Impact of the Work Culture and Suppliers of Equipment on the Benefits of TPM

José Roberto Diaz Reza[1], Deysi Guadalupe Marquez Gayosso[2],
Valeria Martínez Loya[2], Julio Blanco Fernandez[1], Emilio Jimenez-Macias[1]

[1] University of La Rioja,
Spain

[2] Autonomous University of Ciudad Juarez,
Mexico

roberto.diaz.reza@gmail.com, {emilio.jimenez, julio.blanco}@unirioja.es,
{marquezdeysi, valeriie_05}@hotmail.com

Abstract. Today's markets are uncertain and highly competitive, surviving in them becomes a challenge for companies. Therefore, companies should be at the forefront having its equipment in optimal conditions to avoid failures, in addition the updating of personnel in order to ensure that their processes provide quality products. For this reason, it is necessary to perform maintenance of the machines regularly. In that sense, a tool that facilitates this process is Total Productive Maintenance (TPM), which has played an important role within companies in recent times. Because of this, the objective of this research is to quantify the impact of the human factor in the benefits that TPM provides. The Structural Equation Modeling technique is considered in the development of this research which considers three latent variables related to Total Productive Maintenance (TPM), Suppliers, Work Culture and the TPM's benefits.

Keywords: Structural equation modeling, total productive maintenance (TPM).

1 Introduction

Manufacturing companies operating in the fast changing market and highly competitive in the last two decades have adopted the principles of Lean thinking. In doing so, they are reorganized into cells, and value stream to improve the quality, flexibility and customer response time in their manufacturing processes [1]. A key point that all authors note regarding Lean Manufacturing is not about reducing headcount, but rather the improvement of productivity in the broadest sense of the concept and costs are seen as a result of practices, systems and processes, which means that the cost reduction occurs when you manage to improve them [2].

Lean Manufacturing concepts were developed mostly in Japanese industries, especially Toyota, but today Lean Manufacturing tools are used for waste reduction as suggested by many authors, [1, 3-5], but in practice, Lean Manufacturing maximizes product value through the minimization of waste [5]. Lean principles define the value of the product / service as perceived by the customer and then make the flow in line with customer attraction and pursuit of perfection through continuous improvement to eliminate waste by classification activities that add value (VA) and activities that do not add value (NVA) [5].

When a company is Lean simultaneously minimum inventory is obtained in the form of raw materials, work in process, finished products, minimum product nonconformance, rework, rejects and returns, losses minimal production through unplanned downtime and planned change and transition time, fee reductions and short stops, and quality problems, minimum cycle time of the system, minimum lag times between processes, minimal variability in the rates of production and processes, minimum unit cost production, excellent performance of on-time delivery, customer satisfaction, and gross profit, etc. [2].

One of the tools most used in lean manufacturing production systems is the Total Productive Maintenance (TPM), which essentially seeks to improve equipment performance, reduce variability, and shorten the period of the offer, but later, improved total operating performance became the main objective of TPM, even including the gradual improvement of the quality, maintenance, cleaning and order; new manufacturing technologies, and work on all employees with advanced technology equipment. [6].

Total Productive Maintenance (TPM) is defined as a philosophy designed to integrate maintenance of equipment in the manufacturing process. It is a system that maintains and improves the integrity of production systems and quality through the machines, equipment and processes that add value to the product [7]. TPM focuses on maintaining all equipment in good condition to avoid breakdowns and delays in the manufacturing process also strives to avoid minor stops and defects during the production process and provides a safe working environment [7].

Therefore, it appears that TPM provides a comprehensive enterprise-wide approach to the management of maintenance, which can be divided into elements in the short and long term. In the long term, efforts will focus on the design of new equipment and the elimination of downtime where the participation of the different areas of the organization is required. In the short term, TPM activities include autonomous maintenance program for the department of production and a planned maintenance program for the maintenance department [8].

In summary, based on the definition and activities of TPM, it can be concluded that the objective of TPM is to continually improve the availability and prevent degradation of equipment for maximum effectiveness thereof and to achieve this, strong support is required management as well as the continued use of work equipment and small group activities for improvement [9].

In [9] it mentions that operators and maintenance workers need to have a greater understanding of the functions performed by each and occasionally, to acquire new skills. For example, operators need to learn to anticipate problems and be able to solve minor adjustments and basic preventive maintenance such as checking routines, cleaning and lubrication, a more important role in multiple skills is viewed as an essential support.

To achieve its objective, the TPM requires a number of elements, and it would not be possible to make proper repairs on your machine if you do not have the parts or components required at the time they are needed, or that maintenance personnel not know the methods and procedures for carrying out such repairs. From this, we conclude that the human factor is very important and so is the relationship with suppliers of machinery and components.

Therefore, the objective of this research is to investigate the impact of the human factor in obtaining the benefits TPM offers, so three latent variables and relationships, which are being studied: Suppliers, Culture and Employment Benefits TPM. The results are intended to provide from a quantitative point of view the impact between the variables, so that managers can determine those variables that are important from those that are trivial.

1.1 Work Culture

Charles Roger (2014) cited for [10] mentions that the culture of the organization is to the values, beliefs, attitudes and behaviors that employees share and use every day in their work. Culture determines how employees describe where they work, how they understand the business, and how they see themselves as part of the organization. Culture is also a driver of decisions, actions, and ultimately the overall performance of the organization.

The role of human resources, skills and abilities is considered the most important in the company and in all the operations it performs, but especially in the care we have with the materials and equipment operating in the production process [11] and it is why the management and senior management must work in generating a working culture for the company. Remember that employees are those planning activities in general terms about the company and therefore, are those who know of a better way its equipment, including strengths and weaknesses, so that the plans and maintenance programs should include [12].

1.2 Equipment Suppliers

With the globalization of the economy, market competition becomes more intense in order to maintain a competitive edge, companies try to form an alliance with partners, customers, suppliers, among others; for which it requires trust, loyalty of its members. Therefore, a good and stable supplier-buyer relationship is crucial to a strong partnership between a supplier of industrial equipment and the manufacturer [13].

Make a good selection of suppliers of equipment and industrial components significantly reduce purchasing costs and improve competitiveness of companies, it is why many experts believe that the selection of suppliers is the most important activity in any company for the acquisition your product and in this case, machinery and production equipment [14].

Yuqi Wang [15] Wang Yuqi mentions that it is important for manufacturers of large and complicated sure you have an effective after-sales service and fast, this in order that maintenance can be provided promptly in case of failure or falling equipment. It also mentions that the selection of suppliers of maintenance and repair of machinery of precision parts is very important in products after-sales services.

The maintenance service is an important part of product service and quality of service and attention during customer use of the products will have great influence on product branding, customer return rate, Gronroos [16] mentions that the service provider does not transfer value, but therefore, the value of the service is created by the supplier and the customer together [17] and then it becomes crucial to seek to have a good relationship.

The provider of maintenance services can help companies manufacturing complex to choose the right service provider, thus reducing maintenance costs and improving the standard capacity maintenance management and servicing products and this is of great importance for improving the competitiveness of the products. [17].

As can be seen in paragraphs, it appears that the success of TPM depends largely on management to perform the administrative part with the supplier and therefore the following hypothesis is proposed:

H_1: Work Culture towards TPM has a direct and positive about suppliers used in the production process equipment impact.

1.3 Benefit Productivity

Having a good administration of TPM, you are allowed to increase productivity and to improve it in an industrial plant, it is necessary to selecting the tasks getting less consumption of resources, to achieve this it is necessary to combine many actions of organizational, management and technologies, and appropriate use of resources. In [18] a number of benefits arising from the implementation of TPM, such as improving the quality of the final product, the total productivity of the company is improved, the yield rate is improved, among others are reported.

Similarly, (Koelsch, 1993) cited by [19] provides a range of percentages of improvement in some areas of the companies that have implemented TPM, these percentages are provided by Constance Dyer, Director of Research and Product Development TPM, Productivity Inc. these percentages include: 50% reduction in failures work rates, 70% reduction in lost production, 50-90% reduction in set-up, 25-40% capacity increase, 50% increase in labor productivity, and 60% reduction in unit costs of maintenance.

According to [20] in the current industrial scenario, large losses / waste on the shop floor occur. These wastes are due to operators, maintenance personnel, tooling problems, the unavailability of components on time, etc., [20]. Therefore, management should raise awareness in employees in relation to the cost of having to have a detained without producing plant, which is achieved by creating an appropriate work culture. Therefore, the following hypothesis is proposed:

H_2: Work Culture has a direct and positive impact on the productivity benefits.

However, these benefits are obtained from the TPM and are reflected as indices of operating efficiency in the company, have several sources, one of which is the good relationship and collaboration we have with suppliers of equipment. It would not be possible to have high levels of machine efficiency if not delivered on time to repair components thereof. [21]. For example, it is reported that the supply of parts is crucial in highly integrated, such as the Chinese automotive industries [22], where efficiency aspects associated directly to providers.

Similarly, it has been associated with TPM processing quality final product [23], with the economic performance of the company [12] and the material flow along production lines [24]. Therefore, given the importance of suppliers in obtaining productivity indices of the company, the following hypothesis is proposed:

H_3: Equipment suppliers have a direct and positive effect on the productivity benefits of the company.

A summary of the hypotheses is illustrated in Figure 1.

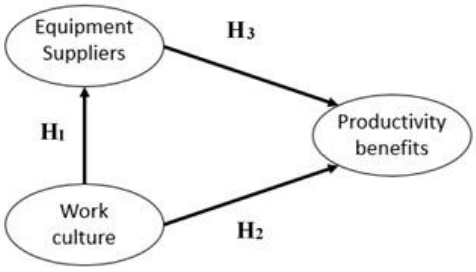

Fig. 1. Proposed Hypotheses.

2 Methodology

This section describes the methodology used for this research. This work was carried out by using a questionnaire that focus on the industrial sector in northern Mexico, specifically in Ciudad Juarez, Chihuahua.

2.1 Questionnaire Design

First, a questionnaire was designed, which consists of 23 items which are divided into four sections. The first section deals with demographics of the sample as the industrial sector to which the company belongs, position, years of experience and sex of the respondent (4 items), the second section is intended for “equipment suppliers”, the third is focused the "work culture" and the fourth section is focused on the "productivity benefits", same as described below in Table 1 and which refer to authors who justify it becomes.

Table 1. Latent variable equipment suppliers.

Latent Variable	Item
Equipment Suppliers [25, 26, 27]	Do suppliers provide adequate maintenance manuals of the machines?
	Do suppliers provide technical assistance?
	Does the company signed some kind of agreement with suppliers?
	Are providers comply with the guarantees?
	Does the machine supplier provides training?
	Does the supplier provide training of the machinery in the buyer´s plant?
	The supplier is responsible for the installation and commissioning of machinery that is sold?

Latent Variable	Item
Work Culture [20, 18]	The company emphasizes in placing all the tools and accessories?
	Work places areas are clean and tidy?
	Does the company is kept clean at all times and in all departments?
	Do employees receive training to properly multitasking?
	Does the scheduling of maintenance is carried out in coordination with the production department?
Productivity Benefits [16, 19, 26]	Eliminate losses that affect plant productivity
	Improved reliability and availability of equipment
	Reducing maintenance costs
	Improving the quality of the final product
	Lower financial costs for spare parts
	Improve company's technology
	Increased responsiveness to market movements
	Create competitive capabilities from the factory

In order to answer the questions, likert scale with values from 1 to 5, the scale is a function of the frequency with which tasks are performed and the advantages are obtained during the process of implementing TPM is used. Table 2 shows the values and their meaning.

Table 2. Importance levels.

Scale	Description
1	Never
2	Sporadically
3	Regularly
4	Very often or almost always
5	Always

2.2 Data Collection

As mentioned above, the questionnaire was administered exclusively in the industrial sector in northern Mexico (Ciudad Juarez) and was answered by people involved in the maintenance area, and was applied at different hierarchical levels, such as managers, technicians, engineers, operators that perform or execute maintenance plans. The principle of inclusion should be that had an administrative position or had relationships with suppliers of equipment, since this variable is also being examined.

2.3 Capturing Information and Data Debbuging

After gathering information from the different questionnaires, the next step is to capture the information in the statistical software SPSS 21®, where each line represents a case or completed survey and each column lists all the elements or variables that make up the questionnaire.

After the capture of information, we proceeded to make debugging database, which is to identify the missing values (unanswered questions) for each of the cases, if missing values are equal to or greater than 10 % this questionnaire is removed [28] , done this, the standard deviation of each of the cases is calculated, and those questionnaires are removed with, after that less than 0.5 standard deviation, and extreme outliers are identified, which may be due to data entry errors data. Missing values are filled with the median, which because it has an ordinal scale and extreme values are replaced by this measure of central tendency.

Once the database was refined, the following was the validation of all latent variables, some indexes for this validation were used. Index Cronbach's alpha was used to measure the internal consistency of a dependent variable that consists of other measurable. [29], this index is considered acceptable from 0.7 and has been used in numerous studies [30]. Discriminant validity is measured by the average variance extracted (AVE), the minimum cutoff value is 0.5 [31].

2.4 Structural Equation Model

The structural equation modeling (SEM) is a well-established statistical technique that has become popular in social science research [32], It is why the WarpPls 5.0® software for modeling of this technique is used. The versatility of SEM is that it can handle estimation problems involving latent variables and measurement errors [32].
Within the structural equation modeling three effects, the direct, indirect and total effects are analyzed.

3 Results

From the surveys and after purging the database, a total of 341 valid questionnaires were obtained, Figure 2 shows the percentage of registered industrial sector surveys show. In the graph we can see that the people who answered the questionnaire were the automotive sector, followed by the electronics industry and can see that there was a percentage of 1% unanswered.

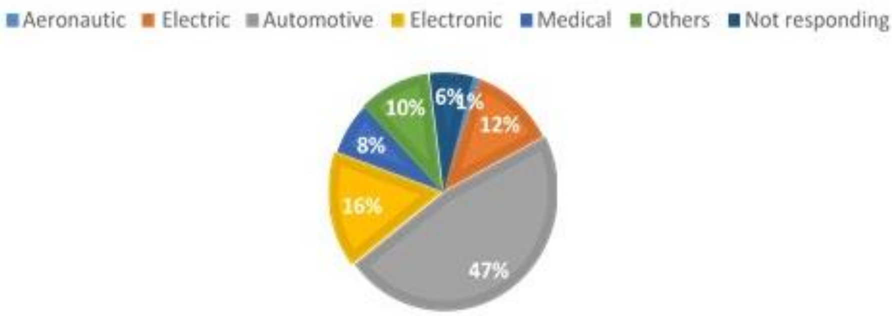

Fig. 2. Industry sector.

Table 3 shows the experience of people in his position shown and analyzed against gender, of the 317, where 24.3% are women and 75.7% men, also it notes that there are 159 people who have more than 2 years of experience which represents 50% of respondents, and finally notes that a total of 24 undeclared.

Table 3. Experience vs. Gender.

Years	Gender		Total
	Female	Male	
0-1	28	62	90
1-2	12	56	68
2-5	23	50	73
5-10	11	48	59
More than 10	3	24	27
Total	77	240	317

3.1 Validation

Table 4 shows the levels of quality and validity for each of the variables analyzed in the model. According to the R-Squared can conclude that the variables have predictive validity from a parametric view, this because the value is greater than 0.2, which is the minimum cutoff. Based on the positive values of Q-Squared and close to R-Squared, one can conclude that the model has predictive validity from a nonparametric view. The Cronbach's alpha indices show that it has adequate internal validity because the values are greater than 0.7. The birds above 0.5 show that all variables have convergent validity.

Table 4. Latent variables coefficients.

	Productivity Benefits	Equipment Suppliers	Work Culture
R-Squared	0.327	0.329	
Aadj. R-Squared	0.323	0.327	
Composite Reliab.	0.957	0.906	0.854
Cronbach´s alpha	0.948	0.876	0.784
Avg. Var. Extrac.	0.734	0.617	0.541
Full Collin. VIF	1.424	1.615	1.63
Q-Squared	0.329	0.33	

The Figure 3 shows the structural equation model with the results for each of the relationships among variables according to the methodology described above. Similarly, the figure shows for all parameters or latent variables their estimated values, the P-values that determined their statistical significance, and the R-squared values that indicated their percentage of variance.

3.2 Model Fit and Quality Indices

The following indices are used:

- Average path coefficient (APC) = 0.410, P<0.001,
- Average R-squared (ARS) = 0.328, P<0.001,
- Average adjusted R-squared (AARS) = 0.325, P<0.001,
- Average block VIF (AVIF) = 1.378, acceptable if <= 5, ideally <= 3.3,
- Average full collinearity VIF (AFVIF) = 1.557, acceptable if <= 5, ideally <= 3.3,
- Tenenhaus GoF (GoF) = 0.455, small >= 0.1, medium >= 0.25, large >= 0.36.

According to APC, ARS, AARS indexes, it can be concluded that the model variables are statistically significant, as they have a value of P <0.05 therefore valid. The index goodness of fit Tenenhaus with a score of 0.445 which is higher than recommended 0.36, indicating that the model is efficient.

3.3 Direct Effects

Based on the values of the betas that you have in Figure 2, hypotheses are concluded, which have been formulated based on the direct effects:

H_1 There is enough statistical evidence to say that latent variable equipment suppliers have a direct and positive impact on latent variable productivity benefits because when the first latent increases its variable standard deviation by one unit, the second does in 0.31 units.
H_2 There is enough statistical evidence to say that latent variable work culture has a direct and positive impact on the latent variable equipment suppliers because when the first latent variable increases its standard deviation by one unit, the second does it in 0.57 units
H_3 There is enough statistical evidence to say that latent variable work culture has a direct and positive impact on latent variable productivity benefits because when the first variable increases its standard deviation by one unit, the second does it in 0.35 units.

3.4 Indirect Effects

For this model you have only an indirect effect that occurs between the latent variables *work culture* towards *productivity benefits* through the mediating variable latent *equipment suppliers* with a size of 0.176 and P <0.001 value.

3.5 Total Effects

Table 5 shows the total effects, which are obtained from the sum of the direct and indirect effects that the variables have each other. Suppliers have a direct effect on productivity benefits, also, the work culture has a direct effect on the productivity benefits and finally the work culture has an indirect effect on the productivity benefits through equipment suppliers.

Table 5. Total effects.

	Productivity Benefits	**Equipment Suppliers**	**Work Culture**
Productivity Benefits		0.307	0.524
Equipment Suppliers			0.574
Work Culture			

4 Conclusions

According to the analysis of the results, it can conclude that equipment suppliers have a direct and positive about the productivity benefits impact, which is why it is very important to have a good relationship with them as an important part of the maintenance process and consequently the productivity benefits. In addition, it can be concluded that it is important to have a good working culture within the company and to equipment suppliers since this may depend we have a good relationship with them because the latent variable work culture has a direct and positive impact on the latent variable equipment suppliers. Finally, it is concluded that the work culture has a direct and positive impact on the productivity benefits because with good work practices can get many benefits.

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