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**Evaluation of chemical additive preferences for  
procurement management in Colombian  
construction market using statistical perception  
techniques**

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**Abstract**

Construction is one of the largest economic sectors due to the impact on employment generation, trade-in materials, and development of essential infrastructure in the nations. Consequently, global economies demand to satisfy new and more significant needs. These caused by a growing population, technological development, internalization, deregulation, and market liberalization. Together, with knowledge economies related to organizational learning, business improvement, and acquisition of new methodologies, in parallel with the requirements in attractive sales costs, optimal deliveries, and better service conditions. Therefore, it's required to follow a marketing approach, together with procurement management, supported by recent production, distribution and consumption processes of materials in the construction sector, especially cement, considered as the most consumed manufactured material in the world, satisfied by the development, support and introduction of chemical additives in the technological formulations of new materials and construction processes. In consequence, the present investigation seeks to establish an understanding of markets related to the acquisition management around the commercialization of chemical additives in the construction sector of Colombia. It will be done through statistical tools of perception like Conjoint Analysis (CBC) and Multidimensional Scaling (MDS), which allow determining similarities and preferences of the users in the valuation of brands, prices, and applicability, establishing client inclinations. These use of statistical and quantitative techniques for procurement management where applicability is the attribute most desired by users related to traditional construction methods and, in turn, to some price indexes of the construction sector in Colombia.

**Keywords:** Procurement management; Conjoint-analysis; Colombia; Marketing; Multidimensional-scaling.



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## 1. Introduction

The construction sector has become more complex and competitive because of features as technological development added with globalization, the internalization of markets, liberalization, and deregulation of economies in union with the knowledge economies. Consequently, organizations must prepare and plan appropriate strategies to continue their relevance in the industry (Abu Bakar, Yusof, Tufail, & Virgiyanti, 2016). Therefore, it is necessary to introduce different methodologies in the acquisition of construction inputs and materials. That allows mitigating the risks associated with compliance within project restrictions, seeking to supply the growing demand for construction. This phenomenon has been mostly satisfied by the development and introduction of chemical additives, allowing the advancement and change in the use of cement and steel considered the most demanded materials by the construction sector and transforming the existing relationship with construction methods and labor used (Isaksson, 2016). For this reason, during initial procurement planning activities, specialized techniques aimed at identifying products, services, or results need to be included within procurement planning together with items requiring external suppliers (Project Management Institute, 2016). Therefore, it is essential to adopt techniques that allow the collection of perceptions on the type and characteristics in the acquisition of new materials. Especially chemical additives, generally added in relatively small quantities (0.005% to 2% in weight of cement), which has enhanced growth of modern infrastructure in the whole spectrum of civil works needs to be demanded by the society. (D.S. Shah, M. Shah, & Pitroda, 2014), (Biernacki et al., 2017).

However, the low level of investment in research and development of these new materials in the construction sector and their impact on the market concern, restricting their ability to innovate and learn from best practices, in conjunction with the limited scope and use of new technologies. These affect their application and understanding of the perception of their impact, benefits, and environmental, social, and economic considerations. Furthermore, these new concepts are not entirely related to management methods, which must initiate within organizations. Market research becomes an invaluable tool during supply planning, emphasizing the availability or scarcity of the primary construction materials and variations in price and quality, representing a risk that can seriously affect the ability to complete a project within the budget in the established time. Therefore, this research will evaluate the perception of stakeholders in the acquisition of additives in the construction sector using statistical perception techniques. These techniques allow us to establish an understanding of users, preferences, and behaviors derived from their experiences in construction. This knowledge is decisive in the use of novel materials such as additives. Consequently, the need of a quantitative oriented procurement management approach implementing statistical tools such as multidimensional scaling (MDS) and Conjoint Analysis based on Choice (CBC) are essential to reveal and quantify stakeholder preferences for particular products, designs or prices (Myers, 2017), (Mansour & Radford, 2016).



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## **2. Methodology**

### **2.1 Selection of the geographical environment.**

Boyacá is one of 32 territorial entities, called Departments, conforming to the Republic of Colombia; in this region are located the leading steel mills, cement quarries, and chemical additives companies in the country, supplying the primary construction materials in large part of it. In consequence, the department's contribution to the national GDP is 2,5%, of which the construction sector contributes 10% equivalent to  $8 \times 10^8$  USD per year. Additionally, its proximity to Bogota DC (26% of the Colombian GDP) allows a constant and representative trade of the dynamics related to the construction sector (Departamento Administrativo Nacional de Estadística –DANE, 2018). Based on the above, the selected samples represent a large part of the trade dynamics related to the construction sector in Colombia.

### **2.2. Sample selection criteria.**

For the selection of a representative sample, individual profiles were selected on behalf of 20 Colombian companies, attached to the Chamber of Commerce of Construction (CAMACOL), residents in the department of Boyacá-Colombia. 50% of the respondents are construction companies familiar with the use of additives in the construction of civil works, and an additional 50% correspond to companies marketing construction materials and chemical additives; the companies selected through the CAMACOL construction industry directory.

### **2.3. Data collection**

Data collection was by presenting the stimuli or attributes of a separate card (profile) for each subject in a group of individual profiles; this allows the respondent to focus only on the product under evaluation (Pérez López, 2004). Finally, the cards delivered were classified in order of preference from highest to lowest, generating in a preference matrix using the statistical program SPSS Statistics®, for the estimation and simulation of the global analysis in the prediction of attributes and sub-attribute.

The combinations between each of the attributes and levels generated using an orthogonal design, forming a system of 20 cards, corresponding to 16 different products that can be released to the market to evaluate and infer consumer preferences. The three main attributes selected, given the impact on the market behavior of the products like the type of application, provided by the additives to modify the physical or chemical properties of the cement mixture in its fresh or hardened state. They were initially selecting ten attributes, establishing the preference of the users through MDS, and later debugging and determining the most demanded applications through CBC. Another characteristic chosen is the brand, which usually influences the perception and attitude of consumers, stimulating the actual purchase behavior (Zhang, 2015). Therefore, two types of chemical additive brands selected for the concrete mixtures found in the Boyacá department, Brand 1, Brand 2 and the perception of the use of a new additive brand, to determine its influence on the market and contribution to the marketing of traditional and new ecological additives (Stobart, 1994). The last determining attribute selected, for its relevance in the choice and use of chemical additives, is the price. Consumers usually



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infer the price-quality, due to the success of a construction project is judged by the fulfillment of cost criteria with the budget, schedule, and quality. Therefore, the effective estimate and cost become an essential factor in the success of a construction project (Schmidt, Sonebi, Brouwers, Kühne, & Meng, 2013), (Vasista, 2017); prices are grouped in three different ranges, chosen through a market analysis conducted throughout the Boyacá-Colombia department.

## 2.4. Multidimensional Scaling (MDS)

It is a statistical method that maps proximity data in pairs of objects in distances between points in a space, which is usually two-dimensional. It relates to the gaps between the points that represent the stimuli or preferences (Borg, Groenen, & Mair, 2018). Consequently, the use or choice of some properties of the additives evaluated by the users is analyzed. Initially, ten applications were selected, defined as the quality or characteristic of the chemical additive in fresh cement mixtures. These properties were determined by classification, according to ASTM C-494 (American Society for Testing and Material [ASTM], 2004). It used as a reference when the respondent is asked about its use or preference at the time of its marketing or usage (S Shah et al., 2014), (Albayrak, Canbaz, & Albayrak, 2015), (Cheung, Roberts, & Liu, 2016). An additional property evaluated was the natural origin of the additive, given the need to integrate environmental aspects into the design and development of products around the construction sector (Lamé, Leroy, & Yannou, 2017); the previously selected attributes showed in Table 1.

Table 1: Attributes of the chemical additives evaluated by MDS

Stimulus number	Stimulus name
1	Plasticizer
2	Retardant
3	Waterproofing
4	Natural origin
5	Viscosity Modifiers
6	Autogenous shrinkage reducer
7	Porosity Reducers
8	Workability Improvers
9	Corrosion inhibitor
10	Water reducer

Source: Own elaboration

## 2.5. Conjoint analysis based on choice (CBC)

One of the fundamental problems of market research is the need to discover the essential characteristics for users in the purchase decision. Therefore, it is relevant to have methodologies to estimate a user's judgment value towards the specific attributes of a product and define its relative importance that make up the preferential structure of consumers. It is useful in procurement management when requirements demand correctly delivered products in quality, time, and cost (Pons, 2008), (Rao, 2014); this type of measurement focuses on responses to conceptual stimuli rather than actual notions, allowing for an understanding of the subjective process of acceptance. It is also a practical method for developing new products. The dependent variables are distinctive attributes of the product evaluated through the perception that the user receives from it, generating an individualized model per respondent and for the entire



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population sample, as a result in the sum of the valuation assigned to the individuals to each attribute (Pérez López, 2004).

The analysis with CBC focuses on the responses to the stimuli towards a global preference, helping to understand the subjective process of acceptance and development of new products. Its broad appeal comes from its capacity to assist in the design of products or services and pricing decisions. The market disposition around the best attributes and the benefits in the development of a product line in a specific segment; answering questions about the product, price, or attribute levels of each in the actual market scenario (Voleti, Srinivasan, & Ghosh, 2017). Concerning the criteria selected in the data acquisition, the attributes evaluated showed in table 2.

Table 2: Attributes of the chemical additives evaluated by CBC

Attribute	Category
Brand	Brand 1
	Brand 2
	New brand
Application	Application 1
	Application 2
	Application n.
Price	Price 1
	Price 1 to Price 2
	Price 2 or higher

Source: Own elaboration

## 3. Results and discussion

### 3.1. Multidimensional scaling

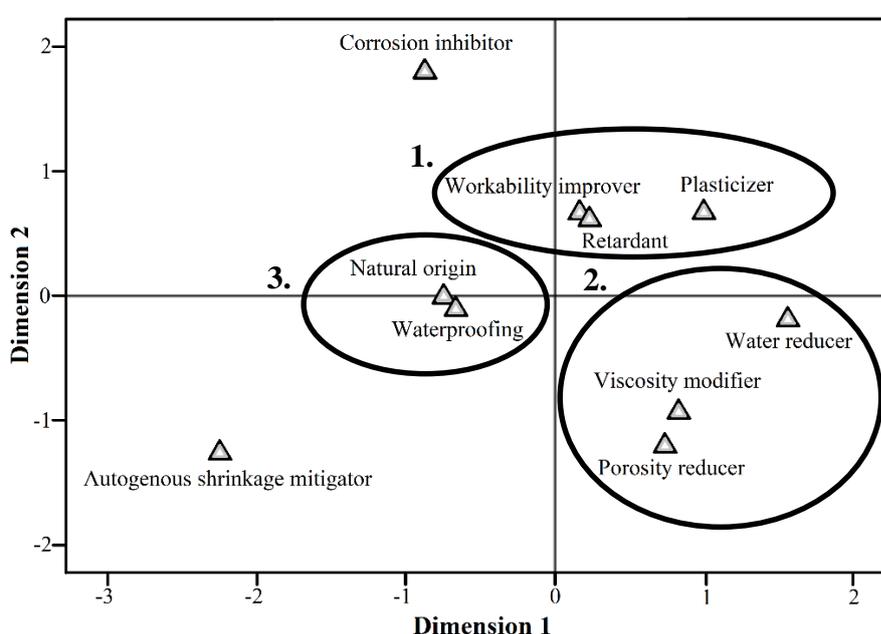
The results of the MDS represented in a Cartesian plane with arbitrary axis orientation, understood as a measurement "scale" in terms of distances between the different applications of the additive using its quantitative evaluation (Borg et al., 2018), (Pérez López, 2004), (Navarro Chávez, Zamora Torres, & Cano Torres, 2015). This visual representation is of great use to analyze the information obtained from the perceptions of the respondents about the preference of attributes or applications of the additives represented in Figure 1. The result divided into three groups that express similarities in the property of the additives around use and utility. Cluster 1 represents the perception with the most significant predilection in these two properties, led by plasticizing additives about the increase in fluidity and consequently greater ease of disposal of cement mixtures in the fresh state in the worksite (Albayrak et al., 2015), (Cheung et al., 2016). Respectively, additives for workability and retardants have a similar perception in importance and use by those surveyed due to the benefits generated in the construction processes in terms of ease of mixing and a higher amount of time. However, there are additives on the market that include plasticizing and retardant properties in a product (Plank, Sakai, Miao, Yu, & Hong, 2015).



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Figure 1: Conceptual map of the coordinates of the attributes



Source: Own elaboration

Cluster 2 involves some properties related to the use of plasticizers concerning changes in viscosity that generate greater fluidity with less water; this, in turn, reduces porosity and consequently higher mechanical resistance (Albayrak et al., 2015), (Marchon, Kawashima, Bessaies-Bey, Mantellato, & Ng, 2018). Therefore, the differences in perception linked with the name of the product to differences in physical properties generated in cement mixtures in the fresh state and of less importance in the changes made in the hardened state as an increase in mechanical resistance. Unlike clusters 1 and 2, in cluster 3 there is a lack of interest in natural origin additives and waterproofing. The former not related to any property generated and the latter to the little use in fresh cement mixtures; likewise, waterproofing is considered an auxiliary application in hardened concrete structures (Lu, Ding, Zhao, & Zhang, 2018).

The perception of some properties outside the clusters, such as corrosion inhibiting additives and autogenous shrinkage mitigators, increase durability in concrete (hardened cement mix). However, those properties are not widely used by the users surveyed. Yet, corrosion inhibitors have high importance due to the visual impact and knowledge of adverse effects on corrosion deterioration in reinforcing steel in concrete, quantified as 80% of the durability problems in this type of structure. Together, the absence of maintenance and quality control has generated



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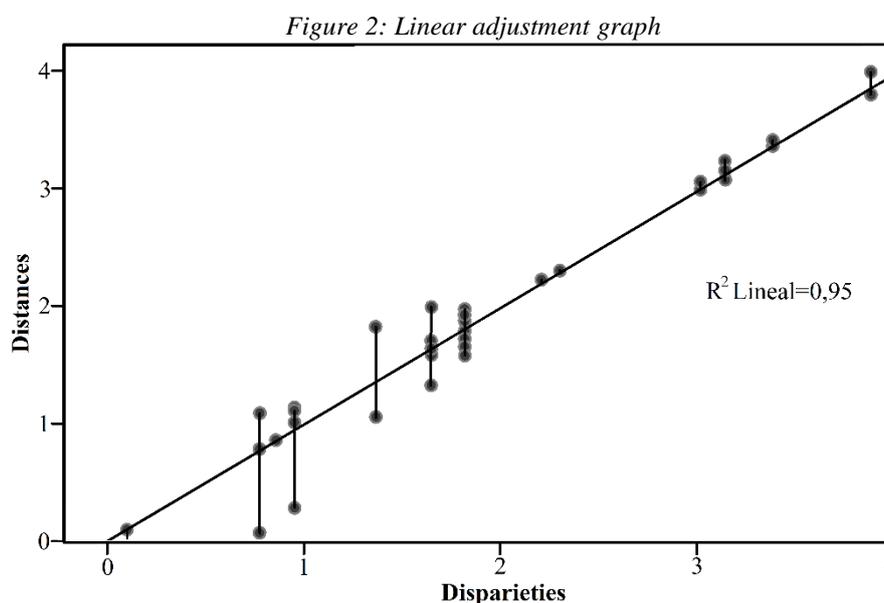
in the users the habit of solving this type of issue after the damage caused by corrosion when the corroded steel is visually exposed. It creates complicated and expensive repairs.

On the contrary, the additives that reduce autogenous contractions have no importance and use by the users. This tendency caused by techniques used in traditional construction methods, where large quantities of water are used for temperature control, avoiding the contraction and generation of cracks in the hardening process of the cement mixture. Therefore, this product does not generate any impact in use or application by the respondents (El-Reedy, 2018), (Tazawa, 1998).

Consequently, the properties provided by the additives to improve the working capacity in cement mixtures are the attributes most requested by the users. Traditional construction methods employ labor for the preparation of civil structures through the use of conventional construction materials. Since labor is the factor of higher growth in contrast with the low participation of machinery and equipment represented in the housing construction cost indexes (Departamento Administrativo Nacional de Estadística –DANE, 2019). On the other hand, the use of additives that provide mechanical resistance improvement properties and long-term durability are of low usage and little importance.

### 3.1.1 Model validation and verification

Figure 2 shows the linear relationship between distances and disparities related to a linear regression; their respective correlation was 0.95, indicating that the quality of the adjustment is great.



Source: Own elaboration

The stress measurements and the RSQ (Stress and Squared Correlation) calculated. The purpose to establish the validity and reliability of the results valued at 0.09 and 0.95, respectively. It interpreted according to the Kruskal-Wallis test, based on linear placements, used to compare the independence of two or more samples, measuring the goodness of fit



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between the set-up distances and the disparities. According to this test, the calculated stress indicates a good model, however, it is possible to reduce it for greater reliability of the results by increasing the number of observations and reducing the number of parameters to more accurately estimate users' perceptions (Navarro Chávez et al., 2015), (Hong & Lee, 2014), (Linares, 2001).

### 3.2. Conjoint analysis based on choice results

The results obtaining from MDS, an attribute was selected for each cluster found, the brands supplying these and prices in the market. The results obtained through CBC are the summary of global evaluations of the groups and subgroups used as parameters for the user surveys. Table 3 summarizes the main attributes, categories, global estimate of all respondents, and the standard error obtained.

Table 3: Global estimation of user preferences linked to the construction sector

Attribute	Category	Importance value between factors (%)	Utility estimation	Standard error
Brand	Brand 1	24,45	0,897	0,675
	Brand 2		-0,613	0,675
	New brand		-0,283	0,807
Application	Water reducer	55,07	-1,48	0,969
	Retardant		0,92	0,969
	Corrosion Inhibitor		-2,54	0,969
	Plasticizer		3,58	0,969
	Waterproofing		-0,48	0,969
Price	\$2 a \$ 5 USD	20,48	-0,364	0,647
	\$ 6 a \$10		-0,729	1,294
	Over \$11		-1,093	1,941

Source: Own elaboration

The results obtained from CBC show that the companies linked to the construction sector prefer the properties offered by the additives independently of the price, distributed through a recognized brand. Likewise, the errors generated from the degree of adjustment to the model (linear), high errors are observed in prices above 6 USD, denoting that the linear model is not the most suitable for this factor. Likewise, the predictive ability of individual models developed tested by Pearson R correlation. It indicates the degree of relationship or fit of users' perceptions and an estimated evaluation, using decision models derived from ordinary least squares regression; the result of the Pearson test was 0,74, indicating a good correlation (Pérez López, 2004), (Shepherd & Zacharakis, 2018)

The following is an analysis breakdown and discussion into the different attributes evaluated, which separated into the various subcategories of the price ranges. Global preferences formed, indicating the existence of a low choice for this attribute in all its categories with an average value of -0,674. The varieties of the groups with the lowest preference are proportional to the costs, with the lowest interest for costs exceeding 11 USD. The brand is an essential attribute for users at the time of purchase, allowing to identify goods and services from one or a group of sellers, differentiating products, representing a promise of value, and product quality



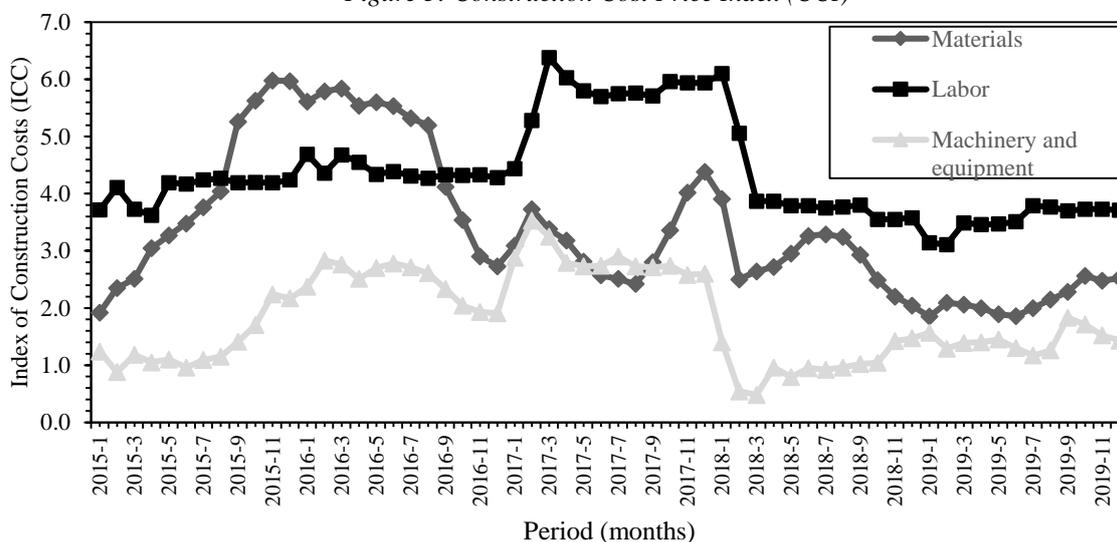
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(Ghodeswar, 2008). The brand evaluation relates the supplier quality ensuring the delivery of products according to the users' preferences regardless of their price. Also, results suggest that a single brand dominates most of the market, consequently brand two or a new brand was not accepted by users. This result confirms the attitude and image of the brand in the role of the value story; this implies that you should consider this attribute in stakeholder management to ensure a positive user perspective (Ghodeswar, 2008), (Rao, 2014), (Zhang, 2015).

MDS results show plasticizing preference; on the other hand, MDS and CBC results show a plasticizing and retarding additives preference. Due to the relation, they generate in the ease of cement mixtures and the increase in processing time, transport, and placement in the worksite (Cheung et al., 2016), (Schmidt, Alexander, & John, 2017). Conversely, there is little interest in additives related to the durability of cement mixtures in the hardened state. The use of additives focused on improving fluidity and increasing hardening times in relation to the labor-intensive production in construction processes, given the little technique and the use of specialized equipment as established by the Construction Cost Index (CCI) formulated by DANE and exposed in figure 3. This event agrees to observe the behavior of the costs of the main inputs used in construction and also constitutes an important reference point for the updating of budgets, contracts, and other aspects related to the evolution of the prices of this type of construction.

Figure 3: Construction Cost Price Index (CCI)



Source: Own elaboration.

Figure 3 shows the factors that make up the ICC, established as materials, labor, and machinery. This last factor has historically contributed to a smaller proportion; likewise, labor has remained predominant. Together with the intensive use of materials along with user perception, which focuses on the preference of market additives related to the use of workability modifiers in the workplace, validate the results found through CBC. In the same way, some physical properties generated by plasticizing additives such as water reduction, an increase of resistance and durability are rejected or unknown. Law 1796 of 2016 (Congreso de la República de Colombia, 2016) establishes a control and surveillance mechanism aiming at durability conditions and



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structural stability in time. Thus, the market around the preference of additives changes, and the use of quantitative tools may require carrying out market studies concerning the management of acquisitions around new technologies in the construction sector.

## 4. Conclusion

Through the statistical analysis tools, the stakeholder's requirements around cement additives and some causes of user behavior in the preference of certain properties offered by these products effectively established around the construction methods used concerning capacities in the construction sector. The inclusion of theoretical concepts and robust quantitative formulations generate an orientation towards standardization in procurement management, ensuring the final product quality in parallel with market selection criteria. These through the identification and simplification of the additive procurement process, identifying prices and quality requirements, and the selection of suitable suppliers, achieving relevant work to the stakeholders' needs.

The use of new materials in the construction sector provides better performance in the construction processes optimizing final product delivery with superior qualities. However, the perception of some durability and resistance properties of cement mixtures in a hardened state is not relevant for the interested parties. The same way, the natural origin of the additive and the importance of implementing actions around the environment; therefore, the advantages and considerations, around the impact in the additives are not clear by the users; these uncertainties can lead to problems related to the quality of the civil works in the future. However, a market change will be expected due to the new policies implementation of mechanisms that generate an increase in the durability and safety of buildings. Therefore, the use of statistical perception tools will facilitate the management of purchases around additives or other products in the construction market.

The use of certain properties provided by additives is linked to the intensive use of labor around traditional construction processes, impacting the economic indexes of construction costs. Therefore, thanks to the implementation of statistical perception techniques, it is possible to relate global phenomena to the framework of the management of acquisitions around the construction sector and market segments. Then, the present market research on procurement management establishes the usefulness of statistical perception tools in sector studies, which allows reducing risk uncertainty that can seriously affect the ability to complete a project on time, within budget and to the satisfaction of the stakeholders.

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