RFId and Returnable Transport Items Management: An Activity-based Model to Assess the Costs and Benefits in the Fruit and Vegetable Supply Chain

Giovanni Miragliotta, Alessandro Perego and Angela Tumino

Department of Management, Economics and Industrial Engineering
Politecnico di Milano, 20133 Milano, Italy

Abstract. Radio Frequency Identification (RFId) technology promises to enable substantial benefits in Returnable Transport Items management. Lured by this opportunity, some companies (e.g. Metro Group) are carrying out pilot projects, but the difficulties in quantifying the costs and benefits stemming from such applications still prevent many companies from using this technology. This paper describes an analytical model to assess the profitability of such investments, focusing on the fruit and vegetable supply chain.

1 Introduction

Radio Frequency Identification (RFId) technology is deemed to have great potential to improve the efficiency and accuracy of asset management in different supply chains. More specifically, the management of Returnable Transport Items (RTIs) - i.e. “all means to assemble goods for transportation, storage, handling and product protection in the supply chain which are returned for further usage, including for example pallets with and without cash deposits as well as all forms of reusable crates, trays, boxes, roll pallets, barrels, trolleys, pallet collars and lids” [1] - has always been a critical issue in the Fast Moving Consumer Goods supply chain. Therefore, a substantial interest in RFId potentialities has arisen, and some pilot projects have been launched by supply chain leaders, e.g. Metro Group [2]. However, many companies are still biding time, primarily because of a lack of confidence in the benefits and, consequently, in the impact on Return On Investment, which generates a greater perception of risk [3].

Consistent with this premise, this paper aims to present an activity-based model to evaluate the profitability of RFId applications supporting RTI management in the fruit and vegetable supply chain. The paper is structured as follows. Section 2 provides a classification of the main scientific contributions on the evaluation of RFId applications. Section 3 presents the objectives and the methodology. and Section 4 describes the model. Section 5 illustrates the application of the model to the supply chain of a prominent Italian retailer and discusses the main business implications. Finally, Section 6 draws some conclusions and suggests future research paths.

Miragliotta G., Perego A. and Tumino A. (2009).
RFId and Returnable Transport Items Management: An Activity-based Model to Assess the Costs and Benefits in the Fruit and Vegetable Supply Chain.
In *Proceedings of the 3rd International Workshop on RFID Technology - Concepts, Applications, Challenges* , pages 39-48
DOI: 10.5220/0002192800390048

2 Literature Review

The assessment of the value related to the implementation of ICT solutions has fascinated for years researchers, and various studies have been conducted. However, most of them have been carried out at the industry and economy levels, or at the firm level, providing limited support to understand where and how the benefits are generated. Only few authors analyse the impact of ICT on business processes, which is essential to understand how value is created (e.g. [4]). If we focus on RFId, in recent years members of both academic and generalist press have devoted much attention to the evaluation of RFId projects. The available contributions can be classified in three main groups.

1. Qualitative papers that describe the strategic implications of applying RFId to supply chain management (e.g. [5]), provide a taxonomy and a qualitative evaluation of the benefits achievable through RFId technology (e.g. [6], [7]) and analyze the implementation process (e.g. [8]).
2. Quantitative analyses based on empirical evidence (e.g. case studies) or experts' evaluations, which mainly focus on the Fast Moving Consumer Goods supply chain, where the first pilot projects were launched. These papers seek to provide both a taxonomy and a quantitative evaluation of the benefits stemming from the adoption of RFId (e.g. [9], [10]).
3. Quantitative studies based on structured assessment models, that present mathematical and simulation models to assess the impact of RFId on supply chain performance (e.g. [11], [12], [13]).

While the first attempts were mainly based on empirical evidence, in recent years more attention has been paid to mathematical and simulation models. However, they mainly focus on the benefits that can be achieved applying the RFId tags on the products (i.e. pallet loads, cases, items), while little attention has been paid to the benefits enabled by the tagging of RTIs (e.g. [9]).

3 Objectives and Methodology

Consistent with the premises, this paper aims to present a structured model to assess the costs and benefits stemming from the RFId tagging of RTIs, and to eventually inspire the decision making process of managers. More specifically, the model focuses on the management of the RTIs which are commonly used to transport fruit and vegetables in the Fast Moving Consumer Goods supply chain. The structure of the model is general, i.e. it can be applied to any retailer who uses RTIs to transport fruit and vegetables, and consists of three strictly related components: the assessment of the benefits in productivity, the assessment of the benefits enabled by the increased process quality and visibility, and the assessment of the capital and operational expenditures (CapEx and OpEx). The paper present the results of the model application to a prominent Italian retailer (Nordiconad).

The research program was divided into three phases, which resorted to *ad hoc* methodologies. In the first phase, direct interviews with the involved companies (producer, retailer, pooling company) were performed in order to analyze the processes. In the second phase, the analytical model was developed, resorting to the well-established activity-based modeling approach, as used by other authors (e.g. [14]). More specifically, in order to understand the impact on business processes, each activity was first split into a hierarchy of elementary activities. Then, the impact of RFId in terms of reduced resource requirements based on relevant operational resource consumption drivers was evaluated. In order to improve its usability, the model has been coded into an MS-Excel based tool. Finally, direct interviews and technological tests were carried out to collect the required inputs and analyze the results.

4 The Model

4.1 The Reference Supply Chain

The typical fruit and vegetable supply chain consists of four members: the pooling company, the producer, the retailer (distribution center, stores) and the carrier. (cf. Figure 1).

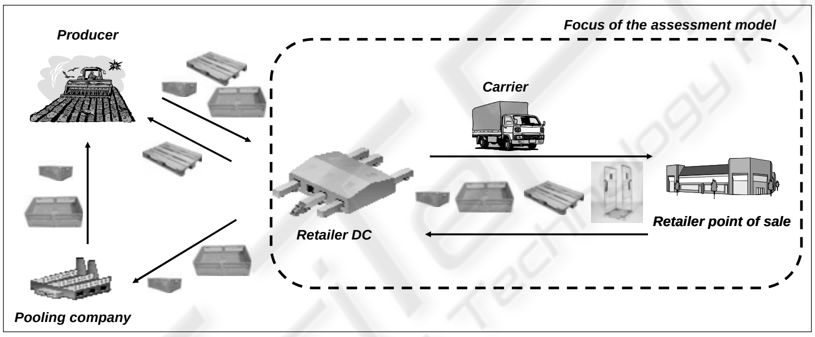

Fig. 1. The reference supply chain.

The model considers two kinds of RTI, one being used as secondary packaging (plastic crates and bins), while the other as tertiary packaging (pallets, roll containers). Other relevant characteristics of this flow are as follows:

- Crates and bins are provided by a pooling company which sends them to the producer, so that the latter can fill them with fruit and vegetables. In accordance with the retailer’s orders, the producer sends the RTIs full of fruit and vegetables to the retailer DC, who temporarily stores them. Then, the stores order the products, and the retailer DC picks the requested crates and bins and ships them to the points of sale. Finally, the retailer DC is responsible for the collection of the RTIs, and for their shipment to the pooling company (thus closing the loop);
- Both roll containers and pallets are used to ship the products from the retailer DC to the stores, while the producer uses only pallets;
- The owner of the crates and bins is the pooling company, while the pallet and roll containers are owned by the retailer;

- The carrier is responsible for the transport of RTIs from the retailer DC to the stores.

More specifically, the model is focused on a sub-part of the previously illustrated supply chain (cf. Figure 1) which consists of the retailer DC, the carrier and the stores. For each of these nodes the model focuses on the RTI receiving, shipping and administrative activities. The latter have been analyzed in depth and the associated consumption of resources has been modeled using an activity-based approach (cf. Section 3). The results have been extensively reviewed and validated by the logistics directors of the involved companies.

4.2 The Technological Scenarios

We considered an RFId scenario in which every RTI is provided with a re-usable RFId tag. The latter is initialized when the asset enters into the system according to the Electronic Product Code (EPC) standard, which states that a unique identifier has to be written on the tag. The costs of the RFId tags are sustained by the company who owns the RTIs, i.e. the pooling company for the crates and bins, and the retailer DC for the pallets and roll containers.

According to the current performance of RFId technology, a non-zero reading time has been assumed to ensure perfect reliability, i.e. 100% reading rate (cf. Section 5.1).

All the supply chain nodes are provided with the RFId hardware and software required to identify all the entering and exiting RTIs. More specifically:

- The loading and unloading docks of the retailer DC are provided with RFId gates consisting of an RFId reader, four antennas, a movement sensor, a traffic light to confirm the correct reading, and a monitor;
- The stores are provided with RFId handheld readers;
- All the nodes are provided with appropriate software which collects the data gathered by the hardware infrastructure.

As a benchmark, we chose a base-line scenario (B) which assumes a visual, non-automatic identification. In fact, while the bar-code standard is commonly used to identify the goods, it is still less used for RTI identification and management. Moreover, the number and typology of shipped RTIs is written on the shipping documents manually or electronically. As for the plastic bins and crates, the retailer has to collect information on their usage, which is sent to the pooling company.

4.3 The Assessment of the Benefits

As stated in Section 3, two main classes of benefit were considered. Indeed, we included both benefits related to productivity increases within the material handling and the administrative processes (called “operational benefits”), and benefits that accrue through better process accuracy and visibility.

An activity-based approach was used to assess the operational benefits. In particular, receiving and shipping activities, along with the related administrative processes, have been split into a hierarchy of elementary activities. Then, the impact of RFId in terms of reduced resource requirements has been assessed. For the sake of illustration, the model regarding the “Shipping of full RTIs from the retailer DC to the stores” will be detailed here (cf. Figure 2). After completing the picking activity, the worker registers the number of RTIs that have been used. Then, two documents are prepared and printed: the shipping document and a control document, which contains the typology and the total number of RTIs that are going to be shipped to the stores. Before the goods are loaded on the truck, a worker counts the number of RTIs that have been used, and compares it with the data reported in the control document. If needed, he corrects the document with the right number of RTIs. Thanks to RFId technology, the assets counting can be automated. For the interested reader, the complete model (i.e. description of the activities, inputs, formulas) is available on request.

RETAILER DC				
Macro-activity	**Activity**	**Elementary activity**	**Input**	**Formula**
Shipping - Full RTIs (t_ship_full)	Registration in the Information System (t_write_IS)	Write the number of RTIs in the Information System (t_write_IS)	Time to register the data in the IS (t_IS)	t_ship_full = t_write_IS + t_doc + t_cont t_write_IS = (t_IS * n_ord) / η t_request = (t_find_sd * n_truck) / η t_print_sd = (t_pr * n_truck) / η t_print_cd = (t_pr * n_truck) / η t_move = (t_ld * n_truck) / η t_count = (t_RTI * n_RTI) / η
			Workforce usage factor (η)	
			Number of orders per year (n_ord)	
	Preparation of the shipping documents (t_doc)	Request to the Information System (t_request)	Time to find the shipping document in the IS (t_find_sd)	
			Workforce usage factor (η)	
			Number of trucks exiting from the retailer DC per year (n_truck)	
		Print the shipping document (t_print_sd)	Time to print a document (t_pr)	
			Workforce usage factor (η)	
			Number of trucks exiting from the retailer DC per year (n_truck)	
		Print the control document (t_print_cd)	Time to print a document (t_pr)	
			Workforce usage factor (η)	
			Number of trucks exiting from the retailer DC per year (n_truck)	
	Controls (t_cont)	Move to the loading dock (t_move)	Time to move to the loading dock (t_ld)	
			Workforce usage factor (η)	
			Number of trucks exiting from the retailer DC per year (n_truck)	
		Counting (t_count)	Time to count an RTI (t_RTI)	
			Workforce usage factor (η)	
			Number of RTIs shipped to the stores (n_RTI)	

Fig. 2. The benefits evaluation – Shipping of full RTIs from the retailer DC to the stores.

As regards the benefits enabled by the increased process accuracy and visibility, a brief description of those which have been quantified is reported here.

- **Shrinkage.** RFId-enabled automatic identification helps reduce process errors and improve asset visibility, leading to a reduction in penalty costs when an RTI is not found. In fact, when an RTI is lost, the supply chain node which is in charge of it has to pay a pre-defined amount of money to the asset owner.
- **Contentious Issues.** “Lost RTIs” means that contentious issues are likely to arise between the involved nodes. In fact, it is not easy to understand when and where the loss occurs, since currently the RTIs are not individually tracked. The RFId-enabled automatic identification of all the RTIs supports their tracking and tracing, thus reducing the insurgency of contentious issues.
- **Better Process Control.** The automatic identification allows to introduce new counting controls, which today are not performed because of time (and cost). This benefit has been assessed in terms of amount of time (and related costs) which would have been needed in the base-line technological scenario to perform the RTI counting enabled by RFId.

In addition to the benefits that can be quantitatively assessed, others are of a more qualitative nature. For example, the RFID-enabled tracking and tracing of all the RTIs allows to create a database which contains the current location of all the assets. This allows to improve the rotation of RTIs, as well as to better plan their maintenance.

4.4 The Assessment of Capital and Operational Expenditures

The implementation costs of an RFId project include both the initial investment (Capital Expenditure, CapEx) and the recurrent annual costs (Operational Expenditure, OpEx). More specifically, CapEx includes the costs of hardware (e.g. readers, antennas, re-usable tags), software (middleware and software development/integration), and project management (design, implementation, test and change management, project management). The OpEx includes the maintenance of the RFId infrastructure and the annual training costs.

5 The Application of the Model

5.1 The Parameters

The model has been applied to the fruit and vegetable supply chain of a prominent Italian retailer, i.e. Nordiconad. The main flows which characterize the supply chain are reported in Table 1.

Table 1. The RTI flows (thousands of RTIs).

		Retailer DC			**Carrier**			**Store**		
		C1	*C2*	*C3*	*C1*	*C2*	*C3*	*C1*	*C2*	*C3*
Inbound pallets (kpallets/year)	Full	30	30	60	35	115	210	35	115	210
	Empty	35	115	210	35	115	210	-	-	-
Outbound pallets (kpallets/year)	Full	35	115	210	35	115	210	-	-	-
	Empty	30	30	60	35	115	210	35	115	210
Inbound rolls (krolls/year)	Full	-	-	-	145	460	860	145	460	860
	Empty	145	460	860	145	460	860	-	-	-
Outbound rolls (krolls/year)	Full	145	460	860	145	460	860	-	-	-
	Empty	-	-	-	145	460	860	145	460	860
Inbound bins (kbins/year)	Full	6	6	11	6	6	11	6	6	11
	Empty	6	6	11	6	6	11	-	-	-
Outbound bins (kbins/year)	Full	6	6	11	6	6	11	-	-	-
	Empty	6	6	11	6	6	11	6	6	11
Inbound crates (kcrates/year)	Full	4,200	4,200	8,000	4,200	4,200	8,000	4,200	4,200	8,000
	Empty	4,200	4,200	8,000	4,200	4,200	8,000	-	-	-
Outbound crates (kcrates/year)	Full	4,200	4,200	8,000	4,200	4,200	8,000	-	-	-
	Empty	4,200	4,200	8,000	4,200	4,200	8,000	4,200	4,200	8,000

Three different scopes of analysis have been considered, which differ in terms of costs and benefits:

- *Case 1 (C1)*, in which the RFId project involves only the sub-part of one retailer DC that is in charge of managing the fruit and vegetables, and the carriers and stores who receive these products. The RTIs which are used to transport all the other products are not provided with RFId tags, and the related activities are not considered.

- *Case 2 (C2)*, in which the RFId project involves one retailer DC, which adopts the technology to support not only the management of the RTIs used to transport fruit and vegetables, but also of those which are used to transport all the other grocery products. All the carriers and stores who receive products from the considered DC are included in the analysis.
- *Case 3 (C3)*, in which the retailer adopts RFId technology in all its DCs to support the management of all RTIs (both those which are used to transport fruit and vegetables and those which are used for other grocery products), including the DCs which do not manage fruit and vegetables. All the carriers and stores who receive the products from the retailer DCs are considered.

The profitability analysis compares the RFId scenario with a base-line scenario (B), whose main performance parameters are reported in Table 2. As regards the RFId scenario, two different identification solutions can be used accordingly to the facility needs, namely RFId gates or handhelds. For sake of illustration, the RFId gates are used to identify the RTIs entering in (or exiting from) the retailer DCs, while the RFId handhelds are preferred in the points of sale because of their higher flexibility. These two solutions differ in terms of time to identify the RTIs (cf. Table 2).

Table 2. The main performance parameters.

	Base-line	RFId	
		Gate	*Handheld*
Time to identify all the crates/bins on a pallet/roll (s/pallet; s/roll)	145	7.5	15
Time to archive the control documents (minutes/day)	90	0	
% errors in the control documents prepared by the retailer DC	2%	0%	
% errors in the control documents prepared by the store	5%	0%	

5.2 The Results

Figure 3 shows the benefits enabled by the RFId adoption, for the three considered scopes of analysis ("*Case 1*", "*Case 2*", "*Case 3*").

First, the RFId adoption allows to achieve both significant productivity benefits, which range from 260,000 €/year in "*Case 1*" to 880,000 €/year when all the products and distribution centers are impacted by RFId ("*Case 3*"). Second, it yields also substantial benefits enabled by the increased process accuracy and visibility, which range from about 100,000 €/year in "*Case 1*" to 475,000 in "*Case 3*". Therefore, the total benefits range from 360,000 €/year to more than 1,350,000 €/year.

Interesting results emerge from the breakdown of the benefits by activity and by supply chain stage. Overall, the supply chain members enjoy different benefits. More specifically, it is the retailer DC that reaps most of the benefits, significantly reducing the costs of both receiving the empty RTIs from the stores and performing administrative activities. Shrinkage and contentious issues reduction is significant too. As regards the stores, in the base-line scenario the most critical activity is to ship the empty RTIs to the retailer DC, since every error would lead to a contentious issue.

Therefore, most of the benefits are related to the automatic counting and the contentious issues reduction. The benefits achieved by the carrier, instead, are mainly related to the possibility of eliminating the controls performed when receiving the RTIs, because RFId technology enables a more objective and accurate measure of the number of received assets.

Looking at the supply chain as a whole, the receiving and administrative activities reap most of the total benefits. The contentious issues reduction and the improved process control are significant too.

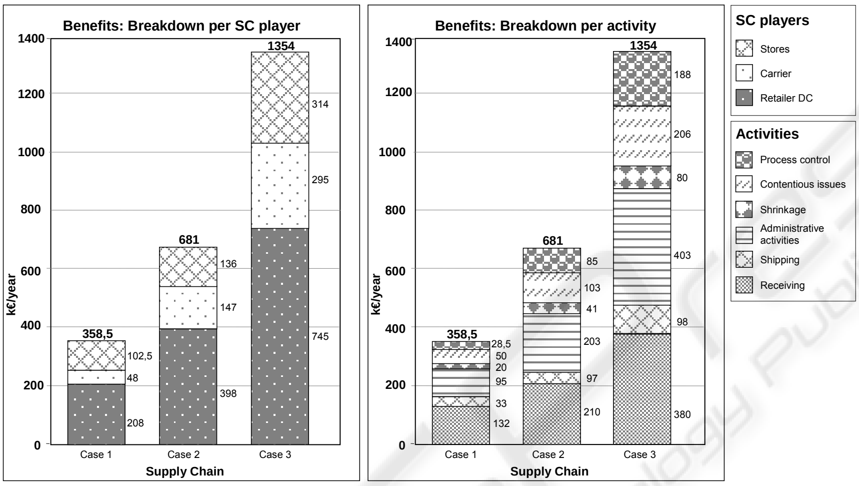

Fig. 3. The results of the model – The benefits in the RFId scenario.

Table 3 reports the Capital and Operational Expenditures incurred by the supply chain members.

Table 3. CapEx and OpEx in the RFId scenario.

	Retailer DC			Stores			Supply Chain		
	C1	*C2*	*C3*	*C1*	*C2*	*C3*	*C1*	*C2*	*C3*
CapEx (k€)	**733**	**827**	**1,738**	**214**	**275**	**584**	**947**	**1,102**	**2,322**
RFId HW – Tags	685	690	1,350	-	-	-	685	690	1,350
RFId HW – Other	37	114	328	190	230	486	227	344	672
RFId SW	10	20	50	15	35	75	25	55	105
Training	1	3	10	9	10	23	10	13	23
OpEx (k€/year)	**45,6**	**82,3**	**165,5**	**18**	**25**	**52**	**63,6**	**107,3**	**217,5**
Maintenance – HW	30	65	130	15	18	39	45	83	169
Maintenance – SW	1,5	3	7,5	2,2	6	11	3,7	9	18,5
RFId tags on new RTIs	14	14	27	-	-	-	14	14	27
Training to new people	0,1	0,3	1	0,8	1	2	0,9	1,3	3

As stated before, each RTI is provided with a re-usable RFId tag, whose cost depends on the specific RTI. More specifically, the tags which are put on pallets, crates and bins cost about 0.2€/tag, while special tags are used on the “metallic” roll containers (10 €/tag).

The payback time and the Net Present Value (NPV) have been computed, as shown in Table 4, taking into account a “transitory period” (1 year) during which we have assumed that the benefits can only be partially achieved. The Net Present Value has been computed using a five-year time horizon and a discount rate of 4%, whereas the payback time is based on non-discounted cash flows.

If we consider only those RTIs used to transport the fruit and vegetable flows of a single distribution center ("*Case 1*"), a positive Net Present Value cannot be realized from a supply chain perspective, because only the carrier benefits from the technology adoption. But when we consider all the RTIs used by one ("*Case 2*") or more ("*Case 3*") retailer DCs to transport all the grocery products, the investment becomes profitable from a supply chain perspective. Moreover, Table 4 shows that the best adoption strategy for the retailer is to adopt RFId in one Distribution Center, which manages both fruit and vegetables and other products. The results obtained by the retailer DC in "case 3" are only apparently inconsistent. We could expect the investment profitability to be similar to that calculated in "*Case 2*", but the lower investment profitability in "Case 3" is due to the fact that some of the additional DCs included in the analysis do not manage fruit and vegetables (cf. Section 5.1), which require most of the efforts in the base-line scenario.

Table 4. The investment evaluation – NPV and Pay-back time.

	Retailer DC			**Carrier**			**Stores**			**Supply Chain**		
	C1	*C2*	*C3*	*C1*	*C2*	*C3*	*C1*	*C2*	*C3*	*C1*	*C2*	*C3*
NPV (k€)	-263	180	-33	138	385	755	-27	-105	-112	-151	460	610
Pay-back time (years)	7.7	3.7	6.7	0	0	0	5.3	8.0	5.8	5.6	3.1	3.6

A sensitivity analysis has been carried out in order to analyze how the results change in function of the most significant parameters. In particular, different reading time performance of the RFId technology (± 100%) and different costs of the RFId tags (± 20%) have been considered. The analysis proved that, considering a lower performance level and a higher tag costs, the investment remains profitable in "*Case 2*" and "*Case 3*", with a pay-back time of 4.0 and 4.7 years respectively. Moreover, when best technology performance and lower costs are considered (which can jointly be obtained thanks to a technological improvement and/or a more accurate analysis of the best tagging position), the investment becomes profitable also in "*Case 1*", with a pay-back time of about four years.

6 Conclusions

This paper shows that RFId technology has the potential to improve the efficiency and accuracy of the Returnable Transport Items in the fruit and vegetable supply chain. The results are strongly dependent on the adoption level in terms of facilities and products which are supported by RFId technology ("*Case 1*" vs. "*Case 2*" vs. *Case 3*"). In fact, while the application of RFId to support only the management of RTIs which are used to transport fruit and vegetables seems to be unprofitable, a positive Net Present value is obtained when an entire facility is considered.

The model presented in this paper has a few limitations. The most important is that it does not consider the pooling company and the producer, both of whom could significantly benefit from RFId adoption. Moreover, a wider sensitivity analysis should be performed, since only the identification time has been considered so far. Moreover, the application of the model to other retailers would allow to compare the project profitability in different real contexts, thus providing interesting information. Finally, only some of the accuracy and visibility benefits have been quantitatively assessed. Future developments of the research should overcome these limitations.

Acknowledgements

We would like to thank GS1 Italy and Nordiconad for their valuable support during all the phases of the research project.

References

1. ISO: ISO TC104 – Supply chain applications of RFId – Returnable Transport Item, ISO/CD 17364, ISO 2005
2. Wolfram G.: RFId/EPC value-added applications in the supply chain at Metro Group, RFId/EPCglobal in Europe, Düsseldorf, 2006
3. RFId-IPO, Italian Permanent Observatory on RFId Technologies: RFId: alla ricerca del valore, research report (in Italian), 2007
4. Mooney J.G., Gurbaxani V., Kraemer K.L.: A Process Oriented Framework for Assessing the Business Value of Information Technology, Proceedings of the 16th Annual International Conference on Information Systems, 2001
5. Srivastava B.: Radio Frequency ID technology: the next revolution in SCM, Business Horizons, Vol. 47, No. 6 (2004), 60-68
6. Helders B., Vethman A. J.: Beyond 2005: how RFId will change the global Supply Chain, Chain Store Age, Vol. 79, No. 12 (2003), 39-48
7. Curtin J., Kauffman R.J., Riggins F.J.: Making the 'MOST' out of RFId technology: a research agenda for the study of the adoption, usage and impact of RFId, Information Technology and Management, Vol. 8 (2007), 87-110
8. Wu N.C., Nystrom M.A., Lin T.R., Yu HC.: Challenges to global RFId adoption, Technovation, Vol. 26, No. 12 (2006), 1317-1323
9. Chappell G., Ginsburg L., Schmidt P., Smith J., Tobolski J.: Auto-ID on the Line: The Value of Auto-ID Technology in Manufacturing, Auto-ID Center, MIT, 2003
10. Hardgrave B.C., Waller M., Miller R.: Does RFId reduce out of stocks? A preliminary analysis", ITRI, University of Arkansas, 2006
11. Atali A., Lee H., Ozer O.: If the inventory manager knew: value of RFId under imperfect inventory information, Stanford University, 2004
12. Wang S., Liu S., Wang W.: The simulated impact of RFId-enabled supply chain on pull-based inventory replenishment in TFT-LCD industry, International Journal of Production Economics, Vol. 112, No. 2 (2008), 570-586
13. De Kok A.G., van Donselaar K.H., van Woensel T.: A break-even analysis of RFId technology for inventory sensitive to shrinkage, International Journal of Production Economics, Vol. 112, No. 2 (2008), 521–531
14. Subirana B., Eckes C., Herman G., Sarma S., Barrett M.: Measuring the impact of information technology on value and productivity using a process-based approach: the case of RFId technology, MIT, 2003