Significance of Total Quality Management and Doing Right First Time in Promoting Environmental Sustainability

Importancia de la Gestión de la Calidad Total y de Hacer las Cosas Bien a la Primera Vez para Promover la Sostenibilidad Medioambiental

Importância da Gestão da Qualidade Total e de Fazer as Coisas Certas na Primeira Vez para Promover a Sustentabilidade Ambiental

Luis Javier Márquez Figueroa[1], *Jorge Luis García Alcaraz* [2,*], *José Roberto Diaz Reza*[3]
Jesús Alfonso Gil López[4]

Recibido: 29/04/2024 Aceptado: 09/10/2024

Summary. - This article reports a study that analyzes a structural equation model that relates lean manufacturing tools associated with quality control to the benefits obtained in the maquiladora industry of Ciudad Juarez (Mexico). A questionnaire was designed and administered to the regional industry to obtain information about the implementation levels of Total Quality Management, Doing Right First Time, and environmental sustainability. The variables were related through three hypotheses, validated by empirical information from 176 responses to the questionnaire. The results indicate that the relationship between Total Quality Management and Doing Right First Time is strongest in the model. Sufficient statistical evidence affirms that these tools influence environmental sustainability in the Mexican maquiladora industry. Therefore, it is recommended that top management focus their efforts on quality control to guarantee environmental sustainability, focusing on production systems that make quality products for the first time and reduce waste in the process.

Keywords: Total Quality Management; Environmental Sustainability; Structural Equation Model; Quality, Improvement.

(*) Corresponding Author.
[1] PhD Student, Department of Electric Engineering and Computer Science, Universidad Autónoma de Ciudad Juárez (Mexico). al216623@alumnos.uacj.mx , ORCID iD: https://orcid.org/0000-0002-8285-1911
[2] Full time professor, Department of Industrial Engineering and Manufacturing, Universidad Autónoma de Ciudad Juárez (Mexico), jorge.garcia@uacj.mx,ORCID iD: https://orcid.org/0000-0002-7092-6963
[3] Postdoctoral Student, Department of Electric Engineering and Computer Science, Universidad Autónoma de Ciudad Juárez (Mexico), inv.pos07@uacj.mx , ORCID iD: https://orcid.org/0000-0002-0099-9171
[4] Full time profesor, Departamento de Economía y Empresa, Universidad de La Rioja (España), alfonso.gil@unirioja.es , ORCID iD: https://orcid.org/0000-0002-8180-4769

Memoria Investigaciones en Ingeniería, núm. 27 (2024). pp. 76-90
https://doi.org/10.36561/ING.27.6
ISSN 2301-1092 • ISSN (en línea) 2301-1106 – Universidad de Montevideo, Uruguay

Resumen. - *Este artículo reporta un estudio que analiza un modelo de ecuaciones estructurales que relaciona las herramientas de manufactura esbelta asociadas al control de calidad con los beneficios obtenidos en la industria maquiladora de Ciudad Juárez (México). Se diseñó y aplicó un cuestionario a la industria regional para obtener información sobre los niveles de implementación de la Gestión de la Calidad Total, el Hacerlo Bien a la Primera y la sustentabilidad ambiental. Las variables se relacionaron a través de tres hipótesis validadas con información empírica de 176 respuestas al cuestionario. Los resultados indican que la relación entre Gestión de la Calidad Total y Hacerlo Bien a la Primera es la más fuerte del modelo. Se concluyó que existe suficiente evidencia estadística para afirmar que estas herramientas influyen en la sustentabilidad ambiental de las industrias maquiladoras mexicanas. Por lo tanto, se recomienda que la alta dirección enfoque sus esfuerzos en el Control de Calidad para garantizar la sustentabilidad ambiental, enfocándose en sistemas de producción que hagan productos de calidad a la primera, reduciendo el desperdicio en el proceso.*

Palabras clave: *Gestión de la Calidad Total; Sustentabilidad Ambiental; Modelo de Ecuaciones Estructurales; Calidad; Mejora.*

Resumo. - *Este artigo relata um estudo que analisa um modelo de equações estruturais que relaciona as ferramentas de manufatura enxuta associadas ao controle de qualidade com os benefícios obtidos na indústria maquilhadora de Ciudad Juárez (México). Foi elaborado e aplicado um questionário à indústria regional para obter informações sobre os níveis de implementação da Gestão da Qualidade Total, Fazer Certo da Primeira Vez e sustentabilidade ambiental. As variáveis foram relacionadas por meio de três hipóteses validadas com informações empíricas provenientes de 176 respostas ao questionário. Os resultados indicam que a relação entre Gestão da Qualidade Total e Fazer Certo na Primeira Vez é a mais forte no modelo. Concluiuse que existem evidências estatísticas suficientes para afirmar que estas ferramentas influenciam a sustentabilidade ambiental das indústrias maquilhadoras mexicanas. Portanto, recomenda-se que a alta administração concentre seus esforços no Controle de Qualidade para garantir a sustentabilidade ambiental, focando em sistemas de produção que produzam produtos de qualidade desde a primeira vez, reduzindo desperdícios no processo.*

Palavras-chave: *Gestão da Qualidade Total; Sustentabilidade Ambiental; Modelo de Equações Estruturais; Qualidade, Melhoria.*

1. Introduction. - Lean Manufacturing (LM) eliminates non-value-adding activities and processes to improve efficiency, waste reduction, and product quality while reducing time, resources, and prices [1].
Lean manufacturing uses multiple tools to improve production line consistency, quality, problem-solving, and human use [2]. These techniques decrease waste and increase product quality, making LM environmentally, economically, and socially sustainable.

Some of the essential LM tools are related to quality assurance, including Total Quality Management (TQM), Doing Right First Time (DRFT), Kaizen, 5Whys, and root cause analysis [3]. These tools seek to improve a company's products and services and satisfy customers. TQM also emphasizes participative management, customer focus, teamwork, continual training, and measuring and analyzing results to find new ways to improve.
TQM improves product quality, customer happiness, order rejection, and waste from errors and defects in the manufacturing lines. If certified, TQM improves process management, production efficiency, and international recognition [4]. Employee morale and belonging improve while creating a culture of excellence, productivity, and transformation [5].

The Doing Right First Time (DRFT) program, based on Crosby's zero defects and no-cost quality concept, helps managers achieve TQM benefits by preventing errors and executing procedures and jobs right the first time [6].
DRFT must identify essential processes, improve staff training and coaching, identify and remove quality problems, set standards, and encourage measurement and analysis [7]. Companies with ISO 9001 and ISO/TS 16949 certifications benefit from the TQM and DRFT. However, these norms cannot ensure quality [8]. The waste-related benefits of DRFT include the fact that there are no faulty items to reprocess, which increases labor, scrap, and energy costs significantly. For example, ReVelle [9] reported a high cost of non-DRFT production. Wang Wang, et al. [6] found that hospitality clients did not return after an error. Parker, et al. [10] employed DRFT in healthcare to obtain an accurate diagnosis.

LM has improved quality and sustainability. For example, García-Alcaraz, et al. [2] found that LM deployment minimizes environmental consequences by removing barriers. Kalyar, et al. [11] linked LM to Pakistani enterprises' economic and environmental sustainability.

Several studies have linked TQM with sustainability. For example, Zairi [12] suggested analyzing the TQM sustainability paradigm, whereas Ho [13] suggested integrating them. Many managers need to be convinced of TQM's sustainability link. However, Tan, et al. [14] provided several engineering-based responses that management could grasp. When applied to DRFT, TQM has been shown to reduce waste, rework, and improve environmental sustainability. For example, Green, et al. [15] stated that this relationship is direct and reinforced by a good supply chain and JIT, where suppliers are key.

UK, Malaysia, India, and Portugal have investigated TQM, DRFT, and environmental sustainability. However, only one Mexican study has examined sustainability as a variable encompassing social, environmental, and economic factors [16]. However, the Mexican Manufacturing Industry (MMI) has 5158 national maquiladoras, 485 in Chihuahua State and 323 in Ciudad Juárez; therefore, it is important to apply quality-focused tools to obtain positive environmental results, since Ciudad Juárez is among the cities with the highest number of maquiladora companies and represents a large percentage of the number of jobs registered in the city [17]. A maquiladora is a Mexican subsidiary of a foreign corporation that imports raw materials and exports all goods.

This study used a structural equation model (SEM) to analyze the implementation of these three latent variables in a questionnaire for the maquiladora industry in Ciudad Juarez, Mexico. It aims to advance this field and to better understand the relationship between TQM, DRFT, and environmental sustainability. This study shows decision-makers how these variables interact directly and indirectly.

The literature review must fully explain the application of DRFT and TQM as tools related to ENS. Therefore, this study sought to expand the relationship between these quality tools and their environmental impacts.
The remainder of this paper is organized as follows: Section two reviews the literature and explains the hypotheses.

Section 3 presents the approach for attaining the goal, Section 4 discusses the outcomes, and Section 5 presents the conclusions and future work.

2. Literature Review and Hypothesis. -

2.1. Total Quality Management (TQM). - The need for quality and competitive performance has spawned TQM. Texas Instruments, Xerox, IBM, and Motorola used TQM. The Malcolm Baldrige Award, European Foundation for Quality Management, and Deming Award recognize firms implementing TQM, encompassing quality excellence [18]. However, TQM uses numerous methods to ensure product quality.

2.2. Doing Right First Time (DRFT). - DRFT stresses the correctness of the production process and identifies human error concerns to suggest improvements. Crosby created a DRFT and zero-fault motto. DRFT is used in medical, healthcare, and Industry 4.0 manufacturing to reduce waste and accidents [8].
Participating in quality programs and achieving zero faults can help TQM-DRFT attain sustainability. Combining TQM-DRFT helps firms reduce sustainability risks, allowing us to propose the following hypotheses:
H_1. TQM directly and positively affects the implementation of DRFT in MMI.

2.3. Environmental sustainability (ENS). - Previous research has shown that sustainability involves environmental, social, and economic concerns. For example, Caldera, et al. [18] provided a paradigm for SMEs to use LM and achieve business sustainability. Also, de Sousa Jabbour, et al. [19] found that internal and external TQM elements affect environmental and social performance. Green manufacturing systems, information technology, and greenhouse gas reduction are valuable enterprise investments.

With the push toward sustainability, firms are going green. This requires external change and government incentives for SMEs. Henao, et al. [20] says LMs promote internal green efforts. Other research has shown that LM and green practices differ fundamentally, affecting performance. These contradictions can be avoided by analyzing LM as a philosophy rather than a practical performance impact.

TQM-ENS reduces environmental effects by improving energy efficiency by minimizing defects and reworking. TQM-ENS focuses on ENS during TQM implementation to find improvements in environmental impact, allowing us to suggest the following hypothesis:
H_2. TQM directly and positively affects ENS implementation in MMI.

As a basis for sustainability, DRFT-ENS helps the industry produce quality products for the first time, which improves machinery use, makes production more efficient, and avoids sending products to landfills or reprocessing them. If management implements DRFT in LM programs, sustainability goals can be met. Thus, we propose the following hypotheses:
H_3. DRFT directly and positively affects the implementation of ENS in MMI.

To distinguish between the different hypotheses, Figure 1 shows the relationships between variables.

3. Methods. -

3.1. Application of the questionnaire. - This study examined MMI in Ciudad Juarez, Mexico, and the Manufacturing, Maquiladora, and Export Services Industry suggested possible responders. Due to COVID-19 constraints, the questionnaire was uploaded to Google Forms. Workers in the maquiladora and production and manufacturing departments were eligible.

Respondents had to have led two LM-based improvement projects for at least one year in their jobs. If no answer was received, a reminder followed the invitation email. The questionnaire ran from June 12 to September 12, 2022, and cases were rejected after two attempts at not obtaining information.

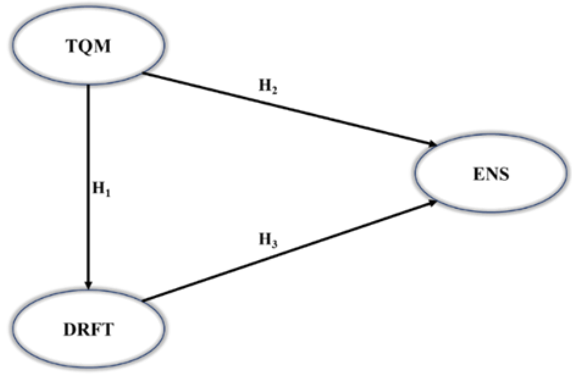

Figure I.- Proposed model.

3.2. Information gathering and debugging. - On September 12, 2022, Google Forms® data were downloaded in Excel format for analysis using SPSS v.25®, with debugging activities as follows:

1. Duplicate cases were excluded from future analyses.
2. The standard deviation of each case was calculated, and values below 0.5 were excluded to identify non-committed respondents.
3. Standardizing each category and substituting absolute values more significant than four with the median identified extreme values.

3.3. Validation of variables. - The following indices validate the three latent variables in Fig. 1's model [21]:

- R-squared and adjusted R-squared assess para-metric predictive validity (≥0.2 accepted), whereas Q-squared measures parametric validity (similar positive values accepted).
- Use Cronbach's alpha and composite reliability index to assess internal validity (≥0.7 approved).
- The variance inflation index (VIF) was calculated to assess collinearity (values ≤5 were allowed).
- The average variance extracted (AVE) measures convergence validity, accepting values above 0.5.

It is essential to mention that estimating some indices is performed iteratively because eliminating some items helps improve the analysis.

3.4. Descriptive Analysis of the Sample and Items. - The cleaned database was analyzed descriptively because SPSS® statistical software is widely used in research reports [22, 23]. Demographic data were evaluated using cross-tables to describe the sample. The medians and IQR measured the central tendency and dispersion, respectively.

3.5. Structural Equation Model (SEM). - Model validation WarpPLS 7.0® software used SEM and PLS to validate the hypotheses presented in Figure 1. SEM-PLS is used for small samples with ordinal data or non-normal variables [24]. Before PLS-SEM interpretation, the model efficiency metrics were assessed at 95% confidence using the following indices [25] :

1. The average path coefficient (APC) was used to measure the statistical significance of the parameter regression, 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 less than five were accepted.
4. Tenenhaus GoF (GoF), which should be greater than 0.36, was used to measure the data fit.

Direct effects - hypotheses validation: The validating hypotheses in Fig 1 involve measuring the direct effects between latent variables using parametric regression and evaluating the null hypothesis H0: β=0 with the alternative hypothesis

H_1: β≠0 with 95% confidence [25]. If hypothesis testing reveals β≠0, statistical evidence supports a link between the variables, regardless of the sign.

In addition, the Effect Size (ES) for each direct effect measures the variance explained by the independent variable in the dependent variable. The total ES of the dependent variable is R^2.
The sum of Indirect and Total Effects: A mediating variable must exist to transmit indirect effects between the variables. This study summarizes the indirect effects of ES and the p-values. Finally, each relationship's overall effect is the sum of its direct and indirect effects, along with ES and p-values.

Sensitivity Analysis: WarpPLS v7.0® software presents standardized indices, allowing probabilistic sensitivity analysis to determine hidden variable situations in the examined variables [25]. This analysis examined scenarios with a high probability of occurrence, indicated by a standardized variable larger than or equal to one $P(Z \geq 1)$. A low situation occurs when the standardized variable is equivalent to or less than minus one $P(Z \leq -1)$.

The following three probabilities were calculated:

1. Probability of variables occurring alone at high and low levels.
2. Cooccurrence probability of two variables in the high-low scenario combination.
3. The conditional probability of occurring the dependent variable is in any scenario given that an independent variable had occurred.

4. Results. -

4.1. Descriptive Analysis of the Sample. - Ciudad Juárez companies provided 176 valid responses out of 704 emails sent. Table I illustrates the sample's descriptive analysis by the industrial sector and respondent position. With 60 respondents, the automotive industry dominated this sample. In contrast, twenty-eight respondents were from an unlisted industry, and twenty-four were from the electronics industry. These three industries dominate the sample. Engineers and supervisors constituted 50% of the survey respondents.

Industrial Sector	Job title					Total
	Mngr	Eng	Sup	Tech	Other	
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 I. Industry sector and job position.
Mngr: Manager, Eng: Engineer, Sup: Supervisor, Tech: Technician.

Table II shows respondents' gender and years of experience. Male and female responders were evenly split, with two to five years of experience being the most common, followed by more than ten, five to ten, and one to two.

Sex	**Years of Experience**					**Total**
	0 a 1	**1 a 2**	**2 a 5**	**5 a 10**	**> 10**	
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%

Table II. Years of experience.

4.2. Descriptive Analysis of the Items. - Table III presents the medians and IQR of the latent variable items. All medians for items were more significant than 4.0, indicating respondents believed the investigated technologies provided the intended benefits. However, the IQR of 1.30 to 1.52 implies a significant consensus among respondents with no severe differences in replies.

Items	**Median**	**Interquartile Range**
TQM		
Participatory management aimed at continuous improvement is promoted in all operations.	4,31	1,33
The concept of total quality is promoted from the procurement of raw materials to after-sales customer service.	4,34	1,36
Decision-making for improvement is justified with facts and data.	4,29	1,38
DRFT		
Using quick-release fixtures, star knobs, and locking levers often.	4,25	1,47
Verification gages are mounted on the machines or workstations and are easily replaceable.	4,25	1,45
Replacement of a malfunctioning machine or equipment is easy.	4,22	1,52
ENS		
Solid waste reduction	4,36	1,30
Reduction of liquid waste	4,30	1,34
Reduction of gas emissions	4,32	1,32
Reduction of environmental mishaps	4,37	1,32

Table III. Descriptive analysis of the items.

4.3. Validation variables. - The variables were validated, and Table IV summarizes the final values to show that they all met the objective values in the last column.

Indixes	**TQM**	**DRFT**	**ENS**	**Best if**
R^2		0,367	0,468	>= 0,2
R^2 adjusted		0,363	0,462	>=0,2
Composite Reliability	0,934	0,950	0,954	>=0,7
Cronbach's Alpha	0,894	0,921	0,936	>=0,7
Average variance extracted	0,825	0,863	0,839	>=0,5
Collinearity (VIF)	1,724	1,867	1,810	<=3,3
Q^2		0,367	0,465	>=0,2

Table IV. Validation of the LM latent variables used in the questionnaire.

4.4. Structural Equation Model (SEM). - Model validation: Latent variables were integrated into the model and run because they met the validation indices, as shown in Table V. The model had predictive validity, no collinearity, and robust data fit because each indicator reached its target value.

Index	**Results**	**Best if**
Average path coefficient (APC)	0,456; P<0,001	P<0,001
Average R^2 (ARS)	0,417; P<0,001	P<0,001
Average adjusted R^2	0,412; P<0,001	P<0,001
Average Block VIF (AVIF)	1,575	Ideally <=3,3
Average full collinearity VIF (AFVIF)	1,800	Ideally <=3,3
Tenenhaus GoF (GoF)	0,593	Better if >=0,36

Table V. Model efficiency indices.

Figure II shows the SEM data. At the 99% confidence level, β values below 0.001 indicated statistical significance for each variable connection. This model explains 37 and 47% of the dependent variables, such as DRFT and ENS, respectively, with R^2 values of 0.37 and 0.47.

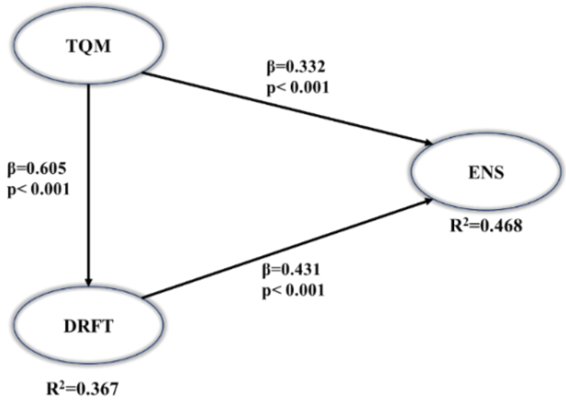

Figure II.- SEM showing WarpPLS® results.

Validation of Hypotheses–Direct Effects: Table VI lists the hypotheses, variables, p-values, and decisions. The SEM analysis showed that all relationships were accepted. H_1 offers sufficient statistical data to show that TQM directly and positively affects DRFT implementation because an increased standard deviation increases DRFT by 0.605 units.

H_i	Relation	β (p-value)	Decision
H_1	TQM→DRFT	0,605 (<0,001)	Accept
H_2	TQM→ENS	0,332 (<0,001)	Accept
H_3	DRFT→ENS	0,431 (<0,001)	Accept

Table VI. Summary of tested hypotheses.

Sum of indirect and total effects: The proposed model has only one indirect effect between TPM and ENS through DRFT as a moderating variable. This effect is statistically significant at the 99% confidence level with an ES of 0.154, indicating that TQM explains 15.4% of the variance in ENS.
The three cumulative impacts of the variables in Table 7 are statistically significant with 99% confidence. The results of β and ES indicate that TQM affects DRFT and ENS.

	TQM	DRFT
DRFT	β=0,605 (p<0,001) EN=0,367	
ENS	β=0,592 (p<0,001) EN=0,351	β=0,431 (p<0,001) EN=0,272

Table VII. Total Effects.

4.5. Sensitivity Analysis. - Table VIII shows the sensitivity analysis with columns for the independent variables and rows for the dependent variables. High-level situations are marked "+," while low-level scenarios are marked "-." Given a TQM+, the likelihood of a DRFT+ is 0.596, showing that exemplary TQM implementation guarantees 59.6% of DRFT outputs. However, low TQM implementation led to adverse DRFT outcomes, with a conditional probability of 0.571, putting senior management at 57.1% risk.

Level		TQM+	TQM-	DRFT+	DRFT-
	Probability	0,295	0,159	0,267	0,159
DRFT+	0,267	& = 0,176	& = 0,006		
		If = 0,596	If = 0,036		
DRFT-	0,159	& = 0,023	& = 0,091		
		If = 0,077	If = 0,571		
ENS+	0,284	& = 0,165	& =0,011	& = 0,153	& = 0,006
		If = 0,558	If = 0,071	If = 0,574	If = 0,036
ENS-	0,148	& = 0,028	& = 0,068	& = 0,017	& = 0,085
		If = 0,096	If = 0,429	If = 0,064	If = 0,536

Table VIII. Sensitivity analysis.

5. Discussion of results. -

5.1. From the SEM. -

H_1. TQM improves DRFT by 0.605 units when its standard deviation increases by one unit in MMI, providing statistical proof that it directly and positively affects the DRFT. This finding aligns with García Alcaraz, et al. [8], who found that TQM and DRFT positively impact firm revenue. These findings suggest that top management should prioritize TQM deployment in companies' production models for commercial and economic gains.

To achieve this relationship between TQM and DRFT, management must promote a quality culture and train and develop employees who turn raw materials into finished products. Managers win economically from client happiness and on-time deliveries as well as socially and environmentally.

H_2. ENS increases by 0.332 units when TQM increases its standard deviation by one unit, indicating that implementation directly benefits ENS. These findings support Green, et al. [15] who found that TQM and green supply chain techniques work together in the US industry and improve environmental performance.

For MMI, a high-quality program can reduce processing waste because continuous improvement reduces energy use and emissions, which helps meet environmental regulations. TQM also requires sustainability planning and design, which leads to product innovation and process improvements, with reduced environmental effects and increased corporate social responsibility.

H_3. When DRFT increased its standard deviation by one unit, ENS increased it by 0.431 units, suggesting a direct and beneficial influence. Barratt, et al. [26] found that DRFT improves orthopedic treatment quality and lowers costs in England.

MMI finds that utilizing the DRFT methodology reduces production waste, trial and error waste, person hours, and machine energy. This decreases pollutant emissions, conserves water, and lowers MMI's carbon footprint, boosting its business image.

The combined use of TQM and DRFT positively affected ENS results. Therefore, the industry's use of these LM tools will create a company with positive environmental results.

5.2. Sensitivity analysis. - This study assumes that TQM is a philosophy that adopts other quality methods. The three ideas show how DRFT helps TQM improve ENS. Table VIII presents the results of the sensitivity analysis.

TQM+ directly preferred DRFT+ and ENS+, with probabilities of 0.596 and 0.558, respectively. TQM+ is unrelated to DRFT- and ENS- results, which helps management understand that MMI efforts to implement TQM+ produce quality parts and reduce environmental impacts by reducing waste and reprocesses in energy efficiency and resource consumption. TQM helps companies comply with environmental requirements that may result in administrative consequences, improve their image, and produce environmentally friendly products [27].

The study shows that TQM- is dangerous because the odds of DRFT- and ENS- are 0.571 and 0.429, respectively. Implementing TQM at an elevated level is crucial for a company's management to reap the benefits of DRFT+ and ENS+ because TQM is not linked to them. This suggests that TQM- generates more production waste and employs wasteful resources. Consumers will accept only high-quality products. TQM can also result in environmental violations, missed client delivery dates, and loss of competitiveness and corporate image [28].

DRFT+ created an ENS in 57.4% of the cases with a conditional probability of 0.574. Therefore, the management should prioritize DRFT to improve the environment. Additionally, no correlation was found between DRFT + and ENS -. Top management should prioritize obtaining quality parts first to avoid waste, use unnecessary resources, limit polluting emissions, meet production orders on schedule, and boost their workers' corporate image and sense of belonging by providing excellent products [29].

DRFT- has no link with ENS+, but its conditional probability with ENS- is 0.536, indicating a significant likelihood of low DRFT implementation and ENS. Management needs to avoid DRFT- very much. Managers should immediately address these DRFTs- because they indicate a lack of employee training, defective designs, quality control and supervision in the production process, communication issues, feedback, poor equipment and machinery, unclear work methods and standards, and absence of improvement programs.

TQM and DRFT positively impact the environment; thus, to obtain an ENS+, they must be implemented to reduce negative impacts and contribute to the ENS [30].

The results of obtaining TQM+ and DRFT+ together are high (above 50 %), so obtaining ENS+ remains at a similar probability in combination with the other tools. Managers who focus on applying TQM and DRFT at higher levels will improve their ENS results.

6. Conclusion. - This study used structural equation modeling to examine TQM, DRFT, and ENS. The results demonstrate that TQM programs increase the implementation of DRFT, and LM activities significantly increase company's environmental benefits. With a quality control management program, LM helps develop products and processes that are done right the first time, wasting raw materials and energy and hurting the company's environmental goals.

So, companies must adopt a defect-free approach to promote ENS deployment in MMI, as DRFT improves ENS development and also, TQM has a modest impact on the ENS but significantly improves the DRFT. Management should prioritize TQM to boost ENS indirectly through DRFT.

In conclusion, by using these combinations of LM tools, MMI companies in Ciudad Juárez can achieve positive results on the company's bottom line. However, it is important to focus their resources and efforts on generating quality, low-cost products, seeking to reduce waste as much as possible to increase environmental benefits, and becoming leaders in this area.

7. Limitations and Future Research. - Due to the COVID-19 pandemic's limits on industry access, this study received few responses. Thus, we pursued the following themes:

- We plan to increase the sample size and tools to examine and link them to social and economic sustainability by conducting more surveys and evaluations.
- The survey will be conducted in various Mexican cities to assess the tools' effects and compare manufacturing cities.
- It is essential to clarify that this information is limited to a general study of the manufacturing industry in Ciudad Juárez Chihuahua, Mexico. There is a risk that the same will not occur in other states of the country or in foreign companies, since each case must be analyzed and necessary comparisons must be made.

Data availability: Data supporting the results of the present study are available upon request from the corresponding author.

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Author contribution:

1. Conception and design of the study
2. Data acquisition
3. Data analysis
4. Discussion of the results
5. Writing of the manuscript
6. Approval of the last version of the manuscript

LJMF has contributed to: 1, 2, 3, and 5.

JLGA has contributed to: 1, 4, 5 and 6.

JRDR has contributed to: 2 and 3.

JAGL has contributed to: 4 and 6.

Acceptance Note: This article was approved by the journal editors Dr. Rafael Sotelo and Mag. Ing. Fernando A. Hernández Gobertti.