Evaluating Mental Workload for Improved Workplace Performance

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Companies are in constant search of greater productivity and better use of resources; however, they have neglected the human being. In this regard, it is important to analyze the presence of the psychosocial factors to which workers are exposed at all levels. These factors exert both a positive and a negative influence and indeed turn into a risk when they are not in balance with worker capabilities. This literature review aims to provide a comprehensive understanding of the psychosocial factors present in the manufacturing industries. The methodology consisted of conducting a search in two databases in addition to government pages. A combination of keywords was used for the search, and each publication was classified according to the factors analyzed, the type of evaluation, and the area of application. Out of all 2,468 publications found, eight were selected. Finally, work-related psychosocial factors were found to be the most analyzed.

Mental workload is a popular topic for ergonomics, psychology, and organizational behavior-related studies. Difficulties and differences in defining and measurement of mental workload engage the attention of scholars to the concept. Furthermore, the importance of mental workload on performance and burn out increases attention to the topic for empirical studies. In this chapter, the authors reveal the relations between mental workload, burnout, and job performance. Data were obtained from 144 academicians in Turkey. Results demonstrated that mental workload has a 1) positive impact on burn out and 2) negative impact on job performance of academicians. Moreover, it was found that burn out and job performance are negatively correlated. Finally, findings reported that there are differences among some demographic variables in accordance with mental workload, burn out, and job performance.

The changing nature of higher education systems and academic work all around the world generally and in Turkey specifically highlight the need for academics to use, analyze, and process so much information simultaneously, and deliver results at a specific period of time, which cause them mental workload. Thus, this chapter addresses the problem of understanding and exploring the dynamics of mental workload in Turkish academic setting. The main data for the analysis comes from a wide field research, including 505 questionnaires and 45 in-depth interviews with academics in various universities of Turkey. The mixed methods research revealed that growing publication pressures, administrative work, teaching and supervision hours, the unpredictability of academic positions, the curse of flexibility, and the bureaucratic nature of universities are some of the factors, leading to mental workload in Turkish academia. The other dynamics, such as academic incentive system, demanding nomination/promotion criteria, lack of family-work life balance, were also explored.

Section 3
Performance Evalutation

At present, the manufacturing industries require the implementation of more efficient and flexible fabrication processes to offer high-quality products. The changeover methodologies can be used to reduce the setup times, allowing the industries to be more competitive. The application of changeover methodologies is mainly influenced by the 4Ps model, which is composed of organizational and design factors, such as people, practices, product, and processes. However, this model is not useful in determining the relationship between each one of the Ps and the changeover activities. In this chapter, the authors have developed an exhaustive review of the references to establish the indicators to design an instrument composed of 79 items and divided into the five constructs of the 4P model, which was statistically validated using the Kendall W indicator and the Cronbach´s alpha indicator.

At the global level, the service industry represents a critical component for the economy and its growth trend is above of the other sectors. This sector alone is responsible for 63% of the gross domestic product and 45.5% of labor occupation worldwide. Despite its role in modern economies, the sector receives very little attention. In the literature, the authors have found the efforts that have been made to increase the efficiency and productivity of this type of organizations: adapting philosophies, tools, and/or techniques that were born to achieve this goal in the manufacturing industry, such as Lean manufacturing, total quality management, six sigma, lean six sigma, among others. The objective of this study is to perform an exhaustive literature review of the critical success factors reported in diverse studies of the implementation of these tools or philosophies in the service sector, as well as their differences, similarities, and results.

Currently, organizations seek to position themselves in the market as the most competitive and profitable in their branch, through the continuous improvement of their processes, products, and/or services, applying various techniques, tools, and methodologies. Particularly in this chapter, focus on Six Sigma (SS) will be shown, a strategy used in companies to achieve competitive objectives, continuously improving processes. In this sense, it is considered important to identify and know the main factors that are involved in its implementation. Likewise, the organizations are presenting a culture towards the sustainability and the environmental care, derived from this, the methodology used to develop a measurement instrument that allows to identify the CSF in the implementation of SS, the sustainable benefits that can be achieve with correct implementation, the procedure used for the validation of the content of the instrument, the validity of internal consistency and the obtained results.

Foreword

The book *Evaluating Mental Workload for Improved Workplace Performance*, edited by Doctors Arturo Realyvásquez-Vargas, Karina Cecilia Arredondo-Soto, Guadalupe Hernández-Escobedo and Jorge González-Reséndiz offers and important contribution to the field of mental workload, within the science of Ergonomics. The book contains 12 chapters provided by authors from six countries, and it is divided into three sections named Theoretical Contributions to Mental Workload, Mental Workload Evaluation, and Performance Evaluation.

Information provided in this book will help to understand the importance of mental workload level and its effects on employees in different productive or services sectors. Also, it will help promote ergonomic interventions in more countries and industrial sectors from a cognitive approach. In some countries, such as Mexico, mental workload represents a topic that is ignored by middle and top management in most of the companies in different labor sectors. Moreover, this topic is not included in most of the educational programs of undergraduate or graduate. Therefore, students and academicians unknow how to evaluate it and the effects it may cause on employees' health. In addition, there are relatively few people that research and publish about mental workload. This situation makes mental workload is unknown for the middle and top management of companies. This book can help fill that gap both in educational institutions and in companies from different sectors of work.

All chapters include topics that presently represent challenge in different industrial sectors for enterprises of all sizes that try to improve employees' health and optimize their organizational performance. The book contains theory, assessment methods and case studies that readers can apply in similar situations. People interested in Ergonomics will benefit from the content of this book, which deserves to be in libraries and bookstores that deal with the topic of Ergonomics, and more specifically with mental workload.

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Preface

INTRODUCTION

Mental workload is defined as the amount of effort involved in performing a particular task. Currently, employees of different labor sectors (agriculture, aviation, manufacturing, education, services, among others) are involved in different projects in the company for which they work. This fact leads to employees have to use, analyze, and process so much information at a same time, which cause them mental workload. Moreover, employees are pressed to deliver results at a specific period of time, which increase the mental workload. Therefore, there exists a need for an edited collection of original research in the area of mental workload, its causes and effects, methods to evaluate it, strategies to decrease it or control it, and different case studies in any labor sector from around the world.

The general objective of this book is to increase knowledge about mental workload, its causes, effects, methods of evaluation, case studies, and strategies to decrease it or delete it in any labor sector (agriculture, manufacturing, bank, supermarket, education, aviation, construction, etc.). Specific objectives include developing of new theories, applying specific methods to evaluate mental workload, or developing new ones. Another specific objective is promoting the adoption of strategies to decrease or delete mental workload.

The target audience of this book will be composed of professors, managers, employers, ergonomists, researchers and students working in the field of Ergonomics of any labor sector. More specifically, the target audience include ergonomists, manufacturing engineers, agricultural engineers, aviation engineers, industrial engineers, industrial designers, researchers, industry practitioners, research scientists, academics, and any employee that manages information at any level.

ORGANIZATION THE BOOK

This book is the result of the research and applications of different colleagues located in six different countries: Arab Emirates, Chile, India, Mexico, Turkey, and Ukraine. The Mental Workload plays a very important role in the productive processes and in the investigations of the different areas such as theoretical contributions, assessment methods, and performance evaluation.

Section 1: Theoretical Contributions to Mental Workload

Chapter 1 presents information about the methods that combine physical and mental workload/fatigue during ergonomic evaluation. The methods were identified through a systematic literature review. The search criteria were done through a literature search in databases like SciFinder, SciELO, ScienceDirect, etc. As result, the following methods described: Global Load Scale, Multivariate Workload Assessment, Subjective Fatigue Symptoms Test, Fatigue Assessment Scale, Scale of Recovery for Exhaustion of Occupational Fatigue, Scale of Estimated Fatigue-Energy Points, Swedish Occupational Fatigue Inventory, NASA-TLX, Combined Cognitive and Physical Assessment, Laboratory Method of Economics and Sociology of Work, OWL Method, Ergonomic Checklist Method, RENAULT Method, Joyce Method, NERPA Method, ARBAN Method, and MAPFRE Method. As a conclusion, it is possible to affirm that there are some evaluation methods that provide better elements for an accurate evaluation and others lack of basic elements, which causes an incomplete/not accurate evaluation.

Chapter 2 aims to provide a comprehensive understanding of the psychosocial factors present in the manufacturing industries. The methodology consisted of conducting a search in two databases in addition to government pages. A combination of keywords was used for the search, and each publication was classified according to the factors analyzed, the type of evaluation, and the area of application. Out of all 2468 publications found, eight were selected. Finally, work-related psychosocial factors were found to be the most analyzed.

Chapter 3 reveals the relations between mental workload, burnout and job performance. Data's were obtained from 144 academicians in Turkey. Results demonstrate that mental workload has a 1) positive impact on burn out and 2) negative impact on job performance of academicians. Moreover, it was found that burn out and job performance are negatively correlated. Finally, findings reported that there are differences among some of demographic variables accordance with mental workload, burn out and job performance.

Chapter 4 addresses the problem of understanding and exploring the dynamics of mental workload in Turkish academic setting. The main data for the analysis comes from a wide field research, including 505 questionnaires and 45 in-depth interviews with academics in various universities of Turkey. The mixed methods research revealed that growing publication pressures, administrative work, teaching and supervision hours, the unpredictability of academic positions, the curse of flexibility, and the bureaucratic nature of universities are some of the factors, leading to mental workload in Turkish academia. The other dynamics, such as academic incentive system, demanding nomination/promotion criteria, lack of family-work life balance were also explored.

Chapter 5 is spotting a correlation in the planning stage process-centered approach and its effect on employees workload design. The quality definition is the fitness for use or purpose at the most economical level. Literature suggests that many organizations have realized both savings and growth by implementing Total Quality Management as an evolution that contributed to the development of principles and practices, the tools, and techniques for continual improvement to partners as employees, customers, suppliers, and owners.

Section 2: Mental Workload Evaluation

Chapter 6 aims to know the mental workload level and its effects on middle and senior managers in manufacturing companies. The chapter aims to know the mental workload level related to gender, age range, civil status, number of children, years of experience, and worked hours per week. As method, the NASA-TLX method was implemented. This method measures mental workload based on six dimensions: mental demand, physical demand, temporal demand, effort, performance, and frustration level. Data was collected by applying an online questionnaire. Results indicated that some dimensions contributed to mental workload in the following decreasing order: mental demand, temporal demand, effort, performance, frustration level, and physical demand. Similarly, results from mental workload level varied from 55.73 to 64.10. Nevertheless, there was no clear relationship between the gender, age range, civil status, number of children, years of experience, worked hours per week, and mental workload level. Finally, employees manifested mental workload mainly due to stress, mental fatigue, and headache.

The International Labour Organization (ILO) considers mental workload one of the most important psychosocial risk factors associated with the characteristics of the task and is paramount in the metalworking industry. The objective of Chapter 7 was to analyze the levels of risk of the psychosocial factors that workers present, considering their physical, social and mental environment, to respond to the Mexican Official Norm NOM-035-STPS and the ILO guidelines. The methodology consisted of applying to 125 workers a questionnaire of 74 items with 10 factors. The answers were assigned a score of 0 to 4, to later determine the risk level of each factor. The results revealed that the factors with the highest risk are working hours (93%), workload (71%) and lack of control over work (34%). It is concluded that the higher risk factors affect the mental workload of workers in the metalworking industry and associated with the characteristics of the tasks they perform.

The main objective of Chapter 8 is to evaluate the techno stress perception in the Chilean higher education system professors, a system with a strong market orientation regarding the careers free choice and their professional orientation, which is mainly offered in face-to-face mode. In the techno-stress levels identification it is important to distinguish if these are such that they can affect the teaching performance. For this, techno-tensors and factors are used that determine the technology impact levels in the academics stress, in the components: skepticism, fatigue, anxiety and inefficacy. A quantitative approach methodology and non-random design is used, with a snowball sampling obtaining the 190 academics opinion from Chilean universities. Detecting in general low techno stress levels, being the fatigue slightly higher in comparison to the other three components.

In Chapter 9, the authors propose the application of Artificial Intelligence (namely Expert System and Neural Network) for estimating the mental workload of air traffic controllers while working at different control centers (sectors): Terminal Control Center, Approach Control Center, Area Control Center. At each air traffic control center, air traffic controllers will perform the following procedures: coordination between units, aircraft transit, climbing, and descending. So with the help of the Artificial Intelligence (AI) and its branches Expert System and Neural Network, it is possible to estimate the mental workload of dispatchers for a different number of aircraft, compare the workload intensity of the air traffic control sectors and optimize the workload between sectors and control centers. The differentiating factor of an AI system from a standard software system is the characteristic ability to learn, improve, and predict. Real dispatchers, students, graduate students and teachers of the National Aviation University took part in these researches.

Section 3: Performance Evaluation

In Chapter 10, the authors have developed an exhaustive review of the references to establish the indicators to design an instrument composed of 79 items and divided into the five constructs of the 4P model, which was statistically validated using the Kendall W indicator and the Cronbach´s alpha indicator.

The objective of Chapter 11 is to perform an exhaustive literature review of the critical success factors reported in diverse studies of the implementation of these tools or philosophies in the service sector, as well as their differences, similarities, and results.

Chapter 12 focusses on Six Sigma (SS) will be shown, a strategy used in companies to achieve competitive objectives, continuously improving processes. In this sense, it is considered important to identify and know the main factors that are involved in its implementation. Likewise, the organizations are presenting a culture towards the sustainability and the environmental care, derived from this, the methodology used to develop a measurement instrument that allows to identify the CSF in the implementation of SS, the sustainable benefits that can be achieve with correct implementation, the procedure used for the validation of the content of the instrument, the validity of internal consistency and the obtained results.

Acknowledgment

Sincerely, editors want to acknowledge to all participants, researchers, academicians and students who contribute with their chapter to achieve this book. The book includes 14 chapters that provides theory, methods and case studies of mental workload. Authors of book chapters are from six different countries (Arab Emirates, Chile, India, Mexico, Turkey, Ukraine) and from 15 institutions of affiliation.

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Chapter 12

Determination of the Critical Success Factors (CSF) in the Implementation of Six Sigma (SS) and Its Sustainable Benefits: Content Validity and Internal Consistency of the Measurement Instrument

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ABSTRACT

Currently, organizations seek to position themselves in the market as the most competitive and profitable in their branch, through the continuous improvement of their processes, products, and/or services, applying various techniques, tools, and methodologies. Particularly in this chapter, focus on Six Sigma (SS) will be shown, a strategy used in companies to achieve competitive objectives, continuously improving processes. In this sense, it is considered important to identify and know the main factors that are involved in its implementation. Likewise, the organizations are presenting a culture towards the sustainability and the environmental care, derived from this, the methodology used to develop a measurement instrument that allows to identify the CSF in the implementation of SS, the sustainable benefits that can be achieve with correct implementation, the procedure used for the validation of the content of the instrument, the validity of internal consistency and the obtained results.

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INTRODUCTION

As is already known, organizations are in search of competitiveness, continuous improvement, profitability and recently of sustainable development and the environmental care, for the achievement of these strategic objectives supported by various techniques, tools and methodologies that help them to lead the path of success. Of the diverse techniques that exist for the continuous improvement of the processes, products and services; this chapter will present an approach towards Six Sigma (SS), used mostly in organizations to achieve competitive objectives, continuously improving the processes developed within it, in this sense, for Tlapa, Limon, García-Alcaraz, Baez and Sánchez (2016) the adoption of SS has increased significantly in those organizations that seek to apply best practices to increase or maintain competitiveness.

Therefore, it is necessary to identify the main factors that are immersed in the deployment of SS, which support successful implementation, the literature reports them as Critical Success Factors, and are defined by O'Sullivan (2009) as variables once identified and managed by the organization, they lead to success and the goals planned, while Suarez Amaya and Díaz Barrios (2013) define them as all those actions, capacities, resources, advantages, knowledge and skills that constitute a competitive advantage, while for Amberg, Fischl, and Wiener (2005), they are a limited number of areas in which the results is satisfactory, ensure a successful competitive performance for the organization, those characteristics, conditions or variables that, when maintained a properly management can have a significant impact on the company success that competes in a particular industry and as a this factors that, if addressed significantly improve the project implementation.

It is important to indicate that, in relation to the CSF, the literature reports a great variety, because each case study reports what for them represented a factor of success in the deployment of SS. Initially, a total of 145 factors were located through the literature review, from which a detailed analysis was carried out to identify and select the main ones to integrate this research. In another sense, in the recent literature Cherrafi et al., (2016), Faulkner and Badurdeen, (2014) there is a tendency for organizations to give priority to projects that include an evaluation or improvement of the environmental impact on the processes or product development.

In terms of the various benefits that can be obtained by properly deploying the SS strategy, sustainability is one of these, so organizations that implement continuous improvement and Green principles simultaneously consider having a better performance (Chugani, Kumar, Garza -Reyes, Rocha-Lona and Upadhyay, 2017). In this sense Dües, Tan, and Lim (2013), mention that only a group of environmental experts and researchers have investigated until now the relationship between the aspects of continuous improvement practices and Green.

In relation to sustainable benefits, Alhuraish, Robledo, and Kobi (2017) mention that a competitive advantage is achieved when companies maintain practices consistent with sustainable development strategies and, as such, control waste and the implementation of practices that are environmental and socially responsible.

With respect to the link between SS and sustainable development, there is the impression that SS can indirectly influence sustainable development through the application of its tools to environmental management systems, Sagnak and Kazancoglu (2016) and Camia et al., (2009).

Taking into account the above, it is considered pertinent and necessary to generate a measurement instrument that allows to identify the CSFs considered by the organizations that have developed SS, as well as to prove the relationship between the development of SS and the sustainability positive results.

For this, first, a literature review was developed, taking into account mainly articles that presented results on the implementation of SS and those that mentioned sustainable results from its deployment.

Once the CSFs were identified, the constructs to be evaluated were defined, the variables were operationalized and with these elements the research instrument was constructed.

The instrument was subjected to content validations through expert judgment and validation of internal consistency. The results of these procedures are described in detail in later sections of this chapter.

BACKGROUND

Contextualization of Six Sigma (SS)

At the present time, companies seek to be recognized through the development of competitive strategies that position them closer to achieving the objectives, according to M. Juran cited by Gutierrez Pulido (2014) it is important consider the quality trilogy to achieve quality in products and processes, the Juran trilogy considers the interaction of three universal processes of quality management, which are plan, control and improve; this trilogy remains in force, as organizations continue to aim at things better, faster and at a cheaper cost. Seeking compliance with the aforementioned and in relation to quality improvement, SS is one of the main strategies for continuous improvement used in large organizations that pursue total quality control and the achievement of objectives and goals.

Kaouro Ishikawa cited by Gutierrez Pulido (2014), was a great precursor of quality in Japan, due to its contribution with innovative ideas for quality, for example the DEMING quality circle, cause-effect diagram, known as Ishikawa diagram. This philosophy of total quality control took importance in Japan and establishes that all areas are responsible for quality, led it by senior management and management in charge of large organizations, these leaders seek to take advantage of competitive strategies that allow them to reach all the metrics, it is here that SS has a place as a competitive strategy that comes to strongly support to achieve the organizational objectives.

To understand the importance and usefulness of SS, it has been considered convenient to expose its beginning, evolution and development. In addition, the description of the concepts and definitions will allow the reader to contextualize SS as a competitive strategy.

SS is a strategy of continuous business improvement that has different meanings for different groups within an organization. Considering the entire company, it is a strategic initiative that seeks to achieve a significant improvement in business growth, capacity and customer satisfaction, Gutiérrez Pulido (2014). SS implies a change in the way of operating and making decisions, the strategy must be understood and supported from the highest levels of the organization, starting with the top leader.

Regarding the beginning of SS, Vinod, Devadasan, Sunil, and Thilak (2015) mention that SS emerged in Motorola in the mid-1980s, at that time it was possible to facilitate that companies achieve the desired profitability. Through this, SS was implemented in many parts of the world, the companies that carried out their implementation, they did it through the application of phases, known as DMAIC (Define, Measure, Analyze, Improve and Control), some companies that obtained significant financial benefits are General Electric, Motorola and Allied Signal (now Honeywell), (Swink & Jacobs, 2012).

SS has been defined by numerous authors in different ways, with the main objective of supporting companies towards competitiveness and profitability, achieving continuous improvement in their pro-

cesses, products or services, in general terms and with the objective of knowing the different approaches to SS, some concepts identified in the literature will be retaken.

For Arturo Garza-Reyes, Flint, Kumar, Antony, and Soriano-Meier (2014) SS is considered one of the most important developments for quality management and process improvement of the last two decades, they mention that SS focuses on the critical quality characteristics of the product or process that are relevant to customers and that mainly seeks to identify and eliminate defects, errors or failures that may affect business processes or systems, in this sense, Arturo Garza-Reyes et al, Sagnak and Kazancoglu (2016), Acharya and Mathur (2016), Linderman, Schroeder, Zaheer, and Choo (2003) and Al-agha and Al-agha (2015) state that SS has three meanings, first, that it is a statistical measure of variation that when it is achieved, a process would produce 3.4 defects per million opportunities, second, which is a philosophy and management strategy that allows organizations to obtain lower costs, guaranteeing competitive operations and third that is a problem solving and improvement methodology that can be applied to all types of processes to eliminate the root cause of defects

For Furukawa, Cunha, Pedreira, & Marck, (2016), SS identifies the ability of the process to generate products within pre-established specifications, while Aslan (2005) mentions that defects in a process can be prevented if the variations are controlled and as SS focuses on the variations that cause defects in a process has been widely accepted, it also states that the SS methodology requires structured preparations and training courses.

SS is also defined as a business strategy that focuses on improving the understanding of customer requirements, commercial systems, productivity and financial performance (Mehrabi, 2012), meanwhile, Thakore, Dave, Parsana, and Solanki (2014) extend this definition, considering it as a quality initiative that reduces variations in a process and helps reduce the cost of the product and process, mentioning that the key strategy for the successful implementation of SS is that the industry that applies it must follow a correct methodology and the use of tools and techniques is done in such a way that it gives an effective solution to the respective problem.

Linderman, Schroeder and Choo (2006) mention that the SS approach to process improvement employs many objectives and that it provides an ideal context to study the relationship between objective theory and quality management, while Tjahjono et al., (2010) propose four interpretations that define SS, the first of them defines it as a set of statistical tools, the second as an operational management philosophy, the third as a business culture and finally as an analysis methodology that uses scientific methods.

Finally, Hoerl and Snee (2003) mention that the future of SS is brilliant. It is about improving and there will always be a need for improvement since we live in a dynamic and ever changing world with new customers' needs, new markets, innovation and social changes.

Relationship of SS With Sustainable Development

Recently it has been reported that organizations are presenting a trend towards sustainability and care for the environment, since environmental concern has become a concern for all, De Freitas, Costa, and Ferraz (2017). Sustainability has become a crucial element around the world, allowing the generation of profits and citizens live in a healthy environment at the same time.

Research has reported that if SS is properly implemented, it can generate sustainable benefits, although initially it has not been one of the objectives, so it is considered important to investigate existing theories and case studies that identify the way to relate a strategy of continuous improvement with sustainable benefits and environmental care.

For Zhang and Iru (2012), sustainable manufacturing is the creation of manufactured products through economically viable processes that minimize negative environmental impacts, conserving energy and natural resources simultaneously, improving the employee's safety, the community and products.

De Freitas, Costa, and Ferraz (2017) mention that sustainability has become, in recent decades, a very relevant issue for organizations, mainly due to the pressures generated by the interested parties and the change of thinking experienced by the society.

In relation to the sustainable benefits that can be obtained through the implementation of SS Vinodh, Arvind, and Somanaathan (2011) conducted a literature review in order to know the proven case studies that report environmental benefits and found that several companies they have successfully implemented continuous improvement principles (within which SS is found) to achieve sustainable benefits. With a correct implementation of SS, it is possible to produce fewer defects, therefore, less waste, improving the durability and reliability of the product; therefore, it increases the useful product life generating less negative impact on the environment.

Cherrafi et al., (2016), mention that, the possible integration of SS and sustainability has received increasing attention and that many academics and professionals have contributed to the research and development of this field, Fliedner (2008) mentions that many organizations have discovered that a byproduct of lean principles is an improved "green" or environmental performance, even when lean activities were not initiated for environmental reasons, it notes some examples of environmental benefits observed through the deployment of SS:

- Fewer defects that reduce the energy and resources needs; avoiding waste.
- It concentrates attention on reducing the conditions that cause accidents, spills and malfunctions, thus reducing solid and dangerous waste.
- Improving the product durability and reliability can increase the product useful life, reducing environmental impacts.

In the literature review has been observed the impact of SS on the care of the environment, Chugani et al (2017), Chiarini (2014), De Freitas and Costa (2017), Sagnak and Kazancoglu (2015) have positively linked the SS impact on energy issues, global warming, pollution and resources use, in addition, conducted research determine if the tools of continuous improvement reduce environmental impacts, obtaining positive results and recommending further research and increase sustainable processes within the organizations, so it is observed that when deploying SS projects, favorable results are obtained in sustainable terms and that, the relation to SS applications, the obtained contributions and benefits in the sustainable theme can achieve positive results on innovation and organizational sustainability.

Through the relationship identified between SS and the sustainable benefits and with the objective of deepening more in this research, in the elaboration of the measurement instrument it is considered a section to verify the existing relationship between SS and the sustainable benefits in the organizations that develop SS.

Identification of Critical Success Factors (CSF)

To carry out the search, the procedure suggested by Colicchia & Strozzi (2012) and Tranfield, Denyer, & Smart (2003) was taken into consideration. The main databases considered for the search and selection of the articles were EBSCO, ELSEVIER, EMERALD, SPRINGER and TAYLOR & FRANCIS, taking

into account a period from 2013 to 2017, mainly, the keywords used were Six Sigma, Administrative strategy, Applications, Implementation areas, Critical success factors.

Through the various applications of SS, numerous critical factors for success have been identified; the literature suggests that these factors be taken into account in the continuous improvement projects developed in the organizations.

In that sense, the CSF that have been considered most relevant according to Júnior and Lima (2011) are the lack of alignment of the SS project with the objectives of the company, the quality of the projects did not meet the expectations of senior management, low participation of leaders and development of projects at inadequate times for the company, for Alhuraish, Robledo, and Kobi, (2017) CSF include communication, culture change and the commitment of top management, however, diverse authors, consider numerous critical factors for the development of SS projects in organizations, of which a generalized consensus has not been identified.

In the first stage of the research project, the objective was to search and select studies that explore the critical success factors in the development of SS projects in different organizations, where 145 factors were initially identified, of which the most relevant were selected for achieve the success of the implementation of SS.

In this sense, the literature has allowed to identify numerous factors that have been considered for the success of the implementation of SS, Table 1 shows 145 factors that were identified in the review, grouped into seven large groups named constructs, Senior Management Support, Strategy Implementation, Collaborative Team, Customer Relationship, Supplier Relationship, Education and Training, and that are considered critical success factors. It is important to mention that as a main contribution to the research, an additional construct was added to evaluate the sustainable benefits that can be obtained with a correct implementation of SS, which will be described later.

Finally, through the review and selection, the CSF considered in this research are *Senior Management Support, Strategy Implementation, Collaborative Team, Customer Relationship, Supplier Relationship, Education and Training*.

To design the measuring instrument (questionnaire), the grouping presented in the table was considered, as well as instruments used in various investigations; in the following section each construct and instrument integration are described in general, and will be measured through the observable variables (questions that conform the instrument). In this part of the investigation it is not appropriate to indicate specifically the questions that conform the instrument, since the investigation is still in final validation, however it is planned to make another writing where the final conclusion is given to the reader of research, as well as recommendations for future studies. In this sense, a way to guide those interested in the construction of the questionnaire, column "Similar Factors" (Table 1) and diverse researchers opinions were considered.

Table 1 was constructed based on an overview of the CSF considered in the literature and in various applications, giving a total of 145 factors, in the first investigation, later were grouped according to characteristics or because they had the same meaning but that the authors named them differently in their investigations, and those finally considered for the proposal instrument of this research.

Table 1. Group of the initial list of critical success factors

Group	Similar factors	Quantity
Senior Management Support	1. Executive commitment 2. Executive leadership and senior management commitment 3. Project selection and prioritization 4. Organizational infrastructure 5. Senior management involvement 6. Senior management support 7. Monitoring and evaluation of the project 8. Involvement and commitment of management 9. Commitment and participation of senior management 10. Leadership and commitment of senior management 11. Involvement and commitment of senior management 12. Project selection 13. Middle management commitment 14. Strong leadership and administrative commitment 15. Leadership 16. Administration support 17. Encouragement of employees 18. Evaluation 19. Leadership and support 20. Motivation 21. Leadership Participation 22. Vision and support of leaders 23. Leadership, team and focus 24. Leadership skills 25. Management commitment 26. Participation and commitment of management 27. Quality of projects do not meet the expectations of senior management 28. Recognitions or incentives of the company 29. Lack of logistics support 30. Lack of consideration of the human factor 31. Selection and start of projects 32. Project monitoring and measurements 33. Lack of communication between managers and workers 34. Lack of cooperation and trust between workers and managers 35. Project leadership 36. Responsibility	**36**

continues on following page

MEASUREMENT INSTRUMENT DESIGN

In relation to the importance of the implementation of SS and the varied results that have been reported in the literature, it is considered necessary to gather information that allows to establish the factors through which the possibilities of achieving success in the implementation can be increased, for this, a measurement instrument based on research and literature review was designed, which by means of reagents (items or questions), associated with each construct (section) measure those factors that those who implement SS consider most important to achieve success in the implementation, the instrument also includes a section with items related to the sustainable benefits obtained by the deployment of SS projects.

Table 1. Continued

Group	Similar factors	Quantity
Strategy Implementation	1. Adopting the philosophy 2. Zero defects mentality 3. Linking SS to the business strategy 4. Integration of SS with financial responsibility 5. Understanding the methodology 6. Understanding methods and tools 7. Understanding techniques and tools within SS 8. Structure of the SS role 9. Structured procedure in SS 10. SS focused on metrics 11. Establishment of the SS framework 12. Use of Six Sigma tools 13. Alignment of SS projects to business objectives 14. Integrating six sigma with the financial infrastructure 15. Bad selection of SS tools 16. Little knowledge of SS tools 17. SS techniques and practices 18. Lack of recognition of the need for SS projects 19. Lack of experience in SS projects 20. Development in DMAIC 21. Lack of recognition of the benefits of SS 22. Lack of a route model to guide implementation 23. Replicate the SS strategies of another organization 24. Lack of a development measurement system 25. Measurement 26. Process documentation 27. Regular audits 28. Process administration	**28**

continues on following page

Variables Operationalization

Senior Management Support

The participation and commitment of top management is one of the most important factors in the implementation of SS, since without the commitment and support the true importance of the initiative could be weakened, management must participate in the establishment, criteria and administration system, as well as participating in the projects, this should begin with the selection and prioritization of projects of SS, Tlapa, Limon, García-Alcaraz, Baez and Sánchez, (2016); Zu, Robbins and Fredendall, (2010); Ho, Chang and Wang, (2008); G. Dileep and S.S. Rau, (2009); Banuelas Coronado and Antony (2002).

Strategy Implementation

The implementation of the strategy for SS implies that the projects focus on the objectives of the organization and the commercial strategy and that the members have project management skills and a defined strategy to supervise and control projects.

The implementation of the strategy refers to the project execution, the project administration and monitoring of the results, Goldstein, (2001); Zu, Robbins and Fredendall, (2010); Flynn et al., (1995); Breyfogle et al. (2001); Ho, Chang and Wang, (2008); G. Dileep and S.S. Rau, (2009).

Table 1. Continued

Group	Similar factors	Quantity
Collaborative Team	1. Organizational Structures / Infrastructures 2. Team building 3. Team communication 4. Team involvement 5. Effective communication 6. Culture and organizational infrastructure 7. Based on the team 8. Participation of all staff 9. Clear definitions and understanding of the roles of all team members 10. Cooperation and communication 11. Adequate development of the human resources management system 12. Teamwork 13. Multifunctional work team 14. Lack of adequate development of the human resources management system / Lack of qualified personnel 15. Lack of multifunctional teamwork 16. Incompetence within the organizational structure 17. Selection of team members 18. Organizational understanding of work processes 19. Organizational flow adjustment 20. Capacity of key members 21. Lack of team autonomy 22. Few organizational capabilities 23. Clear roles in the project structure 24. Knowledge of the organizational structure 25. Full time dedication of black belts 26. Clear allocation of green belts 27. Attitude 28. Lack of commitment and employee participation 29. Green belts y black belts behavior characteristics 30. Worker resistance 31. Lack of perseverance 32. Lack of communication 33. Constant review of interest groups 34. Lack of employee empowerment 35. Interfunctional conflicts 36. Linking SS to human resources	**36**
Customer Relationship	1. Close relationships with customers 2. Customer focus 3. Participation and customer service 4. Relationship with the client 5. Business strategy based on customer demands 6. Adequate implementation of the client management system 7. Linking customer quality initiatives 8. Lack of proper implementation of the customer management system 9. Demand 10. Lack of relationship of the project objective with the main goals of the company and customer demand 11. Lack of understanding for different types of customers 12. Lack of communication with customers 13. Linking SS to the client	**13**

continues on following page

Table 1. Continued

Group	Similar factors	Quantity
Supplier Relationship	1. Close relationships with suppliers 2. Relationship with the supplier 3. Adequate development of the supplier management system 4. Linking quality initiatives to the supplier 5. Personal Quality of suppliers / Personnel Administration 6. Weak relationship with suppliers 7. Lack of communication with suppliers 8. Lack of influence on suppliers or lack of involvement of suppliers with the current implementation 9. Lack of supplier collaboration 10. Linking SS to providers 11. Lack of adequate development of the supplier management system 12. Lack of cooperation with suppliers	**12**
Education and Training	1. Training 2. Education and training 3. Knowledge transfer 4. Knowledge management 5. Parallel training / learning structure 6. Staff development 7. Development culture 8. Investment and training framework for trainers and mentors 9. Coordination with a knowledge management system 10. Understanding to start the project 11. Training 12. Lack of training and education 13. Bad selection of candidates for belt training 14. Training for master black belts and black belts 15. Mass training for yellow belts or White belts 16. Training for directors and employees 17. Lack of consultants and training in the market 18. Lack of formal training of managers 19. Lack of formal employee training 20. Six Sigma Training	**20**
	Total de factores =	**145**

Source: By the author

Collaborative Team

Teamwork is a fundamental element within SS. The collaborative team is characterized by members who know and fully understand the methodology, techniques and tools of SS, in addition, has the appropriate leadership, effective communication and team participation, the value of teamwork formed by teams multifunctional will create a sense of ownership, better communication, teamwork value and a general vision of the organization, Zu, Robbins and Fredendall, (2010); Banuelas Coronado and Antony, (2002); Aviation Week, (1998); Hurley and Hult, (1998).

Customers Relationship

The needs and expectations of the client are evaluated, customers are involved in quality improvement projects, customer satisfaction is measured and there is close contact with key customers. The processes must be established to monitor levels of customer satisfaction, receive customer feedback and resolve their concerns, Zu et al., (2010); Ho et al., (2008); G. Dileep and S.S. Rau, (2009); Zu et al., (2006), Banuelas Coronado and Antony, (2002).

Suppliers Relationship

A well-developed supplier management system, where the main criteria for selecting suppliers are based on quality aspects, has a positive impact on the success of the SS since the processes must be built to monitor the quality performance levels of the suppliers . The participation of suppliers in SS helps to provide a high quality of products and services to end customers, Zu et al., (2010); G. Dileep and S.S. Rau, (2009); Banuelas Coronado and Antony, (2002); Zu et al., (2006).

Education and Training

Training is the first essential step in preparing the implementation of the SS methodology, which allows establishing new goals, asking employees to face the change thinking and acting differently, performing new tasks and participating in new ones, the training is a crucial factor in the successful implementation of SS projects, Tlapa et al., (2016); Ho, Chang, and Wang, (2008), G. Dileep and S.S. Rau, (2009), Banuelas Coronado and Antony, (2002); Szeto and Tsang, (2005); Henderson and Evans, (2000).

Sustainability

Sustainability is part of the benefits that can be obtained through a correct implementation of the SS strategy, since the deployment of SS allows focusing on the reduction of defects to improve product quality, which helps reduce environmental waste (it means, the material, the consumption of water and energy and the generation of waste), while sustainable manufacturing is the creation of manufactured products through economically viable processes that minimize negative environmental impacts, conserving energy and resources simultaneously enhance the safety of employees, the community and products.

Content of the Measuring Instrument

The measuring instrument was composed of 39 items (reactive) in total, distributed in 7 sections (constructs) that supported the identification of the main CSF in the implementation of SS and its relationship with sustainability, in this sense, the table 2 shows the constructs that make up the instrument, as well as the items corresponding to each section, the first six constructs were defined with the objective of identifying the CSF, the construct *management support* consists of 7 items, *collaborative team* for 7 items, *relationship with clients* for 3 items, *relationship with suppliers* for 5 items, *education and training* for 3 items, *implementation of the strategy* for 8 items and finally the construct which measures the relationship of SS with Sustainability, *Sustainable benefits* was integrated by 6 items, giving the total of 39 in the whole instrument.

The questions that make up each construct were proposed taking as reference the 145 CSF shown in table 1, obtained from previously validated measuring instruments and applied in investigations similar to this one.

Table 2. Content of the measuring instrument

Construct	Items	Total per construct
Support to senior management:	1,2,3,4,5,6,7	7
Collaborative team	16,17,18,19, 20,21, 22	7
Relationship with customers	23,24,25	3
Relationship with suppliers	26,27,28,29,30	5
Education and training	31,32,33	3
Strategy implementation	8,9,10,11,12,13,14,15	8
Sustainable benefits	34,35,36,37,38,39	6
Total in the instrument		**39**

Source: By the author

STATISTICAL VALIDATION OF THE MEASUREMENT INSTRUMENT

Validation of the measurement instrument was carried out through content validation (Expert judgment) and internal consistency validation (Pilot sample, n = 30).

Content Validity

To carry out the content validity of the first version of the instrument, the evaluation was requested through expert judgment, for Escobar-Pérez & Cuervo-Martínez (2008) the expert judgment is an informed opinion of people who have experience in the subject, that are recognized as experts and that can give information, evidence, judgments and assessments, is this sense Corral (2009) mentions that through the expert judgment can be known the probability of probable error in the configuration of the instrument and that is intended have reasonably good estimates. Corral (2009) indicates that expert's judgments can be obtained by group methods or by a single expert and there are also different types of methods, such as the individual aggregate method, Delphi, nominal group technique and the consensus group method.

Validity of Internal Consistency

For Corral (2009), the validation of an instrument consists of quantifying the extent to which the items or reagents of an instrument are representative of the universe or trait that is to be measured, in this sense Escobar-Pérez & Cuervo-Martínez (2008) mention that the validity content is an important component in estimating validity because it provides evidence about construct validity and provides a basis for constructing parallel forms of a test in large-scale evaluation.

To evaluate the reliability in instruments with polycotomic responses, with likert scales, it is common to use the Cronbach's alpha coefficient, which can take values ranging from 0 to 1, where 0 means zero reliability and 1 means total reliability, which represents that the greater the linear correlation between the items, the higher the Cronbach's alpha, in this sense Corral (2009) refers to Sierra Bravo (2001); Orozco, Labrador and Palencia (2002) who mention that levels above 0.70 indicate a very strong and high reliability coefficient, likewise, Gómez, Toledo, Prado and Morales (2015) cite Lévy and Varela

(2003); Hair et al (2010), since they suggest a recommended minimum value of *0.75*, Gliem & Gliem (2003) refer to George and Mallery (2003), which indicates that a correlation coefficient greater than 0.90 is excellent for the validation of the instrument.

RESULTS

The results obtained are presented in the following sections, starting with the demographic description to whom the instrument will be applied (target population), followed by the results of the statistical validation of reliability of the instrument, made through the statistical analysis recommended by the literature.

TARGET POPULATION

The target population for the application of the measurement instrument will be the managers, supervisors, engineers of various areas and people who have experience and have participated in continuous improvement projects where they have applied SS belonging to the aerospace industry, in figure 1 it is observed the distribution of the companies shows that the highest concentration is in Tijuana and Mexicali, so it is expected that the answers tend to concentrate on both.

Table 3 shows the percentages of companies in the aerospace industry in Baja California, the cities with the greatest presence, mentioned previously.

Figure 1. Aerospace industry in Baja California
Source: By the author

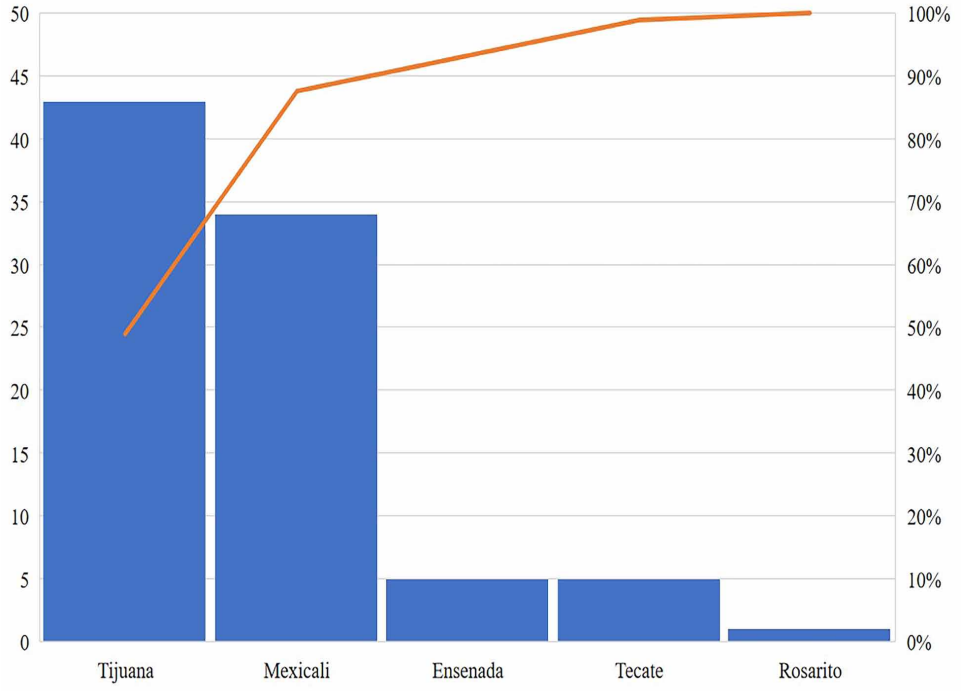

Table 3. Percentage distribution of the aerospace industry in Baja California

City	Tijuana	Mexicali	Ensenada	Tecate	Rosarito
Percentage distribution	48.86%	38.63%	5.68%	5.68%	1.13%

Source: By the author

RECOMMENDED STATISTICAL ANALYSIS

W of Kendall

To evaluate the reliability of the measurement instrument, 5 experts were asked to issue their opinion from two main characteristics that would allow us to improve the first version of the instrument, that is, the experts rated each of the items in relation to their clarity and relevance, in relation to *clarity*, a scale of 1 to 4 was used, where 1 is *the item is not clear* and 4 *the item is clear and adequate*, this part allowed to improve the writing of the items and identify if there were repeated items or that were being measured through others, as well as the elimination or modification of them, in relation to the *relevance* the scale used from 1 to 4 indicated the following, 1 *the item can be eliminated without affecting the dimension* and 4 *the item is very relevant and should be included,* in this sense it was possible to evaluate the agreement or the degree of agreement between the experts, through the evaluation of the coefficient of concordance W of Kendall, Escobar-Pérez & Cuervo-Martínez (2008) define it as a coefficient that is used to know the degree of association between the set of ranges *k* is particularly useful when the experts are asked to evaluate the items through ranges, for example from 1 to 4, as in our case. The minimum value that the coefficient can take is 0 and the maximum value is 1, which means that if the coefficient is 1 it indicates perfect agreement between the evaluators, if it is 0 it indicates that the agreement is not greater than expected by chance (there is no agreement between the evaluators).

In order to estimate the W of Kendall coefficient, the following research hypotheses were proposed:

Ho: There is no agreement between the evaluators.
Ha: There is significant agreement between the evaluators.

Based on this, the estimation was carried out, through the software SPSS 22, obtaining a **coefficient of agreement of *0.405***, although it is true that it is not an index that indicates a perfect agreement between the evaluators, however, the software showed **a level of significance of *0.000***, less than 0.05 defined in the hypothesis test, table 4.

Table 4. Coefficient of agreement

N	5
Kendall's W[a]	**.405**
Chi-Square	89.198
df	44
Asymp. Sig.	**.000**

Source: By the author

Considering Escobar-Pérez & Cuervo-Martínez (2008), it is concluded that there is significant agreement between the ranks assigned by the judges, so the measurement instrument passes the reliability assessment through expert judgment and is accepted the validity of content. Figure 2 shows the behavior of the answers given in the evaluations carried out by the evaluators, where it states the agreement in the answers assigned to each item in relation to the relevance indicated by each evaluator. As can be seen in the figure, the lines present a reasonable parallelism in almost all the items with the exception of the item 19; this is an indication that the evaluators have a concordance in the evaluated attributes for each item.

Cronbach's Alpha

To validate the instrument, we considered a sample of 30 individuals who have participated in SS projects, with experience and knowledge of the methodology, with the results obtained, the statistical validation of the instrument was made through the SPSS 22 software, the alpha of Cronbach was calculated for each of the constructs that make up the instrument, obtaining the results shown in table 5:

Finally, the Cronbach's alpha obtained for the complete instrument was ***0.959***, in the coefficients obtained it can be seen that the relationship with clients and education and training constructions have obtained the lowest rates within the whole instrument, *0.708* and *0.798* respectively, however, George and Mallery (2003) mention that indexes higher than 0.70 are acceptable within the validation of the instrument, so that with the reliability indices obtained, the internal consistency of the instrument is validated.

Figure 2. Comparison of responses between evaluators, content validity
Source: By the author

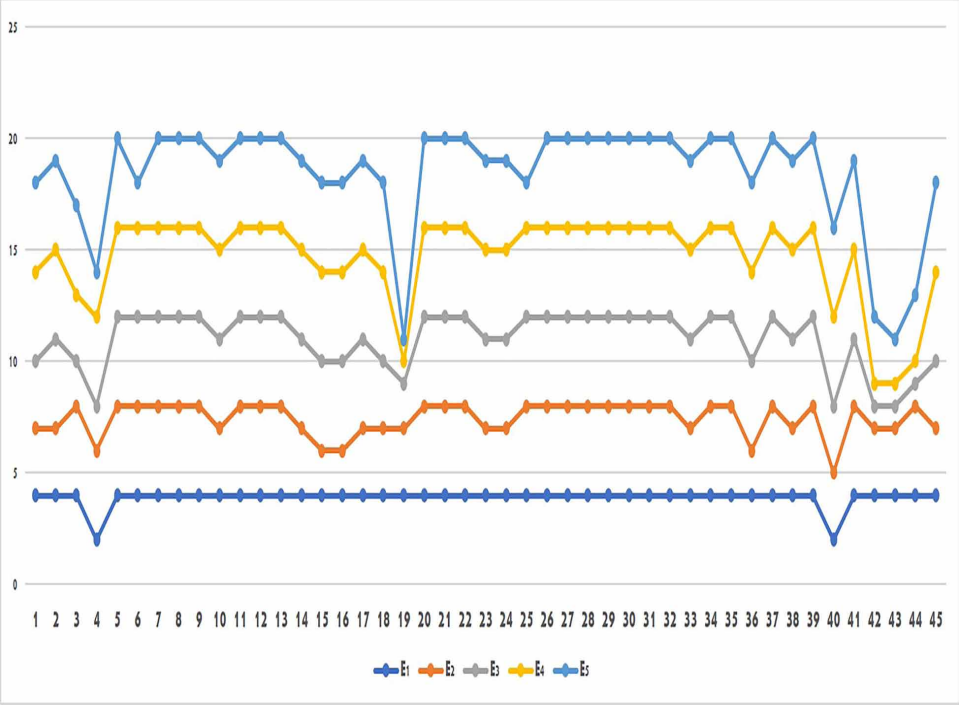

Table 5. Validity of internal consistency per construct

Construct to evaluate	Cronbach's Alpha
Management support	0.880
Strategy implementation	0.923
Collaborative team	0.864
Relationship with customers	0.708
Relationship with suppliers	0.805
Education and training	0.798
Sustainable benefits	0.896
Complete instrument	0.959

Source: By the author

RESULTS INTERPRETATION

In relation to the validation of content and according to Escobar-Pérez & Cuervo-Martínez (2008), the following is concluded:

Since the level of significance obtained in the hypothesis test is **0.000** and it is **< 0.05**, the Ho is rejected, and it is concluded that **there is significant agreement between the evaluators**, so there is an agreement among the experts to validate the content of the instrument.

The values of Cronbach's Alpha show, for all constructs, an acceptable, good and excellent reliability of the instrument, since they exceed the minimum values recommended by George and Mallery (2003), which indicates that values between 0.70 and 0.79 will be acceptable, between 0.80 and 0.90 will be good and values greater than .90 will be excellent.

With the results obtained from the statistical evaluations made, considering the statistical coefficients mostly recommended for studies of this type in the literature, the content of the instrument is validated, so it can be applied in the target population and continue with the next phase of the investigation.

FUTURE RESEARCH DIRECTIONS

Although the utility and advantages that can be obtained with the implementation and development of SS are widely recognized in the literature, it is recognized that there are areas in which it can be deepened. During the literature review, certain gaps identified as an area of opportunity for researchers were identified, in this sense it is suggested that in future research it be deepened mainly in the areas of sustainability and environment, health and medicine, as well as document the practices that they are carried out in the services sector, in addition to this enriching the literature with case studies where models that support the development of projects are clearly developed, where factors that may have an impact on the achievement of the objectives of the project in an organization can be considered from the outset.

CONCLUSION

About the CSF, it is based that there are no satisfactory explanations, that they mention in which of them more attention should be paid, the resources that must be taken into consideration and how to achieve that the projects provide the desired results, besides, that there are few articles that emphasize quantitative research that includes mathematical models and that provides clear guidance for those who wish to develop and implement SS.

In the literature review, 145 CSFs were initially determined, which were analyzed and selected those considered most important for the achievement of the objectives. Through these it was possible to design the integrated measurement instrument for a total of 39 items grouped into 7 constructs, management support, strategy implementation, collaborative team, relationship with customers, relationship with suppliers, education and training and sustainable benefits

Although it is true, only with the knowledge of the CSF cannot ensure the achievement of the objectives set, it requires hard work where they are taken into account from the planning and prior to the execution of projects, in addition to a commitment of management throughout the execution process, as well as the participation of all members of the organization. In this sense the researchers report that, if the CSF are considered and taken into account from the planning and execution of SS can achieve better results and objectives, derived to this will take the organization and its leaders to improve continuous and consequently to achieve the success in the implementation.

Finally, the CSF that is sought to identify through the application of the instrument in the aerospace sector in Baja California, will be part of the main contribution of this research to the existing theory in the field of knowledge of the administration, also, it is considered that The factors considered are part of a precedent that will allow the managers of the organizations to identify, plan and schedule actions that allow them to achieve a successful implementation of SS as a competitive strategy.

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