Analysis and Enhancement of Medical Equipment Management

The case study of José de Mello Saúde

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Abstract

Over the late 60s, early 70s, regulations have been formulated regarding the medical equipment management by the healthcare facilities. Despite the constant growth in health sector, there are still some questions on which is the best method manage health equipment. Recently, new regulations come up with drastic changes in the ways hospitals manage its equipment, which require more money, time and staff dedicated to medical equipment maintenance. It is in this context that emerges the main problem regarding this study that will be developed at José de Mello Saúde Group. José de Mello Saúde Group, owner of one of the biggest healthcare networks in Portugal (CUF), intended to reformulate its current equipment management, always keeping high level of healthcare service. The group emphasizes the maintenance and replacement of the equipment activities as the main processes to consider. In order to address this problem, a methodology was developed, which entails two steps: (i) analysis and characterization of an equipment sample and (ii) analysis of the maintenance contracts and construction of an equipment replacement method. The work developed proposed a set of actions that should be taken so as to improve the equipment management, based on a proactive management always linked to costs reduction.

Keywords: Medical equipment management, Classification, Maintenance, Replacement.

1. Introduction

In Portugal, the health sector represented, approximately, 5.7% and 10.2% of GDP at the end of 1990 and 2012, respectively, which saw an almost 5,5% increase in health care spending (OECD, 2015). According to APHP (*Associação Portuguesa de Hospitalização Privada*), the private hospitals turnover in Portugal exceeds € 1 500 million, which 80% is compressed between four groups. José de Mello Saúde (JMS) Group is one of them (Agência Lusa, 2014).

With the growth of modern society, the rapid evolution of technology is creating awareness in health public, raising their expectations on the quality and effectiveness of healthcare delivery. So, the hospitals feel obliged to meet the client desires, within the rage of their budget and financial status. The client choice of the hospital is mostly biased by the technological level of the healthcare provider. The privates' healthcare are the ones that handle more with this problem due to high market competition. Based on this factors, JMS Group wants to reframe all of it base equipment management.

This paper will study the management of JMS Group medical equipment. In this sector, the equipment are directly linked to the revenue of the company. Firstly, we will analyze the

Imagiology department, in order to select a sample of equipment to study in detail. Secondly, we will analyze the maintenance contracts of a small group of equipment in order to suggest a better management of the equipment. Additionally, the replacement process of the equipment will be subjected to special analysis.

The paper is organized as follows: in section 2 the most relevant literature is reviewed; section 3 presents the case study, analyzes and characterizes the adopted criteria; in section 4, the results in the previous section will be applied to: (i) the study of the maintenance contracts and (ii) the equipment purchase; finally, in section 5 the main conclusions are drawn.

2. Literature Review

2.1. Maintenance

According to *Maintenance and Spare Parts Management* (Gopalakrishnan & Banerji, 2013), maintenance can be defined as a set of activities required to keep a facility or an equipment, in order to preserve its original productive capacities. The maintenance is a critical and difficult activity, which objective are the upkeep of equipment for prolonging its life, assuring operational readiness and optimal availability for production when it is needed.

On the contrary, a bad maintenance can lead to an increase in the number of faults, bad equipment performance and an increase in the number of substitutions of the equipment, due to the decrease of the operating lifetime (Tambe, P. P., & Kulkarni, M. S., 2013).

Swanson (2001) enumerates three main types of maintenance strategies: corrective maintenance, preventive maintenance and predictive maintenance.

Corrective maintenance is a run to failure strategy, where the equipment are used until a break, and only then the equipment is repaired or replaced. This approach reduce the costs associated to equipment monitoring and prediction of failures. However, Coria et al. (2014) advertises that the occurrence of failures is unpredictable, which can lead to problems in the service provision.

In health industries, this strategy is used on a large number of equipment in a hospital, which are not providing life support to patients, like lamps and cables. So, a failure of these devices does not jeopardize the patient's life. Also, this strategy is used when back-up devices are freely available in the hospital.

Preventive maintenance is a based schedule policy, used to anticipate or predict failures from occurring, at a fixed or adaptive time intervals, regardless of the equipment conditions at the time (Coria, et al., 2014). This type of maintenance is able to prolonging life of the equipment, thereby bringing a better and efficient management of resources and budgets. However, it can also be exhaustive if there is a bad schedule management.

Predictive maintenance is an advanced preventive policy, which monitor the physical condition of the system through several parameters as temperature, vibrations, lubrication and corrosion. Only when one of these indicators reaches a specific threshold value, a repair of the equipment is made. In this type of maintenance, there is no need time intervals between the equipment verification, which save costs (Coria, et al., 2014).

There are also several others different types of maintenances policies, as: maintenance cluster (Gits, 1992); reliability centred maintenance (Herbert, 2008); total predictive maintenance (Weil, 1998), between others.

2.2. Equipment classification

Inventory classification is one of the main solutions to control an inventory with a large number of equipment, which can minimize the risk of the items loss (Mohammaditabar, et al., 2011). Several authors have been studying the process of classification, and some of them actually proposed methods as: ABC analysis, for just one criteria (Mohammaditabar, et al., 2011); bi-criteria (two criteria) and multicriteria analysis (more than two criteria) (Partovi & Anandarajan, 2002).

The traditional ABC analysis was developed by Dickie (1951), based on Pareto principle, also known as the 80–20 rule. According to Chu et al. (2008), the ABC classification separates an inventory into three groups: A items (15%-20% of the items that account for 75-80% of the annual inventory value), C items (40%-50% of the items that account for 10%-15% of the annual inventory value) and, in the middle, the B items (30%-40% of the items that account for, approximately, 15% of the annual inventory value). Torabi et al. (2012) refers that the annual inventory value is the most used criteria. This traditional ABC analysis can incorporate more criteria, according to Flores & Whybark (1987).

2.2.1. Multicriteria Analysis

Over the years, many authors have been developing different multicriteria inventory classifications (MCIC). Torabi et al. (2012) and

Goodwin & Wright (2004) list some examples: artificial neural network (ANN), joint criteria matrix, cluster process, Analytical Hierarchy Process (AHP), Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), additive aggregation model, between others.

The additive aggregation model is one of the most used models in the aggregation of criteria, and can be represented by the following equation (Lourenço, 2002):

$$V(a) = \sum_{j=1}^{n} k_j \times V_j(a)$$
$$with \sum_{j=1}^{n} k_j = 1 \; and \; 0 < k_j < 1, \quad (1)$$

where: $V(a)$ represents the global attractiveness of option $a \in A$; $V_j(a)$ is the partial value of option a in the criteria *j*; k_j is the normalized weighting of criteria *j*.

In order to define the value function $V(a)$ to each criteria, several numerical and non-numerical techniques can be used. Direct Rating and the bisection method are two examples of numerical techniques (Winterfeld & Edwards, 1986), and MACBETH is an example of a non-numerical technique (Bana e Costa et al., 2012).

Direct Rating is a numerical estimative with an anchored scale. The decision maker (DM) is asked about the score that translates the attractiveness of a certain stimulus, in relation to the extremes.

In the bisection method, the most and least preferred stimulus are identified by the DM as the function extremes. After, DM needs to pinpoint an equidistant stimulus between the extremes.

Finally, in order to complete the addictive model, we need to calculate the weighting coefficients. These can be obtain through numerical and non-numerical methods. Lourenço (2002) lists three weighting techniques: Trade off procedure, swing weighting procedure (numerical methods) and MACBETH (non-numerical method).

Trade off procedure was proposed by Keeney et al. (1976). This technique compares two fictitious alternatives at the time, which performance differ only in two fundamental points of view. Consequently, the two alternatives have the same performance in the remaining points of view (PV). The trade off of this procedure consists in adjusting the level of impact of one of the alternatives of the reference PV, in order to obtain a relation of indifference between the two alternatives.

Swing weighting procedure, proposed by Winterfeldt & Edwards (1986), can be divided in three main steps (Goodwin & Wright, 2004): (i) ordering of the weighting coefficients of the PV; (ii) quantification of the values to assign to the weighting coefficients of all the PV; and (iii) normalization of the weighting coefficients such that their sum is equal to 1.

2.3. Management of medical equipment

Between 1960 and 1970, there were increases in the health sector. This leap is attributed to the advances in equipment technology (Whelpton, 1988). Behfard et al. (2015) outline that health equipment are capital goods, very expensive and can be used for a long period (five to thirty years). However, their downtime is critical, in terms of costs, quality of service and safety risks.

Healthcare technology management is an important segment due to its main role in the healthcare transformation (JCAHO). According to the same source, the role of this department implicates the optimization of acquisition and use of the technology, in order to achieve a maximum impact in the healthcare results. Having in sight this scenario, the hospitals need to take into account several criteria as the equipment life cycle, maintenance, use and replacement.

Ouda et al. (2010) list three criteria that the hospitals should consider in the medical equipment replacement: (i) technical criteria, as utilization, downtime, operating life ratio, after sales support; (ii) financial criteria, as service, operating costs, availability of backup; and (iii) safety criteria, as hazards and user/staff errors.

Healthcare units are continually needing to replace old equipment that is no longer cost effective or is becoming obsolete. As most hospitals do not have sufficient budget to approve all equipment replacement requests, it is imperative to develop a methodology to prioritize all medical equipment replacements, thus providing a more efficient management of the budget (Rajasekaran, 2005). This same author introduces a replacement methodology known as Equipment Replacement Planning System (ERPS).

3. Case study

3.1. Inventory Classification

This section presents the inventory classification divided into three analysis: (i) ABC analysis with cost of maintenance contracts as the criteria; (ii)

ABC analysis with equipment age as criteria; and (iii) spare parts analysis. The objective of this section is, through a combination of the three criteria, outline the study sample.

- **ABC analysis with cost of maintenance contracts as the criteria (Analysis 1)**

The first ABC analysis has as criteria the cost of maintenance contracts, which cover maintenance costs, transportation costs and spare parts purchase costs.

The results are presented in Table 1, in which we can see that 34.85% of the equipment account for 80.19% of the maintenance costs.

Table 1: ABC analysis results, with cost of maintenance contracts as criteria

	Contracts value (€)	Cumulative of contracts cost (%)	Nº items	% Cumulative of nº items
Class A	1 212 549 .85	80 .19%	23	34 .85%
Class B	208 890 .00	13 .81%	17	25 .76%
Class C	90 728 .55	6 .00%	26	39 .39%
Inventory	1 512 168 .40	100%	66	100%

In order to better understand how much each equipment affects the value of class A, we calculated the ratio between the sum of the maintenance cost for each group of equipment and the sum of the maintenance cost of all class A (Table 2).

Table 2: Sum of the maintenance cost (MC) for each group of equipment i and the ratio between it and the sum of the maintenance cost of all class A***

i	$\sum MC_i$ (€) *	$\frac{\sum MC_i}{\sum MC_A}$ (%)**
Angiography	43 860	3.62%
Nuclear Medicine	137 360.78	11.33%
MRI scan	467 995.74	38.6%
Computed tomography	563 333.33	46.46%
Total	1 212 549.85	100%

According to Table 2, the computed tomography group comprehends 46.46% of the total maintenance cost of the class A, followed by MRI scan with 38.6% of the costs. Hence, we concluded that computed tomography is the most critical group of equipment when the maintenance cost is the criteria taken into account. Also, this group represents 37.25% of the total inventory costs.

- **ABC analysis with equipment age as criteria (Analysis 2)**

This analysis highlights the equipment that are about to attain the limiting age, which allows the adoption of a proactive maintenance. So, we added the functional lifetime predicted to the acquisition date, in order to predict the end year of functional lifetime. For that, we required the information of the *Central de Negociação* of the Group JMS and the suppliers.

We divided the inventory into three classes, according to the replacement predicted year (Table 3).

Table 3: Results of the analysis 2, with equipment age as criteria

	Observations	% Items
Class A	Predict year of replacement until 2017.	39.4%
Class B	Predict year of replacement between 2017 and 2020.	16.7%
Class C	Predict year of replacement over 2020.	43.9%

We can conclude that 39.4% of the inventory had only two more years left (year of 2017). In addition, 80.77% of the equipment in class A are from radiology, which is the critical group in this second analysis.

- **Spare parts analysis (Analysis 3)**

This paper considers only two main types of spare parts: critical spare parts and non-critical spare parts. The first ones, according to JMS Group, have high costs, low functional lifetime and are fundamental for the equipment operation. The second ones are cheaper and easier replaceable (chairs, tables, screens).

According to this criteria, the angiography, radiology and CT groups are the only ones with two critical component: x-ray tube and radiation detectors. However, the x-ray tube has a low and unpredictable functional lifetime and the radiation detectors have a functional lifetime of 10 years. So, for that reason, we decided to lay the radiation detectors as a critical spare part on this paper, and considered only the x-ray tube.

The nuclear medicine and MRI scan do not have any critical spare part.

3.2. Sample Characterization

After the three previous analyses with different criteria, we can conclude which group of equipment is the most critical (Table 4).

Table 4: Inventory classification resume

	Analysis 1	Analysis 2	Analysis 3
Angiography	Class B	Class C	2
Nuclear Medicine	Class B	Class C	0
Radiology	Class C	Class A	2
MRI scan	Class B	Class C	0
Computed tomography	Class A	Class B	2

Taking into account the most important classification in each group of equipment, the computed tomography (CT) group was the selected one to be the study sample. This conclusion was discussed with JMS Group, who validated it.

In this second round, the CT equipment have been subject to three analysis, each one with different criteria. Morais & Mühlen (2003) list several criteria, always taking into account the medical equipment: risk, equipment characteristics, costs, among others. For this study, we selected the three most important criteria that were validated by *Central de Negociação* team: number of corrective maintenance (NCM), age and wear rate (WR).

The number of corrective maintenance is important because it is directly related to the corrective failures, associated to a reactive management. The equipment age helps to prevent how many years are left, and to predict when the equipment is replaced. At least, the wear rate translates the physical condition of the equipment.

After consulting JMS Group, we assumed the following: (i) six as the extreme between a high NCM and lower NCM, (ii) five as the extreme between a high age and lower age, and (iii) 100% as the extreme between a high and lower WR (Table 5).

Table 5: Resume of the extremes for each criteria: number of corrective maintenance (NCM), age and wear rate (WR)

Classification	HIGH	LOW
NCM	NCM > 6	NCM ≤6
Age	Age > 5	Age ≤5
WR	WR≥100%	WR <100%

Table 6 resumes the criteria classifications, for all the equipment.

Table 6: Classification of each equipment, according the three criteria: NCM, age and WR

Equipment	NCM	Age	WR
CCB	Low	Low	Low
HCC	High	High	Low
HCD I	------	Low	High
HCD RT	High	High	Low
HCIS	High	High	High
HCP	Low	High	Low
HCTV	Low	High	Low
HB I	High	Low	High
HB U	High	Low	High
HB RT	Low	Low	Low
HVFX	High	Low	High

The first analysis was performed based on the criteria NCM, in which 55% of the equipment had a number of corrective maintenance higher than six – value of reference. Despite this percentage is not very high, it still represents more than half of the equipment, manifesting the lack of proactive management owned by JMS Group. As second analysis, the equipment age was taken into account. We conclude that only 45% of the equipment were older than 5 years – value of reference. In the third and last analysis, we used the wear rate criteria, in which 50% of the equipment presented a WR higher than 100% - value of reference.

3.2.1. Multicriteria Classification

In order to better understand the relationship between the three upper criteria, we built three decision matrix. Each matrix represents the relation between two criteria, and has four levels, from I to IV. I is the less critical criteria and IV is the most critical criteria (Figure 1).

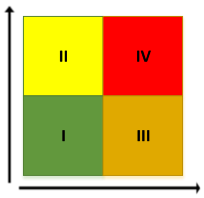

Figure 1: Decision matrix with the four levels

According to the criteria applied, the levels are divided as followed (Table 7):

Table 7: Thorough description of the three matrix

	Level	Observation
NCM vs Age	I	Age lower or equal to five and NCM lower or equal to six
	II	Age over five and NCM lower or equal to six
	III	Age lower or equal to five and NCM over six
	IV	Age over five and over six
NCM vs WR	I	WR lower or equal to 100% and NCM lower or equal to six
	II	WR over 100% and NCM lower or equal to six
	III	WR lower or equal to 100% and NCM over six
	IV	WR over 100% and NCM over six
WR vs Age	I	Age lower or equal to five and WR lower or equal to 100%
	II	Age over five and WR lower or equal to 100%
	III	Age lower or equal to five and WR over 100%
	IV	Age over five and WR over 100%

After the analysis of the results obtained in each decision matrix, we draw some conclusions, namely: (i) all the equipment with a higher WR also have a higher NCM; (ii) there is no direct relation between the WR and the equipment age. The first conclusion confirmed that a higher equipment use results in a higher number of fails. The second conclusion does not come along to all the expectations, in which the WR increases with the equipment age. In this specifically study, this divergence can be justified by the correlation of the WR with the healthcare facility activity and with the high equipment utilization, and not with equipment age.

3.3. Final Classification

The decision matrix can be useful to correlate two criteria, but are useless when we need to study the relation between all the three criteria. Thus, we calculated a global value for each equipment. Hence, we converted the performance of each criteria, by equipment, to a scale of values, according to the following methodology: (i) conversion of performance to value; (ii) weighting criteria; (iii) calculation of the performance global value (PGV); and (iv) sensitivity analysis.

3.3.1. Conversion of performance to value

The purpose of this method is to quantify the performance of each equipment, according to the three criteria (NCM, age and WR). Hence, we applied the bisection method to the three criteria to obtain three different value functions, one for each criteria.

After we have the value functions, we continued with the weighting criteria, in order to understand how the DM is affected by the criteria.

3.3.2. Weighting criteria

For the weighting criteria we used the swing method. The weighting coefficients represent the relative importance that the different criteria affects the DM. Furthermore, the weighting also reflects how the criteria performance affects the PGV, taking always into account the points of view: PV1 (NCM), PV2 (age) and PV3 (WR).

Hence, we compared the reference alternatives, for each point of view. In this case, we used as reference the worst and best levels that correspond to the values of 0 and 100, respectively.

Firstly, the facilitator asks the DM to consider all the three PV in the worst levels, and to sort them according to a preferable order. The DM indicates that it is preferable to go from the worst level to the best level in PV3 than in PV1, which in turn is preferable to make this change in PV1 than in PV2 (Figure 2).

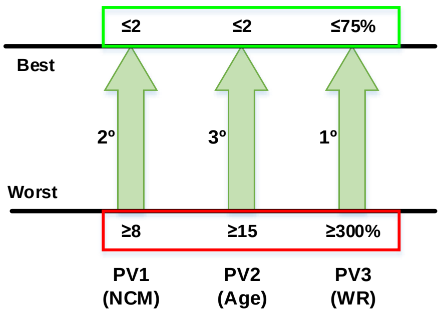

Figure 2: Diagram of the Swing Weighting

Secondly, we proceeded to the quantification of the values to assign to the weighting coefficients of all the points of view. So, the DM compares the swing from the worst to the best level in PV1, knowing that the increment of the worst level to the best level in PV3 is equal to 100. The facilitator repeats the question to PV2 using PV1 as reference. The DM answered 95 and 25 as the swings of PV1 and PV2, respectively.

Finally, the third step is the normalization of the weighting coefficients obtained in step two, such that their sum is equal to 1. For that, we used the following equation:

$$k_j = \frac{k_j'}{\sum_{j=1}^{n} k_j'}, \forall\, j = 1,2,3, \qquad (2)$$

where: k_j' is the non-normalized weighting coefficient, of the point of view *j* (obtained in the second step); k_j is the normalized weighting coefficient of the point of view *j*.

The resume of the non-normalized and normalized coefficients, for each point of view, is in Table 8.

Table 8: Resume of the weighting coefficients, for the three PV: NCM (PV1), age (PV2) and WR (PV3)

Point of view	Non-normalized weighting coefficient (k_j')	Normalized weighting coefficient (k_j)
PV1	95	0.43
PV2	25	0.11
PV3	100	0.46

3.3.3. Calculation of the performance global value (PGV)

For the calculation of the PGV, we used the simple additive model. Hence, the PGV is the result of the combination between the value functions and the normalized weighting coefficient of each criteria. The result represents the level of criticality of each equipment, and was divided into four groups, according to the PGV value:

- Level I: $PGV \in [90; 100]$;
- Level II: $PGV \in [75; 90[$;
- Level III: $PGV \in [50; 75[$;
- Level IV: $PGV \in [0; 50[$.

Finally, the PGV represents a direct criteria of the equipment physical performance, allowing JMS Group to have a quickly reaction about an equipment status. Table 9 contains, for each CT, the correspondent PGV and its classification level, sorted by the level' criticality.

Table 9: PGV and its classification level for each CT

Equipment	PGV	Classification
HVFX	25.3	IV
HB U	27.8	IV
HB I	31.8	IV
HCC	46.8	IV
HCIS	48.4	IV
HCD RT	52.1	III
HCD I	61,2	III
CCB	87.5	II
HCP	90.8	I
HCTV	91.8	I
HB RT	96.2	I

In summary, it can be said that: 45% of the CTs had a PGV lower than 50, with a level classification of IV; 18% of the CTs had a level classification of III, with value between 50 and 75; only one CTs (CCB) was classified as level II; and the others 27% of the CTs were classified as level I, with an PGV higher than 90. Since level IV is the most critical group and it contains more equipment, it can be concluded that JMS Group works with a more reactive management than with a proactive one.

3.3.4. Sensitivity analysis

In order to test the variation of the normalized weighting criteria and its influence on the PGV, we performed three sensitivity analysis, to each criteria. We took into account that the variation of only one criteria influences the others two, since they are normalized and its sum cannot be higher than 1.

The results were analyzed and discussed with JMS Group, who validated the initial weighting coefficients (Table 8).

4. Main Results and Discussion

After the data analysis and the PGV calculation, we applied it in two scenarios, in the present section: (i) maintenance and (ii) equipment replacement.

4.1. Analysis of the Maintenance Contracts

Regardless of the equipment supplier, there are four types of maintenance contracts. After some meetings with JMS Group, they confirmed that do not want to support any risks with the equipment, which means that they do not want to exclude the corrective maintenance from the contract. Therefore, for this study, we only considered two maintenance contracts: partial contract (without spare parts) and full contract (with spare parts). The critical spare parts used was the x-ray tube.

For the analysis of contracts risk, we executed some cost-benefit analysis, where we changed the number of critical spare parts needed and the partial contract price. In this way, we could conclude what is the most profitable contract and, if there is a change of options over the analysis, what is the break point of this turn of events.

Finally, we combined the analysis results with the PGV to conclude what is the most suitable contract for each CT and its characteristics (Table 10).

Table 10: Resume of the PGV and its critical level, and the proposed contracts for each CT.

Equipment	PGV	Maintenance Contract suggestion
CCB	87.5 (II)	Partial
HCC	46.8 (IV)	Full
HCD I	61.2 (III)	Full
HCD RT	52.1 (III)	--------
HCIS	48.4 (IV)	Full
HCP	90.8 (I)	Partial
HCTV	91.8 (I)	Full: (if contract value Partial > 23 000€) Partial: (if contract value Partial ≤ 23 000€)
HB I	31.8 (IV)	Full
HB U	27.8 (IV)	Full
HB RT	96.2 (I)	Partial
HVFX	25.3 (IV)	Full: (if contract value Partial > 24 000€) Partial: (if contract value Partial ≤ 24 000€)

According to the HCD RT equipment, we did not suggest any maintenance contract, because we couldn't get the data about the x-ray tube.

The CTs HCC, HCIS, HB I and HB U have a level IV PGV, which means that these equipment have a critical physical performance and need to be constantly under supervision. Adding this conclusion with the previous analysis, we suggested a full maintenance contract, with lower risks associated.

The lack of the HVFX record with a PGV level IV, leads to a difficult decision in the choice of the maintenance contract. In this case, we suggested JMS Group to discuss with the supplier about the prices: if the partial contract price is lower than 24 000€, a partial contract can be adopted with lower associated risk; however, a full contract is better if the partial contract price is over 24 000€. Nevertheless, we alerted JMS Group to this CT instability and its high WR.

Although the CT HCD I has a PGV in level III, the previous analysis of its maintenance contracts proved that a full contract is the most suitable due to its high utilization.

The CTs HCP, HCTV and HB RT have a PGV in level I. This level is characteristic of a non-critical equipment. Therefore, a partial contract is the most suitable for these three equipment.

The remaining CT CCB has a PGV in level II, due to its number of corrective maintenance. However, the WR is low and the equipment age is also low. Hence, we suggested a partial contract, because the WR is the criteria to take into account when an impasse situation.

4.2. Equipment Replacement

The equipment replacement is an extreme scenario and high investment that implies a huge financial availability.

For this study we defined a replacement decision tree based on the criteria previous study in this paper. The tree options were discussed and validated by the *Central de Negociação* team.

We only used the criteria NCM and WR, since the equipment replacement can happen regardless of its age. Other factors as technology innovation, financial availability and market opportunity are topics that JMS Group have always in mind when an equipment replacement is needed. By market opportunity we mean that there is available a reconditioned equipment, with lower WR, at lower cost.

Before any study, firstly JMS Group analyze if there is a need to introduce a more innovative technology. If the old equipment is not obsolete and there is no need of a new technology, the decision tree is applied until an output.

After, since the WR is the most important criteria, as seen in the previous section, this is the first criteria followed by NCM. The decision tree has three solutions for the equipment replacement: buy a new equipment, buy a reconditioned equipment or do an upgrade to the old equipment.

Therefore, these were the criteria used to build the decision tree (Figure 3).

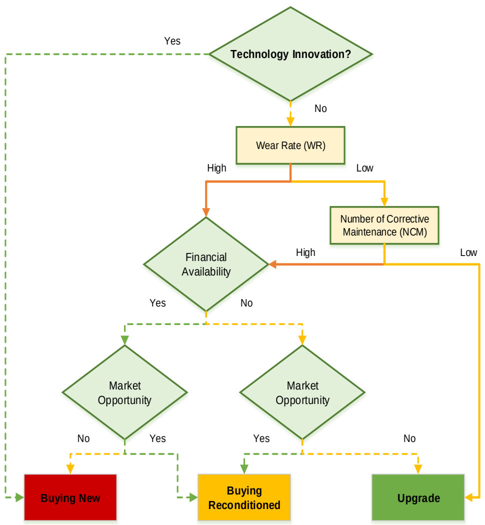

Figure 3: Equipment replacement decision tree

The upgrade is the most reactive solution and also the cheaper one. Normally, an upgrade is used when the equipment has low both NCM and WR, linked to a lower utilization of the equipment. With an upgrade, the equipment software and hardware are renewed and the equipment wins more 5 years of functional lifetime.

Thus, the prevention and prediction of the equipment replacement allows JMS Group to have a proactive management, associated with lower costs and risks. The equipment replacement turns into a planned decision, in which the benefits overcome the initial investment.

5. Conclusions

The main goal of this work was to improve the logistic department management of the equipment, particularly to reduce the reactive management to a proactive management of the inventory.

This paper was divided into two parts. In the first part, described in section 3, we characterized the Imagiology inventory, with the purpose of select an equipment sample. Secondly, we characterized the equipment sample according three criteria (NCM, age and WR) and, finally, we applied an aggregation model to these three criteria, in order to calculate a PGV.

The application of a multicriteria model to the three criteria allowed us to obtain a physical value that translates directly the performance of the equipment. Hence, it is possible for JMS Group understand in an easy way how to manage the equipment.

In the second part, described in section 4, first we analyzed the actual maintenance contract in order to suggest a new ones. In this stage, we combined the equipment analysis with the PGV previously calculated. We concluded that for all 64-slices tomography, a full contract is the better option, while in the 16-slices tomography the type of contract relies in the WR. Hence, for an equipment with a higher WR, a full maintenance contract is the best option.

Secondly, we drew a replacement decision tree. The main function of this methodology was to improve the logistic performance of JMS Group, with the implementation of a proactive management. According to the performance of the equipment, there are three different outputs: buy a new equipment, buy a reconditioned equipment or do an upgrade to the old equipment.

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