RADIO FREQUENCY IDENTIFICATION: TECHNOLOGIES AND APPLICATIONS IN LOGISTICS

Svetlana Nikoličić [a*], Jasmina Pašagić Škrinjar [b], Dejan Mirčetić [a], Predrag Atanasković [a]

[a] University of Novi Sad, Faculty of Technical Sciences
[b] University of Zagreb, Faculty of Transport and Traffic Sciences

Abstract: *Monitoring and management of complex logistics processes could not be realized without appropriate information and communications systems. A well-structured and technically safe information flow of valid data has come to form an essential element for designing and extending materials-flow systems. Radio frequency identification technology (RFID) plays an important role in supporting logistics and supply chain processes due to their ability to identify, trace and track information throughout the supply chain. The paper focuses on the technical characteristics of RFID systems, their opportunities, challenges, barriers and standards. Furthermore, the paper discusses the results of RFID application in the realization of logistics processes. The main goal of the paper is to stimulate further interest in this area by providing a comprehensive review of RFID application, which will be a good resource for researches interested in the RFID systems.*

Keywords*: logistics, RFID, supply chain management*

1. INTRODUCTION

The realization and management of logistics processes includes a number of technologies, primarily transport, reloading, storage and information technologies. All of them are essential for logistics, and their development in the previous period has caused reoccurring waves of changes in the organization and management of logistics processes. Technical possibilities of the means in transport, storage and reloading in the area of the goods flow have been greatly researched and employed; hence, the directions for further rationalizations in this area are being investigated in the new approaches for the realization of logistics processes and in new strategies of logistics management. The important factor in the creation and realization of new logistics strategies are the contemporary information and communications technologies. Their significance is even greater considering that the companies in the last decade have begun to be more and more oriented towards their key competencies, causing in its turn the trend towards the outsourcing of business processes, and thus enlarging the network for adding new values and increasing the logistics cross-section between partners exchanging goods and information (Nikoličić, 2011).

Manifold transport, reloading and storage processes during the logistics process realization

* cecan@uns.ac.rs

demand for a fast goods identification and stock updates. The unambiguous identification of goods and the related data exchange have presented the basis of the efficient processes in logistics process management and control (Guenthner, 2004). Identification systems are only the first step, i.e. the link between goods and computers, directly linked to the supervising computer system for process management. In this paper, the emphasis is on the auto-ID systems that enable wireless option for accepting and transferring data using radio waves, i.e. systems for radio frequency identification (RFID). The paper presents the technical properties of RFID systems, as well as the advantages, drawbacks and examples of the RFID application in the logistics process realization. The main goal of the paper is to stimulate further interest in this area by providing a comprehensive survey of the RFID application.

2. RFID TECHNOLOGY

RFID technology enables automatic and non-contact identification of objects, people and animals using radio signals being emitted at a certain frequency (VDI nachrichten, 2004a). A typical RFID system consists of tags and readers, application software, a computing hardware, and a middleware. Tag (transponder) is the basic component of the RFID system, presenting in the essence the microprocessor chip and containing the electronically memorized data. Generally, when a tag is in the field of a RFID reader, it is activated and it transmits the data stored on its memory chip to the reader. The tag has an identity that can be broadcast to a reader that is operating on the same frequency and under the same tag protocol. The reader then converts the radio waves returned from the tag into digital data and forwards them to a computer system that collects and processes them (Figure 1).

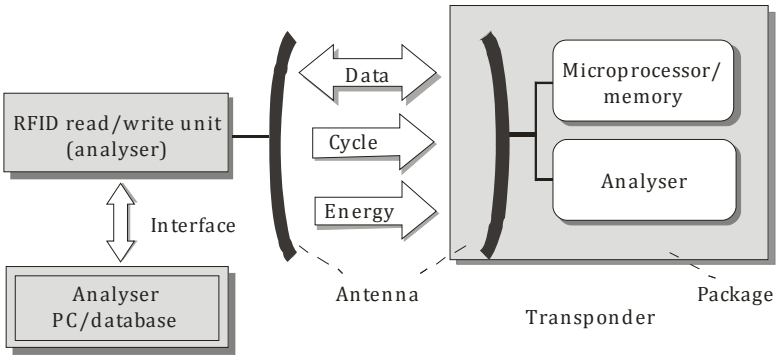

Figure 1. Functioning principle of an RFID system (VDI 4472, 2006)

RFID systems have more determinants for differentiation and for establishing the area of their application. The following can be stated as the basic determinants of an RFID system: working frequency (LF, HF, UHF, MF), tag power source (active, passive, semi-passive tags), data input possibilities (read only, write once read many, read-write), memory capacity (from 32 Byte to 1 kByte), reading range (from 0.15m to 30m), etc. The frequency on which the RFID system operates designates the intensity of the radio waves used to transmit information and is a key factor in determining the performance levels and applications for the system (Tajima 2007). All this demonstrates the wide range of the RFID and the possibilities for their implementation into diverse areas (animal detection, logistics and supply chain management, waste management, museums, retailing, etc.). The general RFID system characteristics may be the following: high reading velocity and relatively large distance between the reader and the object to be identified; possible reading outside the visual range; simultaneous multiple data reading; automated data registration; identification and monitoring of individual products, containers and means of transportation, even in extreme conditions; possibility to memorize great amounts of data and the communication directly on the product level; decentralized data storage in the product itself; ability of writing information on the tag (depending on the type), etc. (VDI nachrichten, 2004a).

In addition to the above advantages of RFID system, there are also some barriers: the price, the share of mistakes, radio interference, removal problems, underdeveloped conscience of users, security and privacy issues. The following are four frequently cited barriers for widespread adoption of RFID: a lack of return on investment (ROI), technical risks, the popularity of bar codes, and privacy concerns (Tajima, 2007).

3. RFID SYSTEMS IN LOGISTICS

Although commercial applications of RFID date back to the 1960s, the use of RFID in supply chain management is relatively new (Tajima, 2007). At the beginning of this century, a significant stimulus for developing and introducing RFID in supply chain management came from the world's leading retailers such as Metro Group, Wal-Mart, Tesco, Carrefour, etc. Since 2002, the reoccurring paper topic in European journals has been related to the diverse aspects of the RFID application in logistics (Behrenbeck, 2004). This section comprises from two parts: the first part provides a short overview of academic publications where diverse aspects of the RFID system application in logistics were researched, while the second part presents the description of the examples of the RFID system applications in practice.

3.1 RFID researches

The research in the application of RFID in logistics and supply chain management are diverse and oriented towards different segments: technical problems related to the implementation, methodological procedure of implementation, as well as the evaluation and determination of the technology usefulness for different participants in the supply chains. The overview and the systematization of academic literature are provided by several authors (Tajima, 2007; Sarac et. al., 2010; Zhu et al., 2012). Very interesting and useful is the general classification of papers according to the most used approaches and the main topics of the publications on the RFID applications in a supply chain (Sarac et. al., 2010), presented in Table 1.

Table 1. Types of publications

Publications	Most used approaches	Main topics
Practical papers	Pilot projects Case studies ROI analyzes	Inventory management Logistics and transportation Assembly and manufacturing Asset tracking and object location Environment sensors
Academic papers	Analytical approach Simulation approach Case studies ROI analyzes Literature review	Inventory inaccuracy Bullwhip effect Replenishment policies

Bottani and Rizzi (2008) quantitatively evaluated the effects of the RFID technology and the EPC system (Electronic Product Code) on the major processes of fast moving consumer goods supply chains. A feasibility study was conducted on the basis of qualitative and quantitative data related to the logistics processes of all participants. As a result, it was concluded that the use of the RFID technology on the level of pallets produced positive effects from the income aspect for all participants in the chain; on the other hand, at the product level, negative economic results were recorded.

Ustundag and Tanyas (2009) used a simulation model for the calculation of the expected benefits of the RFID systems integration into a three-stage chain. It was concluded that the value of products and demand had a significant impact on the expected benefits of the RFID

technology. The increase of the product value increased the total chain cost savings, and the increased demand uncertainty reduced savings in the chain.

In order to improve the inventory management, an experiment was performed for determining the improvement in the inventory record accuracy before and after implementing RFID-enabled adjustments to the inventory management system (Hardgrave et al., 2011). As a result, it was concluded that the effectiveness of the RFID tagging was not homogenous for all products. Reductions in the percentage of stock-outs ranged from 21% to 36%, depending on the category.

The Supply Chain RFID Investment Evaluation Model that is based on the classic economic order quantity (EOQ) model considers the possibilities of the RFID investments to improve order efficiency, JIT efficiency and operational efficiency (Lee and Lee, 2010). For the aforementioned efficiency factors, analytical procedures were developed to determine the optimal level of investment in the RFID.

For the practical usage, the VDI guideline (VDI 4472, 2006) can be very useful, containing, apart from the detailed costs list, a list of individual process effects in the supply chain. The essential prerequisite for the implementation of the RFID technology are the positive economic effects; in that sense, the recommendation is to have a consistent and clear system for evaluation.

Kok at al. (2008) conduct break-even analysis of the RFID technology implementation focusing on the costs resulting from inaccurate inventory data. The break-even analysis also includes the main factors like: technology costs, length of review period, etc. The results are presented with exact analytical expressions for the cost-effective price of RFID, and show that there is a high correlation between the cost of RFID technology and the value of products lost.

Between the participants in the supply chains there are disagreements on the necessary investments and achieved benefits from the RFID technologies (Karkkainen and Holstrom, 2002). Most savings are achieved in the retail, while the suppliers are burdened with the costs of introducing RFID (Smith, 2005).

3.2 RFID in practice

The potentials of the RFID applications in logistics processes are manifold; however, there are still many barriers for the wider application in practice (e.g. necessary investments, popularity of barcodes, and question of privacy). This section of the paper describes the experiences of companies that implemented the RFID for logistics processes monitoring and management.

In 2003, Metro AG began the project named Metro Extra Future Store that implemented and tested the RFID technologies in real surroundings (Behrenbeck et al., 2004). In 2004, the first phase of the implementation of this system was completed, and the test demonstrated that the costs of out-of-stock, ranging from 9% to 14%, could be reduced for 17%; thefts were reduced from 11% to 18%, and the working costs from 8% to 11%. In 2006, another 300 suppliers were included. In 2008, the RFID project was expanded to 200 Metro centres. That process included 1.3 million palettes annually (LOG.m@il Newsletter, 2008).

In Wal-Mart projects, as one of the potential options for the improvement, they investigated the influence of RFID on the out-of-stock reduction (OOS situation) that provided a number of benefits for retail, suppliers and consumers. As a result, it was concluded that the application of RFID reduced the out-of-stock for 26% (Hardgrave et al. 2005). Furthermore, the surplus of stock in the supply chain was minimized (LOG.m@il Newsletter, 2007).

Best Buy tested the RFID usage in the storage level in two distribution centres. During the testing, 70 suppliers used RFID for palettes and packaging, and the data were processed automatically in the software system for business management. Very positive results were obtained, i.e. stock in storage was reduced for 20%, while the participation of the cross-docking process was increased.

Apart from following the goods flow in order to rationalize it, RFID can be applied for security reasons as well. Hutchinson corporation, with the annual turnover of 44 million containers, introduced sensors inside and outside for every container, which could detect, among other, light, humidity, air pressure, certain chemical parameters, etc., being ready in any given moment to send an e-mail alarm to the central unit. In some ports (e.g. Los Angeles and Long Beach), the active RFID system is used for security reasons and for solving problems of the congestion in ports. All trucks entering the ports need to have RFID tags being read in entrance and exit (VDI nachrichten, 2004b).

SSA Marine, one of the leading worldwide cargo companies, introduced the RFID technology for container monitoring in several ports on the Western coast. On the container hoist, there is a reader, while the active tag is on the container, enabling the identification of the appropriate container and loading onto the appropriate truck (Voyles, 2005).

The company Iveco in cooperation with Kuehne + Nagel uses RFID to manage spare parts in the automotive sector. The system in the plant in Torino simplifies orders for parts replacements from suppliers. Kuehne + Nagel receive the parts and add EPC Gen 2 marks coded with the identification number and printed together with the barcode, hence dealers can use them for tracing and monitoring (Wessel, 2010).

DHL integrated RFID into their trucks for delivery in order to achieve faster parcel delivery. This initiative was named SmartTruck and it achieved a number of goals. They accomplished the expected savings in fuel consumption and CO_2 emission, and increased the accuracy in parcel collection and delivery (Neely, 2009).

4. CONCLUSION

RFID systems show a great potential for the improvement of processes and the reduction of costs associated with the supply-chain management. However, some of the basic problems of the RFID system application include the introduction and development costs. Opinions of experts on the implementation of the RFID systems in supply chains are still divided, though, the opinion that the time of the RFID technology is still to come seems to dominate.

The paper demonstrated the basic principles in utilizing the RFID system, together with the potential application in logistics. A short survey of published papers has demonstrated a great interest of scientists for researching diverse effects of RFID in logistics, while the examples from the practice emphasise that the RFID system application is possible in diverse companies and that it is directed towards the increase in the logistics process efficiency. It is only hopeful that this paper will represent a valuable basis for the researchers interested in researching the RFID systems.

ACKNOWLEDGMENT

The study was financially supported by the Serbian Ministry of Education and Science (Project No. TR36030).

REFERENCES

[1] Behrenbeck, K., Küpper, J., Magnus, K.H., Thonemann, V., (2004). Zwischen Euphorie und Skepsis. Logistik Heute, 12/2004.

[2] Bottani, E., Rizzi, A., (2008). Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain. Int. J. Production Economics 112, 548–569.

[3] de Kok, A.G., van Donselaar, K.H., van Woensel, T., (2008). A break-evan Analysis of RFID technology for inventory sensitive to shrinkage. Int. J. Production Economics, 112, 521–531

[4] Guenthner, W., (2004). RFID-Technologie als wegbereiter neuer Logistikstrukturen. TIL 2004, Niš.

[5] Hardgrave, B.C., Goyal, S., Aloysiu, J.A., (2011). Improving inventory management in the retail store: The effectiveness of RFID tagging across product categories. Oper Manag Res 4, 6–13.

[6] Hardgrave, B.C., Waller, M., Miller, R., Walton, S. M., (2005). Does RFID reduce out of stocks? Working Paper. University of Arkansas, Fayetteville, Arkansas.

[7] Karkkainen, M., Holstrom, J., (2002). Wireless product identification: enabler for handling efficiency, customisation and information sharing. Supply Chain Management: An International Journal, 7 (4), 242-252.

[8] Lee, I., Lee, B.-Ch., (2010). An investment evaluation of supply chain RFID technologies: A normative modeling approach, Int. J. Production Economics, 125, 313–323.

[9] LOG.m@il Newsletter (2008). Metro, 9/08.

[10] LOG.m@il Newsletter (2007). Wall-Mart will Einsatz von RFID ausweiten, 19/07.

[11] Neely, B., (2009). DHL Says Its SmartTrucks Save Money, Time and CO2. RFID Journal, Sep 30.

[12] Nikoličić, S., (2011). A contribution to the improvement in existing methods and models with a view to establishing the performance of the retail logistics system. (in Serbian). Dissertation. University of Novi Sad, Serbia.

[13] Sarac, A., Absi, N., Dauzere-Peres, S., (2010). A literature review on the impact of RFID technologies on supply chain management. Int. J. Production Economics, 128, 77–95.

[14] Smith, A.D., (2005). Exploring radio frequency identification technology and its impact on business systems. Information Management & Computer Security, 13 (1), 16-28.

[15] Tajima, M. (2007). Strategic value of RFID in supply chain management. Journal of Purchasing & Supply Management, 13 (4), 261–273.

[16] Ustundag, A., Tanyas, M., (2009). The impacts of Radio Frequency Identification (RFID) technology on supply chain costs. Transportation Research Part E 45, 29–38.

[17] VDI nachrichten, 49 (2004a). RFID Technik fehlen Standards, Berlin, Beuth Verlag

[18] VDI nachrichten 51/53, (2004b). Contanierschutz verteuert welweite Logistikketten, Berlin, Beuth Verlag.

[19] VDI 4472 (2006). Part 1, Part 2 Handbuch – Requirements to be met by transponder systems for use in the supply chain General, Berlin, Beuth Verlag.

[20] Voyles, B., (2005). SSA Marine Adds RFID to Quicken. RFID Journal, (available at: http://www.rfidjournal.com/articles/view?1488).

[21] Wessel, R., (2010). Iveco to Expand RFID System for Managing Replacement Parts. RFID Journal, (available at: http://www.rfidjournal.com/articles/view?7352).

[22] Zhu, X., Mukhopadhyay, S.K., Kurata, H., (2012). A review of RFID technology and its managerial applications in different industries. J. Eng. Technol. Manage, 29, 152–167.