MITIGATING UNCERTAINTIES IN DECISION MAKING IN EARLY PHASES OF RFID IMPLEMENTATION

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Abstract. Radio Frequency Identification (RFID) is still a relatively new technology for many manufacturing and logistics companies. These companies experience uncertainties about RFID implementation, so they take steps to mitigate them. This article presents multiple case studies to design a conceptual framework to mitigate such barriers. The goal of this research was to test propositions that companies: often are not convinced about the maturity and performance of RFID technology; perform typical actions to test uncertainties; and need proof of the benefits of RFID technology before implementation. It was demonstrated that companies conduct proof of RFID technology activities (demonstrations and reference visits) to test RFID performance. These are required to test the technology in operation. Conclusions of this research may serve RFID systems providers and end users of technology by facilitating a better understanding of decision making processes during early phases of RFID implementation.

Keywords: Radio Frequency Identification (RFID); multiple case study; project scoping and feasibility; mitigating uncertainties

INTRODUCTION

Supply chains consist of flows of goods, data, ownership and/or responsibility, and money. Problems in supply chain management are related to improper flow of data and improper communication processes in general. Flows of goods and data should be concurrent, accurate, and trans-parent to enable decision-making based on real and accurate data – the key for successful supply chain management.

Automated identification (auto-identification) technologies eliminate communication distortions and delays or errors in data flow. One such technology is Radio Frequency Identification (RFID), which is receiving increasing interest among manufacturing and logistics companies. RFID has two key benefits; it enables data flow at the moment the flow of goods takes place – thereby eliminating communication delays, while simultaneously eliminating errors due to improper identification. RFID has wide application, but it is still a relatively new technology for many companies. This is especially true considering the Polish market. As the technology is not well-known or commonly used, companies require careful tests before they make investment decisions (Gladysz, 2014). There has been limited discussion regarding the impact of adopting RFID and how those decisions are effected by other factors (Ramanathan et al., 2014). This study aims to highlight a conceptual framework of activities taken by manufacturing and logistics companies to mitigate uncertainties about RFID implementation.

For this study, each time radio frequencies (RF) are used to identify and/or locate a tagged object, they are classified as RFID technology. RFID technology is every technology based on radio frequencies (no matter the standards) that enable the process of identification and/or location.

There are many areas of RFID applications; warehouse inventory tracking and management, manufacturing logistics, control of material flows, management of picking, receiving and shipping, process monitoring, tracking of work in progress (WIP), quality control, tool management, external supply chain management, life cycle management and return logistics (Liukonnen, 2015). Detailed description of the physics involved and RFID applications has been subject of many publications (Dobkin, 2012; Finekenzeller, 2010).

However, application of RFID technologies has not always been effective, nor economically feasible (Bendavid et al., 2009). One such analytical process uses a modular approach to early decision making and strategic assessment, addressing: 1) evaluation of strategic potential of RFID-based improvement of supply chain; 2) selection of a process for RFID-based improvement; 3) design of new and/or improved processes; and 4) evaluation of proposed RFID-based improvements (Gladysz, 2015).

RFID is an increasingly popular technology supporting supply chains and logistics (Elia and Gnoni, 2013). It is a dynamic, developing, and innovative technology, especially considering the economy of Poland (Gladysz, 2014; 2012).

RFID is a type of information and communication technology (ICT), and uses a similar implementation framework. Therefore, it is important to focus on hardware and software issues, and their integration with other ICT (e.g., enterprise re-sources planning), physical systems (e.g., dock doors), or cyber-physical systems.

Ngai et al. (2010) proposed a seven stage frame-work for RFID implementation processes: 1) project feasibility and scoping; 2) project team formation; 3) ‘as-is’ assessment; 4) process redesign – ‘to-be’ processes; 5) hardware adaption to the environment; 6) system implementation; and 7) continuous improvement. A very similar approach was proposed by Ting et al. (2013), including six stages: 1) project scoping; 2) analysis of the existing system; 3) system design; 4) prototype testing; 5) implementation; and 6) continuous improvement. These two frameworks are generic and applicable to any ICT implementation. In both processes, strategic assessments of RFID implementation in manufacturing companies are applicable (Gladysz, 2015). Key success factors for RFID implementation projects do not differ significantly from other projects and include: 1) vendor selection; 2) organizational motivation; 3) cost/benefits evaluation; 4) top management support; 5) user involvement; 6) extent of progress supervision; 7) staff competence and training; and 8) policy, structure and operation process compatibility (Ngai et al., 2012).

Numerous authors reported benefits of RFID applications in different sectors; production logistics (Zelbst et al., 2012), warehousing (Osyk et al., 2012), and external supply chains (Sarac et al., 2010). At the same time, authors identified difficulties with return on investment calculations and high costs. Based on a study of 10 companies, Mehrjerdi (2011) proposed detailed list of 79 types of possible benefits from RFID implementation. Such benefits may be summarized in two main categories; 1) increased efficiency and speed of processes, and 2) increased visibility and accuracy of processes. The benefits are substantial, especially when the flow of objects is massive and hard to manage, and/or goods are valuable, so it is necessary to identify the value of goods and de-lays or lack of information flow that lead to mis-takes and/or increased costs. Reyes et al. (2016) discussed determinants of RFID adoption stage discussing benefits (customer service, productivity, asset management and communication) and barriers (cost issues, lack of understanding, technical issues and privacy issues). They highlighted, that internal drivers, top management leadership, cost barrier and firm size are significant determinants of the stage of RFID adoption.

Although RFID is not a new technology and there are many examples of successful implementation, it is still not commonly adopted in many industries. According to Moore’s (2014) model, RFID technology is currently crossing this chasm (Roberti, 2017). However, this effort has been expected for the past 10 years (Alien technology, 2017). In many industries, early adopters still face problems with assessing potential implementation barriers. It is unclear what actions are necessary and if they would be effective. The goal of this study is to analyse examples of early adopters and examine what actions do they perform in early phases of the decision making process.

METHODOLOGY

The literature on RFID, its applications, benefits and implementation frameworks is very broad. It primarily addresses how to manage implementation projects (Ngai et al., 2010; 2012; Ting et al., 2013). Benefits and costs are widely discussed using simulation and case studies (Zelbst et al., 2012; Osyk et al., 2012; Sarac et al., 2010; Mehrjerdi, 2011). However, it is not clear what limits the implementation process in the context of manufacturing and logistics companies and why many projects are stopped during the early phases. An attempt to these problems is an aim of presented research. Research procedure is depicted on Fig. 1.

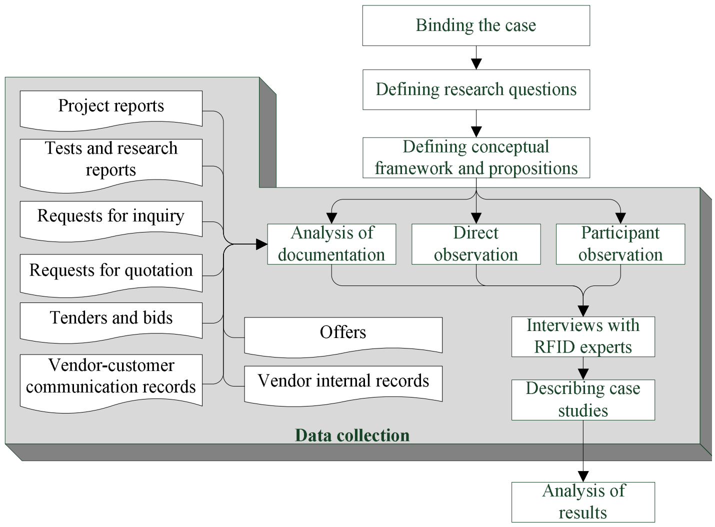

Fig. 1. Research procedure

This research focuses on three research questions:

- Q1. How do decision makers mitigate uncertainties about RFID immaturity (poor performance) in the context of selected manufacturing and logistics companies?
- Q2. Are there repetitive activities performed to mitigate uncertainties mentioned in Q1?
- Q3. Which activities were successful in terms of uncertainties mitigation mentioned in Q1?

These general questions address the “how” and “why” of the implementation process. Because behaviours of organizations involved in the study could not be manipulated, contextual conditions are relevant and are therefore addressed. Accordingly, the case study format was selected as a relevant methodology to create robust and reliable results (Yin, 2003). Multiple case studies are included to understand the similarities and differences across the field. To avoid questions too broad in scope, or a topic that has too many objectives for one study, boundaries are placed for each presented case; time, place, definition, and context (see Table 1) (Baxter and Jack, 2008).

Table 1
Boundaries of case study

Time	related to years 2011-2016
Place	limited to implementations in Poland
Definition and context	related to the RFID definition presented in the section “RFID technology”
	limited to: - manufacturing and logistics (M&L) companies of C (manufacturing) and H (transportation and storage) code of NACE (Eurostat, 2008) - medium and large companies - cases that passed first sales stages (presentations etc.), cases when customer decided to participate actively in further activities e.g. in terms of costs - cases when vendor/integrator was included in project scoping and feasibility - limited to cases when potential customers showed commitment to the project and RFID was “pulled” by them, rather than “pushed” by vendor

Three experts implementing RFID in Poland since 2006, and having implemented a dozen RFID systems from 2011-2016, were interviewed. Three propositions were formulated based on their professional and scientific experience:

– P1. Manufacturing and Logistics companies often are not convinced about the maturity of technology and want to check it in terms of read accuracy, read range, and durability.
– P2. There are typical actions performed by Manufacturing and Logistics companies to test above uncertainties (see P1).
– P3. Decision makers from Manufacturing and Logistics companies require proof of RFID technology.

Cases were examined to find appearance of some specific activities performed during early decision making; demonstrations, tests, and reference site visits. The following definitions were adopted for those activities:

1. Demonstration: a relatively short presentation (preparation plus half day or less) of technology in action for decision makers. It illustrates the general ability of the technology to operate effectively within assumed demonstration conditions;
2. Tests: evaluations required and performed at the demand of the customers who want to actively participate and analyse results in order to make decisions;
   a. Internal tests – tests performed by solution provider internally, without customer's involvement and interest in the process. These tests are common practice and necessary in any implementation, and are therefore out of the scope of this study;
   b. Tests at customer site – a type of extension of a demonstration, which is necessary from customer's point of view to examine RFID effectiveness for somehow longer period (ca. 2 weeks). Period is longer than for a demonstration and conditions of activity are much less controlled. Customer examines technology in different and sometimes fuzzy scenarios (Grabia, 2015);
   c. Laboratory tests – activity related to a very detailed analysis of technology performance is conducted to determine optimal RFID and its environment settings (chips, location, and orientation of tags, antennas, etc.) (Gladysz et al., 2017);
3. Reference site visit: an activity showing similar solutions to final users and decision makers. "Similar solution" is fuzzy term, but relates to a system operating in same branch, industry or process type, where the logic of improved process, tagged objects and reading points is understandable by decision makers and translatable to their own processes and environment. Ideally, it is a system that is applicable with some relatively minor adaptations.

A conceptual framework (see Fig. 2) was con-structed to describe who will and will not be included in study and what relationships may be present, based on logic and experience of interviewed RFID experts. That framework was con-structed using the notation industrial dynamics (Forrester, 1961).

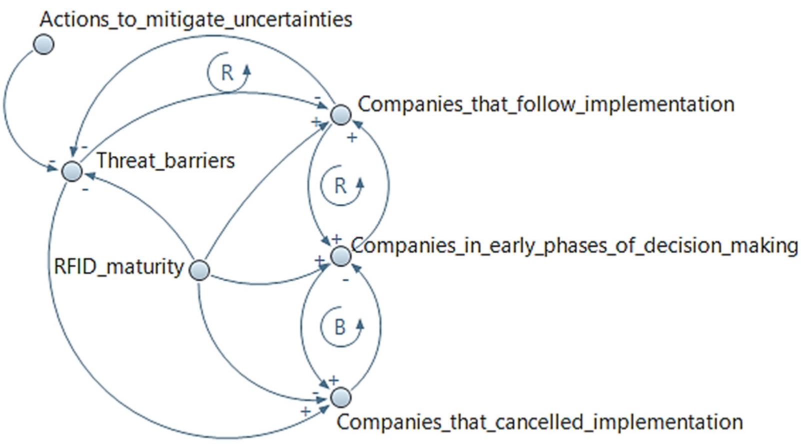

Fig. 2. Conceptual framework

“Actions to mitigate uncertainties” refers to the set of above discussed activities; demonstrations, tests, and reference visits. It was assumed that an implementation process is slowed down and/or cancelled during early phases due to the lack of proofs regarding: 1) RFID technology maturity, and 2) its capability to operate under specific conditions of the company that makes decision. It is assumed that this uncertainty is over-come by the execution of the “Actions to mitigate uncertainties”. Data sources include documentation and archival records, implementation project reports and records, test and research reports, vendor-customer communication records, requests for inquiry, request for quotation, offers, tenders and bids, and vendor internal records. Interviews were performed with two RFID experts from RFID systems vendor/integrators and decision makers at the side of RFID users. Direct and participant observations were also employed.

RESULTS

Thirteen cases were studied from 2011-2017. Description of their details is presented in Appendix A. Main characteristics of analysed case studies are collected in Table 2 and statistics in Table 3.

Table 2
Characteristics of case studies

Case	Demonstration	Tests at customer’s site	Laboratory tests on customer’s demand	Reference site visit	Status
A	+/– (hardware)	–	–	+	finished
B	+ (hardware)	+	–	–	paused for 0.5 yr
C	+ (hardware)	+/–	–	–	cancelled
D	+ (software)	–	–	–	finished
E	+ (hardware)	+	–	–	cancelled
F	+ (hardware)	+	+	–	paused for 1 yr
G	+ (hardware)	+	+/–	–	in progress
H	+ (software)	–	–	+/–	finished
I	+ (hardware)	+	–	–	finished
J	+ (software)	–	–	–	finished
K	K1. + (hardware) K2. + (hardware)	+	–	–	paused
L	–	–	–	+	finished
M	+ (hardware)	+	–	–	cancelled
Legend: +/– partial (e.g. not main hardware component); + full; – not present					

Table 3
Statistics of case studies

Characteristic		% of occurrence
Application type	Closed loop	85%
	Open loop	31%
Integration with other organizations	Yes	15%
	Partial	8%
	No, but ready	38%
	No	38%
Standards	UHF	92%
	UWB	15%
Actions present	Demonstration	92%
	Tests at customer's site	61%
	Laboratory tests on customer’s demand	15%
	Reference site visit	23%
	One or more of above	100%
	Two or more of above	77%
	Three or more of above	15%
	Four of above	0%

DISCUSSION

It was difficult to identify typical reasons for cancellations or pauses of projects because each case presented unique conditions. But high investment costs and inappropriate definition of assumptions did impact implementation, necessitating re-scoping of the project.

A few statistics from the cases analysed are of interest (see Table 2). 85 percent of cases were closed-loop applications of RFID, while only 31 percent were open loop. Case F had both applications.

There was only one case when a company was uncertain about RFID effectiveness (Case L). In this case, the implemented solution was highly similar to another implemented by a customer previously discussed. In this case, a reference site visit was the only action taken, but necessary to promote project to all phases of implementation. All other cases included actions related to testing RFID effectiveness, read accuracy, etc. RFID systems are not off-the-shelf solutions and always require customization for specific to customer needs. Considering all cases, at least one action (demonstration, tests at customer's site, laboratory tests, or a reference site visit) was always pre-sent (see Table 3). The proposition was con-firmed.

Cases were examined in terms of the use of the following actions: demonstration, tests at customer's site, laboratory tests on demand of customer, and reference site visits. Analysis confirmed that there were some activities usually undertaken to test uncertainties about RFID effectiveness. Demonstrations and tests at customer sites seemed typical, occurring 12 and 9 times respectively, in 13 total cases (see Table 3). Demonstration was not present at all in case L. Case L included a reference visit and integration with the supply chain in which the customer was already operating an RFID solution. In other cases, an RFID system was demonstrated. If demonstration of all the components was not possible or too costly, then demonstration of an information system (implemented together with RFID) was performed carefully (cases D, H, and J). However, the proposition cannot be fully confirmed, as there was no single action present in all cases. The only generalization drawn from the analysed cases is that all contained some evaluation activities, but there no single action that can be found in all cases.

All the cases included at least one of following phases: demonstration, tests at customer site, laboratory tests on customer's demand, or a reference visit. Four cases (A, D, J, and L) included only one of the listed phases, but 10 cases included two or three phases (see Table 3). There was no case including all the mentioned phases. This is likely due to the fact that reference visits were rarely possible (only three cases) and laboratory tests were rarely expected and only if a reference visit was not possible. Although reference visits were rarely possible, they seemed to be very effective to overcome uncertainties. Two cases (A, and L) of successful implementation included only a reference visit. There were cases without considered actions. The proposition was con-firmed, as companies analysed needed proof of RFID technology.

CONCLUSION

This research gave promising results in terms of positive verification of the propositions. How-ever, findings are limited due to very general sample selection. This research should proceed further, with separate focus on manufacturing and logistics companies. Due to the nature of the case study format, findings are limited to the conceptual framework. Case studies were limited to Polish companies, as it was assumed that Polish companies are unique due to their operating and economic environment. However, research should be extended to examine what similarities and/or differences exist, dependent on the economy. Nevertheless, research limited to large sized Polish manufacturing and logistics companies represents a good starting point for further study. It may provide generic guidelines for any RFID adopter whose company has similarities to those examined in this study. It may also serve as a guideline for RFID solution providers and system integrators on how to operate within similar markets.

As a result of this study, two of the three defined propositions were confirmed. One proposition could not be confirmed. It was demonstrated that a significant barrier to companies considering implementation of RFID is the lack of effectiveness in terms of read accuracy, reading distances, etc. This uncertainty results from lack of data due to low levels of adoption in Polish companies, leaving implementation to innovators and early adopters. It was demonstrated that Polish companies usually perform some typical actions to test uncertainties, including; demonstration, tests at company sites, and reference visits, to see the technology in operation. Users (decision makers and/or their advisors) want to see and actively participate in proof of RFID technology (demonstrations or reference visit) to test its performance and potential. In this regard, RFID systems do not differ significantly from other products (systems), especially those that are in the early phases of their lifecycles. Another direction of future re-search is an extension of the conceptual causal loop and design of the stock-flow model, as presented above. The purpose is to simulate the process of mitigating uncertainties in early phases of decision making.

This research needs further advancement to test differences between manufacturing and logistics companies, and assess customer points of view. To this end, interviews and questionnaires with decision makers are recommended.

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APPENDIX A. DETAILS OF CASES

Ca-se	Main products / services	Area of implement-ation	Size of a com-pany	Approx. number of tags[1]	Approx. number of reading points[a]	Tagged objects	Open / closed-loop	Integration in a supply chain	Stan-dards
A	Transportation of fuel	Rail logistics	Large	12,000	200	Rail cars	Closed	Yes	UHF EPC
B	Freight transport by road and warehousing of fresh goods	Monitoring and tracking of forklifts and temperature	Large	30	100	Forklift trucks	Closed	No	UWB RTL S
C	Paper	Monitoring of trucks in recycling plant	Large	30	4	Trucks	Closed	No	UHF EPC
D	Bulk chemicals for construction industry	Warehousin g of finished goods	Large	150,000 per year	15	Pallets of finished goods	Open	Parti al[2]	UHF EPC
E	Freight transport by road	Tracking moveable assets	Large	20,000	20	Trucks' equipment	Closed	No, but ready	UHF EPC
F	Bulk chemicals for agriculture	Storage of pallets of finished goods	Large	1,000,000 per year	100	Pallets/ bags of goods Forklift trucks	Open[3] Closed[4]	No, but ready	UHF EPC[3] UWB RTL S[4]
G	Rubber products	Quality and returns of sold goods	Large	500,000 per year	10	Item level finished goods	Open	No, but ready	UHF EPC
H	Freight transport by road; Warehousing	Warehouse of goods of customers	Large	1,000,000 per year	100	Pallets of goods Forklift trucks	Open[c] Closed[d]	No, but ready	UHF EPC
I	Freight transport by road of fresh goods	Temperatur e monitoring	Large	100,000	100	RTIs[5] Trucks	Closed	No, but ready	UHF EPC
J	Transhipment services of bulk goods	Monitoring of trucks in yard and facility	Large	100	20	Trucks	Closed	No	UHF EPC
K	Gaskets for automotive	Work in progress monitoring	Large	500	20	Kanban cards	Closed	No	UHF EPC
L	Road and rail transport of liquids	Rail logistics	Large	1,000	5	Rail cars	Closed	Yes	UHF EPC
M	Assembly of automotive subassemblies and parts	Work in progress monitoring	Large	100	10	Kanban cards	Closed	No	UHF EPC

[1] considered in roll-out
[2] via barcode on labels, but ready for full integration
[3] pallets
[4] forklifts
[5] returnable transport item