Relationship between 5S and good manufacturing practices and their economic benefits

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Abstract

Lean Manufacturing is an approach for the systematic identification and elimination of waste associated with manufacturing systems and services through continuous improvement by the flow of the product or service to the customer and in the pursuit of organizational sustainability. This article presents a structural equation model that relates the 5s and good manufacturing practices as independent variables with the economic sustainability (dependent variable) of maquiladora companies in Ciudad Juarez. The model proposes three hypotheses validated using the partial least squares technique integrated into the WarpPLS 7.0 software with the information obtained from 119 responses to a questionnaire applied to the local maquiladora industry. Likewise, a sensitivity analysis was performed in which the importance of properly implementing the 5s and what happens when they are not implemented correctly is observed. The results show that the 5s is a facilitator of good manufacturing practices since, through them, a reduction in the different costs incurred by the maquiladora industry is obtained.

Keywords
Maquiladora Industry, 5s, Economic sustainability, Structural equation model

1. Introduction
Companies are looking for new manufacturing strategies to improve their performance and become more competitive in today's competitive markets. As part of these strategies, they implement Lean Manufacturing (LM) practices, which is an approach for the systematic identification and elimination of waste associated with manufacturing systems and services through continuous improvement by the flow of the product or service to the customer in the pursuit of sustainability of organizations (Radnor, 2011). LM comprises a management philosophy with tools aimed at eliminating waste, optimizing workflow, reducing costs and improving quality (Thawesaengskulthai, 2010). One such tool that helps in the sustainability of companies are is 5S, as they are considered the main LM initiative and have a solid potential to improve efficiency, quality, production, delivery fulfillment, safety and cost optimization, and act as a basic requirement for other quality improvement programs (Randhawa & Ahuja, 2017b). The maquiladora is a sector of the industry that has used the tools of LM to achieve competitiveness and stay in the market in recent years.

The term "maquiladora" today refers to "any particular activity in an industrial process for, example, assembly or packaging performed by a party other than the original manufacturer" (García-Alcaraz et al., 2016). Export maquiladoras gained importance in the Mexican economy during the last two decades. These plants import raw materials, components, machinery and equipment to assemble or process in Mexico and then re-export, mainly to the United States, paying taxes only on the value-added (Carrillo & Zárate, 2009; J. L. García-Alcaraz et al., 2015). Such Mexican maquiladoras have established strategies to reduce costs and waste and usually apply advanced production processes and implementation of novel methodologies since they import all raw materials and export all final products, and the flow of materials in their supply chain is an area of opportunity for research (Jorge Luis García-Alcaraz et al., 2015).

According to the manufacturing and export industry (IMMEX) in Ciudad Juarez is an important source of investment, as IMMEX companies ended 2021 with total exports of $293.073 million and imported more than $238.847 million. The above represents 9% at the national level (INDEX, 2022c). It is the second city with the most companies of this type (323), only behind Tijuana. Of these 323 companies, 32% correspond to the automotive sector, 29% to the electronics sector, plastics and metals with 12%, among others (INDEX, 2022a). Likewise, Ciudad Juarez has one of the most important sources of employment in the city, employing more than 336,000 people, representing 66% of the employment in this industry in the state (INDEX, 2022b).

As can be seen, IMMEX is a very important industry for the city. That is why these companies need to be aware of the most important factors when implementing LM tools to improve their production processes, increase their productivity, improve product quality, and reduce costs, impacting economic sustainability. In this way, these companies will remain in the market, in the city and, above all, will continue to be an important source of employment for the population.

In general terms, there is research that relates LM to the sustainability of maquiladora companies. For example, García Alcaraz et al. (2021) reports the effect of quality on the commercial benefits obtained, where 5S aspects are integrated, and Diaz analyze the benefits of SMED in that sector. However, Mojarro-Magaña et al. (2018) are the first to specifically analyze the role of 5s and its relationship with the operational benefits of the maquiladora industry and indicate that these are converted into financial and economic benefits, Ferrua-Breña, Rivas-Marcatoma, and Raymundo (2022) indicate that 5s increase the availability of machines and tools, which translates into higher financial benefits.

In this sense, this research aims to quantify, using a structural equation model, the effect of the 5s on the good practices of maquiladora companies and their economic sustainability. The above is within the regional maquiladora industry established in Ciudad Juarez.

2. Literature review and Hypothesis

2.1 5S

The 5S approach is a principle and tool used to organize and manage the workplace to improve the work environment (Ishijima, Eliakimu, & Mshana, 2016). 5S is a system in which waste is reduced, and productivity and quality are optimized by observing an orderly work area (Bayo-Moriones, Bello-Pintado, & de Cerio, 2010). The 5S changes employees' approach to their work and workplaces and improves communication between different functions and departments of the company (Randhawa & Ahuja, 2017a). A well-organized workplace provides a safe and efficient production environment that boosts employee morale and promotes a sense of ownership, pride in their work, and responsibility (Randhawa & Ahuja, 2017a). Having a well-organized and clean workplace helps reduce time spent searching for tools (Gupta & Jain, 2015).

The 5S are composed of five different elements. Each of them starts with the letter "S" in the Japanese language: Seiri (organization), Seiton (neatness), Seiso (cleanliness), Seiketsu (standardization) and Shitsuke (discipline) (Randhawa & Ahuja, 2017c) and Table 1 presents a brief description of these according to Srinivasan, Ikuma, Shakouri, Nahmens, and Harvey (2016).

Table 1. Metodología 5s

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Seiri	Seiton	Seiso	Seiketsu	Shitsuke
Remove unneeded, broken and expired items from the work area by "red-tagging" them and removing them.	Provide efficient storage areas for the remaining items.	Thoroughly clean the work area. Daily schedules for cleaning the area are created to maintain these changes.	Create standard operating procedures or apply them if they are already available.	Create habits of change maintenance and communicate them appropriately to the organization.

The implementation of 5S helps in reducing time, waste, and cost (Hough, 2008). This implementation organizes the work environment, standardizes the manufacturing workflow, and assigns each employee clear ownership of the process (Srinivasan et al., 2016). Conducting the 5S audit allows organizations to identify the potential level of quality improvement and, at the same time, can analyze the capability and weakness of each division of the company (Ab Rahman, Khamis, Zain, Deros, & Mahmood, 2010). (Table 1)

2.2 Do it right at first time

In order to maximize the value and quality of the product for the customer and reduce lead times and costs, manufacturers often adopt the LM philosophy as a continuous improvement tool to help them perform activities correctly (Marinelli, Deshmukh, Janardhanan, & Nielsen, 2021), to use methods or tools such as Poka-yoke that help operators avoid errors in their work caused by choosing the wrong part, omitting a part, installing a part backward, etc. Another of the activities or tools that help companies increase productivity through the maintenance of machinery to avoid downtime due to these deficiencies is total productive maintenance. The benefits obtained are the gradual improvement of quality, productive maintenance, cleanliness and order, new manufacturing technologies, and harmonization of equipment in advanced technology with employees (Arslankaya & Atay, 2015).

Workplace organization not only manages to optimize production but also creates a safe and under-control environment (Khan, Kaviani, J. Galli, & Ishtiaq, 2019). The 5S program facilitates the development of self-pride, consideration of others, and teamwork among employees, solving organizational growth problems with a collective effort (Randhawa & Ahuja, 2017d). 5S helps to reduce defects and injuries in the workplace, which impacts speed, implying that since the tools in the workplace are well organized, workers can work with ease without asking questions or searching for work tools (Shah & Naghi Ganji, 2017). 5S could be incorporated with some management system practices as an approach for an integrated management system to improve productivity, quality service delivery and safety (Jamian, Ab Rahman, Deros, & Ismail, 2012). 5S helps reduce downtime, lead time, waste, and defects (Khan et al., 2019). In that sense, the following hypothesis can be put forward:

H_1: 5S has a direct and positive effect on getting activities right the first time in the maquiladora industry.

2.3 Economic sustainability

Sustainability is any process that directs decision-making towards sustainability (Bond, Morrison-Saunders, & Pope, 2012). In manufacturing, the economic facet of sustainability refers to the impact on the economic well-being of stakeholders and local and national economic systems (Butnariu & Avasilcai, 2015). Sustainable economic performance refers to employment, profits, value-added and sales, which are also the main elements of any business (Venkataraman, 2019).

Based on the theory and concept of economic, social, and environmental sustainability, sustainable manufacturing is the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees and communities, and are economically sound (Hutchins, Robinson, & Dornfeld, 2013), whereby economic outcomes are measured in transaction costs (Theißen, Spinler, & Huchzermeier, 2014). Ahmad, Wong, and Rajoo (2019) report a series of indicators used by manufacturing companies to measure economic sustainability, such as costs of materials, raw materials, packaging materials, waste disposal, energy, maintenance, environmental fines, defective products, among others. Likewise, it includes profit indicators such as revenue, market value, return on investment, payback period, and turnover (inventory sales).

Poka-Yoke recognizes that there will be errors as long as human beings are involved in the process activities. Poka-Yoke can be implemented to avoid failures (Muralidharan, 2021). Error-proofing devices have many advantages, as they reduce redesign, rework and repair requirements, eliminate the need for inspections, minimize defect rates and reduce lengthy documentation (Wasim et al., 2013). Poka-yokes also help reduce or eliminate machine readability errors, i.e., out-of-specification machines (Wasim et al., 2013). Ideally, the poka-yoke approach should be included in the product design phase. Otherwise, companies would not follow modern quality principles, which state that products should be manufactured correctly the first time to avoid additional costs arising from modifications (Rahman, Sharif, & Esa, 2013). In that sense, the following hypothesis is proposed:

H_2: Getting it right the first time has a direct and positive effect on economic sustainability in the maquiladora industry.

Some of the benefits associated with synchronizing LM and sustainability principles are reduced costs and lead times, improved process flow, meeting customer expectations, improved environmental quality, and improved employee morale and commitment (Vinodh, Arvind, & Somanaathan, 2011). The 5S concept aims to organize, clean, standardize and maintain discipline in the workplace to pursue sustainable improvements in productivity, efficiency, cost optimization and waste reduction in an organization (Marasinghe, 2012). By planning, managing and regulating the production process, 5S facilitates the process, saves operating space, capital and time, and produces goods with fewer defects (Shahriar, Parvez, Islam, & Talapatra, 2022). In addition, with 5S, cleaner places are obtained, workplace safety and product quality increase, problems are easy to detect and prevent, waste and costs are reduced, and the product or service meets customer needs most efficiently. In that sense, the following hypothesis can be put forward: H_3: 5S has a direct and positive effect on economic sustainability in the maquiladora industry.

Figure 1 shows the hypotheses as a graph.

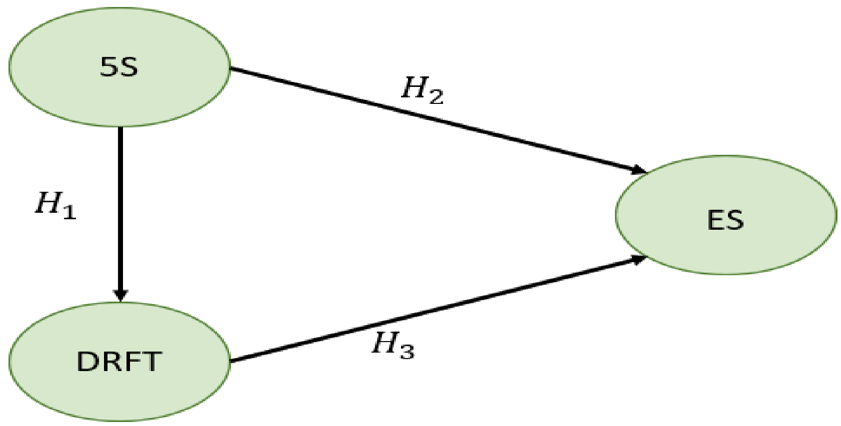

Fig. 1 Proposed Model

3. Methodology

3.1 Questionnaire design

A questionnaire was designed through a literature review using keywords corresponding to each of the LM tools to identify the most important activities to implement each of the LM tools and thus obtain the benefits they bring once they are implemented to collect information. Once the activities were identified, the first validation by the expert judgment was performed to identify the relevance of the questions and adapt them to the regional context. A five-point Likert-type scale was used to answer each of the questions, where 1- disagree, 2- disagree, 3- neutral, 4- agree, and 5- strongly agree. A section was also added with a list of questions to collect demographic information. Information was obtained on the industrial line of business and the company's size, where people work, and their experience in their job.

3.2 Questionnaire administration

Once the questionnaire was validated by expert judgment, it was uploaded to a specialized platform for distribution to potential participants, who were identified through the maquiladora association, which represents the maquiladora industry in the region. An e-mail was sent to ask workers to participate, inviting them to participate along with the link to the questionnaire. If no response was received within 15 days, another questionnaire was sent with a reminder to participate. If no response was obtained, that case was discarded. Each of the questions was programmed as mandatory to avoid missing values, and once the response period was over, a file with the information was downloaded in Excel format.

3.3 Data base debugging

With the information gathered, a database was created for debugging. To do this, first, the non-committed persons were identified at the time of answering the questions, so the standard deviation of each of the questionnaires was calculated; if this is less than 0.5, it is considered a non-committed person. Therefore, this case was eliminated(Kock, 2019). Likewise, the extreme values were obtained for each of the questions; if this value is below -4 or above 4, it is considered an extreme value (Hoffman, 2019) and is replaced by the median.

3.4 Descriptive analysis of the sample

In order to show the demographic information, cross tables were made to present the information corresponding to the industrial sector and the position held by each person, as well as the years of experience within the industry.

3.5 Validation of latent variables

It must undergo statistical validation before integrating the latent variables into a structural equation model. To do the above, the indexes shown in Table 2 were used, which were proposed by Kock (2017). Table 2 shows the coefficients, the tests for each coefficient and the acceptable values.

Table 2. Coefficients for validation of latent variables

Coefficient	Test	Acceptable Value(s)
R^2 and Adj. R^2	Parametric predictive validity	≥ 0.2
Q^2	Non-Parametric predictive	≥ 0 and similar to R^2 values
Cronbach´s α and internal consistency	Internal Validity	≥ 0.7
Average Variance Extracted (AVE)	Convergent Validity	≥ 0.5
Variance inflation factor (VIF)	Collinearity	< 5; ideally < 3.3

3.6 Structural Equation Model

To test the structural equation model, WarpPLS 7.0 software was used, which uses the Partial Least Squares - Structural Equation Model (SEM) technique. WarpPLS allows factor-based SEM modeling; it also allows for nonlinear analyses in which nonlinear functions that best fit each pair of structurally linked variables in the path models are estimated and subsequently used to estimate path coefficients that account for nonlinearity (Kock, 2019). PLS-SEM is easy to use and is recommended when there are small samples or no normal distribution, or the data come from assessments on a Likert scale (Kock, 2019).

Once the latent variables have been validated, they are integrated into a SEM. Before making any conclusions about the model, it should be validated using the quality and fit indices (Kock, 2017) using a confidence level of 95%, which is shown in Table 3.

Table 3. Model Fit and quality index

Index	**Accetable value**
Average path coefficient (APC)	P < 0.05
Average R-squared (ARS) and Average adjusted R-squared (AARS)	P < 0.05
Average block VIF (AVIF)	Acceptable if ≤ 5, ideally ≤ 3.3
Average full collinearity VIF (AFVIF)	Acceptable if ≤ 5, ideally ≤ 3.3
Tenenhaus GoF (GoF)	≥ 0.36

3.6.1 SEM effects

Three effects can be identified within the SEM evaluated in this research. The first corresponds to the direct effects equivalent to each of the hypotheses proposed and are those influences not mediated by any other variable in the model. For each effect, a β value is obtained, which represents the change value of the dependent latent variable due to the independent latent variable. To prove if an effect is statistically significant, a hypothesis test is established at 95% confidence, where H_0: $\beta = 0$; H_1: $\beta \neq 0$. Indirect effects consist of all paths from one variable to another mediated by at least one additional variable, and finally, total effects are equal to direct effects plus indirect effects. (Bollen, 1987).

3.7 Sensitivity Analysis

A sensitivity analysis was performed for each of the relationships (hypotheses). The probability that the activities are performed in an adequate manner (high level) $P(Z > 1)$ and the probability that they are not performed in an adequate manner (low level) $P(Z < -1)$ were obtained. This was done individually for each variable. We also calculated the probability of performing the activities adequately in both variables for each hypothesis (&) and, finally, we obtained the conditional probability (if) that the activities of each dependent latent variable are performed adequately or inadequately, given that the activities of the independent latent variable are performed adequately or inadequately.

4 Results

4.1 Sample description

A total of 119 valid questionnaires were obtained from the administration of the questionnaire, distributed as follows. Regarding the position held by the workers, the position with the highest participation was that of engineer with 29.4%, supervisors with 19.3%, technicians with 17.6% and manager with 13.4%. The majority (58.9%) of the workers have between 2 and 10 years of experience in the industry. Finally, the industrial sector that participated in the highest percentage was the automotive sector with 41.2%, followed by the electronics and medical sectors with 10.9% each, machining with 6.7%, electrical and rubber and plastics with 3.4% each, logistics with 2.5%, aeronautics and textile and apparel with 0.8% each.

4.2 Latent variable validation

Table 4 summarizes the values of the indices used to validate the latent variables regarding the values of R2 and Adj. R2 values, it can be concluded that there is predictive validity since the values are greater than 0.02. The composite reliability and Cronbach's α values are greater than 0.7 and indicate sufficient internal validity. AVE values greater than 0.50 indicate that the variables have sufficient convergent validity. Concerning the VIF values, it is concluded that there are no collinearity problems. Finally, values above 0.02 in Q2 indicate sufficient predictive validity from a non-parametric point of view. Once the variables have been validated, they can be integrated into a structural equation model.

Tabla 4. Latent variable validation indices

	Best if	5S	DRFT	ES
R^2	> 0.02		0.350	0.432
Adj. R^2	> 0.02		0.345	0.423
Composite reliability	> 0.70	0.957	0.932	0.933
Cronbach´s α	> 0.70	0.945	0.902	0.914
AVE	> 0.50	0.786	0.775	0.699
VIF	> 3.30	1.655	1.822	1.713
Q^2	> 0.02		0.352	0.433

4.3 Structural Equation model

Once the structural equation model was run in WarpPLS 7.0, the following indices were obtained: APC = 0.442 (P < 0.001), ARS = 0.391, (P < 0.001), AARS = 0.384, P < 0.001, AVIF = 1.559, AFVIF = 1.730 and GoF = 0. 543. The APC, ARS and AARS values indicate that there is predictive validity since the P values are less than 0.05. Regarding the AVIF and AFVIF values, it is concluded that there are no collinearity problems and finally, the GoF values indicate a good fit of the data.

Figure 2 shows the β values for each of the hypotheses raised and the p-values for each of these and indicates that all three are statistically significant. Likewise, an R2 value is shown, representing the variance explained by the independent latent variable over the dependent latent variable. In the case of DRFT, 0.350 is explained by 5S, and 0.432 of ES is explained by 0.170 by 5S and 0.262 by DRFT.

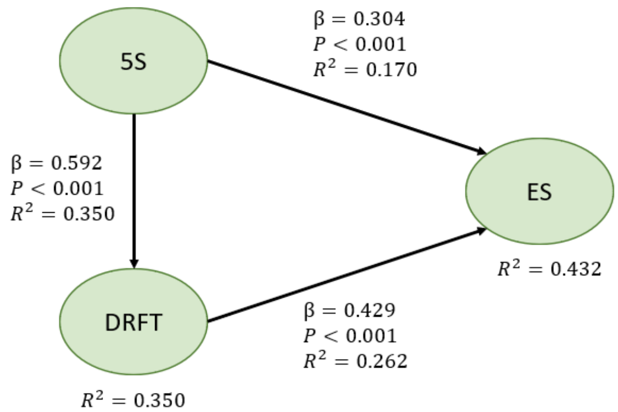

Fig. 2 Evaluated model

Table 5 summarizes all the effects presented in the evaluated model. The largest direct effect is presented of 5S on DRFT with a value β = 0.592, then DRFT on ES with a value β = 0.429. 5S has a direct effect on ES of β = 0.304, plus an indirect effect of β = 0.254 through DRFT, which yields a total effect of β = 0.558..

Table 5. Model overall results

Hi	Hypothesis	Direct effect	Indirect effect	Total effect	Effect Size
H_1	5S → DRFT	β = 0.592 (P < 0.001)		β = 0.592 (P < 0.001)	$R^2 = 0.350$
H_2	5S → ES	β = 0.304 (P < 0.001)	β = 0.254 (P < 0.001)	β = 0.558 (P < 0.001)	$R^2 = 0.170$
H_3	DRFT → ES	β = 0.429 (P < 0.001)		β = 0.429 (P < 0.001)	$R^2 = 0.262$

4.3.1 Sensitivity Analysis

Table 6 shows the sensitivity analysis showing the possible scenarios for each hypothesis presented in Figure 1. The table shows the probability of occurrence of the scenarios where the activities in each tool are carried out adequately (+) and inadequately (-). It also shows the probability of scenarios occurring together (&); for example, the probability of 5s+ and DRFT+ is 0.067, 5s- and DRFT- is 0.084. As can be seen, these are very low probabilities, but if managers ensure that the activities are carried out correctly, this probability can increase since, if within 5s the activities are carried out properly, there is a probability of 0.471 that DRFT will occur properly. Conversely, if the 5s is not implemented properly, there is a 0.588 probability that there will be difficulties performing the activities properly the first time. The same is true for 5s and ES. If the 5s are implemented, there is a 0.412 probability of having ES+.
Conversely, if 5s are not implemented properly, there is a 0.471 probability of having ES-. Finally, if DRFT+ is present, there is a 0.412 probability of having ES+. Conversely, if DRFT- is present, there is a 0.450 probability of having ES-.

Tabla 6. Sensitivity Analysis

Level		5S+	5S-	DRFT+	DRFT-
	Likelihood	0.143	0.143	0.143	0.168
DRFT +	0.143	& = 0.067 If = 0.471	& = 0.000 If = 0.000		
DRFT -	0.168	& = 0.017 If = 0.118	& = 0.084 If = 0.588		
ES+	0.176	& = 0.059 If = 0.412	& = 0.000 If = 0.000	& = 0.050 If = 0.353	& = 0.000 If = 0.000
ES-	0.126	& = 0.008 If = 0.059	& = 0.067 If = 0.471	& = 0.000 If = 0.000	& = 0.076 If = 0.450

5. Conclusions

The following conclusions can be reached according to the analysis shown in the structural equation model evaluated in Figure 2:

- The 5s are a facilitator to perform activities properly, i.e., 5s help to meet customer expectations regarding quality and delivery times since quick-fixing devices are frequently used, verification gauges are used on machines or workstations, and they are easily replaceable, and it is easier to replace a machine or equipment when it is malfunctioning. The above can be corroborated as 5s directly and positively affect DRFT with a value $\beta = 0.592$ and $P < 0.001$. When 5s increases its standard deviation by one unit, DRFT increases by 0.592 units.

- The 5s approach helps maquiladora firms improve firm productivity through cost reduction. That is, keeping areas clean, tidy and orderly frequently; if these methods are standardized and documented, if companies conduct audits to ensure that the work area is kept clean and tidy, companies can realize cost savings in production, product development, energy, inventory, scrap, rework and waste treatment since 5s has a direct and positive effect on economic sustainability with a size of $\beta = 0.304$ and $P < 0.001$ when 5s increases its standard deviation by one ES unit it does so by 0.304 units.

- Striving to perform activities right the first time guarantees economic sustainability in companies since it facilitates the reduction of costs associated with production, energy, inventory, rejects, rework and waste treatment. The above is affirmed because DRFT has a direct and positive effect on ES with a value of $\beta = 0.429$ and $P < 0.001$; when DRFT increases its standard deviation by one unit, ES does so by 0.429 units.

- Finally, 5s help in cost reduction since maintaining order and cleanliness within the work areas facilitates performing activities properly the first time, since there is an indirect effect of 5s on ES through DRFT with a value $\beta = 0.254$ and $P < 0.001$ that adds to the direct effect, there is a total effect of $\beta = 0.558$ and $P < 0.001$ of 5s on ES.

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