Key factors to improve sustainability adoption in the automotive industry in Mexico

This social science study conducted in Mexico's northeast region explores factors enhancing sustainability adoption in the automotive industry. It emphasizes implementing energy management systems, promoting gender equality, human development through training, and improving worker well-being. Other factors include using clean energy, reducing carbon emissions, enhancing productivity, and minimizing solid waste. The research investigates the perceived impact of these factors on sustainability adoption in regional automotive plants. Findings suggest empirical support for some factors but lack evidence on renewable energy and carbon reduction effectiveness. These insights can contribute to the generation of long-term economic prosperity, while simultaneously minimizing the environmental impact and adhering to an ethical social framework.

Keywords: Sustainable development (Q01), automotive industry (L62), environmental impact (Q51), social development (M14), economic growth (M21)

1. Introduction

The industrialization era has been beneficial to humanity (Horn et al., 2010), but it has also led to significant environmental degradation, economic inequality, and social stress on a global scale. To address these interconnected challenges, sustainable development has emerged as an alternative approach that aims to holistically address economic, environmental, and social issues. According to Brundtland, sustainable development is a development paradigm that satisfies the needs of the present without compromising the ability of future generations to meet their own needs. The sustainable development concept was introduced by the UN (1987) and is being adopted by the OECD (2020) and its member states, including Mexico.

Automotive manufacturers worldwide are increasingly embracing environmentally friendly practices, as the industry in Mexico continues to grow and reach new heights, with production reaching 2.9 million vehicles in 2021 (Industrial Cluster, 2022). The northeastern region of Mexico is home to two prominent automotive industrial clusters, the Nuevo León Automotive Cluster (CLAUT, 2023) and the Coahuila Automotive Industrial Cluster (CIAC, 2023), which are under pressure from various stakeholders, including customers, vendors, the community, future generations, and employees, to adopt sustainable practices. This pressure makes sustainability adoption a pressing concern.

In 2022, both Nuevo León and Coahuila emerged as key destinations for foreign investment in Mexico's automotive industry (Industrial Cluster, 2022). This surge in investment coincides with the growing trend of nearshoring, characterized by the relocation of business operations from one country to another. Nearshoring is driven by

various factors including proximity, time zone compatibility, cultural affinity, transportation cost, and regulatory similarities (Braun et al., 2023). From an economic and environmental standpoint, nearshoring brings substantial external investment into the region. However, it is imperative that this economic development be implemented sustainably, particularly given the finite nature of the region's resources, notably water. Socially, participation in the international supply chain necessitates Mexico's adherence to labor standards comparable to those of developed nations. This entails ensuring fair wages and working conditions, aligning with global expectations for ethical labor practices. Such measures are essential for Mexico to compete on a level playing field with more developed countries.

The study is relevant to the automotive industry in the region and to understand key factors that contribute towards sustainability adoption in automotive manufacturing plants in Mexico's northeastern region. Failure to adopt sustainable industrial practices could squander the opportunities presented by this external investment influx. It is therefore crucial for the region to prioritize sustainable development practices to ensure long-term prosperity while meeting international standards for both economic and social progress.

1.1. Literature review

Drawing from a thorough international literature review, the research identifies the critical elements required for improving sustainability practices in these facilities.

The dependent variable for this study is the (Y) improvement of sustainability adoption, which encompasses three classical dimensions: economic, social, and environmental sustainability (Artaraz, 2002). Sustainable development can be achieved if these three dimensions coexist. In line with the findings of other authors (Pourvaziry et al., 2020), this

study defines sustainable development as the generation of long-term economic wealth, production with low environmental impact, and socially responsible treatment of employees, communities, and customers.

A study in the automotive industry in India also confirms the triple bottom line for the assessment of sustainability level, but with just five organizations (Swarnakar et al., 2021), with an Analytical Hierarchy Process. However, an international empirical study did not find evidence that strategies in favor of environmental and social practices contribute to financial performance (Szasz et al., 2021).

Previous studies conducted in the automotive context have highlighted that sustainable development serves as a strategic tool for competitiveness (Wellbrock, 2020) and can contribute to the success of organizations in the present as well as in the long term.

A study in Mexico with 460 companies was conducted by Rodriguez-Gonzalez et al. (2022). They find that sustainable performance has a significant positive impact on the financial performance of organizations. This is an example of how sustainability adoption is not just an environmentally and socially effective tool but also a good way to improve economic performance.

X_1, implementation of an energy management system (EMS), which is an energy management system that focuses on improving energy efficiency and reducing the associated costs. ISO 50001 is the most widely adopted certification system in this region.

A study conducted by Cahyono and Yudoko (2022) on sustainability in business in Indonesia, found that integrating occupational safety, health, and environmental certifications could contribute to sustainability efforts. This study employed cause-and-effect analysis to examine the interrelationships between these factors and a qualitative

analysis was conducted. Similarly, a study conducted in an automotive factory in Turkey by Yavas et al. (2022) aimed to understand the impact of EMS on sustainability. The findings of this study are consistent with those of a study conducted on the hotel industry in Serbia by Rajic et al. (2022). Both studies revealed that EMS such as ISO 50001 promote the adoption of sustainability practices. The study, conducted in Serbia, included a sample of 280 hotels and demonstrated significant results. These studies highlight the positive role of ISO 50001 (EMS), in driving sustainability efforts and their potential impact across different industries. It is suggested that implementing an EMS has a positive impact on improving sustainability adoption.

H_1: Implementation of an EMS has a positive impact on the improvement of sustainability adoption.

$X_{2\ (A,B,C)}$. This study emphasizes the promotion of gender equality in the workforce is a crucial factor. According to definitions from various authors, such as the United Nations (UN, 2021), Subrahmanian (2005), and Oluwadamilola (2016), gender equality in this context refers to achieving equal representation of both genders in lower-medium-high hierarchical level positions within industrial plants, particularly in the automotive industry where floor manufacturing jobs make up a significant portion of the workforce. A study conducted in Nigeria by Adebosin et al. (2018) reveals a robust and positive correlation between gender equality indicators and sustainable development measures. Furthermore, research has shown that countries with higher women's participation in parliaments tend to have higher levels of sustainability adoption (Boer et al., 2023). These findings indicate that gender equality is not only crucial for promoting sustainable development, but also has implications for the sustainability efforts of the automotive

industry. According to the regional automotive clusters (CIAC and CLAUT), the stratification of personnel in industrial plants is 2% for the high hierarchical level, 12% for the medium hierarchical level, and 85% for the low hierarchical level. From the literature review, increasing the number of women in the workforce at low-medium-high hierarchical levels in manufacturing plants enhances the adoption of sustainability.

H_{2A}: Promotion of gender equality in the workforce at lower hierarchical level positions has a positive effect on the improvement of sustainability adoption.

H_{2B}: Promotion of gender equality in the workforce at medium hierarchical level positions has a positive effect on the improvement of sustainability adoption.

H_{2C}: Promotion of gender equality in the workforce at high hierarchical level positions has a positive effect on the improvement of sustainability adoption.

Access to health, longevity, and education are objective components of human development, as measured by the Human Development Index (UNDP, 1990). In the context of this study, human development can be achieved by increasing the education level of the workforce and improving workers' well-being (Yumashev et al., 2020; Hickel, 2020). In line with previous concepts, there are two important factors to assess. The first variable X_3, improving human development through training initiatives, refers to the process of enhancing individuals' capacity and opportunities through appropriate training programs. Second, variable X_4, improving workers' well-being, which is a measure of the quality of life for workers in manufacturing plants. Otoo (2019) and Ma (2019) found that improving individual competencies enhances the competitiveness of organizations. While numerous studies examining the relationship between compensation and performance, such as Nurlia's (2022) study, there is limited research directly exploring the connection

between worker well-being and the improvement of sustainability adoption. This study suggests that human development can be achieved by increasing educational levels and improving workers' well-being.

H_3: Increasing human development through training initiatives has a positive impact on the improvement of sustainability adoption.

H_4: Increasing workers' well-being has a positive impact on the improvement of sustainability adoption.

The definitions provided by IEA (2020), Rozansky (2020), and Harjanne et al. (2019) are used within the context of manufacturing plants in the automotive industry. Variable X_5, utilization of clean and renewable energy is defined as a type of energy technology that utilizes energy sources that are replenished at a rate faster than they are consumed and characterized by low emissions. A study conducted by Yumashev et al. (2020) compared data from OECD countries and found a positive correlation between the improvement of sustainable development and the use of renewable energy. The study revealed that a 1% increase in renewable energy usage contributed to a 0.31% improvement in the sustainable development indicator, with a significance level of 0.01. This indicates that the adoption of renewable energy sources has a positive impact on reducing pollution and greenhouse gas emissions, thereby influencing the social and environmental dimensions of sustainability (Egli et al., 2018; Cîrstea et al., 2018).

H_5, Utilization of clean and renewable energy has a positive impact on the improvement of sustainability adoption.

Another independent variable is X_6, the reduction of carbon dioxide emissions. This greenhouse gas is generated by the combustion of fuels and consists of one carbon atom

and two oxygen atoms. The reduction of carbon dioxide emissions from combustion is considered an important factor for automotive industry plants to align with international sustainability objectives. There is a scientific consensus that global temperature is correlated with carbon dioxide emissions generated by human activities (NASA, 2019) (NOAA, 2023) (Berkeley Earth, 2020). According to the International Energy Agency (IEA), the automotive industry is responsible for approximately 23% of direct carbon dioxide emissions. However, when considering the industry's entire supply chain, including indirect emissions from the transport sector, buildings, and other factors, the overall contribution to CO_2 emissions is even greater (IEA, 2022). Yumashev et al. (2020), in their study using data from OECD countries, found a negative correlation between CO_2 emissions per capita and the sustainable development indicator, indicating that higher emissions harm sustainable development.

H_6: Reduction of carbon dioxide emissions has a positive impact on the improvement of sustainability adoption.

X_7, the enhancement of workers' productivity can be defined by its outputs. Some of these outputs (Feldstein, 2017) are their efficiency in time, and their quality (Clements-Croome et al., 2000). However, this performance is strongly related to other factors such as skills, knowledge, motivations, work environment, absenteeism, and very long work hours (Durdyeva et al., 2017). Pang et al. (2018) found that employee performance has a positive effect on the organization's financial performance. In a study of productivity as an independent variable and economic growth as a dependent variable, a strong positive relationship was also found (Prasetyo, 2019). The operationalization of productivity in this context focuses on individuals rather than specific products or processes.

H_7: Enhancement of workers' productivity has a positive impact on the improvement of sustainability adoption.

X_8, the reduction of solid waste materials in the plants of the automotive industry through the actions of recycling, reusing, reducing materials, surplus resources, or remnants of the production process of the plant (Minh et al., 2019); using strategies such as waste management (Filatov, et al., 2019), circular economics (Vinante et al., 2020) or processes such as the life cycle assessment of products and processes or LCA or by its acronym in English (Ghosh et al., 2019). Pourvaziry, in his study on sustainability in world-class manufacturing for the Iranian automotive industry, found within the indicators of the environmental dimension of sustainability that its resource conservation variable weighs 0.212, the strongest among five environmental criteria, which gives it the greatest importance within the environmental dimension that I study (Pourvaziry et al., 2020).

H_8: Reduction of solid waste materials has a positive incidence on the improvement of sustainability adoption.

To validate all hypotheses section 2 will present the materials and methodology. Then section 3 results with validation of the hypothesis and the details about the regression model.

2. Materials and methods

This study is a quantitative analysis, specifically an exploratory one, as the topic is not well developed in the local context. The aim is to describe the phenomenon and explore correlations between variables. A questionnaire was used for data collection, distributed to participants selected from the sample representing the population. The research design

is non-experimental, and quantitative data analysis was conducted. This cross-sectional study focuses on one point in time (Hernandez, Fernandez, & Baptista, 2014.

2.1. Questionnaire

Table 1 contains information on the variable name, definition, and type, which was obtained from the literature review. The questionnaire was administered digitally between February and June 2022. To ensure confidentiality and random selection, a unique code was used to identify the survey. The scale used for the numerical variables was a Likert scale of 1 to 5.

Table 1. Operationalization of the variables

	Variable	Items	Value
Y	Improvement of sustainability adoption	7	1: strongly disagree 2: somewhat disagree 3: neither agree nor disagree 4: somewhat agree 5: strongly agree
X_1	Implementation of an EMS	1	
X_3	Increasing human development through training initiatives	3	
X_4	Increasing workers' well-being	3	
X_5	Utilization of clean and renewable energy	4	
X_6	Reduction of carbon dioxide emissions	4	
X_7	Enhancement of workers productivity	6	
X_8	Reduction of solid waste materials	4	
$X_{2(ABC)}$	Promotion of gender equality in the workforce	1	1: 0% to 20% are women and the rest are men 2: 20% to 40% are women and the rest are men 3: 40% to 60% are women and the rest are men 4: 60% to 80% are women and the rest are men 5: 80% to 100% are women and the rest are men

The questionnaire was evaluated by a panel of 10 experts, including five from academia and five from the sustainability sector in manufacturing. They assessed the questionnaire's relevance and consistency for both variables and their respective items. After the validation process, the final questionnaire was organized into three main

sections: a cover page, general demographic questions, and questions focused on the variables of interest in the study.

2.2. Population and sample size

The study was conducted in automotive manufacturing industrial plants from organizations affiliated to the automotive the Nuevo León Automotive Cluster (CLAUT, 2023) and the Coahuila Automotive Industrial Cluster (CIAC, 2023). The type of plants was from OEM, Tier 1, and Tier 2 type of companies. Those plants manufacture different products or services. All the plants are part of the Nuevo Leon and Coahuila zones, but their headquarters are international. 78% were big plants, 15% were medium, and 7% were small size; 78% of the plants were part of a multinational group and 20% were national. The selection of the sample was done randomly. The object of the study comprises a population of 101 manufacturing plants. To calculate the sample size for a finite population, the study used Equation 1:

Equation 1

$$n = \frac{N * z^2 * p * (1 - p)}{(N - 1) * e^2 + z^2 * p * (1 - p)}$$

The sample size (n) of 80 industrial plants was determined based on the following parameters: N (101) representing the size of the population, Z (1.96) as the confidence interval, and e (0.05) as the allowable error. The probability of failure (q) and success (p) were both taken at 50% to maximize the sample size. The sample of 80 industrial plants was stratified proportionally, with 18 plants belonging to CIAC and 62 plants to CLAUT. The research examines Mexican professionals working in automotive plants and involved in sustainability, operations, and energy committees. These individuals hold high-level positions and possess extensive knowledge on sustainability issues in their field. The

committees focus on sustainability, energy management, human development, and social responsibility. Out of the sample, 73% were men.

2.3. Data set validation

A pilot test was conducted with 22 participants to assess the reliability of the instrument or questionnaire. Cronbach's Alphas were calculated for the variables, and they demonstrated good internal consistency, ranging between 0.7 and 0.9. The following Table 2 shows the Cronbach Alphas. However, one variable (Cronbach Alpha of 0.588) showed a poor level of reliability. Nevertheless, this issue was mitigated by increasing the number of participants to achieve the desired sample size. Variables promotion of gender equality in the workforce were composed of only one item each and were not subjected to the test.

Table 2. Cronbach Alphas

No.	Cronbach Alpha
Y	0.813
X_1	NA
X_{2A}	NA
X_{2B}	NA
X_{2C}	NA
X_3	0.588
X_4	0.782
X_5	0.906
X_6	0.823
X_7	0.785
X_8	0.767

Before applying linear regression to the complete dataset of 80 participants, various tests were conducted to assess linearity, autocorrelation, heteroscedasticity, and residual normality. All independent variables confirmed their significance less than 5% of linearity. However, in the autocorrelation test, variables X_5 and X_6 showed a correlation of 0.74, indicating similarity and leading to their exclusion from the step-forward regression

process Was demonstrated correlation between the response variable and the independent variables with significance less than 5%. The Breusch-Pagan test for heteroscedasticity revealed no issues between constructs significances over 5%. Tests for normality using Kolmogorov-Smirnov and Shapiro-Wilk methods indicated significance, confirming the normality of the residuals with significances over 5%.

3. Results

The following Equation 2 model shows the initial model derived from the graphical model and the literature review. The intercept β_0 or constate coefficient provides a baseline for the dependent variable. The error ε or residual represents all differences between the observer values of the dependent variable and the predicted value.

Equation 2. Initial model

$$Y = \beta_0 + \beta_1 * X_1 + \beta_{2A} * X_{2A} + \beta_{2B} * X_{2B} + \beta_{2C} * X_{2C} + \beta_3 * X_3 + \beta_4 * X_4 + \beta_5 * X_5 + \beta_6 * X_6 + \beta_7 * X_7 + \beta_8 * X_8 + \varepsilon$$

3.1. Linear regression models

In this work, multivariate linear regression using successive steps (forward) was employed. This algorithm is one of the most used in scientific research. At each step, a variable is added or subtracted, and SPSS Software generates several models as outputs. The regression is tested using the F and t-tests, with a significance level of less than 5%. In this study, six models were identified. Table 3 displays the models found, with models 1 to 5 being discarded, while model 6 was further investigated.

Table 3. Summary of the models.

Model	Predictors	R^2 adjusted	Sig.
1	X_3	0.318	0.000
2	X_3, X_7	0.405	0.000
3	X_{2A}, X_3, X_7	0.508	0.000
4	X_{2A}, X_3, X_7, X_8	0.541	0.000

5	X_{2A}, X_3, X_4, X_7, X_8	0.565	0.000
6	X_1, X_{2A}, X_3, X_4, X_7, X_8	0.587	0.000

Model 6 stands out in the regression analysis due to its highest R^2 value and inclusion of 6 out of the 10 variables. R and R^2 indicate the correlation and how well the model describe the phenomenon, respectively. Adjusted R^2, considering predictors, suggests Model 6's good predictive ability, with an adjusted R^2 of 0.587. The F significance for Model 5 is <0.000 (desirable), implying that independent variables explain the dependent variable's variation. The Durbin-Watson parameter, measuring consecutive residuals' correlation, should ideally fall between 1.5 and 2.5 for statistical significance; values outside this range suggest autocorrelation in the residuals.

Table 4. Model 6 Main parameters from the regression.

Parameter	Value
R	0.786
R^2	0.618
R^2 Adjusted	0.587
Significance F	0.000
Durbin Watson	1.942

3.2. ANOVA

The ANOVA in Table 5 is a method of analysis of variance. The sum of the squares is shown, as the degrees of freedom for model 5. It is indicated that the significance of the model is 0.000.

Table 5. ANOVA.

Model 6	Sum of squares	df	Mean square	F	Sig.
Regression	15.183	6	2.531	19.703	0.000
Residual	9.376	73	0.128		
Total	24.559	79			
Predictors: Constant, X_1, X_2, X_3, X_4, X_7, X_8					

3.3. Coefficients

Table 6 presents key parameters for standardized and non-standardized beta coefficients in a linear regression model. Non-standardized betas show the magnitude and direction of the relationship between independent and dependent variables, crucial for model building. Standardized betas lack a unit of measurement but help compare the relative impact of different variables. The table also provides t and P values, with P values under 5% indicating statistical significance, aiding hypothesis testing. In summary, Table 6 offers essential insights into coefficient significance and their impact on the dependent variable, assisting researchers in understanding variable relationships and drawing conclusions from the analysis.

Table 6. Coefficient from the model.

Coefficient / Variable	Beta unstd. coef.	Beta std. coef.	t	Sig.	VIF
β_0	1.115		3.550	0.001	
β_3 / X_3	0.154	0.215	2.386	0.020	1.550
β_7 / X_7	0.222	0.287	2.875	0.005	1.900
β_2 / X_2	0.188	0.342	4.554	0.000	1.077
β_8 / X_8	0.109	0.185	2.344	0.022	1.195
β_4 / X_4	0.175	0.225	2.459	0.016	1.607
β_1 / X_1	0.079	0.169	2.218	0.030	1.105

The VIF parameter helps to verify multicollinearity. If this parameter measures more than 10, there is a high probability of having multicollinearity problems between the independent variables.

3.4. Results

The following Equation 3 is the final linear regression model.

Equation 3. Final model

$$Y = \beta_0 + \beta_1 * X_1 + \beta_{2A} * X_{2A} + \beta_3 * X_3 + \beta_4 * X_4 + \beta_7 * X_7 + \beta_8 * X_8 + \varepsilon$$

The non-standardized B coefficients are employed for forecasting with the model, whereas standardized coefficients are utilized to discern the relative predictive influence of each coefficient on the response variable.

Analyzing the standardized coefficients in Table 7, it becomes evident that the variable X_{2A}: has the most positive impact on the adoption of sustainability.

Table 7. Standardized coefficients

Coefficient / Variable	Variable	Std. Beta
β_{2A} / X_{2A}	Promotion of gender equality in the workforce at low hierarchical levels	0.342
β_7 / X_7	Enhancement of workers productivity	0.287
β_4 / X_4	Improving workers' well-being	0.225
β_3 / X_3	Human development through training initiatives	0.215
β_8 / X_8	Reduction of solid waste materials	0.185
β_1 / X_1	Implementation of an EMS	0.169

The following Table 8 shows the significance of the excluded variables.

Table 8. Excluded variables.

Coefficient / Variable	Beta In	t	Sig.	Partial Correlation	Collinearity statistics		
					Tolerance	VIF	Minimum tolerance
β_5 / X_5	0.035	0.375	0.709	0.044	0.614	1.629	0.508
β_6 / X_6	0.111	1.262	0.211	0.147	0.674	1.484	0.499
β_{2C} /X_{2C}	0.034	0.446	0.657	0.052	0.907	1.103	0.525
β_{2B} /X_{2B}	-0.133	-1.668	0.100	-0.193	0.806	1.241	0.525
Predictors: Constant, X_1, X_{2A}, X_3, X_4, X_7, X_8							

The following Table 9 shows the results of the causality hypotheses that were accepted and rejected, as well as the significance value.

Table 9. Hypothesis results

No	Variable	Sig.	Result
H_1	X_1	0.030	Accepted
H_{2A}	X_{2A}	0.000	Accepted

H_{2B}	X_{2A}	0.000	Rejected
H_{2C}	X_{2A}	0.000	Rejected
H_3	X_3	0.020	Accepted
H_4	X_4	0.016	Accepted
H_5	X_5	0.709	Rejected
H_6	X_6	0.211	Rejected
H_7	X_7	0.005	Accepted
H_8	X_8	0.022	Accepted

The study aimed to determine the factors that influence the improvement of sustainability adoption in the automotive industry in the northeastern region of Mexico, focusing on the Nuevo León and Coahuila automotive clusters. These clusters are significant players in Mexico's automotive industry, and this research provides insights into the factors that contribute to the adoption of sustainable practices in the sector.

4. Discussion

The research objectives were successfully accomplished, covering aspects such as background analysis, literature review, variable definition, questionnaire development and field application, and hypothesis testing. This sets the stage for the discussion section, which evaluates the extent to which the research question was addressed.

4.1. Implementation of an EMS

The research demonstrates that the introduction of an EMS, such as ISO 50001, has a measurable impact on enhancing sustainability practices. This finding supports Hypothesis H_1. This certification is often adopted by manufacturing plants that face customer pressure to address energy and sustainability concerns. However, despite its growing popularity, ISO 50001 is still less prevalent than other traditional certifications (ISO 9001, 14000, and 45001) in most industrial plants.

The respondents' perceptions of the dependent variable Y and independent variable X_1 indicate a positive correlation. Several studies support this finding, including those by da

Silva et al. (2019), Trianni et al. (2019), Yavas et al. (2022), and Rajic et al. (2022), all of whom confirmed the importance of ISO 50001 certification in enhancing the degree of sustainability adoption.

Implementation of the ISO 50001 certification for the EMS could be a good option to improve the dimensions of economic and environmental sustainability. Economic due to initiatives related to improving efficiency and cost around energy vectors. Environmental because this management system promotes sustainable energy sources. Most manufacturing plants implement this certification because of pressure from their customers. From the plant surveyed, ISO 50001 is a certification that has a lower degree of implementation than classical certifications.

The 20% top plants for sustainability adoption have optimal levels of clerical certifications, such as ISO 14001, 9001, and 45001. However, this plant also has an optimal ISO 50001 level.

4.2. Promotion of gender equality in the workforce

The variable X_{2A}, the promotion of gender equality in the workforce at low hierarchical levels shows statistical significance with the response variable Y improvement of sustainability adoption, supporting Hypothesis H_{2A}. This finding is consistent with that of Morais (2017), Adebosin et al. (2018), Yildirim et al. (2017), and Looze (2018). It is important to note that the X_{2A} variable represents most of the plant population (86%), as was directed to workers at the lower hierarchical level.

The deficit in women's participation in the automotive industry could be attributed to gender preferences for working in this sector, as suggested by Falk et al. (2018). Incorporating more women into the industry under suitable conditions is crucial, as it can

lead to increased productivity by integrating underutilized human resources. However, the lack of proper social conditions could be another factor that hinders gender equality. Addressing barriers that prevent women from actively participating in the automotive industry is essential.

Variables X_{2C} and X_{2C}, for medium a high hierarchical level positions didn't have a significant impact on the variable Y. This could be possible because the middle and high hierarchical positions were covered by professionals of both genders. However, more empowered professional women may prefer to work in sectors other than the automotive industry. In some countries, incentives for women to study STEM careers (science, technology, engineering, and mathematics) have shown an increase in female enrollment, but this trend might decrease once the incentives are no longer in place (Amon, 2017) (Piani, et al., 2017). Empowered women may have more opportunities to choose where they want to work.

Promoting gender equality in low hierarchical level positions positively impacts the adoption of sustainability in the automotive industry, and efforts to incorporate more women into the industry should be accompanied by understanding and addressing the factors influencing their career choices. However, this was not demonstrated for higher and middle-level hierarchical positions. It is important to highlight that variable X_{2A} has a greater impact on sustainability adoption than all the other variables with their hypothesis accepted studied here.

For practical implementation of the key factors to improve sustainability adoption, the specific recommendations considering the highest levels of sustainability adoption from the top 20% plants surveyed. Suggest that these types of plants have near 40% of women

participating in the low hierarchical level. Even medium and high hierarchical levels were not significant.

4.3. Human development through training initiatives and improving workers' well-being.

Among the two variables related to human development: improving human development through training initiatives (X_3) and improving workers' well-being (X_4). Thus, Hypotheses H_3 and H_4 both were accepted. This finding is consistent with the works of Otoo (2019) and Ma et al. (2019), who found a correlation between education and training factors with the improvement of sustainability. Hickel's study (2020) also supports this correlation, showing a strong link between the level of human development in general and sustainability.

The respondents in the study perceived a positive relationship between factors of human development, such as training and the standard of living, with improvement in sustainability adoption, which aligns with the established theory. Consequently, factors contributing to personal development can also improve sustainability in the social dimension.

This study indicates that efforts to promote human development through training and improvement in the standard of living can positively influence the adoption of sustainability. However, the role of occupational safety in this context may be less influential because of its standardization and industry-specific nature.

This group of plants has high living standards and extensive training programs for employees. Employees' productivity is at high levels but with low absenteeism and

overtime. This productivity could be achieved owing to the extensive amount of training, motivation, and work environment proposed by the company.

4.4. Utilization of clean and renewable energy and reduction of carbon dioxide emissions

The variable X_4, the utilization of clean and renewable energy did not achieve sufficient statistical significance, remaining at 21.8%. Similarly, the independent variable X_5, the reduction of carbon dioxide emissions. Did not exhibit statistical significance, with only 15%. As a result, the causality hypotheses H_5 and H_6 were rejected in the context of this study. Both also pertain to environmental factors.

This phenomenon may be attributed to a lack of technical knowledge and education concerning sustainability. The perceptions of those surveyed suggest that the use of renewable energy and the reduction of carbon dioxide emissions do not significantly contribute to increasing the adoption of sustainability. This contrasts with other studies, such as the work conducted by Yumashev et al. (2020), who found that renewable energy and the reduction of carbon dioxide emissions positively impact the sustainability index.

In this study, there was no strong evidence to support the notion that using renewable energy and reducing carbon dioxide emissions significantly enhances sustainability adoption. The discrepancies with other studies may reflect variations in the specific contexts and participants involved, as well as differences in the level of understanding and awareness regarding sustainability issues. Further research and analysis are required to gain a deeper understanding of the relationship between these environmental variables and sustainability adoption in the automotive industry in the northeastern region of Mexico.

Mexico is internationally committed to reducing its greenhouse gas emissions by 25% by 2030. Many automotive industries have more challenging goals. Policies must be implemented to develop more renewable energy and decarbonization strategies (Banacloche et al., 2020). These policies could help make investments in green energy and carbon dioxide mitigation projects more attractive. Enhancement of workers productivity

4.5. Enhancement of workers' productivity

The variable X_7, enhancement of workers' productivity has demonstrated acceptable significance with a positive impact on the dependent variable Y. Palvalin's (2019) findings support this, indicating that enhancing the work environment and individuals' attitudes and skills can lead to improved productivity. This theory aligns with the findings of Czyżewski et al. (2018), Pang et al. (2018), Busu (2019), Prasetyo (2019), and Baharin (2020), all of whom have shown that improving factors such as the work environment or individuals' characteristics contribute to improving productivity and, consequently, the adoption of sustainability.

Therefore, Hypothesis H_7 was accepted. This suggests that efforts to enhance personnel's productive performance positively influence the adoption of sustainability in the automotive industry in the northeastern region of Mexico. By focusing on factors that contribute to improving productivity, companies can be better equipped to embrace sustainable practices and achieve higher levels of sustainability performance.

4.6. Reduction of solid waste materials

The variable X_8, the reduction of solid waste materials significantly impacted the response variable, as it has achieved a statistical significance of less than 5%. As a result,

Hypothesis H_8 was accepted. The findings from the literature review are validated, and this agreement is observed in studies conducted by authors such as Yildimir et al. (2017) and Pourvaziry et al. (2020).

Additionally, Woolley et al. (2018) emphasized the economic benefits of waste recovery, particularly in terms of energy generation in the form of heat. Considering the global scarcity of resources, as highlighted by the FAO (2019), it is essential to use resources efficiently to minimize strain on the planet, as indicated by the WWF (2020). Efficient resource utilization is vital not only for environmental sustainability but also for meeting the needs of humanity, as people depend on products and services derived from these inputs.

Reducing the waste of solid material resources is crucial for improving the adoption of sustainability in the automotive industry. Not only does it align with environmental concerns related to resource scarcity and planet preservation. It also offers economic benefits through waste recovery and efficient resource utilization. Emphasizing sustainable practices that minimize waste generation and resource consumption can significantly contribute to industry's overall sustainability performance.

Finally, the top 20% plants with higher sustainability adoption implemented projects related to waste management, circular economics, and others.

5. Conclusions

The adoption of EMS is highly recommended because of their positive impact on improving sustainability adoption. This type of certification brings benefits across the three sustainability dimensions. Economically, adopting ISO 50001 makes industrial operations more efficient, leading to lower energy costs and improved economic competitiveness for

organizations. In terms of the environment, ISO 50001 promotes the use of renewable energy and encourages decarbonization efforts, contributing to the reduction of greenhouse gas emissions and conservation of natural resources. From a social perspective, certification creates new employment opportunities in energy-management-related fields and supports the promotion of clean and non-polluting manufacturing practices.

ISO 50001 certification complements traditional ISO certifications, working together to enhance standardization and continuous improvement in industrial plants, but with a specific focus on sustainability from a technical standpoint. By encouraging the use of renewable energy and the reduction of carbon dioxide emissions in industrial plants, ISO 50001 not only helps achieve sustainability goals but also fosters a broader awareness of sustainability issues.

The implementation of an EMS is a valuable step for organizations aiming to improve their sustainability performance. It offers comprehensive economic, environmental, and social benefits, making it a powerful tool in the journey towards more sustainable and responsible industrial practices, this is alighted with Yavas et al. (2022) findings. In summary, the key advantages of implementing ISO 50001 in manufacturing plants are improved energy efficiency, cost savings, environmental impact reduction, compliance with regulations and standards, and enhanced corporate social responsibility.

Promoting gender equality in the automotive industry is crucial because it brings several benefits, including integrating a larger population into production chains and harnessing the diverse perspectives and talents of both genders. However, achieving gender equality requires addressing various aspects that differentiate men and women. The adaptation

of manufacturing lines to the physical abilities of men and women is a classic example of lean manufacturing practices. This will have a positive impact if is done on the lower hierarchical levels. To achieve it will be necessary to improve policies about inclusivity, diversity, flexible work, education, and training.

One of the primary challenges is the existing societal norms and education systems that can lead girls, boys, women, and men to develop predefined career choices. To tackle this issue, education systems must be reformed and made aware of the importance of providing equal opportunities for both genders. By offering a diverse range of activities and perspectives, individuals can make choices that align with their true passions and potential, leading to fulfilling and satisfying career paths.

Striving for gender equality in the automotive industry is essential to fostering a diverse and innovative workforce. By challenging existing norms and providing equal opportunities for both genders, we can create a more inclusive and successful industry that benefits from the unique contributions of all individuals regardless of gender. Future studies need to be performed to understand the barriers that limit the participation of more women at low hierarchical levels in the automotive industry. Adebosin et al. (2018) and Boer et al. (2023) found similar results in Nigeria, for this study in Mexico, this was demonstrated just for low hierarchical positions.

Improving the standard of living of employees at all hierarchical levels is indeed a relevant and beneficial activity for enhancing the degree of sustainability adoption within industrial plants. This approach can result in a win-win situation for both companies and employees. By developing training programs that enable employees to enhance their skills and knowledge, companies can increase their economic perceptions. This can lead to

improved productivity, which can compensate for the increased costs associated with higher salaries, ultimately resulting in an improved standard of living for employees.

On a broader scale, raising the standard of living for most societies, especially those at the bottom of the economic pyramid, can positively affect the overall economy. When people have higher purchasing power, they contribute more to economic growth and development.

Improving the standard of living and investing in human development, including training, is an essential strategy for companies aiming to enhance their adoption of sustainability. These initiatives not only benefit employees but also contribute to the overall economic growth and success of the organization, fostering a more inclusive and sustainable business environment.

Otoo (2019) and Ma (2019) found also found that well-being improves sustainability adoption. Nurlia's (2022) study coincides with human development through education or training, which is a factor that can improve sustainability.

Indeed, improving productive staff performance is a crucial aspect of enhancing sustainability adoption in the automotive industry. To achieve this, companies can focus on several key areas to reduce absenteeism, minimize overtime, improve skills and competencies, motivate employees, and foster a positive work environment.

Additionally, initiatives to improve the standard of living, such as increasing salaries and offering training opportunities, can play a significant role in enhancing employee satisfaction and overall wellbeing. Employees who feel valued and supported are more likely to be motivated and productive, ultimately contributing to the success of sustainability efforts within the organization.

Durdyeva et al., 2017 also found a positive relationship between employee productivity and the improvement of sustainability adoption. Where workers' productivity is related to factors such as skills, knowledge, motivations, work environment, absenteeism, and very long work hours.

Reducing the wastage of solid material resources has several benefits for optimizing resource usage, such as lower car prices, addressing global resource scarcity, and a circular economy. Pourvaziry et al. (2020) also found similar results within world-class manufacturing plants in Iran's automotive industry. This factor improves economical and environmental performance of the sustainability.

Overall, focusing on employee performance and resource optimization are essential strategies for automotive industry players to improve their sustainability practices. By incorporating these measures, companies can not only enhance their environmental responsibility but also contribute to a more sustainable and resilient future for society.

This contrasts with the rejected hypothesis. Increasing awareness among respondents about the positive impact of using renewable energy and reducing carbon dioxide emissions is crucial, despite their current perception indicating no statistical significance in improving the adoption of sustainability.

Rejecting variables X_5 and X_6 is a significant finding; thus, the perception of sustainability adoption does not include developments in topics related to the decarbonization and usage of renewable energy. Carbon dioxide emissions are a significant driver of global warming as they contribute to the greenhouse effect. Therefore, reducing these emissions is crucial for mitigating the impact of climate change. On the other hand, renewable energy offers a cleaner and more sustainable alternative to conventional fossil fuels. Not

only do they not produce carbon dioxide, but they are also abundant and have become increasingly cost competitive.

Those findings are against the ones found by Egli et al. (2018) and Cîrstea et al. (2018). It is an important finding that is recommended to be studied in more detail. Renewable energy and decarbonization practices are something that should be perceived as factor that help to enhance sustainability adoption, but in the manufacturing, plants study those practices are not well implemented.

Implementing training programs in the industry to increase awareness of environmental impact and reduction measures is crucial. This includes adopting renewable energy sources and executing projects to decrease carbon dioxide emissions. Integrating these initiatives with the EMS via ISO 50001 certification streamlines and simplifies the implementation process.

The contribution to the literature stems from the development of scientific studies in the social sciences that will assist regions like these in understanding the perception of these phenomena or variables to grasp the keys to improving sustainability and to change the behaviors and perceptions of stakeholders. On one hand, understanding how the improvement of social conditions influences the economic benefit of industrial organizations. On the other hand, why renewable energies or decarbonization efforts are not perceived in the industrial environment as key factors for sustainability improvement.

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