The use of Quality Tools to solve problems in manufacturing companies in Cd. Juarez - Mexico: A meta-analysis study

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Resumen
Para resolver los problemas de calidad y productividad, las empresas implementan varias estrategias entre ellas, se destacan Lean Sigma y Six Sigma. Estas estrategias contienen diversas metodologías y técnicas que tienen diferentes usos y enfoques dependiendo del objetivo del proyecto, por lo que es de vital importancia cuando se considera el propósito de un proyecto el seleccionar las herramientas adecuadas para lograr los objetivos designados. Este documento presenta un análisis que utiliza la metodología de metanálisis de 84 proyectos de mejora de manufactura elaborados entre 2006 y 2016 que se aplicaron en diferentes industrias manufactureras ubicadas en Cd. Juárez, señala las herramientas más utilizadas en el entorno de fabricación de Cd. Juárez, buscando de esta manera facilitar la toma de decisiones sobre los tipos de herramientas a utilizar.

Palabras clave: Manufactura Lean Sigma, Herramientas de Calidad, Meta-Análisis.

Abstract.
In order to resolve quality and productivity problems, companies implement several strategies among them; Lean Sigma and Six Sigma stand out. They contain diverse methodologies and techniques which have different uses and approaches depending on the objective of the project, so it is of vital importance when considering the purpose of a project to select the appropriate tools to achieve the designated objectives. This document presents an analysis using the meta-analysis methodology, of 84 manufacturing improvement projects presented between 2006 and 2016 that were applied in some manufacturing industries located in Cd. Juarez, pinpoints the most used tools in the manufacturing environment of Cd. Juarez, seeking in this way to facilitate decision making on the types of tools to be used.

Keywords: Lean Sigma Manufacturing, Quality Tools Practices, Meta-Analysis.

Introduction
To improve the levels of competitiveness, companies develop strategies and implement them throughout the organization. One way to achieve this is through methodologies that use various tools to accomplish a specific purpose, although this is not an easy selection, because there is a large number of tools available for specific scenario that may arise, reason why in many occasions the adequate tools for each stage are not well known and even used erroneously (Tague, 2000), this open the opportunity to external training and consulting that makes the cost of the solution more expensive. Such situation makes it necessary to have a guide that explains not only the applications, but also the purpose of the tool and the precise conditions required for the correct applications. In addition to this, there are occasions when the tools used are not completely efficient, which causes a decrease in the quality of the metrics of the company, as they tend to cause confusion (Abdolshah & Jahan, 2006).

To identify the main tools used successfully in manufacturing companies of Cd. Juarez - Mexico, a systematic review (SR) of the literature was carried out, known as Meta-Analysis (MA). A SR is a review of a clearly formulated question that uses systematic and explicit methods to identify, select and critically evaluate relevant research and to collect and analyze data from studies included in the review (Moher et al., 2009); for Basu (2017), MA is essentially systematic review, but the analysis also numerically pools the results of the studies and arrives to valid statistical conclusions. MA also is considered as analysis and method of disorganized knowledge, for its integration and organization. It is a process based of statistical analysis of the whole body leading to a valid synthesis. Although the methodologies developed for MA applications have been carried out mainly in the social, medical and psychological areas, some recent MA applications have been in Mexican companies, such as: Kanban and Demand Flow (Valles et al. al., 2006); Manufacturing (Colín, 2007); Cell manufacturing (Noriega et al., 2010); and Competitive Intelligence (Ojinaga, 2018).

There is a great amount of tools that are used in the methodologies for the solution of problems, however the ignorance of the purpose for which each of them is implemented and even the existence of them causes that sometimes they are used erroneously, for different purposes and even they are omitted, this phenomenon creates the need to develop a study to identify the tools that are most used in manufacturing environments in Cd. Juarez. The main purpose of this study is to understand which tools in the manufacturing projects developed in Cd. Juarez aimed at solving problems are the most used and to recognize some pattern that allows us to establish what types of tools are most appropriate for their use in problem solving projects.

Methodology

The way to solve problems is the basis for a successful business administration, however, it is not an easy task because the problems vary in form and complexity and may even have more than one solution, so that decision making could become difficult. It is useful to have the right tools that can provide support to make the right decision.

Materials

For the identification of the tools used successfully in problem solving practices in CD manufacturing companies. Juarez - Mexico, a search was made of Manufacturing Improvement Projects (MIP) related to applications in the Industrial Engineering program of the Autonomous University of Cd Juarez - UACJ between 2006 and 2016, and then a review of the documents found was made based on The reading of the Introduction, Summary and Conclusions.

Method

The eight steps of the MA methodology (Noriega et al., 2010) was applied to generate statistical support and to obtain a high grade of confidence about the papers for the study. The steps of the MA methodology are described as follows:

1. Definition of the problem. In this step, the problem must be defined clearly and precisely. In this case, it was defined as the determination of the problem-solving oriented tools used successfully to increase the levels of different metrics in the manufacturing company.
2. Identification of the sources of information and the studies to analyze. Once the limits of the meta-analysis are determined, all studies that meet those limits will be determined. The purpose of this step is to list the sources of the literature. In this research, the total number of MIP considered was 84, among them.
3. Discrimination of information. In this step, the information is classified according to the degree of scientific rigidity, credibility and trust. For this purpose, a set of inclusion and exclusion criteria is developed that applies to all documents, excluding documents that do not meet the criteria. This is one of the two quality filters. In this step, it was reduced from 84 to 58 projects.
4. Database of publications. The purpose of this step is to generate a database of documents in order to facilitate the management, location and processing of information collection.
5. Evaluation of the manufacturing improvement projects. The purpose of the projects evaluation is to determine, based on the established criteria, whether a project should be included or not for MA. In this stage, a questionnaire was applied to all the documents. Each document is judged and assigned a rating according to a Likert scale of 1 = not important to 5 = more important. In this step, it was reduced from 58 to 32 MIP.
6. Classification and coding of information. In this process, the extraction of data from each study is based on a coding sheet that specifies what data to extract and a key that interprets the various aspects that were performed. The coded information is summarized to identify moderating variables, which will be

used to group studies to perform MA.

7. Statistical analysis. In this step, the objective is the application of statistical methods to the studies that were selected for inclusion in MS. The selection of the appropriate ones depends on the specifications of the comparisons to be made. For this investigation, the statistical treatment began with the normality test applied to the final results. The differences in the means test were made to determine the relative contributions of the Quality Tool and to establish the most important of them.
8. Generation of Conclusions. This is the last step of this methodology, which consists of the interpretation of the results obtained and generates the conclusion for the defined problem. The results of an MA are simply tests that can be used in an attempt to integrate the results of multiple studies. In addition, the assumptions necessary for the MA must be evaluated for the adequacy of the study.

Results

The results obtained from the MA application to the problem-solving tools practices are presented in this section. The flow of information of the different phases of a SR/MA proposed by PRISMA statement (Moher et al., 2009) is shown in Figure 2.

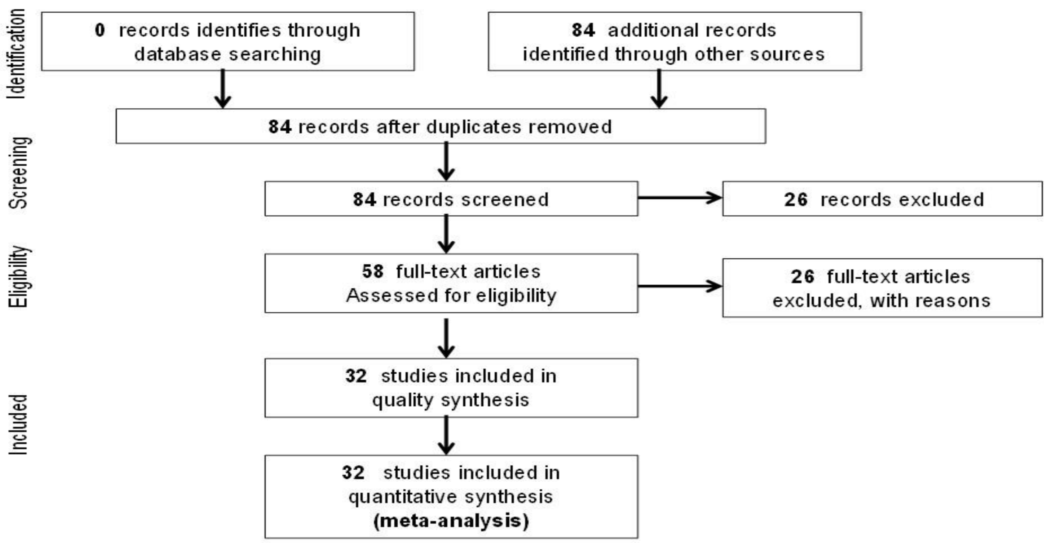

Figure 2. Four Phases flow diagram of a Systematic Review/Meta-Analysis.

After the first stage of the analysis was carried out, only 32 completed MIP'S were considered, out of a total of 84; then, to facilitate the review, the MIP'S were grouped into turns: a) Applications in the automotive industry, b). Applications in the electronic industry and c). Applications in other industry; d). Applications in the other industry; as presented in table 2.

Table 2. Description of three themes

Theme	Description	Quantity of papers
Application in the automotive industry	Manufacturing improvement projects related to the elaboration of parts and / or components dedicated to the automotive market	16
Application in the electronic industry	Manufacturing improvement projects related to the elaboration of parts and / or components dedicated to the electronic market	5
Application in the medical industry	Manufacturing improvement projects related to the elaboration of parts and / or components dedicated to the medical market	3
Application in the other industry	Manufacturing improvement projects related to the elaboration of parts and / or components dedicated to the other markets or sector	8

In this step, 32 MIP'S on the use of problem-solving tools in manufacturing companies located in Cd. Juarez, Mexico were identified; Appendix A shows Author, Year and Name of each of them.

The next step is to determine the tools that are critical to the success implementation of MIP (Table 2). For this step it is necessary to summarize the frequency of each tool, a total of 40 tools were found in the reviewed MIP.

Table 2. Problem-solving tools identified

Code	Quality Tools	Frequency
DE 1	2 sample t	10
DE 2	1 sample t	6
St 1	Descriptive statistics	24
St 2	Histogram	9
St 3	Boxplot	11
St 4	Proportions chart	4
St 6	Stratification	41
IC 1	Capability analysis	19
IC 11	X-R Chart	8
IC 16	1 proportion	7
IC 2	Normality test	34
IC 3	Design of experiments (DOE)	6
IC 7	R & R Study	6
QT 1	Pareto Chart	47
QT 2	Brainstorming	15
QT 3	Ishikawa diagram	14
QT 4	5 Why's	14
Z 1	Other (frequency = 1)	12
Z 2	Other (frequency = 2)	10
Z 3	Other (frequency = 3)	18

Once the total frequency is counted, it is necessary to perform a normality test. Although the results show that the data are not normally distributed, a means test is carried out to identify successful quality tools in Lean Sigma practice. The Means Analysis (ANOM) test can be used with normal response distributions, but ANOM with binomial or Poisson distributions can also be used. The test determined that 5 of the 40 quality tools can be considered critical, the most used tools are Descriptive statistics, Stratification, Capability analysis, Normality test and Pareto chart as shown in Figure 3.

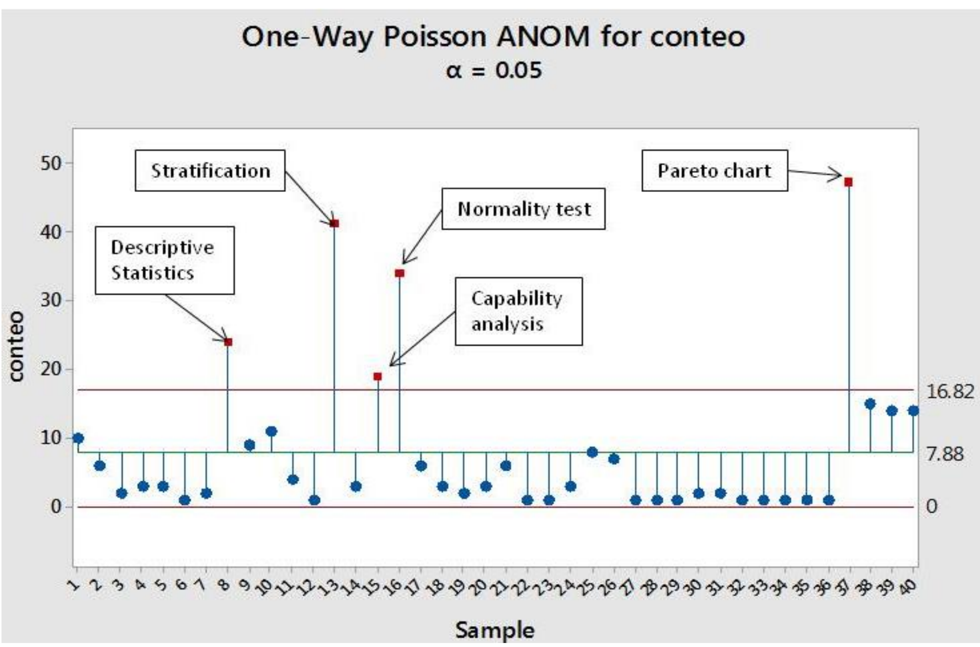

Figure 3. Analysis of Means for Tools Identified

Figure 3 reflects the most used critical tools that were identified in the projects oriented to the solution of problems in companies located in Cd. Juarez, nevertheless when giving a more in-depth follow-up on the obtained results it was found that the tools specified in the study are used in the first stages of the projects to obtain a description of the behavior of the processes, likewise it was observed that the same tools are also used in the last stages of the processes using the information they provide as a reference to measure the impact of the changes implemented in the project. In addition, the most commonly used tools used in problem-solving projects were collected in stages (Table 3).

Table 3. Top three of tools used in problem solving projects in Cd. Juarez by stages.

Stage	Top	Tool	Number of times used
Definition	1	Pareto	15
	2	Stratification	13
	3	Normality test	3
Analyze	1	Stratification	31
	2	Pareto	28
	3	Normality test	16
Implement	1	Pareto	19
	2	Ishikawa's diagram	14
	3	Brainstorming	12
Control	1	Pareto	38
	2	2 sample t test	18
	3	Descriptive statistics	17

The results of the identification of the most used tools by stages indicate that the analyzed studies seek to reflect the information in a simple way, since the fact that the Pareto tool is in all the stages denotes this situation.

Final Remarks

As shown in this review, companies in Cd. Juarez, México have been applying problem-solving tools to raise the levels of his metrics, innovations with a high impact on the market, and development of better products.

This investigation shows the problem-solving tools identified as the practices of manufacturing companies in Cd. Juarez, México. This research has the interest of identifying problem-solving tools used successfully and is intended to present a new perspective for professionals and researchers. The results show that at least 32 projects out of 58 mentions or explain the use of problem-solving tools in different cases or approaches. Therefore, the research to identify the problem-solving tools used successfully in the practice is a contribution to the field. Regarding the application of the MIP in engineering areas, for the use of problem-solving tools within the framework of research practices, it can be considered useful.

The study also shows that the most used tools are those that provide simple information to understand, likewise it was found that to reflect the impact of the change implemented, the same tools used to define the problem are used, implying that other types of information are unknown tools that can provide different types of information that support the results of the project

Even though the limitation of the study is the size of the sample (58), it is considered acceptable given that Hunter and Schmidt (2000) mention that the size of the study sample (from 25 to 1600), the Type I error for random effects it is always 5% as in the fixed effects with homogeneous cases. The results obtained are of great value, since they could be used to carry out more in-depth studies on the use of problem-solving tools in specific cases and even to propose new strategies for their application.

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