# STATISTICAL APPROACH TO MINIMIZE WASTE IN TYRE MANUFACTURING PROCESS: A CASE STUDY

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**DECLARATION OF THE CANDIDATE**

I hereby declare that the work presented here in genuine work done originally by me except as cited in the reference and has not submitted elsewhere for the requirement of degree programme or published any time before.

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**DECLARATION OF THE SUPERVISOR**

The above candidate has carried out research for the Master Dissertation under my supervision.

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**ABSTRACT**

The main focus of this study was to assess the wastes occurring because of defect tyres in air tyre manufacturing process in the Loadstar Pvt. Limited. This lost accounts for 37.75 million during the last five months. In this study a complete statistical analysis about defect tyres were carried out for five tyre types in air tyre manufacturing process by means of Parato diagram. The average run lengths were found for each tyre type. Explanatory statistical analysis revealed that the defect tyre cost is high due to factors such as under cure, bladder pleat, air bubble in, plate damage, air bubble lug, low pressure and less side wall thickness. These statistical analyses are recommended to help manufacturers to identify the exact issues in the manufacturing process and rectify those.

**Keywords:** Average run length, Chi-square test, NP chart, Parato diagram, P chart, X-bar chart

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# CHAPTER 1

# INTODUCTION

## 1.1 Description of the Company

Loadstar Company owned three tyre manufacturing plants with a total capacity of 7200 tones/month. The major industrial plants as follows.Katugoda Tyre Division, Ekala Tyre Division and Midigama Tyre Division.

Loadstar Private Company is the largest single Export Company in Sri Lanka. Company accounts for approximately 3% of total export of the country of worth Rs. 30 billion annually. The main products of the company are Industrial Pneumatic tyres, Solid rubber tyres Construction Tyres, Rubber tracks and Rims.

Product target as per requirement of foreign companies such as Toyota, Nissan, Komotsu, Mitsubishi, JCB and Caterpillar. The products are mainly exported to USA, Europe, Australia and African countries. Industrial Pneumatic tyres are used in Industrial equipment such as an air craft, support GSE, static and special applicants and Industrial Trailers. The construction tires are used in Access Equipment, Skid Seer, Backhoe Loaders, Graders, Wheeled Excavators and Tele handlers, rubber tracks are used for Mini/Maxi Excavators and tracked skid steer equipment.

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## 1.2 Air Tyre Production Process

Air tyre production process mainly divides two sections as tyre building area and tyre curing area.

### 1.2.1 Tyre building Area

Ply (Inner Liner) is the input of building area which is taken from semi-product line and output is green tyre.

Several machines have installed to facilitate to the production line as follows.

As depicted in Figure1.1 the seven types of machines in the building area consist of following types,

1. Pocket machine
2. Building machine
3. Inflating machine
4. Brushing machine
5. Warming and thread rolling mill
6. Drilling machine
7. Airbag inserting machine

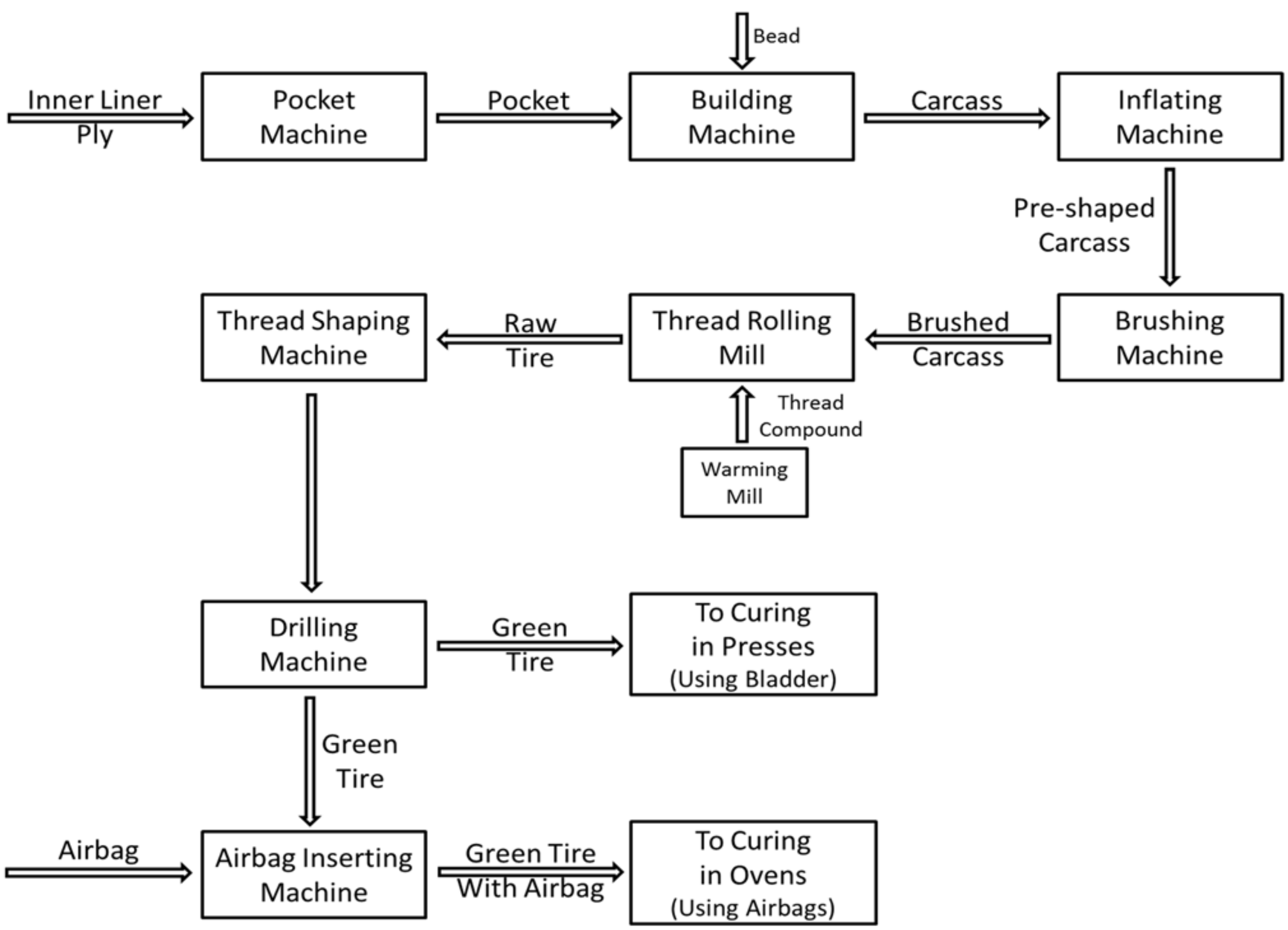


**Figure 1.1** Process layout of tyre building area

#### 1.2.1.1 Pocket Machine

Consist of two parts in the pocket machine namely Roll Feeding Side and the Finishing Side. In Roll feeding side up to five rolls of liners can be handled with different thickness according to the tyre size. The finishing side drum roll to three or four layers of liners according to the tyre size to make pocket. These layers of liners consists of inner liner which is prepared from Layer Calendar and second layer (Ply) with tyre code is also prepared from fabric calendar. Number of layers changes with inner liner according to the tire size.

#### 1.2.1.2 Tyre Building Machine

The Finished pocket which is coming from pocket machine is fixed on to the building machine to fix two bead wires on both side of and also to fix final two or three layers which is called carcass. Building machine operates pneumatically and electrically to open and close the drum to load pocket and remove the carcass.

#### 1.2.1.3 Inflating Machine

The finished carcass will be fixed on to the Inflating Machine bladder where the bladder will inflate with the carcass to get the shape of tyre.

#### 1.2.1.4 Brushing Machine

The pre-shaped carcass will be fixed on the brushing machine to brush the outside area before going to the thread rolling mill. The brushing machine removes all impurities outside of the carcass and it allows proper bonding and thread compound with the carcass

#### 1.2.1.5 Warming and Thread Rolling Mill

Warming mill takes compound from the mixer and keep it warm and transfers it to the thread rolling mill according to the tyre size and the weight. Then this quantity of compound will roll on to the pre-shaped carcass by the thread rolling mill which has come from inflating machine.

#### 1.2.1.6 Thread Shaping and Drilling Machine

This semi-finished product will fix on to the thread shaping to get brushed the outside of the thread rolled area of the carcass and transfers into the drilling machine to drill holes to remove air bubbles inside the layers. The finished product is called Green Tire.

#### 1.2.1.7 Airbag Inserting Machine

If tires curing inside the ovens, air bag should be inserted into the green tire. Air bag should loaded on the hook of airbag inserting machine according to the tyre size and inserted it to green tyre by means of this machine.

### 1.2.2. Tyre Curing Area

Curing area has been divided in to two parts namely curing in ovens and curing in presses

#### 1.2.2.1 Curing in Ovens

Oven boxes made of stainless steel plates including inside glass wools. Glass wools act as insulator material. Oven door of the top side has fixed heating elements and door is operating automatically. Bottom side of the box also has fixed consists a heating elements to heat the moulds. The common press which powered by hydraulically and PLC (Programmable Logic Controller) controlled is used to insert a green tyre with airbag, inside the heated mould. After inserting green tyre in to the mould, close the mould and put into the oven. After mould put into the oven connect air valve and transmit 8 bar air pressure in to the airbag after finish the curing cycle. Curing cycle is varying according to the tyre size.

#### 1.2.2.2 Curing in Presses

At here presses are operated by hydraulically and PLC controlled. Top and bottom side of the presses are heated using heating elements in Bagomatic (BOM) presses, using steam coils in Australian pressure. Mould has mounted to the presses permanently. Presses are insulated to reduce heating loss to the outsides. After reached to the required temperature press should be opened and inserted Green tyre, closed the press and insert air pressure inside the bladder after finish the curing cycle. The finished product (green tyre) which comes from building area are sent to the different presses for curing according to the tyre sizes. Curing times and cycles depend on the size of the tyre. When the complete cycle is finished (curing) the finished product will come out and the finished tyre will go to the post curing inflator (PCI) and quality control department for testing and quality check.

### 1.3 Categorization of Tyres

In Quality Control Department, checked the quality of the tyre which passed through from post curing inflator (P.C.I) section and categorize tyres as,

1. First choice tyres
2. Defect tyres

#### 1.3.1 First Choice Tyres

Confirmed tyres under all the specifications such as weight, hardness, outer appearance, inside appearance, dimensions, section width are called first choice.

#### 1.3.2 Defect Tyres

If there are discrepancies against specification with respect to the above standard, these tyres are called defect tyres. Minor defect tyres can be repaired within the specification and categorize as first choice.

In the Quality control department every tyre went through an intensive checking and ascertain the weather confirm to the quality standard of the tyre.
Rest part of the tyres which are out of specification are categorize as defect or scrap.

### 1.4 Objective of the study

Objective of this study are,

- To analyze the total cost of defective tyre types  by means of X bar chart
- To Calculate ARL value of tyre types by means of p chart
- To analyze the process within the control limit or out of control by means of np chart
- To check the performance of the process.
- Identify main reasons for defective production by means of Parato diagrams

# CHAPTER 2

# LITREATURE REVIEW

## 2.1. Introduction

As Rachel Louise Carson (1907-1964) successfully noted in her phrase “The human race is challenged more than ever before to demonstrate our mastery - not over nature but of ourselves”, we are challenged to find ways to produce more energy, reduce our waste production while minimizing use of limited natural resources. Although recycling of materials has a history going back to the times of Plato BC400 and collecting scrap bronze &metals in Europe in pre-industrial times (Wikipedia, 2011), the high demand roar for raw materials in the 19th and 20th centuries with industrial development caused cheaper alternative of reusing scrap material rather than discarding them out. Interestingly, 21st century’s major driving force has additional items on top of the existing reasons of using recycled material, such as reducing consumption of limited natural resources and lowering carbon dioxide emissions against the greenhouse effect. The increasing demand for energy production and dealing with larger amounts of waste contaminating the nature, forces mankind to find innovative ways to deal with the produced pollutant waste, emit lesser amounts of $CO_2$, and generate more energy. Recycling of scrap tires turns out to be a perfect match for the recent requirements of the 21st century. This chapter discusses various ways of recycling scrap tires and how they relate to the recent energy, material, and nature needs of our times.

Recycling of scrap tires until the 1960’s in the US can be taken as an example; about half of the manufactured automobile tyres used to be recycled since only synthetic or natural rubber was used in the tyre manufacturing process and tyres could have been directly used without major processing. Recycling of used tires was further encouraged by the fact that these materials were also expensive. The increasing use of the synthetic rubber, however, lowered the manufacturing costs and reduced need for recycling. Moreover, the development of steel belted tires in the late 1960’s was almost the end of tire recycling since additional processing of tires was needed. Consequently, by 1995, the rate of rubber recycling fell up to only 2% [Reschner].

Highway construction industry is a big alternative market for recycling scrap tires. Many studies have been carried out on crumb rubber modified asphalt. In 1995, it was required by all federal states in the U.S. to fund paving projects with tire modified asphalt. After that, the consumption rate of wasted tires in modified asphalt projects was increased, and in some states a maximum recycling rate of 20% was reached [Sheehan]. Other methods to gain the raw material and energy available inside scrap tires are further discussed under each.

The outcomes of scrap tire recycling are not only limited by easy access to cost-efficient material such as rubber and steel, but also have positive effects on the environment: Recycling of scrap tires on a global scale can drastically reduce waste yards, soil and atmospheric contamination caused by dump yards and large scale tire fires.

### 2.2 Scrap tire disposal related problems

Massive disposal sites of scrap tires is common in many cities of modern times as about 1 scrap tire is produced per person every year. The stored used tires slowly degrade under the effects of solar radiation as well as rusting of steel takes place. Degraded material would slowly contaminate soil and underground water over years. The disposal sites waiting under the sun for extended periods of time might catch on fire either by accident or because of bottles or broken glass focusing sunlight. Tires burn with thick black smoke and heat, quickly spreads over the whole disposal area, and leaves oily residue contaminating the soil. Such fires are difficult to put off and generates significant amount of air pollution. One of the overseen problems of scrap tire disposal yards is that these areas become breeding places for rodents and mosquitoes. Stagnant water that collects inside tires is a suitable breeding place for mosquitoes. Elimination of scrap tire disposal sites by proper recycling would also have secondary advantages of eliminating disposal related problems.

### 2.3 Major methods and reasons of recycling tires

The recycling of scrap tires may be defined under two different categories:

i) using the scrap tires as whole or mechanically modified shapes (in crumps or shredded)

ii) Chemical decomposition or separation of scrap tire contents into different materials. Recycling as-is or after mechanical process has the advantages of directly using scrap tires without major investment. For example, scrap tires can be directly used as boat bumpers at marinas to protect ships from scratching or hitting at the side of wharf. (Similarly, old tires can be placed side by side in half tire shifted pattern for slope stability or under roads for improved stability (Mechanical Concrete). Ripped tire pieces in large chunks can be directly used as light weight infill material at embankments. Smaller scrap tire pieces can be used as mixture in concrete as gravel substitute to improve tensile capacity or in asphalt paved roads for better traction. Smaller crumbs can be bonded together to generate walking or running mats or soft surfaces for playgrounds. Drainage around building foundations, erosion control for rainwater runoff barriers, wetland establishment, crash barriers at sides of race tracks are other uses of scrap tires without much modification.

Scrap vehicle tyres make a significant contribution to the generation of waste. For instance, the rate of scrap tyre generation in industrialized countries is approximately one passenger car tyre equivalent (PTE, or 9 kg) per capita per year. Furthermore, it is estimated that an additional 2-3 billion scrap tyres are stockpiled on unregulated or abandoned piles throughout the US, a figure which represents the cumulative scrap tyre generation of approximately 10 years. For EU Member States, it is reasonable to assume illegal or semi-legal scrap tyre accumulation in the same order of magnitude.

### 2.4 Historical perspective

It is fair to say that rubber recycling - in one form or another - is as old as the industrial use of rubber itself. In 1910, natural rubber cost nearly as much as silver, and it thus made perfect sense to reuse as much as possible of this valuable commodity. During this time, the average recycled content of all rubber products was over 50%.

By 1960, the recycling content in rubber products dropped to around 20%. In the subsequent decades, cheap oil imports, the more widespread use of synthetic rubber and the development of steel-belted radial tyres have all contributed to a steady decline in rubber recycling.

As of 1990, the established tyre and rubber industry used only around 2% recycled material. However, in the past decade the tyre recycling industry has experienced a tremendous growth, thanks to a legal framework requiring the safe disposal of scrap tyres, the availability of reliable size reduction technologies and the emergence of innovative, economically viable applications for recycled rubber.

**2.5 Scrap tyre disposal statistics**

Statistical data on scrap tyre generation and disposal are published by a number of organizations, most prominently the US Rubber Manufacturers' Association and the European Tyre Recycling Association (ETRA).

**2.6 Rubber recycling**

The traditional tyre and rubber manufacturing industry currently uses only 2-5% post-consumer recycled rubber. The low recycled content in conventional rubber products does not tell the whole story, however. Effective size reduction methods and innovative applications for crumb rubber led to a significant increase in the use of tyre-derived crumb rubber in the past decade. Some important applications are discussed below, in the section 'Common applications for recycled rubber.

In 2009, ABC Tyre company decided to implement a BPM ( Business Process Management ) project with the goal to decrease the manufacturing cost per tyre and increase revenue from each tyre sold. After implementing the BPM project ABC tyre company reviewed the value of the project after a year. This report presents an analysis of the impact of Business Process Management project implementation on the organizational financials. Financials of cost structure have been evaluated after the implementation of BPM process with respect to baseline data about the relative cost structures.

Prior to implementing the data ABC tyre company was having following cost and prizing structure for the tyre manufacturing and selling. The data present the base line data for 2009 that sets the basis of comparison for determining whether BPM system implementation in the company leaded to reducing the costs associated with tyre manufacturing or not.

Business Process Management (BPM) system implementation enhances the business performance by providing opportunities to increase productivity, reducing cost and extending the company's ability to turn the business on agility .It is highly important to ensure that baseline data is accurate. In cases, when base line data are based on estimations. High deviations may occur in the proceeding results. This may leads to making wrong derivations from the results.

### 2.7 Background of the Information

In tyre manufacturing process of Midigama factory Number of defect tyres came out from the production process was increased day by day. When increasing number of defectives total wastage cost also increased because of tyre manufacturing cost is high. Therefore wastage cost is the main problem of the company.

There are 71 tyre types produce in this air tyre manufacturing process of this company. In generally, rubber compound, chemicals, tyre codes, beads and paints were use as raw materials to produce the tyres. Further material cost, machine cost and labor cost include for the manufacturing cost of the tyre.

In generally, among the various tyre types even smallest tyre weight is more than 10 Kg.The smallest tyre type was 600-9 and manufacturing cost is Rs 3501.00 and 26.5-25 is largest tyre type and manufacturing cost is Rs 120406.00

I have collected past five month number of defectives and calculated total cost for each tyre types separately. The cost of total defectives is Rs 37.75million during the last five month.

## 2.8 Theory

### 2.8.1 Control charts

Control chart is a graph of variation in the response variable requesting a sequence of sample statistics. It consists of central line, upper control limit and lower control limit. There are two types of control charts namely variable control chart and attribute control charts.

#### 2.8.1.1 How to check the process

Process is out of control if one or multiple points out side of the control limit eight points in a raw above the average value and multiple points in a raw near the control limit.

Process is in control if the sample points fall between the control limits, there are no major trends forming that is the points vary both above and the below the average value.

Run is the state in which points occur on one side of the central line. The number of points in a run is called the length of the run.

#### 2.8.1.2 Variable control chart

Variable control chart deals with items that can be measured. There are three types of variable control charts namely X bar chart, R chart, MA Chart. X bar chart deal with a average value in a process.

#### 2.8.1.3 Attribute control chart

Attribute control chart that factor in the quality attributes of a process to determine whether the process is performing in or out of control. There are four types of attribute control charts namely P chart, np chart, c chart and the u chart.

P chart use for the defective analysis. P chart is a fraction rejected control chart and np chart is a number rejected control charts.

In my study P chart have used for calculating ARL values. On the other hand X-bar chart and np used for analyzing defects.

### 2.8.2 Chi-square test

Chi-square test is a statistical test commonly used to compare observed data with data we would expect to obtain according to a specific hypothesis. For example, if, according to Mendel's laws, you expected 10 of 20 offspring from a cross to be male and the actual observed number was 8 males, then you might want to know about the "goodness to fit" between the observed and expected. Were the deviations (differences between observed and expected) the result of chance, or were they due to other factors. How much deviation can occur before you, the investigator, must conclude that something other than chance is at work, causing the observed to differ from the expected. The chi-square test is always testing what scientists call the null hypothesis**,** which states that there is no significant difference between the expected and observed result.

The formula for calculating chi-square ( $\chi^2$ ) is:

$$x^2 = \quad (o-e)^2/e$$

That is, chi-square is the sum of the squared difference between observed (*o*) and the expected (*e*) data (or the deviation, *d*), divided by the expected data in all possible categories.

### 2.8.3 Parato diagram

A Pareto diagram is a simple bar chart that ranks related measures in descending order of occurrence. The principle was developed by Vilfredo Pareto, an Italian economist and sociologist who conducted a study in Europe in the early 1900s on wealth and poverty. He found that wealth was concentrated in the hands of the few and poverty remain in the hands of the many. The principle is based on the unequal distribution of things in the universe. It is the law of the "significant few versus the trivial many." The significant few things will generally make up 80% of the whole, while the trivial many will make up about 20%.

The purpose of a Pareto diagram is to separate the significant aspects of a problem from the trivial ones. By graphically separating the aspects of a problem, a team will know where to direct its improvement efforts. Reducing the largest bars identified in the diagram will do more for overall improvement than reducing the smaller ones.

There are two ways to analyze Pareto data depending on what you want to know majority sutlered from poverty. Count Parato principle has used for analyzing the data.

**2.8.3.1 Counts Pareto**

Use this type of Pareto analysis to learn which category occurs most often, you will need to do a counts Pareto diagram. To create a counts Pareto, need to know the categories and how often each occurred.

# CHAPTER 03

# DESCRIPTION OF THE DATA AND METHODOLOGY

## 3.1 Description of the data

Below table 3.1 shows part of the data which used for the analysis. Considering above data table it include tyre type, ply rating information, tyre type, serial number of the tyre , name of the shift and time duration separately.

**Table 3.1:** Few data of Data set

| DATE | TYRE SIZE | PR | TYPE | BRAND | SERIAL NO: | DEFECT | SHIFT | PERIOD |
|---|---|---|---|---|---|---|---|---|
| 1-Apr-2011 | 11L-16SL | 10 | MRF3 | SOLIDEAL | 091 2877 | SW.CRACKS | C | NIGHT |
| 1-Apr-2011 | 355/55D-625 | 14 | OUT | OUTRIGGER | 090 3888 | UNDER CURE | C | NIGHT |
| 1-Apr-2011 | 39X15-22.5 | 14 | OUT | OUTRIGGER | 091 2868 | BLADDER LEAK | C | NIGHT |
| 1-Apr-2011 | 11L-16SL | 10 | MRF3 | EBTLED | 090 4114 | UNDER CURE | A | DAY |
| 1-Apr-2011 | 10.16.5 | 10 | HA | BOBCAT | 090 3217 | UNDER CURE | A | DAY |
| 1-Apr-2011 | 6.00-9 | 10 | ED | SOLIDEAL | 090 8060 | BLADDER LEAK | A | DAY |
| 1-Apr-2011 | 240/55-17.5 | 12 | LB | GRAY-NM | 090 4258 | TWO COLOR | B | DAY |
| 1-Apr-2011 | 7.00-12 | 12 | ED | SOLIDEAL | 090 2706 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 7.00-12 | 12 | ED | SOLIDEAL | 089 2538 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 7.00-12 | 12 | ED | SOLIDEAL | 090 2704 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 7.00-12 | 12 | ED | SOLIDEAL | 089 2535 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 7.00-12 | 12 | ED | GRAY-NM | 090 2817 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 7.00-12 | 12 | ED | GRAY-NM | 090 2811 | AIR BUBBLE IN | C | NIGHT |
| 1-Apr-2011 | 7.00-12 | 12 | ED | GRAY-NM | 090 2821 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 1400-24 | 16 | G2 | ECR-SD | 091 2215 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 1400-24 | 12 | L3 | SOLIDEAL | 090 2136 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 1400-24 | 12 | L3 | SOLIDEAL | 090 2134 | less under tread thickness | C | NIGHT |
| 1-Apr-2011 | 1400-24 | 12 | L3 | SOLIDEAL | 090 2133 | less under tread thickness | C | NIGHT |

### 3.2 Methodology

The data was collected with regard to defective products during last consecutive five months. Then data was analyzed defective vs. associated cost of them.Next five tyre categories were selected base on high cost as well as high number of defective by means of matrix plot. After that X bar chart, p chart, np chart were drawn and calculated ARL values for each tyre type separately. Then Parato diagram were drawn for selected tyre types. Then chi-square test was done to identify association between the defective in months and tyre type.

# CHAPTER 04

# RESULTS AND DISCUSSION

### 4.1 Relationship between number of defect and total cost

By considering past five month defective tyres related to the each tyre types are categorize to four ranges 0-25, 26-50,51-100, and 101-300. The tyre types 11L-16SL, 19.5l-24, 20.5-25,1400-24,355-55D-625 and 700-12 fall in to 51-100 range. The tyre type 10-16.5 and 12-16.5 falls within the 101-300 range.

**Table4.1:** Number of defectives of each tyre type.

| NUMBER OF DEFECT | TYRE TYPE | | |
|---|---|---|---|
| 0-25 | 10.5-18 | 265/50D-20 | 385/45-28 |
| | 12.5/80-18 | 14.9-24 | 16.5-24 |
| | 15-19.5 | 1100-20 | 265/50D-20 |
| | 18-22.5 | 27X10.5-15 | 14.9-24 |
| | 23X10-12 | 385/65-19.5 | 1100-20 |
| | 240/55-14.5 | 8.00-16.5 | 26X12-16.5 |
| | 240/55-17.5 | 1200-20 | 26X12-12 |
| | 26X10-12 | 21L-24 | 405/70-24 |
| | 27X10-12 | 315/85-15 | |
| 26-50 | 18-625 | 16.9-30 | 7.50-16 |
| | 1300-12 | 8.25-15 | 23.5-25 |
| | 10.0/75-15 | 1000-20 | 6.00-9 |
| | 9.00-14.5 | 12.5/80-18 | 1300-24 |
| | 16.9-24 | 11L-16SL | |
| 51-100 | 11L-15SL | 20.5-25 | 355/55D-625 |
| | 19.5L-24 | 1400-24 | 7.00-12 |
| 101-300 | 10-16.5 | 12-16.5 | |

**Table4.2:** Cost of defectives of each tyre type.

| COST CLASSES (Rs) | TYRE TYPE | |
|---|---|---|
| LESS 50000 | 8.00-16.5 | 10.5-18 |
| | 27X10.5-15 | 240/55-14.5 |
| | 18-22.5 | 240/55-17.5 |
| | 15-19.5 | 27X10-12 |
| | 265/50D-20 | 23X10-12 |
| | 385/45-28 | 26X10-12 |
| | 12.5/80-12 | |
| 50000-150000 | 27X8.5-15 | 6.00-9 |
| | 29X12.5-15 | 31.5X13-16.5 |
| | 14.9-24 | 385/65-19.5 |
| | 16.5-24 | 1100-20 |
| | 26X12-12 | 26X12-380 |
| | 26X12-16.5 | |
| 150001-300000 | 1300-12 | 7.50-16 |
| | 18-19.5 | 11.5/80-15.2 |
| | 31X15.5-15 | 405/70-24 |
| | 21L-24 | 12.5-18 |
| | 10.0/75-15.3 | 265/50-20 |
| | 1200-20 | 28X9-15 |
| | 315/85-15 | |
| 300001-400000 | 8.25-15 | 405/70-20 |
| | 15.5-625 | 15-625 |
| | 445/55-19.5 | 9.00-14.5 |
| | 36X14-22.5 | |
| 400001-525000 | 11L-15SL | 15-19.5 |
| | 15.5/80-24 | 12.5/80-18 |
| | 16.5/85-24 | 11L-16SL |
| | 39X15-22.5 | 33X15.5-16.5 |
| 525001-800000 | 18-625 | 15.5-25 |
| | 385/65-22.5 | 7.00-12 |
| | 17.5L-24 | 1000-20 |
| 800001-2000000 | 1400-24 | 26.5-25 |
| | 1300-24 | 16.9-30 |
| | 355/55D-625 | 16.9-24 |
| | 17.5-25 | |
| 2000001-4000000 | 12-16.5 | 20.5-25 |
| | 23.5-25 | 10-16.5 |
| | 19.5L-24 | |

By considering past five months cost incurred for defectives are divided into eight cost groups. Those are less than 50000.00, 50000-150000, 150001-300000, 300001-400000 and 400001-525000. Among those 12-16.5, 23.5-25, 20.5-25,19.5L-24 and 10-16.5 tyre types fall within the maximum incurred cost range.

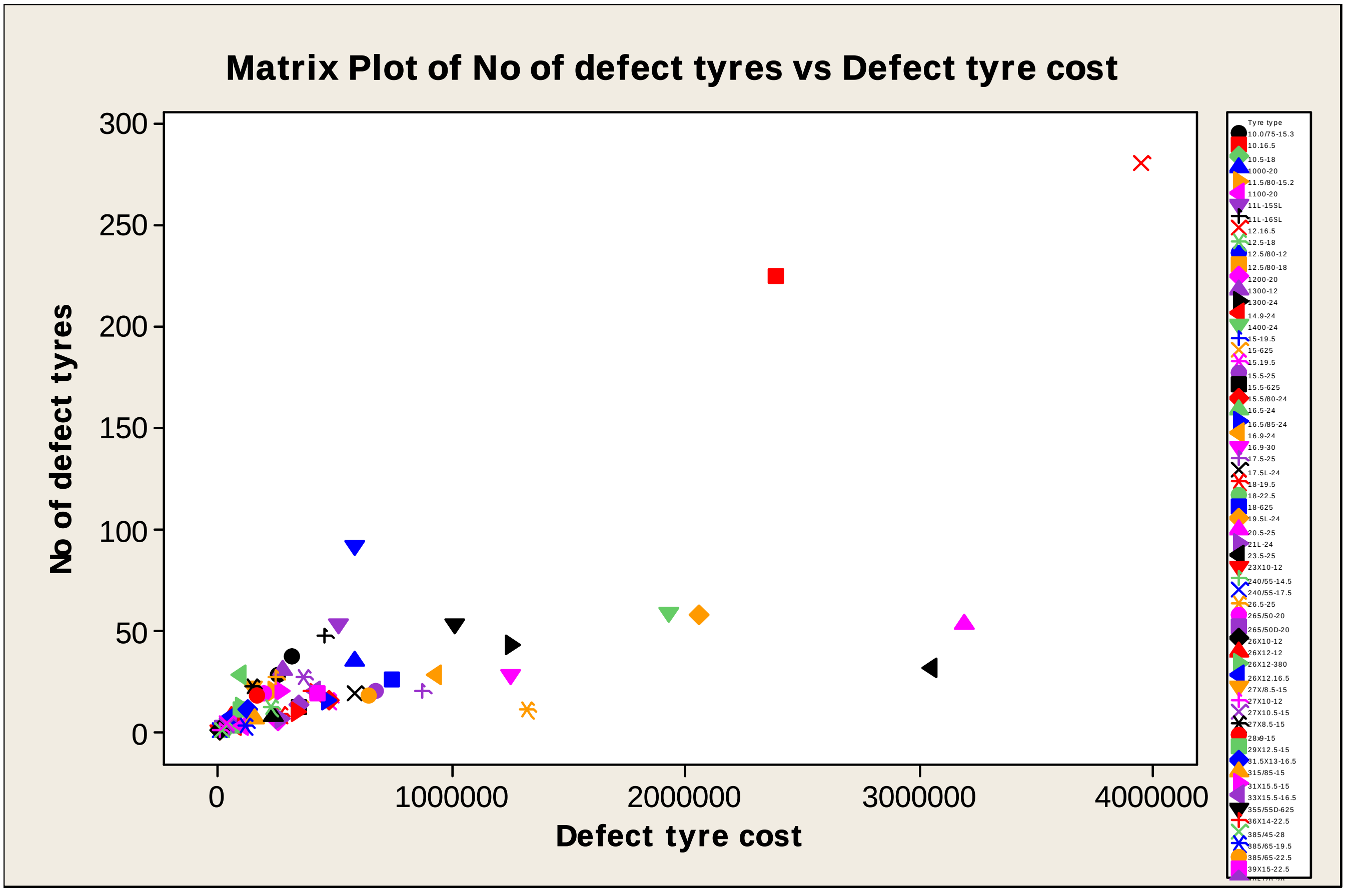


**Figure 4.1:** Number of defectives vs. cost of defect tyre

12-16.5 tyre type has both number of defectives and cost highest value. Therefore firstly we can select.12-16.5 tyre type (Type I) for the analyzing. Then next tyre type highest values of both reasons is 10-16.5 tyre type then next tyre type is 10-16.5 (Type II) .There are three tyre types which have higher cost but low defectives we have selected three tyre types giving priority only the highest cost with more than 50 number of defectives. According to the above figure 20.5-25(Type III), 19.5l-24 (Type IV) and 1400-24(Type V) has selected for the analyzing.

### 4.2 Reasons for defectives

To identify the major reasons responsible for defectives of each tyre type the no of defectives due to the following reasons would be recorded.

| | |
|---|---|
| Pressure Leak Mark | Pre Cure |
| Low Pressure | Bladder Leak |
| Air Bubble In | SMSW |
| Under Cure | Less under Thread Thickness |
| Sponge | AB Lug |
| Bladder Pleat | less Liner Thickness |
| Foreign Matter | Center Out |
| Flash Open | Air Bag Damage |
| Chafer Out | Two Color |
| I.L Damage | Plate Damage |
| SW Crack | Wrong tire |
| Thin Bead | less Side Wall Thickness |
| O-ring Leak | Bladder Damage |
| ABSW | Air Bag Leak |
| Over Cure | SM.Lug |
| Turn Mould | Bead Out |
| No PCI | I.L Pleat |
| IN Side Pleat | M.P.I |
| L.C.B | Bead Damage |
| Bead Pre Cure | Air Leak |
| Tire Damage | Air Bag Pleat |
| AB. Bead | Crack In Side |
| Wrong Core | Lug Damage |
| SW Damage | Wrong Plate |
| Bladder Mark | Wrong Ply |
| Bead Cracks | Hose Leak |
| Double Tire | Over Weight |

For further analysis of reasons with at least one defective out of the above measured reasons would be used.

## 4.3 Results

This section provides the results of quality control analysis of five tyre types separately.

### 4.3.1 Tyre type I

The Figure 4.2 shows the number of defective type I tyres produced over the study period of five months which had 141manufacturing days. The total tyres produced in this type were 58301 and out of those 281 were defective tyres. The cost of manufacturing one type of this tyre is Rs 14060.The net cost for producing a good quality tyre is 14156.96 which implies Rs 96.96 is added to the cost of production of the manufactured good tyres due to manufactures rejected tyres.

The P chart for the defective tyre produce over the study period is given in Figure 4.2. A good quality control schemes can be adopted to control this cost. The suggested control scheme is set up based on the principle that there should not be more than 10% of the rejected tyre' cost to be added to the good tyres.

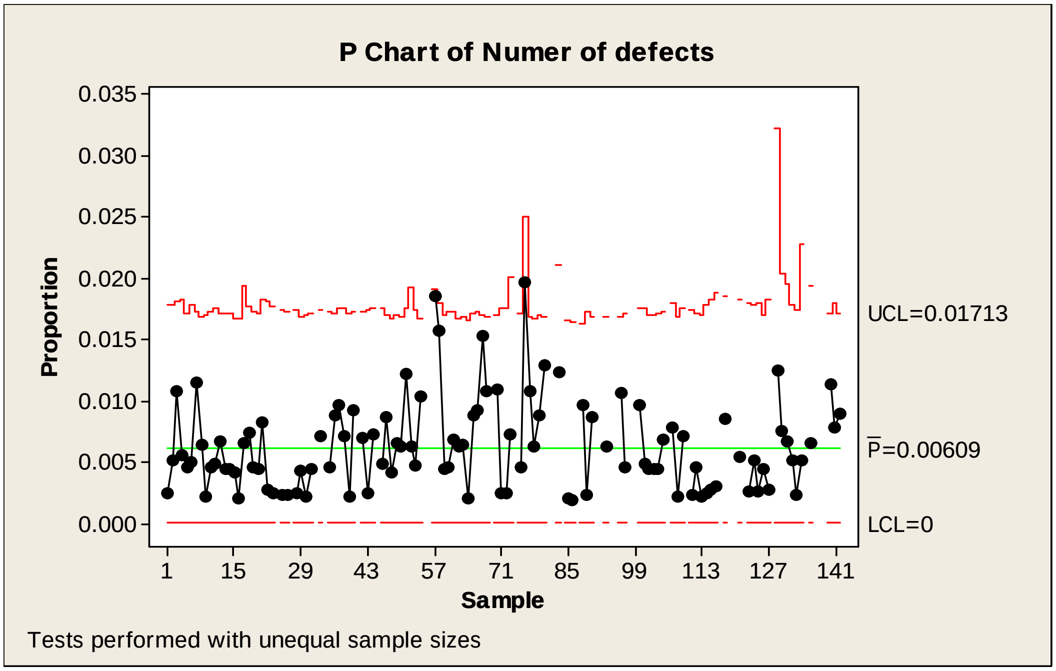


**Figure 4.2 :** P chart of tyre type I

According to the figure 4.2, there is a one point outside the upper control limit. That means that process is out of control.

$$ARL = \frac{1}{P}$$

$$ARL = \frac{1}{0.00609}$$

$$ARL = 145$$

In average one will expect one defective tyre for every 145 tyres produced for the tyre type 12-16.5.

$$\frac{Number\ of\ production \times Unit\ prize\ of\ the\ tyre}{Numberof\ good\ tyre\ production}$$

$$\frac{58301 \times 14060}{58020}$$

14128.09

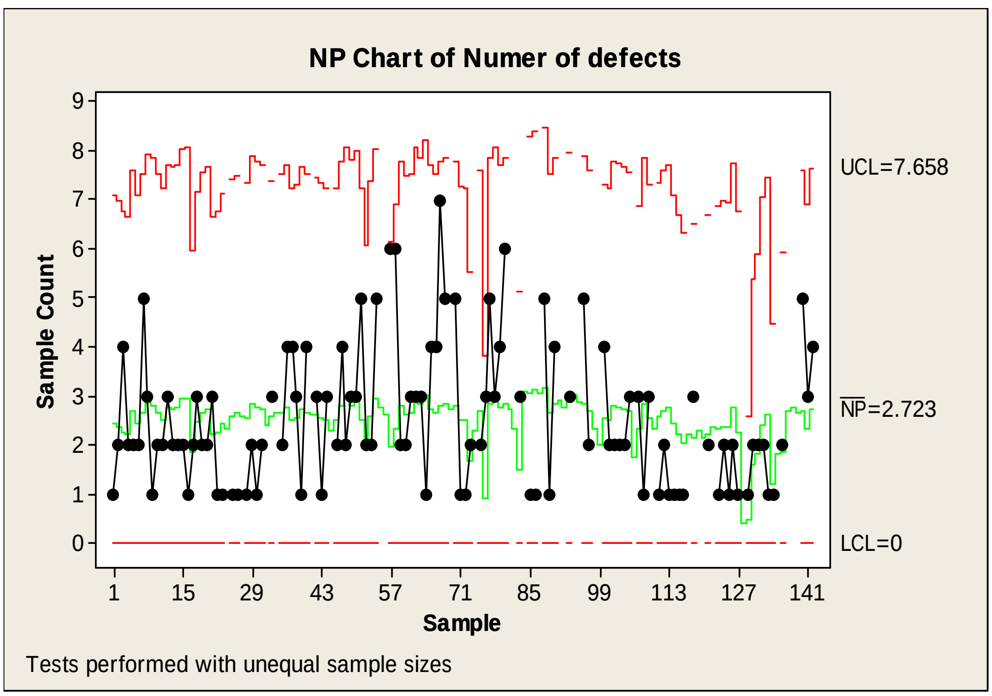


**Figure4.3:** –NP chart of tyre type I

According to the figure 4.3, all points within the control limits. Therefore the process is in control

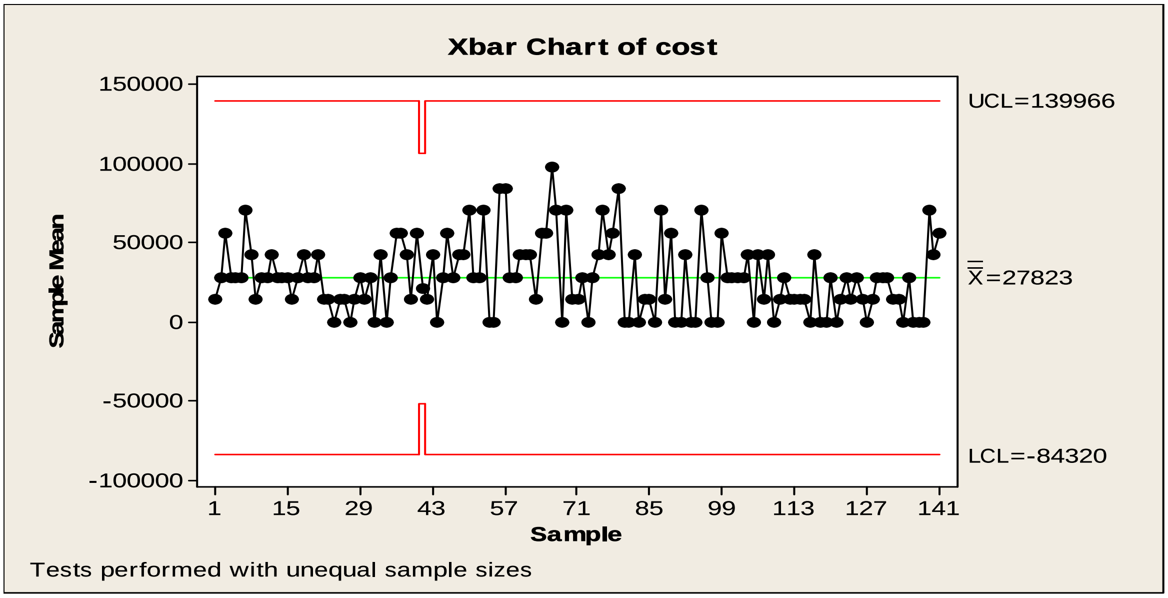


**Figure 4.4:** Xbar chart of cost for tyre type I

<u>Specimen calculation for tyre type I</u>

$N = Number\ of\ production$

$p = Failure\ probability$

$c = The\ cost\ of\ production\ one\ tyre$

$nc = The\ cost\ of\ production\ tyres$

$n(1-p)c = The\ cost\ of\ good\ tyre$

$npc = The\ cost\ of\ reject\ tyres$

$$p = \frac{Number\ of defectives}{total\ tyre\ production}$$

$n = 58301 \qquad number\ of\ defectives = 281$

$p = \frac{281}{58301}$

$p = 0.0048198$

$c = 14060$

$nc = 58301 \times 14060$

$= 819712.60$

$n(1 - p)c = 58301(1 - 0.0048198)14060$

$= 815761211.20$

$nc \leq \left(n(1 - p)\right)1.1$

$819712060 \leq 815761212.80 \times 1.1$

$8197160 \leq 897337320$

**Table 4.3:** Reasons of defectives of 12-16.5 tyre type

| **Reason** | Number of N Number of defectives |
|---|---|
| Under Cure | 27 |
| Low Pressure | 13 |
| Bladder Leak | 59 |
| Bladder Pleat | 61 |
| Less Liner Thickness | 2 |
| Pressure Leak Mark | 12 |
| Less Under Thread Thickness | 3 |
| Two Color | 3 |
| Thin Bead | 21 |
| Plate Damage | 15 |
| Air Bubble In | 2 |
| AB lug | 12 |
| Flash Open | 7 |
| Foreign Matter | 5 |
| ABSW | 3 |
| SW Crack | 8 |
| Less Side Wall Thickness | 3 |
| I.L Damage | 1 |
| Turn Mould | 2 |
| SM.Lug | 7 |
| Air Leak | 1 |
| O-ring Leak | 4 |
| No PCI | 1 |
| Center Out | 5 |
| SW Damage | 1 |
| L.C.B | 1 |
| Over Weight | 1 |

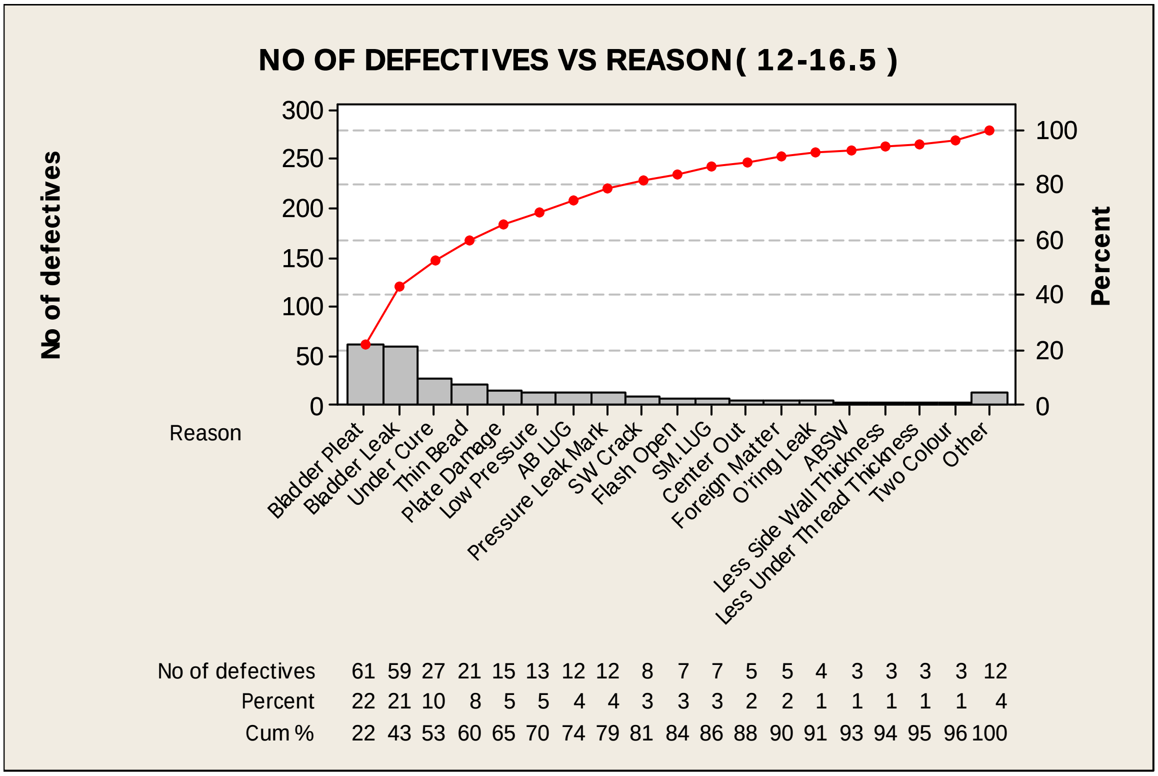


**Figure 4.5:** Parato Diagram of tyre type I

According to the Figure 4.5, Bladder pleat, Bladder leak, Under cure ,Thin bead, Plate damage, Low pressure, AB lug, Pressure leak mark, Sidewall crack are the reasons which cause to tyre type I and each reason contribute 22%,21 % 10%,8 %,5%, 5 %,4%,4% and 3% respectively. High defect are due to bladder pleat and the bladder leak.

Out of above reasons Bladder pleat, Bladder leak, Under cure ,Thin bead, Plate damage ,Low pressure, AB lug, Pressure leak mark are the eight largest bars. Reading from cumulative line to the right axis they represent approximately 79 % of the data. This means that out of all the reasons these eight reasons have taken up most defectives.

In this figure there is a substantial difference between two reasons and the remaining bars. So tackling the first two bars has substantial advantage.

**Table 4.4:** Reasons for tyre type I Bladder pleat defect

| Reasons for Bladder pleat defect | Number of defect tyres |
|---|---|
| Low pre shaping pressure | 25 |
| Wrong bladder Fixing height | 10 |
| Packing leak when press closing | 16 |
| Poor application of bladder releasing agent | 10 |

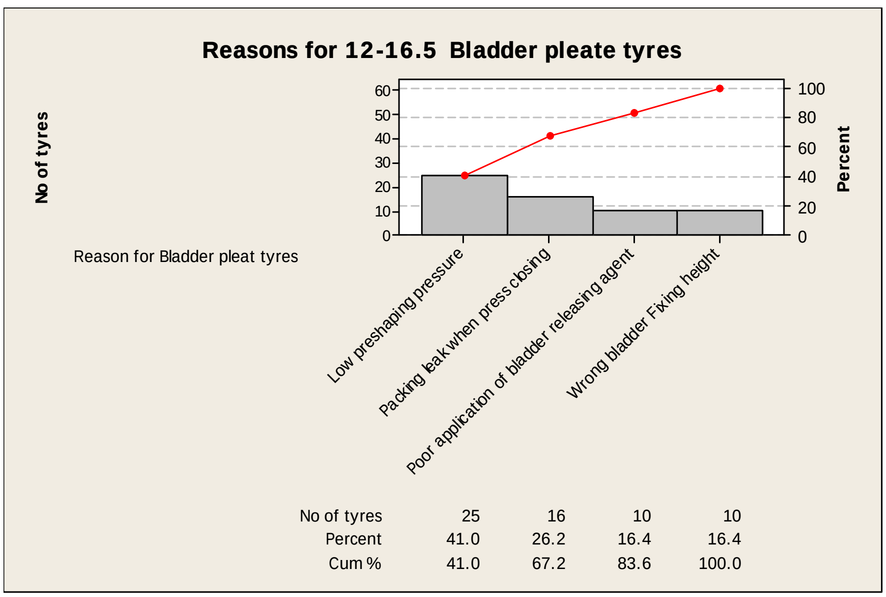


**Figure 4.6:** Reasons for tyre type I Bladder pleat defects

Considering Figure 4.6 Low pre shaping pressure, packing leak when press closing are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 67% of the data. This means that out of all the reasons for defectives these two reasons have taken up the most defectives.

According to the figure 2, there is a substantial difference between the first two reasons and the remaining bars. So tackling the first two bars has substantial advantage.

**Table 4.5**- Reasons for tyre type I Bladder Leak defect

| Reasons for Bladder leak defect | Number of defect tyres |
|---|---|
| Melt the bladder due to low N2 purity before the target | 14 |
| Poor Bladder quality | 20 |
| Stretch the bladder between core and raw tyre | 25 |

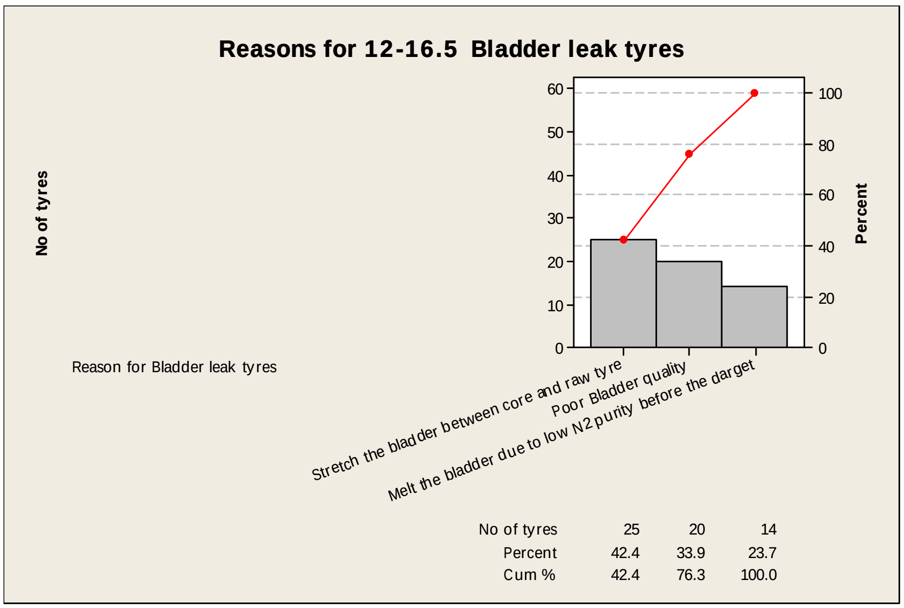


**Figure 4.7:** Reasons for tyre type I Bladder Leak defect tyres.

According Figure 4.7 Stretch the bladder between core and raw tyre, Poor bladder quality are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 77% of the data. This means that out of all the reasons for defectives these two reasons have taken up the most defectives.

In this figure, there is a substantial difference between the first two reasons and the remaining bars. So tackling the first two bars has substantial advantage.

**Table 4.6:** Reasons for tyre type I Under cure defect

| Reasons for Under cure defect | Number of defect tyres |
|---|---|
| Electrical element off | 13 |
| Water seal leak | 3 |
| Air leak from the bladder core | 4 |
| Tyre curing with low steam pressure | 2 |
| Low curing time than the specification time | 5 |

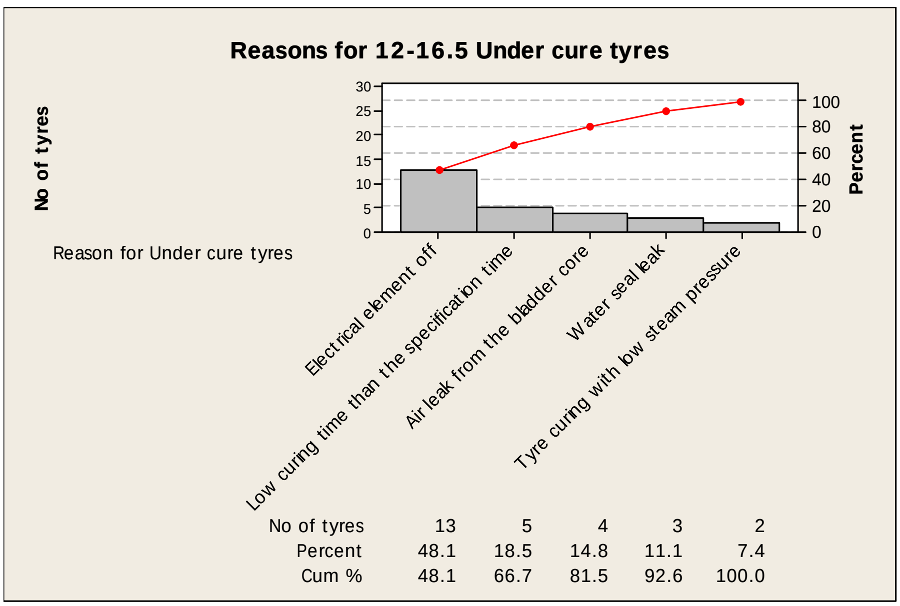


**Figure 4.8:** Reasons for tyre type I Under cure defect

According Figure 4.8 Electrical element off, Low curing time than the standard time are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 70% of the data. This means that out of all the reasons for defectives these two reasons have taken up the most defectives.

In this figure, there is a substantial difference between the first reason and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.7:** Reasons for tyre type I Thin Bead defect

| Reasons for Thin bead defect | Number of defect tyres |
|---|---|
| Pocket centre out | 3 |
| Inner liner center out | 5 |
| Bead center out in the building machine | 2 |
| Low layer width | 6 |
| Chafer out | 2 |
| Use wrong bead ( low no of wires) | 1 |
| Raw tyre center out | 2 |

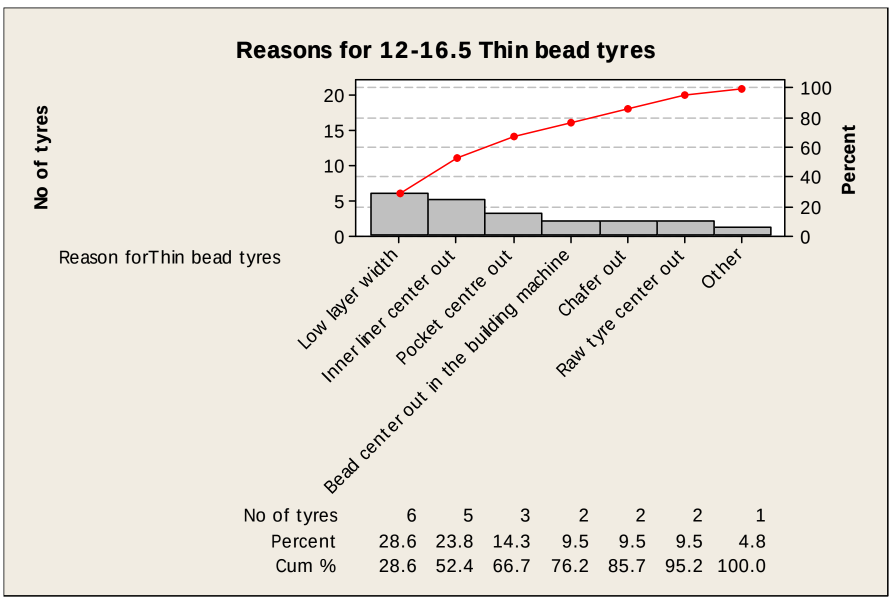


**Figure 4.9:** Reasons for tyre type I Thin Bead defect tyres

According Figure 4.9, Low layer width, Inner liner centre out are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 53% of the data. This means that out of all the reasons for defectives these two reasons have taken up the most defectives.

**Table 4.8**: Reasons for tyre type I Plate damage defect

| Reasons for Plate damage defect | Number of defect tyres |
|---|---|
| Wearing thread of the nail | 9 |
| wearing tread of the side ring | 6 |

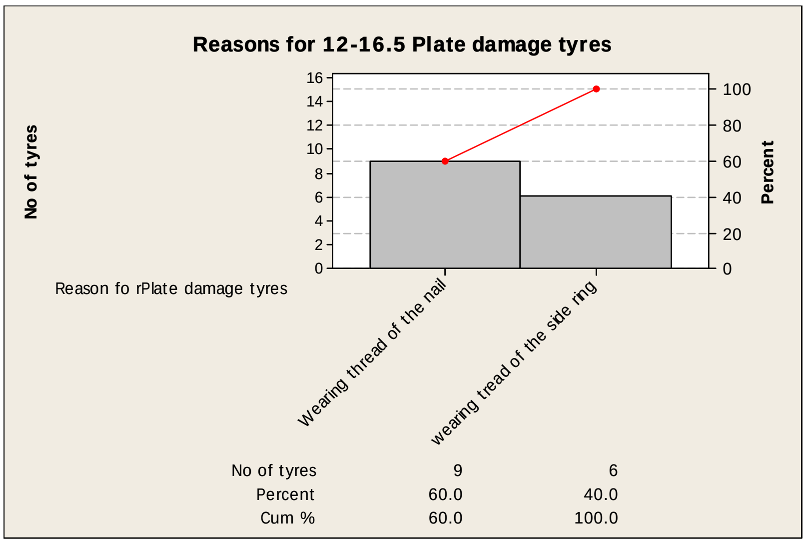


**Figure 4.10:** Reasons for tyre type I Plate Damage defect tyres

Considering Figure 4.10, Wearing tread of the nail is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 60% of the data. This means that out of all the reasons for defectives first reason has taken up the most defectives.

**Table 4.9:** Reasons for tyre type I Low Pressure defect

| Reasons for Low Pressure defect | Number of defect tyres |
|---|---|
| Delay apply hydraulic pressure | 6 |
| Hydraulic pressure release when tyre curing | 2 |
| Tyre curing with low N2 pressure | 3 |
| Press open when tyre curing due to not timer zero | 2 |

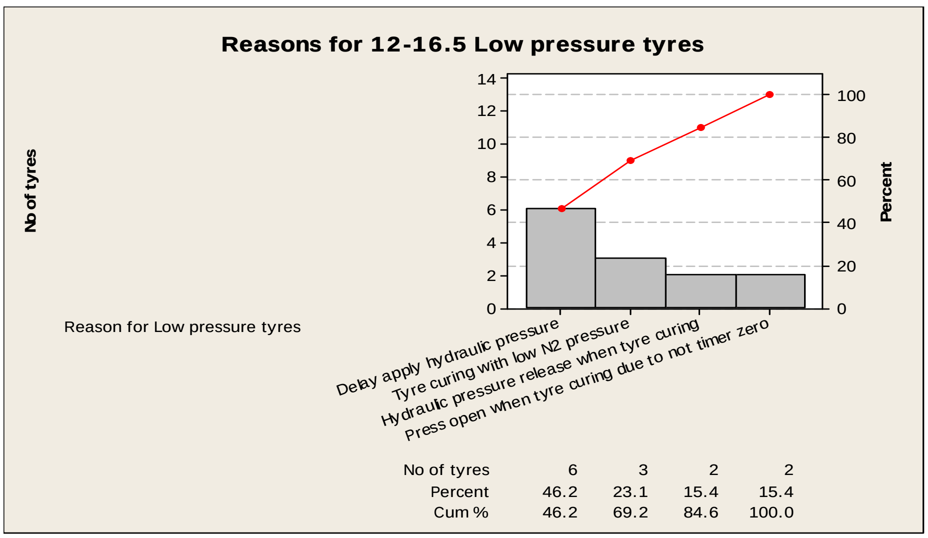


**Figure 4.11:** Reasons for tyre type I Low Pressure defect tyres

Considering Figure 4.11, Delay apply hydraulic pressure, Tyre curing with low $N_2$ pressure are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 70% of the data. This means that out of all the reasons for defectives these two reasons have taken up the most defectives.

In this figure, there is a substantial difference between the first reason and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.10:** Reasons for tyre type I Air Bubble lug defect

| Reasons for Air bubble lug defect | Number of defect tyres |
|---|---|
| Poor drilling | 8 |
| Poor tread shaping | 2 |
| Curing with over temperature | 2 |

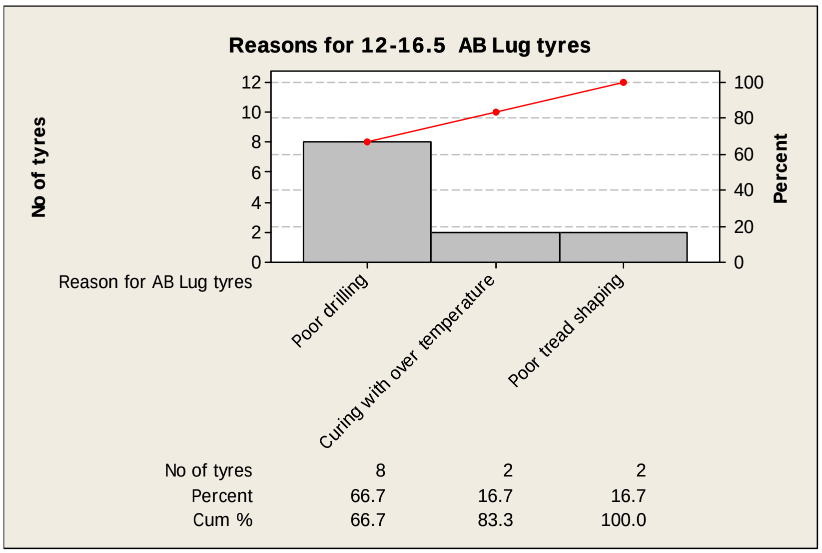


**Figure 4.12:** Reasons for tyre type I Air Bubble lug defect

According Figure 4.12, poor drilling is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 67% of the data. This means that out of all the reasons for defectives first reasons has taken up the most defectives.

In this figure, there is a substantial difference between the first reason and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.11:** Reasons for tyre type I Pressure Leak defect

| **Reasons for Pressure leak defect** | **Number of defect tyres** |
|---|---|
| Low pre shaping pressure | 6 |
| Not properly drill the carcass | 4 |
| Air leak from the bladder | 2 |

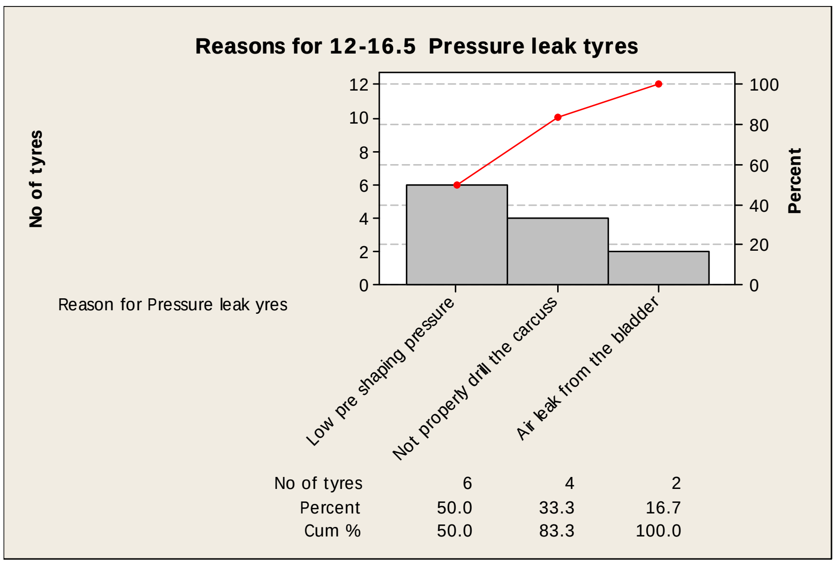


**Figure 4.13:** Reasons for tyre type I Pressure Leak defect tyres

According to the Figure 4.13 Low pre-shaping pressure is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 50% of the data. This means that out of all the reasons for defectives first reason has taken up the most defectives.

**Table 4.12:** Chi-square calculation of tyre type I

| MONTH | Number of defects(O) | E | O-E | (O-E)2 | (O-E)2/E |
|---|---|---|---|---|---|
| JANUARY | 58 | 56.2 | 1.8 | 3.24 | 0.0576 |
| FEBRUARY | 70 | 56.2 | 13.8 | 190.44 | 3.3886 |
| MARCH | 79 | 56.2 | 22.8 | 519.84 | 9.2498 |
| APRIL | 33 | 56.2 | -23.2 | 538.24 | 9.5772 |
| MAY | 41 | 56.2 | -15.2 | 231.04 | 4.111 |
| | | | | $\chi 2=$ | **26.3842** |

Critical value $\chi 2_{4,0.05} = 9.488$

Test statistic > Critical value

26.3842 > 9.488

Therefore there is a relationship between the defects in months and the 12-16.5 tyre type

**4.3.2 Tyre type II**

The Figure 4.15 shows the number of defective type II tyres produced over the study period of five months which had 141manufacturing days. The total tyres produced in this type were 67562 and out of those 225 were defective tyres. The cost of manufacturing one type of this tyre is Rs 10624.The net cost for producing a good quality tyre is 10673.59, which implies Rs 46.59 is added to the cost of production of the manufacturing good tyres due to manufactures rejected tyres.

The P chart for the defective tyre produce over the study period is given in Figure 4.15. A good quality control schemes can be adopted to control this cost. The suggested control scheme is set up based on the principle that there should not be more than 10% of the rejected tyre' cost to be added to the good tyres.

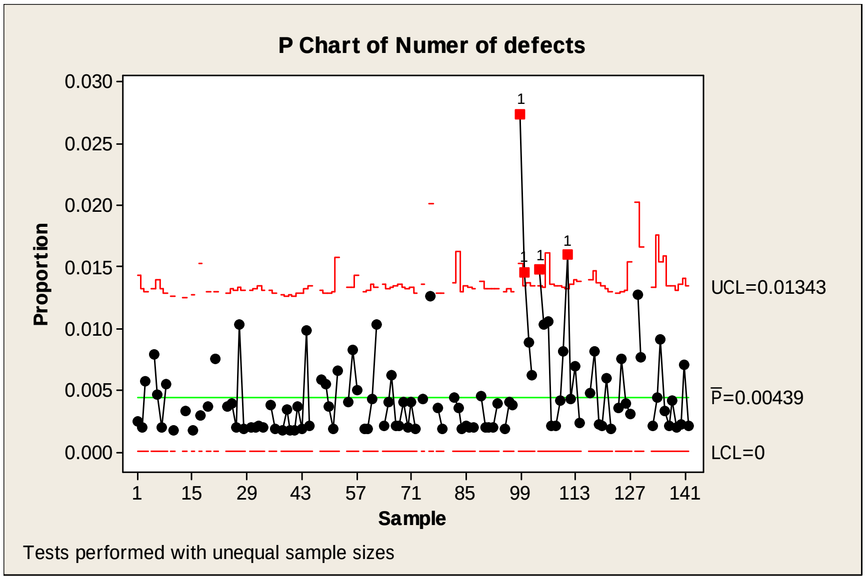


**Figure 4.14:** P chart of tyre type II

According to the figure 4.14, there are four points out side of the upper control limit. That means that the process is out of control.

$$AR = \frac{1}{P}$$

$$ARL = \frac{1}{0.00439}$$

$$ARL = 228$$

In average one will expect one defective tyre for every 228 tyres produced for the tyre type II

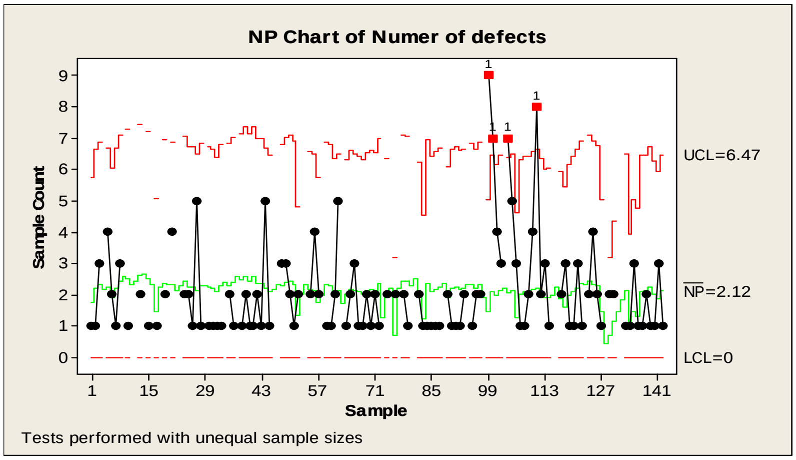


**Figure 4.15:** NP chart of tyre type II

According to the figure 4.15, there is four pint outside of the upper control limit. There for process is out of control.

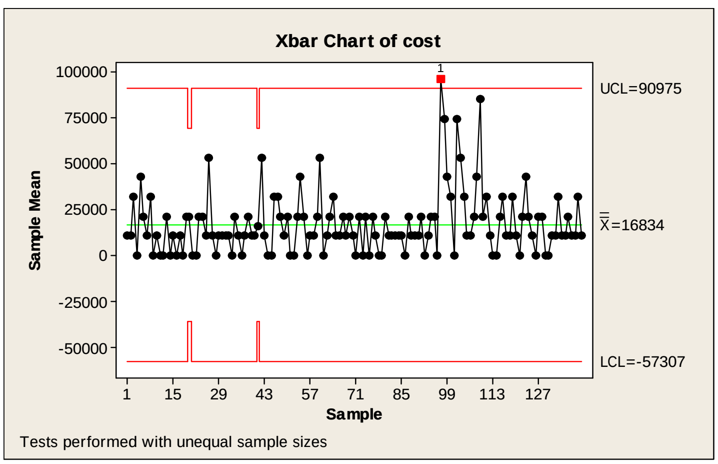


**Figure 4.16:** X bar chart of cost for10-16.5 tyre type

According to the figure 4.16, one point outside the control limit. That means the process is out of control.

According to details of tyre type II

$$nc \leq \left(n(1-p)\right)1.1$$

$$717778688 \leq 786927116.80$$

**Table 4.13:** Reasons of defectives of tyre type II

| Reason | Number of Defectives |
|---|---|
| Under Cure | 49 |
| Low Pressure | 15 |
| Bladder Leak | 31 |
| Bladder Pleat | 6 |
| Less Liner Thickness | 2 |
| Pressure Leak Mark | 28 |
| Less Under Thread Thickness | 9 |
| SMSW | 10 |
| Two Color | 18 |
| Thin Bead | 9 |
| Plate Damage | 7 |
| Air Bubble In | 4 |
| AB LUG | 2 |
| Flash Open | 2 |
| Foreign Matter | 10 |
| ABSW | 9 |
| SW Crack | 5 |
| Turn Mould | 1 |
| Wrong tire | 1 |
| Air Leak | 1 |
| Wrong Core | 2 |
| M.P.I | 1 |
| Bead Damage | 1 |
| SW Damage | 1 |
| Tire Damage | 1 |

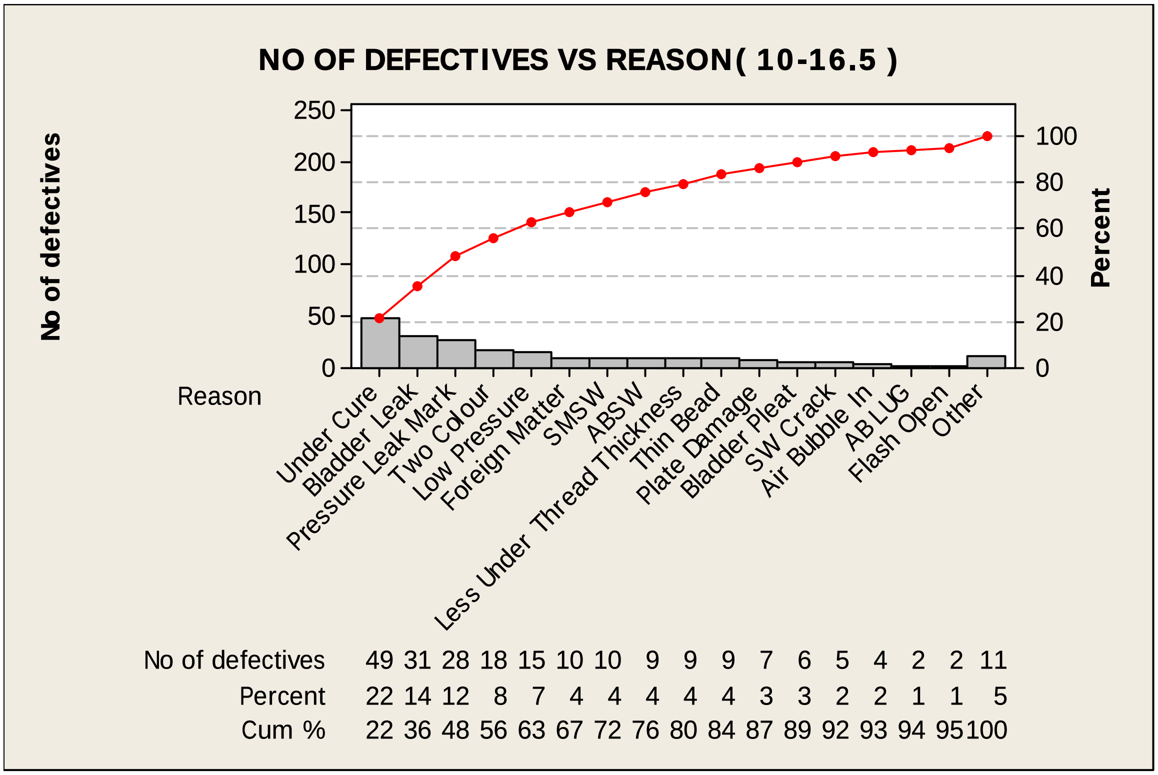


**Figure 4.17:** Parato Diagram of Tyre type II.

According to the Figure 4.17, Under cure ,Bladder leak , Pressure leak mark ,Two color, Low Pressure, Foreign matter, Short Mould Side Wall(SMSW), Air Bubble Side Wall(ABSW ), Less under tread thickness are the main reasons which cause to tyre type II and each reason contribute 22%,14 % 12%,8 %,7%, 4 %,4%,4% and 4% respectively. High defects are due to under cure and bladder leak.

Out of above reasons Under cure ,Bladder leak, Pressure leak mark, Two color and Low pressure, Foreign matter, Short Mould Side Wall(SMSW), Air Bubble Side Wall(ABSW ), Less under tread thickness are the nine largest bars. Reading from cumulative line to the right axis they represent approximately 80 % of the data. This means that out of all the reasons these nine reasons have taken up most defectives.

In this figure there is a substantial difference between first five reasons and the remaining bars. So tackling the first five bars has substantial advantage.

**Table 4.14:** Reasons for tyre type II Under cure defect.

| Reasons for under cure defect | Number of defect tyres |
|---|---|
| Electrical element off | 25 |
| Water seal leak | 4 |
| Air leak from the bladder core | 10 |
| Tyre curing with low steam pressure | 5 |
| Low curing time than the specification time | 3 |

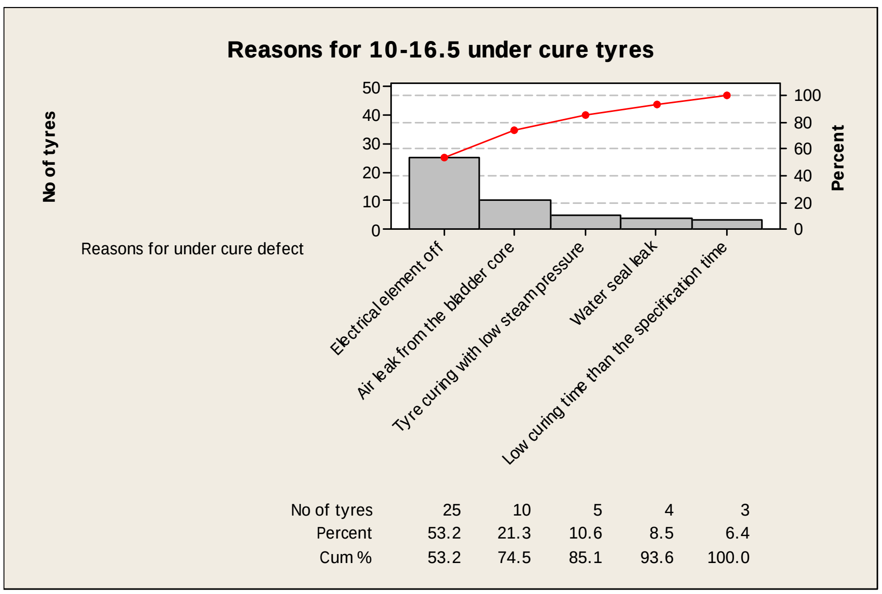


**Figure 4.18:** Reasons for tyre type II Under cure defect tyres

Considering Figure 4.18, Electrical element off, Air leak from the bladder core are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 75% of the data. This means that out of all the reasons for defectives first two reasons have taken up the most defectives.

In this figure, there is a substantial difference between the first two reasons and the remaining bars. So tackling the first two bars have substantial advantage.

**Table 4.15:** Reasons for tyre type II Bladder leak defect

| Reasons for Bladder leak defect | Number of defect tyres |
|---|---|
| Melt the bladder due to low N2 purity before the target | 15 |
| Poor Bladder quality | 11 |
| Stretch the bladder between core and raw tyre | 5 |

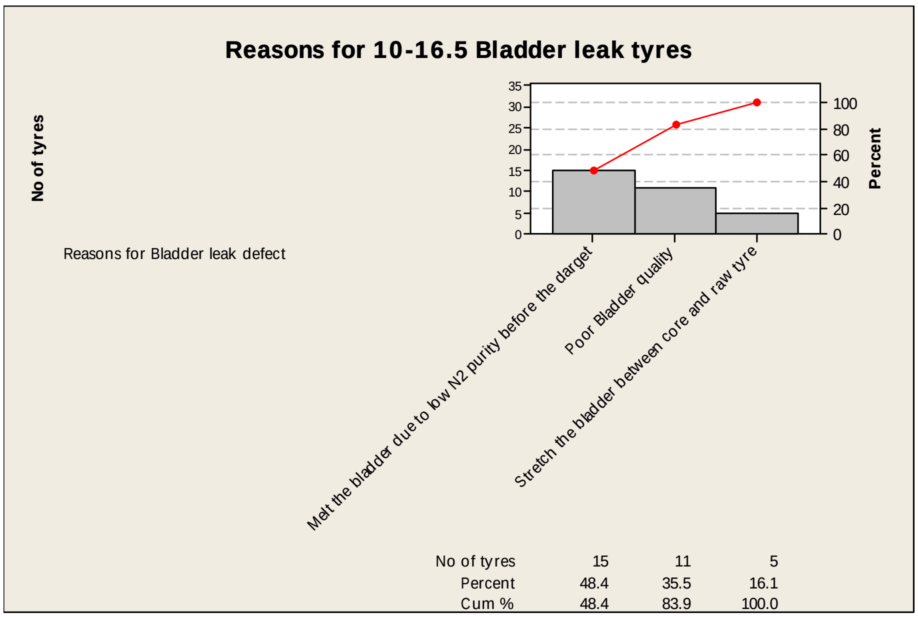


**Figure 4.19:** Reasons for tyre type II Bladder Leak defect tyres

Considering Figure 4.19, Melt the bladder due to low $N_2$ purity before the target, and Poor bladder quality are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 84% of the data. This means that out of all the reasons for defectives first two bars have taken up the most defectives.

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**Table 4.16:** Reasons for tyre type II Pressure Leak defect

| Reasons of Pressure leak defect | Number of defect tyres |
|---|---|
| Low pre shaping pressure | 7 |
| Not properly drill the carcass | 15 |
| Air leak from the bladder | 6 |

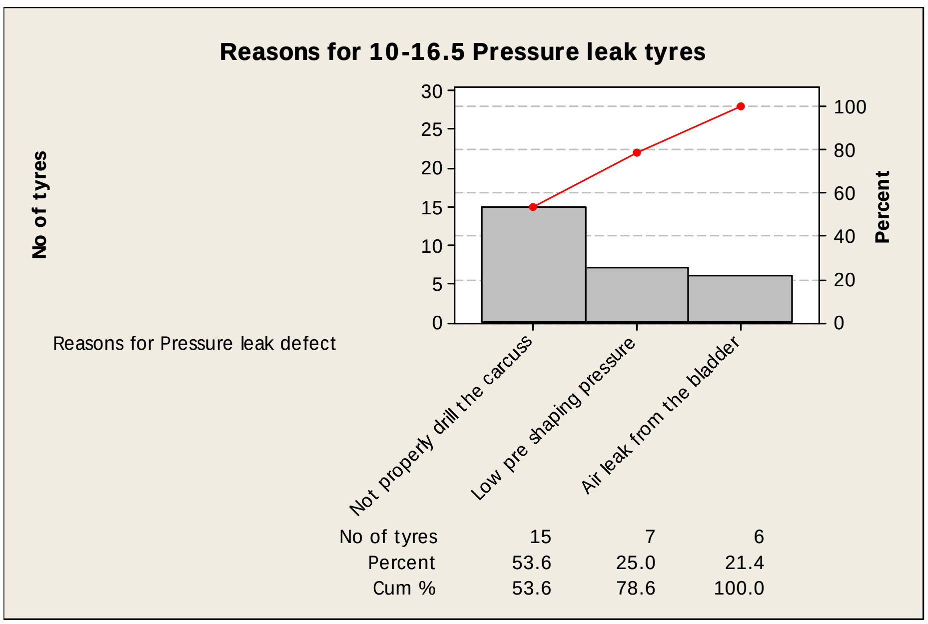


**Figure 4.20:** Reasons for tyre type II Pressure Leak defect tyres

Considering Figure 4.20, not properly drill the carcass and Low pre-shaping pressure are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 79% of the data. This means that out of all the reasons for defectives first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling the first bar has substantial advantage

**Table 4.17:** Reasons for tyre type II Two color defect

| Reasons for Two color defect | Number of defect tyres |
|---|---|
| Black compound particles mix with gray compound | 10 |
| Tread center out | 3 |
| Low starting width | 3 |
| Temperature variation with the mould | 2 |

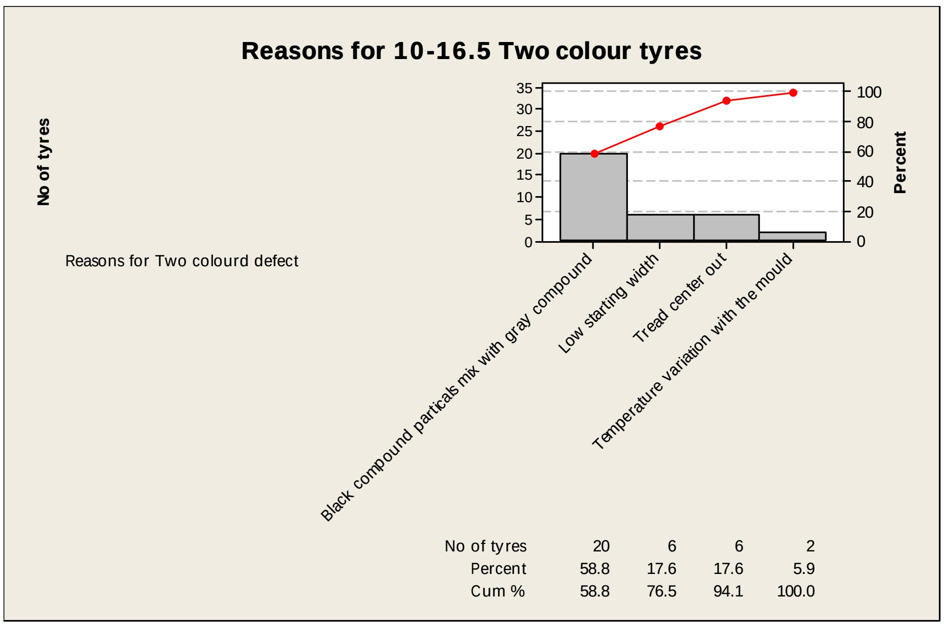


**Figure 4.21:** Reasons for tyre type II Two color defect tyres

Considering Figure 4.21, Black compound particles mix with grey compound and low starting width are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 77% of the data. This means that out of all the reasons for defectives first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.18:** Reasons for tyre type II Low pressure defect.

| Reasons for Low Pressure defect | Number of defect tyres |
|---|---|
| Delay apply hydraulic pressure | 3 |
| Hydraulic pressure release when tyre curing | 4 |
| Tyre curing with low N2 pressure | 7 |
| Press open when tyre curing due to not timer zero | 1 |

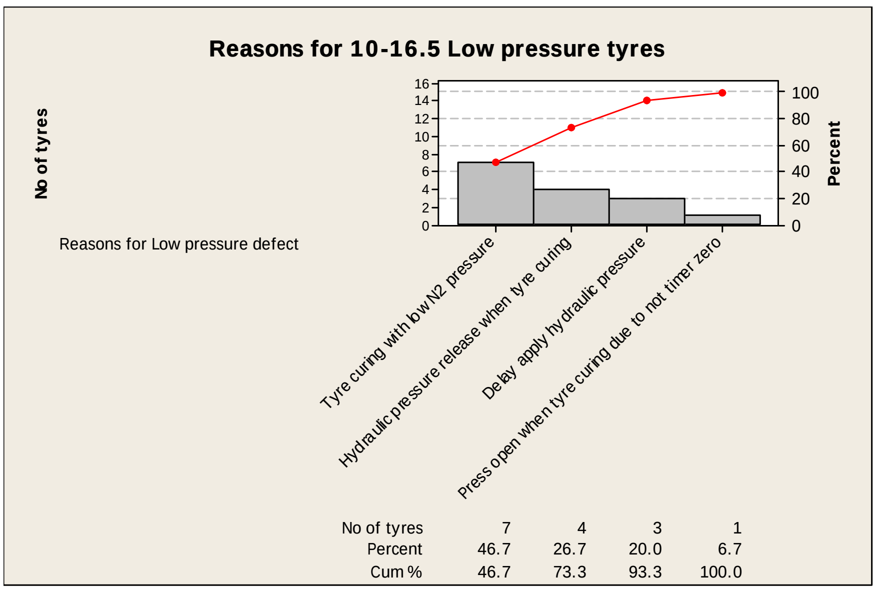


**Figure 4.22:** Reasons for tyre type II Low Pressure defect tyres

Considering Figure4.22, Tyre curing with low $N_2$ pressure and Hydraulic pressure release when tyre curing are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 74% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

**Table 4.19:** Reasons for tyre type II Foreign matter defect.

| Reasons for Foreign matter defect | Number of defect tyres |
|---|---|
| Close venting holes of side ring and the tread ring | 3 |
| Compound not flowing well | 1 |
| Not removing cleaning dust after mould cleaning | 5 |
| Dust outside of the raw tyre | 1 |

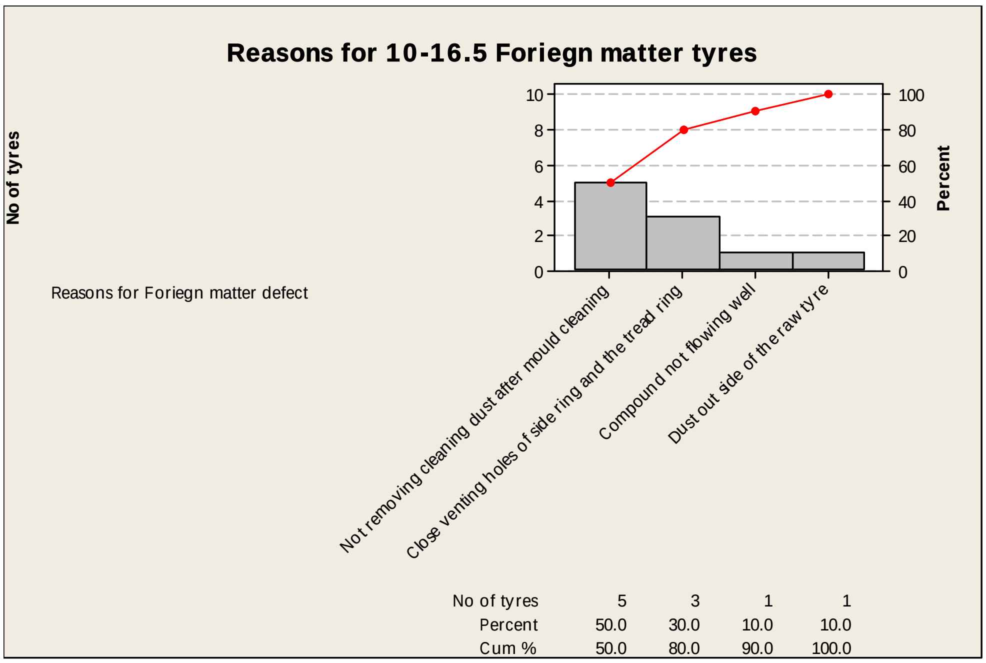


**Figure 4.23:** Reasons for tyre type II Foreign matter defect tyres.

Considering Figure 4.23, not removing cleaning dust after the mould cleaning and close the venting holes of the side ring and tread ring are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 80% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

**Table 4.20:** Reasons for tyre type II Short Mould Side Wall defect

| Reasons of Short Mould Side Wall defect | Number of defect tyres |
|---|---|
| Impurities on side ring | 1 |
| Poor drilling of side ring | 5 |
| Poor drilling of carcass | 2 |
| Impurities in the rubber compound | 2 |

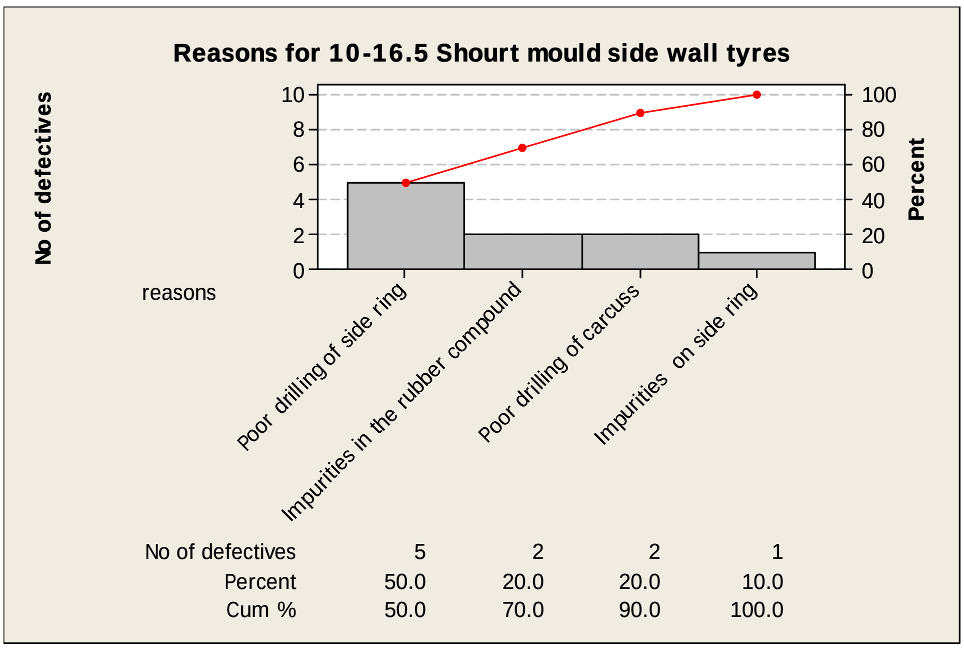


**Figure4.24:** Reasons for tyre type II Short Mould Side Wall defect tyres

Considering Figure 4.24, poor drilling of side ring and impurities in the rubber compound are the largest bars. Reading from the cumulative line to the right axis, they represent approximately 70% of the data. This means that out of all the reasons for defectives first two bars have taken up the most defectives.

**Table 4.21:** Reasons for tyre type II Air Bubble Side Wall defect

| Reasons of Air Bubble Side Wall defect | Number of defect tyres |
|---|---|
| poor drilling of carcass | 3 |
| Impurities in the carcass | 1 |
| Not properly tread shaping | 2 |
| Impurities on side ring of mould | 4 |

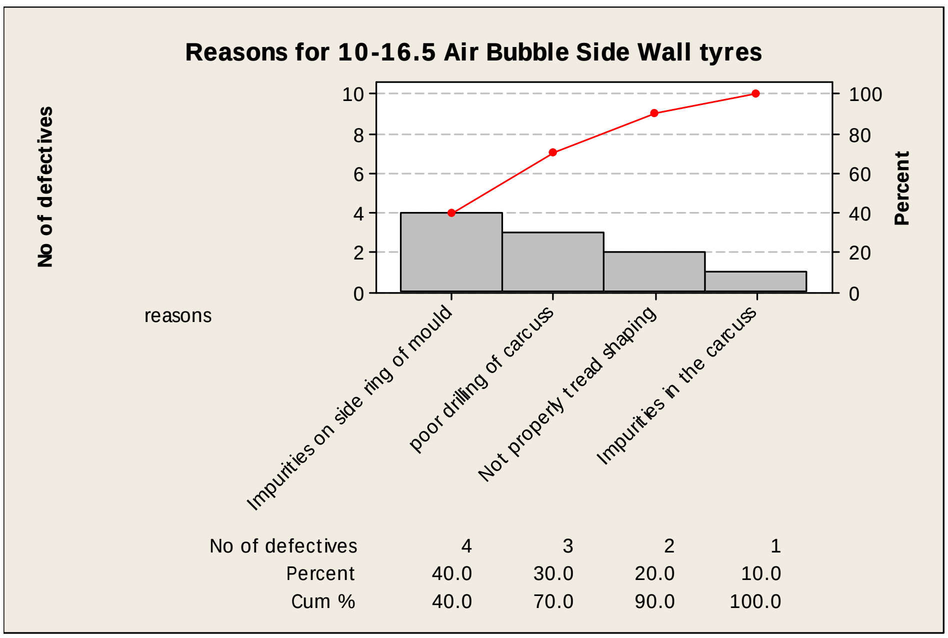


**Figure 4.25:** Reasons for tyre type II Air Bubble Side Wall defect tyres

Considering Figure 4.25, Impurities on side ring of mould, poor drilling of carcass are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 70% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

**Table 4.22:** Reasons for tyre type II Less under tread thickness defect

| **Reasons of Less under tread thickness defect** | **Number of defect tyres** |
|---|---|
| Low tread weight | 4 |
| tread out of center | 2 |
| High tread starting width | 1 |
| When use damage air bag in the inflating machine | 2 |

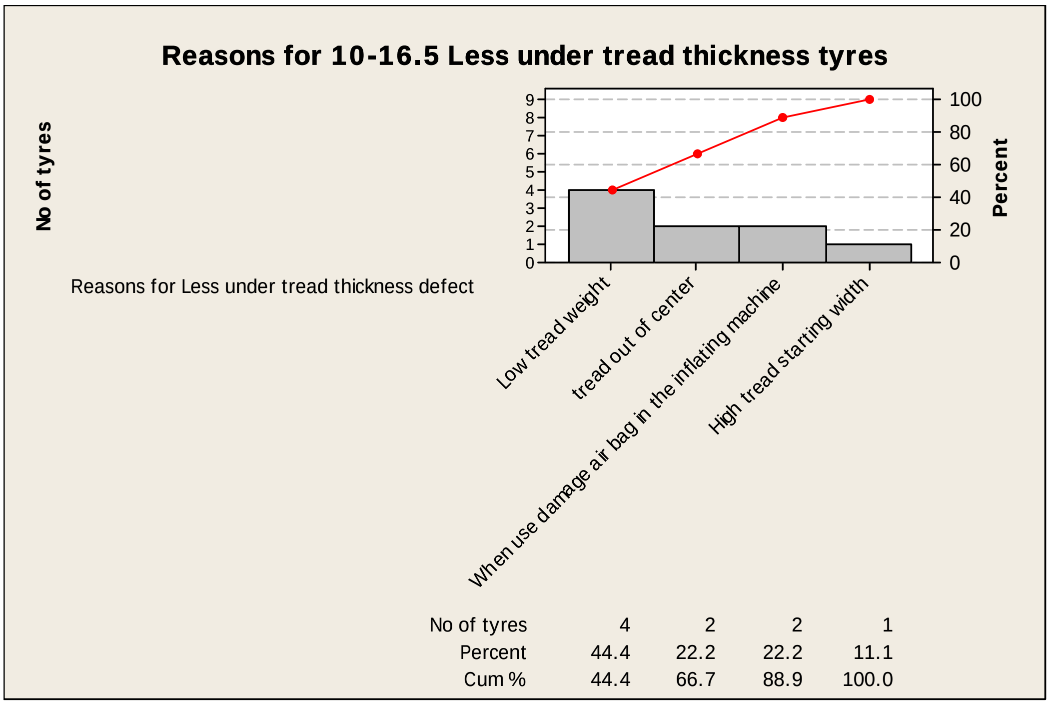


**Figure 4.26:** Reasons for tyre type II Less under tread thickness defect tyres

Considering Figure 4.26, Low tread weight, tread out of centre and when use damage air bag in the inflating machine are the three largest bars. Reading from the cumulative line to the right axis, they represent approximately 90% of the data. This means that out of all the reasons first three bars have taken up the most defectives.

**Table 4.23:** Chi-square calculation of tyre type II

| MONTH | Number of defects(O) | E | (O-E ) | (O-E)2 | (O-E)2/E |
|---|---|---|---|---|---|
| JANUARY | 39 | 45 | -6 | 36 | 0.8 |
| FEBRUARY | 39 | 45 | -6 | 36 | 0.8 |
| MARCH | 39 | 45 | -6 | 36 | 0.8 |
| APRIL | 63 | 45 | 18 | 324 | 7.2 |
| MAY | 45 | 45 | 0 | 0 | |
| | | | | χ2= | **9.6** |

Critical value $\chi 2_{4,0.05}$ = 9.488

Test statistic > Critical value

9.6 > 9.488

Therefore there is a relationship between the defects in months and the tyre type II

### 4.3.3 Tyre type III

The Figure 4.29 shows the number of defective type III tyres produced over the study period of five months which had 141manufacturing days. The total tyres produced in this type were 3959 and out of those 53 were defective tyres. The cost of manufacturing one type of this tyre is Rs 60275.The net cost for producing a good quality tyre is 63014.77 which implies Rs 2739.77 is added to the cost of production of the manufactured good tyres due to manufactures rejected tyres.

The P chart for the defective tyre produce over the study period is given in Figure 4.2. A good quality control schemes can be adopted to control this cost. The suggested control scheme is set up based on the principle that there should not be more than 10% of the rejected tyre' cost to be added to the good tyres.

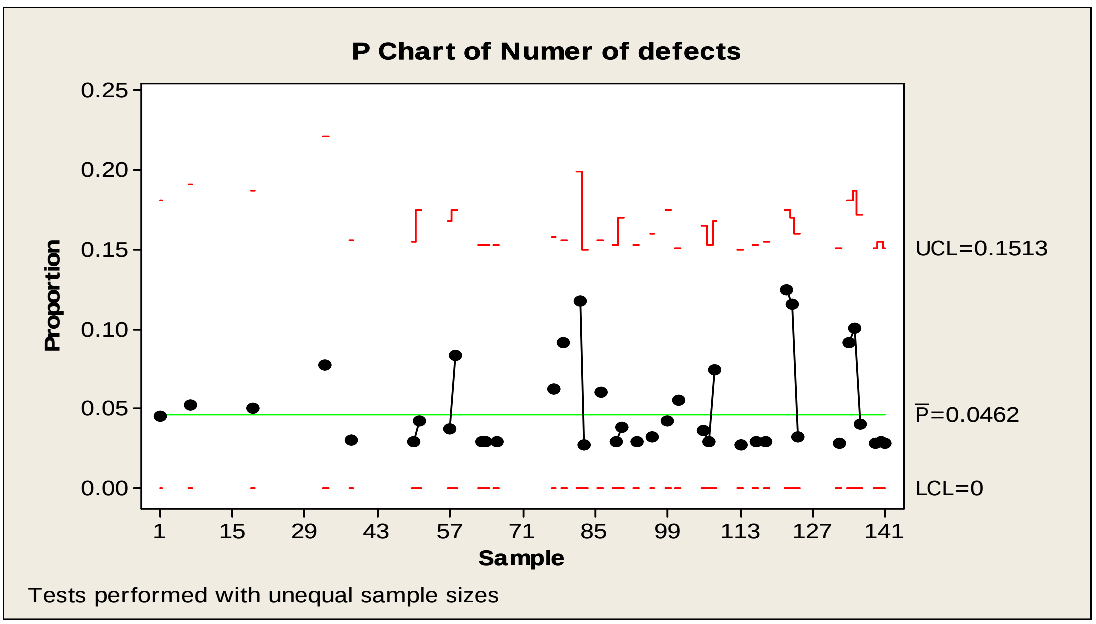


**Figure 4.27:** P chart of tyre type III

According to the figure 4.27, all point within the control limits. There for process is in control.

$$ARL = \frac{1}{P}$$

$$ARL = \frac{1}{0.0462}$$

$$ARL = 22$$

In average one will expect one defective tyre for every 22 tyres produced for the tyre type III. The cost of one defective tyre Rs60275 has to be added to 22 tyres in it manufacturing cost that is Rs 2739.77 (say A) for each tyre type.

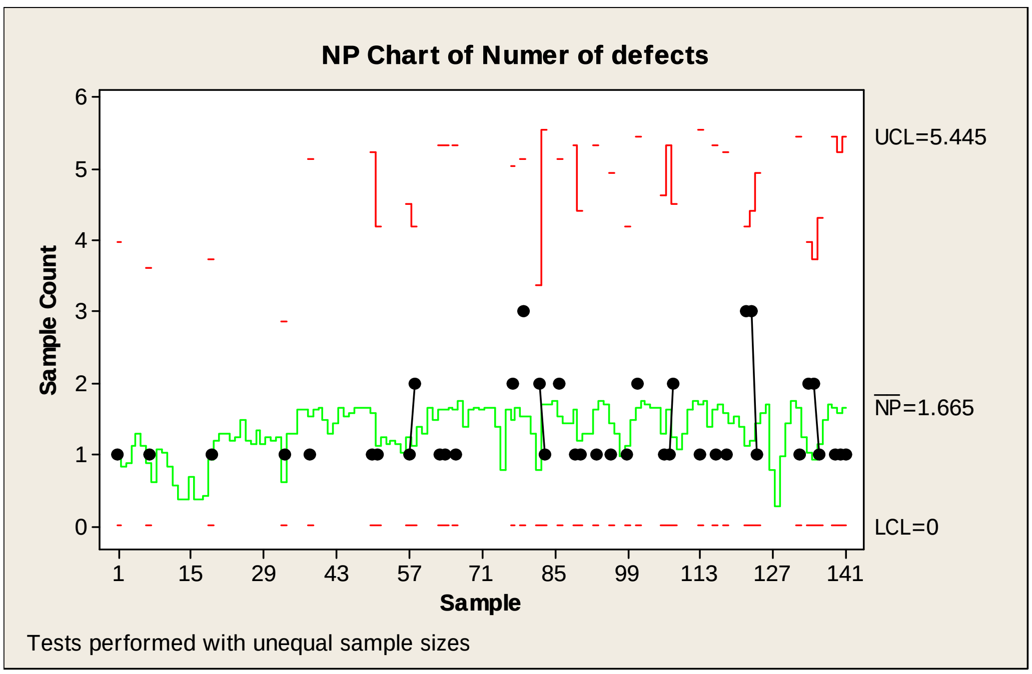


**Figure 4.28:** NP chart of tyre type III

According to the figure 4.28, all point within the control limits. That means that the process is in control.

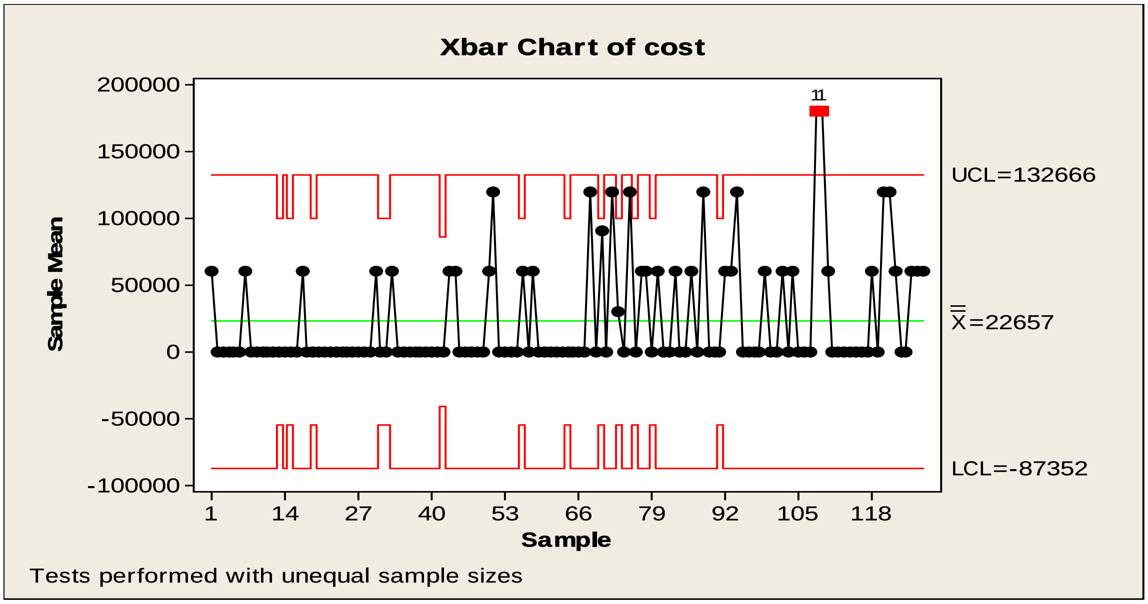


**Figure 4.29:** X bar chart of cost for tyre type III

According to the figure 4.29 all points within the control limit. That means the process is in control.

According to details of 20.5-25 tyre type

$$nc \leq \big(n(1-p)\big)1.1$$

$$241823300 \leq 262491597.50$$

**Table 4.24:** Reasons of defectives tyre type III.

| Reason | Number of defectives |
|---|---|
| Under Cure | 12 |
| Low Pressure | 4 |
| Bladder Leak | 3 |
| Less Liner Thickness | 1 |
| Pressure Leak Mark | 1 |
| Less Under Thread Thickness | 2 |
| Plate Damage | 9 |
| Air Bubble In | 5 |
| AB LUG | 1 |
| Foreign Matter | 2 |
| Less Side Wall Thickness | 4 |
| Air Leak | 3 |
| NO PCI | 3 |
| Sponch | 1 |
| Bead damage | 1 |
| Hose leak | 1 |

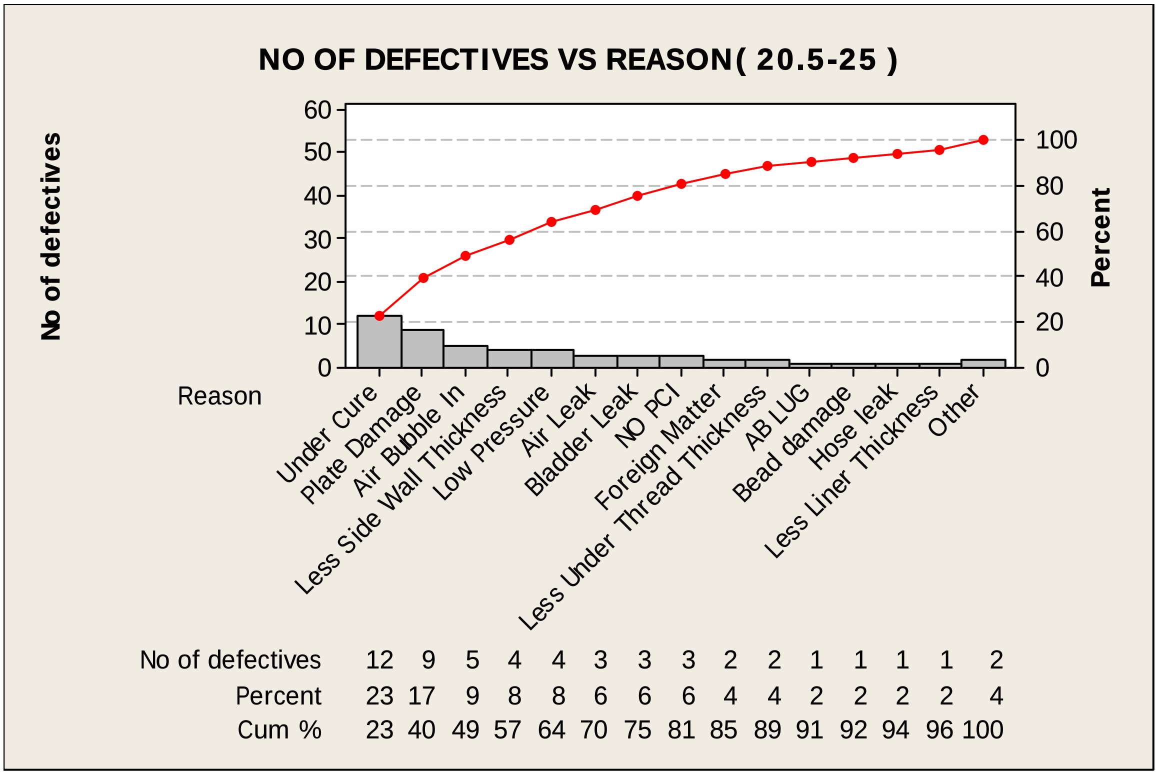


**Figure 4.30:** Parato Diagram of tyre type III

Considering to the Figure 4.30 , Under cure, Plate damage, Air bubble in, Less side wall thickness, Low pressure, Air leak, Bladder leak and No PCI are main cause to tyre type III and each reason contribute 23%,17 %, 9%,8 %,8%, 6 %,6%,4% and 4% respectively. High defect are due to under cure and plate damage.

Out of above reasons Under cure, Plate damage, Air bubble in, Less side wall thickness, Low pressure are the five largest bars. Reading from cumulative line to the right axis, they represent approximately 64 % of the data. This means that out of all the reasons these five reasons have taken up most defectives.

In this figure there is a substantial difference between first five two reasons and the remaining bars. So tackling the first two bars has substantial advantage.

**Table 4.25:** Reasons for tyre type III Under cure defect.

| Reasons for Under cure defect | Number of defect tyres |
|---|---|
| Electrical element off | 6 |
| Water seal leak | 2 |
| Air leak from the bladder core | 2 |
| Tyre curing with low steam pressure | 1 |
| Low curing time than the specification time | 1 |

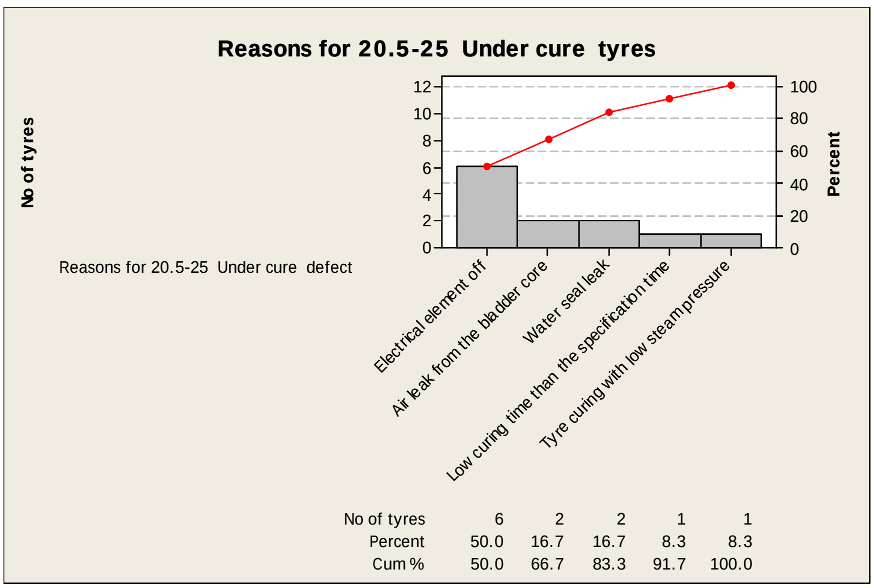


**Figure 4.31:** Reasons for tyre type III Under cure defect tyres

Considering Figure 4.31, Electrical element off and Air leak from the bladder core are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 67% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.26:** Reasons for tyre type III Plate damage defect

| Reasons for Plate damage defect | Number of defect tyres |
|---|---|
| Wearing thread of the nail | 7 |
| wearing tread of the side ring | 2 |

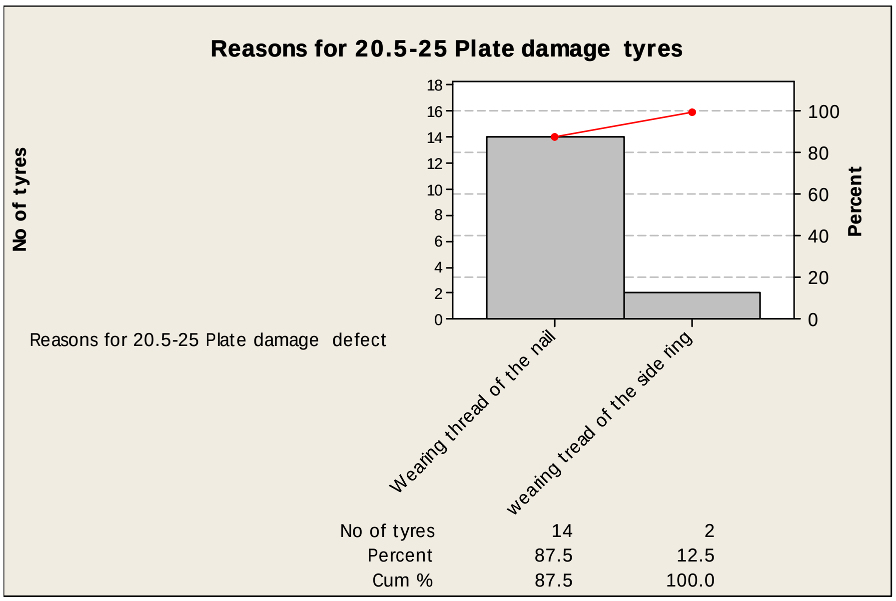


**Figure 4.32:** Reasons for tyre type III Plate damage defect tyres.

Considering Figure 4.32, Wearing tread of the nail is larger one. Reading from the cumulative line to the right axis, it represents approximately 87.5% of the data. This means that out of all the reasons first bar has taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.27:** Reasons for tyre type III AB in defect.

| **Reasons for AB in defect** | **Number of defect tyres** |
|---|---|
| Water seal leak | 2 |
| Low bladder steam pressure | 1 |
| Impurities in the inside of the carcass | 1 |
| O ring leak | 1 |

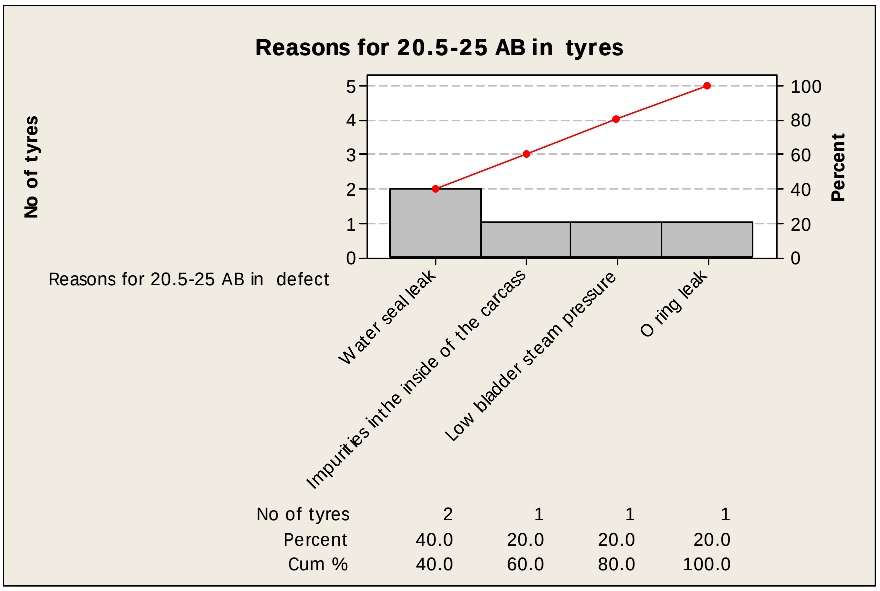


**Figure 4.33:** Reasons for tyre type III AB in defect tyres.

Considering Figure 4.33, Water seal leak, Impurities in the inside of the carcass, Low bladder steam pressure are the three largest bars. Reading from the cumulative line to the right axis, they represent approximately 80% of the data. This means that out of all the reasons first three bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.28:** Reasons for tyre type III Less side wall thickness defect

| Reasons for Less side wall thickness defect | Number of defect tyres |
|---|---|
| Turn up plates | 2 |
| Low side wall thickness | 1 |
| Tread center out | 1 |

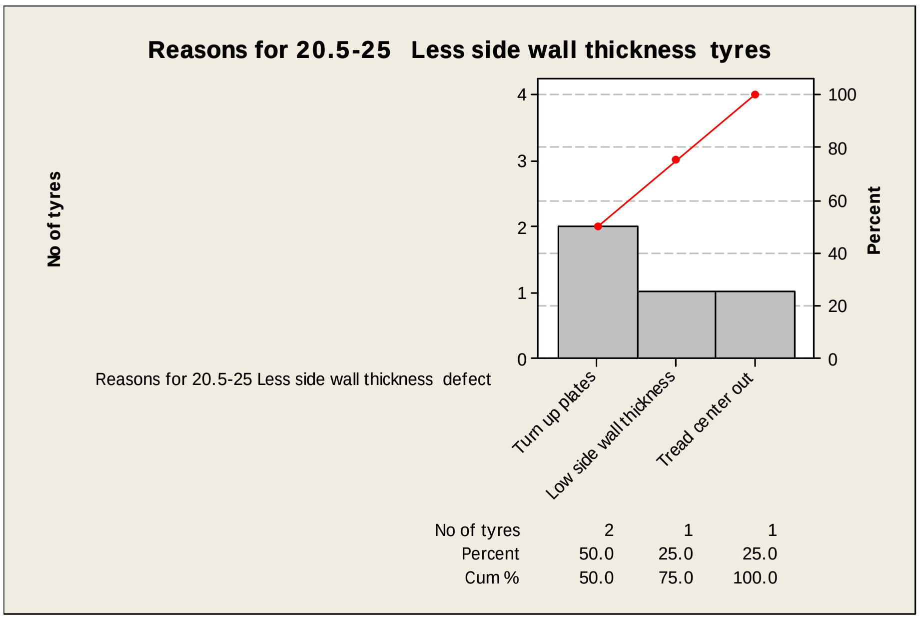


**Figure 4.34:** Reasons for tyre type III Less side wall thickness defect tyres

Considering Figure 4.34, Turn up pleats and Low side wall thickness are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 75% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

**Table 4.29:** Reasons for tyre type III Low pressure defect

| Reasons for Low pressure defect | Number of defect tyres |
|---|---|
| Delay apply hydraulic pressure | 1 |
| Hydraulic pressure release when tyre curing | 1 |
| Tyre curing with low N2 pressure | 1 |
| Press open when tyre curing due to not timer zero | 1 |

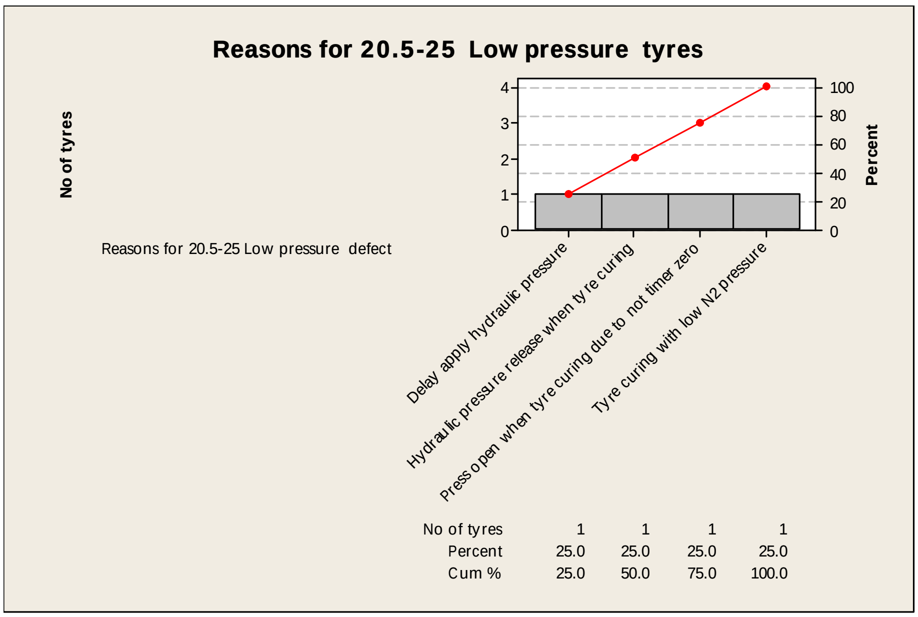


**Figure 4.35:** Reasons for tyre type III Low Pressure defect tyres

Considering Figure 4.35, Delay apply hydraulic pressure, Hydraulic pressure release when tyre curing, Press open when tyre curing due to not timer zero are the three largest bars. Reading from the cumulative line to the right axis, they represent approximately 75% of the data. This means that out of all the reasons first three bars have taken up the most defectives.

In this figure, there is no substantial difference between the first bar and the remaining bars.

**Table 4.30:** Chi-square calculation of tyre type III

| Mounth | Number of defects(O) | E | (O-E ) | (O-E)2 | (O-E)2/E |
|---|---|---|---|---|---|
| JANUARY | 3 | 10.6 | -7.6 | 57.76 | 5.449 |
| FEBRUARY | 7 | 10.6 | -3.6 | 12.96 | 1.2226 |
| MARCH | 14 | 10.6 | 3.4 | 11.56 | 1.0905 |
| APRIL | 10 | 10.6 | -0.6 | 0.36 | 0.03396 |
| MAY | 19 | 10.6 | 8.4 | 70.56 | 6.6567 |
| | | | | $\chi 2=$ | **14.45276** |

Critical value $\chi 2_{4,0.05}$ = 9.488

Test statistic > Critical value

14.452 > 9.488

Therefore there is a relationship between the defects in months and the tyre type III

### 4.3.4 Tyre type IV

The Table 4.38 shows the number of defective type IV tyres produced over the study period of five months which had 127 manufacturing days. The total tyres produced in this type were 7759 and out of those 281 were defective tyres. The cost of manufacturing one type of this tyre is Rs 35561.The net cost for producing a good quality tyre is 36496.81 which implies Rs 935.81 is added to the cost of production of the manufactured good tyres due to manufactures rejected tyres.

The P chart for the defective tyre produce over the study period is given in Figure 4.2. A good quality control schemes can be adopted to control this cost. The suggested control scheme is set up based on the principle that there should not be more than 10% of the rejected tyre' cost to be added to the good tyres.

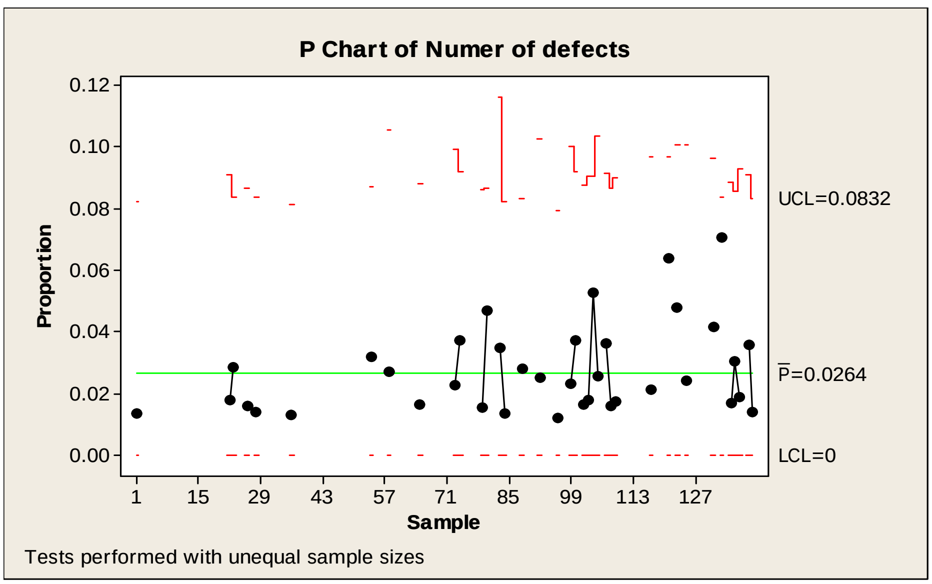


**Figure 4.36:** P chart of tyre type IV

According to the figure 4.36, all point within the control limits. There for process is in control.

$$ARL = \frac{1}{P}$$

$$ARL = \frac{1}{0.0264}$$

$ARL = 38$

In average one will expect one defective tyre for every 38 tyres produced for the tyre type 19.5L-24.

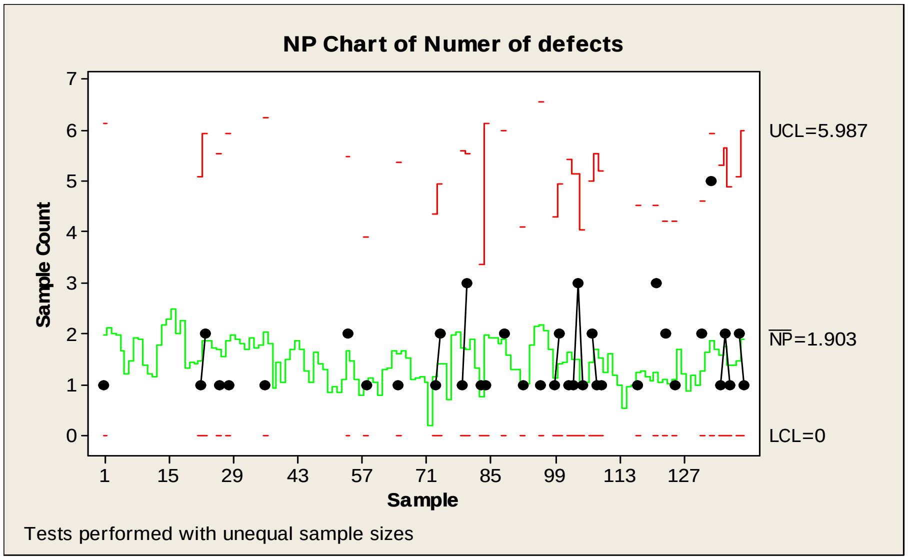


**Figure 4.37:** NP chart of tyre type IV

According to the figure 4.37, all point within the control limits. There for process is in control.

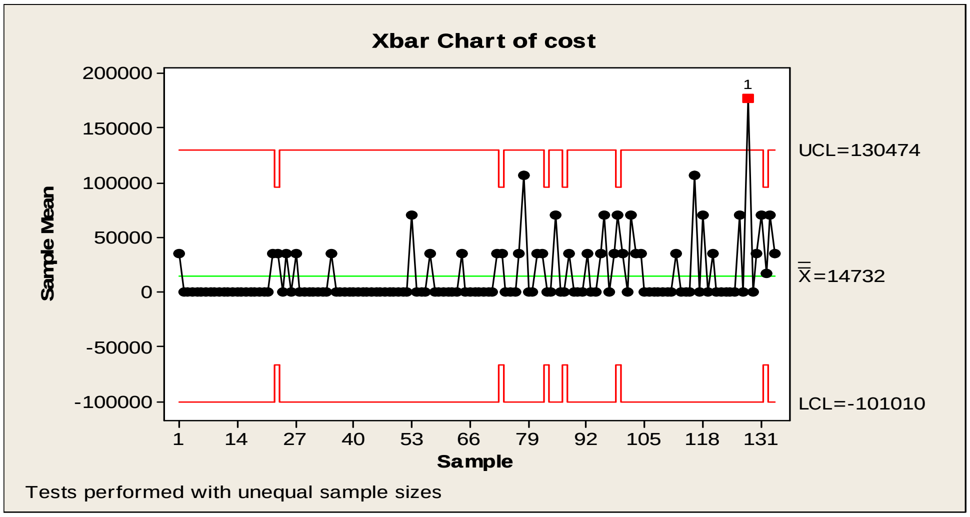


**Figure 4.38:** X bar chart of tyre type IV

According to the figure 4.38 one point outside the control limit. That means the process is out of control.

According to details of tyre type IV,

$$nc \leq (n(1-p))1.1$$

$$275917799 \leq 301240787$$

**Table 4.31:** Reasons of defectives of tyre type IV.

| reason for defect | Number of defectives |
|---|---|
| Under Cure | 20 |
| Low Pressure | 2 |
| Bladder Pleat | 1 |
| Less Liner Thickness | 2 |
| Thin Bead | 2 |
| Air Bubble In | 11 |
| AB LUG | 5 |
| Flash Open | 4 |
| Foreign Matter | 1 |
| I.L Damage | 1 |
| Air leak | 2 |
| Air bag leak | 1 |
| Chafer out | 4 |
| PRE CURE | 2 |

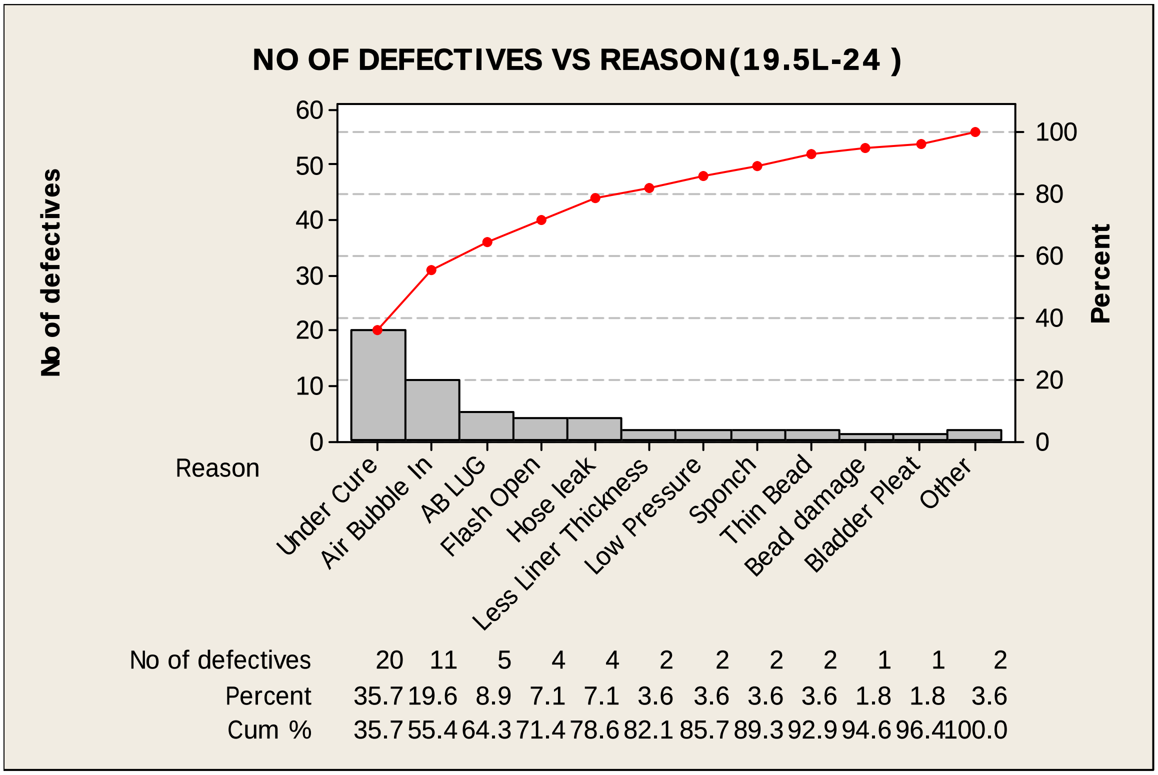


**Figure 4.39:** Parato Diagram of Tyre type IV

Considering to the Figure 4.39, Under cure, Air bubble in, AB lug, Flash open and hose leak are main reasons which cause to tyre type IV and each reason contribute 35.7%,19.6 %, 8.9%,7.1 %, and 7.1% respectively. High defect are due to under cure and air bubble in.

Out of above reasons Under cure, Air bubble in, AB lug, Flash open and hose leak are the five largest bars. Reading from cumulative line to the right axis, they represent approximately79% of the data. This means that out of all the reasons these five reasons have taken up most defectives.

In this figure there is a substantial difference between first two reasons and the remaining bars. So tackling the first two bars has substantial advantage.

**Table 4.32:** Reasons for tyre type IV Under cure defect tyres

| Reasons for Under cure defect | Number of defect tyres |
|---|---|
| Electrical element off | 10 |
| Water seal leak | 2 |
| Air leak from the bladder core | 0 |
| Tyre curing with low steam pressure | 4 |
| Low curing time than the specification time | 4 |

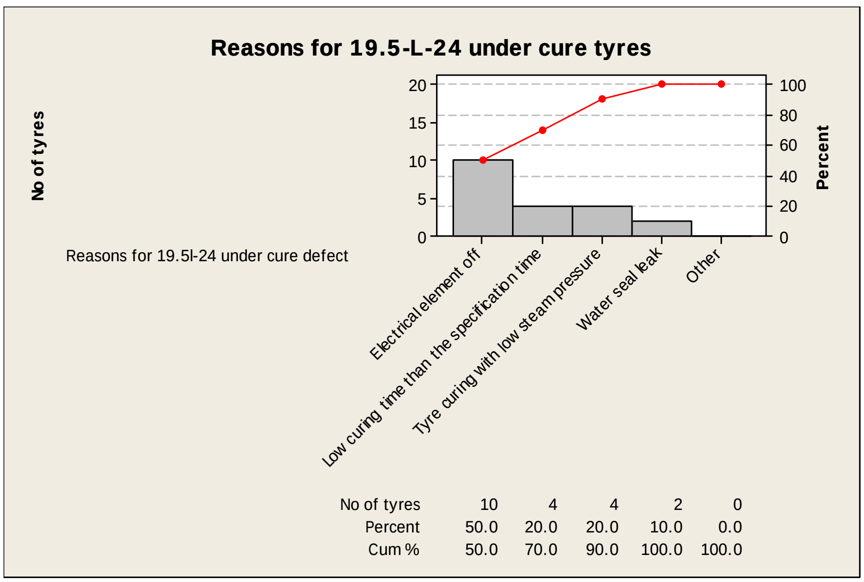


**Figure 4.40:** Reasons for tyre type IV Under cure defect tyres

Considering Figure 4.40, Electrical element off and the low curing time than the specification time are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 70% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.33:** Reasons for tyre type IV AB in defect tyres

| **Reasons of AB IN defect** | **No of defect tyres** |
|---|---|
| Water seal leak | 2 |
| Low bladder steam pressure | 2 |
| Impurities in the inside of the carcass | 3 |
| O ring leak | 4 |

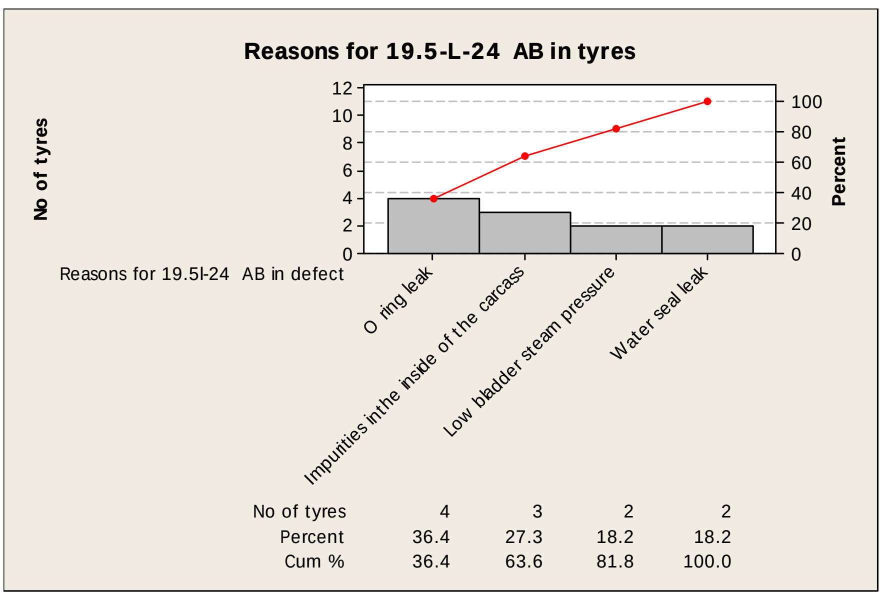


**Figure 4.41:** Reasons for tyre type IV AB in defect tyres

Considering Figure 4.41, O-ring leak and Impurities inside of the carcass are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 64% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

**Table 4.34:** Reasons for tyre type IV AB lug defect tyres.

| Reasons of AB Lug defect | Number of defect tyres |
|---|---|
| Poor drilling | 2 |
| Poor tread shaping | 1 |
| Curing with over temperature | 2 |

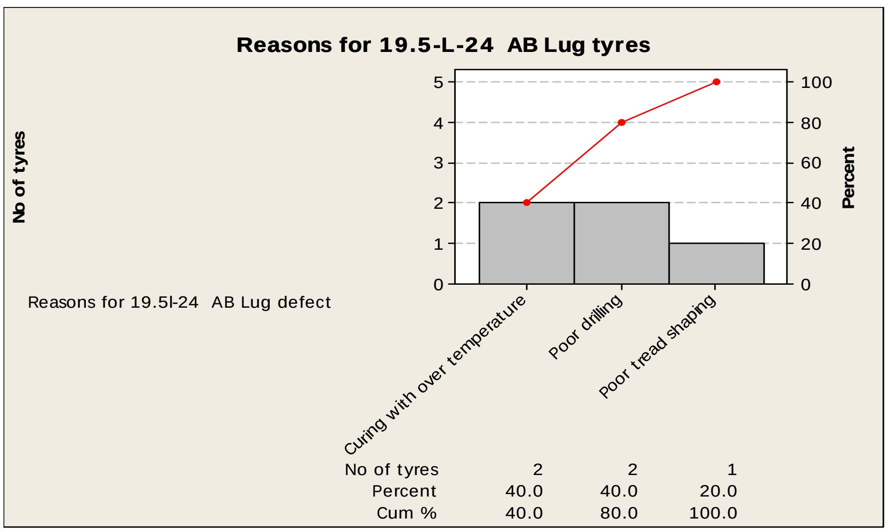


**Figure 4.42:** Reasons for tyre type IV AB lug defect tyres

Considering Figure 4.42, Curing with over temperature and poor drilling are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 80% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

.

**Table 4.35:** Reasons for tyre type IV Flash open defect.

| Reasons for Flash open defect | Number of defect tyres |
|---|---|
| Low hydraulic pressure | 2 |
| Not properly closed mould top and bottom part | 1 |
| Poor tighten the mould clamp | 1 |

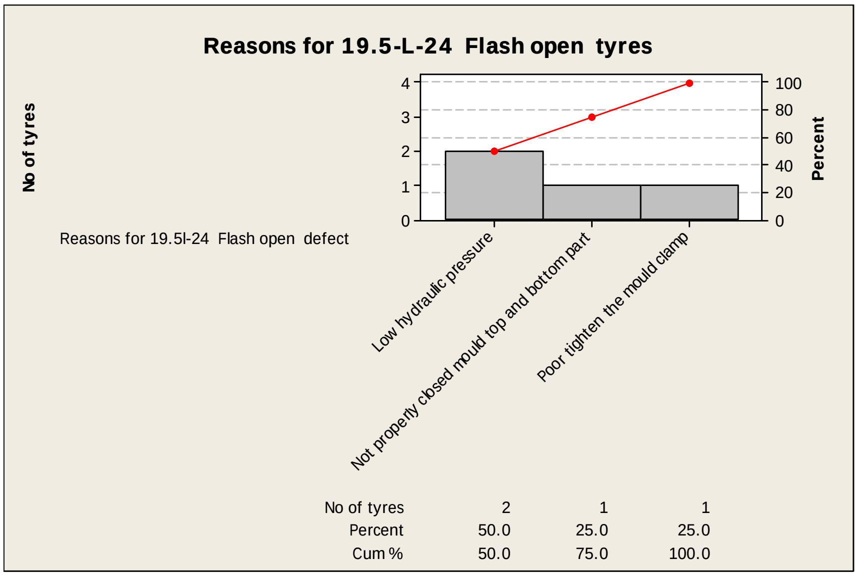


**Figure 4.43:** Reasons of tyre type IV Flash open defect tyres.

According to the Figure 4.43, Low Hydraulic pressure and not properly closed mould top and bottom part are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 75% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.36:** Reasons for tyre type IV Hose leak defect

| Reasons for Hose leak defect | Number of defect tyres |
|---|---|
| Air leak from the L bow | 3 |
| Air leak from the Female coupling | 1 |

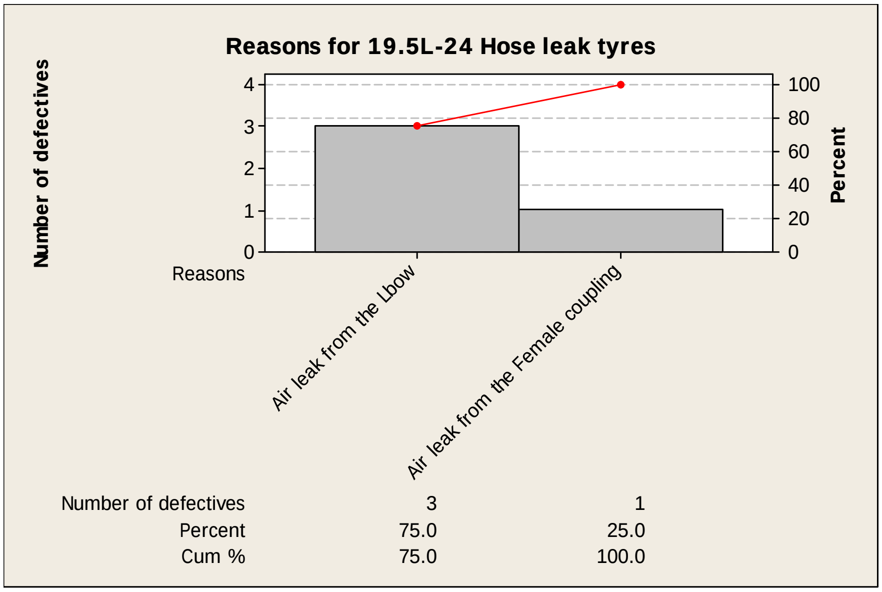


**Figure 4.44:** Reasons for tyre type IV Hose leak defect tyres

Considering Figure4.44, Air leak from the L bow is the largest bars. Reading from the cumulative line to the right axis, it represents approximately 75% of the data. This means that out of all the reasons first bar has taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.37:** Chi-square calculation of tyre type IV

| MONTH | Number of defects(O) | E | (O-E ) | (O-E)2 | (O-E)2/E |
|---|---|---|---|---|---|
| JANUARY | 6 | 13.2 | -7.2 | 51.84 | 3.8939 |
| FEBRUARY | 12 | 13.2 | -1.2 | 1.44 | 0.109 |
| MARCH | 12 | 13.2 | -1.2 | 1.44 | 0.109 |
| APRIL | 15 | 13.2 | 1.8 | 3.24 | 0.24545 |
| MAY | 21 | 13.2 | 7.8 | 60.84 | 4.609 |
| | | | | $\chi2=$ | **8.96635** |

Critical value $\chi2_{4,0.05} = 9.488$

Test statistics < Critical value

8.96635 < 9.488

Therefore there is no relationship between the defects in months and the tyre type IV

### 4.3.5. Tyre type V

The Figure 4.48 shows the number of defective type V tyres produced over the study period of five months which had 127 manufacturing days. The total tyres produced in this type were 7742 and out of those 55were defective tyres. The cost of manufacturing one type of this tyre is Rs 32647.The net cost for producing a good quality tyre is 33341.61 which implies Rs 694.61 is added to the cost of production of the manufactured good tyres due to manufactures rejected tyres.

The P chart for the defective tyre produce over the study period is given in Figure 4.2. A good quality control schemes can be adopted to control this cost. The suggested control scheme is set up based on the principle that there should not be more than 10% of the rejected tyre' cost to be added to the good tyres.

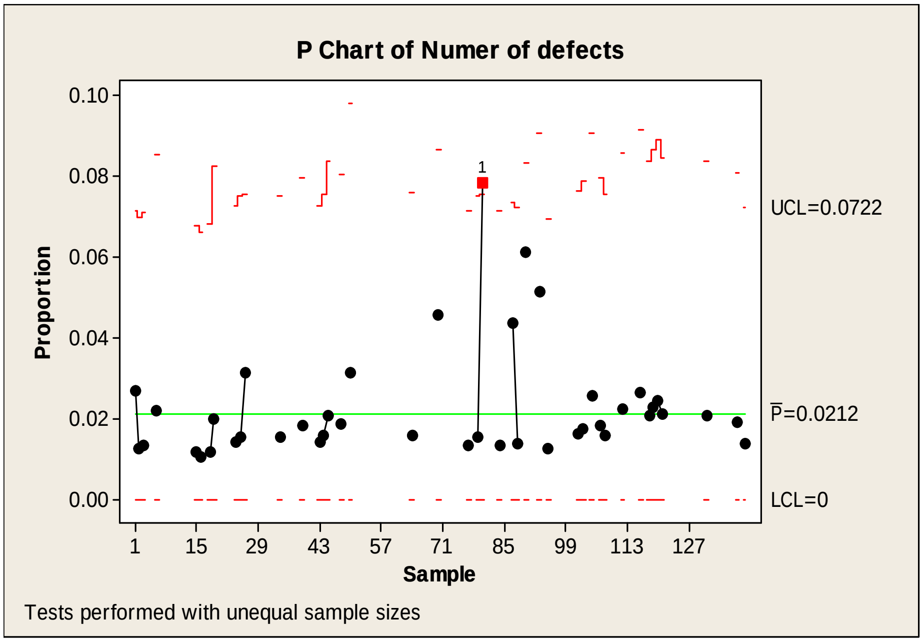


**Figure 4.45:** P chart of tyre type V

According to the figure 4.45, all point within the control limits that mean that process is in control.

$$ARL = \frac{1}{P}$$

$$ARL = \frac{1}{0.0212}$$

$$ARL = 47$$

In average one will expect one defective tyre for every 47tyres produced for the tyre type V

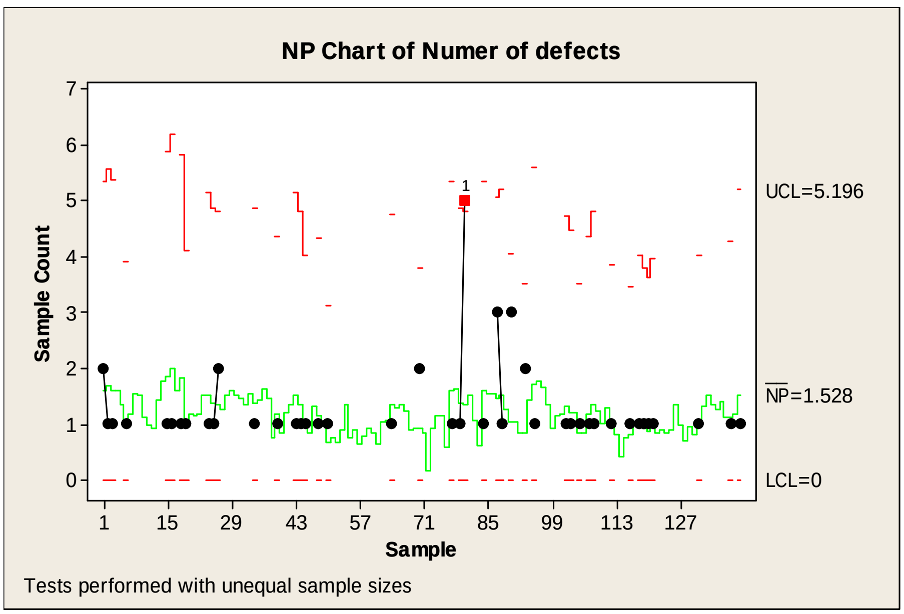


**Figure 4.46:** NP chart of tyre type V

According to the figure 4.46, only one point out of the control limit. That means the process is out of control.

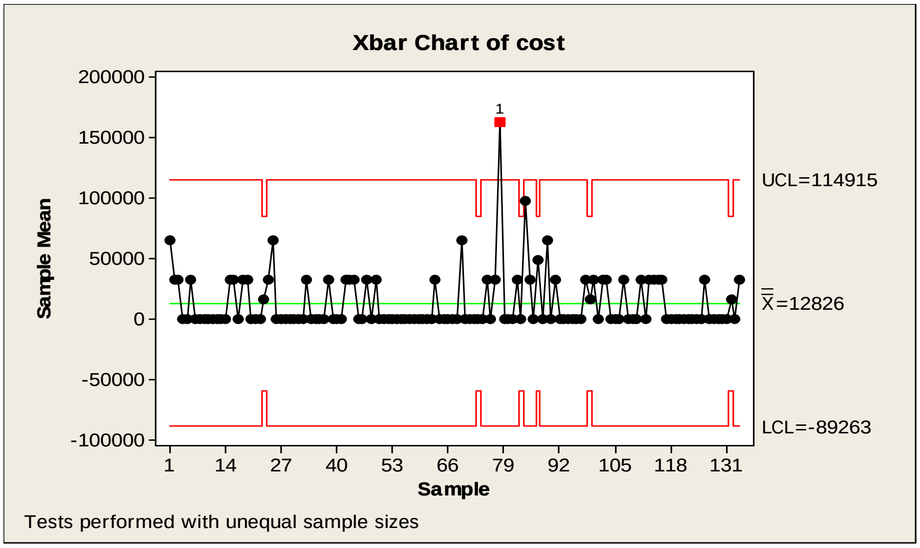


**Figure 4.47:** X bar chart of tyre type V

According to the figure 4.47, two points outside the control limit. That means the process is out of control.

According to details of tyre type V

$$nc \leq \big(n(1-p)\big)1.1$$

$$252753074 \leq 276053237.90$$

**Table 4.38:** Reasons of defectives tyre type V

| reason for defect | Number of defectives |
|---|---|
| Under Cure | 6 |
| Low Pressure | 4 |
| Less Liner Thickness | 1 |
| Less Under Thread Thickness | 7 |
| Plate Damage | 11 |
| Air Bubble In | 2 |
| AB LUG | 1 |
| Flash Open | 2 |
| Foreign Matter | 3 |
| ABSW | 1 |
| Less Side Wall Thickness | 6 |
| I.L Damage | 1 |
| Turn Mould | 2 |
| SM.LUG | 2 |
| Air bag leak | 5 |
| pre cure | 2 |
| over cure | 1 |
| SMSW | 2 |

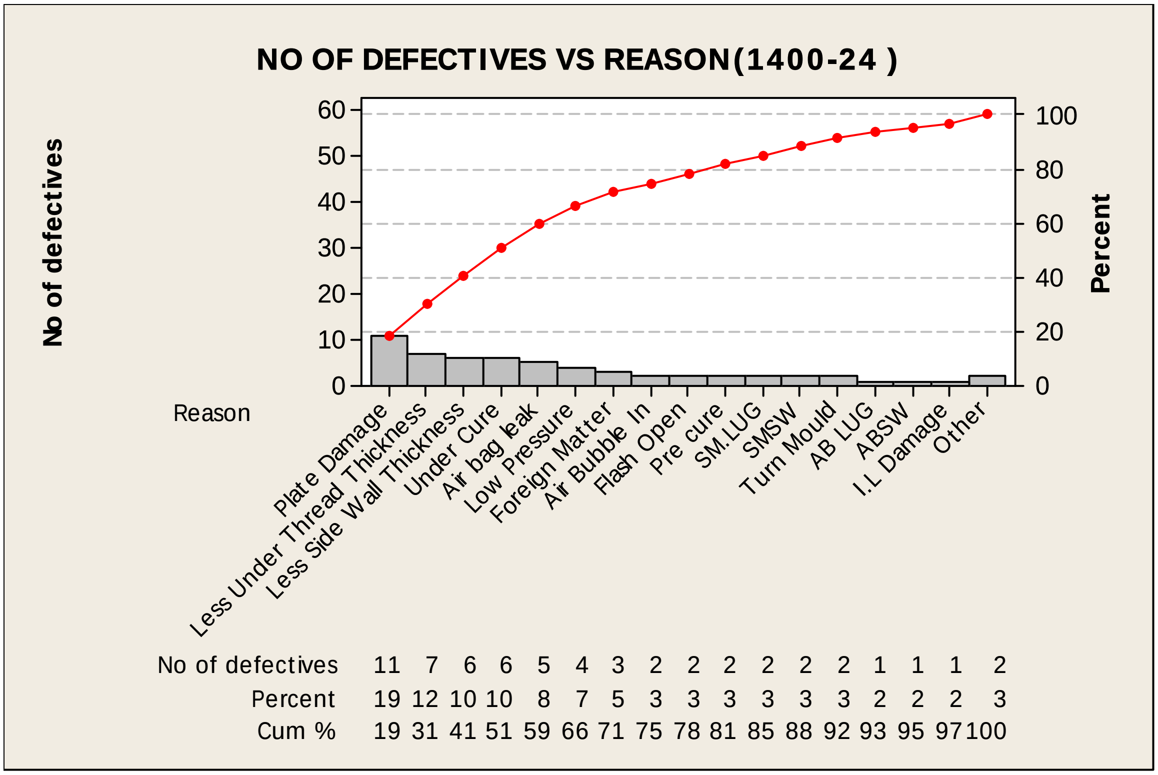


**Figure 4.48:** Parato Diagram of Tyre type V

Considering to the Figure 4.48, Plate damage, Less under tread thickness, Less side wall thickness, Under cure, Air bag leak, Low pressure, Foreign matter ,Air bubble in are main reasons which cause to tyre type V and each reason contribute 19%,12 %, 10%,10 %, 8%, 7% , 5%,3% and 3% respectively. High defect are due to plate damage, less under tread thickness and less sidewall thickness.

Out of above reasons Plate damage, Less under tread thickness, Less side wall thickness, Under cure, Air bag leak, Low pressure, Foreign matter are seven largest bars. Reading from cumulative line to the right axis, they represent approximately71% of the data. This means that out of all the reasons these seven reasons have taken up most defectives.

In this figure there is a substantial difference between first bar and the remaining bars. So tackling the first bar has substantial advantage.

**Table 4.39:** Reasons for tyre type V Plate damage defect.

| Reasons for Plate damage defect | Number of defect tyres |
|---|---|
| Wearing thread of the nail | 3 |
| wearing tread of the side ring | 8 |

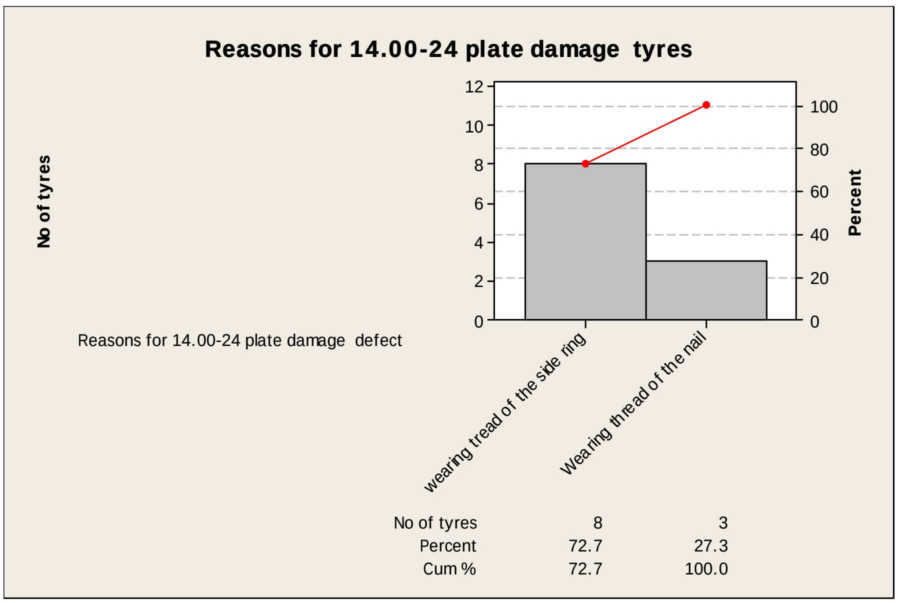


**Figure 4.49:** Reasons for tyre type V Plate damage defect tyres

Considering Figure 4.49, Wearing tread of the side ring is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 73% of the data. This means that out of all the reasons first bar has taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.40:** Reasons for tyre type V Less under tread thickness defect

| Reasons for Less under tread thickness defect | Number of defect tyres |
|---|---|
| Low tread weight | 1 |
| tread out of center | 0 |
| High tread starting width | 2 |
| When use damage air bag in the inflating machine | 4 |

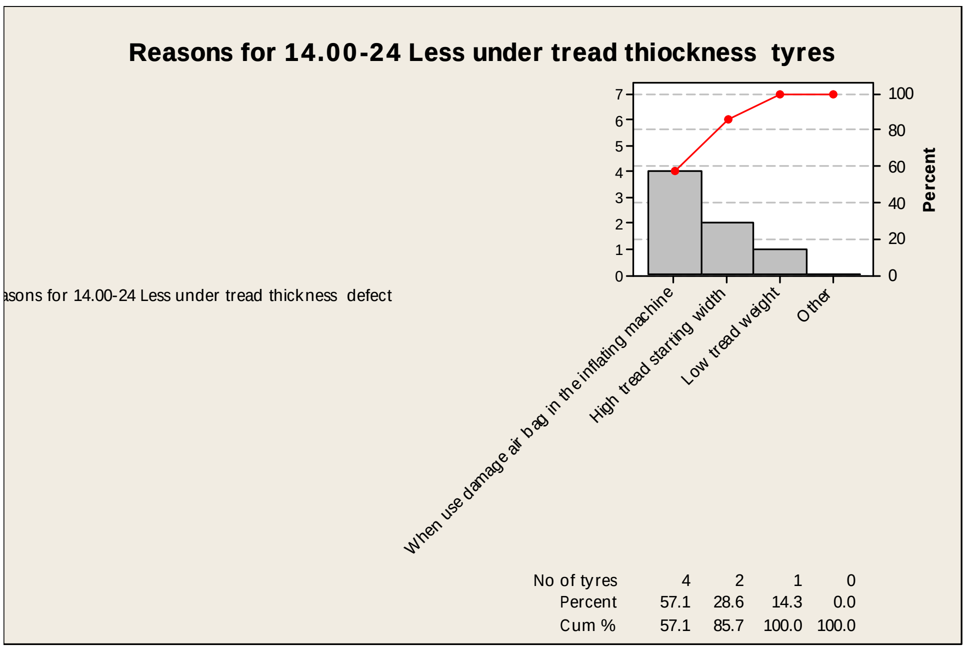


**Figure 4.50:** Reasons for tyre type V Less under tread thickness defect tyres

Considering Figure 4.50, when use damage air bag in the inflating machine and high tread starting width are the largest bars. Reading from the cumulative line to the right axis, they represent approximately 87% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.41:** Reasons for tyre type V Less side wall thickness defect

| **Reasons of Less side wall thickness defect** | **Number of defect tyres** |
|---|---|
| Turn up plates | 2 |
| Low side wall thickness | 0 |
| Tread center out | 4 |

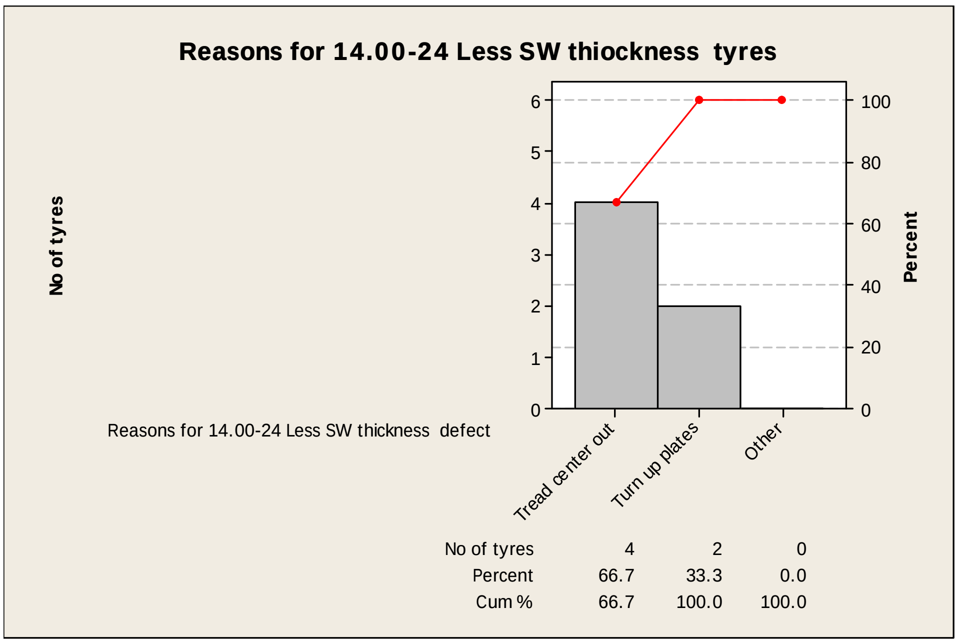


**Figure 4.51:** Reasons for tyre type V Less side wall thickness defect tyres

According to the Figure 4.51, Tread centre out is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 67% of the data. This means that out of all the reasons first bar has taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.42:** Reasons for tyre type V Under cure defect

| Reasons for Under cure defect | Number of defect tyres |
|---|---|
| Electrical element off | 1 |
| Water seal leak | 2 |
| Air leak from the bladder core | 1 |
| Tyre curing with low steam pressure | 0 |
| Low curing time than the specification time | 2 |

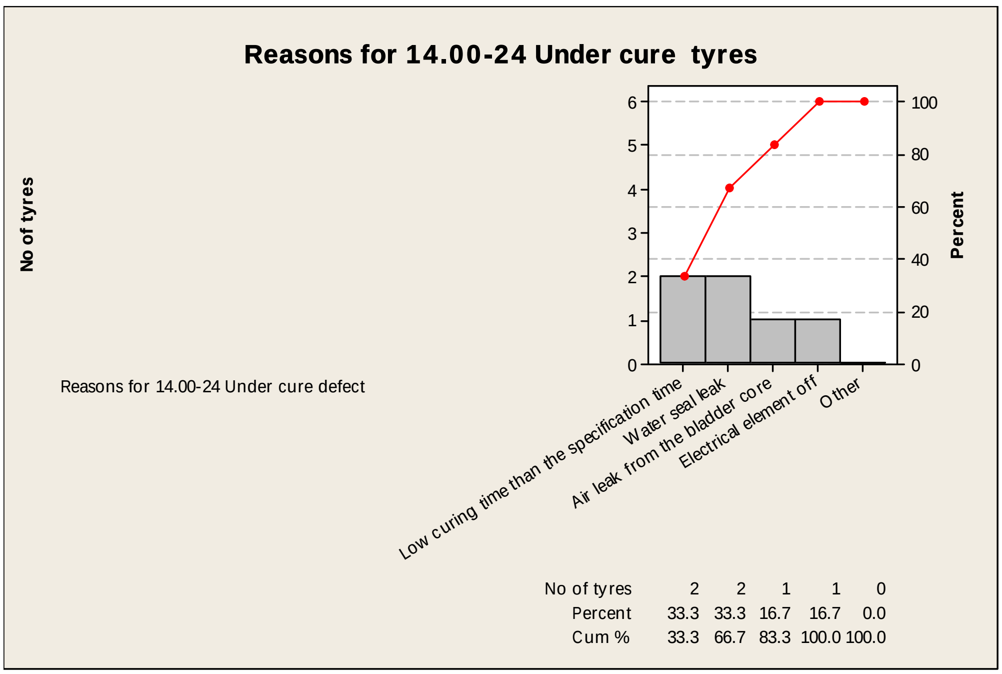


**Figure 4.52:** Reasons for tyre type V Under cure defect tyres

Considering Figure 4.52, Low curing time than the specification time and Water seal leak are the largest bars. Reading from the cumulative line to the right axis, they represent approximately 67% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first two bars and the remaining bars. So tackling first two bars is substantial advantage.

**Table 4.43:** Reasons for tyre type V Air bag leak defect

| Reasons of Air bag leak defect | Number of defect tyres |
|---|---|
| Air leak from the air bag | 3 |
| Air leak from the coupling | 0 |
| Air leak from the Elbow | 2 |

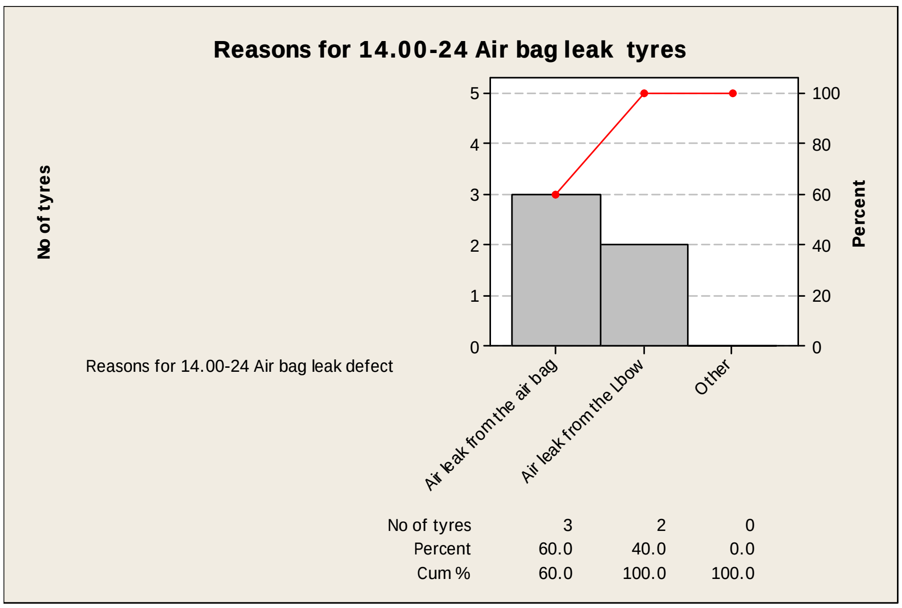


**Figure 4.53:** Reasons for tyre type V Air bag leak defect tyres

Considering Figure 4.53, Air leak from the air bag is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 60% of the data. This means that out of all the reasons first bar has taken up the most defectives.

**Table 4.44:** Reasons for tyre type V Low pressure defect

| Reasons for Low pressure defect | Number of defect tyres |
|---|---|
| Delay apply hydraulic pressure | 1 |
| Hydraulic pressure release when tyre curing | 2 |
| Tyre curing with low N2 pressure | 0 |
| Press open when tyre curing due to not timer zero | 1 |

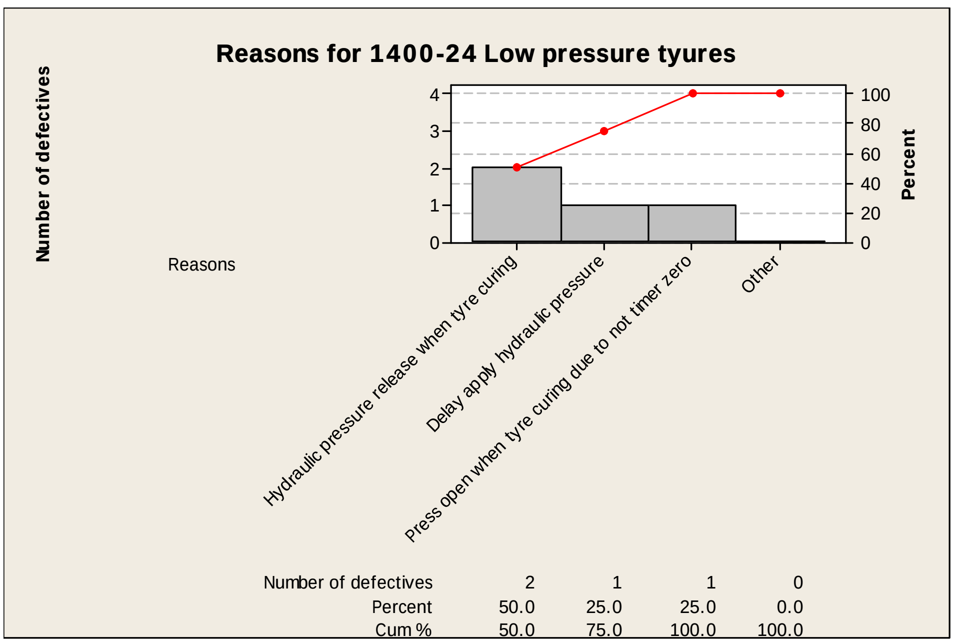


**Figure 4.54:** Reasons for tyre type V Low pressure defect tyres

Considering Figure 4.54, Hydraulic pressure release when tyre curing and Delay apply hydraulic pressure are the two largest bars. Reading from the cumulative line to the right axis, they represent approximately 75% of the data. This means that out of all the reasons first two bars have taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.45:** Reasons for tyre type V Foreign matter defect

| **Reasons for Foreign matter defect** | **Number of defect tyres** |
|---|---|
| Close venting holes of side ring and the tread ring | 1 |
| Compound not flowing well | 0 |
| Not removing cleaning dust after mould cleaning | 2 |
| Dust outside of the raw tyre | 1 |

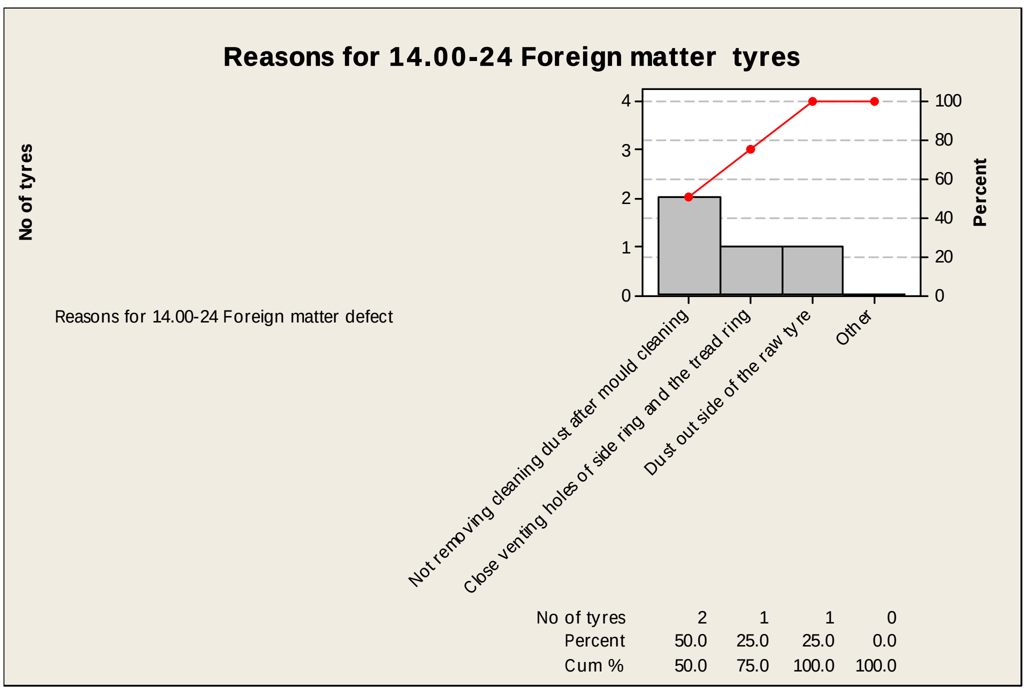


**Figure 4.55:** Reasons for tyre type V Foreign matter defect tyres

Considering Figure 4.55, not removing cleaning dust after mould cleaning is the largest bar. Reading from the cumulative line to the right axis, it represents approximately 50% of the data. This means that out of all the reasons first bar has taken up the most defectives.

In this figure, there is a substantial difference between the first bar and the remaining bars. So tackling first bar is substantial advantage.

**Table 4.46:** Chi-square calculation of tyre type V

| MONTH | Number of defects(O) | E | (O-E ) | (O-E)2 | (O-E)2/E |
|---|---|---|---|---|---|
| JANUARY | 13 | 11 | 2 | 4 | 0.3636 |
| FEBRUARY | 7 | 11 | -4 | 16 | 1.4545 |
| MARCH | 18 | 11 | 7 | 49 | 4.4545 |
| APRIL | 8 | 11 | -3 | 9 | 0.8181 |
| MAY | 9 | 11 | -2 | 4 | 0.3636 |
| | | | | $\chi 2=$ | **7.4543** |

Critical value $\chi 2_{4,0.05} = 9.488$

Test statistic < Critical value

7.4543 < 9.488

.

Therefore there is no relationship between the defects in month and the tyre type V

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

When comparing the five selected tyre type manufacturing processes, higher frequency of defect tyres was observed for tyre type III because it had the lowest ARL of 22. The highest ARL 228 was observed for tyre type II which had lowest frequency of yielding defect tyres. This shows a clear negative relationship between ARL and the defect tyre yield. The cost added to good tyres due to manufacturing defect tyre differs depends on the cost of tyre type and the ARL of the manufacturing process. The cost added to type II tyre is Rs 46.59 and for type III tyre is Rs. 2339.77. Therefore the target of the factory should be achieving higher ARL values while giving special priority for expensive tyres. The Chi-square test results reveal that there are significant associations between defect tyre percentage and time ($P < 0.05$) for tyre type I, II, and III. The reason may by some climatic effect and it has to be explored further. However, such associations were not observed for tyre types IV and V.

The analysis of defects tyres using Pareto diagram, identified the main cause of producing defect tyres is under cure. The reason for under cure is electrical element off. This happens because melting off of electrical element or the connecting bars. The other main reasons for manufacturing defect tyres are bladder pleat, bladder leak, thin bead, plate damage, low pressure and air bubble lug. The said seven reasons account for manufacturing 79 % of the defective tyres.

## 5.2 Recommendations

The ARL of the each type of tyre manufacturing process can be a good indicator for the factory for evaluating the process performance. Application of Pareto diagram for each type tyre manufacturing process is highly recommended to identify the main causes for manufacturing defect tyres and rectify those. Based on this study the following activities are recommended to increase the ARL of the manufacturing process.

a. Check electrical elements, connecting bars and electrical wires frequently and replace if damaged
b. Replace the bladder before getting end the life cycle time
c. Cutting the tread of the side ring and replace by new nails when unloading the mould for cleaning and changing.
d. Replace water seal and O-ring on time
e. Maintain the standard width when cutting the layers
f. Maintaining the optimum temperature by regulating the temperature controls
g. Follow daily check list before use the machines
h. Use skill operators for the machines every time
i. Identify abnormal conditions of the machines in advance with the help of Alarm system

In addition it is required to improve the efficiency and skill of the operators through a proper in-services training.

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# APPENDIX A

Production details of selected tyre types

| Tyre type | Manufacturing cost | Number of defectives | **Total production** |
|---|---|---|---|
| I | 14060 | 281 | 58301 |
| II | 10624 | 225 | 67562 |
| III | 60275 | 53 | 4012 |
| IV | 35561 | 58 | 7759 |
| V | 32647 | 55 | 7742 |

Failure probability results

| **tyre type** | **n** | **no of defectives** | **c** | **nc** | **p** | **1-p** | **(1-p)c** | **n(1-p)c** | **1.1(n(1-p)c)** |
|---|---|---|---|---|---|---|---|---|---|
| I | 58301 | 281 | 14060 | 819712060 | 0.00482 | 0.99518 | 13992.2 | 815761200 | 897337320 |
| II | 67562 | 225 | 10624 | 717778688 | 0.00333 | 0.99667 | 10588.6 | 715388288 | 786927116.8 |
| III | 4012 | 53 | 60275 | 241823300 | 0.01321 | 0.98679 | 59478.7 | 238628725 | 262491597.5 |
| IV | 7759 | 58 | 35561 | 275917799 | 0.00748 | 0.99252 | 35295.2 | 273855261 | 301240787.1 |
| V | 7742 | 55 | 32647 | 252753074 | 0.0071 | 0.9929 | 32415.1 | 250957489 | 276053237.9 |

# APPENDIX B

ARL and additional cost values due to defectives

| Tyre type | ARL | A(Rs) |
|---|---|---|
| I | 145 | 96.96 |
| II | 228 | 46.59 |
| III | 22 | 2739.77 |
| IV | 38 | 935.81 |
| V | 47 | 694.61 |

Chi-square test results

| Tyre type | Chi-square test results |
|---|---|
| I | There is a relationship between the defects and the tyre type I |
| II | There is a relationship between the defects and the tyre type II |
| III | There is a relationship between the defects and the tyre type III |
| IV | There is no relationship between the defects and the tyre type IV |
| V | There is no relationship between the defects and the tyre type V |

## APPENDIX C

Reasons for defect of tyre type III and IV

| **Reasons for defect of tyre typeIV** | Electrical Element off | O' ring leak | Curing with over temperature | Low hydraulic pressure | Air leak from the L bow | **Reasons for defect of tyre typeIII** | Delay apply hydraulic pressure and hydraulic pressure release when tyre curing | Water seal leak | Electrical Element off | Turn up pleats | Wearing tread of the nail |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Under cure | 50% | | | | | Under cure | | | 50 % | | |
| Air bubble in | | 36.40% | | | | Plate damage | | | | | 87.50% |
| Air bubble lug | | | 40% | | | Air bubble in | | 40% | | | |
| Flash open | | | | 50% | | Less side wall thickness | | | | 50 % | |
| Hose leak | | | | | 75% | Low pressure | 50% | | | | |

## APPENDIX D

Reasons for defect of tyre type I and II

| **Reasons for defect of tyre typeI** | Low pre shaping pressure | Stretch the bladder core and the raw tyre | Electrical Element off | Low layer width | Wearing tread of the nail | **Reasons for defect of tyre typeII** | Not properly drill the carcuss | Melt the bladder due to low $N_2$ purity | Electrical Element off | Black compound particles mix with grey compound | Tyre curing with Low $N_2$ pressure |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Under cure | | | 48.1% | | | Under cure | | | 53.2% | | |
| Bladder pleat | 41% | | | | | Pressure leak mark | 53.6% | | | | |
| Bladder leak | | 42.4% | | | | Bladder leak | | 48.4% | | | |
| Thin Bead | | | | 28.6% | | Two color | | | | 58.8% | |
| Plate damage | | | | | 60% | Low pressure | | | | | 46.7% |

Reasons for defect of tyre type V

| **Reasons for defect of tyre typeV** | Wearing tread of the side ring | When use a damage air bag in the inflating machine | Tread center out | Low curing time than the specification time and water seal leak | Air leak from the air bag |
|---|---|---|---|---|---|
| Plate damage | 73% | | | | |
| Less under tread thickness | | 57.10% | | | |
| Less side wall thickness | | | 67% | | |
| Under cure | | | | 67% | |
| Air bag leak | | | | | 60% |

## APPENDIX E

Reasons for defectives of five tyre types

| Tyre type | Reasons for defectives | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Under cure | Bladder pleat | Pressure leak mark | Bladder leak | AB in | AB lug | Flash open | Hose leak | Thin bead | Plate damage | Two color | Low pressure | Less under tread thickness | Air bag leak | Less side wall thickness |
| I | 27 | 61 | | 59 | | | | | 21 | 15 | | | | | |
| II | 49 | | 28 | 31 | | | | | | | 18 | 15 | | | |
| III | 12 | | | | 5 | | | | | 9 | | 4 | | | 4 |
| IV | 6 | | | | | | | | | 11 | | | 7 | 5 | 6 |
| V | 20 | | | | 11 | 5 | 4 | 4 | | | | | | | |

## APPENDIX F

Total cost of defectives for the period of past five month

| TYRE SIZE | Number of defect tyres | Cost of Tyre (Rs) | Total cost defectives (Rs) | Percentage cost of defectives | cumulative % |
|---|---|---|---|---|---|
| 12.16.5 | 281 | 14060 | 3950860 | 10% | 10% |
| 20.5-25 | 53 | 60275 | 3194575 | 8% | 18% |
| 23.5-25 | 32 | 95365 | 3051680 | 8% | 26% |
| 10.16.5 | 225 | 10624 | 2390400 | 6% | 32% |
| 19.5L-24 | 58 | 35561 | 2062538 | 5% | 37% |
| 1400-24 | 55 | 32647 | 1926173 | 5% | 42% |
| 26.5-25 | 11 | 120406 | 1324466 | 3% | 47% |
| 1300-24 | 43 | 29138 | 1252934 | 3% | 50% |
| 16.9-24 | 29 | 43140 | 1251060 | 3% | 53% |
| 355/55D-625 | 54 | 18766 | 1013364 | 3% | 56% |
| 16.9-30 | 29 | 32136 | 931944 | 2% | 58% |
| 17.5-25 | 20 | 43699 | 873980 | 2% | 61% |
| 18-625 | 26 | 28801 | 748826 | 2% | 62% |
| 15.5-25 | 20 | 34029 | 680580 | 2% | 64% |
| 385/65-22.5 | 18 | 36025 | 648450 | 2% | 66% |
| 7.00-12 | 92 | 6398 | 588616 | 2% | 67% |
| 17.5L-24 | 19 | 30939 | 587841 | 2% | 69% |
| 1000-20 | 35 | 16663 | 583205 | 1% | 70% |
| 11L-15SL | 53 | 9785 | 518605 | 1% | 72% |
| 15.5/80-24 | 16 | 30055 | 480880 | 1% | 73% |
| 15.19.5 | 16 | 30055 | 480880 | 1% | 74% |
| 12.5/80-18 | 29 | 16148 | 468292 | 1% | 44% |
| 16.5/85-24 | 16 | 29052 | 464832 | 1% | 75% |
| 11L-16SL | 48 | 9437 | 452976 | 1% | 76% |
| 39X15-22.5 | 19 | 22603 | 429457 | 1% | 78% |
| 33X15.5-16.5 | 21 | 20035 | 420735 | 1% | 79% |
| 36X14-22.5 | 20 | 19965 | 399300 | 1% | 80% |
| 8.25-15 | 27 | 13443 | 362961 | 1% | 81% |
| 405/70-20 | 14 | 24903 | 348642 | 1% | 81% |
| 15-625 | 13 | 26663 | 346619 | 1% | 82% |
| 15.5-625 | 13 | 26663 | 346619 | 1% | 83% |
| 445/55-19.5 | 10 | 33425 | 334250 | 1% | 84% |
| 9-14.5 | 38 | 8253 | 313614 | 1% | 85% |
| 1300-12 | 31 | 8900 | 275900 | 1% | 86% |
| 31X15.5-15 | 20 | 13418 | 268360 | 1% | 87% |

Total cost of defectives for the period of past five months (cont)

| | | | | | |
|---|---|---|---|---|---|
| 21L-24 | 7 | 37987 | 265909 | 1% | 88% |
| 10.0/75-15.3 | 28 | 9158 | 256424 | 1% | 88% |
| 1200-20 | 6 | 42588 | 255528 | 1% | 89% |
| 7.50-16 | 27 | 9067 | 244809 | 1% | 90% |
| 11.5/80-15.2 | 21 | 11367 | 238707 | 1% | 90% |
| 405/70-24 | 8 | 29697 | 237576 | 1% | 91% |
| 12.5-18 | 13 | 17359 | 225667 | 1% | 91% |
| 265/50-20 | 19 | 10532 | 200108 | 1% | 92% |
| 28x9-15 | 18 | 9416 | 169488 | 0% | 92% |
| 315/85-15 | 7 | 23142 | 161994 | 0% | 93% |
| 27X8.5-15 | 23 | 6295 | 144785 | 0% | 93% |
| 27X/8.5-15 | 23 | 6295 | 144785 | 0% | 93% |
| 31.5X13-16.5 | 11 | 12151 | 133661 | 0% | 94% |
| 385/65-19.5 | 4 | 30505 | 122020 | 0% | 94% |
| 1100-20 | 4 | 26179 | 104716 | 0% | 94% |
| 26X12-380 | 13 | 7645 | 99385 | 0% | 95% |
| 6.00-9 | 28 | 3501 | 98028 | 0% | 95% |
| 29X12.5-15 | 11 | 8675 | 95425 | 0% | 95% |
| 14.9-24 | 3 | 26408 | 79224 | 0% | 95% |
| 16.5-24 | 2 | 30050 | 60100 | 0% | 96% |
| 26X12-12 | 8 | 7450 | 59600 | 0% | 96% |
| 26X12.16.5 | 8 | 7334 | 58672 | 0% | 96% |
| 8.00-16.5 | 5 | 8323 | 41615 | 0% | 96% |
| 27X10.5-15 | 4 | 8899 | 35596 | 0% | 96% |
| 18-22.5 | 1 | 30715 | 30715 | 0% | 96% |
| 15-19.5 | 1 | 22828 | 22828 | 0% | 96% |
| 265/50D-20 | 2 | 10532 | 21064 | 0% | 96% |
| 385/45-28 | 1 | 21054 | 21054 | 0% | 96% |
| 12.5/80-12 | 1 | 15148 | 15148 | 0% | 96% |
| 10.5-18 | 1 | 13622 | 13622 | 0% | 96% |
| 240/55-17.5 | 1 | 10221 | 10221 | 0% | 96% |
| 240/55-14.5 | 1 | 10221 | 10221 | 0% | 96% |
| 27X10-12 | 1 | 9605 | 9605 | 0% | 96% |
| 23X10-12 | 1 | 7598 | 7598 | 0% | 96% |
| 26X10-12 | 1 | 7481 | 7481 | 0% | 96% |

**TOTAL** **RS 37.75 Million**