The Adoption of RFID-based Self-Check-Out-Systems at the Point-of-Sale

An empirical investigation

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Abstract. It is the aim of this paper to identify the most important factors that influence a retail company's expectations and motivations regarding RFID implementation at the point-of-sale based on empirical data. The data for our research was gathered by means of a questionnaire and analysed using a structural equation model. The results suggest that retailers which expect a high potential from RFID use intend to adopt early compared to the industry average. Interestingly, the current level of RFID capabilities does not seem to influence the expected timing of adopting RFID-based check-outs. However, our results show that companies which expect high potential benefits have significantly higher levels of RFID knowledge. Customer waiting time seems to be a main driver for companies to examine new technologies such as RFID-based check-out terminals. Retailers that recognize customer waiting time in front of the POS terminal as a problem expect higher benefits from RFID and are more innovative with regard to POS technology. Contrary to our expectations, pressure to save personnel costs did not have a significant impact on the assessment of expected benefits from RFID. This indicates that

the main driver for companies to consider RFID for automating the check-out process is customer service rather than cost savings.

1 Introduction

The technology of Radio Frequency Identification (RFID) and its applications are currently the subject of enormous interest on the part of the retail industry and beyond. Retailers such as Wal-Mart, Tesco and Metro are particularly hoping for gains in operational efficiency in their logistics processes. Until now, RFID roll-outs are limited to case and pallet level tracking, and focus on the upstream supply chain from manufacturers up to the retail shelf. The ultimate goal, however, is item-level tagging which is expected to improve product availability, increase labour efficiency, reduce theft, provide easy access to product information, enable interactive marketing applications, automate the check-out process, etc. [1, 2, 3, 4, 5].

One important field of application for RFID technology on items is point-of-sale (POS) automation. RFID technology makes the bulk identification of objects without line-of-sight possible. This has two fundamental advantages: First, it can reduce personnel costs, and second, it can improve customer satisfaction by reducing waiting lines and putting customers in control of the check-out process. Furthermore, self check-out terminals require significantly less space on the sales floor compared to traditional POS installations.

Retailers that improve the check-out process may achieve an increase in customer service and satisfaction. According to a survey by IBM and the National Retail Foundation (NRF), 76% of customers stated that the check-out process is very important when it comes to improving the shopping experience [6]. These results made the check-out process the most important step in the shopping process in this respect, ahead of product search, purchase decision, after-sales service, and pre-store information. Similar surveys by Capgemini, Intel, Cisco Systems, and Microsoft [7] and KPMG and Indiana University [8] support these findings.

There are, however, some challenges to overcome before the vision of an RFID based check-out becomes reality. Obstacles include the cost of RFID tags, RFID read rates, integration of tags into packaging, and privacy concerns. Furthermore, in order to be practicable, a critical mass of products may need to be equipped with RFID tags before retailers are likely to install RFID-based check-outs. The same phenomenon was observed during the introduction of the bar code when the sales of scanners did not take off before a minimum of 85 percent of all products were equipped with the code. This number was reached in the late 70's, i.e. more than six years after its invention [9].

Against this background, this paper presents an empirical study of factors that influence the timing regarding the introduction of RFID technology for self check-out systems at the POS. The remainder of this paper is structured as follows: First, the paper discusses the use of RFID in the retail industry with a focus on the benefits of POS automation. In the second part, our research model is presented. Then, we briefly describe the data sample, followed by research results and a discussion of

important key findings. The paper closes with a summary and an outlook on future research opportunities.

2 Background

2.1 RFID in the retail industry

RFID technology facilitates the automatic identification of physical objects by radio such as industrial containers, pallets for cargo and freight, drink cans and even people. The identification procedure operates through a transponder label that can be detected without contact or line-of-sight through a reading device equipped with an antenna. In contrast to goods identification by the standard bar code, RFID is characterised by (a) bulk read capability, (b) identification without line-of-sight, (c) unique identification of a single object, (d) data storage on the object, and (e) robustness against environmental impacts and destruction [10, 11].

RFID technology has already been in use for many years in a broad range of applications such as animal identification and asset management, i.e. typical closed-loop applications with high-value goods. In recent years, however, the focus was increasingly shifted to open-loop applications such as fast moving consumer goods (FMCG) and retail scenarios. These applications can be roughly divided into the following classes [12, 13]:

- *Supply chain execution*. Despite the introduction of the bar code and related technologies many years ago as well as industry initiatives such as Efficient Consumer Response (ECR), the retail industry has not managed to eliminate several issues, e.g. shrinkage throughout the entire supply chain and inventory inaccuracy [14]. Automatic identification technologies such as RFID are expected to further improve physical process efficiency and to positively address some of the primary causes that lie beyond the above-mentioned issues.
- *In-store operations*. A second field of application is the optimisation of processes within stores, e.g. in order to reduce out-of-stock (OOS) situations [15]. In the retail sector, 5–10% of required products are not available [16]; in the case of specially promoted products the figure is 15% [17]. For these reasons, retailers such as Wal-Mart and Metro seek to improve the replenishment-from-the-backroom process by placing RFID readers at the gate between backroom and store floor. The readers record the movement of cases between the two locations and thus deliver RFID data that allows for distinguishing between shop floor and backroom inventory [18].
- *Consumer experience*. Socio-demographic changes such as increased number of dual-income, single-parent and technology-familiar households, have significantly altered shoppers' expectations, demands and spending patterns during their traditional shopping experience [19]. Traditional factors of

competition, e.g. price level, selection and location, although still important, are no longer sufficient in order to achieve competitive differentiation. As a result, retailers concentrate on enhancing the end-to-end shopping experience aiming to win customer loyalty by inventing innovative ways of satisfying the new consumer needs [3]. In this context, examples for RFID-based scenarios are product information kiosks and self check-out systems that address the needs of the 'self-service consumer'.

2.2 RFID-enabled Self-Check-Out

In the retail environment, the POS is the place where the actual business and financial transactions take place. This is not to be confounded with the point-of-purchase, which in today's stores has moved to the shelves where customers pick their goods and put them in a shopping trolley. Usually, the POS is the check-out area where customers put all goods that they have placed in their shopping trolley onto a counter or a conveyor belt. The cashier then picks up each of the products, locates their bar code and scans each product code manually. The customer then puts all products back into the trolley or into shopping bags. At last, the payment concludes the transaction.

Modern POS systems have nothing in common with the classic cash register anymore: They contain full fledged personal computers integrated into the retailer's warehouse and supply chain management systems. Nevertheless, today's check-out areas and activities leave an enormous potential for improvements [20]. The above-mentioned sequence of activities obliges consumers to spend more time in the store than they actually wish to, by slowing down the check-out process and accumulating waiting lines. In addition to being uncomfortable for the customer, today's check-out process is labour-intensive and thus expensive for retailers. German retailers' general expenses, for example, constituted 24.1% of revenues in 2003; 41% of these costs were labour costs. Since the average retailer's operating margin has sunk to -4.2% of revenue, the need to cut down on expenses is evident [21].

Self-service solutions have been implemented for years in other industries. Prominent examples are automated teller machines in banks, self check-ins at airports and self-service payment systems at gas stations. Some self check-out systems have also been implemented in the retail industry, e.g. by Metro in Germany and Delhaize in Belgium. In Metro's so-called 'Future Store', for instance, customers may choose between traditional check-outs and bar-code-based self-scanning stations. According to a report by Metro and BCG, the acceptance of self check-outs has increased from 28% in 2003 to 54% in 2005 [22].

Fig. 1. Shopping trolley and tunnel reader in the Migros Smart Store

RFID-based self check-outs offer various additional advantages over bar code scanning. Most notably the customer does not have to scan each single item any more. RFID readers at the POS rather process the contents of an entire shopping basket within a single scan operation. A prototype of an RFID-enabled check-out solution is depicted in Figure 1. In this example from Migros, Switzerland's largest retail company, plastic baskets are scanned in an RFID tunnel reader at the POS.

3 Empirical Study

Against the background of the current interest in RFID and its use at the point-of-sale on the part of the retail industry, we wanted to get a better understanding of the drivers and influences on this specific case of technology adoption. For this purpose, we conducted an empirical study with executives from retailers in the German-speaking part of Switzerland and used the data as a foundation for our analysis. The following sections describe our approach and the main findings that could be derived from the results.

3.1 Research Model

The goal of our investigation was to analyse the most important factors that influence a company's expectations and motivations regarding RFID implementation in its own operations. Since we already had some ideas of the causal relations based on several industry projects, expert interviews, and a review of related literature, we decided to use structural equation modelling (SEM) as a methodology that is adequate to confirm an explanatory model with data that we would acquire from a questionnaire-based inquiry. SEM is an extension of the general statistical linear model that simultaneously estimates relationships between multiple independent, dependent and latent variables. It allows the modeller to explicitly capture

unreliability of measurement in the model, in theory allowing the structural relations between latent variables to be accurately modelled.

Our experiences indicated that companies consider better customer service, resulting from a quicker check-out and reduced personnel costs as the main benefits of RFID-based check-out systems. Therefore, we decided to ask companies how they rate the current situation with regard to personnel costs and waiting time. Our implicit assumption was that the higher the personnel cost and waiting time pressure, the higher a company would rate the potential benefit of RFID-based POS terminals. The perceived benefit, which was assumed to reflect a company's motivation, would affect the timing decision, i.e. when to invest in RFID. Of course, this assessment would also be strongly influenced by the company's expectation regarding the availability of a solution. Furthermore, we expected that the current level of knowledge, as a proxy for a company's technological capabilities, would influence the timing decision. Finally, the level of knowledge was expected to differ between companies, depending on a company's attitude towards POS innovations and its size.

The complete research model is depicted in Figure 2; constructs and hypotheses are summarised in Table 1.

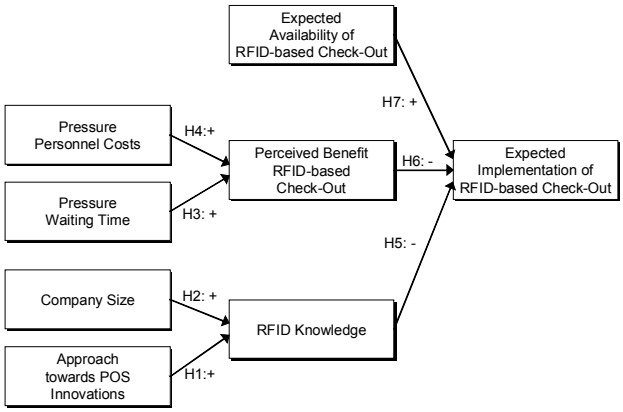

Fig. 2. Implicit a priori research model

Table 7. Description of constructs and hypotheses used in the research model

Construct	Explanation and derived hypotheses
Approach towards POS Innovations	Describes the company's innovation culture regarding POS-related innovations. A company that generally drives innovations in the field of POS should be more likely to drive the innovative RFID self check-out approach. → *H1: A positive approach towards POS Innovations is positively correlated with a large amount of RFID knowledge within the company*.
Company Size	Describes the company's number of affiliates and the number of installed POS systems. A large company with a higher number of POS systems should be more likely to be willing to drive RFID based check-out systems because more resources are necessary to do so.

	→ *H2: Large company size is positively correlated with a large amount of RFID knowledge within the company.*
Pressure Waiting Time	Describes the degree to which waiting lines in front of the POS are considered a problem for the company. A company that regards waiting lines as a serious problem should perceive a higher benefit in a technology that may help it to reduce these lines. Therefore such a company should be more likely to investigate such innovations and drive an early adoption. → *H3: High pressure regarding waiting time is positively correlated with a company's perception regarding the benefit of RFID-based check-outs.*
Pressure Personnel Costs	Describes the degree to which a company considers its personnel costs as a problem to its competitiveness. A company that regards personnel costs as a serious problem will perceive a higher benefit in a technology that may help it to reduce these costs through automation. Therefore such a company should be more likely to investigate such innovations and drive an early adoption. → *H4: High pressure in personnel costs is positively correlated with a company's perception regarding benefits of RFID-based check-outs.*
RFID Knowledge	Describes the amount of knowledge in the field of RFID that a company has accumulated in theory and practice. The amount of RFID knowledge a company accumulates itself is dependant on the constructs 'Approach towards POS Innovation' and 'Company Size'. Furthermore the amount of RFID knowledge accumulated influences the likelihood of an early RFID adoption, because the knowledge necessary for adoption is more likely to be available inside the company. → *H5: Extensive RFID knowledge accumulated within a company is negatively correlated with the expected implementation of RFID-based check-outs within the company.*
Perceived Benefit RFID-based Check-Out	Describes the benefit that a company expects from the adoption of RFID-based check-outs. This perceived benefit depends on the constructs 'Pressure Personal Costs' and 'Pressure Waiting Time'. Moreover, perceived benefit influences the likelihood of early RFID adoption, because a company that perceives a high benefit in the adoption of a technology should be more likely to drive adoption. → *H6: A high perceived benefit is negatively correlated with the expected implementation of RFID-based check-outs within the company.*
Expected Availability of RFID-based Check-Out	Describes the point in time at which companies expect RFID-based check-out solutions to become available. The earlier companies think that RFID solutions will be available the more likely they will drive an early adoption. → *H7: An early availability of RFID-based POS solutions is positively correlated with the expected implementation of RFID-based check-outs within the own company.*
Expected Implementation of	Describes the point in time at which companies expect an RFID check-out solution to be implemented in their own company.

3.2 Data Collection

The data for our analysis was gathered by means of a questionnaire in summer 2005. For the conception of this questionnaire the above-mentioned constructs had to be operationalised. For this reason, they were broken down into several easy to answer questions. The answers to the questions on company profile, expectation of availability, and expectation of implementation were defined as categorical variables. Depending on the question there were 3 to 9 answering options. All other questions had to be answered on a 5-point-Likert-type scale ranging from '1: strongly disagree' to '5: strongly agree'.

The questionnaire was sent by mail to 500 executives (owners, CEOs, as well as marketing, finance, IT and logistics managers) of Swiss retail chains in the German-speaking part of Switzerland. The contact details were taken from a professional address database. Overall, 148 questionnaires were returned. This equals a return ratio of 29.6%. Of these 8 contained double answers so that 140 (28%) were usable. Due to missing data, some questionnaires had to be eliminated and 117 (23.4%) were used for the analysis.

The following basic data on respondents, company profiles and RFID knowledge provides an overview of our study sample (see Figure 3):

- 16% operate a maximum of 10 branches, while 24% operate more than 100.
- 66% sell non-food, 11% food and 23% both food and non-food products.
- 56% of respondents regard themselves as specialty shop.
- 59% of respondents claim to possess a medium to high theoretical knowledge on RFID, while 71% had little practical experience with the technology.
- 60% of respondents expect that RFID-based check-outs will become available within the next 7 years, and 36% expect that their company will implement the technology within this time period.

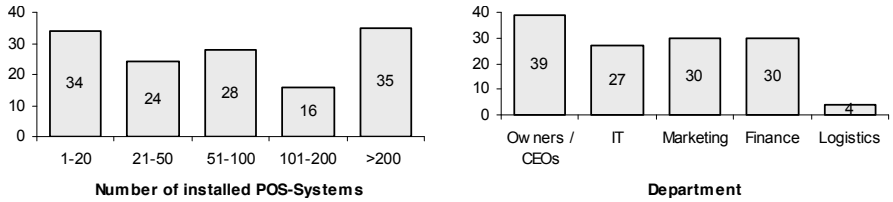

Fig. 3. Respondents separated by Number of POS systems and department affiliation

3.3 Results

After the measurement model was established, the explorative phase using structural equation modelling began. The implicit a priori research model was taken as a starting point. We used the software toolkit AMOS Version 5.0.1 for factorial

analyses and structural equation modelling. The following indices and thresholds were used to test the overall model fit: chi-square/df (≤ 2.0), Tucker & Lewis index (TLI, ≥ 0.9), comparative fit index (CFI, ≥ 0.9), and Steiger's root mean square of approximation (RMSEA, ≤ 0.08).

Our a priori research model already showed acceptable overall fit measures (Chi-square/df = 1.416, TLI = 0.902, CFI = 0.914, RMSEA = 0.060), and all expected regression weights had the expected plus and minus sign. However, not all relationships proved significant at a level of at least 0.05. Specifically, 'Pressure on Personnel Costs' did not seem to have a significant effect on the expected benefits of RFID-based check-out systems, and 'RFID Knowledge' did not seem to influence the company's timing decision. Furthermore, 'Company Size' had no significant effect on 'RFID Knowledge'.

The covariances between the constructs, as estimated in the measurement model, indicated how to improve the fit of the model. Therefore, 'Pressure Waiting Time' and 'Approach towards POS Innovations', as well as 'Approach towards POS Innovations' and 'Company Size' were allowed to covary, which further improved the above-mentioned indices.

The emphasis was to make as few changes as possible to the initial model in order to keep it parsimony and not to extensively respecify the model based on sample data. One relationship was added: Rather than being independent from each other, the empirical findings suggested that, in this case, the motivation to introduce a novel technology influenced the acquisition of technical capabilities. Specifically, 'Perceived Benefit RFID-based Check-Out' seemed to positively influence 'RFID Knowledge'. Running the model with this additional relationship improved the overall fit of the model, and the relationship proved to be significant at p = 0.05. The removal of 'Company Size' from the model further improved the fit. The final model is depicted in Figure 4, including standardised parameter estimates, significance levels and fit measures.

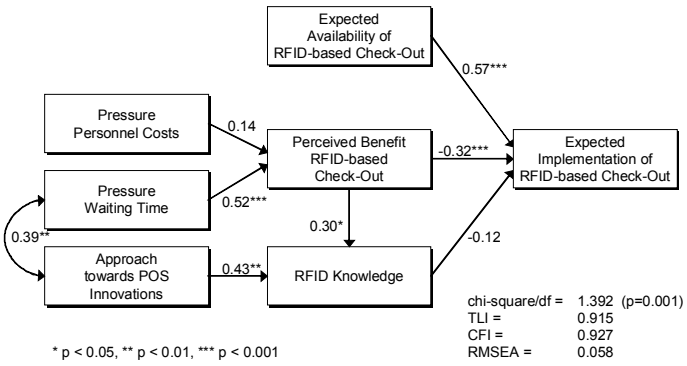

Fig. 4. Final Research Model

As can be seen in Figure 4, our hypotheses H1, H3, H6 and H7 could be confirmed, i.e. a company's innovation culture has an influence on the acquisition of RFID knowledge, the pressure in waiting time does have an influence in a company's perceived benefit of RFID, the perceived benefit correlates with the expected implementation of RFID, and finally the expected availability of a solution influences the expected implementation as well. In addition to these findings, our research revealed that the perceived benefit influences the acquisition of knowledge and that there is a correlation between waiting time pressure and innovation culture.

However, we were not able to confirm our hypotheses H4 and H5. Surprisingly, we could not find a correlation between personnel cost pressure and the perceived benefit of RFID-based check-out solutions. Furthermore, we could not find a significant influence of current RFID knowledge on the expected time of implementation. As mentioned before, H2 was removed from our model in favour of a better overall model fit.

3.4 Discussion

The findings we feel to be most interesting and worthy of discussion are those we could not prove to be consistent with our a priori expectations. The first question we wanted to answer was the lack of correlation between personnel cost pressure and the perceived benefit of RFID-based check-outs. We suppose that the explanation could be the following: RFID-based check-outs will not reduce the number of POS, but rather shorten the waiting lines in front of them. The above-mentioned project at Delhaize in Belgium supports this assumption. In this case example, traditional POS installations were not removed, but rather complemented by automatic check-outs for self-service customers, which are now able to enjoy shorter waiting times. Delhaize's project has not led to a cut in personnel cost but to an increase in customer service and a parallel increase in revenues [23].

The next finding that we found intriguing was that the presence of RFID knowledge within a company does not seem to have an influence on the expected implementation time. An explanation for this might be that the accumulated knowledge itself has no meaning to the company if the corresponding products are not technically mature, unavailable, or still too expensive to allow for a positive ROI.

Analogous to that, we might probably also explain why the perceived benefit does have an influence on the accumulation of knowledge, but the relationship could not be proved the other way around. While a perceived benefit constitutes the necessary motivation for the acquisition of knowledge, this knowledge in itself is not sufficient for an early implementation.

4 Summary

The results of our research indicate that retailers which see a high potential in the adoption of RFID technology intend to adopt relatively early. These retailers already prepare for the future by gathering experiences with the technology today. Interestingly, the current level of RFID capabilities that was acquired because of the perceived benefits does not influence the expected timing of adopting RFID-based

check-outs. This may be due to the fact that the technology is still at an early stage and that the possession of the knowledge by itself is not sufficient for the implementation.

However, although the actual level of knowledge does not influence the timing decision, the model shows that companies which expect high potential benefits have significantly higher levels of RFID knowledge. This indicates that those companies actively engage in exploring the potentials of the technology.

Customer waiting time seems to be the main driver for companies to examine new technologies such as RFID-based check-out terminals. Retailers that recognize customer waiting time in front of the POS terminal as a problem expect higher benefits from RFID and are more innovative with regard to POS technology.

Contrary to our expectations, pressure to save personnel cost did not have a significant impact on the assessment of expected benefits from RFID. This indicates that the main driver for companies to consider RFID for automating the check-out process is customer service rather than cost savings.

In our opinion, the results should be considered as a starting point for further research in various directions:

- Additional empirical research will be needed in order to get a better understanding of the consumer perspective and their expectations regarding POS automation. It would also be interesting to conduct research on the effect of shorter lines on the customers' shopping behaviour. Delhaize, for example, states that customers spend more time actually shopping and leave more money in the stores, when they know they won't have to waste time waiting in line [23].
- Conceptual research will be necessary to improve the design of current self check-out solutions and the services that can be offered at the POS, e.g. through demonstrators and prototypes.
- Not least, our findings should also be considered in the context of the consumer's technology acceptance and risk perception. RFID-enabled services that increase customer convenience might be the key to outweigh the widespread perception of RFID technology as a risk to privacy and health [24].

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