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Different types of inventory control in Brazilian Companies

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Abstract

Effective inventory control is a requirement for operational processes to run smoothly and requires in turn that inventory data be reliable, as undesirable effects may otherwise be produced in different areas of the organization, such as a reduction in service level or a drop in operational efficiency because of unforeseen stoppages or rescheduling of production. This study seeks to identify how various types of inventory control affect inventory accuracy. The study is a descriptive one, and the approach adopted involved the use of multiple cases (seven case studies in Brazilian companies). The main results include classification of the degree of control of inventory operations so that the companies in the study could be classified into three categories: high, medium and low. In addition, the study correlates different types of inventory control with the inventory accuracy index for each of the seven companies and shows the relationship between types of control, the importance attached to inventory control by the organization, the number of inventory items and the accuracy index.

Keywords: inventory control, inventory accuracy, cycle counting, bar code.

1 Introduction

The control of inventory accuracy has been the subject of increasing attention in recent years as companies increasingly seek to reduce logistics costs and reduce inventory levels. Inventory accuracy has thus become an essential requirement for logistics decision making.

The term inventory accuracy is used to refer to the relationship between the quantity of material actually found and the quantity recorded in the information system (Sheldon, 2004) and is currently the subject of many studies. DeHoratius and Raman (2004) examined approximately 370,000 stock records in 37 stores and 2 distribution centers and found an inaccuracy of 65%.

In a benchmarking study into good inventory control practices at 16 US logistics operators (LOs), Collins et al. (2001) propose that LOs with an accuracy index of more than 99.9% be considered as having have world-class performance. These companies use cycle counting (CC) and Radio Frequency Identification (RFIDs) as a form of inventory control and devote around 3,600 man-hours per year and approximately 5% of the annual budget to the inventory control process. In Brazil, a study carried out by IMAM (The Institute for Innovation and Improvements in Modern Administration) in 2003 in 162 Brazilian companies in various sectors found that average inventory accuracy was 92.75% (IMAM, 2003), highlighting an opportunity to identify ways of improving inventory accuracy indexes.

The causes and effects of inventory inaccuracy in organizations and the supply chain vary. One important effect of inventory inaccuracy is difficulties with inventory management (Waller et al., 2006). Other effects include larger purchasing and production batches and uncertainty as to whether demand will be met.

The main aim of the present study was therefore to identify how several types of inventory control affect inventory accuracy. The article has five sections including this introduction. The second section gives details of the method used in the study. The third section consists of a review of the literature on inventory control, inventory accuracy, inventory control processes and cycle counting (CC). The fourth section provides descriptions and analysis of the cases and the fifth section presents the conclusions of this work.

2 Research method

The approach used was based on case studies. A total of seven cases were used and the findings were then compared with those reported in the literature.

The instruments used to collect data consisted of documentation, records in files (accuracy indicators and inventory reports), interviews and direct observation. The interview questions were structured, i.e., they were prepared based on a research protocol for the case studies. The script for the interviews was based on the findings of the literature review and validated in the first case study.

It was decided to analyze the data by relating it to the findings of the literature review and the conclusions of similar inventory control studies. When used in conjunction with the findings of the literature review, the material collected (from interviews, documents and direct observation) allowed a systematic approach to the interpretation of the areas being investigated to be adopted. This approach consisted of five steps, which are shown in Table 1.

Table 1: Research approach

Stages in the Analysis		Details of the Analysis
1	Analysis of the causes and effects of inaccuracy	The data collected in the interviews is compiled according to the causes and effects of inaccuracy so that the average impact of each cause or effect can be determined. Based on the average impact, a list of the main causes and effects and the findings of the literature review is then drawn up.
2	Analysis of the inventory control processes	The receiving, data capture and shipping processes are analyzed to determine the level of control in each company. After this, a more detailed analysis of each process is carried out.
3	Analysis of the use of CC	It is established whether the company uses CC, what methodology is used and if there is an action plan to correct discrepancies. This data is correlated with the inventory accuracy index.
4	Analysis of the use of bar coding (BC)	It is established whether the company uses BC and what improvement is associated with this.
5	Relationship between the different types of inventory control and the inventory accuracy index	The impacts of the different types of inventory control on the inventory accuracy index are analyzed and correlated with the number of direct items controlled by the companies.

3 Literature Review

Some forms of inventory control are known to have an impact on inventory accuracy, as reported by authors such as Wilson (1995), Brown et al. (2001), Piasecki (2003), Waller et al. (2006), Rossetti et al. (2007) and Huschka (2009). These studies sought primarily to identify the impacts but did not describe in detail how different types of inventory control affect inventory accuracy.

Accuracy conveys the idea of precision. Inventory accuracy can be defined as the physical quantity of material expressed as a percentage of the quantity of material recorded in the information system (Sheldon, 2004).

The study by Rinehart (1960) can be considered the first paper on inventory inaccuracy. In it the author analyzes the causes and effects of inventory discrepancies in a US Federal Government Agency. Other pioneering authors who contributed to the study of accuracy were Iglehart and Morley (1972), who analyzed the impact of inaccuracy due to information uncertainty on inventory levels in a US Naval Department.

Inventory inaccuracies normally hide high costs resulting from operational mistakes and even theft. These costs can reach millions of dollars depending on the size of the company and the sector in which it operates. A survey carried out by the US National Supermarket Research Group reported that supermarkets in the US lost approximately 2.30% of total sales in 2001 as a result of internal and external theft, incorrect receiving of goods, damaged products and pricing errors (Shain, 2004) and that this led to a drop in the inventory accuracy index.

A study carried out by IMAM in 2003 into the use of inventory management techniques in around 96 medium-sized Brazilian companies found that 31% of them had reasonably reliable accuracy data; only 24% reported that stock accuracy was within the planned range (IMAM, 2003).

Inventory inaccuracy can be caused by a variety of factors, ranging from issues related to processes and labor to insufficient investment in technology. Table 2 summarizes the main causes of inventory inaccuracy found in the literature.

Table 2: Summary of the causes of inventory inaccuracy

Causes	Authors
Incorrect inventory records update	Wilson (1995), DeHouratius and Raman (2004), Waller *et al.* (2006)
Small salaries	Brown et al. (2001)
Damaged material	Shain (2004), Rekik (2006), Shain and Dalery (2007)
Errors in inventory records	Arnold (1998), Raman et al. (2001). DeHouratius and Raman (2004), Kang and Gershwin (2004), Shain (2004), Rekik (2006), Waller et al. (2006), Shain and Dallery (2007), Shain et al. (2008)
Bar Code not used	Brown et al. (2001)
Cycle counting not properly implemented	Arnold (1998), Brown et al. (2001)
Clear procedures not defined	Shain (2004)
No training	Brown et al. (2001)
Supply	Raman et al. (2001)
Materials counting frequency	Sheppard and Brown (1993)
Materials transport frequency	DeHouratius and Raman (2004), Waller et al. (2006)
Incorrect identification	Wilson (1995), Kang and Gershwin (2004)
Inventory counting interval	Raman et al. (2001)
Incorrect material location	Wilson (1995), Raman et al. (2001), Kang and Gershwin (2004), Shain (2004), Shain et al. (2008)
Number of stored items	Rinehart (1960), Sheppard and Brown (1993)
Obsolescence	Kang and Gershwin (2004), Shain (2004), Shain and Dallery (2007), Shain et al. (2008)
Theft	DeHouratius and Raman (2004), Kang and Gershwin (2004), Shain (2004), Waller (2006), Shain and Dallery (2007), Shain et al. (2008)
Inconsistent material movement records	Arnold (1998)
Turnover	Rekik (2006)
Product value	Sheppard and Brown (1993), Raman et al. (2001)
Product variety	Raman et al. (2001), Rekik (2006)

It can be seen that among the main causes of inventory discrepancies, the most frequently mentioned by the authors in the literature review are errors in records (involving basically receiving, production data

capture, moving, shipping and returns). Two other errors frequently observed are those caused by incorrect location and theft.

Inventory inaccuracy has a series of effects on company performance. The main ones are shown in Table 3, where the literature reviewed is classified according to the effects the authors observed.

Table 3: Summary of the effects of inventory inaccuracy

Effects	Authors
Internal logistics costs increase	Iglehart and Morley (1972), Arnold (1998), Brown et al. (2001), Kang and Gershwin (2004), Shain (2004)
External logistics costs increase	Waller et al. (2001), Shain(2004), Basinger (2006), Rossetti et al. (2007)
Urgent deliveries	Arnold (1998)
Production planning difficulties	Arnold (1998), Brown et al. (2001), Castro (2005), Uçkun et al. (2008)
Collaborative management	Raman et al. (2001), DeHoratius and Raman (2004), Sari (2008)
Corporative image	Shain (2004)
Service level	Arnold (1998), Brown et al. (2001), Shain (2004), Castro (2005), Basinger (2006), Waller et al. (2006), Rossetti et al. (2007), Shain et al. (2008), Uçkun et al. (2008)
Loss of operational efficiency	Arnold (1998), Shain (2004), Castro (2005), Shain and Dallery (2007), Uçkun et al. (2008)
Demand management	Shain (2004)
Retail decrease	Arnold (1998), Raman et al. (2001)

Of the main effects shown in Table 3, those most frequently mentioned in the literature are an increase in costs, an impact on service level and a loss of operational efficiency.

4 Case studies

This section describes the case studies of the seven Brazilian companies that agreed to take part in this study. The case studies were based on interviews, analysis of documents, records and direct observation. Table 4 summarizes the main features of each of the companies.

Table 4: Features of the companies studied

Company	Industry	Product	Number of employees	Number of SKUs	Monthly production (units)	Inventory accuracy index
FS1	Automotive	Driving system	280	2.900	60.000 un	99,00%
FS2	Automotive	Glass and safety systems	500	1.700	528.000 un	99,40%
FS3	Automotive	Stamping	400	500	480.000 un	85,00%
FS4	Electronic components	Wire cables	800	5000	720.000 un	70,90%
FS5	Automotive	Car calotte	40	100	104.000 un	97,20%
FS6	Bank furniture	Bank furniture	100	3000	50 un	65,00%
FS7	Printed circuit board	Printed circuit board	120	500	2.500m^2	99,42%

The cause of inaccuracy with the highest average impact according with interviews was errors when recording the movement of materials; in fact, this had the greatest number of extremely high impacts. This same cause of inaccuracy can be attributed to errors when recording material in the system, errors in the process for recording production data after it has been captured and errors in the process for issuing outgoing invoices.

Interviewees were also asked whether other factors influenced inventory inaccuracy in the company. It can be seen that errors in the bills of materials were identified as one such factor, as six of the seven companies studied referred to this. Based on the case studies and the review of the literature, the main causes of inventory inaccuracy can therefore be identified, as shown in Figure 1.

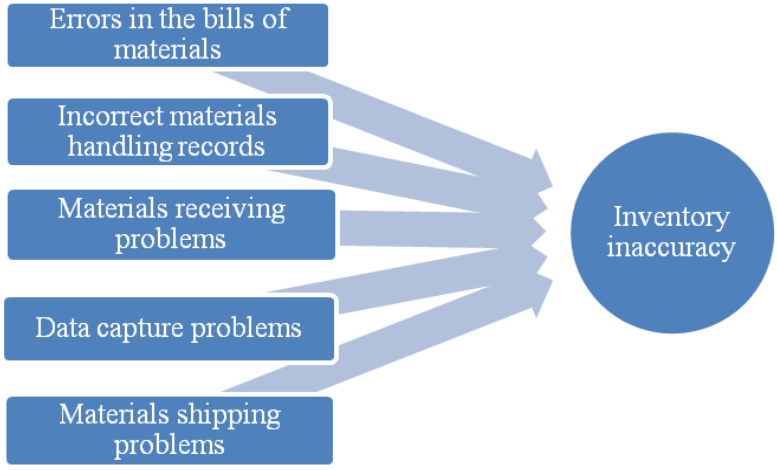

Figure 1. The main causes of inventory inaccuracy.

During the course of the interviews and the direct observations, eight processes that have a direct impact on inventory control in each of the companies were investigated:

- Receiving;
- Quality control;
- Storage;
- Line feeding;
- Data capture;
- Storage of the finished product;
- Shipping;
- Returns.

Of the processes analyzed, the three that generate the greatest inventory discrepancies according to the literature and the interviewees were selected (receiving, data capture and shipping). To allow these processes to be clearly identified, they were broken down into activities: six activities for the receiving process; three for the data capture process; and six for the shipping process. The choice of these three processes was based on the reports of the semi-structured interviews and the direct observations carried out during the case studies. Table 5 shows which activities the companies in the case studies carry out as part of the three processes. Each company is designed as a "FS#".

Table 5: Identification of processes by activity

Process	Activity	FS1	FS2	FS3	FS4	FS5	FS6	FS7
Receiving	Physical check	X	X		X	X	X	X
	Order check	X	X				X	X
	Control form	X	X	X		X		X
	Identification	X	X	X		X	X	X
	BC reading		X					
	Divergences treatment	X	X		X		X	
Data capture	Manual		X		X	X	X	X
	Semi automatic	X		X				
	Automatic							
	Control form	X	X	X			X	X
Shipping	Physical check	X	X	X	X	X	X	X
	Package	X	X	X				X
	Identification	X	X	X		X	X	X
	BC reading	X	X					
	Low customer complaint	X	X			X		X

Companies FS1 and FS2 had the greatest level of control in the receiving process. The only company that carried out all the control activities for this process was FS2, which, in spite of the large number of items received every day, has a strict procedure for controlling the receiving of goods. The company makes heavy use of the WMS system (Warehouse Management System), bar code readers and a specific area for checking and identifying materials. Another point of note in the receiving process in companies FS1 and FS2 is the issuing of the incoming invoice, which is done immediately after the physical check so that the inventory balances are updated more quickly.

In the data capture process, the companies with the best performance were FS1 and FS3, which use bar code reading (BC), an approach that can make data collection more reliable.

For companies FS1, FS2 and FS7, the shipping process was the process with the greatest degree of control. FS1 and FS2 both use BC in the shipping process and also have a well-organized storage facility and a good system for controlling the shipping of goods. This approach is a consequence of the strict controls adopted by the company's clients and the penalties incurred if the wrong materials are sent.

FS7 has a strict inspection system covering labeling, packaging and the checking of material quantities and specifications against order quantities and specifications. It also has an organized area for inspection before loading and shipping.

It can be seen from Table 5 that the companies with the greatest degree of control in their processes were FS1 and FS2, whose processes ensure that inventory discrepancies are less likely to occur during receiving, data capture and shipping. In other words, there is a greater likelihood of a higher inventory accuracy index, primarily as a result of the use of a bar coding (BC) system, strict control of processes, the organization of the physical space and the method for identifying materials.

By analyzing the individual activities in the inventory control processes, the use of cycle counting (CC) and the use of BC, the data can be organized so as to allow an analysis of the various types of inventory control, the number of inventory items in the company and the average accuracy index. This information is shown in Table 6.

Table 6: Types of inventory control

Company	Number of SKUs	Inventory control process level	Type of inventory control			Average IAI
			Periodic inventory	CC	BC	
FS1	400	High	Yes	Yes	Yes	99,99%
FS2	1700	High	Not	Yes	Yes	99,40%
FS3	500	Medium	Not	Yes	Yes	85,00%
FS4	5000	Small	Not	Yes	Yes	70,90%
FS5	100	Small	Yes	Not	Not	97,20%
FS6	3000	Medium	Yes	Not	Not	65,00%
FS7	500	Medium	Yes	Yes	Not	95,42%

It can be seen from Table 6 that although FS1 has the best accuracy index, it has a much smaller number of items (raw materials and finished products) than FS2, which has around 67% more direct items. In other words, although the results for FS1 are excellent and the company has good inventory control processes, FS2 also has a good index, particularly if the number of direct items the company controls is taken into account, as these make inventory control more complex.

FS5 and FS7 have good accuracy indexes. However, it was evident from the interviews and observation of the companies' operations that they have relatively simple operations in terms of materials control and number of items, factors that have a direct impact on inventory control. Hence, an increase in the movement of materials and number of items could directly affect the inventory accuracy index.

Of the companies studied, FS4 and FS6 had the poorest inventory control in terms of the number of activities for each control process, the use of CC, the use of BC and the inventory accuracy index. A relationship can therefore be identified between the extent to which the different types of inventory control analyzed in this study are used and the inventory accuracy index, a finding that corroborates the conclusions of Brown et al. (2001).

5 Conclusion

The case studies revealed an important cause that has not been identified in the literature: errors in the bill of materials related to data being incorrectly recorded and/or failure to update data after product designs are changed.

This study has shown the direct influence that receiving, data capture and shipping have on inventory accuracy. These processes are thus important elements of inventory control and play an essential role in improving the inventory accuracy index and keeping it at a satisfactory level.

The study has also shown that most of the companies that used CC had a better inventory accuracy index. In FS1, for example, this jumped from less than 80% to 99.99% after a significant improvement had been made to the process for controlling raw materials.

It can be seen that for CC to be implemented effectively, the causes of any discrepancies must be analyzed and action plans used to correct them. CC is thus an important tool for identifying and overcoming shortcomings in the inventory control process. Another important finding related to the success of CC is the need to involve employees in the logistics department in inventory control. The importance of this was apparent in FS2, which pays a monthly bonus to employees in the logistics department when the target for the accuracy index is reached.

Of the seven companies studied, three (FS1, FS2 and FS3) use BC and one (FS4) is in the final phase of implementing it. In the companies using this technology, it was apparent that BC had contributed directly to the high quality of the inventory control, particularly as a tool for use in receiving, data capture and shipping operations. Implementation of a BC system can be considered an important requirement for

achieving greater control of inventory processes and, consequently, greater inventory accuracy.

The companies with the best inventory accuracies (FS1 and FS2) had the greatest control of receiving, data capture and shipping processes and used CC and BC systems.

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References

Arnold, J. R. T., 1998. Introduction to Materials Management, third ed. Prentice Hall, New Jersey.

Brown, k. L., Inman R. A., Calloway J. A. (2001). Measuring the efects of inventory inaccuracy in MRP inventory and delivery performance. *Production Planning & Control,* Vol. 12, No. 1, p. 46-57.

Castro, R. L. (2005). Production planning and inventory: a survey with brasilian automotive suppliers. *Master Science Dissertation* – USP, Brazil.

Collins, T. et al. (2001). Benchmarking for Best Practices in Inventory Integrity. *The Proceedings of the 2001 Industrial Engineering Research Conference,* Dallas, Texas.

Dehoratius, N., Raman, A. (2004). Inventory record inaccuracy: An emprical analysis. *Working Paper, University of Chicago*, Chicago, IL.

Dehoratius, N., Raman, A. (2008). Inventory record inaccuracy: An Emprical Analysis. *Management Science*, Vo. 54, No. 4, p. 627–641.

Huschka, K. (2009). Using Statistical Process Control to Monitor Inventory Accuracy. *Thesis Master of Science*, Department of Industrial and Manufacturing Systems Engineering College of Engineering - Kansas State University, EUA.

Iglehart, D. L., Morey, R.C. (1972). Inventory systems with imperfect asset information. *Management Science*, Vol. 18 No. 8, p. 388-394.

IMAM. (2003). *Pesquisa IMAM 2003 sobre Gestão de Materiais*. Available in: www.imam.com.br/logistica/arquivos/PDF_PESQUISAS/GESTÃO%20DE%20MATERIAIS2003.PDF> Accessed in: july 21, 2011.

Piasecki, D. J. (2003). *Inventory Accuracy: People, Processes, & Technology*. Ops Publishing, Kenosha.

Kang, Y., Gershwin, S. B. (2004). Information inaccuracy in inventory systems – stock loss and stockout. *Technical Report*, Department of Mechanical Engineering, Massachusetts Institute of Technology. Available in: <http://cell1.mit.edu/papers/kang-gershwin-autoid04.pdf>. Accessed in: july 10, 2011.

Raman, A., Dehoratius, N., Ton, Z. (2001). Execution the missing link in retail operations. *California Management Review*, Vol. 43, No. 3, p. 136-52.

Rekik, Y. (2006). The Impact of the RFID Technology in Improving Performance of Inventory Systems subject to Inaccuracies. *PhD Thesis*, LGI- Ecole Centrale Paris, France.

Rinehart, R.F. (1960). Effects and causes of discrepancies in supply operations. *Operations Research*, Vol. 8, No. 4, p. 543–564.

Rossetti, et al. (2007). Inventory Accuracy Improvement via in a Two-Echelon Supply Chain. *The Proceedings of the 2007 Industrial Engineering Reserarch Conference*, Dallas, Texas.

Sari, K. (2008). Inventory inaccuracy and performance of collaborative supply chain practices. *Industrial Management & Data Systems*, Vol. 108, No. 4, p. 495-509.

Shain, E. (2004). A qualitative and quantitative analysis of the impact of Auto ID technology on the performance of supply chains. *PhD Thesis*, LGI-Ecole Centrale Paris, France.

Shain, E., Dallery, Y. (2007). A Literature Review on the Impact of Inventory Data Record Inaccuracies on Inventory Management and the Potential of the Rfid Technology to Tackle this Issue. *Proceedings of the 1st Annual RFID Eurasia*.

Shain, E., Buzacotti, J., Dallery, Y. (2008). Analysis of a newsvendor which has errors in inventory data records. *European Journal of Operational Research*, Vol. 188, p. 370–389.

Sheldon, D. H. (2004). *Achieving Inventory Accuracy: A Guide To Sustainable Class A Excellence In 120 Days*. Hardcover: J. Ross Publishing.

Sheppard, G., Brown, K. (1993). Predicting inventory record keeping errors with discriminant analysis: A field experiment. *International Journal of Production Economics*, Vol. 32, No. 1, p. 39-51.

Waller, M. A., et al. (2006). Measuring the impact of inaccurate inventory information on a retail outlet. *The International Journal of Logistics Management*, Vol. 17, No. 3, p. 355-376.

Wilson, J. M. (1995). Quality control methods in cycle counting for record accuracy management. *International Journal of Operations & Production Management*, Vol. 15, No. 7, p. 27-39.