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Tire Management in a Truck Fleet and its Environmental Impact

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Abstract:- When looking at the tire maintenance work in a truck fleet, it is evident that the unplanned corrective maintenance is the most frequent. In this sense, the objective of this work was to develop maintenance engineering to improve tire management in a fleet. The work adopted the case study as its methodological approach and the company studied is a carrier, which serves the entire Brazilian territory and has more than 5,000 tires in its fleet running as assets. As a result, this work presents a tire management model, based on the correlation between all stages of maintenance in a fleet and maintenance engineering. Thus, it was possible to conclude that the proposed tire management model works, is economically viable and reduces the environmental impact of the truck fleet. As a suggestion, other research could be carried out with the model, on a larger scale and in other countries.

Keywords:- *Tire Management; Tire Maintenance; Truck Fleet; Environmental Impact.*

I. INTRODUCTION

The word "transport" comes from the Latin, from the conjunction of trans (from one side to the other) and portare (to carry). In this sense, it can be said that, in summary, transport is the movement of people or things from one place to another. Cargo transportation in Brazil is of great importance and of great participation in the Brazilian economy. Its values stand out and call attention when analyzing its share of 6.7% in the Gross Domestic Product (GDP), an index that analyzes the performance of the national economy year after year [1].

Thus, most of all transport carried out in Brazil is done by road, which makes the road transport the most used transport mode in Brazil for any and all types of transport. Road transport in Brazil draws a lot of attention for generating high values and handling almost two thirds of the country's total cargo. Thus, with advantages and disadvantages, Brazil bet on the road modal, as it is a fast transport [2].

Comparing Brazil to other countries of similar territorial dimensions, such as Russia, Canada, Australia, United States and China, it is concluded that Brazil is one of the countries that most uses the road modal as a form of transport (58%) and, at the same time, which has the lowest percentage of paved roads (16%). There are 218,640 km of paved roads against 1,367,601 km of unpaved roads [3].

According to data from the transport sector, indicated by the IBGE [1], Brazil handles 58.0% of its total cargo transported through the road system, as already mentioned; 25.0% through the railway system; 13.0% via the waterway system; 3.6% through the pipeline system and 0.4% with the aerial transport system.

With regard to the condition of conservation of paved roads, according to the sense made by the National Transport Confederation (CNT), 41.2% of these paved roads are in excellent or good condition, 33.4% in a regular state and 25 , 4% in a bad or bad state [4].

Historically, fleet maintenance management has presented a remarkable feature: it uses its resources in a very inefficient manner, mainly human and material resources, resulting in high and increasing costs. Campos [5] already mentioned that labor and materials represented the areas with great potential for reducing maintenance costs, characterizing an excellent opportunity for immediate gains. This quote was mentioned a long time ago, however, it remains very current.

Regarding the maintenance of material resources, Pecorari [6] describes that, in a cargo transport company, one of the subjects that draws the most attention is the tire, as it is normally the second item with the highest maintenance cost in a company of this profile, being only behind the cost of fuel (diesel oil).

Some preliminary results on the study of tire maintenance in a fleet can be seen in Campos [5], Fernandes [7] and Dario [8]. But, there is no specific project, or planning, for managing the maintenance of such an activity. In this context, the objective of this article is to establish the management with the planning of tire maintenance in a fleet and to verify the result of this action in relation to the environmental impact, using the case study as a research approach, as suggested by Yin [9].

II. LITERATURE REVIEW

➢ *Maintenance history*

Souza [10] highlights that the Maintenance Function has recently undergone major managerial transformations. These transformations have always happened at times when companies faced competitive challenges. These companies seek high quality in their products and services, high availability in their production system, competitive costs, high levels of reliability and commitment to preserving the environment.

Souza [10] emphasizes that these companies also seek, in the maintenance departments, the positive results of performance of their productive system, to guarantee gains in productivity and quality, simultaneously, with the reduction of maintenance costs. In this way, maintenance is now considered a strategic function department, which adds value to the product.

Pinto and Xavier [11] define the maintenance mission as: ensuring the availability of the function of the equipment and installations in order to meet a production or service process, with reliability, safety, preservation of the environment and adequate costs.

Availability is defined as the percentage of time considered in which an equipment or system works successfully [12]. Reliability is defined as the probability that an item can perform a required function, for an established period of time and under defined conditions of use [13].

Another word widely used by modern maintenance organizations is Maintainability, which is defined by Pinto and Xavier [11], as the characteristic of a piece of equipment, or set of equipment, which allows the execution of services to a greater or lesser degree maintenance.

Moubray [13] highlighted that the evolution of maintenance follows the technological and industrial development of humanity. Where, this evolution can be investigated, since 1930, for three generations. The first was characterized by tasks focused on repairs, the second by the focus on improving maintenance planning and scheduling, and the third by the focus on forecasting and prevention, avoiding the consequences of equipment failures.

Dunn [14] comments that the three generations of maintenance were characterized by changes in three areas: (i) changes in maintenance expectations; (ii) changes in the point of view on equipment failures, and; (iii) changes in maintenance techniques. The first generation was marked by the Second World War, the second generation took place between the end of the Second World War and the beginning of the 1970s, and the third generation of maintenance began in the 1970s.

➢ *Maintenance Types*

Pinto and Xavier (2001) comment that, the way in which the intervention in the equipment, systems or installations is made, characterizes the various types of existing maintenance. In this way, six types of maintenance are defined: (i) unplanned corrective; (ii) planned corrective; (iii) preventive; (iv) predictive; (v) detective, and; (vi) maintenance engineering.

Planned corrective maintenance is the correction of less than expected performance, or failure, by management decision, that is, by acting as a result of predictive monitoring or by the decision to operate until the break [15].

Preventive maintenance is the action performed in order to reduce, avoid failure, or drop in performance, obeying a previously prepared plan, based on defined intervals of time [15].

Predictive maintenance, also known as maintenance under condition, can be defined as, the intervention performed based on changes in condition or performance parameters, whose monitoring follows a systematic [16]).

Detective maintenance is the performance performed in protection systems, seeking to detect hidden flaws, or not perceptible to the operation and maintenance personnel. A practical example of this type of maintenance, to discover hidden flaws, is the periodic checks of the spare tire pressure of cars [11].

Maintenance engineering is defined by Xavier [17] as the set of activities that allows for increased reliability and guaranteed availability. In other words, it would be to stop repairing and living with chronic problems, to improve standards and systematics, developing maintainability, giving feedback to the project and technically interfering in purchases.

Therefore, those who only perform corrective maintenance continue to “put out the fire”, and consequently, having very bad results. Meanwhile, the organization that uses corrective maintenance, but incorporating preventive and predictive, will quickly be performing maintenance engineering [17].

➢ *Maintenance and the environment*

In an attempt to correlate the advantages of maintenance to reduce the environmental impact, Kazopoulo *et al.* [18], in a study to evaluate a vehicle inspection and maintenance program, stated that an adequate implementation of a vehicle inspection and maintenance program can be a component of a management strategy for air quality. Such a program may be the best way to identify vehicles in need of maintenance, as engine maintenance directly affects pollutant emission levels.

In this sense, Moghadam and Livernois [19] comment that many jurisdictions in North America and Europe have introduced emission standards for vehicles in use, which are applied with inspection and maintenance programs. This has led to a reduction in emissions from carbon monoxide (CO), hydrocarbon (CH) and nitrogen oxides (N2O) vehicles, especially in urban areas. They cite, as an example, the Canadian province of Ontario, which in the first thirty-three months after the start of its program in 1999, more than four million vehicle inspections were carried out, and subsequent repairs of non-compliant vehicles led to a reduction more than 15% of emissions from vehicles in circulation.

Complementing the statements highlighted earlier, Wursthorn *et al.* [20] and Huang *et al.* [21] report that, the environmental impact is generally less when a vehicle component is repaired, instead of being replaced. Thus, it is evident that maintenance plays a fundamental and strategic role in reducing the environmental impact, promoted by motor vehicles.

III. METHODOLOGY

➢ *Case Study*

The present work can be classified as empirical, as it gathers data collected in the field through direct observation and uses document analysis, internal documents of the organization, made available for research. The data are predominantly of a qualitative nature and contributed to the formation of the proposed model, based on the literature by Richards [22] and Corbin and Strauss [23].

The data were collected through specific literature of the studied organization and contact with some of its members via e-mail and on-site visits. The use of these different instruments and data sources is important for verifying the convergence or divergence of the data, performing a triangulation of the sources of evidence, as suggested by Miguel [24]).

The studied company was selected based on its relevance and the author's easy access. It is, therefore, a case study, with revealing characteristics, as highlighted by Yin [9], with essentially qualitative data.

The unit of analysis studied is dedicated to the activity of road transport. The organization gathers data on the maintenance of all tires found in its fleet. The information is stored in your ERP system and is accessed by all the people involved, with support for maintenance decisions.

The performance of the studied company covers the national market, operating in all Brazilian states. It is a private, privately held company, considered to be medium-sized, which generates around 300 direct jobs and over 300 indirect jobs, with annual sales close to R $ 50 million. It has more than 5,000 tires in its fleet, as current assets, and this makes it an appropriate object of study, given the purpose of this work.

The data, considered the focus of the research, were collected during three visits to the company, with an average duration of two hours each, in contact with members of the organization. These data pointed out how the transport company maintained its truck fleet and how it influenced tire performance.

In this way, this work can be considered of a descriptive (confirmatory) nature, that is, without carrying out a causal analysis. However, this (descriptive) approach is aligned and contributes to the objective of the work, to present a model of tire management, based on the proper planning of tire maintenance in a fleet.

IV. RESULTS

➢ *Causes of tire mileage loss*

In order to use maintenance engineering to reduce the number of corrective tire maintenance in a fleet, and consequently, reduce the environmental impact, this work sought to understand in its field work what were the main causes of loss of tire performance that contributed to the time between vehicle stops.

In the tire maintenance management process, the studied company's fleet presented five main causes that were linked to loss of tire mileage. These causes are the main maintenance failures with the tire, which have a direct connection with the irregular wear of the tread and the premature removal of the tires in operation, when not, of the premature loss of these tires without the possibility of repairing or resurfacing them. . Table 1 highlights what these causes are and the percentage impact of them on the loss of tire performance.

Causes of loss	Mileage loss size
Alignment	Can reduce tire mileage by up to 25%
Balancing	Can reduce tire mileage by up to 20%
Pressure Control	Can reduce tire mileage by up to 25%
Tread Design	Can reduce tire mileage by up to 40%
Pairing	Can reduce tire mileage by up to 25%

Table 1:- The causes of tire mileage loss and its sizes

Thus, to ensure maximum tire performance and, consequently, a reduction in its cost, the fleet must invest in training for the entire maintenance team, and inspections must be carried out on all vehicles, frequently. The results of the inspections can and should be used, as a feedback mechanism, for the training given to the maintenance team. In this sense, the phases of Tire Maintenance Engineering (TME) in a fleet are determined, and subsequently, presented.

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➢ *Phases of Tire Maintenance Engineering (TME)*

- *Phase One*

Phase One of TME in a fleet is the phase that precedes the tire assembly in the vehicle, and in this phase the watchword is Training. The maintenance team must be trained periodically in relation to the following items:

✓ Caring for the application and handling of tires: the tires in stock must already be mounted on the wheels with the appropriate pressure to save time for changing;

✓ Application of the proper tire pressure: the most suitable tire pressure can vary by measure and by application, following the manufacturer's guidance;

✓ Use of the appropriate tread design for each application: there are several tread designs, whether for the new or resurfaced tire, each with its correct application, always following the manufacturer's guidance;

✓ Application of the appropriate pairing to the double tires: when assembling the double tires, attention is needed to verify that the "Perfect Pair" (PP) concept is being followed; for two tires to be considered PP, they must have the same characteristics highlighted below: (i) Size, (ii) Brand, (iii) Model, (iv) DOT (manufacturing data), (v) Cycle of Life, (vi) Tread (for retreaded tires), and (vii) Depth of grooves (for used tires);

✓ PPD Analysis (Position, Pressure and Depth): the PPD Analysis will be used as a predictive (for rolling tires) and detective (for steppe tires) maintenance technique, but it is interesting that the entire tire maintenance team in the fleet has knowledge on this subject.

- *Phase Two*

Phase Two of TME in a fleet involves the phase in which the tire is mounted on the vehicle. At this stage, preventive, predictive and detective maintenance should be carried out.

✓ Preventive Maintenance: for this type of maintenance, the Geometry and Balancing procedures must be provided, which must be carried out within the pre-established deadlines, with the teams properly trained for this purpose, where: in item (i) Geometry, check and correct the following measures for the front axles: Convergence / Divergence, Camber, Caster, and Set-back; and the following measures for the rear and auxiliary axles: Adjusting the impulse angle, Camber, and Convergence / Divergence, and; in item (ii) Balancing, the two types of imbalance must be checked and corrected: static and dynamic.

In some cases, the tire caster can also be adopted as a preventive maintenance practice, to mitigate irregular wear (exception).

✓ Predictive Maintenance: this maintenance will have the objective of monitoring the Fault Development Time (FDT) of the Tire, according to Figure 1.

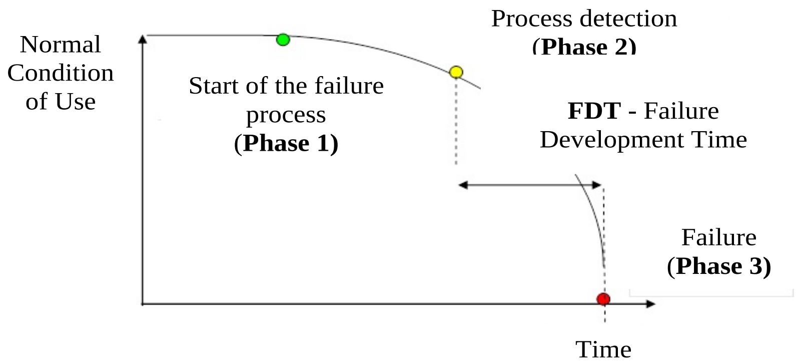

Fig 1:- Tire Fault Development Time (FDT). Adapted from Lafraia [15].

To monitor the time of tire failure, predictive maintenance will be based on the PPD tool: (i) Position, (ii) Pressure and (iii) Depth, where:

In item (i) Position, the number of the tire that is in such position of the vehicle, according to its lay-out and if the pairs are not "Paired", it is necessary to rotate the tires, in the search for pairing. If the rotation does not resolve, the unpaired pairs must be sent to the stock and replaced by Perfect Pairs (PP).

In item (ii) Pressure, it should be checked if the pressure found is within the parameters established by the fleet; if not, it must already be corrected in the vehicle itself.

And in item (iii) Depth, it should be checked whether the groove in the tire tread design is above the TWI (Tread Wear Indicator), or the parameters established by the fleet for its removal.

The TWI is 1.6 mm above the base of the tread design, but the fleets usually set higher values for the removal of tires for retreading, preserving the tire casing of specific characteristics, the terrain through which they travel. Thus, when a tire reaches its point of removal, it will be considered as "flat", regardless of whether it is new or refurbished, and should be removed from operation. In addition, a visual inspection must be carried out on each tire to see if any of them have any symptoms that could compromise their performance, or even their useful life.

- ✓ Detective Maintenance: the same procedure performed with the PPD Analysis in predictive maintenance for the tires running, will be performed with the PPD Analysis for the tires that are in steppes. Recalling that, the tires that are in the steppes can be used, in case of an accident with the tires that are running.

Both in Predictive maintenance and Detective maintenance, Tires that need Corrective maintenance can be found, and in this case, they will have their Corrective maintenance planned.

- *Phase Three*

Phase Three of TME in a fleet refers to the phase at which the tire will need to be disassembled from the vehicle. In this phase, planned corrective and unplanned corrective maintenance can be performed, where:

In item (i) Planned Corrective Maintenance, this type of maintenance will be performed based on what is found in Predictive and Detective maintenance, with a planning for stopping trucks that need maintenance.

While in item (ii) Unplanned Corrective Maintenance, this type of maintenance is caused, mainly in the case of fleets, by accidents that occur on the roads, far from the bases, and consequently, from the maintenance teams. One of the focus of this work is to reduce this type of maintenance.

- ➢ *Management model based on Tire Maintenance Engineering (TME) in a fleet*

From all the mapping carried out on the items that can cause loss of tire performance and the maintenance that can be carried out to reduce the occurrence of these items, according to the moment in which each phase occurs, it was possible to cross the information and develop a proposal for a model that would meet the objective of this work. Table 2 presents the proposal for a management model for tire maintenance engineering in a fleet

Phase	Focus	Target	Item	Frequency
1	Training	Maintenance Team	Care with: Handling of tires; Adequate pressure; Band design; Pairing of doubles; PPD analysis.	Monthly
2	Preventive, Predictive and Detective Maintenance	Truck Fleet	For Preventive: Geometry and Balancing; For Predictive and Detective: PPD Analysis.	Preventive every 10,000 km (adapted by fleet); Predictive / Detective monthly (see FDT).
3	Planned and Unplanned Corrective Maintenance	Truck Fleet	Maintenance found in the PPD Analysis; Maintenance caused by road accidents.	Found with maintenance planning or Unpredictable (Unplanned).

Table 2:- Management model for tire maintenance engineering in a fleet

- ➢ *Environmental impact reduction*

According to ABR [25], to manufacture a new tire, seventy-nine (79) liters of oil are needed, while to manufacture only the tread, twenty-two (22) liters of oil are required. Using this information and knowing that the company studied has about five thousand (5,000) tires running on its trucks, then, it is possible to conclude that, the company studied has about 395,000 liters of oil, in the form of tires, of which 110,000 liters are in the form of tread.

Based on Table 1, which identifies the causes of loss of tire mileage, and considering that any loss of mileage is linked to loss of tread performance, one can simulate the oil savings that Tire Maintenance Engineering (TME) can promote in the studied company fleet, aiming for Zero loss of performance. In this sense, Table 3 demonstrates the simulation carried out on the work data of the company studied, and consequently, the possible reduction in environmental impact, shown in liters of oil.

Causes of loss	Mileage loss size	*Economy 1	**Economy 2
Alignment	Reduces up to 25%	27.500 Liters	27.500 Liters
Balancing	Reduces up to 20%	22.000 Liters	44.000 Liters
Pressure Control	Reduces up to 25%	27.500 Liters	60.500 Liters
Tread Design	Reduces up to 40%	44.000 Liters	80.300 Liters
Pairing	Reduces up to 25%	27.500 Liters	**87.725 Liters**

Table 3:- Economy simulation promoted by TME in a fleet

** Economy 1 indicates the possible savings, in liters of oil, in isolation, for each item, with TME.*
*** Economy 2 indicates the possible savings, in liters of oil, accumulated with TME.*

V. CONCLUSION

In the present work, it was possible to develop a management model for Tire Maintenance Engineering (TME) in a fleet, identifying items that can cause loss of tire performance and observing the maintenance that can be performed to reduce the occurrence of these items, according to the moment in which each phase occurs.

It was also identified that the studied company, by applying the management model properly, can save 87,725 liters of oil, in the form of tread, during each life cycle. In other words, approximately 80% of what the company owns, and enough to manufacture almost 4,000 tire strips for retreading, or even 1,110 new tires. Considering the financial aspect, both for tire retreads and for the purchase of new tires, it is possible to find a savings value of approximately two million reals, or 440 thousand dollars, for the present day.

However, it is worth mentioning that this work has limitations in terms of scope, mainly because it is a single case study, and new research could be applied in other companies. Another future research could also be carried out, in order to discover in practice, the real financial and environmental impact, that the results predicted in theory in this work, could generate for the benefit of cargo transport companies, applying the model proposed in the operation of a transport company.

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