

Identifying Root Causes for Defects of Solid Tires: A Case of Tire Company in Sri Lanka

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Abstract: The quality of a product is vital in this competitive world. In the tire industry also, customers expect to consume error-free products. The tire manufacturing industry is focusing much attention on producing quality products to generate delighted customers and to reduce the production cost. This research is based on solid tires, and the objective is to identify root causes for repairs in the solid tire. Raw material issues, machine failures, employee involvement, lack of supervision, and managerial decisions were considered as independent variables of this study, and they were derived from the literature. The dependent variable was the repairing percentage of the solid tire. The research sample consists of the repairs of the tires that are produced throughout a year. The gathered data were analyzed using a Minitab statistical tool. Multiple linear regression analysis was used as the data analysis method. The results of the analyzed data indicated that all the factors, i.e. raw material issues, machine failures, employee involvement, lack of supervision, and managerial decisions have a positive impact on repairs in solid tires. Although all the factors have affected, employee involvement and machine failures are seen to have a significant impact on repairs in solid tires.

Keywords: Tire industry, Solid tires, Defects

Introduction

The tire manufacturing industry is one of the most important industries in the world

since solid tires are one of the most expensive products within the world context. As a profit-oriented industry, it is important to maintain the status of the business to gain more profit. In modern society, vehicles are becoming an essential element that almost everyone needed. A tire is the most vital part of any vehicle. And also, those should have replaced time to time according to the requirement. Then, the tire manufacturing industry is one of the most important industries considering the present situation.

Delighted customers are the most important asset of any organization. Customer satisfaction may largely be affected by the quality of the product or service. Therefore, one of the main goals of the tire manufacturing industry is to enhance the quality of the tires. The quality of the tire depends on the repair rate of the tires.

Repairs in solid tires may impact the quality of the tire, profit of the organization as well as time consumption to the production process. When there is a repair in a tire, the quality of the tire is varying from the originally produced tire. It may impact the durability, physical appearance, and strength of the tire. Hence, customer satisfaction may be reduced due to the mentioned repairs.

Furthermore, other than the quality of the tires, repair of the tires have some other negative impacts to the organization. Extra time, cost, and workforce should be allocated to the repairing purpose that is

external to the basic manufacturing process. Therefore, this may impact on profit of the organization. The profit of the organization can be affected based on the rate of the defects directly and indirectly.

Reducing the repair rate should be more important when considering the success of the business since business is mainly considered about profit and customer satisfaction. Therefore, it could attract loyal customers to the organization by creating a winning environment over the competitors by identifying causes for repairs and reducing or eliminating them.

In a particular organization in Sri Lanka, the average production of the solid tires is about 1200 and the average repairing amount of the tires is about 250 per day according to the internal records. It is 20.8% as a percentage from the daily total production. Therefore, it could identify that a considerable number of tires from the daily production are sent to the repair area for repairs.

Hence, it is already identified by the practitioners and responsible persons within the organization that this large percentage of repair rate is impacted to the organization negatively since the quality of the tire can be affected by customer satisfaction. If the repair rate is high, quality comes to the low range. Therefore, one of the main goals of the tire manufacturing industry is quality enhancement of the tires cannot be achieved due to repairs are existing. Thus, determining causes for repairs in solid tires and take necessary actions to reduce the repair rate should be a benefit to the organization. This may cause to quality improvement of the tires to increase customer satisfaction.

Accordingly, the repair rate reduction is the most important thing in the tire manufacturing industry. Hence, the

objective of this study is to identify root causes for repairs in solid tires.

Literature Review

Tire manufacturing industry

Considering the present environment, the tire industry can be well influenced to the economy and to the wellbeing of the human as the tires are used for many purposes in different ways. Tires are almost essential to fulfill transportation facilities as well as the agricultural fields with large capacities.

Tire products are used in many industries. Vehicles and equipment that are using tires can be divided into three different categories. Those identified categories are mentioned below.

Accordingly, tire products include:

- small implement tires: bicycle to motorcycle tires.
- motorsport, passenger car, and truck tires
- large agricultural and earthmoving vehicle tires to the field of aviation tires (Evans, 2002).

Factors affecting repairs in solid tires

From the beginning of the tire manufacturing process, it should go through several stages. Therefore, repairs of the tires may occur due to any stage of this process.

By considering those steps of the manufacturing process in solid tires, it can be identified that defects can be occurred in any stage of this process due to many reasons. According to the records, they have currently identified twenty types of defects that can be occurred in the solid tires. There will be many reasons for those identified defects that are,

- Using recycle
- Compounds out of standing time
- Bad dispersion of raw material
- Discharge temperature

- The irregular thickness of layers
- Incorrect application of bead strip
- High feeding speed on compound online
- High extrusion temperature
- Irregular cutting angle or blade cooling

1. Raw material issues

The tire manufacturing process is starting with raw material selection. Raw materials should be selected according to the size of the tire, the color of the tire, the purpose that the tire is going to use, etc. In this step, it should not only select rubber materials but also select materials particular to the tire as carbon, gum, bead wires, etc. The recipe of the raw materials is consisting of different weights of specific components. To produce the final product with better quality, these recipes should be more accurately measured and use relevant components to relevant tire type (Gupta, Jain, Meena and Dangayach, 2018). According to Fragassa and Ippoliti (2016) mentioned in their research paper, compounds that used to produce a tire can vary based on the manufacturer and the requirement of the tire being used. Further performance of the tire may also depend on the raw materials used in production.

By considering factors of the above-mentioned past research papers, issues of raw materials can be affected by the quality of the solid tires. But defects of the tires are not depending only on the quality of the raw materials or mixing error of the compounds used.

2. Machine failures:

Considering the study of Suripa and Chaikittiratana (2008), solid tires are used in vehicles and equipment to handle heavy materials and goods. Those should be tolerated, heavyweights. Therefore, the design of solid tires should be better improved due to the purpose of handling heavy loads. It should maintain the

mechanical properties beginning with the production process. If the design of the solid tire is not up to the quality or if there are any damages it could affect the durability of the tire. Rubber mixing is one of the important stages in the tire manufacturing process. According to Abou-Ali and Khamis (2003), it uses several machines in this stage. Therefore, those machines should be in better condition to get a better result from the mixing stage.

By considering those studies, it can be identified that machine failures have an impact on quality tire manufacturing and occurring defects in the tires.

3. Employee involvement:

According to the tire manufacturing process, almost all steps should require human involvement. Therefore, they should follow specifications according to the standards. Otherwise, it may occur some defects in the final product that could be an extra cost to the organization (Abou-Ali and Khamis, 2003).

In the tire manufacturing process, tire curing time, pressure, and temperature are more important factors. It should be maintained the appropriate conditions to expect quality products. Therefore, first of all, compound designers should be aware of those factors and when the system is not automated, employees should have a clear understanding of the curing conditions (Evans, 2002).

According to the mentioned points from past researches, it could be identified that employees should involve positively in the manufacturing process as well as inspection criteria.

4. Lack of supervision:

One of the most important requirements of the tire manufacturing process is to maintain tire surface quality. For that, it should be considered about the tire molding process. Evans (2002) stated that

mold cleaning and techniques of mold surface design effect clean black and smooth product surfaces which enhance the final appearance of the tire. In that case, the tire molding process should be supervised to omit the imperfections and misleading activities of this process. According to researches Abou-Ali and Khamis (2003), by considering defects identification process during the manufacturing procedure, supervisors play a major role and it is very important to detect those defects to eliminate or reduce the scrap percentage. Furthermore, eliminating or reducing the scrap rate of the tires causes enhance productivity and the profit of the organization by reducing unwanted costs for reworks. Therefore, as an organization scrap minimization should be a strategy for the organization. Better supervision is an important factor during the tire manufacturing process as well as inspection for reducing defects in solid tires according to the above-mentioned past research papers.

5. Managerial decisions:

According to the study of Abou-Ali and Khamis (2003), defects detection of the final product as well as during the production process plays an important role in the tire manufacturing process. Therefore, management of the organization should take necessary actions to fulfill this requirement for a better outcome from their business. Accordingly, researchers proposed a managerial decision to implement an integrated intelligent defects diagnostic system for tire production and service. It is a computer-based system to identify the defects in tires. Curing the tire is one of the most important parts of the tire manufacturing process. It should be maintained appropriate curing time, temperature, and pressure. Concerning Evans (2002), to predict cure times and carry out scenarios to help reduce overall cure times, finite element computer models

are now available. They can call upon non-isothermal cure data, Arrhenius reaction rates, tire shapes, and mold characteristics.

According to the above-noted factors, managerial decisions can be made a major impact on the defects rate in the tire industry by introducing new technologies to the organization and make some restrictions that can only be made by the management.

Repairs in solid tires are affected by the root causes mentioned above in the review. Occurring those repairs may harm the organization. It can be affected by the quality of the product that they provide to their customers. Therefore, the purpose of the particular organization is to identify the causes of the repairs in the solid tires as well as to identify the ways of reducing those repair rates to some extent.

As considering past research papers, researches have mentioned that the above-noted factors are affected by the repairs in solid tires. Hence, the variables mentioned above may affect the repairs in solid tires.

III. methodology and experimental design

This research is carrying out to identify root causes for repairs in solid tires. Past observations will be taken to identify the number of defective items and the frequency of occurring them according to the repair types.

The research model consists of dependent variables and independent variables.

- Dependent variable: Repairs in solid tires
- Independent variables: machine failures, employee involvement, issues with raw materials, managerial decisions, lack of supervision

In this study, regression analysis was applied to identify root causes for repairs in solid tires, by using the above-mentioned

dependent variable and independent variables.

Figure 1 shows the conceptual framework of the study.

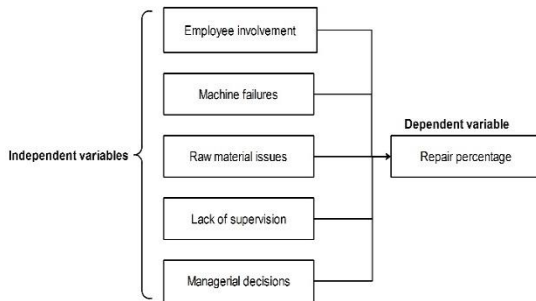


Figure 1: Conceptual framework

Results

Descriptive statistics are used to get a general idea about the data which are collected using records. Then the final part of the analysis is to identify the relationship between variables using regression analysis.

Descriptive analysis

Initially, descriptive analysis was conducted to identify the behavior of data. Here, it summarizes the dataset with mean, variance, median, etc. to get an overall idea about the data.

Table 1. Descriptive Analysis

Variable	Total Count	Mean	Standard Deviation	Variance	Median
Repair percentage	206	10.14	1.46	2.13	10.20
Employee involvement	206	0.79	0.41	0.17	1.00
Machine failure	206	0.73	0.44	0.20	1.00
Raw material issue	206	0.07	0.26	0.07	0.00
Managerial decisions	206	0.52	0.50	0.25	1.00
Lack of supervision	206	0.73	0.45	0.20	1.00

Regression analysis

The regression analysis was used to check the interaction between the dependent variable (repair percentage) and independent variables (employee involvement, machine failure, raw material issue, managerial decisions, and lack of supervision).

The summary of coefficients of the model can be illustrated as shown in Table 2.

Table 2. Coefficients table

Term	Coefficient	T-Value	P-Value	VIF
Constant	7.158	57.31	0.000	
Employee involvement	1.245	9.92	0.000	1.40
Machine failure	1.171	9.56	0.000	1.55
Raw material issue	0.849	4.67	0.000	1.18
Managerial decisions	0.766	5.70	0.000	2.37
Lack of supervision	0.937	8.42	0.000	1.29

The P-value of the independent variables can be considered to identify the significances of the variables.

According to the summary of coefficients, p-values of all the five independent variables are less than 0.05 (p-value <0.05) as shown in Table 02. Therefore, all the five variables are significant at 5% level of significance.

Hence regression equation can be written as follow,

$$\text{Repairs in solid tires} = (1.245 * \text{employee involvement}) + (1.171 * \text{machine failures}) + (0.849 * \text{issues of raw materials}) + (0.766 * \text{managerial decisions}) + (0.937 * \text{lack of supervision}) + 7.158$$

As considering Table 02 and the equation, it can be concluded that all five factors are

affected by the repair percentage of the solid tires.

VIF (Variation inflation factor) in the coefficient table checks the multicollinearity of the variables. As considering VIF values of all the five independent variables, it can be concluded that there is moderate multicollinearity in regression analysis since all the values are less than 5.

Analysis of Variance (ANOVA)

Table 3. Analysis of variance table

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	5	357.462	71.4924	182.78	0.000
Error	200	78.228	0.3911		
Total	205	435.690			

The F-ratio in the ANOVA is used to check the overall regression model as shown in Table 03.

In this study, the p-value ($0.000 < 0.05$) which associated with F-value (182.78) is very small. Therefore, the independent variables can reliably predict the dependent variable.

The goodness of the fitted regression

Table 4. Model summary table

S	R-squared	Adjusted R-squared	Predicted R-squared
0.566582	82.05%	81.60%	80.93%

According to Table 04, R² value (coefficient of determination) is equal to 82.05% which means 82.05% in the dependent variable can be explained by the independent variables.

Discussion and conclusion

All the independent variables (employee involvement, machine failures, raw material issues, managerial decisions, and lack of supervision) have an impact on the dependent variable (repair percentage in solid tires). The overall model is significant and 82.05% of the total variation in the dependent variable can be explained by the fitted regression line.

Further, according to the statistical analysis, employee involvement and machine failures have the highest impact on repairs in solid tires. Therefore, when paying attention to employee involvement, it can be more beneficial to reduce human interaction, and eliminate manual activities. It will cause to reduce the possibility of employee involvement being a root cause for repairs. And also, using new technologies as automated systems and machineries will be reduced the repair percentage up to a considerable level.

In the tire manufacturing process, employees have to work with a greater number of machines and they should have better knowledge about how to operate them. It is better to organize, training and awareness programs in planned time slots for appropriate workers. Machine failures can be reduced by paying attention to on-time maintenance and repairs of the machines.

Since all the factors are affected by the repair percentage, raw material issues, managerial decisions and lack of supervision also have an impact. Hence, there is a responsibility to maintain the standards in raw material selecting and mixing stage. There should have a proper systemized and semi or fully automated format to select the raw materials according to the recipes. And also, more responsible and effective management decisions will reduce the repair percentage. In the manufacturing process, there are

employees to supervise machine operators and other laborers. Their responsibility is taking necessary actions to remain the standards and requirements as mentioned in the standards. Accordingly, guiding employees in right way cause to reduce the repair rate of the solid tires.

By considering those mentioned factors and implementing those suggestions, the organization can reduce the repair percentage while enhancing the benefits.

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