

A Bayesian network for selecting improvement management tools to increase customer satisfaction in the construction industry: case study of Mexico

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Abstract

Purpose – The use of improvement tools in the construction sector has shown to be an important determinant of quality. Companies endeavoring to enhance their daily practices require assistance, evidence, standards, frameworks and quantitative models from existing experts to help them set out for the road. This paper is aimed to assist construction managers in the selection of tools to increase customer satisfaction.

Design/methodology/approach – This piece of research is based on the results of a previous empirical study on the use, within a sample of Mexican firms, of a set of more than 30 tools. It then proposes a Bayesian network (BN) to select them. By analyzing the variables under study, it is possible to establish their interaction and dependencies. The resultant BN comprises 24 nodes, and it is useful for choosing some tools that help to increase customer satisfaction.

Findings – Customers and their needs now have become more complicated and harder to meet than in the past. Then, the use of improvement tools that put quality at the heart of the management strategies is crucial for achieving customer satisfaction. In order to reduce prices, keep product quality and meet delivery times, these tools should be used on a daily basis. Along this line of thought, the overall results from the hypothetical scenarios explored in this were positive, reflecting the relevance of the proposed model. In particular, the use of tools for gathering customer needs, the utilization of technology and the implementation of a quality department are relevant for increasing customer satisfaction in the sector.

Research limitations/implications – The sample size could be further expanded. The customer satisfaction dimensions could be enhanced.

Practical implications – While the sample in which the investigation is based could be expanded along with the number of variables and their states, the BN can help practitioners in the global construction industry to improve their quality practices, to foster loyalty and to grow revenues.

Originality/value – Most of the research reported in the area of continuous improvement in construction focuses on qualitative considerations, and it is still scarce in terms of developing mathematical models for selecting existing tools and, ultimately, satisfying customer's requirements. This investigation is aimed to bridge this gap in the literature.

Keywords Bayesian network, Improvement management tools, Total quality management (TQM), Mexico, Construction projects

Paper type Case study

Introduction

The top five sectors in the Mexican economy during 2020 were the manufacturing industry, the housing, the wholesale and the retail sectors and the construction industry. Their combined contribution to the gross domestic product (GDP) exceeded 50% (INEGI, 2021). Accordingly, firms attempting to improve their practices in both the housing and the construction marketplaces can benefit from theoretical oriented research based on existing empirical information.

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At the end of 2018, the three North American countries signed the United States–Mexico–Canada Agreement (USMCA). The main thrust of the arrangement was to take advantage of a combined market with almost 500 million people, where investments in enterprises, production facilities and construction will be encouraged (OUSTR, 2020). With these ideas in mind, Mexican construction businesses now have the opportunity to work in one of the greatest markets in the world. To do so, they should assume the leadership in improvement efforts to eventually increase their competitiveness and revenue.

Following a broad review of the literature, a diversity of tools, techniques and methods to improve quality have been recognized. It became evident that companies often struggle to identify the most appropriate for them, due to the large number of tools available. Certainly, the selection of tools is a delicate first step in the process of implementing new methodologies (Daalhuizen and Hjartarson, 2022), such as improving customer satisfaction. Then, the main motivation for carrying out this investigation was the lack of systematic research to date to develop a probabilistic mathematical model for selecting quality management tools in the construction sector, aimed at enhancing customer satisfaction.

To advance the use of quantitative models in the quality management arena and to bridge this gap in the literature, a Bayesian Network (BN) will be presented. Its construction has been based on a postal survey conducted in Mexico a little while before by Delgado-Hernandez *et al.* (2017), which utilized the seven groups of tools shown later in Table 1. It is believed that the case of Mexico could be useful for countries in the Latin American region. This is because the nation shares a group of features with its counterparts such as language, culture and economies (WEF, 2019). The novelty of this research is to use the preceding results to provide a new interpretation in the sector, making a synthesis based on Mexican data that hasn't been made before and applying BN in the Latin-American context (Phillips and Johnson, 2022). While the customer survey could be updated with post Covid 19 information, the previous survey is still valid for the sector as the practices remain largely the same over the pandemic period. Consequently, the significance of the research to the construction industry is thought to be relevant.

In the subsequent parts, a brief explanation of the Mexican construction context will be firstly offered. Then, the tools used in the previous survey will be highlighted. Next, the concepts behind BN will be summarized, along with the variables included in the model. After that, the BN and its main characteristics will be discussed in combination with its real use and practical implications. Finally, the conclusions of the research will be established.

Mexican construction context

The Global Competitiveness Index, as reported in the World Economic Forum (WEF, 2019), revealed that Mexico ranked 54th out of 141 countries for infrastructure. The index takes into consideration characteristics such as road connectivity (22nd), quality of roads (49th), quality of railroad infrastructure (58th), quality of air transport infrastructure (80th), quality of electricity supply (81st) and mobile telephone subscriptions (112th). These rankings show that research in the construction quality management field is still required to improve the country's position.

Boadu *et al.* (2020) have reported the challenges that the construction industry in developed nations, such as Mexico, face. They pinpointed fragile monitoring schemes, poor management commitments, absence of training, scarcity of procedures and incompetent enforcement. Moreover, a study conducted by Aire and Aguilar (2021) in the Mexico City subway line 12, recently collapsed, discovered important variability in the materials' quality attributes. They went on to say that a new quality control system should be encouraged

Number	Group	Tools
I	Gathering customer needs	Customer surveys Customer one-to-one interview Customer telephone interview Brainstorming Focus groups
II	Organizing customer needs	Affinity diagram Tree diagram Matrix diagram
III	Formal methods	Quality function deployment (QFD) Theory of inventive problem solving (TRIZ) Concurrent engineering (CE)
IV	Planning tools	Mission statement Gantt chart Critical path method (CPM) Program evaluation and review technique (PERT)
V	Quality control	Teams and teamwork Laws and regulations Checklist Housekeeping (5Cs; also known as 5Ss) Inspection Sampling Quality audits
VI	Performance measure	Contractor partnerships Customer satisfaction survey Customer complaints Litigation
VII	Technology	Departmental purpose analysis (DPA) Planning software (e.g. primavera, Microsoft project) Design software (e.g. AutoCAD for Computer Aided Design) Finite element analysis software (e.g. SAP, 2000 for Structural Analysis Program) Computer network (e.g. electronic mail)

Table 1.
Improvement
management tools for
increasing customer
satisfaction

Source(s): Adapted from: [Delgado-Hernandez et al. \(2017\)](#)

based on their observations. These ideas are in line with anecdotal evidence of the importance that contractors give to the bidding process, grounded on economic aspects, generally neglecting the relevance of quality and technical properties.

Unlike the manufacturing or automotive industries, construction deals with four uncertainties that make it different from other sectors. They are: natural (changing weather conditions), task (projects of varying complexity), organizational (different people each time) and contractual (particular obligations for each project) ([Walker, 2015](#)). Furthermore, professionals should interact with a variety of participants involved in the construction process like clients (who could also be users in some cases), specialists, contractors, regulatory authorities and suppliers. Subsequently, the utilization of management tools aimed at improving their practices would be highly recommended.

Again, while reviewing the literature, it became apparent that managers in the sector regularly struggle to select the best for them, because of the great number of tools available. Then, the emphasis of this piece of research will be on those for managing projects. The tools of interest are based on a preceding study ([Delgado-Hernandez et al., 2017](#)) and will be revisited in the next section. But before presenting them, it is important to note that Mexico is currently building the following major projects: (1) Mexico City airport upgrading, (2) Toluca City airport improvement, (3) "Santa Lucia" Military Base conversion to a new international

airport, (4) Mayan train, (5) “Dos Bocas” refinery, (6) Veracruz new port expansion and (7) Itsmo de Tehuantepec’s interoceanic corridor (Colunga and Mora-Ávila, 2021). Note that project number three has already been cataloged as a poor quality airport, with low customer satisfaction (Hernández-Romero *et al.*, 2022). As is evident from the list, construction specialists working on these projects need guidance to choose the right tools.

The selection of
improvement
management
tools

Improvement management tools in construction

As already stated, the categorization of tools presented by Delgado-Hernandez *et al.* (2017) is adopted. Basically, seven groups are considered: (1) gathering customer needs, (2) organizing customer needs, (3) formal methods, (4) planning tools, (5) quality control, (6) performance measures and (7) technology (see Table 1). While the first set is intended to collect customer desires, the second is aimed at ordering their requirements. The so-called “formal methods” are systematized methodologies that can help to build quality into products. The planning group is useful for scheduling the required resources at the start of the project. The “quality control” unit verifies conformance to existing standards and legal requirements. The “performance measures” cluster considers the success of quality initiatives, and “technology” includes the use of both software and hardware tools. The rationale for this classification can be found elsewhere (Delgado-Hernandez *et al.*, 2017).

In terms of choosing them, the literature reports different approaches. Rocha-Lona *et al.* (2013) developed a methodology for selecting methods and tools in the quality management environment. The six steps involved were (1) quality management system and business processes diagnostic – alignment of both an action plan and the company’s strategic planning, (2) models, methods and tools screening for suitability, (3) assessing the need of applying the candidate tools, (4) analyzing the associated implementation costs, (5) reviewing whether the firm has the necessary resources to put them into practice and (6) examining whether the business is able to achieve its quality goals through the use of the tools. Being a qualitative approach, it can be useful in many sectors, not exclusively in the construction industry.

More recently, Voinov *et al.* (2018) carried out a comprehensive literature review, which yielded an overview of different selecting methodologies. In terms of the qualitative viewpoint, they reported: (1) rich pictures, (2) cognitive/concept mapping, (3) causal loop diagrams, (4) cultural consensus and (5) decision tree analyses. Regarding the semi-quantitative angle, they included: (1) fuzzy cognitive mapping, (2) scenario building, (3) social network analysis and (4) analytic hierarchy process. From the quantitative standpoint, they considered: (1) geographic information systems, (2) empirical modeling, (3) cost-benefit and other economic analyses, (4) system dynamics, (5) cellular automata, (6) agent based modeling, (7) integrated modeling and (8) BN.

Within the construction field, various researchers have recently used a variety of frameworks for selecting either tools or management approaches. For example, Darko *et al.* (2019) reviewed the use of the analytical hierarchy process (AHP) in the sector, highlighting its wide use in the risk management arena. Moreover, Erdogan *et al.* (2019) proposed a multicriteria decision model to choose the best option for sustainable construction management. Last but not least, Aslam *et al.* (2022) developed a framework for selecting lean construction tools based on project objectives and goals.

As can be seen, the approaches for selecting the tools have been the focus of a wide range of research. While the authors do not claim to be exhaustive in the review, the initiatives listed are enough to identify a variety of perspectives. Although all of them have been developed to select tools, the use of BN is still scarce in the construction management arena. As will be discussed later, they may be used not only with diagnostic but also with prognostic and predictive purposes. Therefore, there is a need to generate a Bayesian model aimed at

predicting customer satisfaction through the selection of the appropriate improvement management tools.

The next section will present some of the BN that have been employed in construction. Then, the considerations behind BN will be recapitulated, along with the variables that will be included in the proposed model.

Bayesian networks in the construction management context

The literature includes a great variety of procedures and tools to assess customer satisfaction, such as: tree events, quantitative observations, probability analysis, expert judgment and BN (Arinciheva *et al.*, 2019; Chakraborty *et al.*, 2016; Fatah *et al.*, 2006). Regarding the latter, a comprehensive analysis of the usefulness of BN in the construction sector was presented by Hon *et al.* (2021). They reported applications related to safety management, risk management, contract management, process control, project cost management and quality management.

Just to name a couple of examples of the use of BN for quality management in the sector, Yu *et al.* (2019) employed them to assess the impacts of quality faults in construction projects. Their study showed that the handling of precast elements with quality defects, poor maneuvering and poor quality testing were the most influencing factors for low customer satisfaction. Moreover, Ji *et al.* (2019) proposed an information-based approach to quantify operator quality performance for specific pipes and welds. The research findings have shown that it has effectively helped the company to consolidate its quality management practices, increasing customer satisfaction. Again, the interested reader may consult (Hon *et al.*, 2021) for additional examples.

More specifically, Salini and Kenett (2009) proposed the use of BN for measuring customer satisfaction based on survey information. In the same line of thought, Chakraborty *et al.* (2016) presented a novel application of BN as a management tool for decision making in the railway transport industry. Having said this, now a brief description of what a BN is, will be presented.

A BN is a directed acyclic graph (DAG). In general, it is a probabilistic graphical model that contains: (1) nodes representing random variables and (2) arcs, which help not only to connect nodes but they also imply relationships. The direct predecessors of a node are known as parents, and the direct successors are known as children (Hanea *et al.*, 2015). Moreover, BN represent the information about the joint probability of the nodes, expressed as local distributions for every variable conditional to its parents. Mathematically, the following expression summarizes the conditional probabilities within a BN:

$$P(x) = P(x_1, \dots, x_n) = \prod [P(x_i | pa_i)] \quad (1)$$

where pa_i is the numerical representation for the parents of x_i . BN update the marginal distributions based on new information. A number of algorithms in BN can be found to perform updating processes (Hanea *et al.*, 2015). Even more, a comprehensive analysis of the usefulness of BN was reported by Weber *et al.* (2012). They highlighted their potential to: model complex issues, carry out both diagnostics and predictions, evaluate an event's exact occurrence probability, incorporate original information to update the model, characterize multi-modal variables, offer a visual, user-friendly and simple approach. Having considered these benefits, it was concluded that BN were appropriate to build the model for selecting improvement management tools aimed at increasing customer satisfaction. In the subsequent section, the proposed BN will be presented.

The proposed Bayesian network

The developed network comprises 24 nodes in total, divided into five categories: two company features, seven business activities, seven quality initiatives, seven management

tools groups and the customers satisfaction node. They come from the original data collection instrument used by [Delgado-Hernandez and Aspinwall \(2005\)](#), which included such sections. The first encompasses the number of employees and the ISO 9001 certification nodes. Then, the BN considers seven activities: building, civil engineering, briefing, designing, tendering, construction and commissioning. Next, it includes the initiatives: quality department, cultural change programme, strategies for total quality, employee involvement to improve quality, employees' training, teams and individual recognition.

The seven groups of management tools follow, i.e. gathering customer needs, organizing customer needs, formal methods, planning and programming tools, quality control, performance measures and technology. Note here that this category of the BN originally included more than 30 tools. Therefore, factor analysis was carried out following the steps reported by [Delgado-Hernandez and Aspinwall \(2005\)](#). Having performed the exercise, the data was substantially reduced from 31 tools to a more manageable seven groups. Finally, the customer satisfaction node is taken into account. It is important to mention that twenty-two out of all 24 variables assume two states, false and true. For example, if the ISO 9000 certification node is set to true, it means that the company under analysis has such a certificate. [Figure 1](#) shows the resultant BN, its nodes and their relationships.

Again, every variable can only assume two different states. The node number of employees includes "250 or Less" and "More than 250", and the node customer satisfaction considers "not satisfied" and "satisfied". Note that this variable was measured only by asking respondents whether they considered that their customers were satisfied or not with their performance. Admittedly, a more comprehensive study is still needed to consider customer satisfaction dimensions such as: reliability, responsiveness, assurance and empathy. [Figure 2](#) shows them. Consequently, the model is a discrete BN. All variables present the percentage associated with the "true" state. For instance, number of employees shows the value 68.1%, which means that 68.1% of the businesses sampled had more than 250 people working. The node ISO 9001 has the percentage 39.6%, that signifies that 39.6% of the companies considered had such a certificate. In terms of the customer satisfaction variable, its default

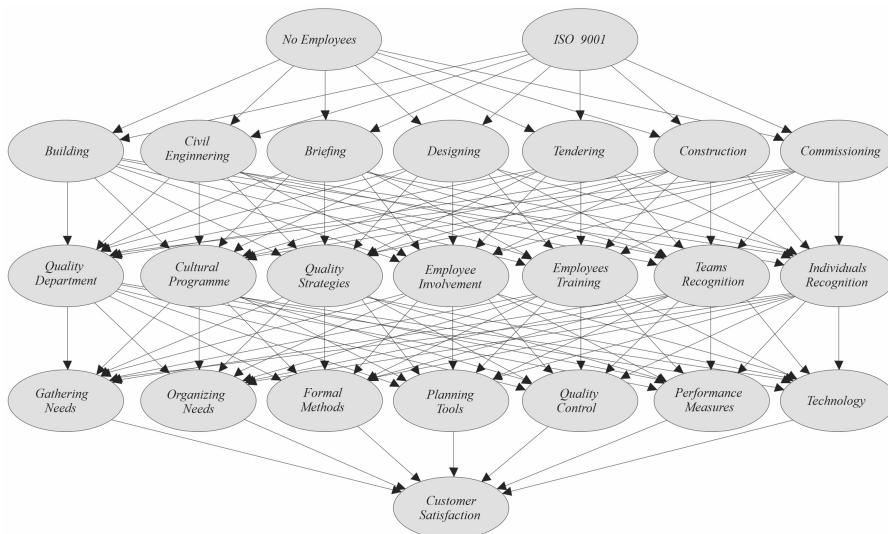


Figure 1.
The proposed BN

Source(s): Adapted from: UNINET®

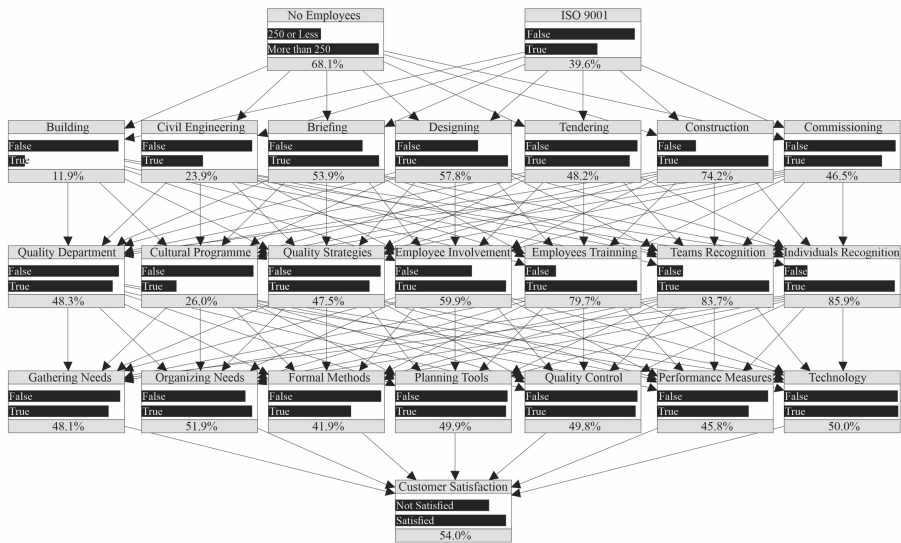


Figure 2.
Nodes' states of the
proposed BN

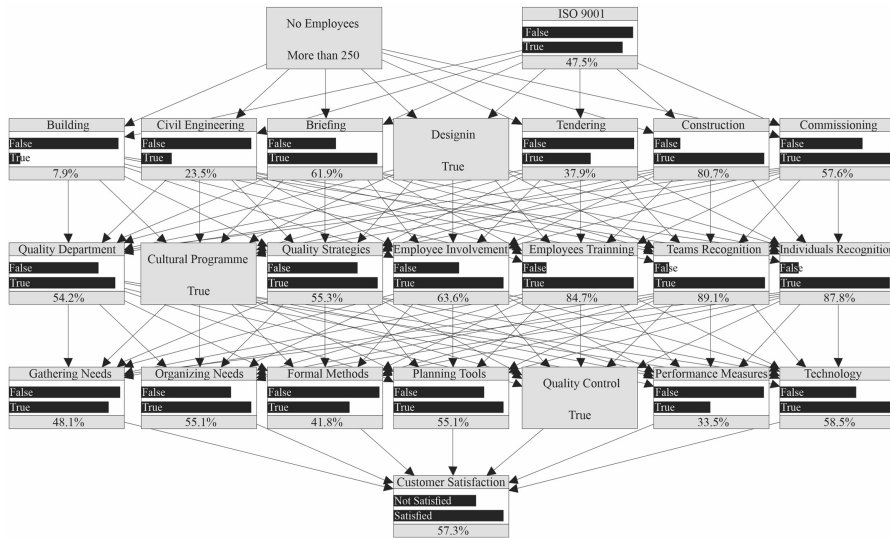
Source(s): Adapted from: UNINET®

value corresponds to 54.0%. This means that, in general, customers of the organizations asked tend to be more satisfied than their unsatisfied counterparts (54.0% vs 46.0% respectively). Prior to their use in this paper, all these percentages were estimated by [Delgado-Hernandez et al. \(2017\)](#), based on the Mexican sample.

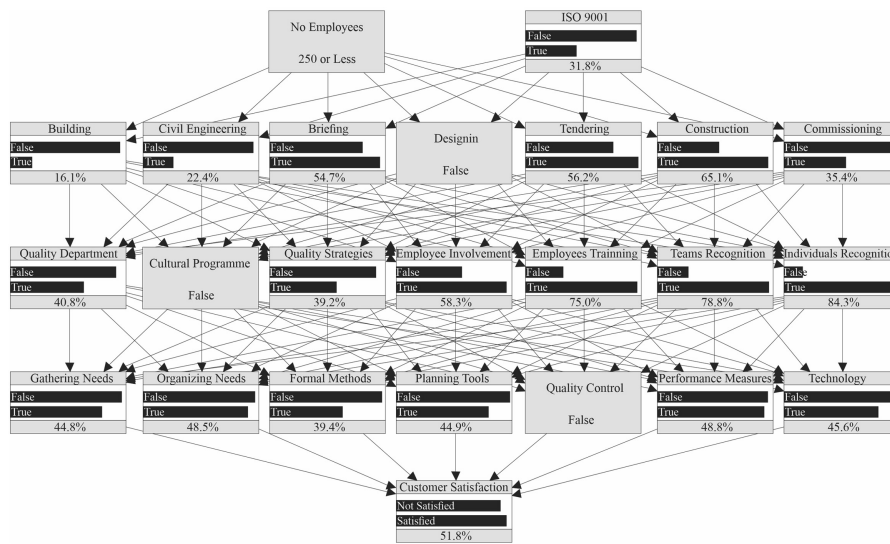
Making use of UNINET®, the network was utilized to carry out different analyses. It should be emphasized that the BN can predict, or diagnose, the performance in any of the Mexican companies included in the original sample ([Delgado-Hernandez et al., 2017](#)). Now that the mathematical network has been described, its use will be illustrated in the following paragraphs.

Bayesian network results

To determine whether the network has made academic advances, some hypothetical scenarios will firstly be explored. Bear in mind that the default value for the variable customer satisfaction is 54.0%. The analyst wants to know the effect of one particular company profile in such a node. Then, assume that it is a firm with more than 250 workers, its main activity is related to the designing process, it has a cultural change programme in place, and it makes use of quality control tools. These tools correspond to the second stage of the quality movement, which are: inspection, quality control, quality assurance and Total Quality Management (TQM). With this evidence, the node customer satisfaction is updated to 57.3%, as shown in [Figure 3a](#). In contrast, now assume that there is a second firm, with less than 250 employees, not directly involved in the designing process, without any cultural change programme in place, and that it neglects the use of quality control tools. This new evidence leads to a value of 51.8% for the customer satisfaction node (see [Figure 3b](#)). Consequently, customers of the first hypothetical business would be more satisfied than those of the second case. The difference would be 5.5% (57.3%–51.8%). This evidence suggests that, as expected, implementing a cultural change programme and utilizing quality control tools have a positive impact on customer satisfaction.



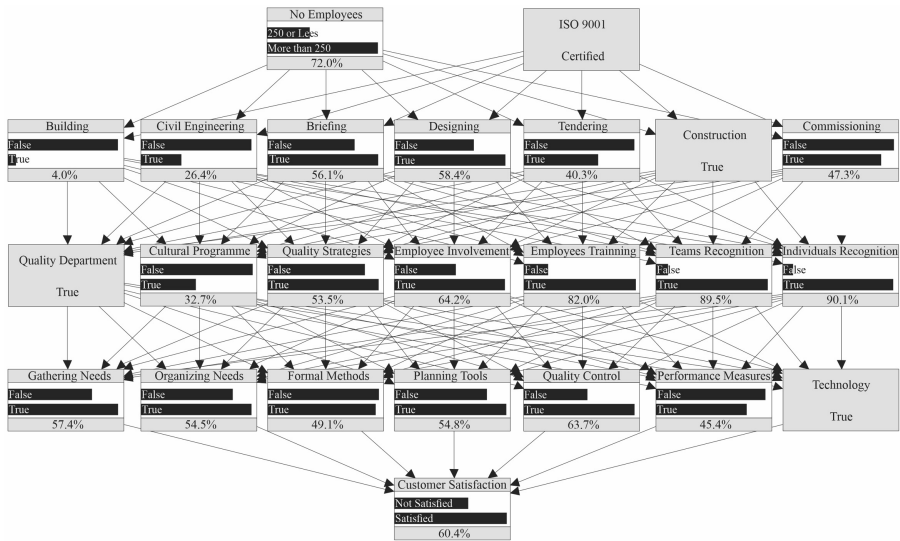
(a)



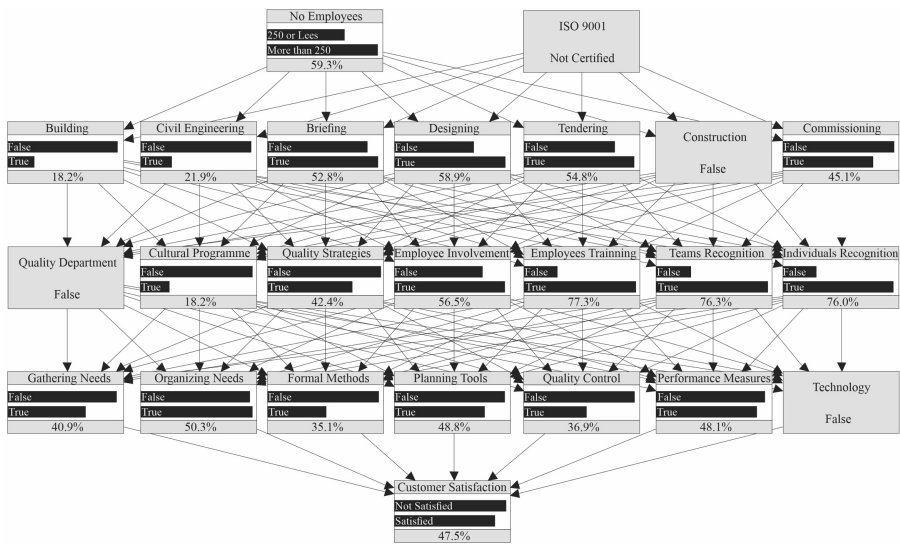
(b)

Figure 3. (a) Model with evidence of a company with more than 250 employees (b) Model with evidence of a company with less than 250 employees

Even more, accept the existence of a company that has been certified to ISO 9001, mainly involved in construction activities, with a quality department in place and that it uses technology on a daily basis. In this case, the customer satisfaction reaches a value of 60.4% (see Figure 4a). In comparison, an organization that has not been certified to ISO 9001, without involvement in construction works, without a quality department and that makes scarce use of technology, would have only 47.5% of customer satisfaction (see Figure 4b). Now the difference is 12.9% (60.4%–47.5%). This means that having both a quality certificate and a



(a)

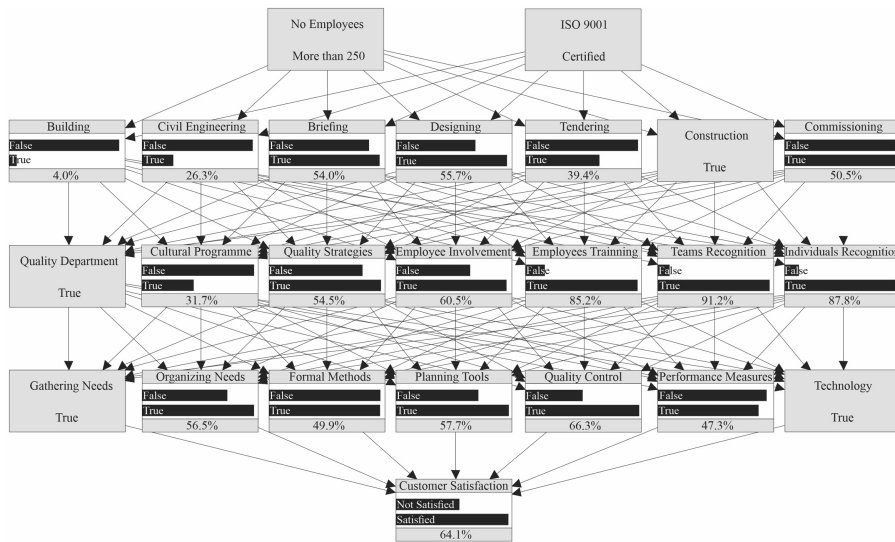


(b)

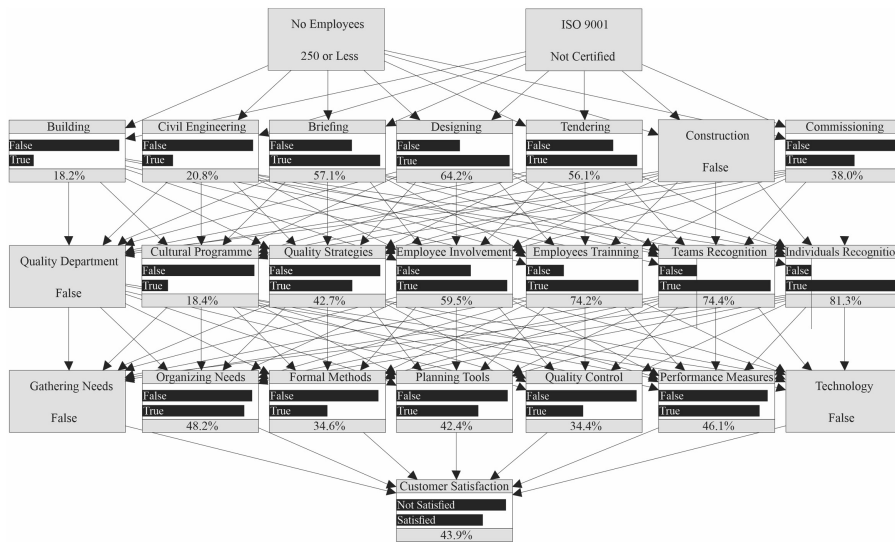
Figure 4.
(a) Model with evidence of a company certified to ISO 9001 (b) Model with evidence of a company not certified to ISO 9001

quality department can contribute to increase the client’s level of satisfaction. It is no surprise to see technology as an important tool, since this is the age of computers and software.

As already stated, the model allows the analyst to consider multiple scenarios. For instance, in the case of a business with more than 250 employees, with ISO 9001 certification, working in construction sites, with a quality department in place, that makes use not only of technology but also of tools for gathering customer needs, the level of satisfaction increases up to 64.1% (see Figure 5a). Its counterpart would only reach a value of 43.9% (see Figure 5b).



(a)



(b)

Figure 5.
 (a) Model of a company with more than 250 employees and certified to ISO 9001 (b) Model of a company with less than 250 employees and not certified to ISO 9001

Now the difference is 20.2% (64.1%–43.9%). This result suggest that the more quality initiatives practiced and management tools utilized, the better is the chance to increase customer satisfaction.

Having presented the previous hypothetical examples, now some actual cases of Mexican organizations will be discussed. So, companies of the original database will be analyzed (Delgado-Hernandez *et al.*, 2017). To establish whether the implementation of quality initiatives and the use of management tools have been translated into better customer

satisfaction in practice, the model has been used. In the exercise, it became clear that the highest value (65.8%) was registered in one firm with less than 250 employees, certified to ISO 9001, involved in five stages of the construction process, with four quality initiatives frequently applied, and two groups of tools commonly utilized. Table 2 shows in detail this company's profile.

The second highest level of customer satisfaction was 64.6%. It corresponds to one organization with less than 250 employees, certified to ISO 9001, involved in two stages of the construction process, with six quality initiatives frequently applied, and three groups of tools commonly utilized (see Table 2). In the same line of thought, the third place reached a value of 62.9%. In this case, the firm had also less than 250 people employed, was certified to ISO 9001, was working only on construction projects, had implemented seven quality initiatives and made use of two groups of tools. The relatively good performance of these businesses could be the result of the adoption of quality management standard's certification. Even more, the three can be considered as small businesses in terms of their number of employees. This is an advantage, since they are flexible with simple structures, result oriented, and with versatile employees.

Categories	Variables	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Company features	Number of employees	250 or less	250 or less	250 or less	More than 250	More than 250	More than 250
	ISO: 9001	True	True	True	True	False	True
Business activities	Building	Default	Default	Default	Default	True	True
	Civil engineering	Default	Default	Default	Default	Default	Default
	Designing	True	True	Default	Default	Default	True
	Briefing	True	True	Default	Default	Default	True
	Tendering	True	Default	Default	Default	Default	True
Quality initiatives	Construction	True	Default	True	True	True	True
	Commissioning	True	Default	Default	Default	True	True
	Quality department	True	True	True	True	Default	Default
	Cultural change programme	True	Default	True	Default	True	Default
	Strategies for total quality	Default	True	True	True	Default	Default
	Employee involvement	True	True	True	True	True	True
	Employee's training	True	True	True	True	True	True
	Teams recognition	Default	Default	True	True	Default	True
Management tools	Individual recognition	Default	Default	True	Default	Default	True
	Gathering customer needs	True	True	True	Default	Default	Default
	Organizing customer needs	Default	Default	Default	True	True	True
	Formal methods	Default	Default	Default	True	Default	True
	Planning and programming tools	Default	Default	Default	True	Default	Default
	Quality control	Default	True	True	True	Default	Default
	Performance measures	Default	Default	Default	True	True	True
Customer satisfaction	Technology	True	True	Default	Default	Default	Default
	Customer satisfaction	65.80%	64.60%	62.90%	51.60%	47.90%	47.90%

Table 2.
Mexican construction companies' profiles

On the other hand, the three lowest levels of customer satisfaction were found in big companies, i.e. those with more than 250 employees. The values were 51.60%, 47.90% and, again, 47.90%. Surprisingly, only one had not been certified to ISO 9001. Another common factor was their involvement in construction activities (see [Table 2](#)).

In terms of the initiatives, they had implemented between three and five, ranging from quality strategies through to all types of recognition. Regarding the use of the management tools of interest, none of the businesses reported the utilization of technology, although they made intensive use of performance measures.

Leaving aside these examples that have only considered cases within the sample under study, a sensitivity analysis was carried out. In the event, the five variables with more influence on customer satisfaction were found to be: Gathering customer needs (G), Technology (T), Performance measures (P), Formal methods (F) and Quality control (Q). To find out what combination of these variables led to the highest customer satisfaction level, a systematic search was performed. Three states were used for each of them: Default (D), True (T) and False (F).

Using the approach proposed by [Montgomery \(2017\)](#), 64 combinations were explored. First, the “true” state was set for the following 32 combinations, leaving the default value in those not considered: G, T, P, F, Q, GT, GP, GF, GQ, TP, TF, TQ, PF, PQ, TQ, GTP, GTF, GTQ, GPF, GPQ, GFQ, TPF, TPQ, PFQ, TFQ, GTPF, GTPQ, TPFQ, GPFQ, GTFQ and GTPFQ. The 32nd set the “default” value for all 5 variables. The second group of 32 combinations was similar, but now using the “false” state. The following notation with parenthesis was adopted to differentiate this case from its “true” counterpart: (G), (T), (P), (F), (Q), (GT), . . . , (GTFQ) and (GTPFQ).

[Table 3](#) shows some of the customer satisfaction levels that a company could expect after using these groups of tools either in isolation or in combination with one another.

As can be seen, the combination GTFQ established the limits of the customer satisfaction levels. The scores ranged from 43.20% to 65.30%, for “false” and “true” respectively. This possibly means that more attention needs to be paid to the combination of tools that help to improve quality, thereby ensuring that customer requirements are met. In terms of the use of the PQ combination, the scores were 51.90% for the “true” case and 55.60% for the “false” case. It was surprising to see that the highest satisfaction value was obtained using the “false” state. This may cause confusion when trying to adopt these approaches in the construction industry, because practitioners could think that neglecting the use of tools will lead to lower satisfaction levels. However, the results revealed the opposite. This is a sign of the importance and relevance of this kind of research.

Essentially, interested readers can follow the steps described here, to support the selection of the appropriate tools for their particular cases. Under these circumstances, in the following section some practical implications will be put forward and the limitations of the study will be pointed out.

Variables/combinations	GTFQ	(PQ)	PQ	(GTFQ)
(G) Gathering customer needs	True	Default	Default	False
(T) Technology	True	Default	Default	False
(P) Performance measures	Default	False	True	Default
(F) Formal methods	True	Default	Default	False
(Q) Quality control	True	False	True	False
Customer satisfaction	65.30%	55.60%	51.90%	43.20%

Table 3.
Results of the sensitivity analysis

Practical implications and discussion

The cases presented are enough to identify concurrent and divergent issues. All the companies shown in [Table 2](#) have implemented at least two out of the seven quality initiatives considered. However, their levels of customer satisfaction vary on the basis of number of employees, quality certifications and management tools. Small and Medium Enterprises (SMEs) perform better than their large counterparts. The flexibility of SMEs is far greater than that of large companies. Maybe this allows them to focus better on their customer needs and to spend more time satisfying them. With reference to the ISO 9001 certification, authors such as [Hadidi *et al.* \(2017\)](#), [Niranjan and Nisha \(2018\)](#) and [Tomic and Brkic \(2019\)](#) have reported a correlation between its application and customer satisfaction. Here, the focus should be on quality management rather than on quality control.

Regarding the existence of a quality department, in general, the firms that have adopted such initiative tend to have better levels of customer satisfaction than those that neglect it. This result is in line with the findings recently reported, in the Mexican context, by [García-Alcaraz *et al.* \(2021\)](#). They argued that the role of a quality department is crucial to deploying quality policies and reaching customer satisfaction and, in the end, loyalty. In addition, they emphasized that attention needs to be paid to the managerial commitment to implement quality strategies.

With regard to the employees' training, either the best or the worst performers in terms of customer satisfaction apply it on regular basis. This finding reveals that construction businesses are aware of the role that training plays in the management of quality. Moreover, this result is in accordance with that reported by [Sweis *et al.* \(2019\)](#), who claimed that there is a positive and strong correlation between employees' training and the performance of construction organizations.

In terms of the management tools, the best companies made use of both the gathering customer needs and the technology groups. As can be seen in [Table 1](#), previously presented, the first group includes: customer surveys, customer one-to-one interviews, customer telephone interviews, brainstorming and focus groups. In the construction sector, the idea to gather the client's requirements has been put forward for a while now. [Delgado-Hernandez and Aspinwall \(2007\)](#) reported the use of questionnaires and focus groups to improve customer satisfaction in the design and construction phases of different nurseries in the UK. More recently, [Juan *et al.* \(2019\)](#) revealed that future public housing projects should take into account multi-generational living arrangements, energy-efficient and barrier-free designs, flexible spaces, crime prevention and self-sufficient farming. These aspects were discovered by means of customer surveys and interviews. As a result of their inclusion in the buildings, customer satisfaction may be increased.

The second group of tools includes: planning software, design software, finite element analysis software and computer networks. Undoubtedly, as [Vasista and Abone \(2018\)](#) sustained, the computer programs and networks can help to improve customer satisfaction by diminishing coordination errors and enhancing participants' understanding for better handling issues and requirements. These results may be integrated in current methodologies for selecting management tools. For instance, in the one proposed by [Rocha-Lona *et al.* \(2013\)](#) and presented earlier. Basically, in their second stage, i.e. models, methods and tools screening for suitability, construction managers should analyze the groups associated with gathering customer needs and technology. One important finding is that the combined implementation of the groups of tools, in general, leads to better satisfaction levels than those obtained with their isolated adoption. But this is not necessarily always the case. In parallel, the associated implementation costs and required resources to put them into practice should be examined. As a result, the best candidate tools should be chosen for increasing customer satisfaction, based on the model's predictions.

Admittedly, the number of variables included in the model, the size of the companies' sample in which its construction was based, and the two states per variable are not exhaustive. They may be used as a starting point to develop a more comprehensive BN.

However, the hypothetical cases analyzed, the actual Mexican construction companies studied and the implications summarized, have helped to show that the model is both practical and applicable. From a professional standpoint, the findings of this investigation will help companies in the sector to choose a variety of management tools useful to enhance customer satisfaction. Essentially, the two groups gathering customer needs and technology should be adopted in first place, prior to implementing more complex groups such as formal methods. Moreover, the establishment of a quality department is highly recommended.

As can be seen, the results presented here provide evidence that these groups of tools have worldwide implications in the industry. Consequently, the main contribution of the Mexican case is the opportunity to help businesses in the global sector to better select the categories evaluated. This in turn is useful to increase customer satisfaction to further expand the competitiveness of the construction community. Having clarified this, the last section of the paper will present the main conclusions of the research.

Conclusions

This paper has dealt with the selection of management tools for improvement in the construction industry. A previous study (Delgado-Hernandez *et al.*, 2017) constituted the foundation to propose a quantitative model for identifying those that can have a positive impact on customer satisfaction. It is a BN with 24 nodes that has been proved both theoretically and practically in a Mexican sample. The first observation is that regardless of their activity in the construction process (i.e. briefing, designing, tendering, construction and commissioning), firms have room for improving user approval. The levels of satisfaction in the sample ranked from 47.90 to 65.80%.

The results also showed that not only the tools designed to gather customer needs were relevant but also the adoption of technology. While the first outcome was expected, the second might be due to its advantages in standardizing information, transferring data between project members and establishing a common language among them. This is in line with previous studies such as those of Vasista and Abone (2018), Tomic and Brkic (2019) and García-Alcaraz *et al.* (2021).

In terms of size, companies with less than 250 employees reached higher levels of customer satisfaction than their large counterparts. The flexibility of small and medium enterprises was an advantage for the implementation of quality initiatives and strategies aimed at satisfying customer needs. Regarding the certification to ISO 9001, the firms that had adopted the standard performed better than those without it. This reflects better internal management, efficiency and, eventually, customer satisfaction. Concerning the use of initiatives, quality department, quality strategies and employees training were the three most relevant for the construction context. Their combined use is expected to improve the client experience. Generally speaking, the findings are consistent with previous investigations carried out in various countries.

While the objectives of the research have been achieved, there are still some limitations related to the work. The number of companies reported in the previous study (Delgado-Hernandez *et al.*, 2017) should be further expanded. Note, however, that the resultant BN has been successfully used in a Mexican sample. With reference to the number of variables and states, new nodes could certainly be incorporated in the future. This point was not considered from the outset, because it was founded on a previous study (Delgado-Hernandez *et al.*, 2017).

Therefore, the originality of the paper lies on that it proposes a BN for selecting improvement management tools to increase customer satisfaction in the construction sector, based on empirical evidence. It is believed that this research will be valuable to many companies not only in Mexico but also in other countries and will encourage future investigations in the construction industry.

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