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Measuring Impact of Lean Manufacturing Tools for Continuous Improvement on Economic Sustainability

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Abstract. Using Lean Manufacturing (LM) tools in production processes is crucial for companies' economic, environmental, and social sustainability success. This study shows a structural equation model (SEM) that shows the relationship between LM Tools like Kaizen (KAI), Gemba (GEM), Value Stream Mapping (VSM) and Key Performance Indicator (KPI) with Economic Sustainability (ECS). Seven hypotheses were evaluated with data from 179 responses to a questionnaire about the Mexican maquiladora industry, showing that these variables are linked. At a 95% confidence level, the model was evaluated using the partial least squares method. The findings indicate that the relationships between KAI and GEM and KAI and VSM have the strongest relationship, followed by VSM and ECS; however, VSM has the strongest effect on ECS. Based on these findings, it is recommended that managers adopt a continuous improvement (KAI) approach based on working directly on the shop floor (GEM and VSM) to support their decisions regarding economic growth (ECS).

Keywords: Lean manufacturing, economic sustainability, structural equation model, quality, improvement

1. Introduction

Manufacturing organizations seek to be more effective and flexible to face globalization and high customer expectations; therefore, they implement strategies, methodologies and production philosophies in their production systems to achieve these objectives (Yadav et al. 2017).

One of the most important production philosophies is lean manufacturing (LM). The lean process was thoroughly described in the book "The Machine That Changed the World" and in a subsequent volume, Lean Thinking distilled these lean principles even further to five: 1. Identify value. 2. Map the value stream. 3. Create flow. 4. Establish pull. 5. Seek perfection (Womack et al. 1990, Womack and Jones 1997).

However, LM originates in the Toyota Production System (TPS), a viable method for making products because it is an effective tool for producing economic benefits. To achieve this purpose, the primary goal of the TPS is cost reduction or improvement of productivity. Cost reduction and productivity improvement are attained through eliminating wastes such as excessive inventory and workforce. Costs in the TPS include manufacturing costs, sales costs, administrative costs, and even capital costs (Monden 2011).

So, LM is one of the most used methodologies to reduce costs because it focuses on eliminating waste. Many authors indicate that LM offers benefits depending on the tool used; for example, García-Alcaraz et al. (2021) say that the Mexican Manufacturing Industry (MMI) gains benefits linked to quality. In contrast, Olaitan et al. (2019) indicated that LM allows a make-to-order production system, focusing only on producing what is already sold, reducing storage and inventory costs, facilitating the Just in Time (JIT) implementation and on-time deliveries (García-Alcaraz et al. 2015) a lean supply chain (Avelar-Sosa et al. 2014).

Also, Kumar and Kumar (2016) and Sahoo (2020) indicate that automotive companies in India obtain higher employee motivation and a sense of belonging by implementing LM. Moreover, García-Alcaraz et al. (2019a) indicated that human factors are indispensable in LM, as they handle machines, maneuver materials, comply with quality specifications, and minimize waste. Also, Gaikwad and Sunnapwar (2021) indicate that LM is associated with six sigma and green practices. So, a quality and sustainable program must integrate LM as the basis (Gaikwad and Sunnapwar 2020, Lokpriya and Vivek 2020).

These LM benefits are of interest to managers because they represent quality, customer satisfaction, and higher performance indices. For example, Driouach et al. (2019) associate LM with business growth rates, which are vital for companies to remain in the market. However, in order to obtain quality and performance, many upstream activities are required, and Tekin et al. (2019) mention that companies have had to use sustainable and flexible production methods and techniques that are cost-effective and less wasteful to meet customer demand expectations, which is achieved through Jidoka and Single-Minute Exchange of Die (SMED) by minimizing operator intervention in production processes to identify defects and speeding up changeover times.

Similarly, Díaz-Reza et al. (2016) refer to SMED as ensuring quality, material flow, and on-time deliveries that guarantee customer satisfaction. Even the benefits from LM are no longer purely industrial, as Yokoyama et al. (2019) report a systematic review of LM applications in administrative areas called Lean Office.

Other authors have focused on specific Lean Manufacturing Tools (LMT). As an example, García-Alcaraz et al. (2019b) analyzed Total Quality Management (TQM) and Human Resources (HR), which relate to the economic benefits of MMI. Costa et al. (2018) showed the relationship between LM and Six Sigma in the food industry, associating waste elimination and product quality for human consumption.

Today, the LM concept and its benefits have evolved toward sustainability. Kumar et al. (2022) define Sustainable LM as manufacturing products through less waste of natural resources and controlling negative environmental impact while transforming them. Furthermore, LM must impact sustainability in three dimensions: social, economic, and environmental, indicating that LM improves the employees' and society's safety and increases economic income. In other words, LM improves operational and economic performance by minimizing waste and has a social and environmental impact, with greater market share and trust from society due to the image generated by sustainable development programs (Kumar et al. 2022).

Another strategy transnational companies use to reduce costs is establishing subsidiaries in other countries with abundant resources. Specifically, in México, 5156 foreign companies have been established that are subsidiaries of others with headquarters in other countries, called maquiladoras. Of these, 484 were in Chihuahua, and 322 were established in Ciudad Juárez. Ciudad Juárez is also the city with the second-highest number of IMMEX companies, only surpassed by Tijuana with 596. However, Ciudad Juárez has the highest number of IMMEX jobs despite having fewer industries, with 340,438 total, surpassing Tijuana in Baja California, which has 260,399 IMMEX jobs (Juárez 2022).

Blyde (2014) indicates that the benefits of the maquiladora in México are provided through the IMMEX program (Manufacturing, Maquiladora, and Export Services Industry), as it allows the temporary and tariff-free import of all inputs, raw materials, and machinery for use in a productive process. In addition, maquiladoras in México have low labor costs compared to their country of origin and high skills (Luna-Garcini 2021).

There are many applications of LM in MMI; for example, Realyvásquez-Vargas et al. (2018) reported the PDCA cycle implementation to reduce soldering defects in electronic boards and their components in Tijuana. García-Alcaraz et al. (2022a) analyzed LMT focused on Continuous Improvement, Support Tools and Machinery and Equipment and related them to the economic, social, and environmental sustainability in Ciudad Juárez.

Also, Velázquez et al. (2006) studied the best sustainable practices in MMI, Munguía Vega et al. (2019) analyzed how human factors and ergonomics are related to sustainability. García-Alcaraz et al. (2022b) analyze how TPM, Jidoka, and Overall Equipment Effectiveness (OEE) relate to environmental, social, and economic sustainability. More recently, García-Alcaraz et al. (2022a) studied the impact of visual management as a means of communication and its impact on sustainability. Those reports indicate that LM and sustainability are linked in the MMI.

Few studies have related LM tools focused on continuous improvement. For example, Klein et al. (2022) focus their study on applying continuous improvement tools in higher education institutions to understand their sustainability. In contrast, Nawangsari (2022) focuses on improving people to obtain sustainability. Some other studies only perform qualitative analyses, so there is no statistical rigor to relate continuous improvement with the sustainable and economic benefits of the companies.

So, there are still several research opportunities in MMI where LMT associated with continuous improvement programs and sustainability must be analyzed. This study aims to relate the most common LMT related to continuous improvement that are applied in the MMI to improve Economic Sustainability (ECS) in companies established in Ciudad Juárez, México. Kaizen (KAI) is the LMT that promotes change and progress by improving all production processes. However, to know what to improve, KAI is supported by Gemba (GEM) to observe deviations in production lines done through the Value Stream Mapping (VSM), which forces the determination of metrics through the Key Performance Indicator (KPI). This study relates those LMTs to the MMI Economic Sustainability (ECS) through a Structural Equation Model (SEM) (Ahmad et al. 2017, Alexander and Iskandar 2023, Baby et al. 2018).

Relating the effects of these LMTs to the ECS of MMI will help managers in these companies know which activities are critical from those that are trivial and focus on using resources to perform them better and ensure their proper implementation.

By using these three LMTs, we can analyze the impact on the ECS; therefore, using a simple model facilitates the analysis of the information, generating a parsimonious model that is easy to interpret and understand. After this introduction, section two defines the tools analyzed and justifies a series of hypotheses raised in the SEM; section three reports the method used, section four reports all the findings and section five discuss the results. In section six, the conclusions and industrial and administrative implications are presented.

2. Literature Review and Hypothesis

2.1 Kaizen (KAI)

In this report, we refer to KAI as a philosophy, a continuous improvement system where small but constant improvements accumulate long-term benefits, such as reducing rejects, increasing competitiveness, facilitating management and organization of working hours, and integrating operators' experience in decision-making (Morales-Contreras et al. 2021).

Several KAI applications have been reported in the literature. For example, Morales-Contreras et al. (2021) applied it to solve operational problems in the service sector by reducing restaurant waste by up to 70%. Morell-Santandreu et al. (2020) used KAI to identify production areas to improve environmental sustainability, and Suárez Barraza et al. (2019) applied it to organize improvement groups in the packaging industry.

In this study, to measure the level of KAI implementation in the MMI, we evaluated whether there was supervision in different work areas, if there was a continuous improvement program, and if the production processes were modified based on it. In addition, we investigate whether the workers' suggestions are listened to and implemented and whether processes and machinery are improved or adapted to their needs.

2.2 Gemba (GEM)

GEM refers to the place where value is created; therefore, the most common usage is on the production lines. However, it can refer to any "site," such as construction sites, the sales floor in a retail store, or someplace where the service provider interacts with the customer, which is amenable to improvement (Cherrafi et al. 2019). Traditionally, a GEM walk is conducted on production lines to identify opportunities for improvement and waste reduction, demonstrating to operators that managers are interested in their work.

The GEM implementation has been studied in the industry. For example, García-Alcaraz et al. (2022a) presented an SEM that integrated the GEM and seven other LMTs, relating them to economic, social, and environmental sustainability. Gupta and Chandna (2019) show that GEM makes it easier to find areas to improve and favors creating visible, straightforward, and measurable improvement plans. In addition, Romero et al. (2020) explored GEM walks that embrace new digital technologies and identified their advantages and disadvantages.

GEM implementation in the MMI is measured by the involvement of production managers in the processes they oversee. It is evaluated by analyzing how it is involved with the workers who operate the machinery and obtaining feedback from them to implement improvement projects. The KAI-GEM combination can generate results through total enterprise participation as a basis for sustainability. The basic idea behind the KAI-GEM is that it allows everyone in an organization to work together to make minor, step-by-step improvements without spending much money.

GEM is part of a continuous improvement strategy. Its implementation is given in deliberate, discrete, and specific initiatives, allowing top management to identify problems in production processes. In other words, KAI-GEM helps organizations minimize risk while achieving sustainability, which allows the following hypothesis to be proposed:

H1. KAI directly and positively affects the implementation of GEM in the Ciudad Juárez MMI.

2.3 Value Stream Mapping (VSM)

VSM is the second principle of LM (Romero and Arce 2017), declared as Map the Value Stream by identifying and mapping the value stream separating activities that add value and do not add value, which is waste. In this part, we can consider non-value added but necessary, non-value added, and unnecessary.

According to Romero and Arce (2017), VSM is an LM technique that, through a graphical representation, allows for visualization and analysis and improves the production flow, indicating the production process parameters. VSM has spread to many industry sectors and supports the LM implementation as it indicates the system's current state.

VSM helps people learn more about how work systems provide value to customers and shows how the workflow looks from the customer's point of view. Therefore, it is a good strategy to set directions for better decision-making and work design because it allows for determining where waste comes from (Rajesh et al. 2019). When VSM is used, lower production costs, faster response times to the customer, and better-quality products are gained (Dhingra et al. 2019).

The VSM implementation has been widely

reported; for example, Chiarini (2014) used it to determine how production affects the environment, and Wang et al. (2012) indicated a reduction in lead time from nine to seven weeks using it in the aerospace industry. In addition, Mojarro-Magaña et al. (2018) recommend using VSM preliminarily before implementing LM.

The VSM implementation in the MMI is measured by graphs showing the available flow of materials, information, and operations. VSM identifies activities that do not generate value for the product and promotes their avoidance or elimination. VSM is part of continuous improvement programs because it helps managers to see how the production system works and determines which activities add value to the product and which do not (Lacerda et al. 2016), proposing possible improvements toward a future state with reduced waste.

The KAI and VSM combination allow for sustainable results. It involves all company members making incremental improvements, explicitly looking for the production process's most essential and non-value-adding task. In addition, VSM is part of LM and is a tool that allows senior management to identify areas that do not add value and seeks the reduction and elimination to achieve sustainability; thus, the following hypothesis is proposed:

H2. KAI directly and positively affects implementing VSM in the Ciudad Juárez MMI.

The GEM-VSM combination has been proven to have a positive outcome in implementing LM and companies' sustainability. The basic idea of GEM-VSM is that it seeks to achieve VSM development from the origin of the productive process, going to the areas where the product is being manufactured to avoid variations between the process documentation and the actual work, thus achieving an accurate VSM (Soltani et al. 2020). In addition, when a correct GEM supports VSM, it achieves improvements without large investments and obtains all partners' cooperation, facilitating top management's development of continuous improvement within the organization (Lorenzon dos Santos et al. 2019), so the following hypothesis is proposed:

H3. GEM directly and positively affects implementing VSM in the Ciudad Juárez MMI.

2.4 Key Performance Indicator (KPI)

KPIs are quantifiable measures that reflect a company's critical success factors and are applied to business units to support decision-making (Kibira et al. 2018). KPIs measure changes in a production process and must be clearly defined, accessible, and transparent; therefore, they identify poor performance and potential for improvement (Singh et al. 2021). That performance can refer to energy use, materials, control and operation, and maintenance, helping determine actions to improve, develop, prioritize, and implement changes based on the current measurement (Patil and Javalagi 2020).

The KPI implementation has been reported in the literature. For example, Flores et al. (2021) found that using KPI helps estimate maintenance and current status in troubleshooting and improving operating conditions in the water treatment industry. Demartini et al. (2018) studied the beverage supply chain and identified the best practices and use of KPIs to improve packaging and water consumption. Pérez-Domínguez et al. (2019) used KPIs to assess the visibility of LM projects and their impact on the performance of manufacturing companies.

To measure the implementation of KPIs in the MMI, we review if companies use indicators to measure performance, review metrics in preset periods and if assess the relevant factors for the company and show their use and dissemination. So, KPIs are achieved directly by visiting the productive area, observing its deviations, and establishing improvement objectives (Nastasiea and Mironeasa 2016). In other words, the GEM is the best way to obtain direct information from a productive system to know the current situation (Prasetyaningsih et al. 2020).

The GEM-KPI combination for sustainability provides accurate results when choosing indicators to improve within the production process. Using KPIs according to what can be improved in the productive area favors top management to obtain results efficiently, identify the current situation in the field, and achieve the sustainability of the process, so the following hypothesis is proposed:

H4. GEM directly and positively affects implementing KPI in the Ciudad Juárez MMI.

Based on Lacerda et al. (2016), Lean metrics are important for analyzing a production system's value stream and making decisions about it. By looking at KPIs and using these metrics in VSM, one can find and eliminate activities that do not add value. In other words, one of the objectives of VSM is to know in a quantifiable way the situation of the production system, which is done through KPIs.

The combination of VSM-KPI within sustainability can generate positive results by identifying areas that do not add value and their reduction or elimination. The basic idea of VSM-KPI is to positively impact the KPIs selected by the company, providing a VSM focused on the KPIs to be improved; this approach facilitates senior management to identify problems that, if solved, positively impact sustainability, so the following hypothesis is proposed:

H5. VSM has a direct and positive effect on KPI implementation in the Ciudad Juárez MMI.

2.5 Economic Sustainability (ECS)

ECS refers to practices that support economic growth in business without negatively affecting the community's social, environmental, and cultural aspects (Shafiq and Soratana 2020). Traditionally, the economic aspect has been considered the main reason in companies and involves indicators related to employment, sales growth, revenue stability, and profitability. However, business development must be sustainable and seek to meet current needs without compromising the capacity of future generations (Lehner and Harrer 2019).

ECS analysis has been widely reported; for example, Nascimento et al. (2019) recommend a circular economy model in the electronics industry, in which elements should be reinserted into the supply chain. Oliveira Neto et al. (2018) show eight actions to promote sustainability, such as increasing the efficiency of resource consumption and limiting resource consumption, considering their recovery rate. To measure the ECS level in the MMI, reduction in energy costs, rejects and rework, waste treatment, and administrative penalties for environmental errors, among others, were evaluated.

Serrano Lasa (2007) shows that putting VSM into place makes it possible to find waste and activities that do not add value to the product. This affects a company's income and, by extension, its ECS. Rajesh et al. (2019) also report a methodology that allows the preparation of a cost-VSM, where the integration of financial aspects is associated with the implementation of the methodology. However, the most evident relationship between VSM and economic aspects was observed in a study by Dhingra et al. (2019), who used it to reduce costs and improve quality.

The VSM-ECS relationship is reflected through the elimination or reduction of production activities that do not add value and for which the customer does not pay. The basic idea of the VSM-ECS relationship is that the focus of ECS is sought within VSM, making it easier for senior management to identify areas of opportunity that will have a positive impact on ECS, working together with different departments of the company and the following hypothesis is proposed:

H6. The VSM directly and positively affects the implementation of the ECS in the Ciudad Juárez MMI.

Obtaining metrics of the production system through KPIs allows companies to know the cost of waste and activities that do not add value to the product, which forces them to propose improvement projects (Fancello et al. 2018), and their execution must be focused on their reduction or elimination. Different studies associate KPIs with the costs of the productive system; for example, Leppla and Lemme (2015) focus on analyzing energy consumption indicators and costs; Prasad and Radhakrishna (2019) associate KPIs with maintenance costs and the cost of sustainable operations, and Johansson et al. (2020) with the cost of sustainable operations.

The relationship of KPI-ECS as a basis for sustainability is related to the search for improvements in the company's results, with a direct focus on the areas that generate an increase in economic, social, and environmental sustainability. The basic idea of KPI-ECS is that it involves the ECS within the KPIs to be improved, which provides senior management with a clear path to achieve sustainable goals and thus reduce economic, environmental, and social risks, so the following hypothesis is proposed:

H7. The KPI directly and positively affects the implementation of the ECS in the Ciudad Juárez MMI.

Figure 1 illustrates the relationships between the variables to distinguish the hypotheses established.

3. Methods

3.1 Development of the Questionnaire

Industry information is required to validate the above hypotheses, so a literature review is conducted to determine what research has already been done on GEM, KAI, KPI, VSM, and ECS, representing a rational validation. Items were found to identify the level of implementation of these LMTs, as well as the main indices associated with the ECS of the companies, which allows for building a preliminary version of a

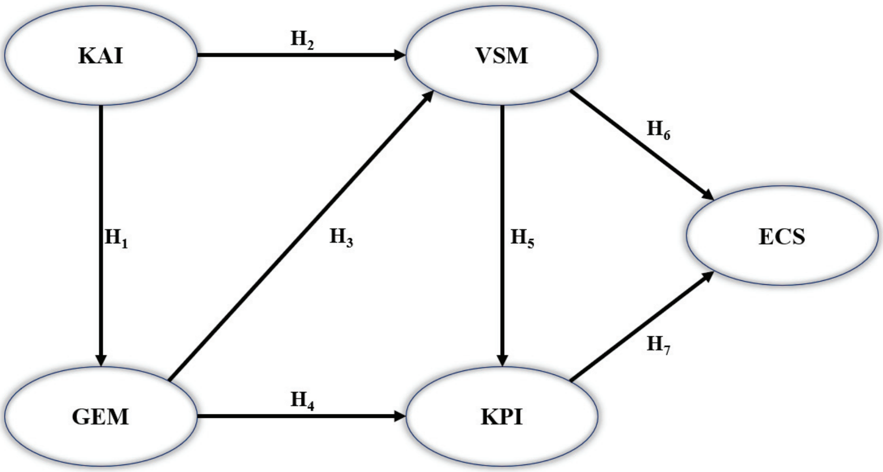

Figure 1 Proposed Model

questionnaire.

However, since no previous questionnaires regarding LMT and ECS were used on the MMI that entirely dealt with this issue, the questionnaire's first draft was validated by judges, having support from active managers and academics for a better fit to the MMI regional context. The final questionnaire comprised three sections: the first focused on demographic aspects such as gender, respondents' years of experience, number of employees, and industry sub-sector. The second section focuses on the LMT analyzed (KAI, GEM, VSM, and KPI), and the third section focuses on the ECS obtained.

The questionnaire used a five-point Likert scale. One means that the activity or benefit is not done or is not received; five means that it is always done or always received; and rarely, regularly, and almost always are used as intermediate values.

3.2 Application of the Questionnaire

The object of this study is the MMI, so the companies established in Ciudad Juárez in the state of Chihuahua were chosen to apply the questionnaire, and potential respondents were identified with the support of the regional IMMEX. However, because of the COVID-19 contingency, access to MMI was limited, so the questionnaire was placed on the Google Forms® platform. To move on, you had to answer all the questions so there were no missing values. From January 15, 2022, to May 15, 2022, respondents could still fill out the questionnaire on the platform.

Respondents had to work in the maquiladora industry and be part of a production or manufacturing department. This ensures that they know about LMT and its benefits. In addition, they must have had at least one year in their position and have led to at least two LM improvement projects.

Potential participants were emailed a link to the online survey, which asked them to participate. If no response was obtained after two weeks, a second email was sent as a reminder, and if the information was not obtained after three attempts, then that case was discarded.

3.3 Information Gathering and Debugging

On May 16, 2022, a file in Excel format was downloaded from the Google Forms® platform, which was then analyzed in SPSS v.25® software, where debugging operations were performed, such as:

- Duplicate cases were identified and discarded from future analyses.
- Non-committed respondents were identified by calculating the standard deviation of each case and discarding those with values lower than 0.5.
- Identify extreme values by standardizing each item and replacing those values greater than 4 in absolute value with the median.

3.4 Validation of Variables

In the model shown in Figure 1, the following indices were used to validate the five latent variables (Kock 2013):

- R-squared and adjusted R-squared to measure parametric predictive validity and values above 0.2 are accepted.
- Q-squared was used to measure the validity of the parameters, and positive values such as R-squared were accepted.
- Cronbach's alpha and the composite reliability index were used to measure internal validity and values above 0.7 were accepted.
- The variance inflation index (VIF) was used to measure the collinearity between items.
- The average variance extracted (AVE) measures convergent validity, and values greater than 0.5 are accepted.

It is essential to mention that the estimation of indices, such as Cronbach's alpha and VIF, is performed iteratively because eliminating some items helps improve. However, other validation indices are reported as supplementary material, such as T ratios for loadings, Dijkstra rho, model fit and quality indices (extended set), Reliabilities (extended set) and Discriminant validity coefficients (extended set).

3.5 Descriptive Analysis of the Sample and Items

A descriptive analysis was performed using the cleaned database in SPSS® statistical software owing to its wide acceptance, user-friendly interface, and use in scientific reports (Avelar 2018) and (García-Alcaraz et al. 2015). The demographic information obtained was analyzed using cross-tabulations to describe the sample.

The median of each item was found to be a measure of the central tendency. High values indicate that activities or benefits are always done or received, while low values indicate the opposite. Interquartile range (IQR) was used to measure the spread of each item. A high value meant that respondents were not in agreement with the median value of an item, while a low value meant that they were.

3.6 Structural Equation Model (SEM)

3.6.1 Model Validation

To validate the hypotheses in Figure 1, we used the structural equation modeling (SEM) methodology with a partial least squares (PLS) approach in WarpPLS 7.0® software, which is recommended for small samples; data were obtained on an ordinal scale, or the variables lacked a normal distribution (Kock 2018). Before interpreting the PLS-SEM results, the model efficiency indices were evaluated at a 95% confidence level. (Kock 2021):

1. The average path coefficient (APC) was used to measure the statistical significance of the regression parameters, and the associated p-value was less than 0.05.
2. The average R-squared (ARS) and average adjusted R-squared (AARS) measure the model's predictive validity, and the associated p-value should be less than 0.05.
3. The average block VIF (AVIF) and average full collinearity VIF (AFVIF) were used to measure collinearity and values of less than five were accepted.
4. The Tenenhaus Good of Fitness (GoF) measures the data fit to the model and must be bigger than 0.36.

3.6.2 Direct Effects - Validation of Hypotheses

To test the hypotheses in Figure 1, we used a standardized regression parameter B to measure the direct effects between latent variables and tested the null hypothesis H0: $B = 0$ versus the alternative hypothesis H1: B not equal to 0 with 95% confidence (Kock 2021). If, through the hypothesis test, it is concluded that B not equal to 0, there is statistical evidence to state a relationship between the variables analyzed, regardless of the sign.

In addition, for each direct effect, the effect size (ES) measures how much the independent variable explains the change in the dependent variable. The sum of all ES in the dependent variable equals the value of $R2$.

3.6.3 The Sum of Indirect and Total Effects

Indirect effects between variables are caused by third variables called "mediators". There must be at least one mediator for two or more segments, and there may be more than one in a relationship. This study only provides the sum of the indirect effects and the p-value that goes with it. Finally, we report the total effects, which are the sum of the direct and indirect effects for each relationship we examined, as well as the ES and p-value for each effect.

3.7 Sensitivity Analysis

The WarpPLS v.8.0 software reports standardized indices that allow sensitivity analysis based on probabilities to determine scenarios of occurrence of the latent variables (Kock 2021). In this case, scenarios are analyzed when the variables have high occurrence probabilities, represented when the standardized variable is greater than or equal to one P(Z greater than or equal to 1). In contrast, the standardized variable occurs in a low scenario when it is less than or equal to minus 1 P(Z less than or equal to –1). There were three calculated probabilities.

1. Probability for a variable occurring in isolation at high and low levels.
2. The joint probability of variables occurring in any combination of scenarios.
3. The conditional probability of the dependent variable occurring in any scenario, given that the independent variable has occurred.

4. Results

4.1 Descriptive Analysis of the Sample

After cleaning the database, 179 responses from different maquiladora companies in Ciudad Juárez, México, were valid, but we sent 685 e-mails, representing a response rate of 26.13%. The descriptive analysis is shown in Table 1,

Table 1 Industry Sector and Job Position

Industrial Sector / Job Title	Manager	Engineer	Supervisor	Technician	Another	Total(%)
Automotive	12	22	12	14	10	39.11
Aeronautics	-	2	1	-	-	1.68
Electric	1	3	3	-	-	3.91
Electronics	2	11	7	3	1	13.41
Logistics	-	5	2	1	1	5.03
Machining	1	3	2	2	2	5.59
Medical	3	4	5	3	5	11.17
Rubber and plastics	-	4	1	1	-	3.35
Textiles and clothing	-	2	-	-	-	1.12
Another	2	7	4	4	11	15.64
Total(%)	11.73	35.20	20.67	15.64	16.76	100

Table 2 Years of Experience

Sex / Experience	0-1	1-2	2-5	5-10	More than 10	Total(%)
Female	8	9	33	13	15	43.58
Male	2	18	40	21	20	56.42
Total(%)	5.59	15.08	40.78	18.99	19.55	100

which shows the industrial sector and respondent's position. The automotive industry represents 39.11% of the participation, while the electronics and medical industry sectors represent 24.58% and 36.31%, respectively. Further, regarding job positions, engineers accounted for 35.20%, followed by supervisors, who accounted for 20.67%.

Table 2 shows the years in their current job position and their gender. According to the results, 40.78% of the respondents had between two and five years of experience, followed by 19.55% with more than ten years and 18.99% with five to ten years. Females participated in 43.58%, while males participated in 56.42%.

4.2 Descriptive Analysis of the Items

Table 3 shows the latent variables' median value (second column) and interquartile range (third column). All variables have medians of 4.0 or higher, meaning respondents think that the expected benefits are realized or obtained at least always.

4.3 Validation of Variables

The variables were statistically validated, and Table 4 summarizes the final values, indicating that they all met the cut-off values established in the indices indicated in the last column.

4.4 Structural Equation Model (SEM)

4.4.1 Model Validation

Given that the latent variables meet the validation indices, they were integrated into the model, and Table 5 shows the model's efficiency indices. The cut-off values established in the last column are met, indicating that the model has sufficient predictive validity, without collinearity problems, and with a good fit of the data.

Table 3 Descriptive Analysis of the Items

Item	Medium	Interquartile Range
KAI		
During the day, do they take time in your work area?	4.02	1.570
Do they continually modify the processes in your production area?	4.09	1.589
Have they implemented improvements in the processes with which you have contact?	4.30	1.343
Annual percentage scraps show a declining trend.	4.00	1.711
Labor productivity shows a rising trend over time.	4.12	1.552
GEM		
Do managers ask questions about how the process works?	4.37	1.289
Do you ask how the machinery operates and ask the opinion of the operators to improve the process?	4.37	1.390
Do they make continuous improvements according to the proposals of the workers?	4.31	1.369
VSM		
Maps indicating the flow of materials, information, and operations, among others, are available.	4.20	1.628
Identifying activities that do not generate value for the product motivates eliminating them.	4.11	1.690
A flow map accurately describes the activities to be performed, which is analyzed to create a target flow map.	4.25	1.385
KPI		
The company has metrics to measure its performance.	4.48	1.110
The metrics are reviewed at pre-established periods.	4.39	1.229
The metrics evaluate the relevant or critical factors for the company.	4.44	1.162
ECS		
Decrease in energy costs.	4.35	1.255
Reduced costs of rejects and rework.	4.28	1.345
Decrease in waste treatment costs.	4.34	1.281
Reduction of administrative penalties for environmental mishaps.	4.38	1.290

Table 4 Validation of Latent Variables of LM Applied in the Questionnaire

Indexes	KAI	GEM	VSM	KPI	ECS	Best if
R2		0.376	0.512	0.303	0.339	≥ 0.2
R2 adjusted		0.372	0.506	0.295	0.332	≥0.2
Composite Reliability	0.889	0.931	0.925	0.913	0.905	≥0.7
Cronbach's Alpha	0.844	0.889	0.877	0.856	0.859	≥0.7
Average variance extracted	0.617	0.818	0.804	0.777	0.704	≥0.5
Collinearity (VIF)	2.152	1.820	2.082	1.425	1.439	≤3.3
Q2		0.374	0.512	0.304	0.337	≥0.2

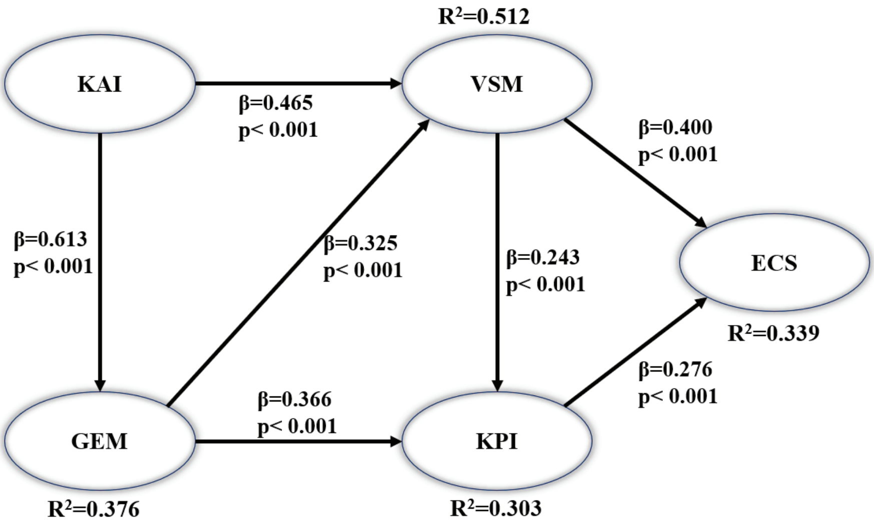

Figure 2 Model Evaluated

Table 5 Model Efficiency Indices

Index	Results	Best if
Average path coefficient (APC)	0.384	p<0.001
Average *R*2 (ARS)	0.382	p<0.001
Average adjusted *R*2	0.376	p<0.001
Average Block VIF (AVIF)	1.512	≤3.3
Average full collinearity VIF (AFVIF)	1.783	≤3.3
Tenenhaus GoF (GoF)	0.533	≥0.36

Figure 2 shows the SEM results. In general terms, the *p*-value is less than 0.001 for all *B* associated with the relationships, which indicates that they are statistically significant at the 99% confidence level. The *R*2 values for the dependent variables are also shown, which means that in this model, ECS is explained by 33.9% of its variance, whereas GEM is explained by 37.6%, VSM by 51.2%, and KPI by 30.3%.

4.4.2 Validation of Hypotheses - Direct Effects

Table 6 summarizes the direct effects. It shows the established hypothesis, the relationship between the variables, the p-value, and the decision. Based on these results, all relationships between the variables should be accepted. For example, for H1, there is enough statistical evidence to say that KAI has a direct and positive effect on GEM implementation because when KAI's standard deviation increases by one unit, GEM increases by 0.613 units.

Table 6 Summary of Tested Hypotheses

Hi	Relation	B (p-value)	Decision
H1	KAI→GEM	0.613 (<0.001)	Accept
H2	KAI→VSM	0.465 (<0.001)	Accept
H3	GEM→VSM	0.325 (<0.001)	Accept
H4	GEM→KPI	0.366 (<0.001)	Accept
H5	VSM→KPI	0.243 (<0.001)	Accept
H6	VSM→ECS	0.400 (<0.001)	Accept
H7	KPI→ECS	0.276 (<0.001)	Accept

4.4.3 The Sum of Indirect and Total Effects

Table 7 summarizes the six indirect effects of the variables within the model, indicating their magnitude, the p-value associated and the ES. Four are statistically significant, whereas two are not (VSM→ECS and GEM→KPI).

Table 8 lists the total effects. Although the sum of the indirect effects is insignificant in some relationships, the total effect is always significant.

4.5 Sensitivity Analysis

Table 9 shows the sensitivity analysis for all relationships in the model. The columns represent independent variables, and the rows are dependent variables. In this case, the "+" sign stands for high-level scenarios, and the "–" sign stands for low-level scenarios. For example, the chance of getting a GEM+ after a KAI+ is 0.622, which means that good KAI results guarantee that good GEM practices will occur 62.2 percent of the time. However, low levels of KAI implementation also led to low levels of GEM, with a conditional probability of 0.556, which is 55.6% and is a risk for managers. The "Discussions of results" chapter shows a more in-depth analysis.

5. Discussion of Results

This research assumed that KAI is a tool that serves as the basis for improvement programs. However, it is supported by others, such as GEM, VSM, and KPI, to improve ECS, which have been related to seven hypotheses. The following is discussed based on the SEM and the sensitivity analysis of possible scenarios (high and low).

H1. KAI has a direct and positive effect on GEM in MMI because when the standard deviation of the first variable increases by one unit, the standard deviation of the second variable increases by 0.613 units. This result is similar to Cherrafi et al. (2019), who showed that KAI and GEM effectively minimize resource consumption and positively impact operational performance. It indicates that if managers focus their resources on improvement directly on the production lines, the benefits will be greater, identifying problems in real-time.

KAI+ directly favors the occurrence of GEM+ with a probability of 0.649 and is unrelated to GEM-, indicating that managers' efforts in the MMI to implement KAI+ always yield results. Additionally, KAI- was observed to be a risk, as it encouraged the occurrence of GEM- at 0.556. However, KAI- is not associated with GEM+; therefore, managers in the MMI will not benefit from GEM if KAI is low.

H2. KAI has a direct and positive effect on VSM in MMI because when the standard deviation of KAI increased by one unit, the standard deviation of VSM increased by 0.465 units. Our findings agree with Kumar et al. (2018), who state that using KAI and VSM can empower small and medium enterprises in In-

Table 7 Sum of Indirect Effects

	KAI		GEM		VSM	
VSM	B=0.199 ES=0.133	(P<0.001)				
KPI	B=0.386 ES=0.174	(P<0.001)	B=0.079 ES=0.041	(P<0.065)		
ECS	B=0.372 ES=0.171	(P<0.001)	B=0.253 ES=0.097	(P<0.001)	B=0.0679 ES=0.035	(P<0.100)

Table 8 Total Effects

To / From	KAI		GEM		VSM		KPI	
GEM	B=0.613 ES=0.376	(p<0.001)						
VSM	B=0.664 ES=0.445	(p<0.001)	B=0.325 ES=0.200	(p<0.001)				
KPI	B=0.386 ES=0.174	(p<0.001)	B=0.445 ES=0.230	(p<0.001)	B=0.243 ES=0.114	(p<0.001)		
ECS	B=0.372 ES=0.171	(p<0.001)	B=0.253 ES=0.097	(p<0.001)	B=0.467 ES=0.247	(p<0.001)	B=0.276 ES=0.127	(p<0.001)

Table 9 Sensitivity Analysis

Level		KAI+	KAI-	GEM+	GEM-	VSM+	VSM-	KPI+	KPI-
	Probs	0.207	0.151	0.302	0.151	0.251	0.190	0.358	0.128
GEM+	0.302	&=0.128 if=0.622	&=0.006 if=0.037	-	-	-	-	-	-
GEM-	0.151	&=0.000 if=0.000	&=0.084 if=0.556	-	-	-	-	-	-
VSM+	0.251	&=0.134 if=0.649	&=0.000 if=0.000	&=0.168 if=0.556	&=0.011 if=0.074	-	-	-	-
VSM-	0.190	&=0.000 if=0.000	&=0.101 if=0.667	&=0.017 if=0.056	&=0.095 if=0.630	-	-	-	-
KPI+	0.358	&=0.140 if=0.676	&=0.028 if=0.185	&=0.201 if=0.667	&=0.028 if=0.185	&=0.156 if=0.622	&=0.034 if=0.176	-	-
KPI-	0.128	&=0.006 if=0.027	&=0.056 if=0.370	&=0.006 if=0.019	&=0.045 if=0.296	&=0.011 if=0.044	&=0.050 if=0.265	-	-
ECS+	0.251	&=0.117 if=0.568	&=0.022 if=0.148	&=0.145 if=0.481	&=0.017 if=0.111	&=0.140 if=0.556	&=0.022 if=0.118	&=0.134 if=0.375	&=0.017 if=0.130
ECS-	0.134	&=0.000 if=0.000	&=0.050 if=0.333	&=0.011 if=0.037	&=0.396 if=0.259	&=0.006 if=0.022	&=0.067 if=0.353	&=0.022 if=0.063	&=0.034 if=0.261

dia. For the MMI, it means that improvement programs can be beneficial for better results in the VSM.

KAI+ directly favors the occurrence of VSM+ with a probability of 0.622 and is unrelated to VSM- indicating that managers' efforts in the MMI to implement KAI+ always yield results. Additionally, KAI- was observed to be a risk, as it encouraged the occurrence of VSM- at 0.667, respectively. However, KAI- is not associated with VSM+; therefore, managers in the MMI will not benefit from VSM if KAI is low.

H3. GEM has a direct and positive effect on VSM in MMI since when the standard deviation of GEM increases by one unit, VSM goes up by 0.325 units. These results agree with Seth et al. (2017), who indicated that using the GEM walk is the basis for developing the VSM, where activities that do not add value are identified. Therefore, to obtain VSM, top management in MMI must motivate GEM walks as a primary requirement to strengthen the impact on the production process and thus obtain better results in eliminating or reducing activities that do not add value.

GEM+ favored the occurrence of VSM+ with probabilities of 0.556. In addition, it has a very low association with VSM-, which indicates that the walks and tours through the production lines always allow identifying areas of opportunity so that the time invested in this activity always offers benefits. Likewise, GEM- favors the occurrence of VSM- with a probability of 0.630 and is poorly associated with VSM+, representing a risk, indicating that it will not be possible to identify problems.

H4. GEM directly and positively affects KPI in MMI since when the former variable increases its standard deviation by one unit, the latter goes up by 0.366 units. This result coincides with Rodrigues et al. (2019), who include GEM walks within the LMT implementation to follow up on KPIs and conclude that top management is more involved in knowing the productive area and its metrics and making better decisions. It means that if managers in MMI spend more time improving the production lines, the goals and metrics will be achieved efficiently, allowing the selection of essential indicators to monitor the production process.

GEM+ favored the occurrence of KPI+ directly, with probabilities of 0.667. In addition, it has a very low association with KPI-, which indicates that the walks and tours through the production lines always allow the acquisition of parameters to improve the process so that the time invested in this activity always offers benefits. Likewise, GEM- favors the occurrence of KPI- with a probability of 0.296 and is poorly associated with KPI+, representing a risk, indicating that it is impossible to establish the appropriate parameters to improve the process.

H5. VSM has a direct and positive effect on KPI in MMI since when the standard deviation of the first variable increases by one unit, the second variable goes up by 0.243 units. These results are consistent with Zhang et al. (2020), who evaluated a production process's current and future performance in Canada by combining KPIs and VSM. Therefore, if MMI managers seek to impact their KPIs, they must implement VSM at a high level based on eliminating or reducing activities that do not add value to the KPIs required.

VSM+ favors the occurrence of KPI+ with probabilities of 0.622 and is associated very little with KPI-. It indicates that knowing the current state of the production system allows for identifying the main parameters that govern it and improving them. However, VSM- favors the occurrence of KPI- by 0.265, indicating that poor execution of VSM could fail to identify the correct parameters of the MMI.

H6. VSM has a direct and positive effect on ECS in the MMI because when the first variable increases its standard deviation by one unit, the second goes up by 0.400 units. This result coincides with Guo et al. (2019), who applied a VSM model combined with DMAIC in an air-conditioning assembly line to verify the feasibility, increasing efficiency and economic benefits. The above indicates that managers in MMI need to implement VSM to achieve ECS since this variable has the greatest impact on increasing economic benefits.

VSM+ favors the occurrence of ECS+ with probabilities of 0.556 and is associated very little with ECS-. It indicates that knowing the current state of the production system allows for more economic income. However, VSM- favors the occurrence of ECS- by 0.353, indicating that poor execution of VSM could fail to reduce the revenues of the MMI.

H7. KPI has a direct and positive effect on ECS in MMI because when the standard deviation of the first variable increases by one unit, the second variable increases by 0.276 units. Our finding coincides with that of Moktadir et al. (2021), who reported on the top ten KPIs for the footwear industry and related sustainability to compliance with these indicators. MMI managers must select the most important KPI to ensure the best ECS.

Finally, KPI+ favors the occurrence of ECS+ with a probability of 0.375 and is weakly related to ECS-, whereas KPI- favors the occurrence of ECS- with a probability of 0.261 and is weakly associated with KPI-. It indicates that identifying the main parameters that govern the productive processes favors the financial income of MMI.

6. Conclusion, Limitations and Future Research

This study allows quantification and statistical validation of the relationships between KAI, GEM, VSM, KPI, and ECS in MMI using information from Ciudad Juárez, and it is concluded that LMTs focused on the improvement of production processes have always generated ECS.

Specifically, it is concluded that the continuous improvement programs in the MMI through the KAI favor proper GEM walk implementation through the production lines. In addition, they facilitate a better understanding of the state in which these are through VSM because the best parameters (KPI) that govern them in real time are identified, representing better economic income (ECS). The findings in this study allow us to conclude that the LMTs implementation should be done from a systems approach since all of them are interrelated, and the success of some depends on the success of others.

The above is demonstrated since the poor implementation of these continuous improvement programs or a poorly implemented KAI is a risk for GEM walk implementation, making it difficult for managers in the MMI to have information and knowledge of real problems in the production lines (VSM). This can lead them to use wrong parameters or indexes (KPI) and make wrong decisions, putting financial income (ECS) at risk.

However, this study was conducted during the COVID-19 pandemic, with several restrictions to access industrial maquiladoras in Ciudad Juárez and can be a limitation. Also, only four LMTs were analyzed due to parsimony in the SEM, and the following are the things that will be done in future studies:

- This report has an $R2$ equal to 0.40, so in future studies, we can add more LMTs to increase this metric so that by using new models, we can obtain more information and be more accurate.
- Continue surveys and evaluations by 2023, increase the sample size, and analyze the implementation of LMT with Environmental Sustainability since Mexican regulations are stringent. The survey could be applied to other cities and Mexican states to compare the results since the cultural approach must differ depending on where the maquiladoras are from.
- The survey comprises 25 LMT and three pillars of sustainability (environmental, social, and economic); therefore, the authors will conduct further analysis with different tools and effects.

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Data Availability

The datasets generated during and/or analysed during the current study are available in the Lean Manufacturing Tools Applied to Continuous Improvement and its Impact on Economic Sustainability repository, https://data.mendeley.com/datasets/c6cjpb4yxs/1.

Conflicts of Interest

The authors declare no conflict of interest.

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