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## **Control of Payment of Suppliers in a Public Hospital: Case Study of Onofre Lopes University Hospital – Brazil**

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**Abstract**

Throughout the last decades, the discussion about the quality in the health service has gained global importance, mainly due to the difficulty in reaching a thorough measurement for the performance of health services based on objective criteria. Thus, the purpose of the present study is to evaluate through Control Charts whether the supplier payment process in a public hospital is being completed within the time frames specified by internal corporate administrative resolutions. Initially followed the Montgomery methodology for non-self-correlated phenomena from which the application of individual control charts and moving range was utilized. Following the charts analysis, it became necessary to verify the conformity of the data in relation to the distribution. Hence, the Kolmogorov-Smirnov and Chi-Square tests were performed, in which it was verified that the Weibull distribution is better suited to the data, and control charts were applied for the Weibull distribution and Capability study. The results of the applications indicated variability in the process, which can be minimized by identifying the bottlenecks inherent to the formalities in the payment process; evaluating the time a given invoice remains with the purchasing coordinator; defining a timeframe necessary to comply with the process verification before validating the invoice and send it to the contract unity; determining the specific time requirements for each stage of the process as to optimize the flow; and establishing key performance indicators in order to attain an in depth understanding of the internal procedures.

**Keywords:** Statistical quality control, hospitals, procurement sector, quality engineering, total quality management, organization and administration.

## Introduction

Throughout the last decades, the discussion about quality in healthcare services has been gaining global importance; given that several countries have adopted as a priority issue the monitoring and improvement of the quality of medical care in response to notorious incidents of systematic malpractices which harm between 2,9% to 16.6% of users of medical facilities<sup>1,2</sup>. There is a growing demand for higher health service standards which derives from the understanding that the health sector is the main influencer on the life quality of the population<sup>3</sup>.

In Brazil, the reality of healthcare facilities is characterized by hospital overcrowding and bed shortage, which indicates the poor performance of the public and private healthcare and emergency systems in response to the increasing demand for the use of these services<sup>4-6</sup>. According to a survey conducted by Datafolha amongst the 2069 respondents, 60% evaluated the public health situation in Brazil from terrible to bad. From this sample space, 54% believe that health should be the priority area of government investment<sup>7</sup>.

The discussion about quality in medical services indicates a recurring difficulty in measuring healthcare service performance holistically on the basis of objective criteria<sup>8</sup>. In order to define quality in services, it is necessary the understanding of the attributes that constitute the healthcare services and the criteria about what "quality care" means<sup>9</sup>. According to Donabedian, the notion of patient satisfaction is one of the main criteria to assess healthcare quality<sup>10</sup>.

According to Normann, quality of service is defined through several "moments of truth" in service provision which will shape the customer experience in the organization<sup>11</sup>. The knowledge, motivation and tools used by the service provider will be tested against the client's expectations. Grönroos and Fornell converge into this definition by understanding that quality must be evaluated according to the client's perception<sup>12,13</sup>.

Moreira argues that there is a conformity quality, wherein a product or service is developed according to the necessary characteristics to attend a given public, thus, the service or product can have quality for a specific public, whereas to other groups, it would not meet their criteria<sup>14</sup>.

According to Juran *et al.*, quality consists of two complementary concepts<sup>15</sup>:

- a) Quality is the fulfilment of specifications, or absence of failures;
- b) Quality is suitability to use; which implies that the specifications in item (a) above shall reflect characteristics in the product that satisfy the customers' needs regarding the use of the product or service.

Garvin evaluates that there are five approaches to defining quality, one of which is consumer-based, which understands quality as directly linked to subjective and personal visions of each customer; the understanding and subsequent satisfaction of these preferences would lead to consideration of that product or service as being of high quality<sup>16</sup>. Campos adds to the discussion when affirming that a quality product or service must attend in detail the conditions of reliability, accessibility, safety and conformity according to clients' specifications<sup>17</sup>. For Carvalho quality is synonym with excellence which must be inherent to the product or service provided and also absolute, without flaws and universally recognize, such vision of quality is a variable that can be measured through the characteristics of the product<sup>18</sup>.

In terms of quality in the healthcare services, it is understood that patients desire their care beyond what is presented in the classic approach, emphasizing the primordial importance of a humane treatment and an empathic approach by the healthcare professionals<sup>19</sup>.

An important tool of quality is the Control Chart due to the objectivity of exposing the relevant results regarding the conformity of the management and production processes. According to Werkema, the variations that result from goods or services arising from the production process must be reduced; however, this natural oscillation cannot generally be excluded in its entirety: it must be frequently controlled in order to analyse the stability of processes so that it does not result in products of poor quality, as to avoid any loss of production and loss of consumer confidence<sup>20</sup>.

According to Trivellato, the control charts aim to identify if there is any special cause triggering variation in the process by assessing how it changes over time and, based on this function, clarify the circumstances with the support of other tools. Its structure is developed based on the values of the quality attribute being controlled (the historical data), a centre line (CL), an upper control limit (UCL) and a lower control limit (LCC), the former being positioned above the central line whereas the latter is positioned below it<sup>21</sup>.

The present article endeavours to assess through Control Charts whether the payment process of suppliers in a public hospital is being completed within the time frames specified by internal corporate administrative resolutions. The case study was developed at the Onofre Lopes University Hospital (HUOL): a hospital institution that serves the population in the city of Natal through the Unified Health System - SUS and the other municipalities of Rio Grande do Norte. HUOL is an affiliated institution to the Empresa Brasileira de Serviços Hospitalares – Brazilian Hospital Services Company (EBSERH). It has an area of 31,569.45 m<sup>2</sup>, offering 242 beds, 19 intensive care units and 12 operating rooms.

## Methods

The attributions of the procurement process comprise the following activities: specification of the purchase needs, selection of suppliers, negotiation and contracting, as well as monitoring the actual delivery of the order and payment of the invoice<sup>22</sup>.

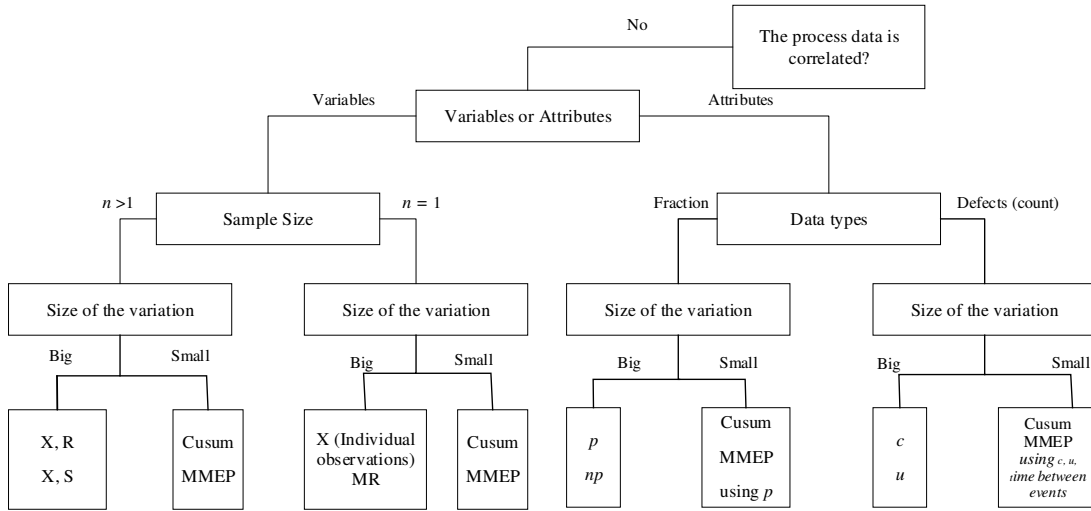
In addition to the usual steps taken in the procurement process, in the Brazilian public sector there is an extra step involved, since it must be done through a bidding process, guided mainly by Law 8.666 / 93. Alike all processes governed by Law, it is important to comply with deadlines established in the bidding process, since the interested parties will be subject to penalties and fines for non-compliance<sup>23</sup>.

As a result of that, the procurement sector in public hospitals is essential for the management of the formalities associated with service provision and payment of invoices. Thus, monitoring the compliance of payment deadlines is strategic for the governance of hospital facilities to maintain the provision of services that benefit users and contribute to meeting the performance and operation maintenance goals<sup>24-26</sup>.

Given this scenario, Statistical Quality Control as a methodology provides significant contributions, so that strategic processes in product development and service delivery can be duly monitored and operational failures are evidenced and corrected. The seven tools of Statistical Quality Control are: Check Sheet, Histogram, Pareto Chart, Control Charts, Ishikawa diagram (Cause-and-Effect Diagram), Scatter Diagram and Stratification (Flow Chart or Run Chart)<sup>23</sup>.

The present study aims to apply the visual Statistical Quality Control tools (Control Charts) due to their non-parametric characteristics that do not demand analysis inference and objectivity in the evaluation of inherent process failures. The workflow that makes possible the development of a study that addresses the use of such tool is defined by Montgomery<sup>24</sup> as follows:

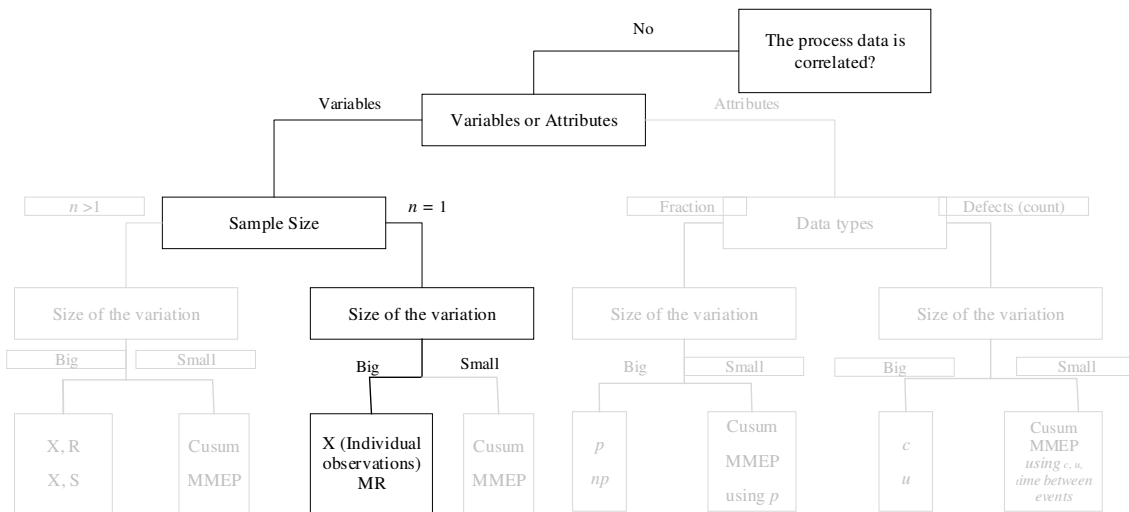
**Figure 1:** Stages of Statistical Quality Control Study for non-self-correlated phenomena



To elaborate this article, it was analysed 80 different data corresponding to the payment of suppliers in 2016. Taking into account the flow in figure 1, the initiatives that will be adopted in the present study are described in the figure 2. The understanding about those stages is owed to the population corresponding to the study data.

Control charts can be classified into two types: Control Chart for Variables and Control Chart for Attributes. According to Henning, the control chart for variables is based on the size of quality attributes on a continuous scale, whereas the attribute control chart depicts the quality properties that identify the conforming and nonconforming elements<sup>25</sup>.

**Figure 2:** The course adopted in this article for the evaluation of the control charts in the evaluation of the payment time of the suppliers in a public hospital



According to Figure 2, the I-MR Chart was chosen and is used to monitor the mean and the variation of its process when there are continuous data which are individual observations and not in subgroups. This control chart is intended to monitor the stability of the process over time so that it is possible to identify and correct the instabilities in it. It is important to clarify that this control card works in accordance to a Normal Distribution<sup>26</sup>.

In order to verify the data compliance in relation to the aforementioned distribution, the data was entered into FlexSim<sup>®</sup> software in its ExpertFit<sup>®</sup> extension. The information obtained from this

computational tool, which evaluates the adherence of the data in relation to a given probability distribution from the Kolmogorov-Smirnov and Chi-Square tests, are presented in the following table:

**Table 1:** Software FlexSim Report

Data Report - Probability Distribution Fitting			
Model	Score	Parameters	
1 - Beta	92.50	Lower endpoint	0.03440
		Upper endpoint	6.677.419
		Shape 1	234.320
		Shape 2	1.004.683
2 - Weibull (E)	90.00	Location	0.54099
		Scale	1.359.418
		Shape	174.520
3 - Gamma	85.00	Location	0.00000
		Scale	444.552
		Shape	284.689
21 models are defined with scores between 0.00 and 92.50			
Absolute Evaluation of Model 1 - Beta			
Evaluation: Good			
Suggestion: Additional evaluations using Comparisons Tab might be informative.			
See Help for more information.			
Additional Information about Model 1 - Beta			
"Error" in the model mean			
relative to the sample mean			-2.8160e-4 = 0.00%

According to the table 1 – which corresponds to the analysis of the probability distribution fitting of the data catalogued *in loco* – the probability distribution that fits the data is the Beta Distribution, followed by the Weibull Distribution. Such situation compromises the results of the I-MR Chart Control Limits, requiring additional observations for an adequate understanding of the data being discussed.

The relevant literature discusses the existence of specific control charts for the distribution of the data currently under discussion. The Beta control chart developed by Brazilian researchers is suitable for monitoring variables measured in fractions (percentage or proportion), which usually follow non-normal and asymmetric distributions<sup>27</sup>. The equations below represent the Beta Distribution, and the Upper and Lower Tolerance Limits and estimators based on simulations.

$$F(y) = P(Y \leq y) = \int_0^y f(y; \theta_1; \theta_2) dy \tag{1}$$

$$LIC = \bar{p} - w_1 \sqrt{s^2(\bar{p})} \tag{2}$$

$$LSC = \bar{p} + w_2 \sqrt{s^2(\bar{p})} \tag{3}$$

$$w_2 = \frac{\psi([1-\frac{\alpha}{2}]; \theta_1; \theta_2) - \bar{p}}{\sqrt{s^2(\bar{p})}} \tag{4}$$

$$w_1 = \frac{\bar{p} - \psi(\frac{\alpha}{2}; \theta_1; \theta_2)}{\sqrt{s^2(\bar{p})}} \tag{5}$$

Sant’Anna<sup>27</sup> also argue that the data such as the presently studied should not be evaluated in accordance with the guidelines of the Beta Chart, since they are not represented in the form of fractions or proportions. Therefore, it is pertinent to evaluate the suitability of the Weibull Chart as to present the points concerning the data discussed in the current study.

In that Chart, there is the possibility of working with data that are not explicit in the form of fractions or proportions, which reinforces their real possibility of being considered in the present study<sup>28</sup>. Furthermore, according to Table 1 this distribution has a satisfactory adjustment to the data. The following equations define the control limits in accordance with the Weibull Chart:

$$LIC = \tag{6}$$

$$LSC = \eta \left[ \ln \left( \frac{2}{\alpha} \right) \right]^{1/\beta} \quad (7)$$

$$f(t) = \beta \eta^{-\beta} t^{\beta-1} \exp \left[ -\frac{t}{\eta} \right]^{\beta} \quad t \geq 0 \quad (8)$$

Considering the use of the Beta Chart for data evaluation, it is essential to use the equations explained above as to define the upper and lower control parameters. Following the determination of these limits, it is necessary to evaluate the process capability focusing on its acceptable variability as a procedure to understand the statistical control of the process. The condition of non-normality of the data impels the search for strategies that allow the understanding of the acceptance of inherent variabilities to the processes.

The process capability analysis for non-normal distribution data has been considerably explored in recent years. For distributions other than the normal, it is determined a natural tolerance, which is the range in which practically all possible process realization must be contained, it is defined by [Goswami and Dutta](#)<sup>29</sup> as:

$$Tn = x_{0,99865} - x_{0,00135} \quad (9)$$

Where:

$x_{0,00135}$ : Value in view of the condition:  $P(x < x_{0,00135}) = 0.00135$

$x_{0,99865}$ : Value in view of the condition:  $P(x < x_{0,99865}) = 0.99865$  (ou seja,  $P(x \geq x_{0,99865}) = 0.00135$ ).

Virtually all possible process implementations must be contained within the range determined by a natural tolerance. The values correspond to the percentiles 0.00135 and 0.99865 which are the values for  $3\sigma$  in any direction from a normal distribution mean. As to guarantee an asymmetric distribution it is added  $x_{0,5}$ , which mean the median  $p(x < x_{0,5}) = 0,5$  where  $x_{0,5} = \bar{x}$  (mean value)

In order to determine the capability, index it is necessary to determine the values  $X_{0,00135}$ ,  $X_{0,5}$ ,  $X_{0,99865}$ . The first form is an exact method requiring knowledge of a probability density function  $f(x)$  determining a distribution of the analysed parameter<sup>30</sup>.

$$\int_{-\infty}^{x_{0,00135}} f(x) dx = 0,00135 \quad (10)$$

$$\int_{-\infty}^{x_{0,5}} f(x) dx = 0,5 \quad (11)$$

$$\int_{-\infty}^{x_{0,99865}} f(x) dx = 0,99865 \quad (12)$$

Clements' Method is one of the most popular methods to calculating estimators of the two basic process capability indices  $C_p$  e  $C_{pk}$  for any type of data distribution, using Pearson's family of curve. Clements' method first requires the calculation of the mean ( $\bar{x}$ ), the sample standard deviation ( $s$ ), the skewness ( $Sk$ ) and the kurtosis ( $Ku$ )<sup>31</sup>.

Clements argued that  $6\sigma C_p$  equation were replaced by the confidence interval between the 0,135 percentage points on the upper and lower distribution part, which means that the denominator in the equation is replaced by  $Up - Lp$ :

$$C'p = \frac{LSC - LIC}{Up - Lp} \quad (13)$$

Where  $Up$  is the upper percentile 0,99865 e  $Lp$  é the lower percentile 0,135. From the respective observations it is reached

$$C'p = \frac{LSC - LIC}{x_{0,99865} - x_{0,135}} \quad (14)$$

Wherein,

$LSC$ : Specification upper limit;

$LIC$ : Specification lower limit;

$x_{\alpha}$ : percentile in the position  $\alpha$ -ésima in the process (5).

The index  $C'p$  evaluates only the dispersion of the process not considering the position in relation to the specification limits which may present an erroneous interpretation about the process



capability<sup>32</sup>. Taking into account the process position, it is possible to obtain Clements  $C'pk$  index, which is understood as the minimum of two indices,  $C'ps$  e  $C'pl$ , defined by the following equations<sup>33</sup>:

$$C'ps = \frac{LSC - M}{x_{0,99865} - M} \tag{15}$$

$$C'pl = \frac{M - LIE}{M - x_{0,135}} \tag{16}$$

$$C'pk = \min\{C'ps, C'pl\} \tag{17}$$

Where in:

$M$ : Process median;

$LSC$ : Specification upper limit;

$LIC$ : Specification lower limit;

$C'ps$ : Unilateral upper specification;

$C'pl$ : Unilateral lower specification.

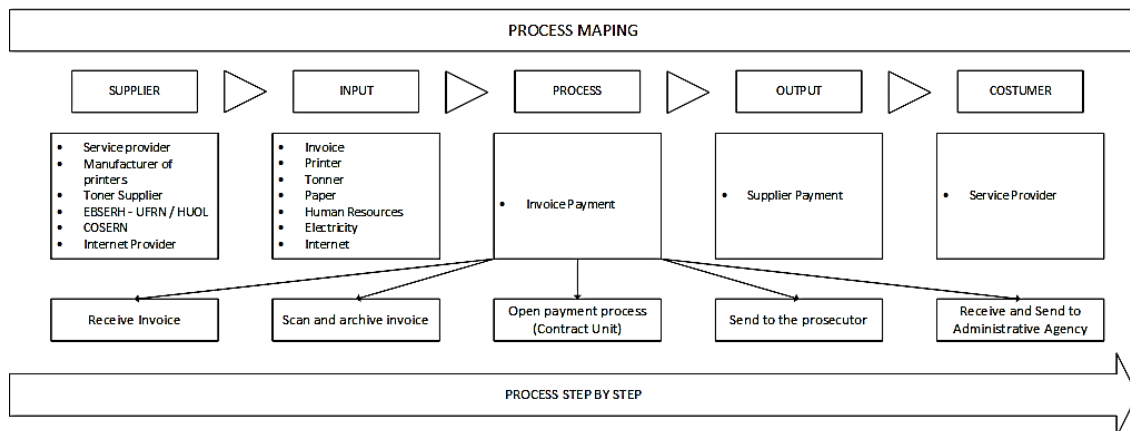
In order to measure each half of the distribution, lower and upper, the median is utilized as a measure of central tendency<sup>34,35</sup>.

## Results

The Onofre Lopes University Hospital was characterised as an additional unity at the *Rio Grande do Norte Federal University* till the year 2013. That situation has changed, however, as the HUOL has become a part of the Brazilian Hospital Services Company (EBSERH), which was created by the Law 12.550 and has been responsible for HUOL management since inception.

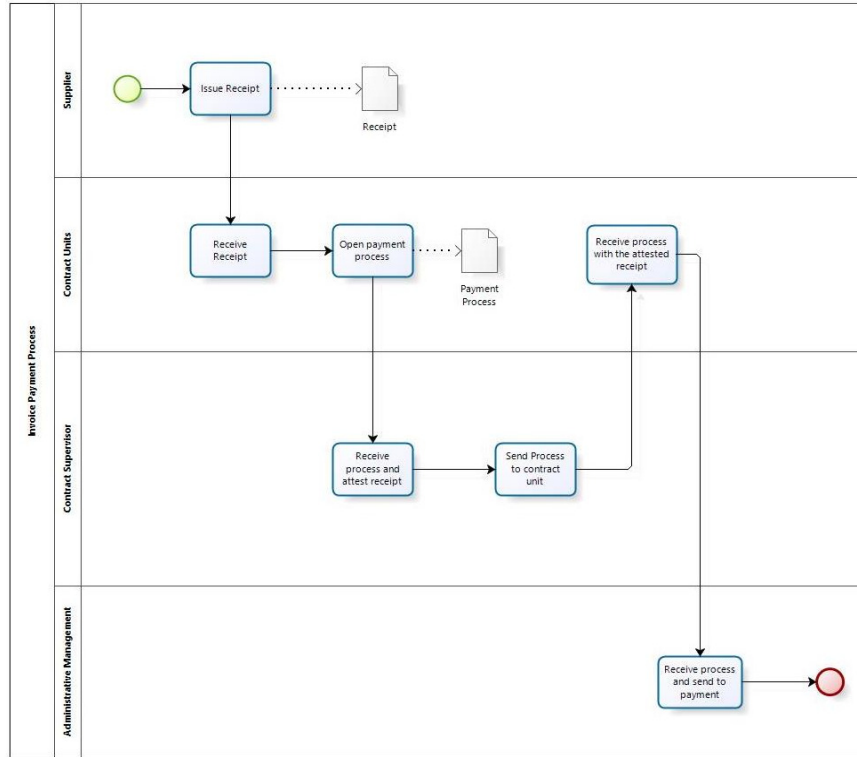
The HUOL attends to the inhabitants of the municipality of Natal who are users of the Unified Health System – SUS, as well as the other municipalities in the state of Rio Grande do Norte. HUOL is a teaching hospital, as a result of that; its users are attended by Residents always under the supervision of a professor or supervisor responsible for the area.

**Figure 3:** Supplier payment process flowchart in details



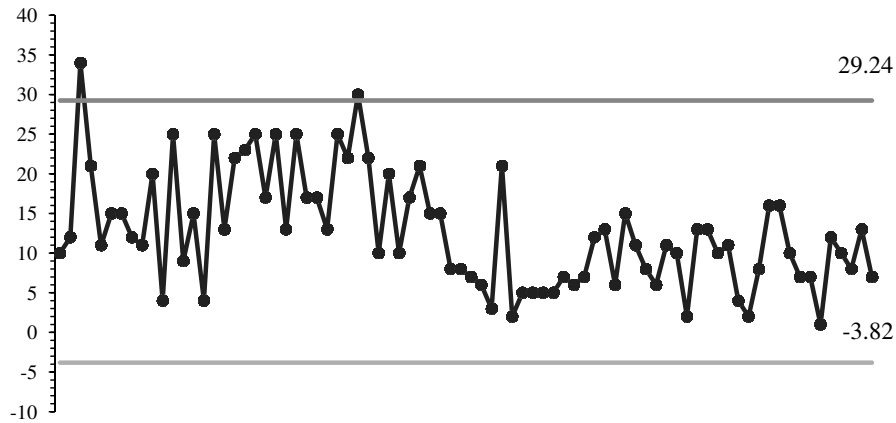
The strategic management of the procurement sector is instrumental to maintain the routine activities at the hospital through recurrent observation of suppliers’ payment periods and deadlines. Thus, after the experimental observations detailed in the methodology section – which were triggered by the necessity to assess the efficiency of the procurement process within HUOL – the principles of Statistical Quality Control were applied into 80 samples from the procurement sector data cataloguing.

**Figure 4:** Supplier payment process flowchart

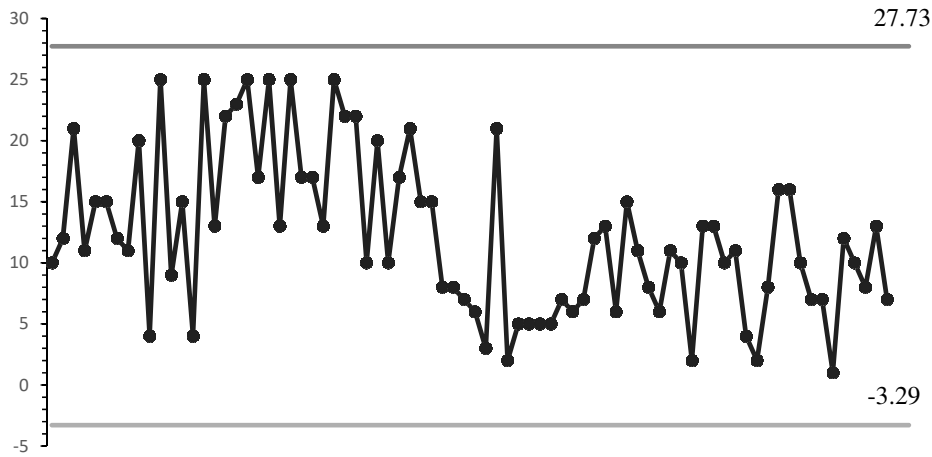


In the present case study, the control chart I-MR (*Individual Moving Range*) and the Weirbull Chart were chosen, as previously stated. The following figures refer to the control charts and their respective rages before and after the removal of points that were positioned above and below the upper and lower control limit.

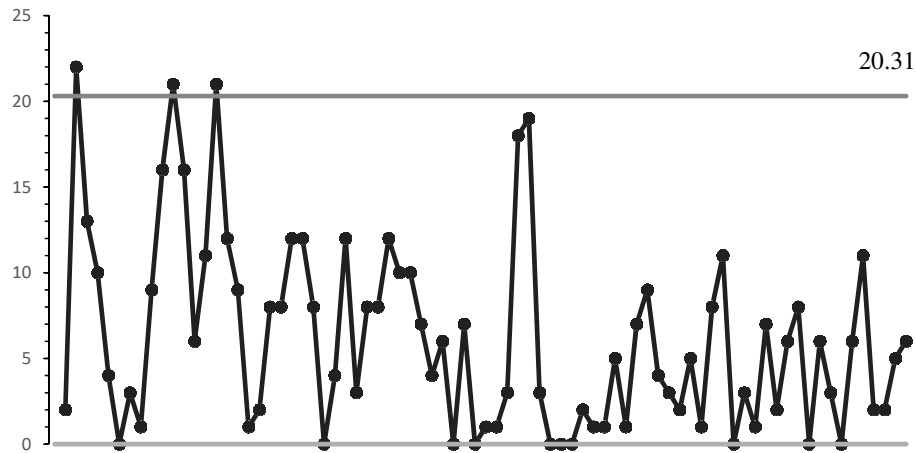
**Figure 5:** Individual Control Chart



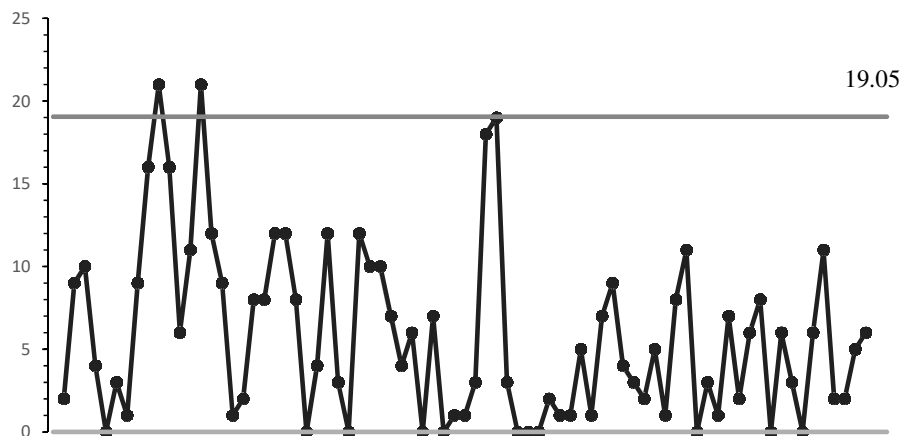
**Figure 6:** Individual Control chart after the removal of points outside the control limit

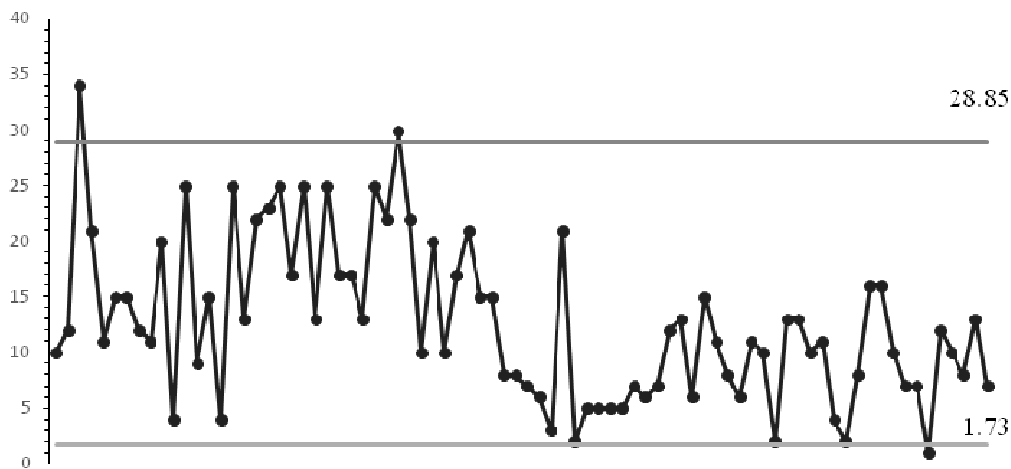
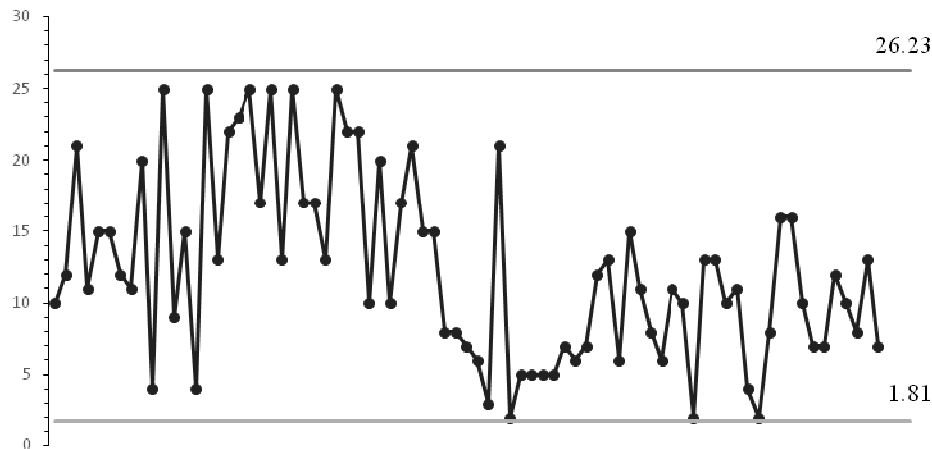


**Figure 7:** Control Chart MR (Moving Range)



**Figure 8:** Control Chart MR (Moving Range)



**Figure 9:** Weibull Control Chart**Figure 10:** Weibull Control Chart after removal of points outside the control limits

Figures 3 and 7 explain points outside the control limits that need to be removed to guarantee process control. In general terms, the reason for those points to be outside the limits derives from the fact that the company providing the service delivered the invoice but failed to deliver the service order on a timely manner. Without the service order, it is not possible to comply with payment policies effectively. The non-normal condition of the data requires a capability study to address this condition. According to HUOL internal corporate procedures, the payment timeframe for the invoices received by the purchasing sector is between 1 to 15 days. From these parameters it is possible to evaluate the capability of the invoice payment process. The equations corresponding to the calculation for non-normal capability procedures are explained below; the control limits considered were expressed by the Weibull control chart, since this distribution is the one most fitting to the data considered in this study and, therefore, the evaluation of its parameters of capability can clearly demonstrate if the process is under control.

$$C'p = \frac{15-1}{25-5,26} \quad (18)$$

$$C'p = 0,709 \quad (19)$$

$$C'ps = \frac{15-11}{25-11} \quad (20)$$

$$C'ps = 0,29 \quad (21)$$

$$C'pl = \frac{11-1}{11-5,26} \quad (22)$$

$$C'pl = 1,74 \quad (23)$$

## Discussions

The individual control chart works with the mean of the process; hence, a considerable shift in the process mean can cause the graph to have out of control data points or generate a pattern of points parallel to the centre line. The chart of moving range assists in the analysis of the individual control graph, because when there is a considerable displacement in the average of the process, the graph of moving range generates peaks of these displacements. Thus, out-of-control points in the moving range plot do not necessarily indicate uncontrolled process<sup>24</sup>.

The Weibull chart has intrinsically the same function as the individual control charts, thus it works with the process mean throughout time; however, it focuses the data that bears Weirbull distribution.

The process capability is a performance measure that states that operations must run according to a specification range, which is the ability of a process to produce a result within predefined limits, which is calculated as the ratio of the specification range to the process operating range. There are different several different ways to analyse process capability, one of them is through the Cpk index. The Cpk uses the process mean and standard deviation and it is based on unilateral capability indices<sup>35</sup>.

The Cpk found was 0.29, which means that the process presents a significant variability, demanding the delineation of control alternatives. According to the variables presented in the equations 18-23 it is evident that the payment process of invoices within the procurement sector at the HUOL is out of control in relation to the upper and lower control limits established by their internal operations resolutions.

That raises the question of what could be done in order to guarantee compliance of the processes. Several initiatives were raised such as (1) identification of bottlenecks inherent to the formalities in the payment process; (2) evaluation of the time a given invoice remains with the purchasing coordinator; (3) definition of a timeframe necessary to comply with the process verification before validating the invoice and send it to the contract unity; (4) determination of specific time requirements for each stage of the process as to optimize the flow; (5) establishment of key performance indicators in order to attain an in depth understanding of the internal procedures. Such initiatives may support the decision-making process both on a strategic and operational level.

## Conclusion

As for future research, it is suggested that the HUOL should develop a study to monitor and control in real time the outstanding invoices as to avoid possible penalizations and operational bottlenecks. Furthermore, it is desirable to empower the management team responsible for monitoring the payment process of the invoices within the procurement sector in order to ensure that a systematic process control is established as to meet the corporate internal procedures by utilizing tools such as the Ishikawa diagram (Cause-and-Effect Diagram), Pareto Chart, Check Sheet, Histogram, Control charts and flow charts.

## Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) -Finance Code 001.

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