

# Six Sigma enablers in Mexican manufacturing companies: a proposed model

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## Abstract

**Purpose** – The purpose of this paper is to extend the understanding of Six Sigma (SS) and the underlying dimensions of its critical success factors (CSF) via an analysis of the effects of top management support (TMS), implementation strategy (IS), and collaborative team (CT) on project performance (PP) in Mexican manufacturing companies.

**Design/methodology/approach** – Based on a SS literature review, a survey was conducted to capture practitioners' viewpoints about CSFs for SS implementation and their impact on performance in manufacturing companies. A factor analysis and structural equation modeling were conducted in order to identify and analyze causal relationships.

**Findings** – The results suggest that CSFs grouped in the constructs TMS, IS, and CT have a positive impact on PP as measured by cost reduction, variation reduction, and quality improvement.

**Research limitations/implications** – Although the empirical data collected supported the proposed model, results might differ among organizations in different countries. In addition, the study did not analyze a unique performance metric; instead, general PP dimensions were used.

**Practical implications** – Boosting the TMS, IS, and CT enhances positive PP of SS in manufacturing companies.

**Originality/value** – IS as a construct has not been studied exhaustively; this work contributes to a better understanding of it and its impact on PP. Additionally, studies of SS in Latin America are limited, so this study gives a complementary vision to practitioners and researchers about it.

**Keywords** Six Sigma, Structural equation model, Critical success factors, Factor analysis

**Paper type** Research paper



## 1. Introduction

The real global market has experienced a significant increase in the use and development of the Six Sigma (SS) methodology in a wide variety of organizations that are constantly seeking best practices to increase or at least maintain competitiveness. This has been manifested by a continued proliferation of literature to the extent that it is becoming difficult to follow all of the developments in the field. Hoerl (2004) argued that organizations foregoing SS will likely find it hard to compete in either cost or quality unless they have found a methodology that is just as good. In this context, SS is a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction (Harry and Schroeder, 1999). A large number of companies have achieved many economic benefits and improved customer relationships through SS. For example, a successful application of SS reduced material waste by nearly £50,000.00 per year. This SS implementation was characterized by critical success factors (CSFs) such as management involvement and commitment, project selection and its links to business goals, among others (Bañuelas *et al.* (2005). In another SS project, the defect rate per unit (DPU) was reduced from 0.194 to 0.029 DPU, leading to estimated savings of US\$110,000; moreover, the project took into account CSFs such as top-level management involvement, open communication, selection and prioritization of projects, aligning project with strategic goals, and organizational infrastructure, among others (Kumar *et al.*, 2007). Other cases included Caterpillar, where successful SS projects helped to achieve \$30 billion in revenue in 2004 (Gillett *et al.*, 2010). Another SS project in an automobile parts company in India reported annualized savings of about US\$2.4 million (Gijo *et al.*, 2011).

However, not all organizations have experienced equal success (Breyfogle, 2003). Despite the immense popularity and the widespread adoption of SS, there is increasing concern about failed SS programs (Chakravorty, 2009a). According to David Fitzpatrick (worldwide leader of Deloitte Consultant's Lean Enterprise), the proportion of companies in this situation is fewer than 10 percent (Bañuelas and Antony, 2002). Similarly, Kanani (2006) found that 144 of 181 SS projects implemented in a company were successful; this suggests a proportion of 20 percent of unsuccessful projects. Gray and Anantatmula (2009) found that 67 percent of the respondents in their study had experienced SS project failure at least once; they identified several reasons for failure, including, among others, failure to identify and manage project stakeholders and their expectations, inadequate project selection process, and inability to align projects with critical organizational priorities. Similarly, Zimmerman and Weiss (2005) argued that less than 50 percent of the survey respondents from aerospace companies were satisfied with their SS programs. In this sense, to avoid failure, it is important to have knowledge of prior experiences. Cooke-Davies (2002) stated that learning from experience is another CSF. Organizations may have differing benchmarks of success for their SS projects as a result of diverging levels of maturity in the deployment of their initiatives (Shenhar *et al.*, 1997). Thus, the term "project success" is used to depict the level to which desired results are achieved. This definition is applicable across different types of projects, and covers the domain of project success for organizations in varying stages of SS deployment (Anand *et al.*, 2010).

CSFs are critical to the success of any organization – if the objectives associated with such factors are not achieved, the organization will fail, perhaps catastrophically (Rockart, 1979). Similarly, Antony and Bañuelas (2002) defined CSFs as essential ingredients without which an SS implementation project will stand little chance of success. Much

recent research has focussed on CSFs, for example, Bañuelas and Antony (2002) reviewed the literature, Kumar (2007) conducted a study of CSFs in Britain, Hilton *et al.* (2008) in Australia, Gosnik and Vujica-Herzog (2010) in Slovenia, Chakrabarty and Tan (2012) in Singapore, and Schön (2006) in Sweden. Until now, even though a considerable amount of research into the implementation of SS has been conducted in North America, only a few studies have been done in Europe and Asia. However, given the globalization of many companies, studies in other parts of the world are needed (Nonthaleerak and Hendry, 2005). As Hoerl (2004) put it, while much of the SS “ground” in the USA has already been “plowed”, there are plenty of fertile fields elsewhere in the world.

In this regard, little information on this subject exists in Latin American countries such as Mexico. A few examples include a factor analysis study that defined CSFs for SS implementation among practitioners in manufacturing companies that export finished goods in Northern Mexico (Coronel *et al.*, 2009) and the application of SS and Taguchi methods in a northwest Mexican electronics company that increased processing capability from 0.56 to 1.45 (Baez *et al.*, 2010).

Given the paucity of information on SS CSFs, it is important to ascertain the status of SS implementation in this region and its relationship to the situation elsewhere in the world by answering the following questions: what are practitioners doing in other countries for successful implementation of their SS projects? Are the individual CSFs reported in the literature measuring many independent factors, or do they measure a few underlying SS success dimensions? Thus, an objective of the research reported here is to determine the main CSFs for SS implementations in manufacturing companies as well as the underlying factors that are being measured by these variables to extend understanding of SS. In a previous work, Kumar (2007) recommended using structure equation modeling to focus on establishing a relationship between CSFs and organizational performance. In the present work, hypotheses that CSFs of SS are grouped into components are tested. In this way, the paper provides a study of the main CSFs of SS, which have been incorporated into a structural model through theoretical constructs, including top management support (TMS), implementation strategy (IS), and collaborative team (CT) in order to positively influence SS project performance (PP). The construct of IS has not been studied exhaustively; hence, this paper contributes to a better understanding of its nature and its impact on PP. In addition, since studies of SS in Latin America are limited, this research provides a complementary vision to practitioners and researchers on the matter.

The paper is organized as follows: the section of theoretical background introduces a review of relevant literature followed by the development of the research hypotheses. The next section describes the methodology followed to test the hypotheses. Similarly, results are later presented, as well as findings. Finally, conclusions, limitations, and future work drawn from the analysis are addressed.

## **2. Theoretical background and hypotheses development**

The SS methodology has become one of the most significant strategies for improving processes and products. It is an organized, parallel-meso structure that reduces variations in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives (Schroeder *et al.*, 2008). Montgomery and Woodall (2008, p. 329) defined SS as a disciplined, project-oriented, statistically based approach for reducing variability, removing defects, and eliminating waste from products, processes, and transactions. According to this definition, the main goal of SS is to increase profits by eliminating the variability, defects, and waste that undermine customer loyalty. Motorola and General

Electric (GE) are SS pioneers who achieved financial growth and recognition of the quality of their products as far back as the 1980s and early 1990s, respectively. Recently, many companies have taken advantage of SS, even nonmanufacturing companies. For example, the Commonwealth Health Corporation has invested about US\$900,000 in SS, leading to savings in excess of US\$2.5 million (Lazarus and Stamps, 2002). Kwak and Anbari (2006) presented some successful SS projects that included Bank of America, which reported a 10.4 percent increase in customer satisfaction and a 24 percent decrease in customer problems after implementing SS. American Express applied SS principles to improve external vendor processes and eliminate non-received renewal credit cards; the results showed an improved sigma level of 0.3 in each case. Bechtel Corporation, one of the largest engineering and construction companies in the world, reported savings of US\$200 million with an investment of US\$30 million in its SS program to identify and prevent reworking and defects in everything from design to construction to the on-time delivery of the employee payroll.

Regarding SS success, numerous papers have reported benefits obtained from its application in different industrial sectors and companies. Table I shows a literature summary of the main CSFs that have recently been in wide use. They have been classified according to the number of times they are cited by other authors. Hence, it can be observed that training and education is the most CSF reported, followed by top management involvement and project selection/prioritization. These three CSFs represent 36 percent of reports found. Furthermore, in this sample, countries such as UK and USA cater for 71 percent of the studies, while developing countries such as Mexico have minimal presence. Further information of CSFs is given in the following paragraphs.

## 2.1 TMS

TMS could drive a good SS project, beginning with the involvement and commitment of top management, which promotes proper project selection and provides the means for an adequate level of education and training of team members.

*Top management involvement and commitment.* Previous studies have indicated that top management involvement and commitment is one of the most important factors in the implementation of SS (Lee, 2002; Hahn, 2005; Kwak and Anbari, 2006; Brady and Allen, 2006). Without top management commitment and support, the true importance of the initiative will be weakened (Pande *et al.*, 2000). In this sense, if management wants improvement leading to bottom-line enhancement, then it must be involved (Hare, 2005). Top management involvement is vital for SS, and a way to maintain and strengthen it is to encourage the training of top management in SS, so they can directly see the methodology, tools and techniques, complications, the need for resources, and the need for additional training. Leaders must invest time, attention, and resources in this effort. Up to now, the focus has been on methodology, with some attention being paid to management "commitment."

*SS project selection and prioritization.* Managers must be involved in establishing criteria and the management system, as well as participating in projects themselves (Eckes, 2000). Their participation should begin with SS project selection and prioritization, which is frequently the most important and difficult part (Pande and Holpp, 2002). Similarly, Kanani (2006) noted that project selection and prioritization is the most important CSF in SS. Successful selection, management, and completion of projects is integral to any business improvement effort. Selection of the right project is a vital factor for gaining early and long-term acceptance of the SS program among the

**Table I.**  
Main critical success  
factors of Six Sigma  
from literature

Type	Country	Critical success factors	Training and education	Top management involvement	Project selection and prioritization	Project leadership/ leadership	Customer focussed and involvement	Understanding methods and tools	Project tracking and reviewing	Cultural change/ change management	Organizational infrastructure	Linking SS to business strategies	Team communication	Goals based involvement	Team involvement	Total
Survey	UK	Antony <i>et al.</i> (2008)	*	*	*	*		*	*		*	*	*	*	*	7
Case study	UK/Mexico	Banuelas <i>et al.</i> (2005)	*	*	*	*		*	*		*	*	*	*	*	7
Survey	UK	Kumar and Antony (2008)	*	*	*	*	*		*	*	*	*	*	*	*	10
Literature review	Hong Kong	Seto and Tsang (2005)	*	*	*	*	*	*	*	*	*	*	*	*	*	8
Case study	UK	Kimi and Morrow (2006)	*	*	*	*	*		*		*				*	7
Literature review	USA	Brady and Allen (2006)	*	*	*	*	*		*	*	*			*	*	8
Viewpoint	USA	Hahn (2005)	*	*	*	*	*		*	*	*			*	*	5
Viewpoint	USA	Kwak and Anbari (2006)	*	*	*	*	*		*	*	*			*	*	4
Research paper	UK	Antony <i>et al.</i> (2007)	*	*	*	*	*	*	*	*	*	*	*	*	*	9
Viewpoint	USA	McCarthy and Fisher (2007)	*	*	*	*	*	*	*	*	*			*	*	8
Viewpoint	USA	Johnson and Swisher (2003)	*	*	*	*	*		*		*			*	*	5
Research paper	Netherlands-UK/USA	Van Iwaarden <i>et al.</i> (2008)	*	*	*	*	*		*	*	*		*	*	*	7
Research paper	India	Antony and Desai (2009)	*	*	*	*	*	*	*	*	*			*	*	10
Research paper	USA	Anand <i>et al.</i> (2010)	*	*	*	*	*		*	*	*			*	*	6
Research paper	USA	Gray and Anantatmula (2009)	*	*	*	*	*		*	*	*			*	*	6
Research paper	UK	Kumar <i>et al.</i> (2009)	*	*	*	*	*		*	*	*		*	*	*	7
Research paper	Slovakia	Tlačáľ and Lyócsa (2010)	*	*	*	*	*	*	*	*	*	*	*	*	*	9
Case study	South Korea	Kim <i>et al.</i> (2010)	*	*	*	*	*	*	*	*	*			*	*	3
Book	USA	Shree and Hoel (2003)	*	*	*	*	*		*	*	*			*	*	4
Research paper	USA	Zu <i>et al.</i> (2009)	*	*	*	*	*		*	*	*		*	*	*	6
Viewpoint	UK	Banuelas and Antony (2002)	*	*	*	*	*	*	*	*	*	*	*	*	*	10
Case study	Italia	Brun (2011)	*	*	*	*	*	*	*	*	*	*	*	*	*	9
Viewpoint	Iran	Mehrjerdi (2011)	*	*	*	*	*	*	*	*	*	*	*	*	*	8
Research paper	UK	Antony and Banuelas (2002)	*	*	*	*	*	*	*	*	*	*	*	*	*	9
Viewpoint	USA	Goldstein (2001)	*	*	*	*	*	*	*	*	*	*	*	*	*	7
Research paper	Saudi Arabia	Aldrisi (2014)	*	*	*	*	*	*	*	*	*	*	*	*	*	12
Total			26	23	19	13	14	13	12	14	13	12	11	11	10	

**Note:** \*denotes presence of the factor in literature

senior managers and other employees in any organization (Antony *et al.*, 2007). Many publications have shown that project selection is the most critical and easily mishandled element during SS project implementation (Fundin and Cronemyr, 2003). To avoid mistakes at this stage, SS organizations have developed formal mechanisms to select SS projects. These mechanisms involve senior management in filtering out SS projects that do not have financial or strategic implications (Carnell, 2003). In this context, actions such as involving upper management champions in the project selection process and thereby helping to guarantee these projects will have a large impact on the business (Lucas, 2002). From this perspective, the power to decide whether or not to initiate a project is allocated to senior management. In contrast, other approaches to quality have taken a bottom-up approach in which workers directly involved with the process initiate improvement projects. Giving the management the decision rights to initiate a project helps ensure that project selection is based on strategic importance rather than on convenience (Plecko *et al.*, 2009).

*Training and education.* According to Szeto and Tsang (2005), companies such as Samsung believe that training is the first essential step in preparing for the implementation of SS methodology, allowing the company to set new goals and, in effect, ask employees to cope with change by thinking and acting differently, performing new tasks, and engaging in new behavior.

Organizations need to continuously learn and adapt the latest trends and techniques from outside the SS domain that might be useful to complement the SS approach (Kwak and Anbari, 2006). In this context, the belt system must be applied throughout the company, starting with top management (i.e. the champions), and it should be cascaded down through the organizational hierarchy (Bañuelas and Antony, 2002). However, resources for training are critical in the SS role structure in developing specialists' expertise (Linderman *et al.*, 2003). At this point, it is necessary to identify and select the types of training and education that staff will receive. In this context, a number of studies (e.g. Callahan *et al.*, 2008) have reported areas of training or continuing education that will be important to the manufacturing professional over the coming years; these include lean manufacturing (77.8 percent), SS (56.3 percent), quality management (QM) (46.7 percent), and statistical analysis (46.0 percent), among others. SS Black Belt (BB) and Green Belt (GB) training and certification is a useful mechanism to select and promote employees (Henderson and Evans, 2000).

## 2.2 IS

Goldstein (2001) pointed out that a lack of understanding or experience in developing a deployment plan is a primary factor that contributed to the failure of some of earlier quality improvement programs. Implementations of SS employ define, measure, analyze, improve, and control (DMAIC) for project management and completion of process improvement projects (Montgomery and Woodall, 2008). However, in order to increase the chances of successful SS implementation, a specific implementation plan/strategy should be developed. IS for SS implies that projects are focussed on the organization's goals and the business strategy, and that members have project management skills and a defined strategy for monitoring and controlling projects.

*Project track and review.* The status of the project has to be reviewed periodically as well as the performance of the SS tools and techniques being implemented. At this stage, the project should be well documented to track project constraints, mainly cost,

schedule, and scope (Kwak and Anbari, 2006). Project reviews could be seen as tollgates, where the project is reviewed to ensure that it is on track. Montgomery and Woodall (2008, p. 335) stated that tollgates:

Provide a continuing opportunity to evaluate whether the team can successfully complete the Project on schedule. Tollgates also present an opportunity to provide guidance regarding the use of specific technical tools and other information about the problem. Organization problems and other barriers to success, as well as strategies for dealing with them, are often identified during tollgate reviews. Tollgates are critical to the overall problem-solving process. It is important that these reviews be conducted very soon after the team completes each step.

*Project management skills.* SS has management and technical components. The technical side is focussed on enhancing process performance by reducing variation. Simultaneously, the management side focusses on identifying process metrics, setting goals, choosing projects, and assigning people to work on these projects (Hu *et al.*, 2005). In order to achieve this, project leaders must have some basic project management skills (Bañuelas and Antony, 2002). The success of the tools and techniques is further assured when these are used as part of a well-managed project or program (Basu, 2004). In addition, as Bañuelas and Antony (2002) have pointed out, SS participants must be taught team tools, including project management skills. Ultimately, effective implementation of SS projects requires the effective execution of project management processes (Gray and Anantatmula, 2009).

*Project goals-based approach.* SS projects are guided and assessed by a mixture of common and unique performance metrics. In addition to typical financial and operational project metrics, SS applies unique measurements including process sigma, critical-to-quality attributes, and defects per million opportunities (Swink and Jacobs, 2012). In this context, execution of the SS focus on metrics also requires support from top management. Thus, the ways in which top management determines an organization's strategic objectives influence the metrics and goals determined for individual improvement projects (Zu *et al.*, 2008). Aligning projects with both business-unit goals and corporate-level metrics helps ensure that the best projects are considered for selection (Montgomery and Woodall, 2008). In addition, challenging goals must be supplemented with tools and methods to solve difficult problems, for example training and supporting the use of problem-solving tools and methods Linderman *et al.* (2006). Byrne (2003) suggested that before an appropriate training regimen is implemented, specific strategic improvement goals (SIGs) should be determined for the organization and the SS projects.

*Linking SS to business strategy.* SS has evolved into a business strategy in many large organizations as well as in small and medium enterprises (SMEs), as pointed out by Kumar and Antony (2008). One of the best examples of aligning SS to the business is GE, which undertook SS as a corporate initiative in 1995 to seek improvement in business performance and profitability. Sanders and Hild (2000) outlined three aspects of SS implementation strategies from a level of implementation perspective, e.g., implementation in all the organization, in a large percentage of engineering staff, and with strategically selected individuals.

Experience has shown that successful implementation of SS is achieved when top management is involved, not just committed. Top management has a crucial role in successful approaches to improvement, supplying strategy, goals, and reviews. At this point, senior managers should use the forum to understand the BBs' accomplishments and insights in the recently completed project phase (Goldstein, 2001). In a similar

context, Antony *et al.* (2008) argued that barriers to the success of SS projects included too few management reviews or poor quality reviews. From this perspective, top management cannot approve SS implementation by just accept the budget for it without having serious involvement and commitment (Goh *et al.*, 2006). On the other hand, quality improvement requires change, and change starts with people. People change when they understand the purpose of the change and have the skills to implement it (Szeto and Tsang, 2005). Appropriate education and training provide those involved with better understanding of the fundamentals, tools, and techniques of SS. Training is part of the communication techniques that are used to ensure that managers and employees apply and implement complex SS techniques effectively (Kwak and Anbari, 2006). Training must be provided to develop the necessary skills (Snee, 2010), i.e. project management skills.

Appropriate TMS can be conducive to the correct IS of SS, with projects being focussed on the organization's strategic goals and business strategy and with project members having project management skills, including a plan for monitoring and control of projects. Thus, the following hypothesis is proposed:

*H1. TMS has a direct and positive relationship with IS.*

### 2.3 SS CT

Collaboration is the extent to which individuals actively communicate, cooperate, and help one another in their work by sharing knowledge and expertise with one another (Thomas, 2006). It is related to mutual sharing of knowledge (Rus and Lindvall, 2002). Support and collaboration may be defined as the degree to which people in a group actively support and help one another with their work (Hurley and Hult, 1998). This can help people to develop a shared understanding of an organization's external and internal environments through supportive and reflective communication (Lee and Choi, 2003). From this perspective, CT is characterized by members knowing and fully understanding the methodology, techniques, and tools of SS with appropriate leadership and effective communication and team involvement.

*Team communication.* In SS projects, the ability of team leaders to communicate openly and frequently with team members is essential to success (Hagen and Park, 2013). A communication plan is important in order to involve the personnel with the SS initiative by showing them how it works, how it is related to their jobs and, the benefits that can be obtained from it (Bañuelas and Antony, 2002). Any quality initiative should also be linked to employees in terms of training, making resources available, and establishing good communication with them (Kumar and Antony, 2008).

*Team involvement and commitment.* Brady and Allen (2006) found that this was the seventh most reported CSF in SS implementation, reflecting its importance in the literature. In connection with team involvement, Denison and Spreitzer (1991) described how emphasis on flexibility, internal integration, and on the group culture values of belonging, trust, and participation provides strategies that are oriented toward developing human relations through cohesiveness, openness, commitment, and attachment. Similarly, Zu *et al.* (2009) pointed out that, by developing a group culture, organizations are able to promote participation, trust, and a concern for human development as their core values. In this context, a supportive environment should be promoted in order to encourage participation in continuous improvement teams.



*Understanding methods, tools, and techniques.* A full understanding of SS methodology and its tools and techniques is a CSF (Antony *et al.*, 2008; Bañuelas and Antony, 2002; Gosnik and Vujica-Herzog, 2010). True understanding of the methodology can be confirmed through verification of savings in the implementation (e.g. SS certification). However, this is not guaranteed; for example, Moosa and Sajid (2010) observed that many training programs throughout the world that claim SS Black/GB certification are not capable of developing sufficient skills for the investigation of causal relationships in complex systems via the use of statistical techniques, resulting in qualified but incapable personnel. In addition, DeRuntz and Meier (2009) pointed out that the SS Black Belt (SSBB) certification is granted by many organizations in both industry and academia, each of which has independently developed its own unique body of knowledge by which its SSBB certification is granted.

*Project leadership.* SS is a data-driven leadership approach that uses specific tools and methodologies leading to fact-based decision making (Gijo *et al.*, 2011). Leadership is not only about involvement but also about delegating responsibility to other committed, responsible, and knowledgeable leaders who have the “edge” to lead the SS program forward (Szeto and Tsang, 2005). In the group culture, the leaders tend to be supportive and participative, encouraging empowerment and interaction through teamwork and concern for employees’ ideas (Denison and Spreitzer, 1991).

During SS training, employees learn three main groups of tools and techniques: team tools, process tools, and leadership tools. Since methodologies vary from organization to organization, there is no standard methodology, and organizations must be capable of choosing the most appropriate tools and techniques applicable to them (Pande *et al.*, 2000). In this context, there is a direct relationship between understanding the method, tools and techniques of SS and training and education. This demonstrates not only the importance of receiving SS training but also the need to verify that such training has been understood. Here, the level of management support is positively related to how well they understand the SS methodology (Nonthaleerak and Hendry, 2005). In addition, the theory of psychology as it relates to management involvement, teamwork, and leadership is essential to success with SS (Montgomery and Woodall, 2008). As for team involvement and communication, when implementing a change control program such as an SS project, it is important to involve people vertically; for example, plant operators and their supervisors, line managers, factory managers, etc. However, it is also important to involve people horizontally, e.g., the department undergoing change and the different departments that interface with it (Gibbons, 2006). Welch and Byrne (2001, p. 2767) called this approach boundaryless, i.e. “removing all the barriers among the functions: engineering, manufacturing, marketing, and the rest.” For this approach, Jack Welch (GE’s chairman) worked to “break down barriers and improve teamwork, up, down, and across organizational lines” (Pande *et al.*, 2000, p. 17). SS is a business program supported by top management and, consequently, closely related to the strategy of the organization (Ricondo and Viles, 2005). However, TMS influences not only IS, but also CT, meaning that everything begins with the example if top management is involved and committed to the SS project, then this is able to spread to the SS team members, via good communication that facilitates team involvement and commitment. Moreover, TMS results in training and education that improve understanding of SS tools and techniques. Thus, it is then further proposed that:

H2. TMS has a direct and positive relationship with CT.

## 2.4 SS PP

When an SS project is implemented, some common results are expected. Zailani and Sasthriyar (2011) found that perceived SS success included cost saving, meeting customer requirements and engineering, and quality performance. Meanwhile, Antony *et al.* (2007) reported benefits such as improved customer satisfaction, a reduced defect rate, reduced process variability, an improved culture of continuous improvement, reduced process cycle time resulting in faster delivery of services, reduced service operational costs, and increased market share. Gosnik and Vujica-Herzog (2010) reported that the most common motivating factors for SS implementation in Slovenian manufacturing companies were reducing the variation of various processes, achieving positive financial goals, and increasing customer satisfaction.

No SS project will be approved unless the team determines the savings generated from it (Kumar, 2007). In this regard, top management has the responsibility to select SS projects that can generate savings. Therefore, top management demonstrates its commitment to the achievement of the quality goals by taking responsibilities for quality and being evaluated based on quality performance (Flynn *et al.*, 1994; Kaynak, 2003). Here, Mahanti and Antony (2006) reported some key performance metrics of SS, including reduction of costs of poor quality (COPQ), reduction of process variation, financial savings, defect reduction, and cycle time reduction. As far as organizational performance is concerned, Trunk *et al.* (2013) reported that perceived organizational performance is a product of objective information on organizational performance and individual attributes, including preceding experiences. Previous works have taken into account organizational performance as perceived by employees (Koys, 2001; Paauwe and Boselie, 2005). The present research proposes an approach to perceived PP that considers variation reduction, cost reduction, and defect reduction, as well as customer satisfaction. Therefore, TMS can drive successful SS PP, beginning with the involvement and commitment of top management, which promotes proper selection of projects and provides the means for an adequate level of education and training of team members. Based on this, it is considered that:

*H3. TMS has a direct and positive relationship with PP.*

The relationship between project IS and CT is positive. When proper IS of SS is promoted it may increase collaboration. This means that projects are focussed on the strategic goals of the organization, which have a defined strategy for monitoring and controlling projects. Moreover, an adequate understanding of the SS methodology is assured, pushing the project forward. At this stage, goals serve as regulators of human action by motivating the project improvement teams (Linderman *et al.*, 2006). These goals help the teams as well the top management to keep track on the advance, because as Kumar (2007) stated, "SS places a clear focus on bottom-line impact in hard dollar savings," and since money is the language spoken by management (Brady and Allen, 2006), project reviews could be seen as tollgates, because provide a continuing opportunity to evaluate whether the team can successfully complete the project on schedule (Montgomery and Woodall, 2008). It is important that these reviews are conducted very soon after the team completes each step in order to foster involvement.

The SS role structure also encourages employees' involvement in QM, offers recognition of their good performance, and considers their interests and satisfaction (Zu *et al.*, 2008). According to Snee and Hoerl (2003), the overall deployment methodology of SS, with accompanying formal infrastructure, is key to its success.

When a proper IS is followed, a SS CT can be promoted. This is characterized not only by members knowing and fully understanding the methodology, techniques, and tools of SS, but also by effective communication and thus team involvement. This leads to the following hypothesis:

*H4. Project IS has a direct and positive effect on CT.*

IS may help ensure benefits from PP of SS. IS begins with project management skills of members who work to establish projects based on goals and linked to business strategy. This enables to track and review in a periodical basis. Linderman *et al.* (2003) stated that SS's use of challenging goals helped alter organization members' perceptions of performance frontiers. At this point in SS, an alignment between measures of the company's strategic objective, CSFs, and performance measures makes them more effective (Kumar, 2007). For instance, GE launched SS projects to align with business goals by focussing on identifying and avoiding variation, reducing cycle time, improving customer satisfaction, cutting down on returns, and improving the speed and accuracy of order fulfillment (Szeto and Tsang, 2005).

As for the role of goals in SS, Linderman *et al.* (2006) found empirical support for the proposition that they affect PP. Changes associated with improving the performance are related to progress review on a regular basis (Snee, 2010). Here, Leonard and McAdam (2002) pointed out that viewing quality from a strategic rather than operational perspective would help ensure that the benefits from quality improvement flow through to strategic dimensions. By using a strategy deployment plan in conjunction with quality function deployment, SS projects are linked to dashboard metrics (Pzydek, 2003). Ingle and Roe (2001) indicated that project management in SS is closely tied to the business goals or business objectives of the organization. Effective project management is essential to the success of any SS project. Project management consists of planning, management, accountability, and the champion's ability to select, prioritize, scope, and remove barriers for SS (Lynch and Cloutier, 2003).

Therefore, a correct IS project suggests that the SS team has an appropriate means to perform its work that enables their communication, involvement, and commitment. In this regard, we suggest the following hypothesis:

*H5. Project IS has a direct and positive effect on PP.*

CT implies that members of a team understand the methodology of SS, including the techniques and tools associated. The team works with appropriate leadership, effective communication, and team involvement. The teamwork, empowerment, and open communication fostered by the group culture are also expected to facilitate the application of tools and techniques in SS for problem solving (Zu *et al.*, 2009). Moreover, employees' attitudes and behaviors are critical for implementing the changes entailed in implementing quality management programs (Van De Wiele *et al.*, 1993). From this perspective, CT enables an appropriate medium through which the team could do their work, enabling communication, involvement, and commitment among all its members. The technical side is focussed on enhancing process performance by reducing variation. Practitioners use data and statistical thinking as part of a disciplined improvement methodology with five key stages: DMAIC (Harry and Schroeder, 1999). In addition, aspects such as motivation, leadership, learning and knowledge in a SS context could help management develop a better understanding of performance and effectiveness (Lloréns-Montes and Molina, 2006).

The importance of CT as a project success enabler is suggested as follows:

*H6.* Higher levels of CT will provide higher levels of PP.

In order to clarify the relationships among constructs and the associated hypotheses, Figure 1 shows the SS framework developed in this study.

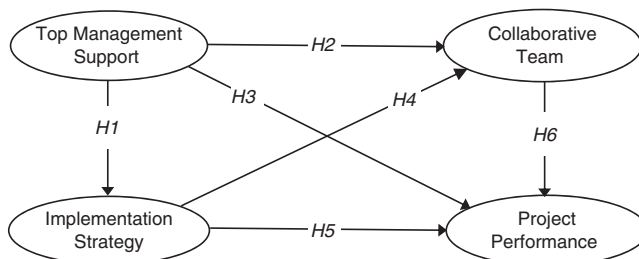
### 3. Methodology

In order to conduct this research, a methodology was followed involving the development of an instrument to collect data and a model generation that explains the relationships among constructs. In deriving causal inferences from existing theory and research, Kaynak (2003) utilized cross-sectional survey data. This research also followed Kaynak approach to collect data. Moreover, the paper follows previous works (Swink and Jacobs, 2012; Langabeer *et al.*, 2009; Anand *et al.*, 2010; Farris *et al.*, 2009; Kleine and Weißenberger, 2013; Antoncic, 2007). This is, admittedly, a controversial approach; nevertheless, Cook and Campbell (1979) stated that it is acceptable to clarify theory and assess specific causal effects from correlational research data with structural and path analyses. Thus, the methodology is composed of four stages, which are described below.

#### 3.1 Instruments and measures

In order to develop the survey, a literature review was conducted to determine the main CSFs reported by SS practitioners, which are shown in Table I. One should not overlook the importance of being well grounded in the substantive theories related to the phenomenon (Devellis, 2012). The survey was used as a strategy to obtain empirical data from SS practitioners with direct knowledge of its implementation. At this point, the main CSFs are considered as items or dimensions in the survey, and they are integrated in three constructs as shown in Table AI, where the measurements scales and items are presented. For TMS, six items were selected from previous scales (Flynn *et al.*, 1995; Doolen *et al.*, 2003; Chen and Paulraj, 2004; Zu *et al.*, 2008; Farris *et al.*, 2009; Feng and Zhao, 2014). Similarly, five items were considered for IS, which agrees with the works of Doolen *et al.* (2003), and Zu *et al.* (2008). Moreover, seven items from previous scales were selected in forming the construct SS CT (Flynn *et al.*, 1995, 1999; Cua *et al.*, 2001; Doolen *et al.*, 2003; Lee and Choi, 2003; Farris *et al.*, 2009). Finally, five items form part of the construct PP (Denison and Spreitzer, 1991; Flynn *et al.*, 1999).

An initial survey was administered to 34 SS practitioners, who were selected from the exporting manufacturing sector (Maquiladora) because of their knowledge and experience in SS implementation and because they have an SS certificate as verified by



**Figure 1.**  
Initial model

their public profiles on professional networks such LinkedIn ®. After feedback, minor changes were made to ensure good understanding of the items, and to obtain content or face validity (García *et al.*, 2014b; Hair *et al.*, 2014). The final survey included four main sections; the first concerned general and demographic data from practitioners, the second section focussed on identifying the degree of importance of CSFs, the third section concerned the degree of use of CSFs, and the fourth section focussed on obtaining information about the degree of success of SS implementation. This research focussed on the degree of use of CSF from the point of view of practitioners, and therefore the survey asked respondents to rate CSFs on a Likert scale (Likert, 1932), with the lowest value (1) corresponding to a CSF that is not useful at all in an SS implementation and the highest value (5) corresponding to a CSF that was very useful. CSFs are considered as items in the survey and integrated in three constructs as follows: TMS integrated by six items, IS integrated by five items, and CT integrated by seven items. Moreover, the construct PP considered five items.

### 3.2 Data collection

Empirical data were collected via internet surveys and a specific search of personnel involved in SS projects was conducted. Through a search on LinkedIn and a database of local companies from the Baja California Economic Development Secretary, a total of 1,180 SS practitioners (managers, engineers, and supervisors) in manufacturing companies in the state of Baja California were contacted via e-mail.

### 3.3 Information analysis

Statistical analysis of the data was performed using SPSS Statistics 22® and Amos 22® software. As a measure of unidimensionality, the Cronbach  $\alpha$  index (CAI) was calculated for statistical validation of the survey to determine the internal consistency of the constructs, with cut-off values of 0.70 (DeVellis, 2012; Garson, 2015; García *et al.*, 2014a). In order to find the underlying factors accounting for patterns of collinearity among multiple variables, the feasibility of a factorial analysis was investigated using a correlation matrix, with most correlations higher than 0.40, as proposed by Hulland (1999). The anti-image correlations matrix was also analyzed. To determine factorability, Bartlett's test of sphericity was used to test the null hypothesis that the intercorrelation matrix came from a population in which the variables were not collinear (i.e. an identity matrix). In addition, communality was analyzed to determine how much of the variance of each CSF is determined by common factors.

A measure of sampling adequacy was calculated using the Kaiser-Meyer-Olkin (KMO) index, which compares the magnitude of the observed correlation coefficient with the magnitude of a partial correlation coefficient. A KMO index higher than 0.8 is recommended to determine the factorability of the correlation matrix (Kaiser, 1970).

Once reliability was ensured, an exploratory factorial analysis (EFA) was carried out to determine the factors by principal component analysis. The important factors were determined using Kaiser's criterion with an upper or equal value to one in their eigenvalues, conditioning the search to 100 iterations for the convergence of the result. In addition, a factor rotation by the Varimax method was performed to provide a better interpretation of the factors. The CSFs that integrate the factors were identified by the highest value among the factorial charges, which is a measure of correlation with the factorial axis. A confirmatory factor analysis (CFA) was then performed to further evaluate the factors affecting PP. Both EFA and CFA were utilized to assess

convergent and discriminant validity (Campbell and Fiske, 1959). Moreover, nomological validity was tested by examining whether the correlations among the constructs made sense (Hair *et al.*, 2014).

In order to assess common method bias (i.e. inflated estimates of the relationships among variables when data are collected from single respondents), we conducted Harman single-factor test CFA as recommended by Podsakoff and Organ (1986), Mossholder *et al.* (1998), and Podsakoff *et al.* (2003).

### 3.4 Structural equation modeling (SEM)

This paper develops a theoretical model of relationship among CSFs using SEM, as in Feng and Zhao (2014). To achieve this, we followed a five-step process including model specification, identification, estimation, testing, and model modification (Schumacker and Lomax, 2010). Model specification involves using all available relevant theory, research, and information to develop a theoretical model. That is, available information is used to decide on the variables to include in the theoretical model and how these variables are related. Cooley (1978) indicated that this was the hardest part of SEM. In order to integrate the theoretical model, a deep literature review was conducted to develop constructs and their related items or dimensions. A detailed list of previous works reviewed for every construct can be found in Table AI.

In order to determine the relationships among CSFs, an initial structural equation model was obtained from a measurement model and a structural model.

For model identification, the number of distinct values in the sample covariance matrix  $S$  was first obtained as  $p(p + 1)/2$ , where  $p$  is the number of observed variables. Then, the order condition was assessed, as described by Bollen (1989). Once the model was specified and identified, the next step was to obtain estimates for each of the parameters specified in the model, thereby producing an estimated matrix  $\Sigma$ , as close as possible to the sample covariance matrix  $S$  of the observed variables (indicators). For this purpose, the maximum likelihood (ML) method was utilized, because it is efficient and is not skewed when assumptions of multivariable normality are met (Schumacker and Lomax, 2010). Once the parameter estimates were obtained, a model test was conducted in order to assess how well the data fitted the model. Both global model fit and parameter fit indices were used for this (Hair *et al.*, 1992). The first criterion was the non-statistical significance of the  $\chi^2$  test and the root-mean-square error of approximation (RMSEA) values. In addition, a goodness of fit index (GFI), adjusted GFI, Tucker-Lewis index (TLI), parsimony fit index and Akaike information index were obtained, since it is recommended that various model-fit criteria should be used in combination to assess model fit, model comparison, and model parsimony as global fit measures (Hair *et al.*, 1992). A second criterion was the statistical significance of each individual parameter estimate. A third criterion involved evaluation of the magnitude and direction of the parameter estimates in order to find meaningful relations. After estimation and testing of the initial model, the next step was to modify the model and subsequently evaluate the modified model as proposed by Schumacker and Lomax (2010). Finally to determine the appropriate sample size in SEM, the critical N (CN) of Hoelter was computed. Hoelter (1983) proposed the CN, which specifies the sample size needed to provide a reasonable indication of whether a researcher's data fits their theoretical model (Schumacker and Lomax, 2010).

SEM was performed using Analysis of MOment Structures (AMOS) of SPSS software. It features a user-friendly graphical interface and has become popular, since it is a relatively easy way to specify models (Garson, 2015). In this sense Clayton and Pett

(2008) stated that AMOS, as a user-friendly program, is appropriate for both novice and advanced researchers. In addition, previous works have tested hypothesized relationships of models using AMOS as well (Yang *et al.*, 2011; Lau, 2011; Hwang and Min, 2013; Hong *et al.*, 2014; Fullerton *et al.*, 2013; Ng *et al.*, 2010).

#### 4. Results

This section presents the results of the investigation, which is divided into subsections as follows.

##### 4.1 Sample descriptive analysis

A total of 130 useful questionnaires were received; this constituted an overall response rate of 11.0 percent. The main descriptive characteristics are shown in Figure 2; for example, the main industrial sectors of the respondents can be seen, and it is notable that 33 percent come from medical device manufacturing companies. All respondents had worked in SS projects, with nearly 63 percent having at least an SS certification. The SS teams are mainly composed of four to six members, with teams of more than ten people being less common. Regarding the frequency of reviews of SS projects by top management, monthly reviews prevailed (38 percent of respondents).

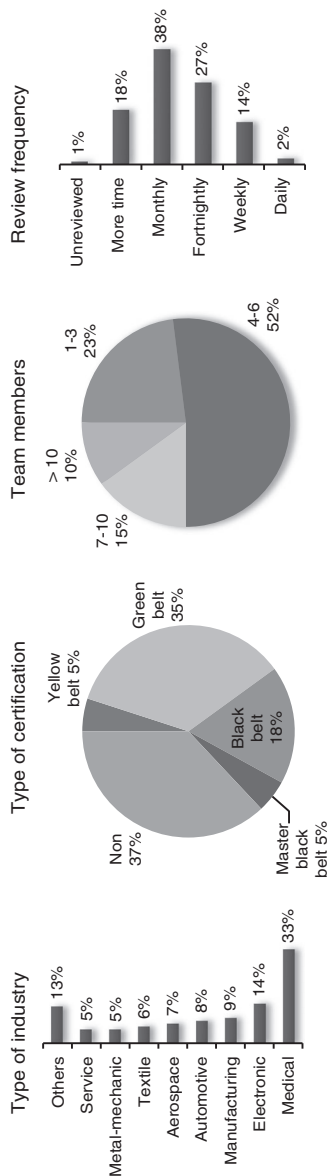
##### 4.2 Statistical survey validation

Regarding the reliability of the scale, calculations of CAI complied with the threshold of 0.70; for example, TMS yielded a CAI of 0.944 after removal of item TMS5 (CAI = 0.853 before to removal). In similar conditions, IS yielded a CAI of 0.991, CT a CAI of 0.955, and finally PP a CAI of 0.990, implying that only three items actually measure PP. This is consistent with the results of Kumar (2007), who found that the majority of operational staff was not convinced by soft factors of success such as customer satisfaction. Table II shows the percentage of variance from rotation sums of squared loadings, where it can be seen that four constructs account for 91.423 percent of the total variance.

##### 4.3 Factor analysis

In order to examine the main SS CSF's and their underlying dimensions, an EFA was conducted using principal components with Varimax rotation. Factor analysis is an essential tool in scale development. It enables to determine the number of factors underlying a set of items (DeVellis, 2012). At this point, sample size plays an important role. Tinsley and Tinsley (1987) suggested a ratio of about 5-10 subjects per item. In this research, 23 items were initially used (see Table AI) and 130 useful questionnaires were received. Therefore, it complies the range of 115 and 230 subjects required.

The software SPSS 22® was utilized throughout the study. Here, the Bartlett test of sphericity yielded a value of 2,500.6 and a *p*-value of 0.000; i.e., the intercorrelation matrix of the analyzed data is significantly different from the identity matrix. The KMO index has a value of 0.871, so it can be seen that the variables considered are measuring some common components. The item's initial EFA loadings are shown in Table AI. CFA was then performed to further evaluate these components. The communalities, i.e., the amount of variance in each item that is measured or accounted for by the components that were extracted with Varimax, are shown in



**Figure 2.**  
Main descriptive  
characteristics of SS  
project practitioners  
in the survey



**Table II.**  
Factor loadings

Latent variable	Manifest variable	Loadings	Communality	Cronbach's $\alpha$	Average variance extracted	Rotated components % of variance
Top management support (TMS)	TMS1	0.938	0.949	0.944	0.784	21.800
	TMS2	0.883	0.850			
	TMS3	0.856	0.843			
	TMS4	0.863	0.810			
Implementation strategy (IS)	IS1	0.928	0.976	0.991	0.855	24.677
	IS2	0.931	0.973			
	IS3	0.932	0.984			
	IS4	0.908	0.936			
Collaborative team (CT)	CT1	0.925	0.929	0.955	0.779	26.617
	CT2	0.919	0.914			
	CT3	0.915	0.908			
	CT4	0.820	0.800			
	CT5	0.829	0.817			
Project performance (PP)	PP1	0.928	0.976	0.990	0.864	18.328
	PP2	0.936	0.982			
	PP3	0.925	0.983			

Table II. Low communalities are considered to be those below 0.4, while those over 0.6 are considered high (Jung, 2013). In factor analysis, only those factors or components with an eigenvalue greater than unity were considered, and only four components met that requirement. Rotated principal components using Varimax with normalization are shown in Table II, where it can be seen that four components are confirmed.

4.4 Measurement model validity

Indicator reliability is considered satisfactory, since all factor loadings exceed the required threshold of 0.7 (Kleine and Weißenberger, 2013). Regarding convergent validity of the constructs, Garver and Mentzer (1999) suggested that the magnitudes of the parameter estimates for the individual measurement items should be reviewed. Table II shows high loadings on factors, indicating that they converge on a common point, i.e., the latent construct; in addition, all factor loadings are statistically significant, values of AVE are higher than 0.50, and the reliability estimates all exceed 0.70. Therefore the items from Table II are retained at this point and adequate evidence of convergent validity is provided (Hair *et al.*, 2014). Finally, discriminant validity exists at the construct level if the AVE estimates for each factor are greater than the corresponding interconstruct squared correlation estimates (Hair *et al.*, 2014). This is supported by the data shown in Table III. Thus, the constructs show both convergent and discriminant validity. Finally, an assessment of nomological validity based on the positive correlations between each construct supports the contention that these constructs are positively related.

Regarding common method bias, all items were loaded on one factor; however, the analysis does not fit the data well, with a relative chi value of 21.28, a GFI of 0.383, an RMSEA of 0.397, and a CFI of 0.487. This lack of fit indicates that common method bias is not a significant concern with the dataset.

#### 4.5 Structural equation model

In order to examine the hypothesized relationship among latent variables, SEM was employed following a two-step model-building approach and the measurement models were tested before the structural model (Jöreskog and Sörbom, 1996). Figure 3 depicts the SEM results for the relationships among TMS, IS, CT, and PP. Each path in the figure indicates the associated hypothesis as well as the estimates of standardized regression weights, with significance level at  $*p < 0.1$ ,  $**p < 0.05$ , and  $***p < 0.01$ . The results reveal that TMS has a positive and significant effect on both IS and CT ( $p < 0.01$  and  $p < 0.05$ , respectively), leading us to accept both hypotheses *H1* and *H2*.

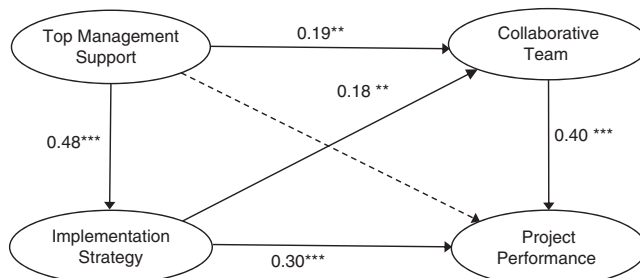
In the initial formulation of our model, it was suggested that TMS has an effect on PP. However, our results indicated a non-significant relationship. Nonetheless, we did confirm an indirect effect of TMS via IS and CT on PP. On the other hand, regarding IS and its effect on CT, we can see a positive significant effect ( $p < 0.05$ ), as well a positive influence on PP ( $p < 0.01$ ), leading us to accept *H4* and *H5*. Finally, hypothesis *H6*, which claims that CT affects PP, is also confirmed, with a positive and significant influence ( $p < 0.01$ ). In addition, IS presented a total variance explained of  $R^2 = 0.22$ , CT yielded a  $R^2 = 0.11$  and PP yielded a  $R^2 = 0.32$ ; all of these values were significant with a 95 percent of confidence.

Typically, three to four fit indices provide adequate evidence of model fit (Hair *et al.*, 2014). For the present study, model fit indices and the acceptable levels recommended by Schumacker and Lomax (2010) are shown in Table IV. It can be observed that GFI

	TMS	IS	CT	PP
TMS	<i>0.784</i>	0.224	0.070	0.061
IS	0.474	<i>0.855</i>	0.070	0.162
CT	0.266	0.265	<i>0.779</i>	0.225
PP	0.247	0.403	0.475	<i>0.864</i>

**Notes:** The values below the diagonal are significant correlation estimates among constructs at the 0.05 level, the italic numbers in the diagonal row are the AVE values for each construct, and the values above the diagonal are squared correlations

**Table III.**  
Correlation analysis



**Notes:** The dashed line indicates statistically non-significant relationships, while the continuous lines indicate statistical significance at  $*p < 0.1$ ,  $**p < 0.05$ ,  $***p < 0.01$ . Overall model fit:  $\chi^2/df = 1.008$ ,  $p\text{-value} = 0.459$

**Figure 3.**  
Final model

**Table IV.**  
Model fit and  
parameter indices

		Measures	Acceptable level	Value obtained
Model fit		$\chi^2$	$p > 0.05$ or $(\chi^2/df) < 3$	$\chi^2 = 98.790$ , $df = 98$ , $\chi^2/df = 1.008$ ( $p$ -value = 0.459)
		Goodness-of-fit-index (GFI)	Close to 0.90	GFI = 0.916
		Adjusted goodness-of-fit-index (AGFI)	Close to 0.90	AGFI = 0.884
		Root-mean-square-error of approximation (RMSEA)	(0.05 to 0.08)	RMSEA = 0.009
Incremental fit measures		Incremental fit index (IFI)		IFI = 0.996
Model comparison		Tucker-Lewis index (TLI)	Close to 0.90	TLI = 0.997
		Normed fit index (NFI)	Close to 0.90	NFI = 0.977
		Comparative fit index		CFI = 0.996
Model parsimony		Parsimony normed fit index	0 (no fit) to 1 (perfect fit)	(PNFI) = 0.798

(i.e. the amount of variance and covariance in  $S$  that is predicted by the reproduced matrix  $\Sigma$ ) yielded a value of 0.916 and AGFI = 0.884, which indicate a good model fit. In addition to this, the goodness of fit was confirmed by the other indices: NFI = 0.977, TLI = 0.997, CFI = 0.996, and IFI = 0.996. SEM estimates were generated using the ML estimation method.

As for the sample size in SEM, the CN of Hoelter was computed using AMOS software 17, obtaining a minimum sample size of 101 for  $\alpha = 0.01$ . That is, a sample size needed to provide a reasonable indication of whether a researcher's data fits their theoretical model (Schumacker and Lomax, 2010). Hence, since the sample was 130, the minimum is exceeded at  $\alpha = 0.01$ . This sample size is supported by different authors who have agreed that the minimum satisfactory sample size when conducting SEM is from 100 to 150 subjects (Ding *et al.*, 1995; Anderson and Gerbing, 1988). Moreover, Bentler and Chou (1987) suggested that a ratio as low as five subjects per variable would be sufficient for normal distributions.

**5. Discussion**

The main goal of this study was to observe whether the TMS, IS, and CT had a positive influence on an SS project in order to obtain benefits for PP in export manufacturing companies located in the Mexican border with the USA. The Mexican border actually concentrates most of these companies. In fact, 3001 establishments are located in this region, 909 of which are situated in the border state of Baja California, in northwestern Mexico, according to the Mexican INEGI (2015).

First, the results provide evidence to support the hypotheses  $H1$  and  $H2$  that  $TMS$  has a positive effect on both SS IS and CT; that is, involvement and commitment of top management, including proper selection of SS projects, in addition to providing an adequate level of education and training for team members, increase the chances of a correct SS IS and CT, with a positive impact on PP. This result contributes to the literature supporting the positive relationship between TMS and success in SS projects (Eckes, 2000; Pande *et al.*, 2000; Mendoza and Mendoza, 2005; Ricondo and Viles, 2005; Carnell, 2003). Giving management the power to initiate the project helps ensure that project selection is based on strategic importance and not on convenience (Plecko

*et al.*, 2009); this is consistent with the view of Montgomery and Woodall (2008), that the job of champions is to ensure that the right projects are being identified and worked on, that teams are making good progress, and that the resources required for successful project completion are in place. At this point, the selection and prioritization of improvement projects are critical, as is the need to follow a structured methodology (Ricondo and Viles, 2005). Regarding project selection, Tkáč and Lyócsa (2010) argued that a wealth of scientifically valid methodologies exists that could potentially be used to select SS projects; however, scientific publications on SS project evaluation and project selection are rare. In this context, there have been some proposals; for example, Yang and Hsieh (2009) suggested that the national quality award criteria (Taiwan) could be used to select an SS project. Snee (2010) emphasized on the importance of integrating financial analysis of a project with the project selection process.

It was noted in this study that the impact of TMS on IS suggests that after they have selected a project, top management should follow it up with regular reviews. This is consistent with the analysis of Bañuelas *et al.* (2005), and Choo *et al.* (2007). For instance, Snee and Hoerl (2003) indicated the importance of management involvement in performing many SS functions, such as selecting improvement specialists, identifying project selection, and facilitating SS implementation.

In addition, TMS has an effect on IS through alignment of the projects to the company's goals and business strategy, as suggested by Zu *et al.* (2009). This implies that leaders tend to be directive, goal-orientated, instrumental, and functional, and are constantly providing structure and encouraging productivity (Denison and Spreitzer, 1991).

This work also found that TMS has a positive effect on CT in a SS implementation in Mexican manufacturing companies. This is consistent with previous studies (Zu *et al.*, 2009; Lloréns-Montes and Molina, 2006). For example, Zu *et al.* (2008) found similar results in the USA, but these differ from what Laosirihongthong *et al.* (2013) found in a study in ASEAN countries, suggesting that cultural issues may be involved. A CT as determined by its human component is critical to successful SS implementation, and even in other quality initiatives. Organizational leaders must be aware that successful deployment of SS requires not only technical understanding, but also behavioral insight (Linderman *et al.*, 2003). In this sense, understanding human motivation is integral to obtaining "buy in" from the team for the application of SS programs (Frings and Grant, 2005). Here psychological insight as it relates to management involvement, teamwork, and leadership is essential for success with SS (Montgomery and Woodall, 2008). As Mullavey (2005) points out, in order to successfully implement SS programs, management must understand SS methodology. A way to increase the quality of results in training and education could be through involving top management in the process of training and understanding SS. If this approach is adopted, then, according to Johnson and Swisher (2003), continuing education and training of managers and participants is important.

Knowledge about variation, what causes it, and how to reduce it by identifying cause and effect relationships is at the heart of almost all SS thinking (Montgomery and Woodall, 2008). At first glance, it can be suggested that training and education as provided by the top management are related to the need to understand methods, tools, and techniques of SS as an element of a CT. This implies not only the importance of receiving SS training but also the need to verify that SS approach is understood. A way to confirm real understanding of the methodology is through demonstration of

experience in attesting the completion of SS projects, as required by SS certification (e.g. the American Society for Quality). In the present study, 63 percent of respondents have a SS certification, with the rest having SS training but no certification. However, certification is not guaranteed; for example, Moosa and Sajid (2010) observed that many training programs throughout the world that claim SS Black/GB certification do not develop sufficient skills for the investigation of causal relations in complex systems.

Top management must be totally committed to the rapid achievement of good results that demonstrate what the program can accomplish (Sandholm and Sorqvist, 2002). In this regard, Eckes (2000) urged managers to participate in projects themselves. TMS when present can foster team communication and involvement (Kumar *et al.*, 2007). Maintaining positive group dynamics may be the most important factor for generating employee motivation to participate in future improvement activities and for developing employee problem-solving capabilities (Farris *et al.*, 2009).

Second, with regard to the positive effect of IS on CT as well as on perceive PP; we found that the results of this study supported hypotheses *H4* and *H5*. Successful SS projects demand a correct project management skills and proper tracking and review of the SS project, oriented to the company's goals and business strategy as well (Rowlands, 2003; Szeto and Tsang, 2005; Kumar and Antony, 2008).

Although DMAIC is a general and very useful approach to managing change and improvement, some controls can be considered to ensure the correct direction of an SS project. In the present study, an approach to complement and enhance the DMAIC methodology has been suggested through an IS that includes adequate tracking and reviewing to ensure that the aims of the project are still consistent with the company's goals and strategy through appropriate project management skills. An approach that shows how goals can be used to drive strategy and linked directly to action was proposed by Pyzdek (2004). Further, the use of challenging goals in SS develops more cohesive groups with better communication, trust, and cooperation (Linderman *et al.*, 2003; Gutiérrez *et al.*, 2009). Similarly, Gray and Anantatmula (2009) found three important themes that define SS project management success: achieving the project's mission or charter, implementing sustainable solutions to identified problems, and controlling the implemented solutions to realized financial gains. In this context, Pzydek (2003) indicated that with the use of a strategy deployment plan in conjunction with quality function deployment, SS projects can be linked to dashboard metrics. Related to this, Linderman *et al.* (2006) described a project evaluation system that performs a pre and post project review of improvement projects to assess the appropriate use of the tools and methods to facilitate achievement of the project goals.

In this scenario, it was found that IS fosters the CT in a positive way. When the project is frequently reviewed, team communication is fostered together with team involvement and commitment. Project leadership has a key role. A supportive and participative leadership style provides the organization with the TMS necessary for quality improvement, such as committing personal participation to the quality program, and developing the cross-functional mechanisms, leadership skills, and team culture necessary for implementing the quality program, creating a climate of open communication about the implementation progress that will enable learning and further change, and investing in training to help employees increase their knowledge, skills and ability (Zu *et al.*, 2009). As a consequence, project reviews help to detect training need in order to understand the methodology correctly. In this context, Kwak

and Anbari (2006) argued that the curriculum of the belt program should reflect the organization's needs and requirements. It has to be customized to incorporate economic and managerial benefits. Training should also cover both qualitative and quantitative measures and metrics, leadership, and project management practices and skills. Pande *et al.* (2000) pointed out that a cross-functional team is necessary to implement SS programs, with the purpose of the team being to provide an ongoing involvement of management in the implementation process. Team and process tools are used to prepare the SS project leader with the required team building and leadership skills for implementation of the project. These tools also help the project leader to create a shared need for the project as well as establishing an extended project team (Szeto and Tsang, 2005). In this context, Bañuelas *et al.* (2005) highlighted that project selection and its link to business goals, training and teamwork, and project progress tracking and monitoring are key factors to consider.

Empirical findings of Kleine and Weißenberger (2013) suggest that personal as well as organizational characteristics are involved in determining the level of joint commitment among the members of a workforce.

Too often, we spend too much time on the technical side of problem solving, forgetting the personal side. To keep people interested, it is therefore essential to evaluate the effectiveness of the completed SS project. Most of the time, management use cost savings as a measurement of project effectiveness. However, the savings from the project cannot be the only criterion for effectiveness, since many projects may not have any financial benefit (customer satisfaction), or the savings potential of two different projects can be different (Ray *et al.*, 2013). Here top-level managers see change as an opportunity to strengthen the business by aligning operations with strategy (Szeto and Tsang, 2005).

Third, our findings support the hypothesis *H6* that the SS CT has a positive effect on perceived PP, similar to the results of Nair *et al.* (2011). That is, in order to obtain benefits from an SS project, the leadership of the SS team, along with involvement and commitment of the members, team communication and understanding of the methods, tools, and techniques of SS, may be considered as having a key role (Lee and Choi, 2006; Pande *et al.*, 2000; Zu *et al.*, 2009).

Chakravorty (2009b) described how successful implementation was dependent on champions and their ability to manage the teams. While technical skills were required of champions, their human skills were more important for this role. As suggested in the supply chain management literature, effective supply chain collaboration requires adaptation to a collaborative culture that entails external and internal trust, mutuality of benefits, information exchange, and openness and communication (Barratt, 2004). In order to understand the personality types of team members and to communicate more effectively, gain cooperation, and overcome resistance, Caulcutt (2004) suggests the use of a Myers-Briggs type indicator tool to assist BBs. This is consistent with the suggestion of Montgomery and Woodall (2008) that a psychological approach to management involvement, teamwork, and leadership is essential to success with SS. Incorporating theories from organizational behavior can help inform the practical consequences of implementing operations management practices. Linderman *et al.* (2006) proposed the application of behavioral theories with technical tools and methods in interesting ways, with the use of technical tools and motivational factors being managed jointly rather than in isolation. The contribution of the present study is in the same direction; SS CTs as positive enhancements may increase the chances of obtaining benefits in the performance of SS projects.

Finally, PP is expected in terms of reduced process variation, fewer defects, less scrap, reduced cycle time and rework rates, and more dependable processes, leading to reduction of COPQ, lower warranty and liability costs, higher efficiency and productivity, and increased return on assets and profitability, among other benefits (Handfield *et al.*, 1998; Bañuelas and Antony, 2002; Kaynak, 2003; Mahanti and Antony, 2006, 2009; Manotas and Rivera, 2007; Zu *et al.*, 2008). In the present study, it was found that TMS does not have a significant direct link with PP, but does have an indirect effect through IS and CT.

## 6. Conclusions, limitations, and future research

This study analyzed the CSFs of SS implementation in manufacturing firms in Mexico, and found that CSFs seem to group in three components. Moreover, it provides support for the hypothesis that TMS tends to have a positive effect on perceived PP through a positive effect on IS and CT. This effect on PP appears in the form of reduction in variation and cost and improvement in quality.

In this sense, TMS could drive a good SS project, beginning with the involvement and commitment of top management, which promotes proper project selection and provides the means for an adequate level of education and training of team members. Further, the results indicate that appropriate TMS could be conducive to the IS of SS, such that projects are focussed on the organization's goals and business strategy, and such that members have project management skills and a defined strategy for monitoring and controlling projects. When a proper IS is followed, a CT could be promoted. This is characterized by members knowing and fully understanding the methodology, techniques, and tools of SS, with appropriate leadership, and also by effective communication and team involvement. However, a study by Laosirihongthong *et al.* (2013) has suggested that TMS does not have a positive effect on people management in the automotive industry in Asia. This could be due to cultural and regional issues. It is very likely that cultural characteristics that support certain practices differ from those cultural characteristics that support other practices (Zu *et al.*, 2009). With regard to the present study, the majority of respondents work in manufacturing companies near the border between Mexico and the USA, mainly in American companies, and it was observed that the results are consistent with previous studies of companies in the USA (e.g. Zu *et al.*, 2008). Further analysis of the impact of SS on different industries and with regard to cultural and regional differences is recommended.

TMS is vital for SS, and a way to maintain and strengthen it is to encourage training of top management in SS, so that it can see directly the methodology, tools and techniques, complications, need for resources and need for additional training.

This study is limited in ways that could be addressed in future research. First, our sample of manufacturing firms is somewhat small and includes a variety across manufacturing types. A second limitation is concerned with the cross-sectional nature of the data. Although the paper presents some advantages, especially when measuring PP of SS operating in different contexts, it can cause some biases. Therefore, future works based on longitudinal data might complement this study by examining how CSFs can evolve and interact with different manufacturing companies. This agrees with works presented by Bortolotti *et al.* (2015) and Sánchez-Rodríguez and Martínez-Lorente (2011). In addition, future research that directly compares SS implementations might extend our understanding of its limits of applicability and particular sources of impact, in large firms as well as in SMEs. Furthermore, the study did not analyze a

unique performance metric, instead using general PP dimensions. Future work could study specific performance metrics, including specific manufacturing sectors and service sectors as well.

Understanding CSFs, obstacles, and experiences with SS provides opportunities for practitioners to better support their organizations. Therefore, information on the correct implementation of SS in Mexican manufacturing companies could be taken into account to future SS implementation. This could help these organizations increase their productivity and the competitiveness in the region. Additionally, results from this research could be extended to Latin America, since idiosyncrasies and ideologies may be highly similar to Mexico. However it would be important to confirm this assumption. Finally, it is imperative to highlight that the use of correct tools and techniques and the consideration of success factors may increase the chances of companies to obtain benefits from implementing SS.

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(The Appendix follows overleaf.)



Appendix

Construct	Item	Adapted from	Initial EFA factor loadings			
			TMS	IS	CT	PP
Top management support (TMS)	Our SS team had enough materials and supplies to get our work done (TMS1)	Flynn <i>et al.</i> (1995), Doolen <i>et al.</i> (2003), Chen and Paulraj (2004), Zu <i>et al.</i> (2008), Farris <i>et al.</i> (2009) and Feng and Zhao (2014)	0.932			
	Top management is supportive of our efforts to implement the SS project (TMS2)		0.877			
	Top management provides adequate technical training for Six Sigma team (TMS3)		0.839			
	The top management selects Six Sigma projects to be implemented (TMS4)		0.865			
	All major department heads within our plant accept their responsibility for SS projects (TMS5) <sup>a</sup>		0.193			
	SS team members have their roles and responsibilities specifically identified. (TMS6) <sup>a</sup>		0.146			
Implementation strategy (IS)	Top management track and review Six Sigma projects (IS1)	Doolen <i>et al.</i> (2003) and Zu <i>et al.</i> (2008)		0.896		
	Members and project leader of the SS team have training on project management skills (IS2)			0.903		
	SS projects are linked to strategic goals of the organization (IS3)			0.896		
	SS projects are related to the business strategies (IS4)			0.888		
	The goals and objectives this team must achieve to fulfill our purpose are clear (IS5) <sup>a</sup>			0.469		
SS Collaborative team (CT)	SS members frequently hold group meetings to communicate and discuss effectively (CT1)	Flynn <i>et al.</i> (1995, 1999), Cua <i>et al.</i> (2001), Doolen <i>et al.</i> (2003), Lee and Choi (2003) and Farris <i>et al.</i> (2009)			0.904	
	Supervisors encourage people who work for them to exchange opinions and ideas (CT2)				0.897	

**Table AI.**  
List of construct  
measurement items

(continued)

Construct	Item	Adapted from	Initial EFA factor loadings			
			TMS	IS	CT	PP
Project performance (PP)	Members of the team understand clearly the methodology, tools and techniques of SS (CT3)				0.893	
	Project management provides personal leadership for Six Sigma project (CT4)				0.801	
	There is a willingness to collaborate across organizational units within our organization (CT5)				0.812	
	Six Sigma teams are encouraged to try to solve their problems as much as possible (CT6) <sup>a</sup>				0.535	
	Most of our team members think this SS project event will serve an important purpose (CT7) <sup>a</sup>				0.509	
	Through Six Sigma project, the variability of key processes were reduced (PP1)	Denison and Spreitzer (1991) and Flynn <i>et al.</i> (1999)				0.877
	Through Six Sigma project, cost were reduced (PP2)					0.886
	Through Six Sigma project, quality was improved (PP3)					0.882
	Through Six Sigma project, customer satisfaction was increased (PP4) <sup>a</sup>					0.385
	Through Six Sigma project, employee esteem was increased (PP5) <sup>a</sup>					0.332

**Note:** <sup>a</sup>The items were dropped after testing the measurement model

**Table AI.**

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