | 0.75 |
| p5/p9 | 0.9 | 1.67 | 1.25 | 1 | 1.25 | 0.94 | 1.07 | 1.33 | 0.75 |
| p5/p10 | 0.9 | 1.11 | 1.25 | 0.8 | 1.43 | 0.83 | 0.88 | 0.8 | 0.86 |
| p6/p7 | 0.9 | 0.88 | 1 | 0.8 | 0.89 | 0.94 | 0.94 | 1 | 1.07 |
| p6/p8 | 1 | 0.7 | 0.78 | 1 | 0.89 | 1 | 1 | 0.95 | 0.94 |
| p6/p9 | 0.9 | 1.17 | 0.88 | 1 | 1 | 1.06 | 1.21 | 1.5 | 0.94 |
| p6/p10 | 0.9 | 0.78 | 0.88 | 0.8 | 1.14 | 0.94 | 1 | 0.9 | 1.07 |
| p7/p8 | 1.11 | 0.8 | 0.78 | 1.25 | 1 | 1.06 | 1.06 | 0.95 | 0.88 |
| p7/p9 | 1 | 1.33 | 0.88 | 1.25 | 1.13 | 1.13 | 1.29 | 1.5 | 0.88 |
| p7/p10 | 1 | 0.89 | 0.88 | 1 | 1.29 | 1 | 1.06 | 0.9 | 1 |
| p8/p9 | 0.9 | 1.67 | 1.13 | 1 | 1.13 | 1.06 | 1.21 | 1.58 | 1 |
| p8/p10 | 0.9 | 1.11 | 1.13 | 0.8 | 1.29 | 0.94 | 1 | 0.95 | 1.14 |
| p9/p10 | 1 | 0.67 | 1 | 0.8 | 1.14 | 0.89 | 0.82 | 0.6 | 1.14 |

*Appendix B: Manufacturers' preferences for qualitative factors*

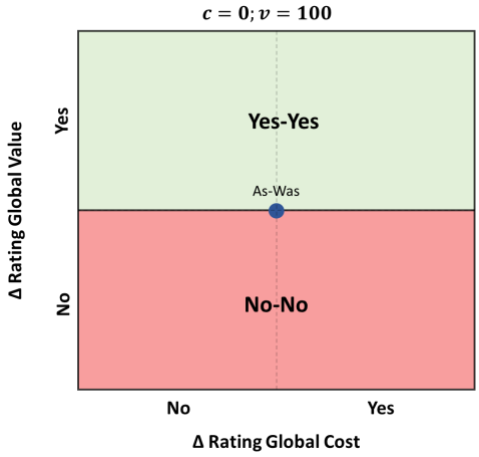
| **Retailers preferences** | **$R_1$** | **$R_2$** | **$R_3$** | **$R_4$** | **$R_5$** | **$R_6$** |
|---|---|---|---|---|---|---|
| p1/p2 | 1.27 | 0.8 | 1.43 | 1.19 | 1.11 | 0.88 |
| p1/p3 | 0.95 | 1 | 2 | 1.19 | 1.43 | 1 |
| p1/p4 | 0.95 | 1.6 | 2.5 | 1.36 | 1.67 | 1.17 |

| | | | | | | |
|---|---|---|---|---|---|---|
| p1/p5 | 1.19 | 1.6 | 1.33 | 1.36 | 1.67 | 0.88 |
| p1/p6 | 1 | 1 | 1.25 | 1.19 | 1.25 | 0.88 |
| p1/p7 | 0.95 | 1 | 1.18 | 0.95 | 1 | 0.7 |
| p1/p8 | 0.95 | 0.8 | 1.11 | 0.95 | 1 | 0.78 |
| p1/p9 | 1.19 | 1 | 1.18 | 1.36 | 1.67 | 1.17 |
| p1/p10 | 1.19 | 1 | 1.25 | 1.06 | 1.25 | 1 |
| p2/p3 | 0.75 | 1.25 | 1.4 | 1 | 1.29 | 1.14 |
| p2/p4 | 0.75 | 2 | 1.75 | 1.14 | 1.5 | 1.33 |
| p2/p5 | 0.94 | 2 | 0.93 | 1.14 | 1.5 | 1 |
| p2/p6 | 0.79 | 1.25 | 0.88 | 1 | 1.13 | 1 |
| p2/p7 | 0.75 | 1.25 | 0.82 | 0.8 | 0.9 | 0.8 |
| p2/p8 | 0.75 | 1 | 0.78 | 0.8 | 0.9 | 0.89 |
| p2/p9 | 0.94 | 1.25 | 0.82 | 1.14 | 1.5 | 1.33 |
| p2/p10 | 0.94 | 1.25 | 0.88 | 0.89 | 1.13 | 1.14 |
| p3/p4 | 1 | 1.6 | 1.25 | 1.14 | 1.17 | 1.17 |
| p3/p5 | 1.25 | 1.6 | 0.67 | 1.14 | 1.17 | 0.88 |
| p3/p6 | 1.05 | 1 | 0.63 | 1 | 0.88 | 0.88 |
| p3/p7 | 1 | 1 | 0.59 | 0.8 | 0.7 | 0.7 |
| p3/p8 | 1 | 0.8 | 0.56 | 0.8 | 0.7 | 0.78 |
| p3/p9 | 1.25 | 1 | 0.59 | 1.14 | 1.17 | 1.17 |
| p3/p10 | 1.25 | 1 | 0.63 | 0.89 | 0.88 | 1 |
| p4/p5 | 1.25 | 1 | 0.53 | 1 | 1 | 0.75 |
| p4/p6 | 1.05 | 0.63 | 0.5 | 0.88 | 0.75 | 0.75 |
| p4/p7 | 1 | 0.63 | 0.47 | 0.7 | 0.6 | 0.6 |
| p4/p8 | 1 | 0.5 | 0.44 | 0.7 | 0.6 | 0.67 |
| p4/p9 | 1.25 | 0.63 | 0.47 | 1 | 1 | 1 |
| p4/p10 | 1.25 | 0.63 | 0.5 | 0.78 | 0.75 | 0.86 |
| p5/p6 | 0.84 | 0.63 | 0.94 | 0.88 | 0.75 | 1 |
| p5/p7 | 0.8 | 0.63 | 0.88 | 0.7 | 0.6 | 0.8 |
| p5/p8 | 0.8 | 0.5 | 0.83 | 0.7 | 0.6 | 0.89 |
| p5/p9 | 1 | 0.63 | 0.88 | 1 | 1 | 1.33 |
| p5/p10 | 1 | 0.63 | 0.94 | 0.78 | 0.75 | 1.14 |
| p6/p7 | 0.95 | 1 | 0.94 | 0.8 | 0.8 | 0.8 |
| p6/p8 | 0.95 | 0.8 | 0.89 | 0.8 | 0.8 | 0.89 |
| p6/p9 | 1.19 | 1 | 0.94 | 1.14 | 1.33 | 1.33 |
| p6/p10 | 1.19 | 1 | 1 | 0.89 | 1 | 1.14 |
| p7/p8 | 1 | 0.8 | 0.94 | 1 | 1 | 1.11 |
| p7/p9 | 1.25 | 1 | 1 | 1.43 | 1.67 | 1.67 |
| p7/p10 | 1.25 | 1 | 1.06 | 1.11 | 1.25 | 1.43 |
| p8/p9 | 1.25 | 1.25 | 1.06 | 1.43 | 1.67 | 1.5 |
| p8/p10 | 1.25 | 1.25 | 1.13 | 1.11 | 1.25 | 1.29 |
| p9/p10 | 1 | 1 | 1.06 | 0.78 | 0.75 | 0.86 |

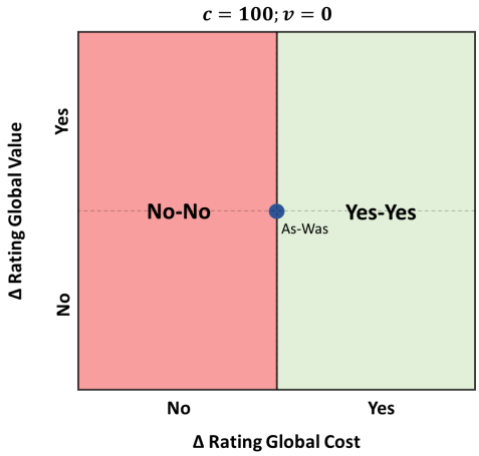
*Appendix C: Retailers' preferences for qualitative factors*




*Appendix D: Bi-Dimensional Decision Matrix c=50; v=50.*




*Appendix E: Bi-Dimensional Decision Matrix c=0; v=100.*




*Appendix F: Bi-Dimensional Decision Matrix c=100; v=0.*