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Product redesigning, cost reduction, component substitution, and their influence in value management in micro and small enterprises

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A B S T R A C T

Value engineering is a methodology developed based on cost reduction and product functionality increase and it has become a competitive factor which allows micro and small businesses owners to improve their performance. This paper proposes a method to identify some techniques of value engineering for improvement and redesigning of products, cost reduction, and component substitution. The proposed method uses the factors in value management of the micro and small businesses of the clothing textiles sector in the region of Arequipa. The results of the research provide some evidences that there is a direct positive correlation between the aforementioned techniques and value management and the results yield significant values, in all cases. A regression analysis is used in product redesigning and cost reduction.

1. Introduction

Value engineering is a methodology developed by Miles at the end of World War II, which is based on the reduction of costs (Miles, 1962). Based on that, Mudge (1971) added a systematic application of known techniques which identifies the function of a product or service. The method was first used in manufacturing, but it is currently used in several types of businesses, especially in construction industry. Most of the studies on this topic have been carried out based on individual and multiple case studies (Gupta, 2009; Amit & Harshit, 2012). The proposed study of this paper is a pioneering technique since it uses quantitative methods for the analysis of value engineering techniques in the MSEs (micro – and small enterprises) on the clothing textile sector of Arequipa region. The objective of the study is to determine whether there is any direct positive relationship between value engineering techniques and other objects; including product redesigning, cost reduction, component substitution, and value management. As a second objective, it was identified whether the use of value engineering techniques used jointly generated a greater influence in value management. This study is divided into six sections. In the first section, the introduction, the summary of the literature and the contribution and the research objectives are presented. In the second section, the review of the literature is presented and the hypotheses are proposed. In the third one, the research methodology is presented. In the fourth one, the results are explained. In the fifth one, the discussion and conclusions are developed. Finally, in the sixth section, limitations and bibliography are referenced.

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2. Revision of Literature

The revision of the literature showed that this methodology was applied with the aim of reducing costs in projects, mainly in the sector of construction, by eliminating unnecessary functions in the products. The first initiatives were presented by Lawrence Miles around 1947 in the United States, after World War II, facing the circumstances of that time, where the same products had to be manufactured despite the scarcity of raw materials. In response to that, some of the materials were changed, giving birth to the study to material replacement by means of a rigorous "work plan", being this the key tool in value engineering. (Miles, 1962). The reason value engineering succeed before other methodologies was because it was different from them, focusing on the product functions and not only in reducing costs. Consequently, if an item is to be manufactured, the function it has for the client must be considered; in this way, it can be ensured that wanted or needed functions will not be sacrificed (Younker, 2003; Lim et al., 2019), achieving reductions of up to 40% in costs and ensuring success (Pineda Bernabel Ronal, 2017). Frequently, when the aim is to reduce costs, one faces the risk of compromising the quality of the product. In that regard, it was found out that a broadly used strategy is to make the client participate in its design, identifying their preferences regarding the attributes of such products, which will be taken into account in the study of the cost structure and in the way they are produced (Sievert, 2016). On the other hand, there is a need to apply this technique associated with concepts of planning and project control (Gupta, 2009) where the functional analysis is evident in addition to an economic assessment of the life cycle, multidisciplinary group work and within a work plan scheme, using creativity techniques (Kelly, 2014) to ensure the achievement of the quality-price relationship (Connaughton & Green Stuart, 1996).

2.1. Value Engineering Process

The value engineering methodology can be applied in all of the stages; however, the greatest benefits have been achieved if it is applied in the first ones, particularly during the design stage (Wen, 2019). From there, the data and information are collected, then the creativity processes take place, alternative methods are proposed for the presentation of the product, productive processes. As a result, the benefits of the project will be effectively improved (Asgari, 2016). Besides, it has been identified as a tool to resolve failure in the manufacturing system, being applied from the design stage, proposing improvements at several stages of the process. The application renders significant improvements in quality and reliability, particularly when placing special attention to functions; problems and their causes are identified (Jantinder & Brajesh, 2014). In order to optimize the value of a product, it is crucial that the functions be defined, analyzed and improved; this must be done in a structured manner, using a multidisciplinary and experienced team, thus achieving the identification and elimination of unnecessary functions (Walk, 2012). In addition, Younker (2003) proposed that it was possible to do more than reducing costs, focusing efforts on improving team work and carrying out proper techniques. In order to achieve this, unbalances in value must be identified and also a work plan must be designed and created, with creative, original and solid alternatives that deliver an increase in value. Similarly, the functionality of the goods and services rendered must be ensured using a broad range of knowledge and experiences focused on the functions the product has for the client (Asgari, 2016). In fact, Meeker and McWilliams (2011) focus on the need to improve the costs of the product, identifying factors of redesign, substitution of parts, selection of suppliers and others, proposing their model in the following way:

1. Recollection of Important data: Information must be collected identifying the cost of each part of the product, making lists of materials, suppliers, operating conditions, recording everything on a database.
2. Errors: Typical errors may be obsolete prices, disinformation, outdated databases, situations that may be overcome through information systems and electronic transfer of data that may be involved in the manufacturing process of the product.
3. Identification of what in the product generates costs: Locate where the highest cost is without leaving unattended the lower costs used frequently.
4. A broader costs environment: Although direct costs are an important part of the sale price of a product, there are indirect costs and sale, research and development expenses that must be taken into account and properly distributed.
5. Application of value engineering techniques with a systemic focus in order to improve the value of the product. It must be considered in the design, cost reduction, component substitution, among others (Meeker & McWilliams, 2011).

The presented proposal becomes a new alternative to apply value engineering when it is time to make quick decisions while facing harsh market conditions where the client seeks and expects more from a product with a lower cost (Meeker & McWilliams, 2011).

2.2. Value Engineering techniques

2.2.1. Redesigning

It is a technique where the formal aspects and appearance of the product are defined again in addition to the features attributed to the product according to the demands of the market and of those participating in the design process (Guerrero Valenzuela & Hernandis Ortuño, 2018)

It is identified as one of the important techniques proposed by Meeker and McWilliams (2011), in order to start the process of value engineering, and it responds to the features that the current market shows, where the clients tend to request different versions of the product, which implies that the company must do what is necessary to identify the clients' needs, provide an improved version, a more attractive presentation, bearing in mind that presenting new products, significant benefits can be obtained for the company, properly exploring the opportunities the design and redesign of the products offer (Lee, 2015). Two interrelated stages can be identified; the first one recognizes the client's requirements and the second, their assessment (Shieh et al., 2008). It is in the first stage where value engineering creativity is applied, presenting a series of ideas that may improve the value of the products, accepting all ideas proposed by the work team without discarding any. Afterwards, the analysis of the functions takes place, which meets every proposal; a list of alternatives is presented for the stage of cost evaluation and quality improvement (Rad & Yamini, 2016). After that, the design and redesign alternatives proposal are determined and the agreement implementation and execution program is structured (Smith et al., 2012). The product redesign implies providing a few special characteristics to the product based on elements that cannot be manufactured at the company, and need to be bought from the market (Ulrich & Ellison, 2005).

2.2.2. Cost Reduction

This technique implies optimizing resources invested during the production process; it is achieved by paying less money for materials and supplies through negotiations with suppliers, discounts for bulk purchases and thus it is possible to contribute to obtaining competitive advantages (Meeker & McWilliams, 2011), with better functions that those provided by the competition (Hansen & Mowen, 2007). It is crucial to determine the objective cost, identifying desirable profit margins, probable sale prices and quality improvement. A good investment in the design stage may produce large profits (Williams, 2001), so it is worth focusing on this stage; however, they will continue being evaluated throughout the production process. In that regard, Lefort (2018) suggests achieving significant reductions in the cost of raw materials, the cost of personnel and the cost of the manufacturing premises.

2.2.3. Substitution of components

La substitution of components is intended to analyze the alternative components, identifying in the products, larger, similar and smaller parts in order to substitute them and therefore achieve cost reduction (Meeker & McWilliams, 2011); however, the replacement of components proposes two key strategic aspects that are immersed in the decision of making or purchasing. In that regard, making implies the decision to manufacture parts and/or products within the company or otherwise, purchasing implies looking in the market for a part or product as a substitute with the intention of purchasing it. In both cases, such decisions are valued considering costs and functionality of the parts or products, (Sosa Vasquez & Chavez Alonso, 2014). In particular, purchasing or manufacturing implies a series of risks to be considered at the moment of making a decision, such as reliability, time of delivery among others (Berck, 2010). Also, purchasing parts or products will depend greatly on the technological capacity that the company has and is directly related to the technological knowledge of its workforce. According to Poppo and Zenger (1998), Suescun (2007) and Parmigiani (2007), companies use both strategies, they produce at the same time that they buy the same product, being this behavior the most recurrent, also known as concurrent sourcing or plural sourcing (Bradach & Eccle 1989; Harrigan, 1986). However, manufacturing or purchasing is determined by a group of factors: position in and trends of the market, products of the company, plant capacity, market rivalry regarding clients, suppliers' competitors, where features, requirements, capacities and others are assessed (Probert, 2014). Now, the decision to substitute components implies a deep analysis for each case and context in particular. This decision may generate great opportunities or problems within the businesses (Probert, 2014). In that regard, it is known that most of the companies under the study develop competitiveness based on costs leadership, therefore, handling costs becomes a key element for their survival and growth. Consequently, redesigning the products and substitution of components become fundamental tools (Meeker & McWilliams, 2011). On the other hand, in highly changing environments, companies do not only compete in cost leadership, but they also develop skills of adaptability and resources alignment with the purpose of providing agile and quick responses to the market so that they generate sustainable competitive advantages (Eckstein et al., 2015; De la Gala & Arredondo, 2019).

2.2.4. Value Management

Value management has become a management style that focuses on motivating employees, developing their skills and creating synergies to promote creativity and innovation in order to maximize general performance of the company (Engineers, 2008). Value management promotes financial sustainability though costs reduction, eliminating the use of unnecessary materials; it has been demonstrated that there is a positive and significant relationship with performance at manufacturing companies and interested parties, also ensuring the quality of the product (Vitalis et al., 2019). Besides, it provides the tools to make better decisions in business, improving competitiveness of the company in its context (Engineers, 2008). In short, after having revised the literature, we propose the following theoretical model for this research, where we present positive direct relations of the components' substitution, redesign of products, cost reduction, with the management of value, presenting the following research hypotheses:

Hypothesis 1. The substitution of components has a direct relationship that positively influences value management.

Hypothesis 2. Product redesigning has a direct relationship that positively influences value management.

Hypothesis 3. Cost reduction has a direct relationship that positively influences value management.

The theoretical model of this research can be seen in the following figure.

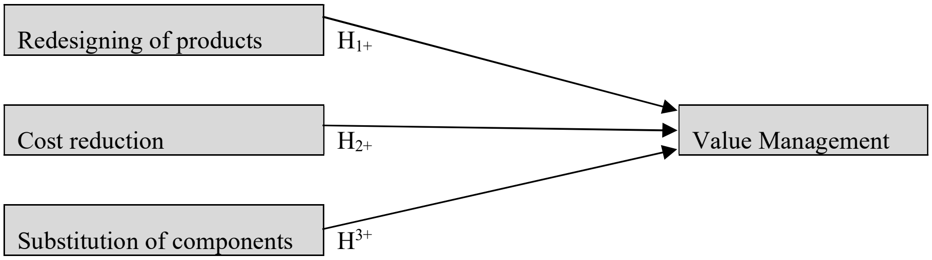

Fig. 1. Theoretical model 1

Fig. 1 shows the hypotheses of work relationships of each of the techniques of value engineering and value management. By the way, the intended aim is to determine whether the techniques of value engineering: product redesigning, cost reduction and component substitution, when acting systemically, generate an increase in the level of relationship with value management, presenting the following hypothesis:

Hypothesis 4. When value engineering techniques are used jointly, they increase the direct positive effect they have on value management.

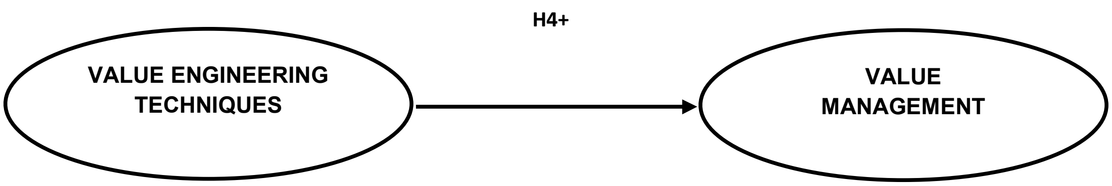

Fig. 2. Theoretical model N° 2

You may see above the work hypothesis of the direct positive relationship of the value engineering techniques in a unidimensional manner and value management.

3. Methodology

3.1 Population and sample

The target population is comprised of micro and small enterprises owners of the textile sector in the region of Arequipa, composed of processors, threaders, knitters of alpaca fiber, and for the most part clothing manufacturers and other types of attire. This population consists of 1,157 micro and small enterprises owners according the internal data of the production management of the regional government up to 2018. Convenience sampling for a sample of 300 businesses was implemented, achieving to collect relevant data of 157 micro and small enterprises (MSEs) owners who agreed to be part of this research, reaching a response rate of 13.57% with respect to the aforementioned population.

Prior to the surveys, open interviews to ten micro and small enterprises owners of the sector were conducted with the purpose of verifying whether the techniques displayed in the theory were being used in their businesses management, and the survey was structured according to the theory and performed interviews.

The central statistics technique used for analysis in this study is the modelling of structural equations through PLS-SEM, using the statistic program Smart PLS v3.2.8. This program is one of the most appropriate for measurements where some of the latent variables are formative and other are reflective and exploratory (Hair et al., 2017), as it is the case here.

3.2 Method and measurements

Quantitative-focused research is non experimental since there is no manipulation of variables and transversal design when collecting data in a single period.

Independent variables, product redesigning, cost reduction, and component substitution as value engineering techniques, were measured in formative ways. This focus of measurement model posits that the indicators cause the formation of the construct. (Hair, et al., 2017) and the dependent variable, value management, has been measured in a reflective manner where the indicators represent the effects or manifestations of the variable (Hair et al., 2017). After mentioning these considerations, we explain the structure of the survey that contains fifteen questions, applying a Likert type scale of 5 positions, where 5 is in complete agreement and 1 is in complete disagreement.

The survey was configured in the following manner: for the product redesign variable, a scale of five items was created; for the cost reduction and component substitution variables, their scales were made of three items; in the case of the value management dependent variable, the scale had four items. Similarly, the questionnaire has five sections: the first one collected general information about the micro and small businesses; the second, third, and fourth sections were for the independent variables and the last section for the dependent variable of value management. Table 1 shows the structure of the survey used in this study according to each of the dimensions of the value management techniques and the value management variable, as we can see in Fig. 3.

Table 1
Survey items

Variables	Items
Product redesign	5
Cost reduction	3
Component substitution	3
Value management	4

3.3 Validity and reliability

In a PLS-SEM environment, the validity and reliability analysis correspond to the assessment of a measurement model (Hair, et al, 2017). Addressing this analysis, in the case of the formative independent variables, creates a group of peculiarities that we will describe referring to the validity of the constructs and reliability of the instrument. We require an analysis of multicollinearity first, then an assessment of the significance of the weights of the observed variables, and finally, the convergent validity of the constructs. In the case of the reflective model of the value management variable, the reliability of the indicator of discriminant and convergent validities is required. (Hair, et al, 2017).

The discriminant and convergent validity of the observed variables under study was performed through cross-loading; additionally, in the value management variable, Cronbach's Alpha and compound validity were used, statistics that cannot be used with formative model variables since these are measurements through variance. (Hair, et al, 2017)

3.3.1 Validity and reflective reliability

The survey comprising 15 items has two types of reliability and validity analysis.

The first type is for the variable measured in a reflective manner: value management (see table 2), where reliability values greater than 0.6 are (Nunnally & Bernstein, 1994) (Hair, Bush, & Ortinau, 2010) (George & Mallery, 2003), allowing even for values between 0.5 and 0.6 for exploratory studies as it is the case. These have been measured through the Cronbach's Alpha statistic, obtaining a value of 0.691. Additionally, an analysis of compound reliability was performed (Werts, Linn, & Joreskog, 1974), (Nunnally & Bernstein, 1994). resulting in a value of 0.814. The discriminant and convergent validity was measured through correlations, using the cross-loading technique (Hair, Bush, & Ortinau, 2010) (Barclay, Higgins, & Thompson, 1995). As a result, every item of the value management construct has been accepted.

Table 2 below shows a summary of the results of the analysis of value management variable measured reflectively.

Table 2
Reflective variable reliability and validity

Statistics	Value Management	Accepted Range	Total
Cronbach's Alpha	0.691	> 0.6; > 0.7	Accepted
Composite Reliability	0.814	> 0.700	Accepted
Discriminant Validity	> others	> others	Accepted
Convergent Validity	> 0.5	> 0.500	Accepted

Table 2 shows the results of reliability and validity tests performed in a reflective manner for the value management variable. In this table, the acceptance level can be seen for all tests carried out.

3.3.1 Formative reliability and validity

The second case of the independent variable is that they have a formative measurement model where multicollinearity verification is prioritized in order to determine the existence of high collinearity, accepting values less than or equal to 3 (Hair et al., 2019). In this study, it was determined that this collinearity factor does not exist. Other aspects are the significance of the weights of the variables and convergent validity. Those are accepted for this study. Table 3 shows a summary of the results of the value engineering dimensions: product redesign, cost reduction, and component substitution, all of them measured formatively.

Table 3
Formative variable validity and reliability.

Constructs	Items	VIF ≤ 3	Factor Loading > 0.5
Cost Reduction	Cost reduction1	1.044	0.710
	Cost reduction2	1.134	0.758
	Cost reduction3	1.125	0.572
Redesign	Redesign1	1.401	0.769
	Redesign2	1.349	0.536
	Redesign3	1.419	0.591
	Redesign4	1.319	0.647
	Redesign5	1.341	0.803
Component Substitution	Component Substitution1	1.272	0.266
	Component Substitution2	1.374	0.520
	Component Substitution3	1.093	0.966

3.4 Analysis Techniques

Data analysis was performed using the statistics software Smart PLS v3.2.8, adequate for this type of exploratory research, which has certain features such as: non-influential sample size, the ability to incorporate reflective and formative models, and generally the fundamental objective is to predict and explain the constructs studied. (Rigdon, 2012).

4. Results and discussion

4.1 Influence of product redesign, cost reduction, and component substitution in value management

The current study has as a primary objective to determine whether a significant relationship exists in the implementation of value engineering techniques identified as: product redesign, cost reduction, component substitution, and value management. This analysis corresponds to what is known in PLS-SEM as assessment of a structural model. Having performed the analysis, it was observed that the structural model, where PLS and bootstrapping were used, was globally accepted since it has good adjustment, given that the SRMR index has a value of 0.052, under the acceptance value of 0.08 and a significance level of 0.000 (Hair et al., 2010). Furthermore, an acceptable effect of all independent variables in value management can be seen, with a determination coefficient of 0.628. In the light of these results, it must be stated that all techniques of value engineering in this study have an influence in value management. Next, each of the relationships of the structural model is discussed:

Regarding the direct and positive relationship of product redesign in value management, it is adequate since a regression coefficient of 0.491 is observed, with a significance level of 0.000. These results help support Hypothesis 1, where product redesign is the most influential technique in value management, possibly because redesigning implies reconfiguring the characteristics of products and, therefore, it improves their functionality and quality, developing greater competitiveness in them.

The direct and positive relationship between cost reduction and value management, we can say that it is great as a regression coefficient of 0.307 can be observed at the 0.001 significance level. These results help support hypothesis 2, where cost reduction does influence value management. This is a very important relationship since cost reduction is fundamental to establish a leadership strategy in this type of business. Furthermore, regarding the direct and positive relationship between component substitution and value management, it is low with a regression coefficient of 0.173 at the 0.042 significance level. These results help support hypothesis 3, where component substitution influences value management. Below are Table 4 and Fig. 3 where there is a nomogram of the results detailed above and a summary of this section.

Table 4
Determination coefficients of the two theoretical models and their relationships between value engineering techniques and value management.

Determination Coefficients of Theoretical Models' 1 and 2	Regression Coefficients	P Values	Determination Coefficients	SRMR
Determination Coefficient of Theoretical Model 1			0,628	0,052
Determination Coefficient of Theoretical Model 2			0,658	0,034
Value engineering techniques →Value management Model 2	0.811	0.000		
Product redesign → Value management Model 1	0.491	0.000		
Cost reduction → Value management Model 1	0.307	0.001		
Component substitution → Value management Model 1	0.173	0.042		

Note: Table 4 displays the very high determination coefficients of both theoretical models, as well as the regression coefficients above the acceptance level of 0.20, except for the relationship between component substitution and value management. Likewise, a significance level below 0.05 is observed in all cases.

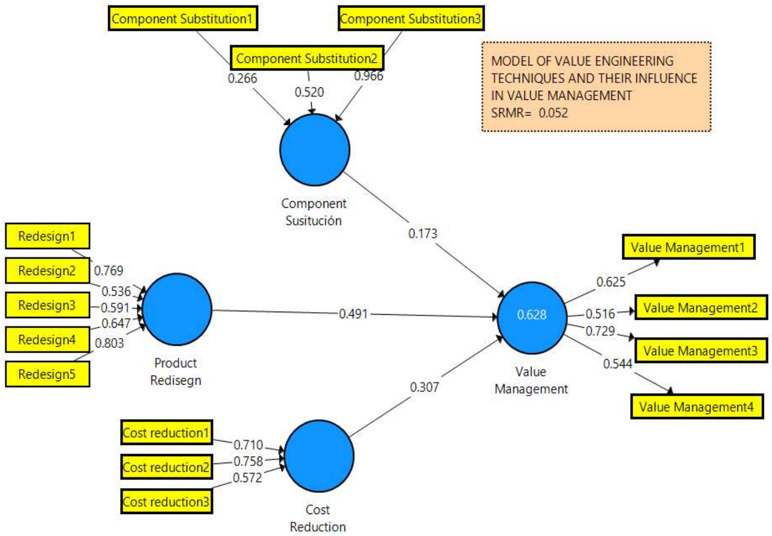

Fig. 3. Model of Value Engineering Techniques and their influence in Value Management

Here the figure shows the nomogram of the first theoretical model, which is accepted in all its relationships by obtaining an SRMR value of 0.052, way below the acceptance level of < 0.08

4.2 Value engineering techniques and their influence in value management

The second objective is to determine whether product redesign, cost reduction, and component substitution, when used jointly, increase the positive effect they have on value management.

For this analysis, PLS and bootstrapping were used, through which it has been determined that this relationship increases, since in the previous analysis, where the techniques had direct positive relationships, analyzed in a group, generated a determination coefficient of 0.628, which is very good.

In this analysis, the techniques behave as observable variables, which comprise the construct, Value Engineering Techniques. A direct positive relationship with value management is observed, with a determination coefficient of 0.658. This shows an increase in the explanation level of 4.77% with respect to the previous analysis. This result helps to determine that the systemic use of value engineering techniques better explains their influence in value management, accepting hypothesis 4 of the study. Furthermore, we must state that the proposed model has a great adjustment and is accepted due to having an SRMR index of 0.034, which is lower than the acceptance level of 0.08 at the 0.000 significance level.

We can observe the figure of the nomogram of the analyzed relationship below:

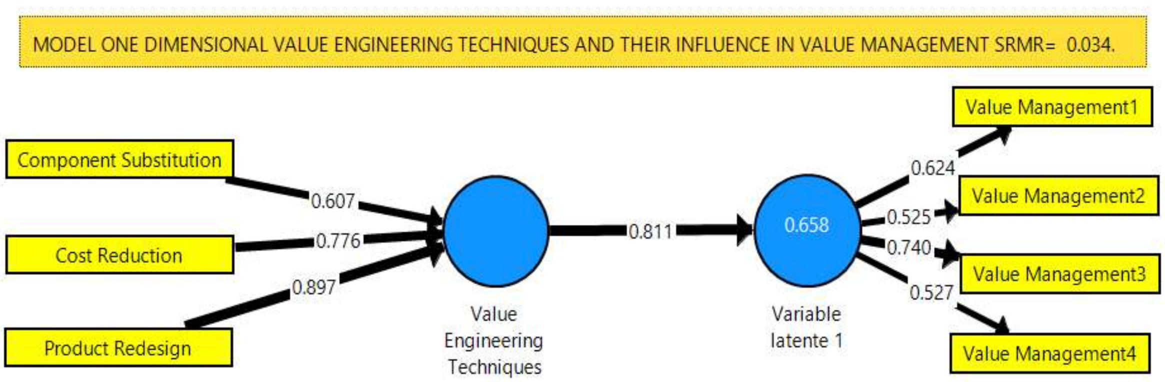

Fig. 4. Model of Unidimensional Value Engineering Techniques and their influence in Value Management

Note: the figure shows the nomogram of the second theoretical model, which shows a very high determination coefficient with a regression coefficient of 0.811. This model is accepted with an SRMR of 0.034, way below the acceptance level of < 0.08

5. Conclusion

Existing literature proposes that value engineering techniques contribute mainly with cost reduction and product functionality. Likewise, the theoretical review proved that there are no studies with measurement of product redesign, cost reduction, and component substitution as value engineering techniques. Additionally, these techniques have not been analyzed as influential in value management. In this sense, and helping fill the existing gap in literature, the primary objective of this study was to determine the influence of product redesign, cost reduction, and component substitution in value management. This relationship was analyzed in a unidimensional manner with the purpose of identifying possible synergies stemming from their systemic use. This research was quantitative, non-experimental, with a transversal design, and was performed in 1157 micro and small enterprises (MSEs) of the textile sector of the region of Arequipa. Out of this population, only 157 were part of the study, obtaining a response rate of 13.57%, collecting data through a survey with 15 questions that referred to the study variables. To reach the aforementioned objectives, a structural equations modeling was carried out using partial least squares (PLS-SEM) and the software SmartPLS v3.2.8. This research showed that important and significant direct positive relationships exist between product redesign, cost reduction, and value management. Similarly, a weak but significant direct positive relationship was found between component substitution and value management. Hypotheses 1, 2, and 3 of the study were accepted. Likewise, the relationship between value engineering techniques, measured in a unidimensional manner, and value management resulted in a key and significant direct positive relationship, proving that the systemic use of these techniques generates a greater influence in value management. Thus, hypothesis 4 of the study is also accepted.

The study has presented theoretical implications as it has contributed to overcome the existing gaps in literature, regarding how value engineering techniques influence value management, opening up a new field of analysis currently unexplored. Similarly, this research also presents important implications for managers. In this aspect, this research has identified the influence of product redesign, cost reduction, and component substitution in value management, which brings along the improvement in product quality and functionality at lower costs. Therefore, micro and small enterprises owners in this productive sector should focus their efforts on the development and intensive use of these techniques that contribute to the creation of competitive advantages through the reduction of costs and innovation of their products.

5. Limitations

Within the limitations of this study, we have that it was carried out on a single productive sector, which has its own dynamics such as market growth, sector rivalry, introduction of new technology, etc., different from those of other productive sectors. Likewise, due to its own nature and the size of the businesses, only managers of these companies were surveyed.

6. Future Research

The results obtained suggest a few future research paths. We assume that the dynamic capabilities are factors that co-assist development and improvement of the use of value engineering techniques. Furthermore, we think that other factors to be analyzed are innovation and adoption of technology, which improve cost reduction and product attributes and, thus, in such path, we believe they can influence value engineering techniques.

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