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MODELING AND MEASURING OF COMPETITIVENESS IN INDUSTRIAL MAINTENANCE IN HOSPITALS: STUDY OF MULTIPLE CASES WITH MULTICRITERIAL ANALYSIS

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Abstract. *The objective of the article is to determine the global competitiveness rate of the maintenance sector of philanthropic hospitals in the state of Rio Grande do Sul – Brazil. The global competitiveness rates (GRC) were estimated from hospital maintenance indicators through a survey, with the aim of identifying the level of competitiveness between the hospitals and stipulate baseline indicators or competitiveness reference. The methodological procedures used were the Likert scale in order of importance, survey, data collect via Software Sphink and utilization of decision-making techniques (AMCD). A total of 15 philanthropic hospitals were sampled across Rio Grande do Sul. The results received were tabulated according to sample data of statistical reliability. After that, the multicriterial analysis method Analytic Hierarchy Process (AHP) was applied to rank the Key Performance Indicator (KPI), Critical Success Factors (CSF) and Fundamental Points of View (FPV). From the application of the methodology, the substitution rates values of each indicator were found and then the building of the global competitiveness rates. The GRC revealed a baseline indicator for the evaluation of adherence levels of hospitals to this indicator, serving as a tool for decision-making at the hospital maintenance sector and as a measure of improvement actions by performance measuring.*

Keywords: *global competitiveness rates, hospitals, industrial maintenance.*

1. INTRODUCTION

The financial crisis in the philanthropics hospitals of Rio Grande do Sul has spread. Several institutions have already closed and/or reduced the number of employees and attendances. Increasingly, the hospitals need high quality and reliability equipments that work with low costs, in order that a competitive pricing policy can be practiced, which is a determinant factor to companies financial health. In that way, it was decided to filter the philanthropic hospitals from cities with more than 100 thousand voters, that accepted to join the study, available for contact and sending the survey. This sampling correspond to 15 large hospitals.

In that context, companies from different areas use different maintenance systems according to their training and expertise in the subject, always trying to improve theirs results. However, not always the procedures adopted are the most effective for each situation. Kumar *et al*., (2013) reinforce that the maintenance use the equipment availability as guiding element.

Facing this situation, the managers of these units work daily aiming to improve the operational efficiency. Due to this need and to the large volume of equipment present in hospital centers, we realize that the qualification of the maintenance processes can significantly contribute to the improvement of the public health as a whole, reducing the expenses practiced through the adoption of good practices. In addition to the financial issue, maintenance improvements can add availability improvements to these equipments, which can be vital points to patient care, taking into consideration that failures or delays of diverse systems within these environments can cost people lives.

In this way, the concepts of the FPV (types of maintenance) were analyzed, exploring the modeling and the measurement of the indicators most used by the hospitals being studied. A survey was carried out to measure the KPI (Key Performance Indicator) and, afterwards, the data obtained was tabulated, analyzed and compared. A modeling was performed through multicriteria analyzes and to present a ranking of FPV, CSF and KPI. The expected result from the application of the KPI structure will not only result in the diagnosis of the type of maintenance most used in each hospital and the most important criteria for this use, but will also improve the coordination of maintenance management according to the global ranking found as reference for this research.

2. THEORETICAL FOUNDATION

Maintenance is a set of actions that have to be performed to keep equipment running and to ensure acceptable production conditions (Chaïb et al., 2014). For Cen (2010), maintenance is defined by the combination of all technical, administrative and management actions during the life cycle of an equipment, it is extremely important to maintain it so that it can perform the required function. Maintenance can represent a significant portion of the cost of organizations, so, the formulation of a maintenance strategy depends on several factors, such as: cost, time, reliability and asset redundancy (Stenström, 2016).

2.1 Maintenance types

The maintenance processes are carried out in different ways, according to the understanding of the subject by the responsible managers. Each one should define which model better suits its situation. In general, the alternatives are splitted into three main groups: corrective maintenance, preventive maintenance and predictive maintenance. For Chen (2016), the corrective maintenance happens after faults occur. In this type of maintenance, actions such as repairing and replacement are carried out. Preventive maintenance is the realization of a set of preventive services pre-established through programming, for example: lubrication, inspection and routine, and can be defined by a calendar unit (Short and Cotrim, 2016). The services always occur before the failure, in order to prevent situations of process stoppage. Predictive maintenance, according to Lima (2015), arises with the concept of presenting the actual operating conditions of the equipment based on data that inform the level of wear or the size of the degradation process. Slack, Chambers and Johnston (2008) explain that predictive maintenance aims to perform maintenance only when facilities actually need it.

2.2 Hospital maintenance

The management of maintenance systems is still a fairly new event in health facilities. Information regarding acquisition date of the equipment is difficult to obtain, especially in public hospitals, where there is a constant change of administrators (Calil *et al*., 1998). During the literary review of this work, we realizaed that this subject is little explored and that the cited references are very recent. The maintenance subject is more approached referring to different types of industries, however, with hospitals, there is a literary lag.

2.3 Maintenance management

For the hospitals management, it is necessary to be able of quantifying, consistently and almost in real time, everything that is done, produced, received and spent: purchase, storage and distribution of inputs, rendered services, demands, billing etc. Without this information, it is no longer possible to manage daily life and plan the future and, once the information is available and well-used, it is stated that most of the possible problems can be solved and avoided (Schout and Novaes, 2007).

2.3.1 Fundamental Points of View (FPV)

The FPV explain the values that the decision maker considers important in its context, defining at the same time the characteristics of the actions that interest the decision maker (Giffhorn, 2007). In the FPV analysis, it is possible to identify the main concerns of the decision maker regarding industrial maintenance in hospitals.

2.3.2 Critical Success Factors (CSF)

Stollenwerk (2001) conceptualizes CSF as variables whose management could significantly affect the competitive position of a company within its field of activity. In this context, the CSF are used, according to Gomes and Braga (2001), to evaluate the attractiveness of the industry and the strength of the business. In other words, they are the key factors that must be presented by the organization so that it can carry out its activities and achieve its objectives (Oliveira and De Sa, 2015). For Leidecker and Bruno (1984), when CSF are properly identified and managed, they

promote better performance and competitiveness of an organization within a specific business segment. In this way, the factors considered critical for the implementation of the survey were identified in the literature.

2.3.2.1 Mainentence Critical Success Factors

In order to evaluate and measure the organization performance we have the CSF are used that influence the operational process performance. They are considerated primordial in organizations, as they affect the competitors differentiation, generating competitive advantage (Pavlov and Bourne, 2011). From these diferents opinions among the authors, during the literature review, the most influent qualitative criteria in maintenance process was defined. Through the authors points of view: Paz (2010), Poór *et al*., (2013), Reis (2015), Marcorin and Lima (2003), Kim (2013), Souza (2012), Kardec, Flores and Seixas (2002) was defined that disponibility, reliability, cost, risk, quality and production efficiency are the most important CSF in the decision-making of the FPV (corrective, preventive and predictive maintenance).

2.3.3 KPI (Key Performance Indicator)

Ehliar and Wagner (2016), the KPI are used in an infinity of fields to measure the change. As such, it is important to define what are key performance indicators before their use (Øien et al., 2011). To this author, a performance indicator is a measurable representantion from a reality aspect. To Reiman and Pietikäinen (2012), an indicator could be any measure, being quantitative or qualitative.

2.4 Multi-criteria approach to decision support

The decision process is associated to the need to attend conflicting objectives in choosing by option considered as the best in a list of viable alternatives, being generally a complex activity due to the incertain about the aspects envolved (Saaty and Vargas, 2012). Gomes and Gomes (2012) state that the success of a system of decision-making support depends, mainly, on the way how the structure of criteria is assembled, having in mind several points of view that "represent the diferents axes along which the various actors of decision-making proccess justify, transform and question their preferences". These criteria should be accepted by the stakeholders along the decision-making process.

2.5 Analytic Hierarchy Process (AHP)

As the main characteristics of AHP method are complexity structuring, because the relevant factors for the process of making-decision are identified and organized in a hierarchical structure (Russo and Camanho, 2015); measured by a rational scale, obtained by comparison of factors in pairs, attributing a importance for each factor, relative to their pairs, in various levels; synthesis, that is the final result with the classification of alternatives, based in importance of factors and preferences of the involved. There are two ways to develop a judgment in a group in this method (Forman and Peniwati, 1998). To accomplish the AHP method it is necessary use the Saaty scale to assign value to the alternatives. Table 1 shows this definition:

Table 1 – Saaty Scale

Value	**Definition**
1	Equal importance
3	Little more important
5	Much more important
7	Very much more important
9	Extremely more important
2, 4, 6, 8	Intermediate values

Source: Saaty (1980).

3. METHODOLOGY

Figure 1 shows the structuring of the problem and the construction of the modeling. For this, it was performed the unfolding of FPV that encompasses the CSF. The construction of the indicators and evaluation scales was carried out following the KPI methodology, since it allows the construction of metrics capable of returning to the users the real situations of each critical success factor that makes up the modeling. The last stage of this phase was the construction of the elements of evaluation. Therefore, a survey was elaborated to collect data that fed the modeling. It was defined as FPV: corrective, preventive and predictive maintenance. As main criteria (CSF), we identified: availability, risk,

quality, reliability and cost. Decision-makers are maintenance managers of the three hospitals chosen for research. The Multicriteria AHP Methodology was chosen as an intervention tool.

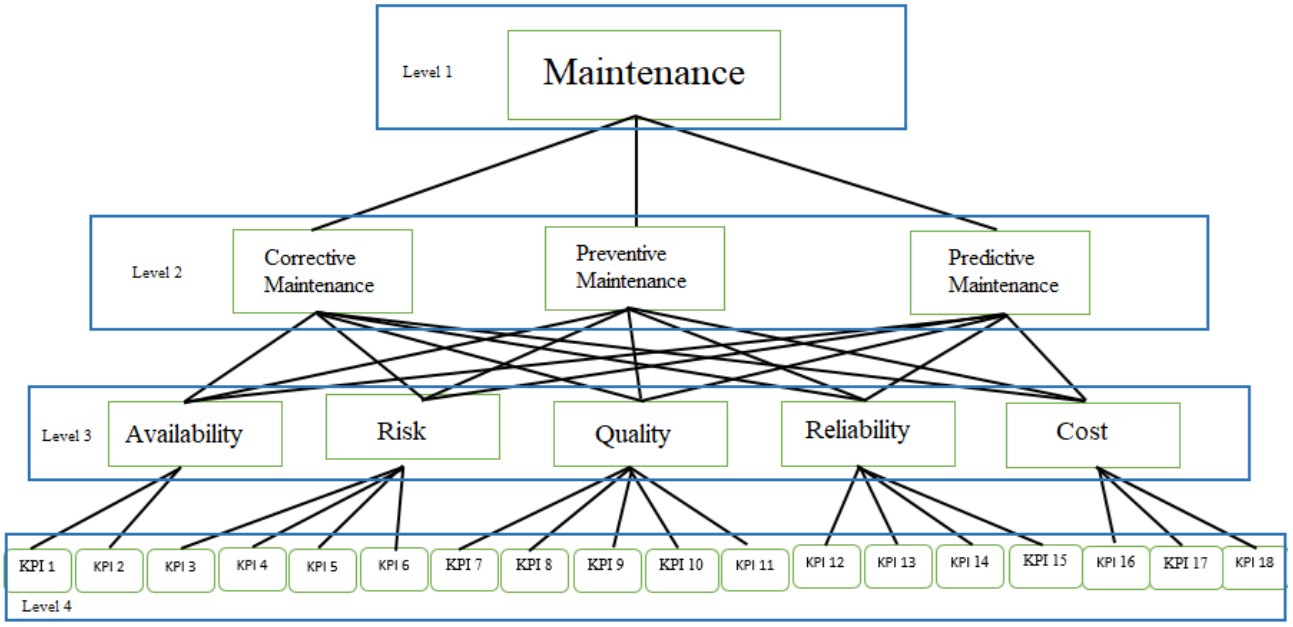


Figure 1: Representation of the decision tree. Source: The authors (2017).

Table 2 shows elaborate questions for the survey, along with the equations for each critical success factor;

Table 2 - Structuring for the application of the survey

FPV			CSF/ FPV	CSF		KPI/ CSF	KPI		Average	TX Sub KPI	TX Sub CSF	TX Sub FPV (AHP)
0,33	FPV 1	Corrective Maintenance	0,2	CSF 1	Availabilit.	0,5	KPI 1	Time between repair	2,09	1,045	0,454	0,178
						0,5	KPI 2	Time between failures	2,45	1,225		
			0,2	CSF 2	Risk	0,25	KPI 3	Knowledge of which risks	3,27	0,818	0,627	
						0,25	KPI 4	Probability of accidents	2,91	0,728		
						0,25	KPI 5	Elimination of risks	3,27	0,818		
						0,25	KPI 6	Total Maintenance	3,09	0,773		
0,33	FPV 2	Preventive Maintenance	0,2	CSF 3	Qualit.	0,2	KPI 7	How many maintenance	3	0,600	0,458	0,751
						0,2	KPI 8	Maintenance planning	2,36	0,472		
						0,2	KPI 9	Exchange your Equipment	2,18	0,436		
						0,2	KPI 10	Time that each equipment fails	1,73	0,346		
						0,2	KPI 11	Hospital Ombudsman	2,18	0,436		
0,33	FPV 3	Predictive Maintenance	0,2	CSF 4	Conf.	0,25	KPI 12	Lifetime of each equipment	2,64	0,660	0,632	
						0,25	KPI 13	Risk rate of each equipment	3,09	0,773		
						0,25	KPI 14	Installation as Manual	3,64	0,910		
						0,25	KPI 15	Knowledge of your costs	3,27	0,818		
			0,2	CSF 5	Cost	0,33	KPI 16	Cost-spent on materials	3,18	1,049	0,599	0,070
						0,33	KPI 17	Cost-spent on labor	3,09	1,020		
						0,33	KPI 18	Annual investment Cost	2,82	0,931		

Source: The authors (2017).

Legend Table 2:
D = Availability;
Mtbf = Average time between failures;
Mttr = Average Time for repair.
R = Risk
R(t) = Reliability;
T(f) = Time for a system fails;
t = Service time.
Cman = Total maintenance costs; Cmat = Material costs; CMO = Labor costs; CFer = Tooling costs and goods usage (depreciation, fees and taxes); Cinv = Investment or fault costs.

In order to determine the global replacement rate, a calculation sequence was required, from the average of the answers obtained, the calculation of the replacement rates of KPI, CSF and FPV in order to quantify the objective answers of the managers in the questionnaire above mentioned.

4. RESULTS

Assembling a small history of the existing hospitals and types of hospitals and what region of Brazil. From this contact, the e-mails were asked for sending the questionnaire. The questionnaire was sent to the 15 hospitals, of which 11 answered, representing 73% of confirmations. The period of sending and answers of the research was stipulated from March to April of 2017, period in which 11 questionnaires were answered, quantity that meets the recommended confidence of the article (95%).

In view of the results, it is observed that each hospital treats the maintenance factors in a different way. It may be noted that some notes are more important to one organization than to another, as pointed out in their answers.

The Table 3 classify the questions (KPI) as the medium importance grade obtened in the hospital answers.

Table 3 - Importance of each KPI for hospitals

KPI		CSF	Average responses	Degree of importance for hospitals
K14	Equipment installed according to the manual	Reliability	3,636	91%
K03	Knowledge of which risks	Risk	3,273	82%
K05	Control for the elimination of the present risks	Risk	3,273	82%
K15	Knowledge of your costs	Reliability	3,273	82%
K16	Monthly costs spent on materials	Cost	3,182	80%
K06	Control of the total maintenance performed	Risk	3,091	77%
K13	Risk rate of each equipment	Reliability	3,091	77%
K17	Monthly cost spent with Labor	Cost	3,091	77%
K07	Control of how many monthly maintenance	Quality	3,000	75%
K04	Probability of accidents	Risk	2,909	73%
K18	Annual investment Cost	Cost	2,818	70%
K12	Lifetime of each equipment	Reliability	2,636	66%
K02	Average time between failures	Availability	2,455	61%
K08	There is special planning for maintenance	Quality	2,364	59%
K09	Exchange your Equipment	Quality	2,182	55%
K11	Hospital Ombudsman	Quality	2,182	55%
K01	Average Time between repair	Availability	2,091	52%
K10	Time that each equipment tends to fail	Quality	1,727	43%

Source: The authors (2017).

To build the modeling, is necessary to use mechanisms that allow to evaluate each criterion quantitatively. It is therefore necessary the definition of substitution rates between the model elements, in order to show the important differences between each one of them (ALMEIDA, 2013). To be possible calculate the substitution rates, was necessary assign different importances to the KPI, CSF and FPV. Initially, was attributed percentages to each CSF in relation to the respective KPI, considering 100% the CSF. Therefore, the 5 Success Critical Factors are attribute as follow:

a) the CSF 1 (availability): there are the KPI 1 and KPI 2 related to this factor that correspond each one to 50% of the availability;

b) the CSF 2 (risk): there are KPI 3, KPI 4, KPI 5 and KPI6 representing, each one, 25% risk;

c) the CSF 3 (quality) has the KIP 7, KPI 8, KPI 9, KPI 10 and KPI 11, that represent, each one, 20% of the quality;

d) the CSF 4 (Reliability) has the KPI 12, KPI 13, KPI 14 and KPI 15, each one representing 25% of realiability;

e) the CSF 5 (cost) has the KPI 16, KPI 17, KPI 18, each having a value of 33,33% of representativeness.

In this way, TSFPV means the ratio of KPI of a CSF comparing to representativeness of FPV as a whole. In the same way, the others substitution rates of PFV were calculated using the same logic, and his representativeness in percentage can be observed in Table 2.

These rates allow checking what the real representativeness of each FPV, KPI or CSF to hospitals interviewed.

In diagnostically analyses by fundamental point of view (FPV), corresponding to the first level of evaluation, to establish the ranking was necessary use the AHP. To analysis, AHP was used as base the Saaty's Scale.
As a base in the Saaty's Scale, was elaborated a relationship matrix, establishing odd numbers for the PFV, as see in Table 4.

Table 4 - Scale established for the FPV

Maintenance	Value	Definition
Corrective	3	Little more important
Preventive	5	Much more important
Predictive	9	Extremely more important

Source: The authors (2017).

After stablished the scale, according the maintenance importance, was applied the AHP method to know which maintenance (corrective, preventive or predictive) is more used in the studied hospitals, according to Table 5:

Table 5 - Ranking of fundamental viewpoints (FPV) with the AHP method

	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance	Auto Vector	Relative priority
Corrective Maintenance	**1**	1/5	3	0,8434	0,1781
Preventative Maintenance	5	**1**	9	3,5568	0,7514
Predictive Maintenance	1/3	1/9	**1**	0,3333	0,0704
Sum	**6,333333**	**1,31111**	**13**	**4,73365**	**100%**

Source: The authors (2017).

The distribution by importance revels that the FPV 2- preventive maintenance – gets first place in the evaluation of the interviewed, represented by an indicator of 0,7514 of substitution rates, followed by FPV 1 – corrective maintenance – with an indicator of 0,1781, followed by the FPV 3 – predictive maintenance. In order to be sure of the AHP analyses result was effective, is calculate the Consistence Reason (RC), that measures how much the judgments was consistent comparing to the big samples of completely random opinions. In this case, the results obtained presents consistent values, because the RC results in 0,025 (below 0,1).

The Consistency Ratio (CR) obtained through the Equation 1:

$$Rc = IC/IR \qquad (1)$$

Advancing the data analysis to the second level of competitiveness indicators, it is detailed, therefore, the managers perception about the 5 Critical Success Factors.

Table 6 - Ranking of CSF

FCS		Average responses	Degree of importance
Reliability	FCS4	3,144	78,61%
Risk	FCS2	3,144	78,59%
Cost	FCS5	3,038	75,95%
Quality	FCS3	2,365	59,13%
Availability	FCS 1	2,287	57,18%

Source: The authors (2017).

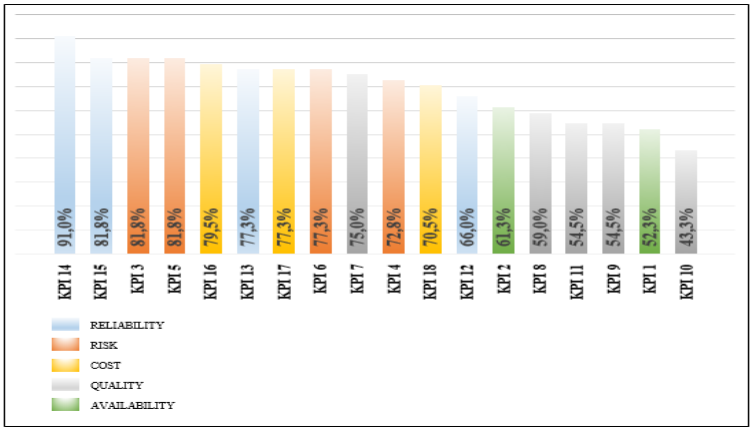
Therefore, the 18 KPI were used, which are demonstrated according to the importance degree to the 11 interviewed hospitals. On Table 7 the KPI are all represented, by importance order, according to the evaluation made by the maintenance managers of the hospitals. The evaluation of the answers allows to evaluate the situation of the hospitals, as well as to verify the points to be improved.

Table 7 - Ranking of KPI

Questions		Answer				Percentage
KPI	Name KPI	Rarely	Occasionally	Often	Very often	Degree of importance
KPI 14	Care in the installation of the equipment	27,30%	36,40%	36,40%	0,00%	91,00%
KPI 15	Knowledge of your costs	9,10%	54,50%	18,20%	18,20%	81,75%
KPI 3	Knowledge of your risks	0,00%	0,00%	72,70%	27,30%	81,75%
KPI 5	Control for the elimination of the present risks	9,10%	27,30%	27,30%	36,40%	81,75%
KPI 16	Monthly cost control spent on materials	9,10%	0,00%	45,50%	45,50%	79,50%
KPI 13	Risk rate of each equipment	9,10%	9,10%	45,50%	36,40%	77,25%
KPI 17	Monthly cost spent with Labor	9,10%	18,20%	36,40%	36,40%	77,25%
KPI 6	Control of the total maintenance performed	27,30%	18,20%	45,50%	9,10%	77,25%
KPI 7	Control of how many maintenance problems	18,20%	54,50%	18,20%	9,10%	75,00%
KPI 4	Probability control of accidents	63,60%	9,10%	18,20%	9,10%	72,75%
KPI 18	Annual Investment cost control	36,40%	18,20%	36,40%	9,10%	70,50%
KPI 12	Control of the lifetime of each equipment	18,20%	18,20%	45,50%	18,20%	66,00%
KPI 2	Middle-time control between failures	0,00%	18,20%	54,50%	27,30%	61,25%
KPI 8	Maintenance Planning Control	0,00%	0,00%	36,40%	63,60%	59,00%
KPI 11	Evaluation of the Hospital Ombudsman	9,10%	9,10%	27,30%	54,50%	54,50%
KPI 9	Control of the exchange of your equipment	9,10%	18,20%	18,20%	54,50%	54,50%
KPI 1	Average-time evaluation between repairs	18,20%	9,10%	18,20%	54,50%	52,25%
KPI 10	Time that each equipment tends to fail	9,10%	36,40%	18,20%	36,40%	43,25%

Source: The authors (2017).

The Graphic 1 shows the distribution of the answers allowing a visual analysis, by importance order. The KPI are being differentiated by colors, according to the group of CSF to which they belong.



Graphic 1 - *Ranking* of KPI. Source: The authors (2017).

According to the analyzed data and by the proposed sampling, the KPI 14 is the most important, whith value of 91%, according to the 11 obtained answers. It refers to the "care with installed equipments as per described on the manual", represented by CSF 4 (reliability). The KPI 15, 3 and 5 have the same competitiveness degree, 81,75%. They are: "knowledge of maintenance costs", "knowledge of the risks of each equipment" and "control to eliminate the existing risks". At this point, the research has necessary data to estipulate the global rate of replacement, establishing a competitiveness indicator to the phylantropic hospitals of Rio Grande do Sul, based on the 11 answers given by the maintenance responsibles.

The Table 8 shows the replacement rate of FPV, CFS and KPI.

Table 8 - Replacement fees

TX Sub KPI	TX Sub FCS	TX Sub PVF (AHP)
1,045	0,454	
1,225		
0,818	0,627	
0,728		
0,818		
0,773		
0,600	0,458	0,178 (Corrective)
0,472		
0,436		0,751 (Preventive)
0,346		
0,436		0,070 (Predictive)
0,660	0,632	
0,773		
0,910		
0,818		
1,049	0,599	
1,020		
0,931		
13,85	**2,77**	-

Source: The authors (2017).

Using the individual rates, we have have the importance given to each question and, from this data, we can establish a Global Competitiveness Rate, to measure the competitiveness. This rate represent the level of competitiveness in certain area, being able to measure the attendance of the indicators. This global rate is the relation betwenn the replacement rates of the fundamental points of view, critical success factors and key performance indicators of an organization, as we can see on the equation:

Calculation of the competitiveness rate of corrective maintenance according to Equation 2

$$TGCFPV1=\Sigma kpin+ \Sigma TSpCSFn+TSpfv1 \quad (2)$$

TGCFPV= 16,79

Calculation of the competitiveness rate of preventive maintenance according to Equation 3:

$$TGCFPV2=\Sigma kpin+ \Sigma TSpCSFn+TSpfv2 \quad (3)$$

TGCCSF= 17,37

Calculation of the competitive rate of predictive maintenance according to Equation 4:

$$TGCFPV3=\Sigma kpin+ \Sigma TSpCSFn+TSpfv3 \quad (4)$$

TGCkpi = 16,69

The global competitiveness rate is the sum of the three maintenances rates (corrective, preventive and predictive), according to Equation 5.

$$TGC=TGCFPV1 + TGCFPV2 + TGCFPV3 \quad (5)$$

The result of the global competitiveness rates of each maintenance (corrective, preventive and predictive) allows to analyze the 11 hospitals individually. The global rates will allow you to analyze what kind of maintenance each hospital works in its maintenance management. The global rates found will serve as a reference to other hospitals, which will be researched in the future.

5. CONCLUSION

The individual analysis of the KPI shows the concern of maintenance managers with the reliability, risks and costs, having good part of its questions on the first positions. Although the reliability of the equipment is important to the hospitals, they showed less importance with the evaluation of the life of each equipment (KPI 12). Another question whose importance given by the hospitals that is not according to the average found on its corresponding CSF (KPI 7) is the one that talks about the control of maintenances that show problems after the service. We can understand that the managers are not concerned with the lack of reliability in maintenance services. There is an overall understanding that these services do not need to be controled with such precision. Something that corroborates to this situation is the fact that maintenance services are usually performed by specialized companies, which give the managers a certain guarantee

According to the analyzed data (KPI 14), the most important, with 91%, is the "care with equipment installed as described in the manual", represented by CSF 4 (reliability). It is an indicator considered easy, not surprising its first place in the ranking of competitiveness. Many organizations install as per manual so as not to lose the warranty of their equipment and for them to operate correctly. The KPI 15, 3 and 5 have the same degree of competitiveness, 81.75%. These are: "knowledge of maintenance costs", "knowledge of the risks present in each equipment" and "control for the elimination of existing present". The KPI 15 aims the knowledge of the costs of the maintenance sector, information relevant to the financial health of the company. The KPI 3 is also part of CSF 4 (reliability) and the hospitals are able to

maintain it in a controlled way due to the equipment manuals that have this information. Only one hospital answered grade lower than 3 (frequently) to KPI 5, also showing its high control within hospital organizations. An organization needs to focus its efforts on eliminating hazards and risks, preventing accidents, being the use of personal protective equipment (PPE) one of the ways of doing it. Fifth is KPI 16, with 79.5%, it represents CSF 5 (cost), targeting in its question the "monthly cost spent on materials". Sixth, seventh and eighth places are of indicators 13 (CSF 4) and 17 (CSF 5) and 6 (CSF 2), with the same competitiveness degree, 77.25%. Consequently, their questions aimed the control of: "risk rate of each equipment", "monthly cost spent on labor" and "total maintenance performed".

To the reliability, cost, and risk CSF were given an importance degree similar by the hospital responses. The CSF 4 (reliability) obtainedr 78.6% of importance, the CSF 5 (cost) reached 78.59% and the CSF 2 (risk), 75.95%. The reliability of equipment (CSF 4) within a hospital is extremely important to the maintenance team as it shows the functionality of their service. However, it is important to the patients, which need to be attended quickly and adequately, not waiting for equipment that is not working.

This CSF covers subjects such as: useful life of each equipment, risk ratr of each equipment and proper installation. Due to the importance given to this CSF by the hospitals, periodic or preventive maintenance should happen in order to have an adequated care. In this way, if each hospital adopts a strategy of realizing periodic maintenance and establishes reasonable maintenance periods, it will consequently achieve operational reliability and bring greater benefits to its customers, who are the most interested. Cost (CSF 5), with 78.59%, almost tied with reliability, ranks second as the most important CSF for the hospitals interviewed. It is extremely important that maintenance managers are aware of their costs in this sector. This subject should be treated in an individualized and controlled manner, allowing a careful evaluation of those expenses that bring greater benefits to the entity. This issue becomes more important in view of the big financial difficulties present in all hospitals. The biggest challenge for people who are involved in maintenance nowadays is not just knowing the techniques but deciding which ones are really important to a particular asset. If you make the right choices, you can improve performance and, at the same thime, reduce maintenance costs, increasing your operational reliability. On the other hand, if there are bad choices, new problems will be created, while those ones already existing tend to get worse. In the 11 responses, it is evident that those in charge of hospital maintenance believe that cost control is essential for the hospital to be competitive, which demonstrates an interest of these establishments in these good practices. With an average of 75.95%, the CSF 2 (risk) was ranked in third place. However, the difference for the two previous CSF can be considered almost negligible, given the statistical variation of the results. In this indicator, it was evaluated the knowledge of the risks, the control and the elimination of them, as well as the accidents probability. Analyzing in detail the answers used to rank this CSF, we can verify that there were four questions, and one of the hospitals answered 1 (minor scale) to three of these questions, thus lowering their average of importance. Thus, we can observe that there is disagreement among different hospitals regarding the importance of this factor to the business success. While some consider it extremely important, others almost despise it. In maintanance, as in any activity, it is important to ensure correct identification of hazards and evaluation of risks to define effective control methodologies and mitigation that provide an adequate level of protection to employee health and, in the case of hospitals, its clients (patients), one of the highest values of any organization. These answers demonstrate that some hospitals do not understand the real dimension of this element in the equipment operation. This low importance given to this item by some institutions may have a direct impact on the health of their patients and employees, especially knowing that these workspaces use equipment whose faults can expose them to risks such as gamma rays in x-ray equipment (extremely carcinogenic) and can also cause errors or distortions in medical examinations, which are decisive factors to take appropriate measures in the treatment of diseases. The CSF 3 (quality) and CSF 1 (availability) were in the last place in the ranking of importance among the interviewed hospitals. The lack of maintenance quality is one of the generators of demand for maintenance services, which consequently decreases availability, increases costs and decreases internal and external customer satisfaction. The quality of the maintenance requires more attention from the hospitals, according to the analyzed answers, being a great opportunity to differentiate from the competition and increase the competitiveness. It is also important to emphasize the importance of the quality, since it can ensure better results in the end service of these hospitals, which is the treatment of their patients. The issue of the less importance given to the theme of availability shows a relative neglect of institutions with the needs of their clients, considering that, especially in hospital services, the question of time to obtain the answers is directly related to the success obtained in the treatments. In this way, it is observed that there is a possible focus of improvement of the current system.

In the analysis of the diagnosis by FPV, corresponding to the first level of evaluation, the distribution by importance reveals that FPV 2 (preventive maintenance) comes first in the interviewees' evaluation, represented by and indicator of 0.7514 of replacement rate, followed by FPV 1 (corrective maintenance), with an indicator of 0.1781, followed by FPV 3 (predictive maintenance), as shown on Table 9. The calculation of the global competitiveness rate of corrective maintenance resulted in 16.79, and preventive maintenance resulted in 17.37 and the global competitiveness rate of the predictive maintenance resulted in 16.69.

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7. RESPONSIBILITY NOTICE

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