RESEARCH ON THE POSSIBILITIES OF THE APPLICATION OF RADIO FREQUENCY IDENTIFICATION TECHNOLOGIES TO SUPPLY CHAIN: LITHUANIAN CASE

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Abstract. In the present article, the possibilities of the application of radio frequency identification technologies (RFID), that are one of the most innovative and currently booming technologies nowadays, in Lithuanian companies, are analysed. The application of this technology to supply chain leads to the constant monitoring of the material flow (feedstock, completing parts and production produced) and informational flow. What is more, it allows shortening the time of movement, preventing errors related to human factor and simplifying the process of the identification of objects. Considering that, the article aims at the determination of the levels of popularity and applicability of RFID technologies in the particular activities of the functional areas of the supply system of Lithuanian companies. The results presented in the article were obtained as a result of employing the methods of comparative analysis, questionnaire survey and interviewing.

Keywords: supply chain, management, RFID, technology, research.

Jel classification: M15, M16, O14, O31

1. Introduction

The rapid development of electronic media and the significant increase in their accessibility have created the opportunity to improve supply chain processes and, what is more, to reduce the costs without diminishing the quality of the product or service.

The application of electronic management tools to the management of the supply chain processes could maximize their effectiveness (Collins *et al.* 2010; Anderssenas *et al.* 2009; Davidavičienė *et al.* 2009; Davidavičienė 2008; Burges *et al.* 2006; Abernathy *et al*. 2000; Cachon, Fisher 2000). The most common problems of the supply chain are related to the lack of effective product identification and control measures in specific functional areas of supply chain; e.g., there is often a lack of consistency and accuracy in such areas as distribution of products during warehousing, supply processes during cargo transportation, and etc. Considering the facts mentioned above and with respect to the changes in the concept of supply chain management, the application of electronic media might be helpful in eliminating all of those problems and ensuring maximally smooth movement of material, informational and financial flows in supply chain (Davidavičienė, Meidutė 2011;

Barjis, Wamba 2010; Bose, Lam 2009; Kelepouris *et al.* 2007).

One of the most popular e-business management tools nowadays, is radio frequency identification technology (RFID). The main idea of this technology lays in the identification of goods, products and cargo using the means of radio frequency (Dobson, Todd 2006; Hansen, Gillert 2008; Hunt *et al.* 2008; Jones *et al*. 2004; Lee, Ozer 2007; Li *et al.* 2010).

The application of this technology to supply chain allows a continuous monitoring of material (feedstock, completing parts and production manufactured) and informational flows. Moreover, it allows shortening the time of movement, preventing errors related to human factor and simplifying the process of the identification of objects (Mehrjerdi 2010; Lumus *et al.* 2001; Mentzen *et al.* 2001).

This method is considered one of the most effective ways to improve logistics, namely for its continuous tracking option, which so far has not been possible by applying any other means (Smart *et al.* 2010; Park *et al.* 2010; Paret 2009; Ranky 2006; Schuster *et al.* 2007). RFID technology is a rapidly spreading mean.

It is believed that, in the future, this technology will completely replace the barcode technology, which was introduced about twenty five years ago, however, nowadays, in comparison to the ad-

vantages offered by RFID, it seems outdated and not sufficiently effective. The advantage of RFID is proved by the fact that such technologies are capable of recording the changes of information as they appear, thus saving a lot of time, especially considering the fact that the time is one of the most important factors related to value-added in the entire supply chain (Struker, Gille 2010; Visich *et al.* 2009; Pedroso *et al.* 2009; Wamba *et al.* 2008; Reyes, Frazier 2007; Wyld 2006).

In the present article, a particular attention is paid to RFID technology, becoming popular rapidly, as one of the most innovative solutions in organizing and managing the activities and processes of supply chain; therefore, the main objective of this article is to identify the levels of popularity and applicability of RFID technology in the particular activities of the functional areas of the supply system of Lithuanian companies.

The results presented in the article were obtained as a result of employing the methods of comparative analysis, questionnaire survey and interviewing.

2. The applicability of RFID technology in various functional areas of activity of supply chain

Vijayaraman (2006), Suhong and Visich (2006) have stated that radio frequency identification technology is a tool that is more suitable for the optimization of business management processes than for acquiring technical superiority. According to the author, in order to apply RFID technology to the optimization of supply chain successfully, it is, first of all, particularly important to examine nowadays' business processes, and then optimize them using RFID technologies.

Although, as the practice shows, the implementation of RFID technologies is related to risky and expensive investments, this technology has its specific advantages. Li *et al.* (2006), Park *et al.* (2010) have pointed out that the key advantage of this technology is the accessibility of real-time information which preconditions:

- improvements in supply chain management;
- improvements in coordination of business processes;
- accuracy in determination of the demand for goods;
- building a sense of social responsibility (natural resources are being saved);
- effective use of the industrial inventory;
- higher sales;
- lower costs of human labour force.

It is obvious that the application of RFID technology to supply chain has advantages at each its area of functional activity.

For example, Ju *et al.* (2008) has carried out a research on the possibilities of the application of RFID to the product manufacturing process; according to the author, the application of RFID technology to manufacturing process could be useful for two areas: achieving the efficient control of manufacturing processes/operations; and achieving the optimization of the entire supply chain (through the separate elements of manufacturing process, such as the increased traceability of manufacturing processes and the entire supply chain in general, availability of real-time information; more effective dissemination of information, and etc.).

The benefits of RFID in manufacturing operations become apparent when product/feedstock unloading operations are proceeding much faster and transparently. Taking into consideration that technology does not require scanning each product separately, the process of scanning does not need direct visibility; therefore, the time required for unloading processes is being saved, and all the information is being recorded to RFID tags and transmitted to the database. The loss of products during manufacturing operations is considered unavoidable, as products may disappear during the transportation process or as a result of the errors related to human factor; cases of thefts during manufacturing processes may occur as well. Therefore, according to Kayakutlu, Buyukozkan (2010), Attaran (2007), Angeles (2005) RFID helps to control the amounts of the production effectively as well as allows to track particular objects at a certain time and place.

Colins *et al.* (2010), Bottani *et al.* (2009), Kim *et al.* (2008), Cachon, Fisher (2000) have demonstrated that the benefits of RFID may affect both a particular supply chain process individually and all of the processes together. It should be noted that the effectiveness of RFID is much higher when the technologies are integrated not just into the manufacturing processes but into the entire complex of supply chain processes (Kayakutlu, Buyukozkan 2010; Angeles 2005; Jones *et al.* 2004).

Mo (2009) has carried out a research in order to determine the impact RFID technology has on supply chain, as well as the benefits it provides during the process of product realization. According to Pedroso (2009), the key advantage of this technology is the following: RFID tag does not require direct contact with the scanner, thus, the process of scanning of goods/products is proceeding faster and, as a result of this, employee productivity increases, especially, considering the fact

that the scanning process is usually being particularly time-consuming.

Table 1. The Benefits of RFID Technology for Supply Chain

Benefits	Effectiveness
More accurate demand forecasting	More efficient reserves management process
Statistical data analysis; timely submission of data; monitoring	Easier and faster way of data collection and presentation for strategic, operative and tactical planning
Transparency in supply chain	Higher level of reliability
Effective work organization	Clear organization of the processes of functional activity areas of supply chain
Effective real-time identification of errors and problem-solving	Less time consumption; faster process organization
Optimal routing	Speed of proceedings
Supply chain process integration	The increase of supply chain efficiency as a result of the processes integrated
Lower losses	Lower costs; higher profits; better provision

Pedroso (2009) have particularly emphasised the fact that the application of RFID technology leads to the possibility to minimize the number of employees thus saving costs, as applying this technology, most processes become fully automated; e.g., the automatic gate control detects whether the vehicle is allowed to enter the territory or not automatically, consequently, an individual worker responsible for this function is not required anymore.

Mo (2009) have also emphasised the fact that product marking with RFID tags provides a lot of opportunities for users, since it allows determining the quantity of demands, capturing sales statistics and preventing thefts.

Kim *et al.* (2008) have argued that one of the biggest problems of the entire supply chain is the lack of communication between its participants. According to the author, the application of RFID technology might lead to the synchronization and optimization of each entity's work since the integration of all supply chain entities is achieved.

If RFID technologies are implemented systematically and sustainably, the comprehensive distribution of the information is guaranteed, thus each entity might benefit from these technologies throughout the entire supply chain, as a result, im-

proving the movement of flows of products and information as well as providing the feedback to all of the participants of the chain (Table 1).

According to many authors (Li *et al*. 2010, Kayakutlu, Buyukozkan 2010, Struker, Gille 2010, Visich *et al*. 2009, Pedroso *et al*. 2009, Wamba *et al*. 2008, Reyes, Frazier 2007, Wyld 2006 Ju *et al*. 2008, Angeles 2005, Jones *et al*. 2004), the development of supply chain activity using RFID technologies could help to optimize both the work of each part of supply chain individually and the work of the entire supply chain, which is achieved by the effective spread of real-time information throughout the entire supply chain.

3. The research on the level of the application of RFID technologies in Lithuania

In order to evaluate the experience of the application of RFID in Lithuania in detail and identify the practical benefits of this technology, the empirical research has been carried out.

The aim of this research was to analyse the experience of the application of RFID to supply chain management as well as general attitude towards it in Lithuanian companies.

The research was carried out in 2010, applying the methods of questionnaire survey and unstructured interviewing. During the research, 114 companies were investigated.

The first part of the research was the questionnaire survey. The questionnaire was composed of the following types of questions: open-ended, when the respondent has free answer options; semi-open-ended, when the respondent either forms the answer individually or selects it from the given options; and closed-ended questions, when the respondent selects the answer from the given options.

The second part of the survey was the structured interview.

Interview could be used as an additional tool to complement other research methods and specify information. It belongs to the category of qualitative research. Qualitative research may also be treated as interpretative one, emphasising the desire of researchers to interpret the phenomena according to the point of view provided by the people researched. Considering the quantitative approach to the study, the research is usually aimed at confirming the hypothesis, whereas, in case of applying the qualitative approach, the explanations arising from the analysis of the situation are seen as more preferable ones. Qualitative research is characterised by flexibility and inductive analysis of data, considering inductive logic of the

investigator as one of the characteristics of the qualitative research, as it is not being dependent on the hypothesis. Flexibility characterizes qualitative research as being unstructured one, without a standard research structure which is applicable to any research environment. It could be made structured later; however, it should be carried out systematically and accurately.

In the present case, this method was chosen in order to investigate the existing situation at the particular consumer market; i.e., to analyse the experience of the participants of supply chain in applying RFID, evaluate their opinions on these technologies and identify deficiencies which might be helpful in providing a guidance for the further development of these technologies with respect to their users.

A qualitative research was chosen in order to identify the opinion of qualified specialist on the benefits of the technology as well as on various aspects related to it. The quality of the answers provided by experts having a good understanding of supply chain management was more important for the results of the research than the number of the respondents. Questionnaire survey was aimed at identifying the opinion of the existing and potential users of RFID on the processes and methods of electronic management taking place in their companies, their disadvantages and problems related to the implementation, integration and operation of electronic devices; what is more, it was tried to identify the expectations of the target groups, which would be completely consistent with the specificities of their activity.

4. Analysis of the results of the questionnaire survey

One of the most important objectives of the survey was to identify the type of company the respondents represented according to its activity. The results of the survey have shown that, of all 114 companies participated, 14.3 % of the respondents were engaged in supplying, 14.3 % − in manufacturing, 21.5 % − in logistics service, 21.5 % − in retail trade and, finally, 28.6 % − in wholesale trade (Fig. 1).

Only 21.5 % of the respondents have indicated that they were using radio frequency identification technologies in their activities.

33.3 % of the companies using RFID were engaged in wholesale trade, 33.3 % in retail trade and 33.3 % in logistics services; thus, the results of the survey have shown that RFID technologies are not popular among the Lithuanian manufacturing companies.
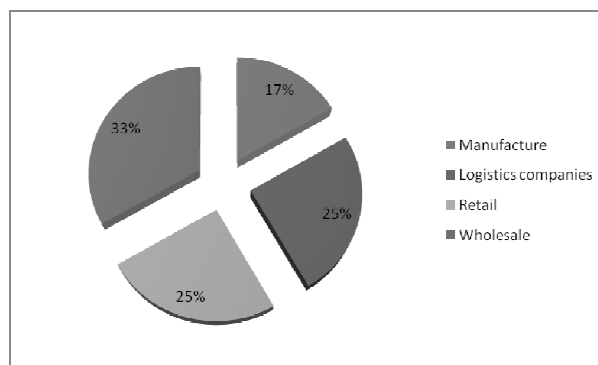

Fig. 1. Percentage Distribution of the Respondents According to Their Companies' Activities

It was estimated that 71 % of the respondents believe that the application of RFID technologies to their activity helps to optimize certain processes, and 28 % of the respondents think that RFID technologies might be useful in their activities as well.

Identifying the type of activities in which the companies surveyed are using RFID technologies (in this case, it was possible to select several answers), it was estimated that:

- 92.9 % of the respondents believe that RFID technologies are significant for tracking the products during their transportation processes;
- 85.7 % of the respondents find it particularly relevant to the identification of products;
- 85 % of the respondents think that RFID is helpful in the improvement of service quality;
- 83 % of the respondents believe that RFID is required for accurate statistical data analysis;
- 79 % of the respondents find the application of RFID important for the efficient product loading/unloading processes;
- 64.2 % of the respondents believe that RFID technologies are useful for product warehousing processes;
- 72 % of the respondents find RFID beneficial in cooperating with other participants of supply chain in order to share important information;
- 35.7 % of the respondents think that RFID technologies are significant for the feedstock storage processes;
- 25 % of the respondents believe that RFID is particularly important for product tracking during the entire manufacturing process (especially considering joint products);
- 11 % of the respondents think that RFID technologies might be useful for demand/supply forecasting;

- 5 % believe that RFID technologies might be employed in order to prevent thefts;
- 2 % of the respondents think that RFID might be employed as one of the staff quality control measures.

Hence, it might be concluded that the main areas of RFID application in Lithuania are the following ones: vehicle tracking; identification of the product's location in the stock (or vehicle); loading/unloading processes; and cooperation with other supply chain participants.

The respondents were also asked to list three key benefits (real or possible ones) of RFID technologies. The answers of the respondents were summarized and presented in the table (Table 2).

During the survey, in order to identify whether RFID technology is able to resolve the problems related to the lack of information and its exchange, the respondents were offered the statements which could have been accepted or denied (the respondents were asked to express their opinion on each of the statements). There were the following results:

- 99 % of the respondents have agreed that the employment of RFID technologies in supply chain ensures timely exchange of information;
- 89 % of the respondents have accepted the fact that RFID helps to ensure an uninterrupted movement of informational flow between the participants of supply chain;
- 78 % of the respondents have mentioned that RFID technologies are helpful in directing informational flow in the point where it is required the most at the given moment (without interrupting other participants of supply chain; i.e., without overloading them with redundant information).

Table 2. The benefits of RFID in particular areas of activity of supply chain

Area of Activity	Benefits
Supply of Raw Materials	Accurate accounting; reduced number of errors; decrease in thefts; accuracy of information
Manufacturing	Constant control of raw materials and products; availability of accurate information related to products; control of raw materials during the process of manufacturing; continuous tracking of goods during the manufacturing process

End of table 2

Area of Activity	Benefits
Logistics Services	Increased automation of processes; reduced number of errors; costs saving; improved service quality; accurate information; increased potential of investment in new technologies; continuous tracking of goods; information about the goods is inserted into tags
Retail Trade	Accurate order fulfilment; improved product quality (extra product validity and quality control); accurate and complete information; continuous tracking of goods; simplified and automated procedures
Wholesale Trade	More accurate order fulfilment; reduced number of errors; tracking of products from their receipt to release; increased process automation; theft prevention; increased information on the availability of goods on stock accessibility; faster inventorization process; more effective control of goods; detailed information on products provided by tags; possibility to identify and track each unit of production

It could be concluded that, according to the majority of the respondents, RFID could be helpful in solving the problems related to the insufficient informational exchange, as the implementation of RFID technologies in supply chain ensures the periodic informational exchange as well as helps to ensure an uninterrupted informational flow between the participants of supply chain.

The survey has showed that 100 % of the respondents believe that RFID technologies could be helpful in reducing the number of errors occurring throughout the entire supply chain; they have mentioned the following advantages of RFID:

- increased automation of processes or individual operations;
- fast and effective identification of certain objects;
- fast and efficiently organized order fulfilment system;
- effective data collection;
- demand forecasting according to the data collected.

Hence, it could be concluded that, according to the respondents, the implementation of RFID in supply chain helps to reduce the number of errors

occurring as it ensures greater automation of processes, which results in reduced number of errors related to human factor, reduced number of errors occurring during storage processes (i.e., the amount, location, lack/excess, validity, etc. of goods are being exactly identified), fast and efficient process of object identification (which helps to ensure that the object reaches the destination in time), reduced thefts and etc.

The respondents have also indicated the benefits of RFID technologies for the customers of their companies, which are:

- improved product quality;
- reduced possibility of unfulfilled order;
- simplified procedures related to the payment for goods;
- reduction in final product prices;
- less possibility of thefts;
- greater accessibility of information about the products and its faster presentation to customers.

Hence, it could be concluded that the greatest benefits of RFID for the final customer are the improved product quality, exact fulfilment of the order, lower product price, easier ordering procedures, and accessible, accurate and comprehensive information about the goods.

5. Analysis of the data collected during the interview

The method of the interviewing was employed in order to indicate the attitude of Lithuanian companies towards the application of RFID to supply chain. The interview was carried out on the basis of the questions which have been offered to the respondents in advance. There were the following questions:

1. What do you think are the key criteria according to which the customer evaluates the effectiveness of supply chain?

2. Which criteria do you personally find the most important to ensure the effectiveness of supply chain processes?

3. What are the most common challenges your company faces when dealing with supply chain processes?

4. Do you think that electronic means are necessary for the efficient functioning of supply chain?

5. What kind of electronic means or e-management methods are used at your company?

6. Does your company use RFID (radio frequency identification) technology? If not, why? Are you going to implement RFID in the future?

7. What benefits of RFID technologies could you name?

8. What weaknesses of RFID technologies could you name?

9. Do you think that these technologies need further improvements? If yes, what kind of improvements?

10. How RFID technologies could be useful to your company's activity?

The results of the survey are presented in the table (Table 3) below.

To sum up, it could be stated that there might be noticed a considerable potential of the popularity of RFID in Lithuania as the majority of the respondents have mentioned a number of possible benefits of RFID for their companies. The benefits mentioned are considerably strong; e.g., the majority believe that these technologies might significantly contribute to the development of their company's activity; the improvement of the quality of the processes performed and, what is more, might help to save time.

Table 3. Summary of survey data

The Question	The Answer to the Question
What do you think are the key criteria according to which the customer evaluates the effectiveness of supply chain?	Speed; number of errors; flexibility; accuracy of the information; duration; order fulfilment; product quality.
Which criteria do you personally find the most important to ensure the effectiveness of supply chain processes?	Elimination of errors; reliability of partners; speed; quality; appropriate software and hardware; staff competency.
What are the most common challenges your company faces when dealing with supply chain processes?	Warehousing; lack of information; violations of labour discipline; technical failure; errors related to human factor; unreliable partners; lack of qualified specialists.
Do you think that electronic means are essential for the efficient functioning of supply chain?	Yes, they are.

End of table 3

The Question	The Answer to the Question
What kind of electronic means or e-management methods are used at your company?	ERP (enterprise resource planning); RFID; GPS/GSM; fuel counters; electronic gate control system; accounting management system; storage management system; route planning system; business intelligence system; automated ordering system; personnel management system; data cubes.
Does your company use RFID (radio frequency identification) technology? If not, why? Are you going to implement RFID in the future?	Yes, it does. Yes, we are going to implement it in the future. No, we are not going to use it because of the high price.
What benefits of RFID technologies could you name?	Faster and easier scanning process; possibility to load more information; easier storage accounting; fuel consumption control; real-time troubleshooting; tags do not require direct contact with the scanner; high level of product tracking.
What weaknesses of RFID technologies could you name?	Low popularity; undisclosed benefits; privacy issues; high cost; the system is easily disturbed.
Do you think that these technologies need further improvements? If yes, what kind of improvements?	Yes, they do.
How RFID technologies could be useful to your company's activity?	To optimize the process of information management.

The interpretation of the results of the interview was carried out, which helped to identify the attitude of the representatives of the Lithuanian companies towards the application of electronic means to supply chain and evaluate their experience related to RFID technologies (which was the main objective of the interview). Moreover, the factors affecting the effective supply chain processes, according to the representatives of the Lithuanian companies, were determined.

The research has also revealed the general opinion that the effective work of supply chain is the one carried out as quickly as possible and with the minimum number of errors. The customer usually judges the work of supply chain according to the visible results, such as quality, or product's delivery time. The final results depend on the number of errors; therefore, in order to minimize the number of errors, the accurate real-time information and flexibility towards the customer are required.

Effective supply chain operation slightly differs from the inside and the outside. As it has been already mentioned, the customer sees the final result−the product is being delivered during a certain period of time; consequently, the quality of the process is judged according to this. The internal process is much more complicated. In order to make a product of good quality and deliver it in time, it is important to ensure the quality of the internal processes. Software and personnel competency are the factors which contribute the most to this. Basically, the quality of the internal processes is ensured by the accuracy of information; however, the information could be efficient only if it is managed properly. High-quality hardware and software, as well as qualified personnel, ensure the purposeful information management and the smoothness of the processes. The storage problem is one of the biggest specific supply chain problems. It is obvious that the majority of the Lithuanian companies are still facing this problem; e.g., there is a lack of storage areas and the efficient system for storage accounting. The storage problem is one of the biggest challenges of supply chain work, as it does not allow making its processes done faster.

The attitude of the respondents towards the application of electronic means to supply chain was absolutely positive. The general opinion that the modern company must be innovative and implement new technologies, as only the implementation of the latest technologies may contribute to the reduction of costs without harming the quality of the product, has been proved. I was estimated that all of the companies participated in the research are using electronic means in the management of certain processes, such as, for example, warehousing, accounting, planning, control and

navigation; however, although it is obvious that the tools used do not solve all the problems, still the representatives of the companies investigated do not lack the enthusiasm in discussing the implementation of more advanced electronic means in the future.

The representatives of the companies investigated are familiar with RFID technologies; however, some of them are hesitating to implement them in their companies. Among the respondents surveyed was only one positive example of RFID use in practice. The key reasons why these technologies are entering the Lithuanian market slowly are their high price and low popularity. The benefits of these technologies are not being properly disclosed. It is obvious that without realizing the great benefits this technology might bring, it is not purposeful to invest into them. However, the respondents have mentioned that RFID could be useful for the activities in which their companies are involved. The respondents have realized the main advantages of the technology clearly enough. The ability of the technology to process information efficiently, which helps to remove errors in time, improve the processes, solve the storage problems, maintain high product quality and improve company's image in the eyes of its customers, has been particularly emphasised.

6. Conclusions

The optimization of supply chain using RFID technologies might be helpful in achieving good results, which have been shown by the benefits of the integration of RFID into supply chain, creating a significant value-added, revealed; e.g., improved product quality, order fulfilment, lower price, information about the product accessible to the final customer; whereas the satisfaction of the needs of the final customer is the main aim of the supply chain functioning. The research has shown that RFID technologies could effectively reduce the number of errors occurring in supply chain processes as the integration of these technologies influences greater automation of supply chain processes and ensures fast and effective object identification; therefore, the number of the errors related to human factor becomes lower; moreover, effective object identification allows to indicate and eliminate in real time the errors occurring.

The research has revealed the fact that RFID could help to solve the problems related to the lack of informational exchange between the participants of supply chain and ensure the feedback, as the integration of RFID into all of the parts of supply chain is beneficial for the optimization of both the processes taking place at certain stages of sup-

ply chain and the work of the entire supply chain as well, for the results of the internal processes optimized are the information spreading fast and effectively throughout the entire supply chain and the visibility of supply chain increased.

The research has also shown that the integration of RFID into supply chain could be effective only when it is applied to business processes of certain organization and is concrete and purposeful; therefore, in order to optimize the processes of supply chain using RFID, it is highly important to develop a model of the interaction of information system, which would help to form processes specific to a particular organization. Such system could be a prototype which would later develop into an electronic control system of each organization. The unified system formed and the processes developed would be optimized using RFID technologies, which would ensure transparent and optimal supply chain functioning.

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