Loading time monitoring via individual control charts

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Abstract

In quality control we find techniques that come from different fields, because the objective is to reduce the variability in quality characteristics, these are control and adjustment of processes. In this work, the individual control charts (Xind and Rm) were used to monitor the loading time of a truck measured during 60 consecutive days of a cargo transport company in Rio Grande do Sul. The results showed that the process is out of control both in average and variability, requiring a systematic monitoring in order for the company to maintain the quality of services provided to its customers.

Keywords*: control charts; variability; loading time;*

1. Introduction

At a time of increasing competitiveness among companies in all sectors, carriers are undergoing a process of modernization that involves adopting measures to monitor their activities, always seeking a better performance of service to their customers (GOMES; RIBEIRO, 2004).

From 1990 on, with the commercial opening since 1993, the Brazilian transport companies started to modernize, meeting the demands of the large industrial and commercial firms (GOMES; RIBEIRO, 2004).

According to NBR ISO 8402/1994, "The services are results generated by activities in the interface between the supplier and the client and, by the internal activities of the supplier, to meet the needs of the client".

The activities and trends in quality in recent decades have undergone major transformations. There is a market-oriented quality revolution and it is now beginning to have an impact on both the industrial and service sectors. In addition to high quality products, consumers expect service excellence.

According to Denton (1990), in order to achieve truly quality services, a cultural and perceptual change within the organizations is necessary. Several statistical tools can be used to monitor the performance of services. In this work, the control charts introduced by Shewhart in 1931, which are simple and effective for monitoring the performance of manufacturing processes and, for this reason, widely used in practice, were used.

According to Montgomery (2000), there are at least five reasons for using control charts: (i) are proven techniques for improving productivity, (ii) are effective in preventing defects, (iii) avoid unnecessary adjustments in processes, (iv) provide reliable information for diagnosing process performance and (v) provide information on process capability, as well as allow assessing whether the behavior of the process, in terms of variation, is predictable.

Variability is an intrinsic feature of any service and, in particular, of the logistics service A process is a set of articulated causes that produce one or more effects (FIGUEIREDO; WANKE, 2000). In this case the process considered is the loading time of a truck.

In any process it is impossible to achieve results without variability. Such impossibility is due to the causes of variation inherent to the processes. Two types of variations can be present in a process, i.e., common causes and/or special causes.

Common (or random) causes of variation are intrinsic to the process (DEMING, 1990) and have a stable distribution. The individual identification of these causes is usually a difficult task. Punctual action attempts on common causes generally reduce little variation, and the significant reduction of these causes requires a re-evaluation of the entire system, entailing high costs for the process maintainer. The special (or identifiable) causes of variation are causes that, acting on the process, cause great variations in it. These causes have an unstable distribution and are generally easy to identify. Actions on special causes, if they exist, should be preferred, because they are low cost and greatly reduce the variation of the process.

This paper aims to present an analysis of the performance of the control charts (X_{ind} and R_m) applied in monitoring the loading time of a truck measured during 60 consecutive days of a small cargo transport company from Rio Grande do Sul.

It can be said that transport means driving or taking from one place to another some good. From a business point of view, transportation is part of the logistics or distribution system of companies operating in the market. Road freight transport is an essential activity for the country's economy. Without transport (whatever the mode), the production of the other economic sectors would not advance at all, since the goods produced would not be able to reach their final consumers. In a certain way, all economic agents depend directly or indirectly on transport to satisfy their needs, which is a link of socioeconomic connection (BASTIDAS; NERY; CARVALHO, 2001).

For Parreiras (1990), the mission of freight transport is "to solve customers' transport problems, making them satisfied and profitable. The cargo transport company sells tranquility".

This article is structured as follows: the second section presents the theoretical foundation, the third section presents the results and the discussion. The article is closed by a section of final considerations.

2. Theoretical Basis

In this item will be presented the theoretical basis for the development of this work.

2.1 Control charts (X_{ind} and R_m)

When only individual measurements are available, the use of X_{ind} and R_m control charts becomes necessary. The X_{ind} chart aims to control the individual process measurements and moving amplitude (R_m) is defined as the difference (in module) between two consecutive individual samples, which serves to control the process variability (BUCHAIM; BARBOSA NETO, 1999; MONTGOMERY, 2000).

According to Montgomery (2000), assuming a process where the quality characteristic of interest X_i to be controlled has a normal distribution with mean μ and standard deviation σ.

If x_1, x_2, x_3,...,x_n are samples resulting from individual observations, that is, samples of size n=1 of distribution with mean μ and standard deviation $\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{n}} = \sigma$, because n=1, that is $\bar{X} \sim N\left(\mu, \sigma_{\bar{X}}\right) = N(\mu, \sigma)$

.

According to the properties of the normal distribution, it is concluded that there is a probability equal to ($1-\alpha$) that the average of the process is between $\mu - Z_{\frac{\alpha}{2}}\sigma$ and $\mu + Z_{\frac{\alpha}{2}}\sigma$, i.e. $P\left(\mu - Z_{\frac{\alpha}{2}}\sigma < \bar{X} < \mu + Z_{\frac{\alpha}{2}}\sigma\right) = 1-\alpha$.

Using the system 3σ, which consists of doing $Z_{\frac{\alpha}{2}} = 3$. In this case, when k=3, it indicates that 99.73% of the observations in the control chart are in the interval $\mu \pm 3\sigma$, that is, $P\left(\mu - 3\sigma < \bar{X} < \mu + 3\sigma\right) = 0{,}9973$ that it is the probability of occurrence of the observations within this interval. Through the system 3σ, we can conclude that the probability of the graph emitting a false alarm is equal to ($1-\alpha = 1-0{,}9973 = 0{,}0027$), which is the probability of occurrence of values outside the interval $(\mu - 3\sigma, \mu + 3\sigma)$ considered.

Using $\hat{\mu} = \bar{X}$ and $\hat{\sigma} = \frac{R_m}{d_2}$ as estimators of μ and σ respectively, the mathematical model of the control chart for individual measurements x_i is defined with the following parameters:

Upper Control Limit

$$UCL_x = \bar{x} + \frac{3}{d_2}\overline{R}_m \qquad (1)$$

d_2 = tabulated constant as a function of the moving range

Center line

$$LM_x = \overline{x} \quad (2)$$

that represents the mean value of the quality characteristic under study that corresponds to the state under inspection.

Lower Control Limit

$$LCL_x = \bar{x} - \frac{3}{d_2}\overline{R}_m \quad (3)$$

where:

The process average is: $\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ (4)

The range of the process is:

$$\overline{R}_m = \frac{\sum_{i=1}^{n-1} R_{mi}}{n-1}$$

(5)

According to Montgomery (2000), in order to evaluate the performance of a control chart and compare several procedures, we can take into account the values of Type I (risk of a point falling outside the control limits, indicating an out of control condition when no significant cause is present) and Type II (risk of a point falling between the limits) errors, when the process is really out of control) associated with decision making and the resulting economic consequences, i.e., the cost associated with the search for the non-existent problem and the cost associated with poor quality that is obtained in the final product since the change occurs until it is detected.

The performance of a control chart can be evaluated in part in terms of sensitivity to detect deviations in the statistics being monitored. This sensitivity can be measured by the number of samples taken until the graph signals that a deviation has occurred, or by the Mean Quadratic Deviation (MONTGOMERY, 2000).

2.2 Performance Measure

The performance measure used, in order to evaluate the effectiveness of the control charts, is the one recommended by (MONTGOMERY, 2000; RUSSO; CAMARGO; FABRIS, 2012), that is, the Mean Quadratic Deviation (DQM), given by:

$$MQD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - T)^2}{n}} \qquad (7)$$

where:

n = number of observations;

T = established default value.

3. Results and Discussion

3.1 Descriptive analysis of the data

The values related to the measurement of loading times of a truck from a transport company in the State of Rio Grande do Sul, obtained during 60 days, are presented in Figure 1.

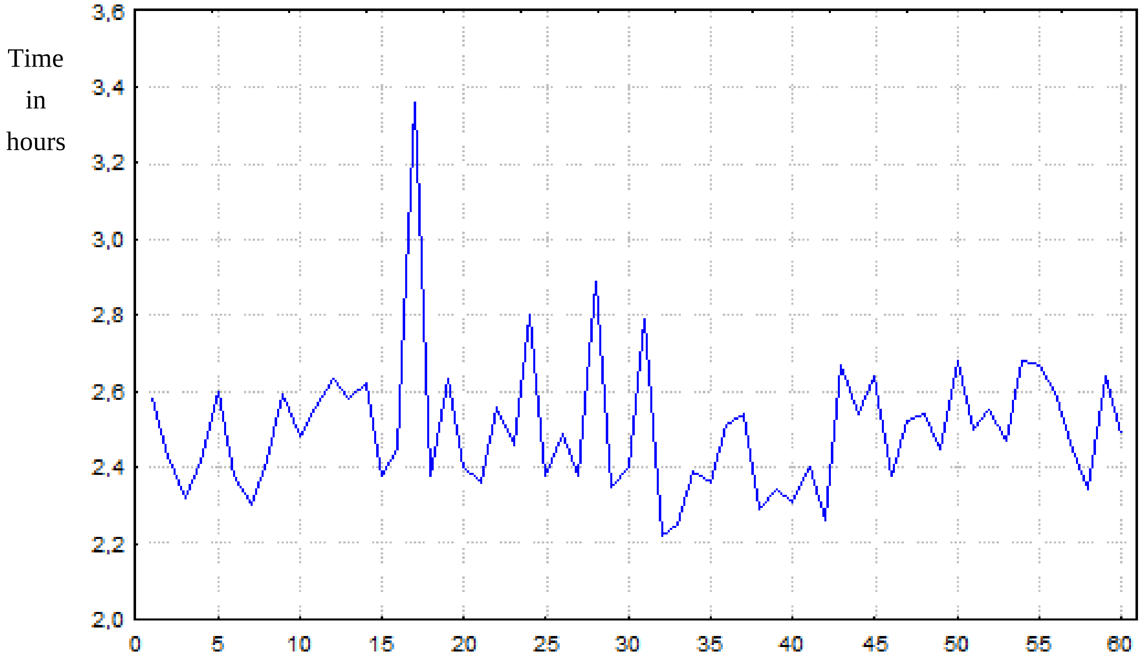

Figure 1 - Representative series of the loading time

It was observed that there was an outlier at observation (t=17), i.e., at observation (t=16) the loading time was 2 hours and 45 minutes, passing to 3 hours and 36 minutes at observation t=17, with an increase of 37.14%. Subsequently in observation 18 there was a reduction of 41.48% to 2 hours and 38 minutes. This variation suggests that a remarkable cause may have occurred, which may mean an abnormality that can be investigated and confirmed through the control charts.

The Kolmogorov-Smirnov test (CONOVER, 1971) was applied to verify the normality of the data, which showed a value of (p-value = 0.27 > 0.05), thus ensuring that the data adjust to a normal distribution, at a significance level of 5%. To test independence, the autocorrelation coefficients presented in Figure 2 were calculated, confirming that the data are independent, since all the autocorrelation function coefficients are within the control limits, i.e., ±2 standard errors.

Thus, the necessary assumptions of normality and independence of the measures are guaranteed and the traditional control charts can be built.

To compare the mean of the measurements (2.50083) with the standard value established by the company, which is 2 hours and fifty minutes, the unilateral student t-test was applied, concluding that the means are equal to the significance level of 5%. Figure 2 shows the autocorrelation coefficients.

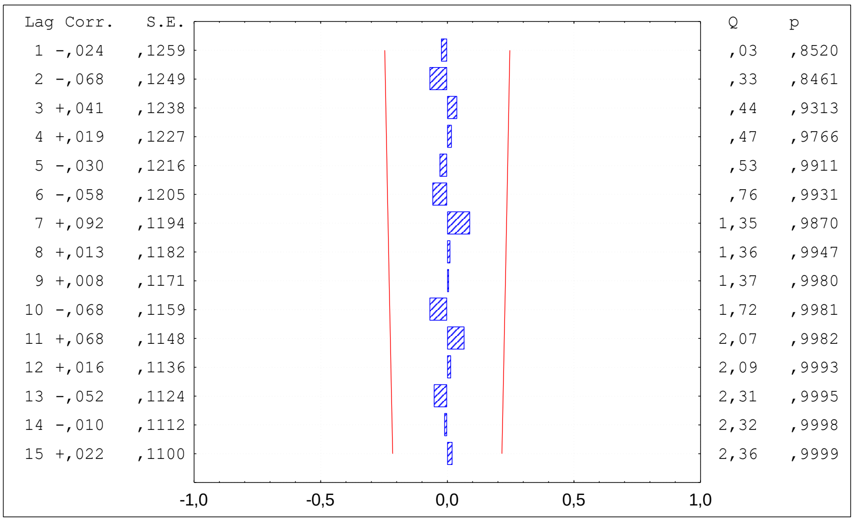

Figure 2 - Autocorrelation coefficients

3.2 Construction of control charts

In Figure 3, it is presented the chart (X_{ind}) to monitor the behavior of the average of the individual values of the loading time.

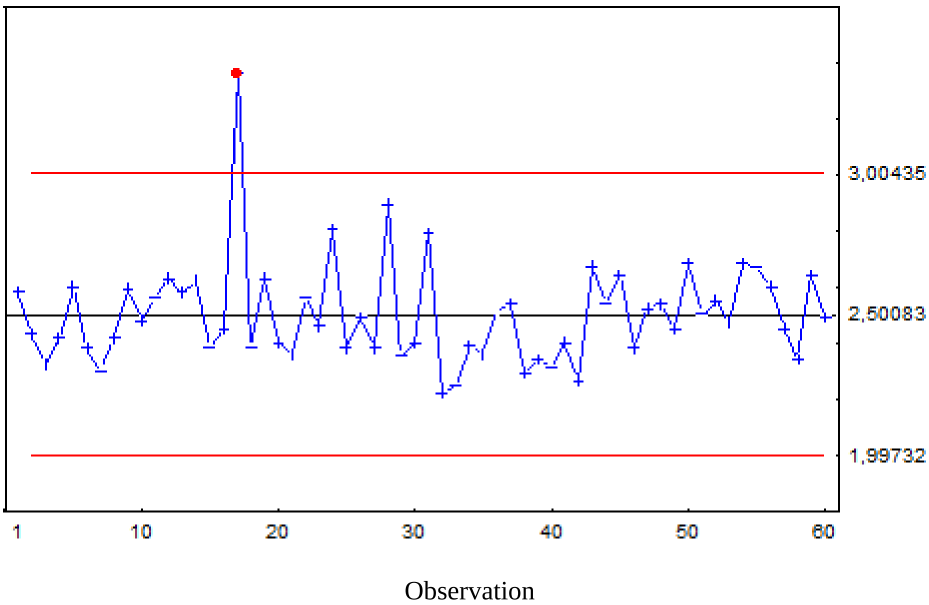

Figure 3 - Control chart for the average loading time

The letter to monitor the dispersion of the process is presented in Figure 4. The X_{ind} chart (individual measurements) presents a special cause. In the observation t=17, as can be seen, there was an increase in the loading time (3 hours 36 minutes), unbalancing the process. On this day there was a shortage of one employee. In Figure 4, it is shown the graph of the control chart for range of the loading time.

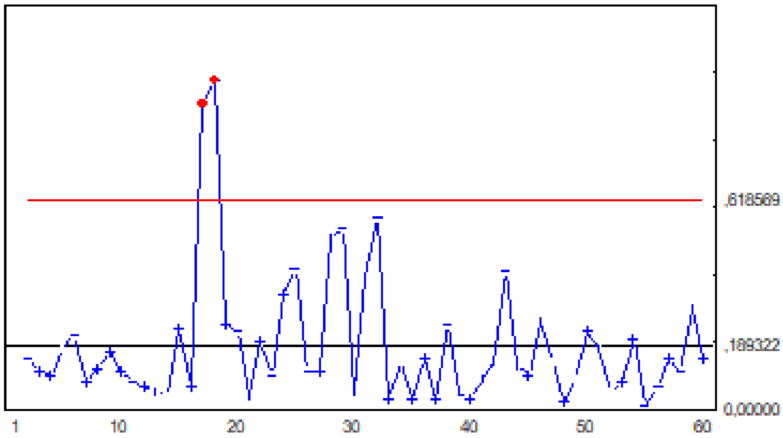

Figure 4 - Control chart for loading time range

In the chart R_m, the presence of special causes acting in the process, that is, in observations 17 and 18. The loading time went from 2 hours and 45 minutes in observation 16 to 3 hours 36 minutes in observation 17, plus 91 minutes. On day 18 when the employee who had been absent on the previous day returned, the time returned to 2 hours 38 minutes in observation t=18, causing a decrease in time of 98 minutes. These variations are shown in Figure 4.

4. Conclusion

The present work found basis in the control chart procedures for individual Shewhart measures (Xind and Rm), used for independent and normally distributed data, which aims to detect changes in the process, both in mean and variability.

In conclusion, it can be said that the control charts are tools that can be used to monitor the behavior of variables in the logistics service, helping professionals in the area to monitor their processes in order to maintain quality services for their customers.

The charts built in this work to monitor the loading time presented satisfactory performance, with a mean square deviation of 0.18 showing that the increase in time on day 17 caused an increase of 29% in process variability.

Thus, the control charts, like any control tool, can help those who control the process and must be used properly. According to Figueiredo; Wanke (2000) "its objective is to show to all who work in the process how it is developing and to inform them quickly the occurrence of some anomaly. This creates in the group an alert consciousness and the interest in solving the problem having it been caused by an equipment failure, a human error or even by some external factor to the system. It also sensitizes the direction of the company to provide all the necessary assistance in order to keep the process under control".

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