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# Six Sigma in Mexican Manufacturing Companies

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***Abstract*—**This work is about Six Sigma (SS) implementation in Mexico by using an empirical study. Main goals are to analyze the degree of importance of the Critical Success Factors (CSFs) of SS and to examine if these factors are grouped in some way. A literature research and a survey were conducted to capture SS practitioner's viewpoint about CSFs in SS implementation and their impact on the performance within manufacturing companies located in Baja California, Mexico. Finally, a Principal Component Analysis showed that nine critical success factors could be grouped in three components, which are: management vision, implementation strategy, and collaborative team. In the other hand, SS's success is represented by cost reduction, variation reduction, experience and self-esteem of the workers, and quality improvement. Concluding remarks arising from the study are that CSFs are changing through time and paying attention to these nine factors can increase SS's success likelihood.

***Keywords*—**Six sigma, Critical Success Factors, Factor Analysis.

## I. Introduction

IN recent years, there has been a significant increase in the use and development of the Six Sigma (SS) methodology in manufacturing industry and also in service; this is observed in a continue increase of literature, which make difficult to follow it. 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 [1]. In a related way [2] defined SS as a disciplined, project-oriented, statistically based approach for reducing variability, removing defects, and eliminating waste from products, processes, and transactions.

Through SS, many companies have achieved billions of dollars in bottom-line benefits and improved customer relationships. However, not all organizations have experienced equal success [3]. Despite the immense popularity and the wide spread adoption of SS, there is a rising concern regarding the failures of Six Sigma programs [4]. According to David Fitzpatrick, the number of companies in this situation is fewer than 10% [5]. In a similar sense, [6] found that 144 from 181 SS projects implemented in a company were successful, this suggest a proportion of 20% of non-successful projects. Reference [7] found in their study that 67% of the respondents have experienced SS project failure at least once; they identified several reasons of failure, which include: failure to identify and manage project stakeholders and their expectations, inadequate project selection process, inability to align projects with critical organizational priorities and others. In a related way, [8] argued that less than 50% of the survey respondents from aerospace companies were satisfied with their SS programs. In this sense, to avoid failure it is important to know prior experiences. Reference [9] stated that learning from experience, is other Critical Success Factor. 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 [10]. 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 [11]. A common term in literature is Critical Success Factor and this factor is critical to the success of any organization, in the sense that, if objectives associated with the factors are not achieved, the organization will fail, perhaps catastrophically [12]. In the same way [13] defined CSFs in the context of SS project implementation, as the essential ingredients without which a project stands little chance of success.

Much research in recent years has focused on Critical Success Factors of Six Sigma, [5] reported a literature review, [14] conducted a study of CSFs in Britain, [15] in Australia, [16] in Slovenia, [17] conducted a survey in Singapore, [18] presented a literature review, [19] made a study in Sweden and many others. In this regard, in Mexico there is little information on this subject, for example a factor analysis study of [20] found five factors related to SS success, these were top management commitment, teamwork and cooperation, six sigma role structure, execution and reward, and mentoring. However, the available information on critical success factors of SS, including Latin America is not enough, thereon, it is important to know the status of SS implementation in this region and its relationship to the existing worldwide literature through answering the questions: What are practitioners doing in other countries for successful implementation of their SS projects? Are the individual CSFs reported in literature measuring as many independent factors, or do they measure a few underlying SS success dimensions?

Thus, the first objective of this research was to determine the critical success factors for SS implementations in manufacturing companies (including maquiladora industry), and the second objective, is to determine underlying factors that are being measured by the variables. In order to achieve this, the following specific objectives are presented:

- Identify the CSF most commonly reported in literature.
- Design a questionnaire with the main CSFs identified.
- Apply the questionnaire to SS's practitioners.
- Conduct an Exploratory Factor Analysis.

In this work the hypothesis that the critical success factors

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of SS more reported in recent years are grouped into components is tested. To achieve the above, a review of published articles about SS from 1995 to 2010 was made at first and with this information was generated a list of CFSs most broadly used recently. Later was made a survey and was applied to users of SS in Baja California, Mexico, in order to collect information about the experience they had had with the CFSs. Finally, using principal component analysis is determined how the factors are grouped into components. This research project is based on three phases that are explained in the following paragraphs.

## II. Methodology

### *A.Survey Construction*

In order to elaborate a survey, a literature review was conducted to determinate frequency of Critical Success Factors reported by SS practitioners. A structured methodology was followed to narrow down the search in different databases from around 2100 papers in English from 1995-2010 mentioning SS to only 117 mentioning CSFs.

A judge validation was obtained by an initial survey applied to 34 SS practitioners, after feedback, minor changes were made. The final survey includes four main sections, the first is about general and demographic data from practitioners, the second section was focused to identify the importance degree of CSFs, the third section included the degree of use of CSFs, and finally, the fourth section was focused to obtain information about degree of success of SS implementation. In this way, survey asked respondents to rate the importance of CSFs on a Likert scale, with 1 corresponding to not important at all and 5 as very important.

### *B.Survey Application and Data Collection*

Empirical data were collected between January and July 2012 via surveys over the Internet. A total of 1180 SS practitioners and companies were contacted through LinkedIn network and database of local companies from the economic development secretary. This survey considered 20 most reported CSFs in recent years, in addition, *reward and recognition* was added, in order to evaluate if this CSF influences six sigma success, this, on a regional culture basis.

### *C.Information Analysis*

Statistical analysis of the obtained data was performed using SPSS v 17®. The Cronbach Alpha Index (CAI) was calculated for statistical validation of the survey in order to determine if the resultant 21 items measure SS success.

Feasibility of a factorial analysis was determined by the correlation matrix, where most of the correlations were higher than 0.40; also, the anti-image correlations matrix were analyzed. A measure of sampling adequacy is calculated through the Kaiser–Meyer–Olkin (KMO) index, which compares the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficient. A KMO index higher than 0.8 is recommended to determine the factorability of the correlation matrix. In a similar sense, the Bartlett's test of sphericity is another important measure that depicts the strength of the relationship among variables. It is used to test the null hypothesis that the intercorrelation matrix comes from a population in which the variables are no collinear (i.e. an identity matrix). In addition, the communality was analyzed to determine how much of the variance of each CSF is measured by common factors.

A factorial analysis was carried out to determine the factors by principal component analysis method using the correlation matrix for the extraction of components. 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 for a better interpretation of critical factors. The CSFs that integrate the factors were identified by the highest value that the factorial charges contained, which is a correlation measure with the factorial axis.

## III. Results

### *A.Literature Review*

Top management involvement and commitment is the most mentioned CSF by authors in SS projects as showed in Table I, it appears in 62 of 117 articles. In contrast, data system, bottom line, and structured approach seems to be less reported.

TABLE I
MOST REPORTED CRITICAL SUCCESS FACTORS OF SIX SIGMA

| Critical success Factors | Total |
|---|---|
| Top management involvement | 62 |
| Project selection and Prioritization | 47 |
| Training and education | 38 |
| Costumer focused and involvement | 31 |
| Cultural change/change management | 31 |
| Organizational infrastructure | 24 |
| Linking SS to business strategies | 23 |
| Understanding methods and tools | 22 |
| Project management skills | 21 |
| Linking SS to the suppliers | 17 |
| Linking SS to human resources | 16 |
| Project leadership / leadership | 14 |
| Project tracking and reviewing | 11 |
| Team involvement | 9 |
| Goals based | 7 |
| Team communication | 6 |
| Right team | 5 |
| Data system | 3 |
| Bottom line | 3 |
| Structured approach | 2 |

### *B.Sample Analysis*

A total of 130 useful questionnaires were received, this constituted an overall response rate of 11.0 per cent. Fig. 1 illustrates the main industrial sectors of the respondents, it can be noticed that manufacturing companies of medical devices, have more SS practitioners.

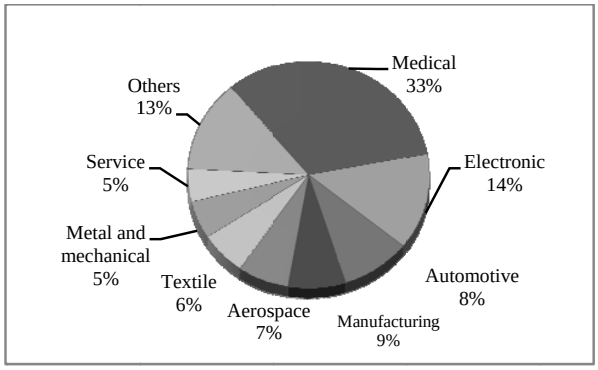


Fig. 1 Main industrial sector surveyed

Table II shows the descriptive analysis applied to the CSFs. In relation to Project Selection and Prioritisation, this CSF has the highest average regard importance in SS application. Unlike the literature, Top management involvement is not the more important CSF, but is between top five amongst SS practitioners. Regarding Understanding methods and tools of SS, and Training and education, both excel in the top three and could indicate a need to verify that the training is actually understood. In Addition, it can be noticed that CSFs related to SS´s team, that is, Team involvement, Team communication and Right team, have more importance than the total average.

*C.Statistical Survey Validation*

Regarding the validation of the scale of the questions associated with CSFs, yielded a Cronbach's alpha index CAI= 0.928, exceeding the 0.70 recommended by the literature. This suggests there is agreement among the 21 items generated to measure the CSFs importance to succeed in SS implementation.

Additionally, the instrument includes measurement of success as reported in the literature taking into account 5 elements (features) that are: variation reduction, quality improvement, experience and self-esteem, cost reduction and profit increasing, and customer satisfaction. Calculations of the reliability of this scale were done using SPSS 17®, resulting CAI=0.572 less than 0.70 which is commonly acceptable. This is could imply that not all users experienced the 5 characteristics, denoting high scores on some of them and low scores in others. However, if customer satisfaction were removed, Cronbach's alpha index would increase to 0.717, implying that only 4 items actually measure success by implementing SS. These are: variation reduction, quality improvement, experience and self-esteem, and costs reduction and increased profits. This is consistent with [14], who found that the majority of operational staff is not convinced with the soft factors of success such as customer satisfaction.

TABLE II
AVERAGE IMPORTANCE OF CRITICAL SUCCESS FACTORS

| Critical Success Factor | Average | Standard Deviation |
|---|---|---|
| Project selection and Prioritization | 4.63 | 0.612 |
| Understanding methods, tools and techniques | 4.54 | 0.586 |
| Training and education | 4.53 | 0.612 |
| Team involvement | 4.50 | 0.662 |
| Top management involvement | 4.45 | 0.683 |
| Team communication | 4.44 | 0.647 |
| Project leadership | 4.42 | 0.656 |
| Goals based | 4.39 | 0.665 |
| Project tracking and reviewing | 4.38 | 0.601 |
| Bottom line | 4.35 | 0.619 |
| Data system | 4.34 | 0.868 |
| Right team | 4.30 | 0.733 |
| Cultural change/change management | 4.28 | 0.715 |
| Project management skills | 4.27 | 0.745 |
| Organizational infrastructure | 4.24 | 0.745 |
| Costumer focused and involvement | 4.12 | 1.004 |
| Compensation | 3.78 | 1.014 |
| Linking SS to the suppliers | 3.67 | 1.130 |
| Linking SS to human resources | 3.62 | 0.942 |
| Linking SS to business strategies | 3.60 | 0.950 |
| Structured approach | 3.59 | 1.002 |

*D.Factor Analysis Feasibility*

To validate information, an exploratory factor analysis was conducted, the Bartlett test of sphericity yielded a value of 566.69 and a p-value of 0.000, i.e., intercorrelation matrix of analyzed data is significantly different from an identity matrix. Kaiser-Meyer-Olkin (KMO) throws us a value of 0.816, so it is observed that variables considered are measuring some common dimensions, and a factor analysis will prove helpful in reducing twenty-one variables into few of them based on common characteristics or features.

In exploratory factor analysis, only those factors or components with an eigenvalue greater than unity were considered, in this sense, only three components met that requirement. As showed in Table III, the explained variance by principal components is up to 73.29 in only three components.

TABLE III
TOTAL VARIANCE EXPLAINED BY PRINCIPAL COMPONENTS

| Component | Extraction Sums of Squared Loadings | | | Rotation Sums Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % variance | % accumulated | Total | % variance | % accumulated |
| 1 | 4.47 | 49.75 | 49.75 | 2.33 | 25.89 | 25.89 |
| 2 | 1.06 | 11.86 | 61.61 | 2.27 | 25.23 | 51.13 |
| 3 | 1.05 | 11.68 | 73.29 | 1.99 | 22.16 | 73.29 |

In turn, the communalities or the square sums of factor loadings of each variable were determined and the results are presented in Table IV. Low communalities are considered below 0.4, meanwhile over 0.6 are considered higher [21]. In

this sense, eight CSFs have a high communality, whereas that project tracking and reviewing has a regular communality. That is the amount of variance in each CSF that is measured or accounted for by the three components that were extracted.

TABLE IV
FACTORS COMMUNALITIES OBTAINED BY PRINCIPAL COMPONENTS

| | Initial | Extraction |
|---|---|---|
| Top management involvement | 1.000 | 0.774 |
| Project selection | 1.000 | 0.761 |
| Training and education | 1.000 | 0.750 |
| Project tracking and reviewing | 1.000 | 0.508 |
| Goals based | 1.000 | 0.742 |
| Project leadership | 1.000 | 0.715 |
| Team communication | 1.000 | 0.895 |
| Team involvement | 1.000 | 0.792 |
| Understanding methods, tools and techniques | 1.000 | 0.660 |

Rotated principal components using varimax with normalization are shown in Table V, where can be noticed that three components with the same number of variables are suggested.

TABLE V
ROTATED COMPONENT MATRIX VARIMAX NORMALIZATION

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Team Communication | 0.886 | | |
| Team Involvement | 0.833 | | |
| Understanding methods, tools and techniques | 0.676 | | |
| Project selection and prioritization | | 0.832 | |
| Training and education | | 0.783 | |
| Top management involvement | | 0.777 | |
| Goals based | | | 0.810 |
| Project leadership | | | 0.710 |
| Project tracking and reviewing | | | 0.693 |

*E.Components Review*

It is noted that the first component is related to SS team and its people. It consists of three dimensions: understanding methods, tools and techniques of SS, team involvement and commitment, and team communication, these components could be named collaborative team.

The second component is associated with management and its support in the initial phases of SS implementation. It consists of three dimensions: top management involvement, education and training, and SS project selection. Management vision represents this component

Concerning the third component, it is connected to an implementation strategy, consisting of three dimensions: goals based projects, project tracking and reviewing, and project leadership. Therefore, the component could be related to an implementation strategy.

Therefore, having made the factor analysis with principal component, results show that nine variables (CSFs) can be grouped into three components or scales. In addition, respect to the response variable success, this is best represented by four variables instead of five as initially proposed.

## IV.DISCUSSION

Six Sigma Project Selection and prioritization is frequently the most important and difficult part, stated [22]. Reference [6] cited project selection and prioritization as the most important CSF; in this work is the second more reported in literature. Reference [23] argued that exist a wealth of scientifically valid methodologies that could potentially be used to select SS projects; however, scientific publications of SS project evaluation and project selection are rare. In this sense, there have been some proposals, for example [24] suggested to use the national quality award criteria (Taiwan) to select a SS Project.

The second more important CSF in this study is to understand methods, tools and techniques of SS, whereas training and education is the third most important. Both, have a direct relationship between them, this could imply the importance of receiving SS training but also verify its understanding. A way to confirm real understanding of the methodology, is through the verification of savings in the implementation, and then could be suggested SS certification. However, this is not guaranteed, e.g., [25] observed that many training programs throughout the world which claim SS black/green belt certification are not capable enough to develop skills for the investigation of causal relations in complex systems through the use of these statistical techniques, resulting in qualified but incapable persons. In addition, [26] stated that the Six Sigma Black Belt (SSBB) certification is granted by many organizations including industry and academia, each of these organizations have independently developed their own unique body of knowledge (BOK) by which their SSBB certification is granted. This inconsistency in the fundamentals of what a Black Belt (BB) should know, regardless of where he or she attained certification and works, has eroded the credibility of the training, certification, and ultimately the profession.

Regard this, resources for training are critical for the Six Sigma role structure in developing the specialist´s expertise [27]. In this sense, it is necessary to identify and select either the type of training and education that staff will receive. Thereon, have been developed some studies, e.g., [28] reported areas of training or continuing education that are important to the manufacturing professional over the next ten years, these would be Lean manufacturing 77.8%, Six Sigma 56.3%, Quality Management 46.7% and Statistical Analysis 46.0% amongst others. Their data was collected from 261 engineers and technology professionals who had a technical component associated with their jobs.

A way to increase good results in training and education could be, involving top management in the process of training and understanding SS. According to this, [29] stated that continuing education and training of managers and participants is important.

Regarding team involvement end commitment, [30] found it was the seventh most reported factor in their research, reflecting its importance in literature; while in this work is the fourth more important. In connection with team involvement, an organizational culture could promote a group culture.

Reference [31] described that emphasizing flexibility and internal integration, the group culture values belonging, trust, and participation, and its strategies are oriented toward developing human relations through cohesiveness, openness, commitment, and attachment. In a related way, [32] stated that, by developing a group culture, organizations promote participation, trust, and a concern for human development as their core value. In this context, a supportive environment should be promoted in order to encourage participating in continuous improvement teams.

Top management involvement and commitment is the most mentioned CSF in literature, and there is evidence to consider important this factor while implementing SS. This is consistent with [33]-[35] and [30]. However in this study is the fifth CSF in importance.

## V. Conclusions

Understanding CSFs, obstacles and experiences about Six Sigma provides opportunities to practitioners for better support their organizations. This work analyzed the importance of CSFs in implementing this methodology in Baja California, Mexico, and was found that nine CSFs seem to be more important. In addition, they are grouped in three components. The component named Management Vision can drive a good SS project, it begins with the involvement and commitment of top management, which promotes proper selection of project and provides the means for an adequate level of education and training of team members.

Management vision as appropriate could be conducive to the implementation strategy of SS, meaning that projects are focused on the organization's strategic goals, which have a defined strategy for monitoring and control of projects, and an adequate leadership to push the project forward. When a proper implementation strategy is followed, a SS collaborative team could be promoted. This is characterized by members knowing and fully understanding the methodology, techniques and tools of SS, but also for effective communication and thus team involvement.

Top management involvement is vital for SS, a way to maintain and strengthen it, is to encourage top management training in SS, so it can see directly the methodology, tools and techniques, complications, need for resources and need for additional training. Thus the involvement and commitment of top management may continue to climb

It is imperative to highlight the use of correct tools and techniques plus a consideration of success factor may increase chances to obtain benefits implementing SS.

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