Analysis of required investment and benefits using RFID in supply chains*

Summary: Strengthening competition, short product life cycles and technological development of information technology (IT) has changed the ways companies operate. Radio frequency identification technology (RFID) is one of the technologies whose use is being rapidly tested in many fields. At the beginning of this century, the leading retail companies, in cooperation with their suppliers, began the testing of RFID systems application in supply chains. An important component of these studies, besides the effects achieved in the supply chains, is determining the required investments. The approach for the feasibility assessment of investments in RFID systems from the aspect of logistics is presented in this paper, and the results obtained for a realistic two-stage supply chain are given as an example.

Key words: RFID, logistics performance, investment, supply chain

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1. INTRODUCTION

Use of computer and communication technology has influenced the changes in methods for the collection, processing and transfer of data between participants in the supply chain, consequently, the changes in the form of logistics management as well. Computer, communication and data storage technologies are capable of manipulating large amounts of data that can be generated at different points of the logistics processes. Costs associated with these new technologies are constantly decreasing, while simultaneously, the needs for integrating different types of systems both within and between companies continually grow.

Collection of relevant information originating from operating systems and their integration through appropriate tools, results in significant improvements for all participants in supply chains. For automatic data collection one of the technologies for automatic identification (auto-ID technology) is frequently used, which should allow rapid and accurate collection and transfer of data between participants in the logistics processes.

Unambiguous identification of products and the related data exchange represents the basis of effective management processes of complex and heterogenic logistics processes, both within the retail system and, even more so, within the whole supply chain. The past thirty years retail cannot function without bar codes, the best known representative of optical identification technologies. However, the disadvantages of this technology (bar–code technology requires visual contact for readout and is limited in terms of saved data capacity) along with trends in retail logistics, influenced the appearance of opinions that bar code technology, in terms of supply chain efficiency, has reached its maximum potential and new potential for supply chain development should be sought in the application of radio frequency identification technologies – RFID /1/.

Large retail chains such as Metro, Wal-Mart, Tesco and Target, have recognized the great potential of RFID systems, especially in managing their complex supply chains. These companies included strategic suppliers in their research, to allow phased transition of RFID technology integration using existing company systems and information and communication technology. RFID systems potentials for supply chain participants are connected to: savings in labor time and labor force, increased level of order coverage, greater product quality guarantee, higher inventory turnover, shorter delivery times, lower average and security inventory, less inventory shortages, reduced employee errors /16; 10; 11; 19; 5/. However, the adoption and introduction of this technology is accompanied by difficulties such as: cost, lack of available tags, participation of errors, radio interference, undeveloped user awareness, security and privacy protection / 15 /. As with most new technologies, initial costs of RFID systems are high, but the more companies that get involved and use this technology, the more costs will decrease. In this phase, it is difficult to predict how much the costs, even decreased, will continue to be prohibitive for companies? /3/. It should be recalled that similar problems existed when bar-codes were introduced /4/.

The focus in this paper is on the research of necessary investments for the introduction of RFID systems in supply chains. Presented in this paper is a literature review, the description of the general methodological approach for the feasibility assessment of investment and its application is illustrated on an example of a realistic supply chain.
2. Literature review

In recent years, many works were published with the analytical assessment of RFID technologies application in logistics processes. Tajima (2007) provides an overview of recent publications that handle different aspects of the value of RFID technology. Two groups of empirical research are separated. One group uses surveys and interviews to discover the general perception of businesses, scientists and consumers, and the second group uses case studies to gather information from companies to determine which areas were improved and draws conclusions on the potential benefits of RFID technologies on that basis. For analytical approach several works are presented in which mathematical models are developed for the illustration of business before and after RFID technologies introduction and assessment of RFID's value as differences in performance.

Bottani and Rizzi /2/ quantitatively evaluate the effects of RFID technology and EPC system (Electronic Product Code) on the major processes of supply chains with high consumer goods revolutions. Examined was a three-stage supply chain consisting of manufacturers, distributors and retailers. A feasibility study was conducted based on the qualitative and quantitative data related to the logistics processes of all participants. As a result, it was concluded that the use of RFID technology on the level of pallets produces positive effects from the income aspect for all participants in the chain, while at product level, negative economic results were recorded.

Kok at al. /9/ conduct break-even analysis of RFID technology implementation focusing on the costs resulting from inaccurate inventory data. The approach is flexible so it also considers potential problems (e.g. errors in reading) that occurred after the implementation of the RFID system. Included in the break-even analysis are 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.

Ustundag at al. /20/ use a simulation model for the calculation of the expected benefits of RFID systems integration into a three-stage chain. The paper examines how the value of products, delivery time and stochastic demand influence the performance of the supply chain. It was concluded that the value of products and demand have a significant impact on the expected benefits of RFID technology. The increase of product value increases the total chain cost savings, and increased demand uncertainty reduces savings in the chain. The results also indicated that all participants in the chain do not receive the same benefits of RFID systems. Costs of lost sales significantly affect the integration of RFID technology. Increases in savings for distributors and manufacturers are nearly equal to the increase of product value. Increase in delivery time reduces the overall savings for the retailer in the chain.

In VDI 4472 /21/, in addition to a detailed list of costs, an effects list of individual processes in the supply chain is given, and the specific consequences for the consumer and finance are discussed. The essential prerequisite for the implementation of RFID technology is a positive economic effect, in this regard, the use of a consistent and clear evaluation system is recommended. In implementing cost-benefit analysis, it is recommended to use RFID test results from laboratories and / or pilot applications with respect for the specifics of individual companies.

Among participants in the supply chain there are disagreements concerning the division of the necessary investments and profit from RFID technology /7, 8/. The majority of savings are realized in retail, while suppliers are burdened with the introduction costs of
RFID /15/. Suppliers will certainly make some profit (through increased sales volume realized with the reduction of stock-outs), but it is unlikely that this benefit will be high enough for them to invest in the system /22/. Research conducted by Nestle center shows that 47% of supply chain managers believe that the costs would exceed the potential benefits of RFID, while 37% believe its implementation would be lucrative /18/. This is supported by IGD’s study from 2004 /6/ which states the use of RFID systems would be lucrative on fresh and frozen food along with cold and ready meals. Sainsbury researched the potential application of RFID technology in supply chains for short-term products. The calculation included only benefits that were the result of more efficient turnover and inventory control in stores on one side, and the necessary investments in RFID technology on the other. Based on the determined savings and necessary investment, it was concluded that the payback period for the RFID system is 2 to 3 years.

3. General model for the viability assessment of the RFID system application in supply chains

Application of RFID systems in supply chains largely depends on whether this technology can create value that will justify investment and how to estimate this value.

The paper only considers the effects realized in the field of logistics. The performance of logistics processes was determined before and after the introduction of RFID systems and RFID’s value is estimated based on their differences. For this purpose, simulation models of two-stage supply chains were developed, and the following were determined as basic logistics performances: active duration of logistics processes, transportation costs, handling costs, information processing costs and costs of other activities identified in the process, costs of applied storage technology, average inventory, inventory expenses, turnover ratio and turnover time of products.

The quantification of the effects of RFID systems and the necessary investments exists to help companies in their decision making whether to invest in these systems.

3.1 Cost analysis

When deciding the implementation of RFID technology, besides the realized effects, all necessary investments in various stages of this technologies implementation should be evaluated (Table 1).

Decision making on investment in RFID technology is mostly based on profitability analysis, which generally includes the following components:

- Process and potential analysis – The use of RFID technology significantly affects the number of logistics processes in supply chains. First, the processes necessary for efficient use of RFID need to be adjusted, second, individual processes are accelerated, simplified, increased in quality or entire processes are eliminated or replaced with new processes.

Therefore, in order to evaluate the economic effects, it is necessary to perform the qualitative and quantitative identification of individual logistics activities and allocate them
to superior processes or functional areas. Simultaneously, they must be temporally and quantitatively determined.

Besides the necessary data for process-level effect calculation, supply chain level data must be determined, such as inventory data, data on availability and lack of goods in the chain (other than the above, data on lost products, or lost sales due to counterfeits can be established).

- System dimensioning – In this stage, for the scenario generation, it is necessary to define the class and type of RFID system, in order to identify the associated costs. Alternative scenarios can differ by:
  - the number of identification points,
  - number of partners involved,
  - the level facilities equipped with RFID,
  - RFID system used.

The number of readout points in the company is the result of individual objectives. Number of RFID components (antenna, reader or server) is determined by the intensity of readout requests and the required time (reader observation speed will affect the number of required components).

- Effect analysis and business case – Effect analysis is based on expected changes in every field. In this way, the dimensioning of the system can be successful or a new scenario can be planned if some processes fail to show effects through the use of RFID.

- Profit valuation / sensitivity analysis – In many cases cost calculation results are not sufficient for a well-based evaluation of potential investments. Sensitivity analysis should demonstrate how the results behave when varying different parameters.

<table>
<thead>
<tr>
<th>Table 1. Costs at various project stages /21/</th>
</tr>
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<tbody>
<tr>
<td><strong>Expense Group</strong></td>
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</table>
| The cost of materials and equipment | ● Use of consulting services  
● Attendance at seminars  
● Professional literature | ● RFID hardware (readers and antenna systems)  
● Middleware, database  
● Materials and installation services, cabling and inter-face programming  
● Materials and services for the implementation of changes  
● Employee training  
● Data medium  
● Informational materials | ● Data medium  
● Energy costs  
● Materials and services for maintenance and repair  
● Return of investment  
● Informational materials |
| Personal costs | ● Information collection  
● Analysis and concept development | ● For internal services, some of the mentioned costs  
● Project management and implementation  
● Corporate communication | ● System maintenance  
● Corporate communication  
● Project control  
● Further project development |
3.2 Research

The research comprised a two-stage supply chain involving a manufacturers finished products storage and a retail facility – supermarket. The observed product is classified within the food category, products with a short shelf-life of 30 days (this generally implies a higher frequency of deliveries consisting of smaller quantities of products). Simulation models were developed based on data collected from real business systems existing logistics processes, followed by their modification in accordance with the requirements and capabilities of RFID systems /12, 13, 14/. When forming the model, the level of product wholeness was considered. Considering the characteristics of existing processing technologies and the cost characteristics of RFID systems, in this paper the equivalent whole unit of cargo – package, was selected. Outputs from these simulation models – logistic performances, enabled the quantification of RFID systems application effects.

For the determination of necessary investments in RFID equipment, in this paper, it is assumed (Figure 1):

- The manufacturer, after completion of the manufacturing process and packaging, labels the product unit parcels with tags (because of consumer goods prices in retail, the application of passive tags is examined) (Position 2 in Figure 1); A forklift that is equipped with RFID equipment transports the formed unit parcels to the storage area, for which it receives the allotted storage position information from the company information system;
- To allow real-time connectivity between mobile devices and the company information system, RF coverage throughout the entire warehouse is required;
- The product unit packets are monitored throughout the chain, until their dissolution while filling the supermarkets retail space (position 7 in Figure 1); mobile readers register the dissolution time and automatically update the product status in the supermarkets retail space and warehouse;
- Package unit identification is done for every chain participant at entry and exit;
- For each participant, when necessary, the identification is done when crossing from one technological entity to another as well (e.g. at manufacturers, when storing packet units in the warehouse; in supermarkets, when dissolving packet units to fill the retail space).

![Figure 1. Course of products from manufacturer to supermarket](image-url)
Only investments in equipment were considered when calculating the cost of RFID technology. The basic components of RFID equipment included in the budget are: tags (passive second generation tags that work at a frequency of 860 Mhz or 960 MHz), mobile and fixed readers.

Table 2 lists the individual prices of RFID equipment taken from catalogues and price lists of manufacturers and vendors, whereby the minimum prices were entered as optimistic, and maximum as pessimistic variants. In table 3, the estimated required investments in equipment for the given supply chain are listed. Determination of the necessary investments is based on the share of the observed products trends in the total trends of individual participants. Provided in parallel are the pre-determined savings by participants (12).

Table 2. Price of RFID equipment /24; 25/

<table>
<thead>
<tr>
<th>RFID equipment components</th>
<th>Optimistic variant</th>
<th>Pessimistic variant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price (EUR)</td>
<td>Price (EUR)</td>
</tr>
<tr>
<td>RFID tag</td>
<td>0,10</td>
<td>0,20</td>
</tr>
<tr>
<td>RFID mobile reader</td>
<td>2000,00</td>
<td>2500,00</td>
</tr>
<tr>
<td>RFID fixed reader</td>
<td>2000,00</td>
<td>2500,00</td>
</tr>
<tr>
<td>RFID equipment for forklift</td>
<td>3000,00</td>
<td>5000,00</td>
</tr>
<tr>
<td>Software</td>
<td>20000,00</td>
<td>35000,00</td>
</tr>
<tr>
<td>RF coverage (€ /m2)</td>
<td>4,00</td>
<td>4,00</td>
</tr>
</tbody>
</table>

Table 3. Investment in RFID equipment for two-stage supply chain

<table>
<thead>
<tr>
<th>Participant</th>
<th>RFID component</th>
<th>Costs (EUR)</th>
<th>Savings (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Optimistic variant</td>
<td>Pessimistic variant</td>
</tr>
<tr>
<td>Supermarket</td>
<td>RFID mobile reader</td>
<td>2,50</td>
<td>3,50</td>
</tr>
<tr>
<td></td>
<td>Surface (m2)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Software</td>
<td>3,00</td>
<td>7,00</td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>5,50</td>
<td>10,50</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Tag</td>
<td>160,00</td>
<td>320,00</td>
</tr>
<tr>
<td></td>
<td>RFID equipment for forklift</td>
<td>33,00</td>
<td>55,00</td>
</tr>
<tr>
<td></td>
<td>RFID fixed reader</td>
<td>22,00</td>
<td>27,50</td>
</tr>
<tr>
<td></td>
<td>RFID mobile reader</td>
<td>44,00</td>
<td>55,00</td>
</tr>
<tr>
<td></td>
<td>Surface (m2)</td>
<td>22,00</td>
<td>22,00</td>
</tr>
<tr>
<td></td>
<td>Software</td>
<td>220,00</td>
<td>385,00</td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td>501,00</td>
<td>864,50</td>
</tr>
<tr>
<td></td>
<td>Total investment / savings:</td>
<td>506,50</td>
<td>875,00</td>
</tr>
</tbody>
</table>

Based on the above, for the optimistic variant, it can be concluded that the investment cost of RFID equipment is approximately equal to the savings achievable in one year. Meanwhile the manufacturer bears 99% of investments and receives around 51% of
savings. For the pessimistic variant of RFID equipment cost, investments in the supply chain: manufacturer – supermarket, return in a little over two years, while the redistribution of savings between the manufacturer and supermarket is required. The main disadvantage of such a calculation is that the necessary investments are determined based on the participation of observed product trends in the total trends of individual participants, and not on their overall portfolio. In further research, this limitation needs to be removed, and the necessary investments should be linked to the full portfolio (for all products that allow the application of RFID), and only then should conclusions be drawn on the viability of investments.

According to forecasts /23/, the cost of RFID equipment has a decreasing tendency, thus it can be expected for the previously expressed optimistic RFID equipment cost variant to become the realistic variant in the near future.

4. Conclusion

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

The potential benefits of RFID in supply chains are numerous and different for different participants in the supply chain. In this paper, we consider only basic quantitative effects achieved in the logistics in two-echelon supply chain. The performance of logistics processes were determined before and after implementation RFID systems. Their difference defined the effects for each participant and the supply chain as a whole. When calculating the cost of RFID technology are considered investments in equipment for each participant individually and supply chain as a whole. The results obtained in the survey agreed with the results of pilot projects in the EU.

We hope that our research and its results will help companies in assessing the viability of investment in this technology. Further research in this field should remove the limitations highlighted in this work and include the qualitative effects of RFID system application.

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