Inventory management in the public sector: a diagnosis of the inventory management in a Brazilian public warehouse and proposal of materials classification using utility theory and ABC curve

Anna Paula Galvão Scheidegger
Universidade Federal de Itajubá

Fabio Favaretto
Universidade Federal de Itajubá

Renato da Silva Lima
Universidade Federal de Itajubá

João Batista Turrioni (joabatu@gmail.com)
Universidade Federal de Itajubá

Abstract
Considering the inefficiencies found in the Brazilian productive sectors, particularly in the public sector and inventory management, this work analyses the inventory replenishment process of a public warehouse. The paper also proposes a multiple criteria materials classification based on utility theory, which points to a better organization and inventory control.

Keywords: Inventory management, Public sector, Utility theory

Introduction
According to Mascarenhas *et al* (2005), Bravo and Mariano (2006), since the early of 90s, the Brazilian public organizations has been undergoing transformations that seek to modernize and restructure their management models, aiming efficiency and quality in service delivery, with optimization of public spending. Public institutions began to incorporate management methods from private sector (Bresser-Pereira 2008). However, according to Kovacic and Pecek (2008), process innovation in the public sector still focuses largely on improvements related to the elimination of bureaucracy and simplifying processes.

As stocks are a substantial portion of the assets of organizations, they can (and should) be seen as a potential factor in the optimization of public resources used, and in cost reduction (Martins and Alt 2011). However, knowing how and when to replenish each material, considering possible variability to which the organization is subject, becomes an extremely complex task, since the lack of an essential material may do more harm to the organization than the maintenance of a minimum stock of the same (Gutiérrez and Vidal 2008, Santos and Rodrigues 2006).
In this scenario, inventory management, one of the oldest questions of production management, still arouses much interest both in organizations and academia (Gomes and Wanke 2008, Garcia and Ferreira Filho 2009). However, Kovacic and Pecek (2008) emphasize that public sector organizations face different challenges from those faced by private companies, since they need to fulfill multiple, often conflicting goals, and are subject to financial, legal, contractual, staff and institutional nature restrictions. Thus, an analysis of inventory management applied in this context becomes relevant.

In addition, Lourenço and Castilho (2006) mentioned that most organizations work with a wide range of products and give the same degree of attention to all items is not a recommended practice, given the peculiarities of each material. Thus a suitable type of control for a product may be inappropriate to another and, therefore, the materials classification becomes important for proper inventory management.

Thereby, the questions that guide the development of this research emerge: (i) "How is currently made the materials management and more specifically, the inventory management in the Brazilian public sector?" (ii) "Which theory can be used to classify the materials based on multiple criteria?" (iii) "Which criteria should be applied in the materials classification, in order to treat them differently?".

To answer these questions, this paper seeks to diagnose the materials management in an object of study of the public sector and to propose, based on multiple criteria, classification of materials, given the particularities of the sector and each material.

As an object of study, it was adopted the warehouse of a University. This choice is justified, since the warehouse of the institution has recently undergone a process of restructuring, changing the unit manager and implementing a new integrated management system. Moreover, after some visits to the warehouse, examples of materials without moving, overdue and / or obsolete were observed and there were reports about situations of lack of material in past periods. These conditions show problems in the inventory management of the institution.

The article, besides the introduction already presented, is structured in more four sections. In the next section is laid a theoretical foundation of inventory management, then the research method adopted is described and the results of the research are presented. Finally, concluding remarks are made.

**Theoretical foundation**

**Inventory management**

The inventory management is regarded as a key element for the reduction and control of total costs and improvement of the level of service provided by the companies (Wanke 2004). For Roy (2012), the area plays very important role in the overall cost of operations and supply chain of any business big or small.

For Han (2007), inventory is used as a cushion against the supply and demand uncertainties. In the same vein, for Khunagornniyomrattana et al. (2007), inventory is a double-edged weapon, since the lack of inventory leads to loss of productivity, while excess inventory leads to loss of profitability. Thus, Oliveira and Rodrigues (2008) argue that inventory management has direct and significant effects on operational efficiency (performance) and company finances and Roy (2012) points out that an effective inventory management will always give a competitive advantage to the business over its competitors.
The inventory management aims to optimize the investment by maintaining adequate and satisfactory levels of materials capable of meeting the needs of customers (Quirino et al. 2011). To meet this goal, according to Chaharsooghi and Heydari (2010), managers need to find the best answer to two questions: "How much to order?" and "When?". To answer these questions, we must deal with the trade-off between the pursuits of cost minimization, while we are seeking the satisfaction of service levels (Aloi et al. 2012).

In addition to this trade-off, with the increasing number of items with different demand patterns and characteristics, complexity increases in material management. Thus, researchers and managers must also deal with the challenges of considering the particularities of each material and each organization, and manage the different sources of uncertainty, as shown by Santos and Rodrigues (2006), Altug and Muharremoglu (2011), Alem and Morabito (2012). Moreover, according to Santos (2006), the government sector needs more efficient inventory controls.

In this context, present a materials classification to their characteristics is of utmost importance for more efficient and effective inventory management.

**Materials classification**

Lopes et al. (2006) argue that there may be low consume materials that are essential to the continuing of organization activities and, therefore, the cost of their lack, may be more costly than the investment to keep their in stock. Thus, one must consider, in addition to consumption, other factors such as difficulty in acquiring the material, supply lead time, volume required for storage, costs, etc... Therefore, a materials classification based on multiple criteria may assist in this matter.

One of the most popular methods for materials classification is the ABC curve, also known as Pareto law, which rests briefly on the fact that there are few critical materials and many insignificant. Other methodologies available for sorting of materials are Analytic Hierarchy Process, Analytic Network Process, Krajilic’s Matrix, Utility Theory, among others.

Gaither and Frazier (2002) state that one of the most frequently used criteria in the ABC classification is valued demand or inventory value, which represents the unit investment of each product multiplied by its demand. However, as already mentioned this method may overlook other important factors and therefore it is suggested the adoption of multiple criteria. Roy (2012) indicates other criteria and parameters to be used in the materials classification, such as: material importance, price, material turnover, difficulty of supply, stability of demand over time, durability, substitutability and reparability.

**Research method**

Regarding the methodological framework, the scientific research can be classified according to its goals, nature, way of approaching the problem and research method.

As to its nature, the research can be classified as applied which according to Marconi and Lakatos (2010) studies a problem concerning the applicability of scientific knowledge.

Regarding its objectives, the work has an exploratory character, since there are no hypotheses to be tested. Rather, the study seeks a better understanding of the current context (Cervo and Bervian 2002).

We opted for the use of the qualitative approach, where the subjective reality of individuals involved is considered relevant to the development of research (Martins 2010).
Because of this characteristic of subjectivity, qualitative approach is often criticized. However, Cooper and Schindler (2011) claim that when conducted with methodological rigor, it is possible to achieve valid and reliable results.

Finally, regarding the research method, it was adopted the case study. According to Yin (2010) the case study is used to examine contemporary events and can handle a wide variety of evidence (documents, interviews, observation, etc.). Moreover, according to Voss et al. (2002), the case study enables to answer questions such as "Why?", "What?" and "How?" with full understanding of the nature and complexity of the phenomenon. Also according to Voss et al. (2002), the use of single case study limits the generalizability of the research findings and the development of new theories, in addition to increasing the risks related to subjectivity in data interpretation. But on the other hand, has as advantage the opportunity to make deeper observations about the object of study. As this paper does not have as goal the development of new theories, but instead aims to verify how is the application of existing theory in practice, the single case study was adequate, despite its aforementioned limitations.

Development

Object of study

In order to carry out the case study, interviews were conducted with supervisors of the procurement and warehouse department at University and warehouse keepers, on-site visits were made and documents were analyzed.

The university, located in the southern of Minas Gerais state, Brazil, is considered the first technological university, was the tenth engineering school in the country and has just turned 100 years. Over the past 10 years, as part of the Brazilian government's program of expansion of Universities, the total number of students increased by about 3 times, bringing the total to 7,455 students in 2012, while the total number of employees has doubled, totaling 827 employees. Still, because of the expansion, spending on permanent materials and consumables increased by about 2 times, totaling approximately R$147 million. This growth has increased the complexity of inventory management at the University, also aggravating old problems, as will be discussed in the next sub-section.

As part of the plan to improve its internal processes, the University bought an integrated management system, developed by other Brazilian university considering the particularities of this type of organization and the legal requirements. Thus, in the beginning of 2013 the new system was implemented at the University and the inventory problems were highlighted.

For this study, it will be considered only the consumables under the responsibility of the city hall of the University campus. I.e. permanent materials or consumables under the responsibility of other departments will not be analyzed.

Diagnosis of the inventory management

According to the visits and interviews conducted and as part of the observation, it was found that the university has been using unscientific inventory control and storage methods and management models.

The inventory records were not properly made, with constant differences between the sheet stock in the warehouse and the system logs. These divergences are due to, among other
factors: materials specifications duplicated (or even tripled); specifications poorly done; theft of materials; lack of procedures for order fulfillment, where warehouse keeper often provided the material but forgot to write down or incorrectly wrote down the quantity; lack of procedures for receiving materials, causing discrepancies between the amount actually received and the amount recorded in the system and lack of procedures to scrap overdue or damaged materials.

Still referring to inventory control, despite trying to follow the First In, First Out (FIFO) method to supply the materials, during the storage the method was not always observed. In addition, the previously installed system did not allow the control of lots of materials as well as their validity. Consequently, numerous materials were expiring and were being held in stock, even without being able to be used.

The purchase orders were triggered based on intuition and experience of the buyers, disregarding often even the inventory level registered in the system. Although the system registered the orders filled, the historical demand records were unreliable and, as the whole purchase process was done on paper, there was no record on the lead time of the suppliers or lead time between placing the order and receiving materials. Thereby, all material purchased has not taken demand and lead time variation into consideration; thus it made the situations of too high or too low inventory arise, causing sometimes materials shortfalls to the University and sometimes loss of material due to obsolescence.

Due to the stiffness of the procurement system in the public sphere and the long lead times, frequently the situations of lack of materials can not be easily contained. This often caused the excess of material that was not used, and lack of materials required and, consequently, an inventory imbalance.

The lack of procedures and inventory control, in general, also brought as a consequence the problem of lack of space in the warehouse and improper storage. Thus, the materials were stored without proper care, such as: food materials stocked with cleaning supplies; food materials stored in contact with the ground; boxes stored without respecting the stacking limits, causing, damage to products and difficulties to find a material when needed and, sometimes, generating unnecessary purchase orders, feeding, thus, the cycle of inventory imbalance.

Regarding the organizational structure, it could be observed that one of the most evident characteristic was the great departmentalization of work. This condition has historical source and is deeply embedded in the sector. This excess departmentalization led to problems such as: unfamiliarity with the process as a whole by employees, hindering the arising of proposals for improvements and causing the accomplishment of the same activity by more than one department; inefficient attitudes as "blaming the other" or "do it anyway just to meet the deadline and then redo" and, consequently, increasing the slowness of the system. Moreover, as the process should strongly follow the laws, employees often use them as an excuse, i.e., they often say that they can not do because something they are not authorized by law (when in fact, they are) or continuously make the activities in a way less efficient, simply because "it has always been done in that way", without questioning of the related legislation, modus operandi or other aspects involved.

Regarding the leadership, centralizing attitudes, due to lack of preparation by managers or due to fear of losing their position inhibit proactive attitudes of employees and autonomy of the same and also cause demotivation, increasing inefficiency of the system. Moreover, the existence of promotions or accomplishment of activities based, sometimes, on friendship and closeness also caused demotivate on employees.
Finally, political interests of the employees, the security caused by job stability in the public sector, the lack of training and the aversion to formal control difficult to implement system improvements and corroborate to the inefficiency of the process.

Therefore, there are evidences showing that if structure, bureaucracy, political environment or other specific characteristics of public organizations are not considered, improvement initiatives could fail. Thus, the management models of private sector should be adapted to the public sector context. In this line, it will be proposed a materials classification considering the particularities of the organization studied here.

Materials classification

Before presenting the proposal of materials classification, it is necessary to define the purpose of the same. Considering the scenario of inventory imbalance and lack of managerial models in the warehouse, there is a need to propose a solution which would aid in the inventory management, identifying those materials which should have a higher safety stock. I.e., it is intended with this classification not only identify the most costly, critical or perishable material, but to identify the materials, according to the criteria adopted, that can or should have a higher safety stock. It may seem strange, but the idea is to identify those materials in which a higher safety stock must be kept by its criticality to the organization or those for which it is possible to maintain a higher safety stock, whereas it is not as perishable or does not occupy much space in the warehouse, thus freeing the buyer to more critical tasks.

The next step is to define the criteria for classification. Based on the literature presented earlier in this article, twelve criteria for the materials classification were initially defined, as shown in Table 1. However, as indicated by the red color, some of the criteria were eliminated because they were redundant and others were eliminated after finding during the data collection that the necessary information was not available. An example is the lead time of acquisition. After analyzing sixty procurement processes, it was found that it was not possible to differentiate the lead time of a consumable versus another, since the materials were usually purchased in a single process and it was not possible to identify the material responsible for any delay for example. Thus, after the elimination of redundant or impossible criteria, six criteria were remaining, which are the criteria that will be used for sorting the materials. They are: cost, average demand, storage space, perishability, difficulty of acquisition and criticality.

<table>
<thead>
<tr>
<th>#</th>
<th>Criteria</th>
<th>Reason for exclusion</th>
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<tbody>
<tr>
<td>1</td>
<td>Cost (demand x cost)</td>
<td></td>
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<tr>
<td>2</td>
<td>Average demand</td>
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<tr>
<td>3</td>
<td>Reliability of supply (percentage of items delivered within the time stipulated in the contract)</td>
<td>Similar to the criterion &quot;Lead time of acquisition&quot;</td>
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<tr>
<td>4</td>
<td>Quality of supply (percentage of items delivered as specified)</td>
<td>Data collection: there were no reported problems in the documents consulted.</td>
</tr>
<tr>
<td>5</td>
<td>Lead time of acquisition (time between placing the order and receiving the product)</td>
<td>Data collection: unable to collect this information (materials are purchased in the same process)</td>
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<tr>
<td>6</td>
<td>Storage space (space required for item storage)</td>
<td></td>
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<tr>
<td>7</td>
<td>Inventory turnover (demand/average inventory)</td>
<td>Similar to the criterion &quot;Average demand&quot;</td>
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<tr>
<td>8</td>
<td>Perishability (validity of items)</td>
<td></td>
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<tr>
<td>9</td>
<td>Difficulty of acquisition (items whose procurement process is complex)</td>
<td></td>
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<tr>
<td>10</td>
<td>Criticality (impact of lack of item and when it will be felt)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Substitutability (if there is another item that replaces it or not)</td>
<td></td>
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<tr>
<td>12</td>
<td>Popularity (number of transactions per item)</td>
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</tr>
</tbody>
</table>

Incorporated into the criteria "Criticality"

Similar to the criterion "Average demand"

Legend

Deleted

Since the criteria were already established, it is necessary to define their weights. The definition was taken through a questionnaire applied to the managers of the City Hall and alignment by the researchers, considering the goal of the classification. The high importance criteria received weight 9, the average importance received weight 5 and the low importance received weight 1. Because of the method used for classification, which will be soon presented on the article, it was necessary to carry out the standardization of weights, which was made using Equation (1).

\[
\text{Standard weight } j = \frac{\text{Relative weight } j}{\sum_{n=1}^{n} \text{Relative weight } n}
\]  

(1)

Where: j is the criterion being analyzed.

Before starting the materials classification, it was necessary to define the method to be adopted. Whereas the decision criteria involved different units of measurement and conflicting goals, such as storage space occupied by the item and its criticality, it was chosen to use the utility theory, which takes all the criteria for the same unit, considering the worst value of the criterion as 0 and the best value as 1.

To calculate the value of each material within each criterion, it was used the Equation (2), where y is the value of the material in that criterion and x is the utility value to be calculated.

\[
\frac{\text{Best value} - \text{Worst value}}{1 - 0} = \frac{y - \text{Worst value}}{x - 0}
\]  

(2)

Thus, being established the criteria of classification and the method to be used, the theory was implemented in Excel®. As an example, to better understand the calculus of utility, it will be presented the calculus of the expiration date criterion. For this case, the shorter the duration, i.e., the more perishable is the item, less it is desirable to keep in stock. So the worst case is the material with lower validity period (0.5 year). And the best case is the materials with the highest period of validity (10 years). Whereas the validity of stamp pad is 3 years, one comes to their utility value for the criterion of validity: 0.263, according to Equation (3).

\[
\frac{10 - 0.5}{1 - 0} = \frac{3 - 0.5}{x - 0} \Rightarrow x \approx 0.263
\]  

(3)
Finally, the average utility of each material, i.e., the final utility of each material is calculated by Equation (4). Where $P_{ci}$ is the relative weight of the criterion $i$ and $V_{cij}$ is the value of the material $j$ for criterion $i$. Since there are 183 different materials, $j$ ranges from 1 to 183 and $i$ ranges from 1 to 6, as there are six criteria.

$$\text{Average utility } j = \sum_{i=1}^{6} \sum_{j=1}^{183} P_{ci} \times V_{cij}$$ (4)

Having calculated the average utility of each material, the classification of the materials is, then, concluded. However, as the utility theory does not allow the material classification in groups, but just an ordering of the same, it was necessary to establish a criterion for sorting the materials in A, B and C groups. After some analysis as number of items in each group and relevance of the items and considering the literature, it was established that 10% of the items would be considered A, 20% considered B and 70% considered C. Examples of material A are: lined foolscap paper; blue, black and red ink refills; disposable cup (coffee and water) and toilet paper towel. Examples of B materials are: pens, unlined foolscap paper, sweetener and board eraser. Examples of C materials are: padlock, kitchen paper towel, scissors, Post-it®, and cardstock.

Conclusions

The article discussed a research regarding the inventory management of consumable materials in the warehouse of a Brazilian University. As conclusion, it is worth noting that:

- The Brazilian public sector has numerous peculiarities, whether organizational or behavioral, compared with the private sector. Such characteristics make it difficult to improve processes in the sector and corroborate to the inefficiency and long lead times observed. Moreover, as noted in the object of study and indicated by Santos (2006), despite the recent modernization of the sector, it still needs more efficient management models. Thus, the adoption of management techniques from the private sector can bring positive results to the processes. But at the same time, it is important to emphasize the need to adapt these techniques to the reality of the public organizations.

- The paper proposed a model for classifying materials based on multiple criteria considering the problems and difficulties in the public sector. This model has some advantages: ease of replication, the use of two decision theories together and the use of multiple criteria. Although the criteria are conflicting, the utility theory allowed to circumvent this issue efficiently and also allowed to achieve the proposed objective for the materials classification. This goal is slightly different from the usual goals of materials classification, viz. identify the most important materials.

Finally, it is important to recognize the limitation of this work that is being a single case study does not allow generalization of the results. However, since it was chosen as object of study a public institution with 100 years of existence and nationally recognized for its quality, the researchers believe that an adaptation of the results to other Brazilian public universities can be easily made.

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Bibliography


