Lean Manufacturing Maturity Model for an automotive cluster: a case study in Mexico.

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Abstract
A challenge of automotive enterprises is to achieve a total implementation of Lean Thinking tools through the manufacturing processes. The Automotive Cluster of Nuevo León (CLAUT) in Mexico developed an instrument which evaluates the use of 23 tools distributed in five levels and 279 criterions to measure the maturity level of its member companies in the implementation of Lean Manufacturing tools. The instrument was made with the collaboration of three companies. This study has the objective to prove, redesign, and standardize this instrument by conducting three rounds of audits with external auditors to a case study in seven companies (OEM, Tier1, and Tier2). The main goal is to decrease the time of evaluation and to standardize it for it to be replicable in different companies of the same industry. The methodology selected was the PDCA cycle, and it was replicated twice. The redesign of the instrument was supported on a theoretical basis, using state of the art as BPM Maturity Model and Lean Enterprise Self-Assessment Tool (LESAT). The results of the audits allow to identify the practical implication of the assessment, and after two cycles led to the improvement of both the application method and the content of the instrument.

Keywords
Business process management; Maturity model; Evaluation of Lean implementation; Lean manufacturing tools; Audit;

1. Introduction
During the last two decades, lean manufacturing tools have had a higher application in the automotive industries to improve the performance of the processes by eliminating wastes. Currently, there are different Maturity Models (MM) being used in the field which were created by various authors and companies to measure the implementation of lean manufacturing tools (Vivares, 2017). The MM are used to evaluate processes in companies and organizations, to measure and compare the level of maturity between each other in a specific industry. These models are a combination of arranged elements from lean manufacturing principles to grant a particular measure of maturity in this topic.
Most of the MM are focused on a specific company process or standard, which make it too difficult to achieve the best level for different companies on the same sector (Tarhan, Turetken and Reijers, 2016). Berenguer (2015) points out that the level of maturity becomes fundamental to assess the performance of an organization and is based on implementation evaluations for its measurement. Due to this, the MM were created to serve as assessments of the current state and provide a guide to identify measures of improvement that allow its future development (Röglinger et al., 2012).
Seven different MM were studied in this research to compare them and used it as a theoretical basis. They include: a) Capability Maturity Model Integration (CMMI) proposed by Chemweno, Pintelon, Van Horenbeek & Muchiri (2013); b) Process Management Maturity Assessment (PMMA) defined by Rohloff (2009); c) Meng Maturity Model (Meng, 2011); d) Purchase Maturity Model (Bermelmans, 2013); e) Maturity model for production Management (Kosieradzka, 2017); Business Process Management (BPM) defined by Chen, Ding., Fu and Huang (2016) and Lean Capability Model (Mize, 2002). The last two MM are specific for Lean Manufacturing (LM) concept and were selected as the main models for this research.

With this aim, a case study regarding the assessment and redesign of lean manufacturing MM was conducted in the state of Nuevo Leon, Mexico, for the automotive industry enterprises. This case was selected due to Mexico's emerging economy leading the automotive sector. According to *Organisation Internationale des Constructeurs d'Automobiles* (OICA) in 2018 Mexico obtained the sixth place in automotive production and was the largest producer in Latin America, producing and exporting more than 4.1 million vehicles (OICA, 2019). At 2017 the automotive industry in Mexico represented 2.9 percent of the national GDP and 18.3 percent of the manufacturing GDP (AMIA, 2018). The automotive sector of the state of Nuevo Leon represents a high impact on the country's economy. The total annual export income of the automotive industry of Nuevo Leon in 2017 represents 36.2 million US dollars. According to the Automotive Cluster of Nuevo Leon (CLAUT), the state holds approximately more than 200 automotive companies. Currently, the automotive industry of Nuevo Leon has a participation of 22 percent of the Foreign Direct Investments (FDI). Also, this industry employs around 70 thousand people. This sector has been transformed and has awakened the interest of auto parts companies in Europe and Asia (N.L. GOB, 2018).
The members of CLAUT designed an instrument to evaluate the degree of implementation of Lean Manufacturing tools in companies located in this state, which evaluates the use of 22 tools distributed in five different levels and 279 criterions. Self-evaluations were carried out in 2018 in each of the ten participating companies, obtaining results for the implementation of each tool. By 2019, two goals were set, the first aimed to conduct a second evaluation with external auditors to get an external perspective about the instrument and the second to contrast the results of the audits with the self-assessment done in 2018.
The main objective of the study is to conduct external audits to then redesign the measuring instrument of maturity levels in the implementation of LM tools in seven-member companies of the CLAUT, which are leading manufacturers of the automotive industry in the state. The main contributions of this research study are to satisfy the need of the automotive sector with the development of an standardized and valid assessment instrument that can be applied to any of the automotive companies to increase the performance of its organizations by define a diagnosis an action plan for improve the implementation of LM tools, as well as to be able to exchange and understand successful manufacturing practices between each other companies.
This article structure is the following: Section 2 shows a literature review in which this study has theoretical support. Section 3 exposes the methodology that consists of the use of the PDCA Deming cycle for the redesign of the instrument. Section 4 presents the results of the audit using indicators to notice the improvement and validity of the instrument. Section 5 shows the discussion of the results, and Section 6 presents the conclusions.

2. Literature Review

Maturity models and maturity levels of different industries and Lean Manufacturing, authors, and years, have different findings on their models based on different types of levels. *Table 1* shows the various authors, years, and countries with the two topics selected and investigated to determine which ones can contribute to the study. These variables were chosen for this research study by the CLAUT needs and the automotive industry of Nuevo Leon. All the authors have investigations and findings of the topics in different countries; most of them are original from America. The base tool for the research is the Capability Maturity Model (CMM), which helps to determine the current state of leanness that the organization has and its ability to accept change. This model is found to be complemented with a model tool called LESAT. Lean Enterprise Self-Assessment Tool (LESAT) helps to evaluate the application of Lean in an organization, the lean transformation process (Setianto, & Haddud, 2016). This model evaluates with a scale of 1 to 5, depending on the state of maturity of the criteria, which makes it harder to have concordance on results from the same criteria by different auditors.

Table 1. Main authors and their contributions

Author	Year	Country	Maturity Model	Lean Evaluation Tool
Anna Kosieradzka	2017	Poland	X	
Chen, P., Ding, Z., Fu, Z., & Huang, L	2016	China	X	
Julia Arango; María del Rocío Quezada	2015	Colombia		X
Maasouman, Mohammad, Demirli, Kudret	2013	Canada	X	

Michael Rohloff	2009	Germany	X	
Alberto Villaseñor	2007	Mexico		X
Deborah Nightingale	2005	USA		X
J. Mize, Joe H.	2002	USA	X	
P. Chemweno, L. Pintelon, A. Horenbeek	2002	Belgium	X	

2.1 Foundations of Maturity Models

The maturity is characterized by aggregate levels, in which the top levels are assembled on the lower levels. There has been determined that there is a positive relation between lean operations and operational performance (Dos Santos Bento & Tontini, 2018). The maturity models help the organizations to apply the tools correctly and create an adequate culture to preserve the positive results. The companies that achieve a high level of maturity can have a better-implemented culture of quality, of operational performance and a lower level of waste on processes, which improves the operational process. Today, maturity models are developed as a response to the need for measuring progress achieved by the organization as a result of continuous improvement (Kosieradzka, 2017). Also, have been developed to specific industries to have a more significant impact on the development.

Throughout the investigation, different authors were found, where the topic of discussion in their articles were the Maturity Models previously defined and evaluation of Lean implementation, which are tools that evaluate Lean practices. These two topics are the basis for our investigation and study. Half of the information of these maturity models come from publications from the United States and Colombia, both countries from America.

2.2 Development of Maturity Models

First, Humphrey developed the CMM maturity model in 5 levels, in 1980, with application in the software industry but with adaptation in project management, this model evolved, in 2002, to more areas being all-inclusive to other areas becoming the Capability Maturity Model Integrated (CMMI) (Dos Santos Bento & Tontini, 2018). The CMMI reach distinctive regions and scopes of different organizations. In the industry of Business Management, there are models of PMMA (Rohloff, 2009) and Purchase Maturity Model (Bemelmans et al., 2013). The PMMA has five levels of maturity; this model follows the principal structure of the CMMI model but has a slight twist in content due to it being based on areas relevant to the BPM model. The PMMA is composed of nine categories that focus on in the business aspect of the company with only one of them focused on methods and tools (Rohloff, M., 2009). The Purchase maturity model is divided into six levels. This is a tool for rapid analysis of purchasing maturity for construction companies. Its' primary objective is to improve the organizational performance by facilitating the procurement specialists an easy and fast way to identify the best practices in the procurement area (Guth, 2010). For the Supply Chain area, the Meng Model (Meng et al., 2011) was found, which measures and improves the relationships between the main actors in the supply chain for the construction industry and has four levels.

Table 2. Maturity models

Maturity Model	Year	Industry Focus	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
CMMI	2002	Software	Not Implemented or implemented informally	Formally implemented	Deployed and documented	Implemented and documented with indicators under control	Implemented, controlled, and continuously improving	
PMMA	2009	Business	Initial	Managed	Defined	Quantitatively Managed	Optimizing	

Meng	2011	Supply Chain	Price competition	Quality competition	Project partnering	Strategic partner/alliance		
Purchase maturity model	2013	Business	Transactional orientation	Commercial orientation	Purchasing coordination	Internal integration	External integration	Value Chain integration
Maturity Model for production Mgmt	2017	Manufacture	Effectively executed production processes	Managed production processes	Defined production processes	Quantitatively Managed production	Optimize Production Processes	
BPM/MMP	2016	Manufacture	Initial implementation	Repeatable and Known	Standardized/ Documented	Automated and Measured	Continuous Improvement	
Lean Capability Model	2002	Lean Manufacturing	Optimization of sporadic production	Basic understanding of Lean and its application	Lean Strategic intervention	Proactive Lean Culture	EME with Lean	

For the manufacturing industry there are three models; the Maturity Model for production management (Kosieradzka, 2017), Business Process Management Maturity Model (Chen et al, 2016) and Lean Capability Model (Mize, 2002) which all three have 5 levels of measurement and are very similar, with the difference that the Lean Capability Model and the BPM are more adapted to the lean industry (Chen et al., 2016). The BPM model has an additional advantage, it being its flexibility to adapt to the need of the process, its easy understanding of each level and the model being the second most recent of all those shown in Table 2.

Five of the seven authors of the maturity models shown in Table 2 establish five levels except for two models that have four levels and six levels. The application of the consulted models depends on the industry; they have been found in the Software, Manufacturing, Supply Chain, Business, Startups, and Lean Manufacturing Industries. The objective of observing the content of Table 2 is to compare how the levels of maturity are evaluated and vary in the different industries, finally with this the most compatible model with the study was selected. The BPM was chosen as the model for the study due to its compatibility with Lean Manufacturing and its recent update. Other models of maturity, such as Lean Capability model and the Maturity Model for Production Management, are adapted to the automotive industry but were discarded because of their year of creation and ambiguity in the levels.

BPM Maturity Model

BPM, also known as Business Process Management, the authors Chen, Ding, Fu, & Huang (2016) define the model as being composed of three parts. These parts produced by the design, the execution, and the optimization of human related activity in the process under study. The authors express that close attention and surveillance must be paid to the possibilities of an in-process appreciation, as well as to avoid the neglection of the potential effectiveness in the process that the life cycle management creates.

The BPM Maturity Model used in the study has the focus of operations; in this version of BPM, it is composed of 5 levels. The first being Initial or Partial Implementation, meaning implementation without system guidance, the idea of "just do the work." The second is Repeatable / Known, involving known by the staff, but without documented practices or processes. There is a practice known by experience, and therefore it is repeated by the new team through the practice of shadowing. The third level is called Standard / Documentation; the processes and information are standardized and documented for their correct replication in the future. The fourth level is Monitoring / Measurement / Automation; the processes are measured, monitored, and recorded to establish, monitor, and compare the KPIs. At this level, we look for problems to be identified as quickly as possible when we see the changes in the KPIs. Finally, the fifth and last level is Continuous Improvement, the search for best practices and the constant evolution of the process through studies and analysis, to optimize, maximize, and minimize critical indicators (Chen, Ding, Fu. & Huang, 2016).

3. Methodology

The study consists of carrying out audits, modifying/simplifying the auditing process and its instrument. The study deliverables are the process and evaluation of updated audit with their formats in pilot test status; as well as the study of times and no concordance (NC). This research seeks to get an ideal maturity model that can be evaluated in different companies of the automotive industry in Nuevo Leon, Mexico. This research contains different maturity models related to lean manufacturing, the methodology chosen to accomplish the objective of the study, the process chosen to evaluate and create a new design of the tool provided by the CLAUT to their member companies and the final results of the redesigned tool.

Within the study, two performance indicators are being considered, the first is time, and the second the NC test. The indicators are set to measure the progress and impact that it has had during the study. These are monitored from the beginning to the end and are compared to define if the changes are of benefit or counterproductive. The time indicator measures the time it takes to complete the audit, by tool and global. It is used to compare the duration of the audit during the first and second round of audits. The NC Test indicator takes into account each time a criterion was rated differently. During the first round, it took into account the differences between the external auditors and during the second round between the external and internal auditors.

The study scope includes the participation of seven companies associated with the CLAUT, this being carried out from January 2019 to May 2019. The instrument must be able to be applied in the different industry categories and processes, such as Tier 1, Tier 2 and OEM categories and foundry, paint, hydro, etc. processes, due to the number of member companies with different types of processes that make up the CLAUT (CLAUT, 2019). The seven participant companies include one OEM, four Tier 1, and two Tier 2. The study excludes any activity and process that is not related to the improvement and application of audits for the evaluation of the implementation of the lean tools within the seven participating companies.

The PDCA model, also known as the Deming cycle, stands for Plan, Do, Check, and Act. According to Svensson (2000), a diagnosis consists of four phases, which are related to the cycle of continuous improvement of Deming. PDCA is a methodology that applies constant monitoring and the use of corrective measures to achieve continuous growth since it has a cycle function it can be repeated as many times as one decides until getting the results needed. This methodology was chosen for the need first to evaluate the original instrument, analyze it, and then modify it.

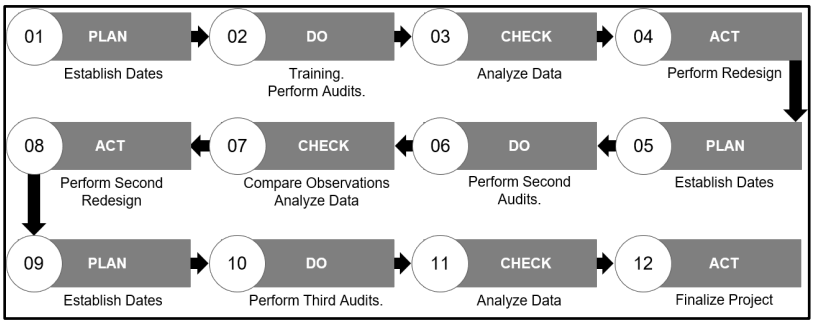


Image 1. PDCA Cycles

This method was applied to the seven companies, which represents one OEM, four Tier 1, and two Tier 2 obtaining the process showed on *Image 1*. The application of the method was done three times. In the first cycle, the audit instrument created by the Automotive Cluster in 2017 was used to carry out the first round of audits with the seven participating companies. The original instrument of the CLAUT has instructions to fill out the form; the auditors were indicated that all criterions should be rated regardless of them being a 1, 0 or Not Applicable (NA). The rating 1 corresponds to accredited, 0 corresponds to not accredited, and finally, NA corresponds to not applicable to the company's process. CLAUT gave training to the external auditors for a better understanding of the evaluation and the variation of process faced in different companies. First, direct contact was made with the companies to explain the study and its scope, as well as defining a date to perform the external audits. With the audits carried out, data was obtained to analyze it, compare the results, and evaluate the tool, gathering the findings and the comments of the clients. The information collected was analyzed to infer the performance of the indicator that measures the progress and impact of the tool during the study. Then the maturity model investigation results were used as pillars for the first instrument redesign to create a tool based on experts' knowledge and to eliminate or modify the criterions that represented a primary company model. After obtaining the results, the tool was redesigned for the first time. The

criterions detected in the analysis as repetitive or irrelevant were omitted, criterions recommended by the experts were included, the weights and the design/format of the instrument was changed. The first redesign of the instrument is developed according to the BPM Maturity Model and the theoretical support of each of the tools. First, an exhaustive study was carried out on each of the tools evaluated in the instrument and the implementation steps stipulated by the theory. Once the information was gathered, the BPM maturity level for each of the criterions was identified. It was found that the original instrument did not follow a specific order and was not based on any theory, so an order/sequence was established within each tool. This was to avoid evaluating criterions that were more advanced before complying with the basics of the tool. Two formats were made, one being sequential and another non-sequential. The sequential format had the instruction of evaluating the criterions in the ordered established, if a criterion was not accredited, then the rest of criterions that follow of the same tool are marked with a 0 as well. In non-sequential format, all criterions of the tool are evaluated and rated no matter the rate of the previous criterion. In both formats the rate of NA does not affect the rating of the next and will not negatively affect the final grade of the tool.

The second cycle began scheduling visits to evaluate the companies once again. The redesigned instrument was applied during the second round of audits, where feedback was received from the participants. The new tool has a sequential order to fill in, except for three tools. This filling was defined to determine precisely in which level the company was, instead of filling all the criterions. The criterions were rearranged in a specific order based on the research of information gathered. The dates for the second round of audits were defined, including four of the seven companies participating in the first round. The companies were asked to provide an internal auditor during the evaluation period in their company. Basic training was given to the internal auditor to understand the purpose for which his participation was required during the second round of audits, as well as the changes made to the instrument and its correct way fill in. A pilot test was conducted with four of the seven participating companies. The pilot test consists in carrying out the audit evaluating the implementation of the lean manufacturing tools with the redesigned instrument. The dynamic was that by the company the selected process is assessed by three external auditors together with an internal auditor, chosen by the company. This to not only evaluate the practices of the company but also the understanding and logic of the redesigned instrument, to analyze if the four audits select the same value for the criterions. In the verification phase, the time durations of the audits were compared with those of the first round, and the concordance test was carried out between the three external and internal auditors. Likewise, the observations of the participants of the second round of audits were documented and analyzed, with the views from the companies and the findings during the audits. With this information, a second redesign was made, and a new cycle of the method started.

From the feedback and the comparison of theory against the practice, the second redesign was created. It was decided to carry out a second redesign of the CLAUT instrument after the pilot test, the feedback given by the participants of the pilot test was analyzed, and it was concluded that the tool could still be improved. The purpose of the second redesign is not only to follow the theory and the BPM Maturity Model, but also to consider the practical and its implementation logic in the floor. The second redesign consists of omitting or modifying criterions and evidence that were confusing to the auditors or unnecessary while evaluating the companies. If the evidence and/or criterion was changed, there was a re-arrange of the BPM levels. Once all criterions were defined on a BPM level, the format was changed to display the level each criterion belonged to, this to visually inform the auditors of the level sections which are essential for the fill out instructions. As part of the redesign, all training criterions were separated from their original tools and made into its group in the instrument. The format was changed as many of the participants expressed the need for more clarification on what each of the criterions meant and asked for. Therefore, a section for a guide was added to each of the criterions explaining exactly what was asked, needed to pass the criteria, and reasons why the criterion could be not applicable in the process. Depending on the need, some include a description/definition, examples, questions, etc. The filling of the redesigned instrument was still sequential for the most part, omitting four tools which are non-sequential. The sequential filling has new instructions, in which the auditor evaluates all the criterions on each tool by level, if all the criterions of the first level are accredited, then they can continue evaluating all the criterions on the second level, but if there is one criterion that isn't accredited, then they can't continue to the next level criterions, and the rest are rated with a 0. The instructions for non-sequential formats stayed the same as in the first redesign. With this new instrument, the dates for the third round of audits were defined, including two of the seven companies that participated in the first round. This audit was made with an intern auditor to evaluate the indicators of the process and to obtain feedback from the companies. During this audit, basic training of the filling was given to the auditors to accomplish the audit. After finishing the audits, the information gathered was analyzed to determine if the second redesign met the objective sought. The third cycle was finished with a second redesigned instrument in pilot test status, and a training manual was made and delivered to the CLAUT, along with the complete instrument.

Due to the purpose of the study, global indicators were set in place. The main focus of the indicators is to collect data and monitor its changes over time to later compare the results and determine if the changes were to the benefit or counterproductive to that who is studied. (Cambridge Dictionary, 2019). Within the study, two performance indicators are being considered, the first being one of time and the second related to the concordance of the auditors in their responses in each criterions of the instrument. For the last, it was measured the percentage of Not Concordance (NC). The Time Indicator (TI) has the objective of comparing the average time it takes to complete the evaluation of the manufacturing tools individually and on a global scale. It is used to compare the duration of the audit during the first, second, and third round of audits. First individually, how much time was spent evaluating each tool on each company. These results were added to recover an average of each company. After auditing all the companies, the percentages of the time spent on the audits were added, taking an average of the whole audit. The NC test indicator takes in the account each time a criterion was rated differently, this means that each time one or more of the auditors rate a criterion conversely from the rest a non-concordance point is gained, the higher the percentage of NC the lower consensus there is between those evaluating the process. During the first round, it took in account the differences between the external auditors, while during the second and third round it took in consideration the differences between the external and internal auditors (external auditors are the authors of this paper and internal auditors those from within the companies that participated in the study).

4. Results

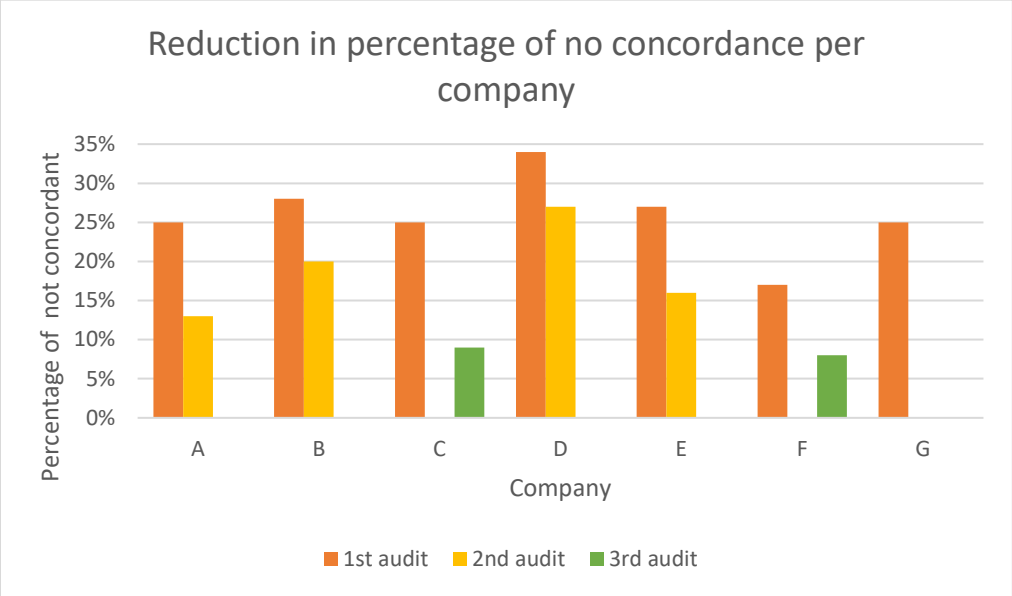
Throughout the study, results from the two redesigns and the three rounds of audits in the seven participating companies are used to analyze it. The results are based on the indicators of the study, the analysis made, and the information recovered. The results vary from company to company and between each audit based on the time and availability of the auditors and the companies. The indicators shown below represent the NC, the time invested in the audits, and the changes made in each redesign. This information is the base to sustain the acceptance of the research and the modifications made on the study.

4.1 No concordance indicator

The following results were obtained for the NC Indicator, considering the first auditory with the original CLAUT instrument, the second auditory from the first redesign and the third one with the final instrument. The percentage needed to accept the maturity model is below 10 percent. As appreciated in *Figure 1*, on the last auditory, the result was of less than required.

The maximum amount of NC was of 34 percent, and the minimum was of 17 percent. These numbers represent a high number of criterions that can be modified to achieve a better understanding. With the same auditory, times spend on it were recovered, the total average time spent on an audit was of 659 minutes, an approximate of 11 hours to complete it all. The average per tool recovered was of 29.95 minutes. The percentage was decreasing during each of the modifications on the instrument. All the companies participated in the first audit, the companies A, B, D, and E, participated during the second audit, and the companies C and F participated in the third audit.

Figure 1. No concordance indicator over the three cycles.

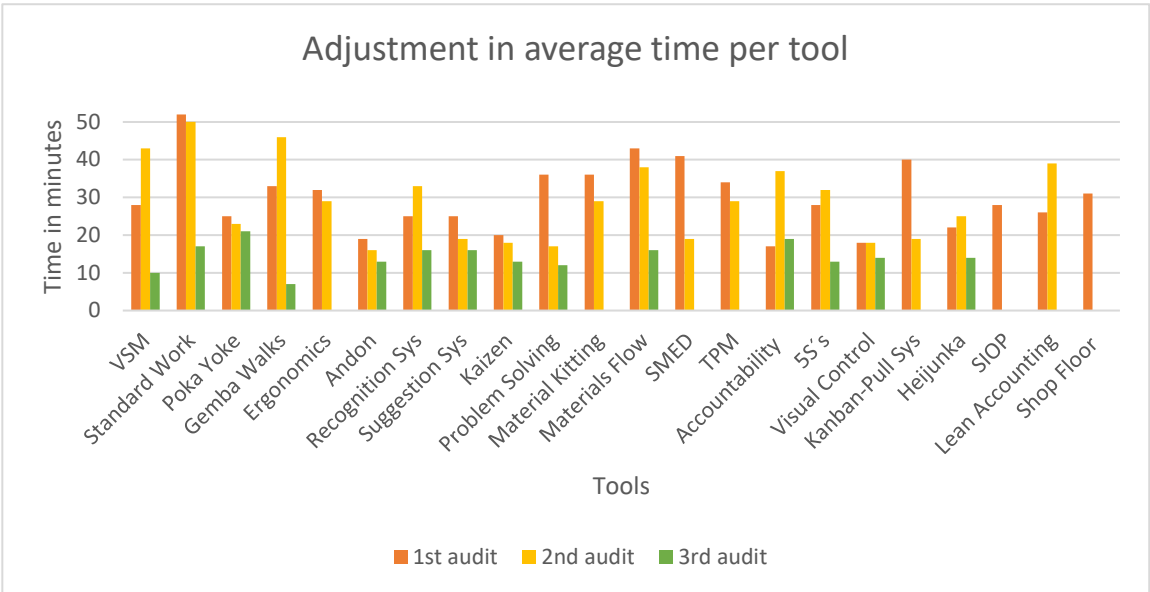


Note: The lower the percentage of NC is the higher the evaluation accuracy

4.2 Time indicator

The TI represents the average time it took to evaluate the criterions of each tool in each audit round. The original instrument takes two whole days to complete it; this indicator was demanded to be reduced with the purpose to be able to evaluate the instrument on different areas of the companies and with a higher frequency to assess the changes made on their processes. As represented in *Figure 2*, some tools take longer during the second audit, then in the first one, but all of them vary no matter the number of criterions they have to be evaluated. For the third audit, in the tools that an average was recovered, it shows that the time for completing the evaluation of each tool is lower than on the original and the first redesigned instrument. Less time does not mean that the instrument is better, but with these results and the concordance results, it was found that the instrument was improved and was able to be implemented in less time.

Figure 2. Time indicator over the three cycles



Note: Tools that do not include a time average in each audit round, where only evaluated in one company. Therefore, no average can be recovered.

4.3 Results comparison

The results in *Table 3* show the percentage of reduction of time duration between the evaluation of the first audit with the original CLAUT instrument and the second audit with the first redesign of the instrument. With this comparison between the two audits that gave the information to recover this data, it shows that the reduction on time is significantly high, with a total of 48 percent less time on average per tool. It also shows a 44 percent time reduction on the average of the total time duration of the evaluation.

Table 3. Results and reduction of time of the audits (Company A, B, C, D, E, F)

Totals	**1st audit Original Instrument**	**2nd audit 1st Redesigned Instrument**	**Time Reduction 1st - 2nd audit**	
Average Time (min)	659	289	370.00	**44%**
Hrs	10.98	4.82	6.17	**44%**
Max (min)	52.00	30.00	22.00	**58%**
Min (min)	17.00	1.00	16.00	**6%**
Average per tool (min)	29.95	14.45	15.50	**48%**

In *Table 4* the final results represent the total reduction of the NC percentage between the first round, with the original instrument, the second round with the first redesigned instrument and the third round with the final redesigned instrument. The original instrument, evaluated by the three auditors, gave a total of 34 percent of NC as the highest result, which means that the three auditors had different grades on the same criterions with the same evidence. After the redesigns, the percentage of NC started to decrease, giving as a lower value of 8 percent on one of the companies with the same three auditors and one intern auditor from the company. This value compared with the first ones obtained, resulted in a reduction of 11 percent as the highest value during the first redesign and a 16 percent as the highest value during the second redesign.

Table 4. Results and reduction of Concordance (Company A, B, C, D, E, F)

Company	**A**		**B**		**C**		**D**		**E**		**F**	
Audit	1st	2nd	1st	2nd	1st	3rd	1st	2nd	1st	2nd	1st	3rd
Items evaluated	279	261	265	240	277	227	164	252	221	261	183	225
Items Not concordant	69	35	73	47	70	20	56	69	60	42	32	19
% Not concordant	25	13	28	20	25	9	34	27	27	16	17	8
Reduction on % of No concordant	**11%**		**8%**		**16%**		**7%**		**11%**		**9%**	

Table 5 depicts the total amount of criterions that were eliminated, modified, or created during the first and second redesign of the instrument. The original instrument included 279 criterions, the first and second redesigns includes 263 and 228 criterions respectably, meaning a reduction of 51 criterions from the original to the final redesign. During both redesigns, all criterions were analyzed, modified, and information was added to help the auditors to look for the same evidence and validate similarly. The criterions with changes represent less than half of the original ones, but these changes do not include the addition of a guide of questions and evidence to look for and the modifications of the evidence requested by the original instrument. The modifications made to the original instrument also includes the

change of the sequence of the criterions on each tool evaluated and the addition of a new tool called, training, which includes criterions from all the other tools and often founded on one specific area of the companies.

Table 5. Modifications made on the original instrument

	1st Redesign				2nd Redesign			
	No. items Original Instrument	No. Items Without Changes	No. Items Changed	No. Items 1st Redesign	No. Items 1st Redesign	No. Items Without Changes	No. items Changed	No. Items 2nd Redesign
TOTAL	**279**	**107**	**222**	**263**	**263**	**96**	**181**	**228**
TOTAL REDUCTION				**51 items removed**				

5. Discussions of the Results

The study gave different quantitative results, two from the selected indicators and one from the number of criterions from the original instrument to the last redesign. The original instrument was implemented in seven companies and got results from the NC analysis.

From the redesigns made, the first one resulted in the decreasing on the number of criterions from 279 to 263, with an 80 percent of changes in total, considering all the changes in redaction, division of criterions, eliminations and the creation of new ones. These changes gave results in time and NC after being conducted in a pilot test. In respect to the time indicator, the results for the original instrument show that the audit takes around 29.95 minutes in average to evaluate one single tool that gives a total average of 659 minutes per audit, about 11 hours to complete it all. With the redesigned instrument it takes around 14.45 minutes on average to evaluate one single tool, giving a total average of 289 minutes, about 5 hours to complete it all. These times vary between all the tools; this is because each tool has a different amount of criterions to evaluate. The difference in the results of the time duration is due to the evaluation instructions established in the redesigned instruments. The original instrument evaluation instructions were to go through all of the criterions; the redesigned instrument develop sequential tools, this means that if you evaluate one as not accomplished, you stop evaluating that tool in that criteria. This method makes the process of auditing faster if the company doesn't have the tool implemented completely.

From the first redesign, the NC analysis recovered, determine if the criterions and the order of the criterions were comprehensive and correctly understood by the different auditors. This second audit includes an internal auditor of each of the companies to have an external vision and opinion. The NC of the auditory with the redesign resulted in reduction between 7 and 11 percent in the companies A, B, D and E. This gave a maximum of 27 percent when in the first auditory the maximum was 34 percent. With these high results on the analysis of NC, it was defined to create a second redesign. After the third round of audits using the second redesigned instrument, the maximum amount of NC in our study was of 34 percent, and the minimum was of 17 percent. The second redesign ended with a total of 228 criterions, which represents a modification/elimination of 51 criterions of the original instrument and 69 percent of changes in total.

From the second redesign, the NC analysis was made with the data recovered from the three external audits and the intern auditor. The values obtained in the companies C and F went down 16 and 9 percent, giving a result of less than 10 percent of NC. With these results, which are not representative because of the number of companies, the redesigned instrument has an accepted NC indicator. These gave a total reduction in average of 10 percent in each of the companies.

The modifications on the redesigns made the instrument easier to apply for any new auditor, and it makes it easier for the company that's being audited to understand what tool is evaluated because of different processes and names for the same tools.

The maturity model used in the study is BPM; this maturity model is composed of five levels of maturity. For the study, it was decided that only the first four levels of the maturity model would be used. The reason for this decision came from the initial need by CLAUT of an instrument that evaluated the implementation of lean manufacturing tools, no continuous improvement of the processes. Since the fifth and final maturity level of the BPM is a constant improvement, it was decided to eliminate the use of that level for the second redesign of the instrument (Chen, Ding,

Fu & Huang, 2016). Many authors of maturity models include optimization/continuous improvement as one of their five maturity levels, authors such as Chen (2016), Macchi and Fumagalli (2013), Hassner-Nahmias (2010) and Perkins (2010) proposed maturity models with five levels each. Vivares (2017) points out that even though many authors propose the use of five leveled models, the BPM model would have to adapt to suit the needs of the study and therefore eliminate the use of the fifth BPM level.

During the redesigns of the instrument several changes were made to its fundamental structure, these include the elimination of the SIOP tool, the merge of the Shop Floor Organization and Accountability Tool as well as the creation of the Training section. The reason behind the elimination of the SIOP tool, also known as Sales, Inventory and Operations Planning, was primarily due to it being an administrative tool, not a tool evaluated in the operational floor. The reason why Lean Accounting was left in the instrument even though it is also an administrative tool is due to its connection with the operational level, the idea of Lean Accounting is to have a connection between production and finance departments. Shop Floor Organization was joined to the Accountability Tool due to its similarities in topics and its need of criterions to at least have one criterion in each of the four BPM levels of maturity. The end product of the joined tool is composed of Shop Floor Organization criterions defined as level one, two and three of the BPM, while the Accountability criterions are defined as level three and four of the BPM. Finally, a section of the training was created in the instrument, the purpose of the section is to gather all the criterions related to the instruction from the other 20 tools and have them all together to simplify the process for the person carrying out the evaluation.

6. Conclusions

The relevance of the study was born from the need of the automotive industry to evaluate the level of leanness in their companies. With the constant need to improve in costs and production, as well as the automotive industry, moving towards 4.0 industry revolution; companies all over the world look to be as updated and relevant as possible. The instrument created has the function to evaluate the level of maturity a company holds in each of the 20 tools and the training section. With it, companies can assess themselves and compare results with other members of the cluster. With this instrument, best practices and champions can be determined for each tool. The identification of champions will create a network of sharing best practices between the members of the cluster, to help each other to better themselves in the areas that others have been able to figure out.

It is through the connection with an educational institution, in this case, the University of Monterrey, in which it was allowed to establish a current external study concerning the evaluation instrument created by the CLAUT. However, the need for the development of a new instrument with different or modified criterions and professional support is evident. Seeking not only it be conducted in less time, but to obtain greater accuracy in the evaluation of the level of implementation, and it is applicable in any automotive process and industry. Then with the data collected information can be displayed for a better comparison. This allows managing the indicators that measure the implementation of Lean tools constantly and straightforwardly to enable decision-making and continuous improvement by the company and as a consequence, the sector. It also gives the CLAUT a benchmark of the best practices between the companies to help and share the processes with other companies to improve their operations.

Due to the process selected for the redesign of the CLAUT instrument, which consisted of basing it solely on theory and the BPM maturity model, it was found that a second redesign was needed to correct the areas of improvement faced while applying the instrument on the field. The process started with the bibliographic investigation to analyze and improve the instrument according to the expert's knowledge. With the first round of audits, it was found that the instrument had many areas of improvement, which led to the first redesign based on the expert's knowledge alone. Using the information gathered from a variety of authors and the basis of the BPM Maturity Model, a new structure and order were given to the original instrument. Once the first redesign was finished the second round of audits was done as a pilot test for the redesigned instrument. During the second round of audits, the integration of an intern auditor of each company was added to the evaluation its own company alongside the external auditors, this with the objective to having an external evaluation (outside of the external auditor's perspective) of the instrument and not only from the ones that created it. It was detected that the instrument didn´t accomplish the results that were expected. In each of the companies, there was feedback to improve the instrument, as well as comments about aspects of the redesigned instrument that were considered as improvements by the team.

After the pilot test with the first redesign, the team realized that the theory and practice in the field do not always work hand in hand. With the feedback of the companies, the knowledge gained during the application of the audits and the research, the second redesign was created. The redesign took in account not only the theory researched from different authors and the Business Process Management Maturity Model, based on processes but included the observations

made by the participants of the second audit alongside the comments made by the team while applying it in the field. As part of the theoretical contributions, the team combined the structures of the BPM maturity model, LESAT format, sequential and non-sequential grading to create a new instrument for the Automotive Cluster of Nuevo Leon. The team concluded in agreement that the topic of the BPM maturity model applied in the tobacco industry by the authors Chen et al. (2016) is of great use for production industries such as the automotive industry. The practical contributions of the study focused on the benefits achieved for the CLAUT. As this instrument can be used to evaluate any process in the automotive industry, and it will be up to the CLAUT to decide if the instrument will be used for their benefit only or if it will be shared with other Mexico's clusters and others Latin American countries.

Due to the time frame given by the university for the study is limited, a second pilot test with the second redesign was done with two of the remaining three companies that did not participate during the second round of audits. It must be said that due to the time limitations of the project, this study was done with seven of the ninety-two-member companies of the CLAUT, and most of them were audited twice for the study. The instrument is given to the client in the status of a pilot test to be re-examined further due to the study small statistic sample.

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