Eindhoven University of Technology

MASTER

RFID technology in outpatient logistics

an analysis of its potential and acceptance

Onurlu, B.

Award date:
2013

Link to publication

**RFID Technology in Outpatient Logistics:
An Analysis of Its Potential and Acceptance**

by Burak ONURLU

BSc Industrial Engineering — Istanbul Yildiz Technical University (2008)
Student identity number 0787609

in partial fulfilment of the requirements for the degree of

**Master of Science
in Innovation Management**

Supervisors TU/e:
prof. dr. ir. Uzay Kaymak
prof. dr. ir. Hajo Reijers

TUE. School of Industrial Engineering.
Series Master Theses Innovation Management

Subject headings: health care, patient care, hospital logistics, information technology, adoption

Table of Contents

List of Tables

List of Figures

Acknowledgements

First and foremost I would like to thank prof. dr. ir. Uzay Kaymak for his continuous support, guidance and positive attitude throughout my research project. He was the primary resource for getting my questions answered and instrumental in helping me to finalize this research. I also would like thank my other supervisor prof. dr. ir. Hajo Reijers for his support and inspirational contribution in the results of the research.

My gratitude also goes to MD, PhD Simone van der Geer, MD, PhD, MBA Gertruud Krekels, Ing. Deniz Shumbiliev for their help, influential ideas and expert opinions throughout the research.

Last but not least, thanks for the family and friends for their unconditional love and support.

Abstract

The dramatic and continuous increase in health care spending threatens the economic stability and safety of the countries. Therefore, the governments and the health care organizations are forced to rethink and redesign their strategies in order to provide timely and cost effective healthcare services. Within this perspective, today's technological developments have drawn attention of decision makers in health care industry due to their potential benefits in terms of efficiency and cost reduction.

In this research, we focus on the main outpatient logistics problems and the recent use of a relatively new technology, Radio Frequency Identification (RFID), in order to solve those problems. In addition, the main concentration of the research is to explore the potential and the adoption of RFID in outpatient logistics. 109 Dutch health care professionals with diverse backgrounds, from doctors and nurses to managers and IT specialists, participated in a web-survey which was based on one of the most popular technology adoption theories, the Technology Acceptance Model.

The proposed research model and the collected data were analyzed by using Structural Equation Modeling. The results of the research shows that perceived ease of use and perceived usefulness are the significant determinants of behavioral intention to use RFID technology in outpatient logistics. They can also explain/predict 67% of the variance in health care professionals' behavioral intention to use RFID technology in outpatient logistics. Moreover, based on the Method Evaluation Model, the results suggest that RFID technology will likely be adopted in practice by health care professionals.

1. Introduction and Background Information

In today's dynamic environment, not only economic turmoil but also other inevitable changes force organizations and governments to rethink their strategies and implement new management fashions in order to maintain their economic stability and safety. Nowadays, decision makers are concerned with increasing high-volume of health care spending, which threatens economic future of organizations and countries.

According to Statistics Netherlands (2011), health care and welfare spending amounted to 87.6 billion EUR in 2010 in the Netherlands with a 3.6% increase with respect to 2009. This amount accounts for 14.8% of the country's gross domestic product (GDP) and might reach to 24% by 2050 with current trends (Pomp & Buskens, 2012). Figure 1 illustrates dramatic increase in Dutch health care spending as a percentage of the GDP over years (Statistics Netherlands, 2011).
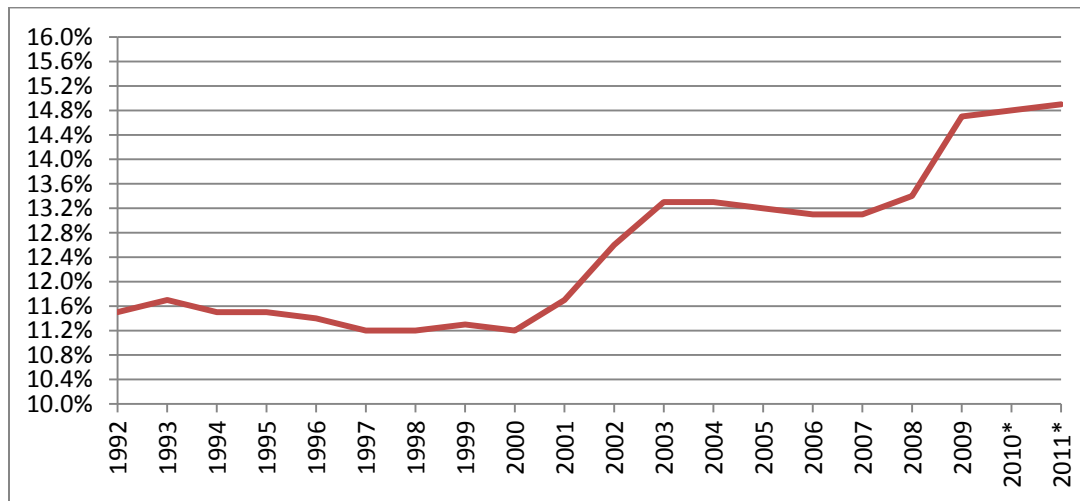
* provisional figures

Figure 1 - Dutch health care spending as % of the GDP (Statistics Netherlands, 2011)

There have been many research efforts from several organizations (such as Organization for Economic Co-operation and Development, Economic and Monetary Affairs of European Commission) that investigate the main drivers behind increasing health care expenditure. Although there are many different and case-specific drivers in such complex environment, the main drivers can be summarized as below.

1. Increased life expectancy and aging population: Average life expectancy of people in OECD countries has increased by more than 11 years since 1960 and reached nearly 80 in 2009 (OECD, 2011). Detailed figures of average life expectancy and increase in average life expectancy over time by countries can be found on Appendix A. Increased life expectancy drives the health care spending based on two aspects. At first, people who are getting older and remain in health care system, generate higher cumulative cost over time. In other words, the more aging population causes the higher long-term care expenditure (Yang, Norton, & Stearns, 2003; Hartman, Catlin, Lassman, Cylus, & Heffler, 2008). Moreover, chronic diseases among elderly people such as chronic heart failure, diabetes, etc., cause significant health care cost over time (Stanton & Rutherford, 2006). At second, according to several researches in different countries, elderly people cause more health care expenditure than young people based on their relatively poor health status and/or their higher health care needs (Stanton & Rutherford, 2006; Zweifel, Felder & Meiers, 1999; Yang, Norton, & Stearns, 2003). In addition, elderly people, on average, require more care than young people need especially if they are close to death. Average healthcare spending of elderly patients start to increase about 2 years before the

death and increase dramatically in the last 6 months of their life (Yang, Norton, & Stearns, 2003).

2. Increased health care demand based on increased income, life comfort and access to health care services: Przywara (2010) stated that increased patient demand based on increased social and economic status is one of the underlying reasons of health care expenditure growth. Increase in both national and individual incomes and public well-being expectations have created additional demand for health care service delivery. In addition, health promotion through disease prevention campaigns also influences patient demand for health care service.

3. Technological developments: Technological evolution in medical science is arguably major factors affecting the level and rate of change in health care spending (Przywara, 2010). Technological evolution including the developments in pharmaceuticals, medical equipment, supportive and administrative systems was supposed to account for 50-70% increase in health care expenditure, according to the earliest studies (Przywara, 2010). Although technological developments provide us benefits and efficiency in many processes from operational tasks to treatment of patients, there is still ongoing argument whether technology leads higher total spending despite its benefits. Reduction in cost based on technological developments may lead to an increase in demand and the total spending may rise (Cutler & Huckman, 2003).

4. Health care resources utilization and integration issues: Health care industry is a critical case in terms of complexity, professionalism and dynamics in highly individualized care processes of patients. Most of the optimization questions in health care are about to the

3

problem how high resource utilization can be matched with a high customer service level (de Vries & Huijsman, 2011). As usual, we have limited resources in health care setting and thus treatment of a patient requires efficient management of the resources. Intra-organizational and inter-organizational collaboration among the actors in the environment, integration and coordination of processes, planning activities and information flows are critical.

1.1 Research Scope and Process

1.1.1 Research Scope, Objectives and Questions

Since more than a quarter of total health care spending in the Netherlands are related to hospital/clinic care and medical practices expenditures (Statistics Netherlands, 2011), this research focused on health care processes in hospital/clinic environment, specifically on patient logistics which is one of today's emerging topics in health care environment especially within supply chain and operations management context (de Vries & Huijsman, 2011). Since the researches focusing on outpatient setting are still limited, this research concentrated especially on outpatient logistics processes.

In addition, this research is a cross-domain study and contributes not only in patient logistics in health care but also in information technology deployment and human aspects of innovation management areas. Today, Radio Frequency Identification (here and after RFID) technology, which is a relatively new identification/tracking technology, has drawn attention of decision makers and actors in health care industry due to its potential benefits in terms of efficiency, cost reduction, etc. RFID is an automatic identification technology that enables transmission of the identity of an object wirelessly by using radio waves (Finkenzeller, 2010). Transmission of the

identity refers not only identifying or tracking an object but also data or information transfer between RFID system components. The Dutch public transportation card (i.e. OV-chip kaart) can be given as a basic example of RFID technology which we use in our daily life on a regular basis. Recently, RFID technology is widely used by manufacturing, supply chain operations, retailing in order to improve efficiency of processes and also receives increasing attention by many other industries (Ngai, Moon, Riggins, & Yi, 2008). RFID market, including tags, readers and software/services, etc., reached 7.67 billion USD in 2012 with a 17.8% growth as compared to 2011 and expected to reach 26.19 billion USD by 2022 (Harrop & Das, 2012).

Health care industry is also an emerging market for RFID deployment. RFID market in health care was accounted for 94.6 million USD in 2009 and expected to reach 1.43 billion USD in 2019 (Bendavid, Boeck, & Philippe, 2011). On the other hand, as stated by Ngai et al. (2008), number of scientific researches relating to RFID implementation in health care is still significantly low as compared to other areas such as retailing or logistics, although the technology is expected to transform health care organizations' existing way of operating. Several researchers have already proposed RFID-based system solutions to innovate health care processes in order to overcome patient logistics problems, increase efficiency/resource utilization and patient safety. On the other hand, acceptance/adoption of an IT system (and thus adoption of an RFID-based IT system) depends not only on the benefits that the system proposes but also on behavioral intention of people who are going to use that system (Davis, 1989). In other words, a new technology does not provide benefits, if it is not used by people. Thus, human aspects of innovation management are critical for the adoption of innovation and we need to understand and predict why people accept or reject a new technology (Davis, Bagozzi, & Warshaw, 1989).

Therefore, the main purpose of this research was to investigate what RFID technology offers for improving outpatient logistics processes and how health care professionals react to it. RFID is said to have a huge potential to improve them, however, it has not been studied in the outpatient setting. Hence this research was aiming to fill that gap by realizing the following objectives.

1. Presenting a classification of problems and issues in outpatient logistics in health care.

2. Presenting a classification of RFID implementations in (out)patient logistics.

3. Categorizing outpatient logistics problems and applicable RFID implementations proposed by scientific literature.

4. Investigating the relationship among health care professionals' perceived ease of use, perceived usefulness and behavioral intention to use RFID technology in outpatient logistics processes.

In order to achieve these objectives, the research was structured around the following research questions.

Research Question I : What are the main problems in outpatient logistics in health care?

Research Question II : What are the recent RFID implementations in (out)patient logistics?

Research Question III : What is the relationship among healthcare professionals' perceived ease of use, perceived usefulness and behavioral intention to use RFID technology in outpatient logistics processes?

1.1.2 Added Value of the Research

By the continuous development of new technologies, user acceptance/technology adoption research in health care has gained significant attention by the researchers, especially after the second half of 1990s. This research provided a test of one of the most popular technology acceptance theories (i.e. Technology Acceptance Model, here and after TAM) in outpatient logistics setting in which the acceptance of RFID technology has not been analyzed before.

According to two recent extensive literature reviews by Holden & Karsh (2010) and Yarbrough & Smith (2007), computerized physician order entry, telemedicine, electronic medical records and web based health applications can be given as examples to the most widely studied technologies within the user acceptance/adoption perspective. In addition, Chen, Wu, & Crandall (2007)'s research is the only research focusing on RFID adoption in health care and investigating factors that contribute to the acceptance of RFID technology. However, their research aim was to investigate the adoption of RFID by medical teams in emergency rooms only. Therefore, this research contributes in two new areas in terms of investigating RFID adoption in health care. First, the research investigated RFID user acceptance in a more generalizable area, in outpatient logistics processes in which RFID implementations are still limited. Second, the research investigated not only physicians' perception regarding to RFID adoption but also included a multi-actor approach which contained the perception of non-doctor actors in health care (such as nurses, IT specialists, managerial/administrative functions, etc.).

1.1.3 Research Process and Methodology

In order to fulfill the aforementioned objectives and answer the research questions, a multi-dimensional literature review and a survey, in which different kind of health care professionals (doctors, nurses, managers, IT specialists, etc.) participated, were conducted. Figure 2 illustrates the main stages of the research process and methodology.
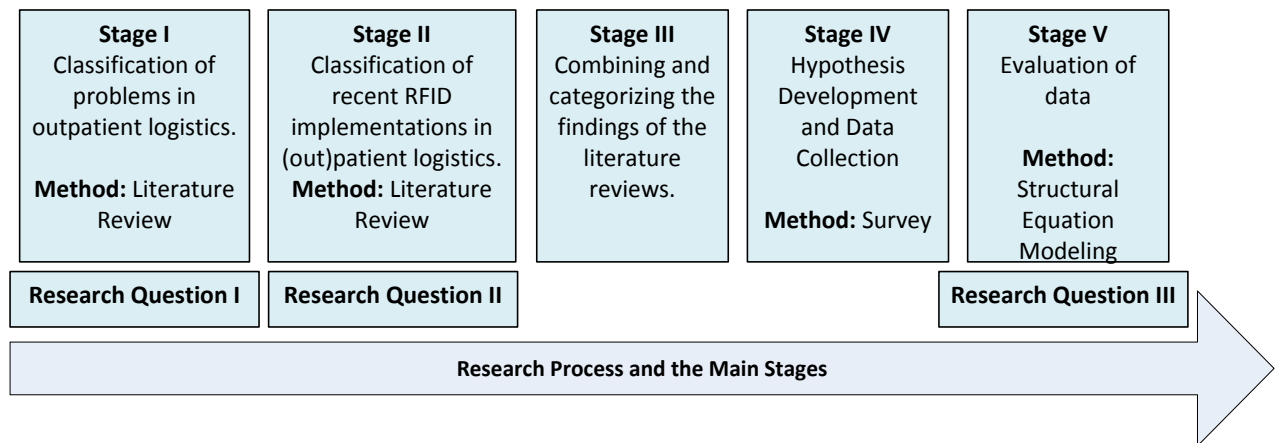
Figure 2 – The main stages of the research

Stage 1: In the first step, we discovered what kinds of problems were highlighted in the scientific literature. Our purpose was to define the main problematic areas in outpatient logistics by conducting a comprehensive literature review. By doing so, we attained the first objective of the research, proposed a classification of problems in outpatient logistics, and answered the research question I.

Stage 2: In the scientific literature, there is not a clear distinction between RFID implementations in outpatient and inpatient settings. Therefore, in this stage, we discovered the recent RFID implementations in patient logistics. We also realized the second objective of the research and answer the research question II.

Stage 3: The knowledge gathered in the former stages was used to develop a matrix. The matrix combined outpatient logistics problem categories and the recent RFID implementations in patient logistics, and demonstrated how we could solve the problems by using RFID. The third objective of the research was attained in this step.

Stage 4: In the fourth stage, we developed hypotheses based on the theoretical framework (TAM) proposed by Davis (1989). TAM was firstly proposed by Davis (1989) and later used by many researchers to understand usage behavior of people regarding to an IT system. Davis (1989) proposed that two specific personal beliefs, perceived ease of use ("the degree to which a person believes that using a particular system would be free of effort") and perceived usefulness ("the degree to which a person believes that using a particular system would enhance his or her job performance"), mainly explain person's behavioral intention to use a new technology. We adapted Davis (1989)'s original framework to RFID context in order to investigate health care professionals' behavioral intention to use RFID technology in outpatient logistics. The main reason behind the selection of TAM was that the theory had already been replicated and validated by several researchers in different areas including health care. The research of Hu, Chau, Sheng, & Tam (1999) on the acceptance of telemedicine technology and the research of Wu, Shen, Lin, Greenes, & Bates (2008) on the acceptance of adverse event reporting system can be given as examples in health care setting.

In this section, we designed a web-based cross-sectional survey which aimed to understand and predict health care professionals' behavioral intention to use RFID technology in outpatient logistics. Our target population was health care actors in Dutch university and non-university

hospitals including doctors, nurses, managers, IT professionals, etc. The survey was distributed through personal contacts and professional social networks (i.e. Linkedin).

Stage 5: During the last step, we analyzed the results of survey. In this research, we had a model with multiple latent constructs and multiple causal relations among latent constructs. In order to evaluate and explain those relations and test hypotheses, structural equation modeling (SEM) was selected as a tool. SEM is a widely accepted methodology to analyze structural models with multi-item constructs which involve direct, indirect and interaction effects. The analysis was followed by conclusions, limitations and implications for the future research. In this section, we answered the research question III.

1.1.4 Chapter Outline

The rest of this research was structured as follows. Chapter 2 presents the classification of the problems in outpatient logistics, the recent RFID implementations in health care and summarizes the main findings of the first and the second literature reviews. Chapter 3 presents the theoretical framework of the research and hypotheses. Chapter 4 explains survey design and data collection procedure and measurement validity. Chapter 5 presents the results of structural equation modeling analysis and as the last chapter, Chapter 6 summarizes the findings and limitations of the research and also implications for the future work.

2.   Outpatient Logistics Problems and the Potential of RFID Technology

2.1   Patient Logistics and Outpatient Logistics

"Logistics" is defined as "the process of planning, implementing and controlling the efficient, cost-effective flow and storage of materials and the related information flow from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements" (definition by Council of Logistics Management as cited in Cooper, Lambert & Pagh, 1997). Similar definitions can also be made for the patient logistics (also called as patient flow logistics, patient-oriented care) as follows, based on logistics literature concerning the health care (Villa, Barbieri, & Lega, 2009; de Vries & Huijsman, 2011; Meijboom, Schmidt-Bakx, & Westert, 2011; Huijsman, & Vissers J, 2005).

- Patient logistics is complicated set of decisions regarding to movement of patients throughout the health care chain in order to match supply and demand.

- Patient logistics is health care delivery structure around the needs of patient which involves all planning and control activities from beginning to end, integration and co-ordination of internal and external organizational processes including information flows, patient flows to reach high resource utilization at high customer (i.e. patient) service level.

- Patient logistics concentrates on strategic planning, demand planning, human and material resource planning and control, patient group planning and control activities and also redesigning of physical environment to meet patients' safety and satisfaction needs.

Patient logistics can be divided into two categories depending on how hospital resources are used; outpatient logistics and inpatient logistics (Hutzschenreuter, 2010). Inpatient logistics

11

focuses on patients who need to be hospitalized for a time to be treated whereas outpatient logistics focuses on patients who visit hospital for diagnosis or treatment without being hospitalized. This research focused on care delivery processes of the latter one.

2.2 The Related Work

The purpose of this sub-section is to classify problems in outpatient logistics in order to provide a better understanding of what the main problems in outpatient logistics processes are. Based on a comprehensive literature review, we discovered the main problems highlighted in the scientific literature.

The literature review was conducted in multiple scientific search engines. ABI/Inform, Web of Science and Google Scholar were used to find relevant articles. Table 1 illustrates search terms used during the literature review. The terms were searched in all areas except "full text" and only scholarly journal articles and conference proceedings published after 2000 were selected. Since some of the search terms were highly popular and gave enormous number of results, additional search terms were used (such as search #2, #4, #6, #8 as illustrated in Table 1) in order to filter the articles which were relevant to the research. In total, 331 articles were selected and aggregated in the first round. After removing duplicates, 133 articles focusing on patient logistics processes were selected. 33% of those articles (i.e. 45 articles) concentrated especially on outpatient logistics processes either by defining a problem(s) or by proposing a solution(s) to the problems.

Figure **3** illustrates selection procedure and criteria of articles.

Table 1 - Search terms used during the literature review

Search No.	Search Terms
1	*(healthcare OR health care)* AND *(logistics)*
2	*(healthcare OR health care)* AND *(logistics)* AND *(patient or patients)*
3	*(healthcare OR health care)* AND *(outpatient)*
4	*(healthcare OR health care)* AND *(outpatient)* AND *(problems)*
5	*(hospital OR clinic)* AND *(logistics)*
6	*(hospital OR clinic)* AND *(logistics)* AND *(patient or patients)*
7	*(hospital OR clinic)* AND *(outpatient)*
8	*(hospital OR clinic)* AND *(outpatient)* AND *(problems)*

Article Selection Procedure

- Number of articles selected in the first round. **(331)**
- Number of articles after the removal of duplicates **(244)**
- Does the article focus on health care or hospital processes? **(198)**
- Does the article focus on patient logistics? **(133)**
- Does the article define a problem or propose a solution to a problem in outpatient logistics context? **(45)**
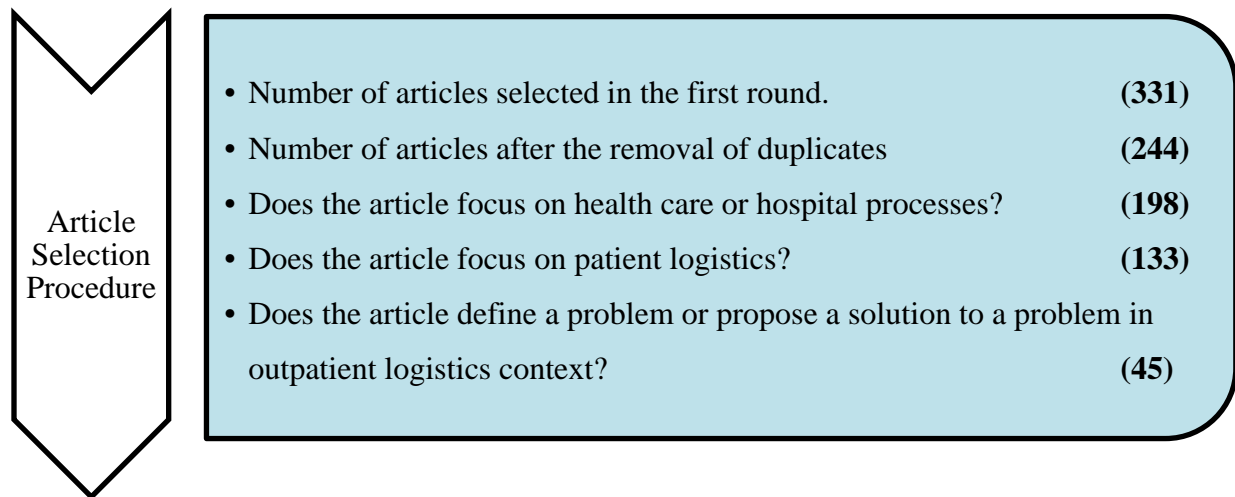
Figure 3 - Selection procedure of the articles

The selected articles were classified into four main categories as planning and scheduling problems (21 articles, 47%), process inefficiencies (13 articles, 29%), patient safety concerns (9 articles, 20%) and physical layout problems (2 articles, 4%). The following sub-sections summarize the main findings of the selected articles in each category.

Table 2 - Classification of the articles by problem category

Article #	Article	Published in	Problem Category
1	Alaeddini, Yang, Reddy & Yu	2011	Planning and Scheduling
2	Bowers, Lyons, Mould, & Symonds	2005	Process Inefficiencies
3	Cayirli & Veral	2003	Planning and Scheduling
4	Cayirli, Veral, & Rason	2008	Planning and Scheduling
5	Chakraborty, Muthuraman & Lawley	2010	Planning and Scheduling
6	Dickson, Singh, Cheung, Wyatt, & Nugent	2009	Process Inefficiencies
7	Edelman	2002	Patient Safety Concerns
8	Friedman, Geoghegan, Sowers, Kulkarni, & Formica	2007	Patient Safety Concerns
9	Gandhi et al.	2005	Patient Safety Concerns
10	Giachetti, Centeno, Centeno & Sundaram	2005	Planning and Scheduling
11	Glowacka, Henry & May	2009	Planning and Scheduling
12	Gupta & Denton	2008	Planning and Scheduling
13	Jansen-Vullers & Reijers	2005	Process Inefficiencies
14	Kaandorp & Koole	2007	Planning and Scheduling
15	Klassen & Rohleder	2004	Planning and Scheduling
16	Kolisch & Sickinger	2008	Planning and Scheduling
17	Kopach et al.	2007	Planning and Scheduling
18	Kumar & Shim	2007	Process Inefficiencies
19	LaGanga & Lawrence	2007	Planning and Scheduling
20	Lillrank, Groop, & Venesmaa	2011	Process Inefficiencies
21	Lippi, Salvagno, Montagnana, Franchini, & Guidi	2006	Patient Safety Concerns
22	Liu, Ziya & Kulkarni	2010	Planning and Scheduling
23	Mans, Schonenberg, Song, Van der Aalst, & Bakker	2009	Process Inefficiencies
24	Martin, et al.	2009	Process Inefficiencies
25	Martin, Hogg, & Mackay	2012	Process Inefficiencies
26	Matta & Patterson	2007	Planning and Scheduling
27	McPhillips, et al.	2005	Patient Safety Concerns
28	Melanson et al.	2009	Process Inefficiencies
29	Murray & Berwick	2003	Planning and Scheduling
30	Muthuraman & Lawley	2008	Planning and Scheduling
31	Ogulata, Cetik, Koyuncu & Koyuncu	2009	Planning and Scheduling
32	Panella, Marchisio, & Di Stanislao	2003	Process Inefficiencies
33	Patrick, Puterman & Queyranne	2008	Planning and Scheduling
34	Robinson & Chen	2010	Planning and Scheduling
35	Singh et al.	2009	Patient Safety Concerns
36	Singh, Naik, Rao, & Petersen	2008	Patient Safety Concerns
37	Soriano-Meier, Forrester, Markose, & Garza-Reyes	2011	Physical Layout Problems
38	Venkatadri, Raghavan, Kesavakumaran, Lam, & Srihari	2011	Process Inefficiencies
39	Vos, Groothuis, & van Merode	2007	Physical Layout Problems

40	Walsh, et al.	2009	Patient Safety Concerns
41	Widjaya, van der Horst, & Seck	2011	Process Inefficiencies
42	Workman-Germann & Hagg	2007	Process Inefficiencies
43	Yokouchi, Aoki, Sang, Zhao & Takakuwa	2012	Planning and Scheduling
44	Zeng, Turkcan & Lawley	2010	Planning and Scheduling
45	Zhang, Youngblood, Murphy, Ramsay, & Xiao	2012	Patient Safety Concerns

2.2.1 Planning and Scheduling Problems

In general, planning and appointment scheduling is the beginning stage of outpatient logistics decisions and thus has a significant effect on the subsequent decisions in the logistics chain. By using appointment schedules, we distribute unpredictable patient demand to acceptable daily level and aim to prevent daily fluctuations in demand and/or overloading which cause low resource utilization and low patient satisfaction (Liu, Ziya, & Kulkarni, 2010). In other words, by the help of the appointment schedules, we manage the flow of patients in order to minimize patient waiting times and doctor/resource idle times.

Appointment scheduling literature contains two extensive reviews about the problems, considerations and major themes. Cayirli & Veral (2003) presented taxonomies for the problems, performance measurement criteria and design characteristics of outpatient appointment systems underlined in the literature. The researchers reached four conclusions; at first most studies in outpatient scheduling are case-specific and there is not any generalized proposal for an appointment system which performs flawlessly under all conditions. On the other hand, the studies depending on queuing models/theories mainly represent single-phase systems and only a few studies consider multi-phase systems where the patients flow through multiple facilities, for instance, registration, examination, laboratories for medical tests, etc. Moreover, appointment rules (block-size decisions, appointment interval allocations, etc.) are still main focus of the

studies, and the use of patient classification, the disruptive effects (walk-ins, no-shows, late-cancellations, etc.) are overlooked. In addition, multiple performance measurements instead of single, traditional criterion such as waiting time or doctors' idle time, should be used during the evaluation of appointment systems. The same researchers also provided a simulation study (Cayirli, Veral, & Rason, 2008) to assess potential benefits of patient classification which can be used for sequencing and appointment interval adjustments. Eighteen appointment systems in sixteen clinics were analyzed and the results pointed out that the appointment systems of which appointment intervals are adjusted by the use of patient classification are successful in improving the patients waiting time and the doctors' idle time.

As a second extensive review regarding to the main practical issues and challenges in appointment scheduling was conducted by Gupta & Denton (2008). According to the researchers in various health care environments, a patient runs into two kinds of access delays, indirect (virtual) and direct (captive) waiting times. Indirect waiting time was defined as the time interval between the patient's request for an appointment and the exact time of that appointment whereas direct waiting time was defined as the time difference between the patient's scheduled appointment time and the time when he/she is served in reality. However, most studies consider either only direct or indirect waiting time costs instead of analyzing both of them. Similar to Cayirli & Veral (2003)'s research, the disruptive effects are major challenges in patient scheduling and usually cause lower resource utilization and longer patient waiting times. Gupta & Denton (2008) also indicated that patients have different preferences and priorities in different health care environments. The patients may have different kind of medical urgencies, need different equipment or staff resources and service time. Arrival process of patients was defined

another complicating factor. For instance, single-batch process in which the patient scheduling decisions are made after observing all demand for a session, is a common procedure for elective surgery scheduling whereas unit process in which the patients randomly request for appointments and scheduled at that instance, is routine for primary care clinics and emergency departments. The appointment system is often regarded as "static", when the arrival process is a single-batch process and assumed as "dynamic" when the arrival process is a unit process. Besides the indirect waiting time, the disruptive effects and patient-specific requirements, the researchers suggested that incentive-based scheduling models which aim to maximize combined benefit not only for the hospital but also for employees and patients, and lack of knowledge in industrial engineering/operating research are open-challenges in patient scheduling.

In order to design optimal appointment scheduling systems, several researches were carried out. Ogulata, Cetik, Koyuncu & Koyuncu (2009) performed a study in a multi-phased radiation oncology clinic in order to assess and increase efficiency of scheduling system. They indicated that the reserved slack capacity of the department was consumed mainly because of the postponement of appointments which have uncertain time intervals due to complexity of the treatment. A similar simulation study was realized by Yokouchi, Aoki, Sang, Zhao, & Takakuwa (2012) in an outpatient chemotherapy department. In other simulation studies, Kaandorp & Koole (2007) presented a search algorithm to find optimal schedule with weighted average of expected waiting times and idle time of doctors; Matta & Patterson (2007) provided a framework to evaluate outpatient scheduling systems with respect to multiple performance criteria. The researchers believed that common key performance measures (such as patient waiting time,

17

throughput time, physician utilization, etc.) should be examined with respect to the patient classes, the facility used, and the day of the week.

As mentioned before, there is significant consideration on the disruptive effects in planning and scheduling activities such as no-shows, late-cancellations, walk-ins, emergency patients, etc. Therefore, there are many researches in the scientific literature focusing on them. According to Alaeddini, Yang, Reddy, & Yu (2011) no-show rates can vary 3% to 80% depending on the type of medical center and demographic characteristics of patients. During their study, they developed a framework, which uses the patients' social and demographics information, and historical attendance records to their appointments, in order to predict the probability of no-shows. The result of the proposed framework can be used to develop more effective scheduling systems which have overbooking methods to decrease the negative effect of no-shows while maintaining short wait times at the same time. Chakraborty, Muthuraman, & Lawley (2010) formulated a sequential scheduling algorithm which considers estimations regarding to the patients' no-shows, appointment cancellations and optimal overbooking decisions. Zeng, Turkcan, & Lawley (2010) conducted a similar study. According to the authors, an optimal overbooking model depends on four key characteristics; the pattern of patients' no-show behavior, the model which shows operational dynamics of the clinic, the objective function aligned with performance criteria and an algorithm which is based on these three characteristics and able to generate schedules of desired quality. The authors concluded the study that clustering patients with respect to their no-show probabilities will help to build more efficient schedules; overbooking is beneficial for (especially open-access) scheduling systems, since it decreases fluctuations in clinic workload; and in order to reduce overtime costs, the patients with low no-show probabilities should be

18

scheduled into early slots whereas the patients with high no-show probabilities should be scheduled into later slots. In another simulation study; Liu, Ziya, & Kulkarni (2010) proposed a dynamic patient scheduling framework under high no-shows and appointment cancellation conditions. They formulated scheduling problem as a Markov Decision Process and combined the formulation with a no-show distribution depending on the number of days between patients' request for appointment and the exact scheduled date. They developed their model further with alternative heuristics and proposed that 2-day booking window approach outperforms other approaches (such as open-access approach) in variety of cases. Glowacka, Henry, & May (2009) proposed another outpatient sequencing model by combining data mining and simulation approaches. As opposed to other studies, in which mathematical modeling was used to predict no-show probability of patients, the researchers followed a rule-based approach. The rules were created by a data mining study depending on both patient characteristics and characteristics of appointments. There different rule sets, composed of 13 rules with higher confidence levels, were selected and tested through a simulation study. 3-equal-sized appointment block approach, in which each clinic session is divided into three equal sessions and patients are scheduled with respect to their no-show probabilities (from lowest to highest), and individual appointment approach, in which the patients are scheduled with respect to no-show probabilities (again from lowest to highest), gave the best results. Muthuraman & Lawley (2008)'s research influenced the most of aforementioned studies which consider establishing overbooking models under high no-show condition. The authors examined historical data to find correlation between patients' characteristics and their no-show probabilities and used these correlations to make appointment scheduling decisions. LaGanga & Lawrence (2007) and Klassen & Rohleder (2004) conducted

similar studies aiming to find optimal scheduling systems in outpatient clinics under no-show and urgent-patient conditions.

Another widely discussed topic in outpatient scheduling and planning context is open access (also known as same-day access, advanced access) approach. Under open access perspective, when patients request for an appointment, they are scheduled to the same or the next day for a consultation. Robinson & Chen (2010) indicated that open-access approach especially useful to eliminate the doctor's idle time due to no-shows, as well as the patients' waiting time caused by overbooking policies. According to them, open-access approach outperforms traditional approach (in which a specified number of patients scheduled well in advance) in majority of examined cases. In their simulation study on effects of clinical characteristics on successful open access scheduling, Kopach et al., (2007) found that open access approach can provide significant performance increase by reducing no-show rate of patients by 50% and thus increase clinic performance. However, they also indicated that if a clinic applies open-access approach aggressively (i.e. scheduling too many patients per day), continuity of care and patient satisfaction decrease. Besides similar researches (Giachetti, Centeno, Centeno, & Sundaram, 2005), Murray & Berwick (2003) proposed qualitative arguments about the effectiveness of open access approach.

Other studies concerning planning and scheduling activities in outpatient environments are the researches of Patrick, Puterman, & Queyranne (2008) and Kolisch & Sickinger (2008) which were focused on dynamic scheduling for diagnostic centers in which different patient classes have different priorities (emergency patients, inpatients, and different types of outpatients).

As a summary, it can be said that the main problem about planning and scheduling in outpatient clinics is designing optimal scheduling system. Existing appointment systems often assume that all patients will show up for their appointments on time and be diagnosed/treated well-timed within predefined appointment interval. The disruptive effects are (the possibility of late-cancellations, no-shows and/or late-arrivals of the patients, etc.) in general overlooked. In addition, service time, resource requirements, etc. vary depending on different patient needs and thus appointment intervals need to be adjusted based on patient classification (based on urgent/non-urgent cases, demographic characteristics, etc.). Therefore, it can be concluded that the problem is replacing traditional appointment systems by dynamic appointment systems which consider unexpected/undesired situation and different needs of patients.

2.2.2 Process Inefficiencies

During the recent years, health care organizations have started to run process improvement projects in order to improve their patient logistics processes. However, most organizations do not apply structured methods (such as lean-six-sigma, business process redesign/reengineering, etc.), since health care professionals are in general unfamiliar with them and process improvements projects are based on simple spreadsheets or static flowcharts (Widjaya, van der Horst, & Seck, 2011). Today, there is an increasing focus on adopting structured process improvement methodologies into patient logistics. The aims of these methods are standardization of processes, elimination of defects and wastes in patient logistics processes such as errors, re-works, repetitions and delays. (Langabeer, DelliFraine, Heineke, & Abbass, 2009).

According to Lillrank, Groop, & Venesmaa (2011), many events in patient flow processes are defined through trial and error logic instead of explicit design. By mapping processes with

respect to time and resource characteristics, we can identify inefficiencies such as unnecessary activities, delays and repetitions. The researchers mapped and analyzed processes in two different clinic environments as case studies, diagnostic processes in an oncology setting and hemodialysis processes which contain inpatient, outpatient and home-care activities. They concluded in their research that there are different possible sequences for a process and there are not explicit rules for choosing between them. In addition, the processes can be interrupted by irregular events and managers should define, classify and standardize the processes in order to overcome them.

Martin, Hogg, & Mackay (2012) analyzed value stream in outpatient processes in a radiology department. By using data from questionnaires in which the patients and the staff participated, and from hospital information system, they defined waste and inefficiencies in the processes and implemented changes according to them. Based on their analysis, the changes provided fewer processes with a reduction in patient journey time and increase in patient and staff satisfaction. Widjaya, van der Horst, & Seck (2011) combined lean-six-sigma with a simulation model in order to redesign digital test order system of a diagnostics laboratory. In this multi-departmental and multi-actor environment, they clarified process efficiencies in four categories, waiting/delays, redundant activities, reworks and over-processing. Similarly, Venkatadri, Raghavan, Kesavakumaran, Lam, & Srihari (2011) combined six-sigma approach with simulation to eliminate high amount of delays in a cardiac catheterization laboratory which involves diagnosis and treatment of emergency patients, inpatients and outpatients. After mapping processes in the department, the researchers realized it is possible to increase utilization of the department, decrease outpatient throughput time and non-value-added time in outpatient

processes. Melanson et al. (2009) ran a continuous improvement project depending on Kaizen and lean management philosophy in outpatient phlebotomy clinic in order to optimize blood drawing process. The researchers redesigned the process by changing staff schedules and opening time of the clinic (since the patients arriving earlier than the clinic's opening time created a backlog in the beginning of the process), increasing chairs in waiting room and by eliminating non-value-added activities of phlebotomists. According to their quantitative and qualitative post-analysis, significant improvements were realized. Similar researches conducted by Dickson, Singh, Cheung, Wyatt, & Nugent (2009) in an emergency department and Martin, et al. (2009) and Workman-Germann & Hagg (2007) in radiology departments.

In addition, several researchers focused on business process engineering approach which aims to analyzing, managing and redesigning workflows and processes. Kumar & Shim (2007) conducted a business-process-reengineering project in an emergency department in which payment event of patients was analyzed. Jansen-Vullers & Reijers (2005) presented seven alternative redesign scenarios for the patient intake process of a mental healthcare institute. The redesigned scenarios were created by the implementation of best practices, such as elimination of non-value-added activities and/or automation of processes by using technology. Through their simulation study, the researchers illustrated increasing efficiency and effectiveness in terms of throughput time and service time and the significant potential of process improvement in health care.

Moreover, some researchers focused on reducing variations in health care delivery structure by defining clinical pathways. Clinical pathway is described as a method for the patient-care management and mainly focuses on standardization of care, reducing risks and variations,

increasing patient satisfaction and increasing the efficiency in the use of resources (De Bleser, Waele, Vanhaecht, Vlayen, & Sermeus, 2006). Panella, Marchisio, & Di Stanislao (2003) analyzed the use of clinical pathways in six different health care setting and their outcomes. They concluded their research that adoption of critical pathways is an effective tool to reduce unnecessary variations and inefficiencies in processes which is critical for health care organizations. Similarly, Bowers, Lyons, Mould, & Symonds (2005) redesigned clinical pathway in an outpatient diagnosis and treatment center by mapping processes in diagnosis and treatment activities, analyzing the demand of patients and their resource requirements. Last but not least, Mans, Schonenberg, Song, Van der Aalst, & Bakker (2009) conducted a process mining study in order to analyze patient flow and performance in a gynecological oncology clinic.

2.2.3 Patient Safety Concerns

Diagnostic errors, medication and medical mistakes are important issues which imperil patient safety. During the recent years, researchers have increased their attention to reduce these errors and mistakes as much as possible.

According to Singh, Naik, Rao, & Petersen (2008) diagnostic errors can be described as failure to use an indicated diagnostic test, misinterpretation of test results or failure to act on abnormal test results. Lack of communication among different actors, including doctors, nurses, laboratory assistants and patients, is defined one of the most important issues which causes these problems. Thus, Singh, Naik, Rao, & Petersen (2008) presented an information-technology-based conceptual framework to improve effectiveness of communication and reduce diagnostic errors. Singh et al. (2009) focused on timely follow-up of abnormal imaging test results in an outpatient setting. Abnormal findings need to be communicated rapidly and effectively to the treating

24

providers to ensure effective follow-up. The communication not only includes information transfer but also requires a response of the recipient such as taken follow-up action. After examining ~1200 cases, the researchers found that 7.7% of total cases were not followed up timely. Edelman (2002) did a similar research in a diabetic clinic and found that 9-18% percent of patients with abnormal diagnostic test results probably have unrecognized diabetes.

Besides diagnostic errors, medication errors are also defined as a serious problem in outpatient setting. Friedman, Geoghegan, Sowers, Kulkarni, & Formica (2007) classified medication errors in five categories; prescription errors (i.e. erroneous prescriptions), delivery errors (i.e. failure to deliver prescribed medication to patient timely), availability errors (i.e. failure to possess at least a 24-hour supply of the prescribed medication), patient errors (inaccurate use of prescribed medication by patient) and reporting errors (i.e. failure to identify the type, dosage, frequency of prescribed medication). During their research in an outpatient oncology setting, Walsh, et al. (2009) stated that 7.1% of patients were associated with medication errors which harm patient safety seriously. Basic computerized prescribing systems are not enough to eliminate these errors and more advanced prescribing and monitoring systems are required according to similar results presented by Gandhi et al. (2005). Medication errors are an even more serious problem in outpatient pediatrics clinics and the frequency of the errors are two times higher as compared to adults (McPhillips, et al., 2005).

In addition, as stated by Zhang, Youngblood, Murphy, Ramsay, & Xiao (2012), timely access to complete and accurate documentation of patient information is crucial to patient safety. The researchers presented an evaluation method to improve documentation practices and information flow within gastroenterology laboratory. On the other hand, Lippi, Salvagno, Montagnana,

Franchini, & Guidi (2006) described problems in outpatient laboratory setting (especially in phlebotomy laboratories). According to the researchers, patient misidentification, collection of inadequate specimens and lack of standardization threat patient safety and cause serious problems in diagnose and treatment processes.

2.2.4 Physical Layout Problems

Besides core health care processes, some researchers focused effects of non-clinical service activities, designing of physical layout of hospitals/clinic wards, on the efficiency of patient logistic processes.

Soriano-Meier, Forrester, Markose, & Garza-Reyes (2011) mapped the process flows in ten wards within a hospital and analyzed operational difficulties relating to the design of hospital layout. Their research aimed to analyze the impact of physical distance between dependent wards on staff perception, use of staff time and time spent in the system by patients. According to the results of their study, an increase in the distance between different wards/units adversely affects perception of hospital staff regarding to service quality and time for the delivery of service. In addition, the layout of the hospital is helpful for the admission/discharge of patients and efficiency of treatment and redesigning of some areas/units can increase the overall performance of the hospital.

Vos, Groothuis, & van Merode (2007) analyzed the layout design idea of two Dutch hospitals which is based on centralized waiting areas. The outpatient clinic that they analyzed has one central waiting area and limited waiting capacity for ambulatory departments. All required activities, tests, etc., were planned before a patient's arrival and when the patient arrives at the clinic, he/she just move from one room to another (e.g. from consultation room to examination

room). Although this design provides efficiency and fast service delivery, the researchers stated that the design is efficient only when the patients are punctual and have standard needs in general. The researchers recommended that standardization of consultation room and additional decentralized waiting areas can increase flexibility of the design.

2.3   RFID in (Out)Patient Logistics

2.3.1   RFID Technology

As stated before, RFID is an automatic identification technology that enables transmission of the identity of an object wirelessly by using radio waves (Finkenzeller, 2010). An RFID system is basically comprised of three main components, transponder or tag which is the data-carrying device/chip and located on the object to be identified, interrogator or reader which is capable to read and/or write on tag and middleware which is used to manage information on tags and readers and provides a software user interface for the RFID system. The power supply to the tag and the data exchange between the tag and the reader are achieved with using electromagnetic fields. In general, valuable information regarding to patients, medical assets or drugs are securely stored (i.e. with an encryption) on a database. The readers facilitate communication between the database and the tags on (wireless) local area network. The tags can either be a smartcard, which is similar to public transportation cards we use in daily life, or wristband given to patients, or a sticker printed by using RFID printers. In addition to fixed readers in rooms or gateways, information on the tags can be read/updated by using mobile readers. Data accessibility and system functionality must be ensured at all times. Figure 4 illustrates a sample RFID system design within a hospital.
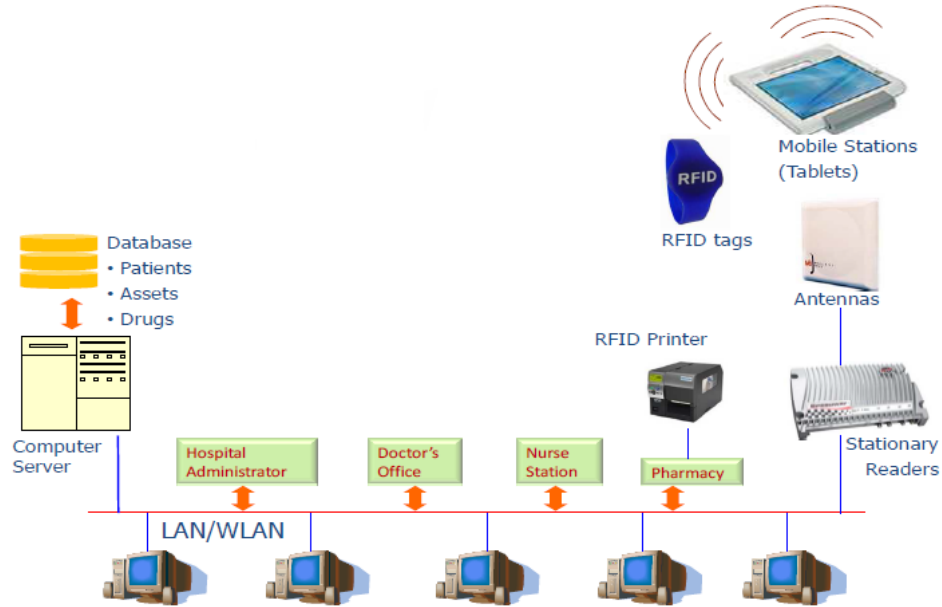
Figure 4 - Illustration of a RFID system design (Polycarpou, et al., 2011)

2.3.2 Recent RFID Implementations in (Out)Patient Logistics

The aim of this sub-section is to discover recent RFID usage and deployment in patient logistics processes in health care. Since there is not any distinct separation between the implementations in outpatient and inpatient logistics, we analyzed the articles independent from their implementation setting. The literature review was conducted in multiple scientific search engines, ABI/Inform, Web of Science and Google Scholar. Table 3 illustrates search terms used during the literature review. The terms were searched in all areas except "full text" and only scholarly journal articles and conference proceedings published after 2000 were selected. Figure 5 illustrates selection procedure and criteria of articles.

Table 3 - Search terms used during the 2nd literature review

Search No.	Search Terms
1	*(healthcare OR health care)* AND *(RFID)*
2	*(healthcare OR health care)* AND *(logistics)* AND *(RFID)*
3	*(hospital)* AND *(RFID)*

28

Article
Selection
Procedure

- Number of articles selected in the first round.   **(138)**
- Number of articles after the removal of duplicates   **(104)**
- Does the article focus on health care or hospital processes?   **(72)**
- Does the article focus on patient logistics?   **(36)**
- Does the article involve or propose a RFID-based solution to patient logistics problems?   **(19)**
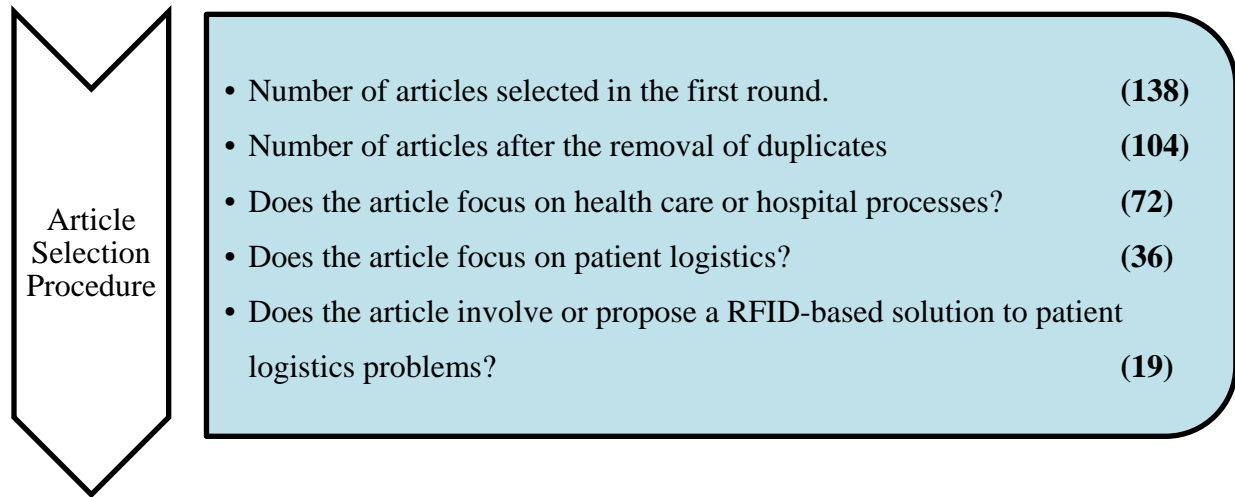
Figure 5 - Selection procedure of the articles

19 articles were selected based on the procedure and classified and matched with the outpatient logistics problems classified in Chapter 2.2. One article is focused on scheduling problems (5%), six articles are focused on process inefficiencies (32%), eight articles are focused on patient safety concerns (42%) and four articles are focused on both patient safety concerns and process inefficiencies (21%). None of the selected articles proposes a solution to physical layout problems category. Table 4 summarizes the selected articles, the characteristics of RFID implementation (i.e. where RFID tags were located) and their matched problem category. The following sub-section summarizes the main findings of the selected articles.

Table 4 - Recent RFID implementations in patient logistics

Article #	Article	Published in	Tags located on	Applicable Problem Category
[1]	Al-Safadi & Zainab	2011	P	Process Inefficiencies
[2]	Bendavid, Boeck, & Philippe	2010	Smart Shelf	Patient Safety Concerns
[3]	Bendavid, Boeck, & Philippe	2012	M	Patient Safety Concerns Process Inefficiencies
[4]	Cerlinca, Prodan, Turcu, & Cerlinca	2010	P	Patient Safety Concerns

[5]	Chen, et al.	2005	P	Patient Safety Concerns Process Inefficiencies
[6]	Jiao, Li, & Jiao	2008	P | S	Process Inefficiencies
[7]	Lin, Chiu, Hsiao, Lee, & Tsai	2006	P	Patient Safety Concerns
[8]	Magliulo, Cella, & Pacelli	2012	P	Patient Safety Concerns Process Inefficiencies
[9]	Marjamaa, Torkki, Torkki, & Kirvelä	2006	P	Process Inefficiencies
[10]	Parlak, Sarcevic, Marsic, & Burd	2012	M	Process Inefficiencies
[11]	Pérez, et al.	2012	P | M	Patient Safety Concerns
[12]	Polycarpou, et al.	2011	P | S | M	Patient Safety Concerns
[13]	Priya, Anandhakumar, & Maheswari	2008	P | S	Planning and Scheduling
[14]	Shim, Uh, Lee, & Yoon	2011	M	Patient Safety Concerns
[15]	Southard, Chandra, & Kumar	2012	P | S | M	Patient Safety Concerns Process Inefficiencies
[16]	Stahl, Drew, Leone, & Crowley	2011	P | S	Process Inefficiencies
[17]	Stahl, Holt, & Gagliano	2011	P | S	Process Inefficiencies
[18]	Thuemmler, Buchanan, & Kumar	2007	P	Patient Safety Concerns
[19]	Yu, Hou, & Chiang	2012	P | S | M	Patient Safety Concerns

P: Tags were located on patients in order to identify/track/monitor the patients.
S: Tags were located on medical staff in order to identify/track/monitor the staff.
M: Tags were located on medical equipment (drugs, specimen, etc.) or valuable medical assets/devices in order to identify/track/monitor them.

2.3.3 The Related Work

Parlak, Sarcevic, Marsic, & Burd (2012) described the process of introducing RFID technology in a trauma bay in order to support complex and fast-paced processes such as resuscitation process. They divided the trauma bay into several zones that represents main locations of object storage and use. Floor-facing and ceiling-mounted antennas were located to read tags on several medical equipment and assets. By using RFID technology, the researchers tracked zone-based location information and motion status of the medical equipment in order to understand team activity during the operations and whether the equipment are in use or not.

In their research, Magliulo, Cella, & Pacelli (2012) coupled RFID system involving patient tracking and document tracking to a medical record system. When a patient arrives at hospital, he/she receives a badge (active tag) and a sticker (passive tag) locating on the patient's

document. The active tag is for detecting the real-time location and the path of the patient and the passive tag is for identifying the location of the document. The hospital's HIS stores all information regarding to the patient's flow and medical documents. According to the researchers, preliminary study shows the feasibility of the system in order to optimize clinical processes.

Southard, Chandra, & Kumar (2012) combined RFID technology and Six-Sigma philosophy in their redesign study in surgical processes of an outpatient clinic. The redesign study examined many aspects of RFID implementation, from traceability and visibility of patients to coordination and cooperation activities to reduce medical errors. The researchers provided a detailed cost-benefit analysis through a simulation study.

Pérez, et al. (2012) presented a multi-purposed RFID system in an emergency department. The first purpose of the system was measuring patient waiting time and service delivery time, whereas the second purpose was to supply correct doses of medication to the correct patient. Active tags were used to identify patients and passive tags were located on drugs to trace availability and dosage of medication given to the specific patient.

Polycarpou, et al. (2011) presented RFID identification system which was based on passive RF tags and aimed to identify patients, real-time location of medical assets and drug inventory monitoring. The authors focused more on readability performance of the system in different clinic settings. However, the research was promising to reduce negative effects of patient safety issues.

According to Stahl, Holt, & Gagliano (2011) in a clinical setting, patients and staff have variety of paths to complete their tasks. By using an indoor positioning system, the researchers examined processes and process durations (patient flow time, patient waiting time and service time) in two

31

different clinics. All clinical staff and patients were tagged by RFID transponders during the clinical processes. At the end of the research, the researchers mapped patient flow alternatives through the clinics with the associated waiting times and service times. They indicated that this insight can be used to identify targets/bottlenecks for process improvements and to measure the consequences of those improvements.

During their research project Stahl, Drew, Leone, & Crowley (2011) analyzed the performance of a real-time location system based on active RFID tags. An outpatient clinic staff were volunteered to wear RFID tags continuously while the tags also used on patients during check-in and check-out processes. RFID tags recorded patient flow time in the clinic (from registration to discharge), patient wait time in waiting room and the service times in operation rooms and laboratory. In addition, assigning of clinical staff to the patients was reorganized. Before the RFID implementation, medical assistants, who are responsible for bringing the patients in from the waiting room and measuring vital signs, had been called by practitioners on an ad-hoc basis from a central working pool. After the RFID implementation, the medical assistants started to be assigned to the specific practitioners. The system provided the clinic to make the arrival rate of patients into the operation room smoother and resulted less idle time and higher utilization rate.

Bendavid, Boeck, & Philippe (2010) presented a smart-shelf design by combining "kanban" philosophy and RFID technology for the replenishment process of supplies and high-value products. RF tags were located on drug boxes which contain two different bins, primary bin and stock-buffer bin. When the drugs in the primary bin run out, nurses remove the tag (containing information of the drugs) from the bin and put it on a board on where a reader is located and could read the tag. A middleware analyzes the data on the tag and transmits the replenishment

32

order to HIS. In the meantime, nurses replenish the drugs in the primary bin by using stock-buffer in the secondary bin and then remove the tag located on the board and put it on the primary bin again. The same researchers (Bendavid, Boeck, & Philippe, 2012) also presented a similar research, a case study, focusing on redesigning of delivery and replenishment process of high value supplies and tracking of medical devices. Instead of smart shelves/cabinets, the researchers presented a system which can capture the product data at the point of entry and at the point of consumption.

Cerlinca, Prodan, Turcu, & Cerlinca (2010) proposed a real time patient identification and monitoring system in order to reduce medication mistakes especially in case of emergency. The proposed system involves the use of electronic patient identity cards, which are passive RFID tags and show the actual health state of the patients. The system helps medical staff to give their decisions based on the information on tags, reduces wrong medication risks and thus improves patients' overall safety. Similar researches were conducted by Yu, Hou, & Chiang (2012) and Thuemmler, Buchanan, & Kumar (2007).

Priya, Anandhakumar, & Maheswari (2008) indicated that patient flow in emergency departments is highly unpredictable and patients must be dynamically scheduled instead of first come-first served basis. Therefore, the researchers proposed a dynamic scheduling algorithm supported by RFID technology The proposed system checks doctors' availability and also number of patients waiting in the queue. The proposed system take several objectives into consideration during dynamic allocation of doctors, patients and resources; such as minimizing patient waiting time and doctors' idle time, and nature (criticalness) of patients' complaint.

Jiao, Li, & Jiao (2008) combined a process reengineering study with RFID technology. The researchers defined the main bottlenecks in the discharge process of an acute care hospital and proposed a redesigned process supported by active RFID tags. Manual tasks carried out by clinic staff, frequent data errors caused by misidentification of patients and long waiting duration at the end of the discharge process were the main bottlenecks. At the end of their simulation study, the researchers demonstrated potential time savings in terms of total waiting time of patients, total busy time of clinical staff, bed occupation time and increase in staff utilization during the discharge process.

Marjamaa, Torkki, Torkki, & Kirvelä (2006) described a wireless patient location system which was designed to track patients' progress in the perioperative process. Their main purpose was to present potential benefits of automatically documented process timestamp based on RF/IR technology as compared to manual recording. According to the results of the research, automatically documented data was available way faster than the traditional data on HIS. The delay in 75% of manual documentation activities was around 9 minutes, whereas it was 2 minutes in RFID-supported automatic documentation. Al-Safadi & Zainab (2011)'s research is another good example to illustrate how the data automatically collected by RFID technology can be useful to analyze and redesign patient logistics processes.

Chen, et al. (2005) applied RFID technology into an emergency department in order to create real-time reminders which aimed to decrease delay in doctors' decisions and improve patient safety. During admission phase, a patient receives bracelets embedded with RFID chip which contains essential medical information such as the patient's birth date, blood type, allergy, prescribed medications, etc. The doctors used real-time patient information into their decision

making process. The researchers analyzed the system for an 8-month period and compared the results to the setting in which RFID technology was not used. According to their results, patient waiting time for acute bed and intensive care were significantly decreased by using of RFID-based system.

Lin, Chiu, Hsiao, Lee, & Tsai (2006) combined RFID, GPS, GIS and GSM wireless technologies into a system solution which aimed to track and monitor elderly patients suffering from dementia and protect their safety. Location of (missing) patients can be found via various mobile devices in less than 45 seconds. The proposed system can be used for similar patients who have to be tracked due to their critical health conditions.

Shim, Uh, Lee, & Yoon (2011) offered an advanced RFID-based specimen labeling and management system which allowed mass data processing and specimen tracking. The researchers proposed that the demonstrated system can improve workflow and specimen management of clinical laboratories significantly.

2.4 Classification of Literature Reviews and Managerial Insights

This section presents a summary for the Chapter 2 and also a classification of outpatient logistics problems and applicable RFID solutions to each problem category. Two literature reviews were combined on a matrix to provide an easy-to-read categorization for both outpatient logistics problems and RFID implementations which can be used to solve problems in them. Figure 6 presents the matrix on which the numbers in cells represent the selected articles in Chapter 2.3.

	Patient	Staff	Medical Equipment / Asset
Scheduling Problems	[13]	[13]	
Process Inefficiencies	[1], [5], [6], [8], [9], [15], [16], [17]	[6], [15], [16], [17]	[3], [10], [15]
Patient Safety Concerns	[4], [5], [7], [8], [11], [12], [15], [18], [19]	[12], [15], [19]	[3], [11], [12], [14], [15], [19]
Physical Layout Problems			

RFID implementations based on tracked / monitored / identified object (column header)
Outpatient Logistics Problems (row header)

Figure 6 - The classification of outpatient logistics problems and the recent RFID implementations in (out)patient logistics

Based on the first literature review, we classified the most problematic issues in outpatient logistics. The literature highlights that scheduling problems, inefficient processes, patient safety problems and ill-designed physical layout are the most serious issues presenting difficulties to outpatient logistics activities. Based on the second literature review, we classified the recent RFID implementations with respect to the tracked/identified object, on which the tags were located, and their problem category. The researchers have presented that the deployment of

RFID technology in health care could provide benefits in terms of several aspects (such as efficiency, cost, etc.). The most common implementation of RFID technology in patient logistics is tracking and identifying patients in health care processes in order to provide real-time correct patient information and collect time-based information to detect and automate manual/inefficient processes. The second most common implementation of RFID technology in patient logistics is monitoring real-time location of medical assets, medical inventory (such as availability of drugs) and tracing dosage of medication given to the specific patient. On the other hand, there a few studies which focused on analyzing service delivery time and (dynamic) allocation of staff by tracking medical staff (especially doctors) with using RFID technology. We did not find any RFID system proposal/design which analyzes and/or presents solution to physical layout problems. In addition to the presented benefits, we gave new insights into each category in order to increase the understanding of health care professionals about how RFID technology can be used further in outpatient logistics processes.

Scheduling Problems: As stated before, scheduling problems is the most serious problem category in outpatient logistics based on its share in the selected articles (21 out of 45, %47). The researchers focused on this problem category had two main purposes. First, they wanted to create the optimum scheduling system which provides the highest utilization rate mainly by decreasing doctors' idle time and patients' waiting time as much as possible. Second, they wanted to overcome the disruptive effects (i.e. unpunctuality of patients, high no-show rates, late-cancellations, walk-ins, etc.) which harm the efficiency of clinics/hospitals dramatically. However, if we look at RFID implementations in patient logistics processes, we only find one article focusing on this category. Priya, Anandhakumar, & Maheswari (2008) proposed a

dynamic scheduling system in which doctors, patients and resources were tracked and allocated dynamically in order to minimize patient waiting time and doctors' idle time. If we adjust a scheduling system by real-time identification and monitoring of patients, we can improve efficiency of the system significantly. For instance, if a patient arrives at the clinic ten minutes later than his/her scheduled appointment time, the doctor can invite another patient to operating room instead of waiting that patient. Similarly, if a patient does not appear for his/her planned appointment for a defined time period, he/she can be regarded as a "no-show patient" and the scheduling system can be adjusted. Therefore, we may get significant benefits in terms of time-saving and efficiency. Dynamic scheduling systems based on real-time monitoring and identification could have a huge potential to overcome scheduling problems.

Process Inefficiencies: Based on the outpatient logistics problems classification, process inefficiencies is the second serious category with respect to 13 selected articles (out of 45 articles, 29%). RFID implementations focusing on this problem category can be analyzed in terms of several aspects. A set of articles aimed to improve the selected problematic processes by automating manual tasks (Jiao, Li, & Jiao, 2008), by satisfying real-time correct information through the processes (Chen, et al., 2005) or proposing alternative designs (Bendavid, Boeck, & Philippe, 2010). In another set of articles, the core purpose was to discover and illustrate bottlenecks/inefficiencies in the processes either by patient tracking or analyzing data automatically collected by the RFID-based hospital information system (Stahl, Holt, & Gagliano, 2011; Al-Safadi & Zainab, 2011). In addition, Southard, Chandra, & Kumar (2012) focused on the potential of RFID-supported health care processes in terms of cost saving. As a summary, we can conclude that RFID technology can have a huge and positive impact on outpatient logistics

processes. We can discover bottlenecks in processes, redesign inefficient processes and find cost-saving ideas by using RFID.

Patient Safety Concerns: Diagnostic errors, medication errors, inaccurate documentation of patient information and misidentification of patients are critical issues which can harm patient safety. RFID implementations focusing on this problem category are mostly based on patient identification and medical asset/equipment tracking. For instance, Cerlinca, Prodan, Turcu, & Cerlinca (2010) proposed an RFID-based patient identification system to provide correct medication to the correct patient. The proposed system allows doctors to obtain electronic medical record of an identified patient anytime, easily. A similar system proposed by Thuemmler, Buchanan, & Kumar (2007) allows medical staff to see critical patient information such as allergy and infectious diseases that patients have. Moreover, Pérez, et al. (2012)'s research aimed to ensure the correct matching between a patient and medication prescribed by doctor for him/her while tracing the location of patients and drugs at the same time. By using a RFID-based system similar to Shim, Uh, Lee, & Yoon (2011)'s proposal, we can find the specimen of a patient easily among thousands of stored specimens in case of emergency and create an automatic precise specimen documentation/management system. In addition, if we have patients who have critical health condition (e.g. patients suffering from dementia, wheel-chaired patients, children, etc.), we can track them in real-time as proposed by Lin, Chiu, Hsiao, Lee, & Tsai (2006). It can be concluded that RFID has a potential to reduce patient safety problems in outpatient logistics.

Physical Layout Problems: Although some researchers (Soriano-Meier, Forrester, Markose, & Garza-Reyes, 2011; Vos, Groothuis, & van Merode, 2007) mentioned that physical setting of

clinics/hospitals can decrease the efficiency of outpatient logistics activities, we could not find any article which has an RFID system implementation/proposal focusing on this area. However, Stahl, Holt, & Gagliano (2011)'s research is a promising example to overcome problems in the area. As mentioned before, by tracking patients through the clinic, the researchers mapped the flow of each patient with the associated waiting times. If we add distance as a dimension to this patient flow map, we can measure how long it takes for a patient to go from a point to another point and analyze the effect of distance on service delivery time, patient waiting time and the efficiency of clinical processes.

3. Technology Acceptance Model

As stated in Chapter 2, the existing literature proposed that RFID could enhance the performance of the health care organizations by reducing mistakes, automating manual processes and/or exploring/eliminating inefficient, redundant tasks. However, a new technology does not provide benefits, if it is not used by people. Thus, we need to understand and predict why people accept or reject a new technology (Davis, Bagozzi, & Warshaw, 1989). Since the last 50 years, user acceptance of new technology and its determinants have received significant attention from many researchers. Several frameworks were proposed to explain technology acceptance/adoption in terms of users' individual characteristics, organizational characteristics and/or characteristics of the new technology. Diffusion of Innovations Model (Rogers, 1962), Theory of Reasoned Action (Ajzen & Fishbein, 1980) and Technology Acceptance Model (Davis, 1989) can be given as examples of those widely recognized and studied technology acceptance frameworks.

In this research, Technology Acceptance Model (TAM), which was adapted from Theory of Reasoned Action (TRA), was selected as the theoretical framework for model development, due to its extensive support through validations, applications and replications by researchers and practitioners (Venkatesh, 2000).

According to TRA, people's beliefs influence attitude and with the combination of subjective/social norms, shape people's behavioral intention. Davis (1986; 1989) used and adapted the theory to TAM in his research in order to explain the determinants of technology acceptance.

3.1   Theoretical Framework and Model Development

According to Davis (1986; 1989), the main goal of TAM is to "provide an explanation of the determinants of computer acceptance that is general, capable of explaining user behavior across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified". Davis (1986) proposed that two specific individual beliefs, "perceived usefulness" and "perceived ease of use", are the major determinants of "attitude toward using the new technology". In addition, a potential user's overall attitude toward using a new technology is the main determinant of his/her "behavioral intention to use the new technology", which influences "actual technology/system use" directly. Figure 7 presents the illustration of TAM proposed by Davis (1986).
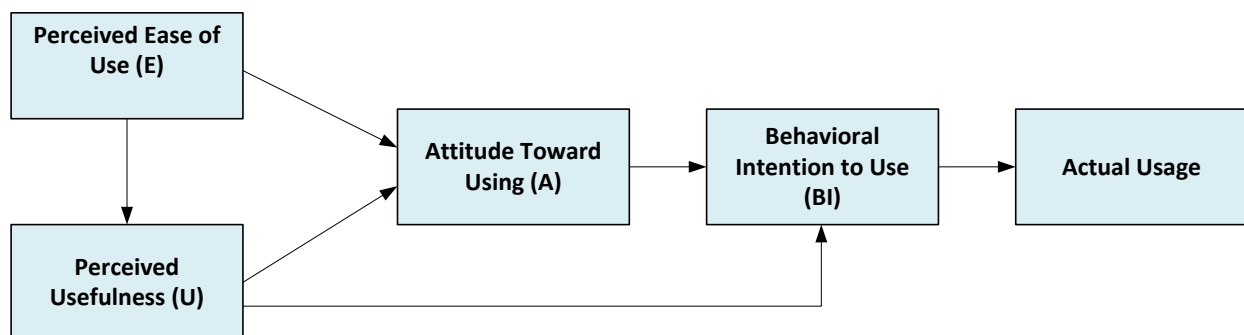
Figure 7 - Technology Acceptance Model (Davis, 1986)

In the final Technology Acceptance Model, attitude toward using was removed from the model, since it was found that there was a weak direct link between attitude towards and perceived usefulness, and attitude toward using only partially mediated the relationship among perceived usefulness, perceived ease of use and behavioral intention to use (Davis, Bagozzi, & Warshaw, 1989; Venkatesh, 2000).

Technology Acceptance Model was accepted and replicated by many researchers in different settings over time. The original model was expanded as TAM2 (Venkatesh & Davis, 2000) and TAM3 (Venkatesh & Bala, 2008) by adding new variables (such as management support, incentive alignment, organizational support, etc.) to explain and predict behavioral intention in a better way.

3.1.1 Hypotheses Development

In this research, our purpose was to examine user acceptance of RFID technology based on explaining and predicting people's behavioral intention to use the technology rather than their actual usage. RFID usage in health care, especially in outpatient setting, is still in a development stage and RFID implementations are very limited. Therefore, it is difficult to analyze the relationship between behavioral intention to use and actual system usage, without observing usage rate of people in practical environment in which RFID technology is deployed.

In addition, the conceptual framework of this research was derived from the original TAM theory instead of the expanded theories such as TAM2 or TAM3. The reasons of this decision were that again the limited RFID implementations in outpatient setting and health care professionals' lack of knowledge and experience in RFID technology. Although we use RFID technology everywhere in our daily life (such as electronic public transportation cards, OV-chipkaart in the Netherlands), most of the people are still unaware of the technology. Therefore, it is not so meaningful to analyze relationship between, for instance, "experience", "output quality" or "perceived enjoyment" (three of the proposed additional variables in TAM2 and TAM3 theories) and perceived usefulness, perceived ease of use or behavioral intention to use. The results of this research also supports this approach, since 60% health care professionals

participated in the research did not have prior knowledge or experience in RFID technology and 87% of them never used RFID in their organizations.

According to TAM, perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" and perceived ease of use is described as "the degree to which a person believes that using a particular system would be free of effort". Moreover, these beliefs are primary determinants of behavioral intention to use a system which is "the degree to which a person has conscious plans to use the system in the future or not". In other words, if a user believes that a particular technology increases his/her performance and/or if learning to operate with that technology requires acceptable effort (from the user's perspective); the user will more likely plan to use the technology in the future. Therefore, similar to original TAM theory, three hypotheses can be developed for the user acceptance of RFID technology in outpatient setting;

> H1: Perceived ease of use has a positive direct effect on behavioral intention to use RFID technology in outpatient logistics.

> H2: Perceived usefulness has a positive direct effect on behavioral intention to use RFID technology in outpatient logistics.

> H3: Perceived ease of use has a positive direct effect on perceived usefulness of RFID technology in outpatient logistics.

Figure 8 shows the research model adapted from the TAM theory with the associated hypotheses.
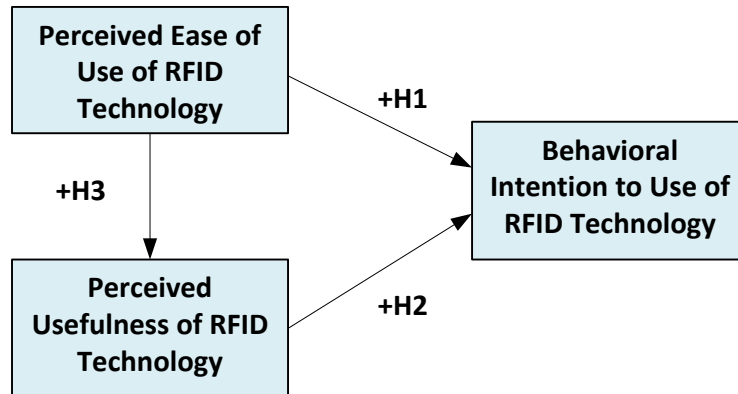
Figure 8 - Research Model

3.1.2 Hypothesis Testing

In order to test aforementioned hypotheses, the required data which included health care professionals' perception of usefulness, ease of use and behavioral intention to use RFID technology, was collected by a survey. Structural Equation Modeling (SEM) was used for analyzing data and testing the hypotheses.

SEM aims to explain relationships among multiple variables and examines the structure of interrelationships similar to series of multiple regression equations (Hair, et al., 2010). The equations present the relationships among constructs (i.e. unobservable or latent factors represented by multiple variables like variables representing a factor in factor analysis).

All structural equation models are distinguished by three characteristics (Hair, et al., 2010).

1. Estimation of multiple and interrelated dependence relationships.

2. An ability to represent latent factors in these relationships including measurement errors.

3. Defining a model to explain the entire set of relationships.

In this research our unobserved/latent constructs are perceived usefulness, perceived ease of use and behavioral intention to use which are represented by observable/measurable variables, in other words, questions/items in survey.

Based on the model of this research, visual expression of the measurement equation model can be found in λ : *Measurement Loading*

$P_{outcome, predictor}$: *Structural Path Coefficient*

e : Error Terms

Figure 9.

Figure 9 - Visual expression of the structural model

The measurement model is the first part of a conventional SEM analysis. It represents the theory which shows how measured variables represent the constructs. The second part is the structural model which shows how the constructs are associated with each other (Hair, et al., 2010).

Structural Equation Model can be expressed by two basic expressions.

- General CFA Model : observed factor = latent construct + error

    For instance, $U1 = \lambda_{U1} PU + e_{U1}$, whereas λ_{U1} is factor loading between PU and U1, and e_{U1} is error term.

- General Structural Equation Model : data = model + error

    For instance, $BI = P_{BI,PE} PE + P_{BI,PU} PU + e$, whereas P is path coefficient between outcome construct and indicator construct, and e is error term.

Explanatory power of the selected theory can be analyzed by coefficient of determination (R^2) which provides a measure how well the observed outcomes can be replicated by the model.

4. Survey Design

The method used in this research included a survey design. From TAM and RFID literature, a survey instrument was developed in order to collect data and opinions from health care professionals. The survey instrument and items were pretested and reviewed by two different experts to evaluate face and construct validity. One of the experts was an active outpatient specialist/doctor who has plenty of experience in outpatient setting and the other one was an engineer specialized in RF and medical device design. The survey items/questions consisted of seven-point Likert scale ranging from "strongly disagree" to "strongly agree". Based on card sorting method, the survey items were randomized and the experts were asked to place them into logical categories. The experts classified the survey items into correct categories (i.e. constructs; perceived usefulness, perceived ease of use, behavioral intention to use) with a minimum accuracy rate of 90%.

The survey instrument began with a cover page which included the purpose of the research, intended use of the collected data and confidentiality statement. Furthermore, a definition of RFID technology and a daily life example (i.e. OV-chipkaart) were presented in order to explain the technology especially for inexperienced health care professionals. The definition was followed by common examples of RFID technology deployment in health care based on the proposed systems/designs in the literature (Polycarpou, et al., 2011; Thuemmler, Buchanan, & Kumar, 2007; Stahl, Holt, & Gagliano, 2011). The format of survey instrument was reviewed and validated by the experts in terms of wording and meaningfulness in the health care context.

In order to prevent missing data and/or incomplete responses, it was compulsory to answer all survey items. In the final version of the survey, the survey items were arranged in a random

order in order to prevent monotonous responses and/or potential ceiling/floor effect. The survey ended with a demographics section. The illustrative version of the survey can be found in Appendix B.

4.1 Data Collection and Sample Characteristics

The target sample of this research was various Dutch health care professionals including doctors, nurses, IT specialists, hospital/ward/clinic managers, etc. The survey was distributed through personal contacts in Dutch health care industry and professional social-networks (i.e. Linkedin). The research is one of the few researches which used contemporary communication technologies (i.e. social networks) as the main data collection source. At first, the survey was posted on the main page of six Dutch hospitals' Linkedin Groups which have approximately 10.000 members mainly composing of Dutch health care professionals. 555 health care professionals, who were members of the groups, were contacted individually based on their titles/responsibility in their organizations and invited to participate in the survey. In total, 127 responses were received, however, 18 of the responses were excluded from data analysis, since the responsibility of the participant in the health care organization was either missing or irrelevant to the research[1]. Therefore, 109 of the responses were included in the data analysis. The sample size was adequate for a structural equation modeling analysis having five of fewer constructs with more than three items (Hair, et al., 2010). The demographics information of the respondents can be found in Table 5.

---

[1] Although responsibility in the organization section was required to be filled, some respondents skipped that area with "space" or "?". In addition, responsibilities/positions such as product manager, clinical trial, PhD etc. were excluded from the data analysis.

Table 5 - Characteristics of sample

	Frequency (n=109)	Percentage in the sample	Avg. Experience (Years)	Min. Experience (Years)	Max. Experience (Years)	Std. Dev. (Years)
Doctor	69	63%	9.59	1	44	8.29
Management Function	13	12%	12.69	4	35	9.48
IT Function	9	8%	11.38	3	25	8.05
Nurse / Nurse Practitioner	8	7%	19.88	7	41	13.31
Consultant / Advisor	3	3%	6.67	2	11	4.51
Hospital Pharmacist	3	3%	16.00	6	25	9.54
Other	4	4%	5.50	0	10	4.43
TOTAL	**109**	**100%**	**10.81**	**0**	**44**	**9.06**

Average working experience of participants in health care industry was 10.81 years. As seen in Table 5, sample characteristics were aligned with the multi-actor approach of the research, since it contained participants with diverse backgrounds. More than half of the total participants were doctors and detailed characteristics of them can be found in Appendix C. 60% of the participants did not have prior knowledge or experience in RFID technology and 87% of them never used RFID technology in their jobs/organizations when the survey was conducted. The participants in management function category stated their responsibility in the organization as director, manager, clinic manager or logistics advisor.

4.2 Measurement Scales and Validity Analysis

The survey was divided into three sections (excluding demographics information section) and expected to measure health care professionals' perceptions regarding perceived ease of use, perceived usefulness and behavioral intention to use of RFID technology in outpatient logistics processes. As stated by Hair, et al. (2010), using measurement scales from prior research gives, in general, better results than inventing new scales. Therefore, the measurement scales was derived from prior researches from Davis (1989) and Venkatesh (2000). The literature suggested

high reliability and validity for the measurement scales, since they were used and their validity were assessed by many researchers (Mathieson, 1991; Venkatesh, 2000).

The validity of measurement scales was evaluated in terms of reliability and construct validity. Table 6 illustrates Cronbach's alpha values of the measurement scale items. Cronbach's alpha is the most common measure of reliability and generally used for testing the reliability of scales which are formed by multiple Likert questions in a survey. The desired Cronbach's alpha value for a reliable measurement scale is 0.70 or above, according to Hair, et al. (2010). All measurement scales had Cronbach's alpha value greater than 0.90 which states that the scales were highly reliable (Hair, et al., 2010).Construct validity of the instrument was analyzed in terms of convergent validity and discriminant validity by using correlation analysis and confirmatory factor analysis. Correlation among items which were supposed to measure the same construct considerably higher than correlation among the other items which were supposed to measure different constructs. For instance, correlation coefficients among U1-U6 were .889, .858, .781, .762 and .855 respectively. On the other hand, correlation coefficients among U1 and E1-E5 were .288, .188, .175, .212 and .248 respectively. In addition, based on confirmatory factor analysis, three components aligning with TAM constructs were extracted. Scree plot also described three components up to elbow. Items which were supposed to measure the same constructs had considerably higher communalities/factor loadings on a single component than on other components. Communalities for each component were marked as bold in component matrix. Table 7 summarizes the findings of correlation analysis and confirmatory factor analysis. The results of correlation analysis and confirmatory analysis showed that the measurement scales used in the survey had adequate construct validity.

Table 6 - Analysis of the measurement scale reliability

Latent Construct and Theory	Item / Variable	Cronbach's alpha
Perceived Usefulness of RFID technology (Davis, 1989)	**U1:** Using RFID technology in my job would enable me to accomplish tasks more quickly	0.96
	U2: I would find RFID technology useful in my job.	
	U3: Using RFID technology would make it easier to do my job.	
	U4: Using RFID technology would improve my job performance.	
	U5: Using RFID technology in my job would increase my productivity.	
	U6: Using RFID technology would enhance my effectiveness on the job.	
Perceived Ease of Use of RFID Technology (Davis, 1989)	**E1:** I would find RFID technology easy to use.	0.91
	E2: Learning to operate RFID technology would be easy for me.	
	E3: It would be easy for me to become skillful at using RFID technology.	
	E4: My interaction with RFID technology would be clear and understandable.	
	E5: I would find RFID technology to be flexible to interact with.	
Behavioral Intention to Use RFID Technology (Venkatesh, 2000)	**B1:** Assuming I had access to the system, I intend to use it.	0.98
	B2: Given that I had access to the system, I predict that I would use it.	

Table 7 - Analysis of measurement scale validity (Correlation Matrix and Component Matrix)

	U1	U2	U3	U4	U5	U6	E1	E2	E3	E4	E5	B1	B2
U1	1.00												
U2	.889**	1.00											
U3	.858**	.826**	1.00										
U4	.781**	.767**	.800**	1.00									
U5	.762**	.731**	.815**	.735**	1.00								
U6	.855**	.831**	.811**	.870**	.817**	1.00							
E1	.288**	.268**	.360**	.233*	.247**	.258**	1.00						
E2	.188*	.162	.206*	.118	.112	.136	.664**	1.00					
E3	.175	.149	.230*	.118	.125	.141	.722**	.818**	1.00				
E4	.212*	.201*	.306**	.301**	.161	.195*	.673**	.666**	.767**	1.00			
E5	.248**	.244*	.357**	.289**	.254**	.213*	.669**	.600**	.620**	.750**	1.00		
B1	.740**	.755**	.690**	.656**	.626**	.716**	.401**	.353**	.326**	.351**	.388**	1.00	
B2	.717**	.730**	.680**	.668**	.633**	.713**	.407**	.334**	.303**	.345**	.386**	.970**	1.00

**. Correlation is significant at the 0.01 level.
*. Correlation is significant at the 0.05 level.

Component Matrix [a]

	Component		
	1	2	3
U1	.870	-.327	.029
U2	.855	-.338	-.027
U3	.881	-.240	.210
U4	.827	-.317	.220
U5	.795	-.343	.208
U6	.858	-.371	.094
E1	.565	.642	.046
E2	.459	.740	-.157
E3	.468	.782	-.029
E4	.526	.710	.184
E5	.549	.624	.208
B1	.868	-.082	-.446
B2	.860	-.088	-.440

Extraction Method: Principal Component Analysis.
a. 3 components extracted

Scree Plot
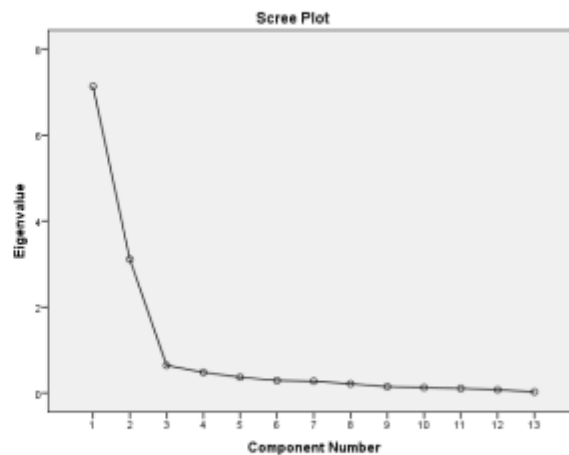
5.   Structural Equation Modeling Results

In order to predict and explain health care professionals' behavioral intention to use RFID technology in outpatient logistics, we analyzed TAM by using structural equation modeling (SEM) on Lisrel 9.1. SEM is one of the most common tools to analyze models which have multiple latent constructs (i.e. perceived usefulness, perceived ease of use and behavioral intention to use) and multiple causal relationships among them.

Before investigating the relationships among the constructs and testing the hypothesis, overall model fit was assessed based on several fit indices as suggested in the literature (Hair, et al., 2010; Schreiber, Nora, Stage, Barlow, & King, 2006; Hartwick & Barki, 1994). The main purpose of fit indices is to analyze how well the collected/observed data fits the suggested model. In other words, fit indices determine how well the specified model (estimated covariance matrix) reproduces the observed relationships (observed covariance matrix). Chi-square / Degree of Freedom, Root Mean Square Error Approximation (RMSEA), Standardized Root Mean Residual (SRMR), Normalized Fit Index (NFI), Non-normed Fit Index (NNFI) and Comparative Fit Index (CFI). All of the fit index values were within desired range except RMSEA. However, according to Hair, et al. (2010) what "good" RMSEA value is debatable and it was best suited to use for large samples (500 and more). It can be concluded that the model fit was reasonably adequate to assess the results of the structural model, based on fit indices. More information regarding to fit indices can be found in Appendix D. Table 8 presents the desirable fit index values and structural model fit index values.

Table 8 - Assessment of overall model fit

Fit Index	Desirable Value	Hypothesized Structural Model
Chi-square / Degree of Freedom	≤ 3.0	2.3
Root Mean Square Error of Approximation (RMSEA)	≤ 0.08	0.11
Standardized Root Mean Residual (SRMR)	≤ 0.05	0.05
Normalized Fit Index (NFI)	≥ 0.90	0.94
Non-normed Fit Index (NNFI)	≥ 0.90	0.96
Comparative Fit Index (CFI)	≥ 0.95	0.96

Based on the structural equation model results, there was a statistically significant positive relationship between perceived ease of use and behavioral intention to use (std. path coefficient = 0.21, $p \leq 0.001$, t = +3.357). It means that every unit increment in perceived ease of use will increase an individual's behavioral intention to use RFID technology in outpatient logistics by 0.21 unit. Therefore, hypothesis 1 (H1) of the research was supported.

In addition, there was a statistically significant positive relationship between perceived usefulness and behavioral intention to use (std. path coefficient = 0.74, $p \leq 0.001$, t = +11.220). It concludes that every unit increment in perceived usefulness will strengthen an individual's behavioral intention to use RFID technology in outpatient logistics by 0.74 unit. Therefore, hypothesis 2 (H2) of the research was supported.

Moreover, there was a statistically significant positive relationship between the perceived ease of use and the perceived usefulness (std. path coefficient = 0.25, $p \leq 0.005$, t = +2.498). It suggests that every unit increment in perceived ease of use will increase an individual's perceived usefulness of RFID technology in outpatient logistics by 0.25 unit. Therefore, hypothesis 3 (H3) of the research was supported.

The explanatory power of the model (i.e. R^2) for behavioral intention to use RFID technology in outpatient logistics was 0.67. It stated that perceived ease of use and perceived usefulness together were able to explain/predict 67% of the variance observed in health care professionals behavioral intention to use RFID technology in outpatient logistics. Figure 10 summarizes the findings of structural equation modeling on path diagram.
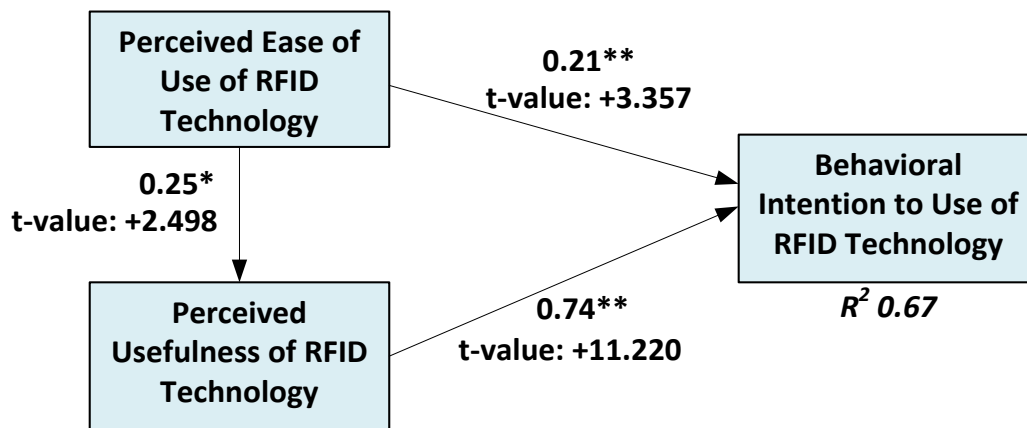
Structural Equation
BI = 0.739*PU + 0.214*PE, Error Variance = 0.330, R² = 0.670
Std. Error (0.066)   (0.064)   (0.051)
Z-values   11.220   3.357   6.479
P-values   0.000   0.001   0.000

**. Correlation is significant at the 0.001 level.
*. Correlation is significant at the 0.05 level.
Structural Equation:

Figure 10- Structural model of behavioral intention to use RFID technology in outpatient logistics

6. Conclusions, Discussions & Limitations and Future Work

This chapter consists of the conclusions of the research project, the main limitations and the possible future works.

6.1 Conclusions

In the beginning of the research, we defined our core focus as analyzing the problems in health care processes in hospital/clinical environment, since more than a quarter of total health care expense was generated in hospital/clinical environment (Statistics Netherlands, 2011). Within this perspective, patient logistics covering all planning and control activities was selected as the main research area. Furthermore, we focused on outpatient logistics problems, a sub section of patient logistics, since the research in outpatient logistics is still limited compared to the research in inpatient logistics setting.

Through a comprehensive literature review, in which more than 300 articles were reviewed, we classified the most problematic issues in outpatient logistics. The literature underlines that scheduling problems, inefficient processes, patient safety problems and ill-designed physical layout are the most serious issues presenting difficulties to outpatient logistics activities.

As the second objective of the research, we investigated the recent implementations of one of the most promising technologies in health care, RFID technology, in order to contribute in information technology deployment area. Various researchers proposed RFID based solutions/designs to solve aforementioned problems. The most common implementation of RFID technology in patient logistics is tracking and identifying patients in health care processes in order to provide real-time correct patient information and collect time-based information to detect and automate manual/inefficient processes. The second most common implementation of

RFID technology in patient logistics is monitoring real-time location of medical assets, medical inventory (such as availability of drugs) and tracing dosage of medication given to the specific patient. On the other hand, there a few studies which focused on analyzing service delivery time and (dynamic) allocation of staff by tracking medical staff (especially doctors) with using RFID technology. We did not find any RFID system proposal/design which analyzes and/or presents solution to physical layout problems.

The aim of the last part of the research was to explain health care professionals' behavioral intention to use RFID technology in outpatient logistics. We tested one of the most influential theories in technology adoption in outpatient logistics setting. Our research model based on TAM theory was evaluated by the data collected from more than 100 Dutch health care professionals with diverse backgrounds. Using the contemporary information and communication technology, professional social networks, was also an innovative approach to collect data. The results suggested the general adequacy and applicability of TAM in this professional context with relatively reasonable fit indices for the model. In agreement with TAM theory, perceived usefulness and perceived ease of use was found to have positive statistically significant influence on health care professionals' behavioral intention to use RFID technology in outpatient logistics.

The results of SEM analysis can be concluded as below.

1) Perceived usefulness is the main determinant of behavioral intention to use RFID technology in outpatient logistics.

2) Perceived ease of use is secondary determinant of behavioral intention to use RFID technology in outpatient logistics.

58

3) Perceived ease of use is also a determinant of perceived usefulness of RFID technology in outpatient logistics.

6.2   Discussions

Personal characteristics and perceptions are critical issues in human aspects of innovation management. There have been many research efforts to understand the relationship between personal characteristics and innovation management (Miron & Naveh, 2004; Shalley & Oldham, 2004). This research also contributes in human aspects of innovation management by investigating the relationship between personal perceptions and the acceptance of a new technology. If decision makers in health care industry want health care professionals to use RFID technology, it is necessary to demonstrate that RFID technology will enhance their performance without spending too much effort. Within this perspective, before implementing RFID technology into health care processes, the advantages of the technology should be clearly communicated with health care professionals either by training activities, workshops or case studies. These activities should stress how RFID technology can help them to increase their efficiency and effectiveness and also show that using RFID technology will be free of effort. Moreover, short but informative video demonstrations can be prepared to illustrate how RFID could be used.

6.2.1   Likelihood of RFID Adoption in Outpatient Logistics

Likelihood of RFID adoption in outpatient logistics was examined by comparing the values of latent constructs with the "zero point" of the measurement scale (i.e. Neutral point of the scale – 4), as proposed by the Method Evaluation Model (MEM) of Moody (2003). MEM presents us whether the mean responses of the participants are significantly positive or negative as compared

59

to neutral/zero point of the scale. Based on the collected data all latent constructs were found to be significantly positive which means that RFID technology is likely to be adopted in practice. The results of the MEM analysis can be found in Table 9. Although all of the constructs were found to be significant, the mean difference of perceived ease of use and behavioral intention use were found relatively higher than the mean difference of perceived usefulness. It can be concluded that health care professionals perceived that they could advance in using RFID technology easily and would likely use it, if it was available for their use. However, they still thought that benefits provided by RFID technology are not so high. Nevertheless, they perceived the usage of RFID technology in outpatient logistics slightly useful.

Table 9 - Likelihood of RFID adoption in outpatient logistics

One-Sample Statistics, Test Value = 4, n = 109					95% Confidence Interval of the Mean Difference	
Latent Construct	**Mean**	**Std. Deviation**	**Mean Difference**	**Significance***	**Lower**	**Upper**
Perceived Usefulness	4.3547	1.47198	.35474	.013	.0753	.6342
Perceived Ease of Use	5.4862	1.03508	1.48624	.000	1.2897	1.6828
Behavioral Intention to Use	5.0413	1.65989	1.04128	.000	.7261	1.3564

*All values were significant at the $p < 0.05$ level.

6.2.2 Insights from TAM Research in Health Care

Table 10 summarizes the prior research of TAM in health care setting, their sample/domain characteristics, the path coefficients and the reported explanatory power of the models for behavioral intention to use and actual usage behavior (if they were available).

Table 10 - Prior research of TAM in health care and their findings

Research	Technology	Sample / Domain Characteristics	Sample Size	Perceived Usefulness (Path Coef.)	Perceived Ease of Use (Path Coef.)	Behavioral Intention to Use (R^2)	Actual Usage (R^2)
Chau & Hu (2001)	Telemedicine	Doctors in Hong-Kong	408	0.36	Not direct relationship	0.44	N/A
Han (2005)	Mobile medical information / communication system	Doctors in Finland	242	0.37	Non-significant	0.70	N/A
Liu & Ma (2006)	Electronic Medical Records	Miscellaneous Health care professionals in the USA	77	0.61	0.21	0.52	N/A
Paré, Sicotte, & Jacques (2006)	Computerized provider order entry	Doctors in a hospital in Canada	91	0.40	Not direct relationship	N/A	0.55
Rawstorne, Jayasuriya & Caputi (2000)	Computerized care plans	Nurses in Australia	61	0.33 0.40 0.42	0.32 0.24 Non-sig.	0.30 0.29 0.24	0.12 Non-Sig. 0.10
Tung, Chang, & Chou (2008)	Electronic logistics information system	Nurses in Taiwan	252	0.23	0.22	0.70	N/A
Van Schaik, Bettany-Saltikov & Warren (2002)	Mobile medical information / communication system	Doctors in the UK	49	0.63	Non-significant	Not reported	0.39
Wu, Wang, & Lin (2007)	Mobile medical information / communication system	Medical Staff at medical centers/hospitals in Taiwan	123	0.22	0.48	0.70	N/A

N/A: The latent construct was not included in the research. Non-Sig: Path coefficient was not found significant.

First, there is no standard research model for TAM studies in health care. The research model highly differs from one research to another. For instance, Rawstorne, Jayasuriya & Caputi (2000) used a research model which was similar to the research model of this study, whereas Tung, Chang, & Chou (2008) included additional constructs in their research model such as "trust" and "perceived financial cost". Similarly, some researches included "attitude toward using" as a construct to their research model (Chau & Hu, 2001). Second, even the different functions of the same technology presented different results. For instance, Rawstorne, Jayasuriya & Caputi (2000) analyzed three different functions of computerized care plans and all of them gave different results. Finally, most of the researches did not analyze the actual system usage. Therefore, it can be concluded that the relationships among the constructs and the explained variances highly differ from one research model, technology/function or setting to another. The differences between them significantly affected the path coefficients and the variance explained in intention/actual system usage.

In addition, the observed explanatory power of this research (i.e. $R^2 = 0.67$) was relatively high as compared to prior researches. The observed relatively high R^2 value could be a result of high influence of perceived usefulness (0.74) on behavioral intention to use.

6.3   Limitations and Future Work

The research presented a cross-sectional analysis of the data collected from various health care professionals and focused on only behavioral intention to use RFID technology in outpatient logistics. However, the relationship between behavioral intention to use and actual system usage should also be examined by longitudinal analysis which includes pre-implementation and post-implementation stages of RFID technology. In addition, health care professionals who participated in this research were volunteers and inevitably subject to self-selection biases. It is possible that health care professionals who were interested in technology adoption might more likely to respond the survey. Therefore, future research should be directed to investigate TAM theory in mandatory usage context.

Another limitation is that most of the healthcare professionals who participated in the survey had never used RFID technology in their job. Thus, the correlation between perceived ease of use and behavioral intention to use could be higher or lower, if they had prior knowledge in RFID technology and if they already experienced required effort to use the technology.

The results of this research can explain/predict 67 percent of the variance observed in behavioral intention to use RFID technology in outpatient logistics. Thus, it is clear that other factors should be included to the model in order to explain the remaining variance. Based on the feedbacks received, especially IT specialists have hesitation to use RFID technology due to security and privacy concerns. Moreover, the factors proposed by other adoption theories (e.g. extended TAM, TRA, TPB) such as management support, peer support, working environment characteristics should be included in the model in the future research.

REFERENCES

Ajzen, I., & Fishbein, M. (1980). *A theory of reasoned action. Understanding Attitudes and Predicting Social Behaviour.* Englewoods Cliffs: NJ: Prentice Hall.

Alaeddini, A., Yang, K., Reddy, C., & Yu, S. (2011). A probabilistic model for predicting the probability of no-show in hospital appointments. *Health Care Management Science, 14*(2), 146-157.

Al-Safadi, L., & Zainab, A. S. (2011). RFID-Based Clinical Decision Support System using Simulation Modeling. *Journal of Applied Sciences, 11*, 2808-2815.

Bendavid, Y., Boeck, H., & Philippe, R. (2010). Redesigning the replenishment process of medical supplies in hospitals with RFID. *Business Process Management Journal, 16*(6), 991-1013.

Bendavid, Y., Boeck, H., & Philippe, R. (2011). RFID-Enabled Traceability System for Consignment and High Value Products: A Case Study in the Healthcare Sector. *Journal of Medical Systems*, 1-17.

Bendavid, Y., Boeck, H., & Philippe, R. (2012). RFID-Enabled Traceability System for Consignment and High Value Products: A Case Study in the Healthcare Sector. *Journal of medical systems, 36*(6), 3473-3489.

Bowers, J., Lyons, B., Mould, G., & Symonds, T. (2005). Modelling outpatient capacity for a diagnosis and treatment centre. *Health care management science, 8*(3), 205-211.

Cayirli, T., & Veral, E. (2003). Outpatient scheduling in health care: a review of literature. *Production and Operations Management, 12*(4), 519-549.

Cayirli, T., Veral, E., & Rason, H. (2008). Assessment of patient classification in appointment system design. *Production and Operations Management, 3*(17), 338-353.

Cerlinca, T., Prodan, R., Turcu, C., & Cerlinca, M. (2010). A distributed RFID based system for patients' identification and monitoring. *In 10th International Conference on Development and Application Systems.*, (pp. 444-448).

Chakraborty, S., Muthuraman, K., & Lawley, M. (2010). Sequential clinical scheduling with patient no-shows and general service time distributions. *IIE Transactions,, 42*(5), 354-366.

Chau, P. Y., & Hu, P. J. (2001). Information technology acceptance by individual professionals: A model comparison approach. *Decision Sciences, 32*(4), 699-719.

Chen, C. C., Wu, J., & Crandall, R. E. (2007). Obstacles to the adoption of radio frequency identification technology in the emergency rooms of hospitals. *International Journal of Electronic Healthcare, 3*(2), 193-207.

Chen, C. I., Liu, C. Y., Li, Y. C., Chao, C. C., Liu, C. T., Chen, C. F., & Kuan, C. F. (2005). Pervasive observation medicine: The application of RFID to improve patient safety in observation unit of hospital emergency department. *Studies in Health Technology and Informatics, 116*, 311-315.

Cutler, D. M., & Huckman, R. S. (2003). Technological development and medical productivity: the diffusion of angioplasty in NY State. *Journal of Health Economics, 22*(2), 187-217.

Davis, F. D. (1986). A technology acceptance model for empirically testing new end-user information systems: Theory and results. *(Doctoral dissertation, Massachusetts Institute of Technology).*

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management science, 35*(8), 982-1003.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management Science, 35*(8), 982-1003.

De Bleser, L. D., Waele, K. D., Vanhaecht, K., Vlayen, J., & Sermeus, W. (2006). Defining pathways., . *Journal of Nursing Management, 14*(7), 553-563.

de Vries, J., & Huijsman, R. (2011). Supply chain management in health services: an overview. *Supply Chain Management: An International Journal, 16*(3), 159-165.

Denton, B., & Gupta, D. (2003). A sequential bounding approach for optimal appointment scheduling. *Iie Transactions, 35*(11), 1003-1016.

Dickson, E. W., Singh, S., Cheung, D. S., Wyatt, C. C., & Nugent, A. S. (2009). Application of lean manufacturing techniques in the emergency department. *The Journal of emergency medicine, 37*(2), 177-182.

Edelman, D. (2002). Outpatient diagnostic errors: unrecognized hyperglycemia. *Effective clinical practice: ECP, 5*(1), 11-16.

Finkenzeller, K. (2010). *RFID handbook: fundamentals and applications in contactless smart cards, radio frequency identification and near-field communication.* Wiley.

Friedman, A. L., Geoghegan, S. R., Sowers, N. M., Kulkarni, S., & Formica Jr, R. N. (2007). Medication errors in the outpatient setting: classification and root cause analysis. *Archives of Surgery, , 142*(3), 278-283.

Gandhi, T. K., Weingart, S. N., Seger, A. C., Borus, J., Burdick, E., Poon, E. G., . . . Bates, D. (2005). Outpatient prescribing errors and the impact of computerized prescribing. *Journal of general internal medicine, 20*(9), 837-841.

Giachetti, R. E., Centeno, E. A., Centeno, M. A., & Sundaram, R. (2005). Assessing the viability of an open access policy in an outpatient clinic: a discrete-event and continuous simulation modeling approach. *the 37th Winter Simulation Conference*, (pp. 2246-2255).

Glowacka, K. J., Henry, R. M., & May, J. H. (2009). A hybrid data mining/simulation approach for modelling outpatient no-shows in clinic scheduling. *Journal of the Operational Research Society, 60*(8), 1056-1068.

Gupta, D., & Denton, B. (2008). Appointment scheduling in health care: Challenges and opportunities. *IIE transactions , 40*(9), 800-819.

H., S., Naik, A. D., Rao, R., & L.A., P. (2008). Reducing diagnostic errors through effective communication: harnessing the power of information technology. . *Journal of General Internal Medicine, 23*(4), 489-494.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). *Multivariate Data Analysis* (Vol. 7). Upper Saddle River, NJ: Prentice Hall.

Han, S. (2005). Does Fragmentation of Working Time and Working Space Influence the Acceptance of Mobile Technology? A Case of Finnish Physicians. . *Turku Centre for Computer Science*.

Harrop, P., & Das, R. (2012). *RFID Forecasts, Players and Opportunities 2012-2022*. Cambridge, UK: IDTechEx.

Hartman, M., Catlin, A., Lassman, D., Cylus, J., & Heffler, S. (2008). US health spending by age, selected years through 2004. *Health Affairs, 27*(1), 1-12.

Hartwick, J., & Barki, H. (1994). Explaining the role of user participation in information system use. *Management science, 40*(4), 440-465.

Holden, R. J., & Karsh, B. T. (2010). The technology acceptance model: its past and its future in health care. *Journal of biomedical informatics, 43*(1), 159-172.

Hu, P. J., Chau, P. Y., Sheng, O. R., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of management information systems, 16*(2), 91-112.

Huijsman, R., & Vissers, J. (2005). Supply Chain Management in Health Care: State of the Art and Potential. In J. Vissers, *Health operations management* (pp. 147-167). Routledge.

Hutzschenreuter, A. K. (2010). A Computational Approach to Patient Flow Logistics in Hospitals (Master's thesis). Retrieved from Retrieved from Dissertations and Theses database of Technische Universiteit Eindhoven.

Jansen-Vullers, M. H., & Reijers, H. A. (2005). Business process redesign in healthcare: Towards a structured approach. *INFOR-OTTAWA, 43*(4), 321.

Jiao, Y. Y., Li, K., & Jiao, R. J. (2008). A case study of hospital patient discharge process re-engineering using RFID. *4th IEEE International Conference* (pp. 1342-1347). IEEE.

Joustra, P. E., Kolfin, R., van Dijk, N. M., Koning, C. C., & Bakker, P. J. (2012). Reduce fluctuations in capacity to improve the accessibility of radiotherapy treatment cost-effectively. *Flexible Services and Manufacturing Journal, 24*(4), 448-464.

Kaandorp, G. C., & Koole, G. (2007). Optimal outpatient appointment scheduling. *Health Care Management Science, 10*(3), 217-229.

Klassen, K. J., & Rohleder, T. R. (2004). Outpatient appointment scheduling with urgent clients in a dynamic, multi-period environment. *International Journal of Service Industry Management,, 15*(2), 167-186.

Kolisch, R., & Sickinger, S. (2008). Providing radiology health care services to stochastic demand of different customer classes. *OR Spectrum, 30*(2), 375-395.

Kopach, R., DeLaurentis, P. C., Lawley, M., Muthuraman, K., Ozsen, L., Rardin, R., . . . Willis, D. (2007). Effects of clinical characteristics on successful open access scheduling. *Health care management science , 10*(2), 111-124.

Kumar, A., & Shim, S. J. (2007). Eliminating emergency department wait by BPR implementation. *2007 IEEE International Conference* (pp. 1679-1683). IEEE.

LaGanga, L. R., & Lawrence, S. R. (2007). Clinic overbooking to improve patient access and increase provider productivity. *Decision Sciences, 38*(2), 251-276.

Langabeer, J. R., DelliFraine, J. L., Heineke, J., & Abbass, I. (2009). Implementation of Lean and Six Sigma quality initiatives in hospitals: A goal theoretic perspective. *Operations Management Research, 2*(1-4), 13-27.

Lillrank, P., Groop, J., & Venesmaa, J. (2011). Processes, episodes and events in health service supply chains. *Supply Chain Management: An International Journal, 16*(3), 194-201.

Lin, C. C., Chiu, M. J., Hsiao, C. C., Lee, R. G., & Tsai, Y. S. (2006). Wireless health care service system for elderly with dementia. . *Information Technology in Biomedicine, 10*(4), 696-704.

Lippi, G., Salvagno, G. L., Montagnana, M., Franchini, M., & Guidi, G. C. (2006). Phlebotomy issues and quality improvement in results of laboratory testing. *Clinical laboratory, 52*(5-6), 217-230.

Liu, L., & Ma, Q. (2006). Perceived system performance: a test of an extended technology acceptance model. *ACM SIGMIS Database, 37*(2-3), 51-59.

Liu, N., Ziya, S., & Kulkarni, V. G. (2010). Dynamic scheduling of outpatient appointments under patient no-shows and cancellations. *Manufacturing & Service Operations Management, 12*(2), 347-364.

Magliulo, M., Cella, L., & Pacelli, R. (2012). Novel technique radio frequency identification (RFID) based to manage patient flow in a radiotherapy department. *In Biomedical and Health Informatics (BHI), 2012 IEEE-EMBS International Conference* (pp. 972-975). IEEE.

Mans, R. S., Schonenberg, M. H., Song, M., Van der Aalst, W. M., & Bakker, P. J. (2009). Application of process mining in healthcare–a case study in a dutch hospital. In *Biomedical Engineering Systems and Technologies* (pp. 425-438). Heidelberg: Springer Berlin.

Marjamaa, R. A., Torkki, P. M., Torkki, M. I., & Kirvelä, O. A. (2006). Time accuracy of a radio frequency identification patient tracking system for recording operating room timestamps. *Anesthesia & Analgesia, 102*(4), 1183-1186.

Martin, A. J., Hogg, P., & Mackay, S. (2012). Martin, A. J., Hogg, P., & Mackay, S. (2012). A mixed model study evaluating lean in the transformation of an Orthopaedic Radiology service. *Radiography., 19*, 2-6.

Martin, S. C., Greenhouse, P. K., Kowinsky, A. M., McElheny, R. L., Petras, C. R., & Sharbaugh, D. T. (2009). Rapid improvement event: An alternative approach to improving care delivery and the patient experience. *Journal of Nursing Care Quality, 24*(1), 17-24.

Mathieson, K. (1991). Predicting user intentions: comparing the technology acceptance model with the theory of planned behavior. *Information systems research, 2*(3 (1)), 173-191.

Matta, M. E., & Patterson, S. S. (2007). Evaluating multiple performance measures across several dimensions at a multi-facility outpatient center. *Health care management science, 10*(2), 173-194.

McPhillips, H. A., Stille, C. J., Smith, D., Hecht, J., Pearson, J., Stull, J., . . . Davis, R. L. (2005). Potential medication dosing errors in outpatient pediatrics. *The Journal of pediatrics, 147*(6), 761-767.

Meijboom, B., Schmidt-Bakx, S., & Westert, G. (2011). Supply chain management practices for improving patient-oriented care. *Supply Chain Management: An International Journal, 16*(3), 166-175.

Melanson, S. E., Goonan, E. M., Lobo, M. M., Baum, J. M., Paredes, J. D., Santos, K. S., . . . Tanasijevic, M. J. (2009). Applying Lean/Toyota production system principles to improve phlebotomy patient satisfaction and workflow. *American journal of clinical pathology, 132*(6), 914-919.

Miron, E. E., & Naveh, E. (2004). Do personal characteristics and cultural values that promote innovation, quality, and efficiency compete or complement each other? *Journal of Organizational Behavior, , 25*, 175-199.

Moody, D. L. ((2003, June)). The method evaluation model: a theoretical model for validating information systems design methods. . *In ECIS*, (pp. 1327-1336).

Murray, M., & Berwick, D. M. (2003). Advanced access. *JAMA: the journal of the American Medical Association, 298*(8), 1035-1040.

Muthuraman, K., & Lawley, M. (2008). A stochastic overbooking model for outpatient clinical scheduling with no-shows. *Iie Transactions, 40*(9), 820-837.

Ngai, E. W., Moon, K. K., Riggins, F. J., & Yi, C. Y. (2008). RFID research: An academic literature review (1995–2005) and future research directions. *International Journal of Production Economics, 112*(2), 510-520.

OECD. (2011). *Health at a Glance 2011: OECD Indicators.* OECD Publishing.

Ogulata, S. N., Cetik, M. O., Koyuncu, E., & Koyuncu, M. (2009). A simulation approach for scheduling patients in the department of radiation oncology. *Journal of medical systems, 33*(3), 233-239.

Panella, M., Marchisio, S., & Di Stanislao, F. (2003). Reducing clinical variations with clinical pathways: do pathways work?. *International Journal for Quality in Health Care, 15*(6), 509-521.

Paré, G., Sicotte, C., & Jacques, H. (2006). The effects of creating psychological ownership on physicians' acceptance of clinical information systems. *Journal of the American Medical Informatics Association, 13*(2), 197-205.

Parlak, S., Sarcevic, A., Marsic, I., & Burd, R. S. (2012). Introducing RFID technology in dynamic and time-critical medical settings: Requirements and challenges. *Journal of Biomedical Informatics., 45*, 958-974.

Patrick, J., Puterman, M. L., & Queyranne, M. (2008). Dynamic multipriority patient scheduling for a diagnostic resource. *56*(6), 1507-1525.

Pérez, M. M., Cabrero-Canosa, M., Hermida, J. V., García, L. C., Gómez, D. L., González, G. V., & Herranz, I. M. (2012). Application of RFID Technology in Patient Tracking and Medication Traceability in Emergency Care. *Journal of medical systems, 36*(3), 3983-3993.

Polycarpou, A. C., Gregoriou, G., Papaloizou, L., Polycarpou, P., Dimitriou, A., Bletsas, A., & Sahalos, J. N. (2011). A healthcare application based on passive UHF RFID technology. (pp. In Antennas and Propagation (EUCAP), Proceedings of the 5th European Conference). IEEE.

Priya, G. N., Anandhakumar, P., & Maheswari, K. G. (2008). Dynamic scheduler-a pervasive healthcare system in smart hospitals using RFID. *In Computing, Communication and Networking* (pp. 1-6). IEEE.

Przywara, B. (2010). *Projecting future health care expenditure at European level: drivers, methodology and main results.* Directorate General Economic and Monetary Affairs. European Commission.

Rawstorne, P., Jayasuriya, R., & Caputi, P. (2000, December). Issues in predicting and explaining usage behaviors with the technology acceptance model and the theory of planned behavior when usage is mandatory. *the 21st international conference on Information systems* (pp. 35-44). Association for Information Systems.

Robinson, L. W., & Chen, R. R. (2010). A comparison of traditional and open-access policies for appointment scheduling. *Manufacturing & Service Operations Management, 12*(2), 330-346.

Rogers, E. M. (1962). *Diffusion of innovations.* Glencoe: Free Press.

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of Educational Research, 99*(6), 323-338.

Shalley, C. Z., & Oldham, G. R. (2004). The effects of personal and contextual characteristics on creativity: Where should we go from here? *Journal of Management, 30*, 933-958.

Shim, H., Uh, Y., Lee, S. H., & Yoon, Y. R. (2011). A new specimen management system using RFID technology. *Journal of medical systems, 35*(6), 1403-1412.

Singh, H., Naik, A. D., Rao, R., & Petersen, L. (2008). Reducing diagnostic errors through effective communication: harnessing the power of information technology. *Journal of General Internal Medicine, 23*(4), 489-494.

Singh, H., Thomas, E. J., Mani, S., Sittig, D., Arora, H., Espadas, D., . . . Petersen, L. A. (2009). Timely follow-up of abnormal diagnostic imaging test results in an outpatient setting: are electronic medical records achieving their potential? *Archives of internal medicine, 169*(17), 1578–1586.

Soriano-Meier, H., Forrester, P. L., Markose, S., & Garza-Reyes, J. A. (2011). The role of the physical layout in the implementation of lean management initiatives. *International Journal of Lean Six Sigma, 2*(3), 254-269.

Southard, P. B., Chandra, C., & Kumar, S. (2012). RFID in healthcare: a Six Sigma DMAIC and simulation case study. *International Journal of Health Care Quality Assurance, 25*(4), 291-321.

Stahl, J. E., Drew, M. A., Leone, D., & Crowley, R. S. (2011). Measuring process change in primary care using real-time location systems: feasibility and the results of a natural experiment. *Technology and Health Care, 19*(6), 415-421.

Stahl, J. E., Holt, J. K., & Gagliano, N. J. (2011). Understanding performance and behavior of tightly coupled outpatient systems using RFID: Initial experience. *Journal of Medical Systems, 35*(3), 291-297.

Stanton, M. W., & Rutherford, M. K. (2006). The high concentration of US health care expenditures. *Agency for Healthcare Research and Quality*, 6-60.

Statistics Netherlands. (2011). Spending on health care and welfare levels off. Retrieved from http://www.cbs.nl/en-GB/menu/themas/gezondheid-welzijn/publicaties/artikelen/archief/2011/2011-038-pb.htm

Thuemmler, C., Buchanan, W., & Kumar, V. (2007). Setting safety standards by designing a low-budget and compatible patient identification system based on passive RFID technology. *International journal of healthcare technology and management, , 8*(5), 571-583.

Tung, F. C., Chang, S. C., & Chou, C. M. (2008). An extension of trust and TAM model with IDT in the adoption of the electronic logistics information system in HIS in the medical industry. *International journal of medical informatics, 77*(5), 324-335.
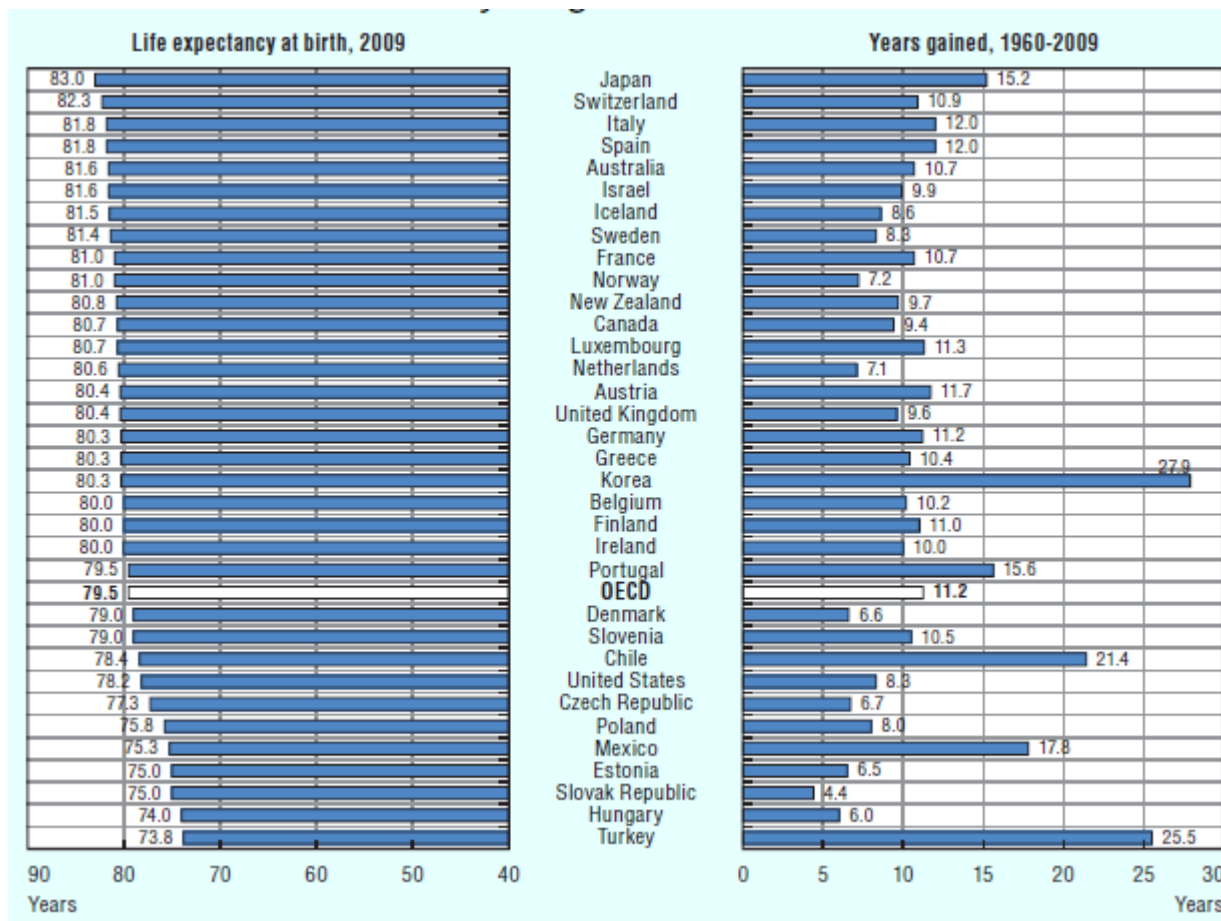
Van Schaik, P., Bettany-Saltikov, J. A., & Warren, J. G. (2002). Clinical acceptance of a low-cost portable system for postural assessment. *Behaviour & Information Technology, 21*(1), 47-57.

van Strien, P. J. (1997). Towards a Methodology of Psychological Practice The Regulative Cycle. *Theory & Psychology, 7*(5), 683-700.

Venkatadri, V., Raghavan, V. A., Kesavakumaran, V., Lam, S. S., & Srihari, K. (2011). Simulation based alternatives for overall process improvement at the cardiac catheterization lab. *Simulation Modelling Practice and Theory, 19*(7), 1544-1557.

Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information systems research, 11*(4), 342-365.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision sciences, 39*(2), 273-315.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management science, 46*(2), 186-204.

Villa, S., Barbieri, M., & Lega, F. (2009). Restructuring patient flow logistics around patient care needs: implications and practicalities from three critical cases. *Health care management science, 12*(2), 155-165.

Vos, L., Groothuis, S., & van Merode, G. G. (2007). Evaluating hospital design from an operations management perspective. . *Health care management science, 10*(4), 357-364.

Walsh, K. E., Dodd, K. S., Seetharaman, K., Roblin, D. W., Herrinton, L. J., Von Worley, A., . . . Gurwitz, J. H. (2009). Medication errors among adults and children with cancer in the outpatient setting. *Journal of Clinical Oncology, 27*(6), 891-896.

Widjaya, R., van der Horst, F., & Seck, M. (2011). Performance Improvement in Healthcare Processes. *Enterprise and Organizational Modeling and Simulation, 88*, 116-129.

Workman-Germann, J., & Hagg, H. W. (2007). Implementing Lean Six Sigma Methodologies in the Radiology Department of a Hospital Healthcare System. *RCHE Publications, 27*.

Wu, J. H., Shen, W. S., Lin, L. M., Greenes, R. A., & Bates, D. W. (2008). Testing the technology acceptance model for evaluating healthcare professionals' intention to use an adverse event reporting system. *International Journal for Quality in Health Care, 20*(2), 123-129.

Wu, J. H., Wang, S. C., & Lin, L. M. (2007). Mobile computing acceptance factors in the healthcare industry: A structural equation model. *International journal of medical informatics, 76*(1), 66-77.

Yang, Z., Norton, E. C., & Stearns, S. C. (2003). Longevity and health care expenditures the real reasons older people spend more. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 58*(1), 2-10.

Yarbrough, A. K., & Smith, T. B. (2007). Technology Acceptance among Physicians A New Take on TAM. *Medical Care Research and Review, 64*(6), 650-672.

Yokouchi, M., Aoki, S., Sang, H., Zhao, R., & Takakuwa, S. (2012). Operations analysis and appointment scheduling for an outpatient chemotherapy department. *Winter Simulation Conference*, (p. 81).

Yu, Y. C., Hou, T. W., & Chiang, T. C. (2012). Low Cost RFID Real Lightweight Binding Proof

    Protocol for Medication Errors and Patient Safety. *Journal of medical systems, 36*(2),

    823-828.

Zeng, B., Turkcan, A. L., & Lawley, M. (2010). Clinic scheduling models with overbooking for

    patients with heterogeneous no-show probabilities. *Annals of Operations Research,*

    178(1), 121-144.

Zhang, B., Youngblood, L., Murphy, G. D., Ramsay, M., & Xiao, Y. (2012). System engineering

    approach to documentation: An evaluation of the documentation process in a

    gastroenterology laboratory. *Journal of Biomedical Informatics, 45*, 591-597.

Zweifel, P., Felder, S., & Meiers, M. (1999). Ageing of population and health care expenditure: a

    red herring? *Health economics, 8*(6), 485-496.

APPENDIXES

Appendix A – Life expectancy at birth, 2009 (or nearest year available), and years gained since 1960

Life expectancy at birth, 2009	Country	Years gained, 1960-2009
83.0	Japan	15.2
82.3	Switzerland	10.9
81.8	Italy	12.0
81.8	Spain	12.0
81.6	Australia	10.7
81.6	Israel	9.9
81.5	Iceland	8.6
81.4	Sweden	8.8
81.0	France	10.7
81.0	Norway	7.2
80.8	New Zealand	9.7
80.7	Canada	9.4
80.7	Luxembourg	11.3
80.6	Netherlands	7.1
80.4	Austria	11.7
80.4	United Kingdom	9.6
80.3	Germany	11.2
80.3	Greece	10.4
80.3	Korea	27.9
80.0	Belgium	10.2
80.0	Finland	11.0
80.0	Ireland	10.0
79.5	Portugal	15.6
79.5	**OECD**	11.2
79.0	Denmark	6.6
79.0	Slovenia	10.5
78.4	Chile	21.4
78.2	United States	8.8
77.3	Czech Republic	6.7
75.8	Poland	8.0
75.3	Mexico	17.8
75.0	Estonia	6.5
75.0	Slovak Republic	4.4
74.0	Hungary	6.0
73.8	Turkey	25.5

Source: (OECD, 2011)

Appendix B – Survey Used in the Research

Thank you for your participation in our survey!

The information you provide will be used in a master thesis as part of TU/e's Innovation Management Program. You will be asked to fill out a short questionnaire that aims to investigate health care professionals' behavioral intention to use RFID (Radio Frequency Identification) Technology in outpatient processes.

The survey begins with a brief technology description followed by 14 questions and takes only ~5 minutes of your time. Your individual privacy and confidentiality of the information you provide will be maintained in all published and written data analysis.

If you have any questions or concerns about the survey please feel free to send an e-mail to burak.onurlu@gmail.com

Thanks for your participation again and Kind Regards,

Burak ONURLU
Eindhoven University of Technology
Master of Science in Innovation Management
burak.onurlu@gmail.com
nl.linkedin.com/in/burakonurlu

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

Continue »

RFID (Radio Frequency Identification) is a wireless technology for the purposes of automatically identifying and tracking tags (chips) attached to objects.

OV-chipkaart is a simple example of RFID technology we are using in daily life.

RFID Reader

Kaart hier

RFID Tag / Chip

Progress Rate

8%

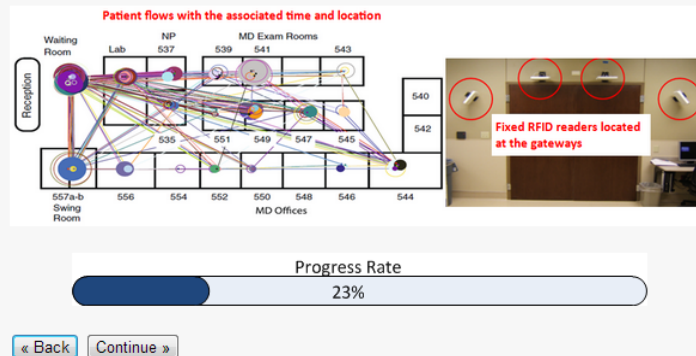« Back   Continue »

Similarly, we can use RFID technology in outpatient setting in which patients visit hospital/clinic for diagnosis or treatment without being hospitalized.

RFID smartcards or wristbands can be given to patients when they arrive at hospital/ clinic.

By using fixed RFID readers, we can monitor/track patients in real time and describe patient flows with the associated time and location.

Progress Rate
23%

« Back   Continue »

By using handheld RFID readers, patients can be identified and medical information regarding to patients can be retrieved/updated.

Illustration of a patient medical data screen

Progress Rate
30%

« Back   Continue »

Appendix C – Characteristics of Participants (Doctors)

	Frequency (n=69)	Percentage in the sample	Avg. Experience (Years)	Min. Experience (Years)	Max. Experience (Years)	Std. Dev. (Years)
Internal / General Medicine	15	22%	6.67	1	15	4.88
Dermatology	14	20%	7.50	1	15	4.52
Surgery	7	10%	12.71	2	30	9.69
Cardiology	6	9%	11.00	2	25	8.49
Multiple Specialization	6	9%	17.50	6	31	10.88
Radiology	4	6%	9.75	8	12	1.71
Pediatrics	4	6%	7.25	5	10	2.06
Oncology	3	4%	14.00	5	30	13.89
Pathology	2	3%	5.00	4	6	1.41
Other	8	12%	9.63	2	44	14.08
TOTAL	69	100%	9.59	1	44	8.29

Appendix D – Fit Indices

Root Mean Square Error of Approximation (RMSEA): The estimate of the discrepancy between the model and the data per degree of freedom for the model. Lower RMSEA value indicates better fit. Several desired values were proposed for RMSEA from ≤ 0.05 to ≤ 0.08 (Hair, et al., 2010; Schreiber, Nora, Stage, Barlow, & King, 2006), although drawing for an absolute cutoff value for RMSEA is inadvisable (Hair, et al., 2010).

Standardized Root Mean Residual (SRMR): The standardized value of root mean square residual which is the measure of the differences between the values predicted by a model and the observed variables (Hair, et al., 2010). According to Schreiber, Nora, Stage, Barlow, & King (2006), the desired value for SRMR is ≤ 0.08.

Normalized Fit Index (NFI) and Non-normed Fit Index (NNFI): NFI is the comparison between the hypothesized model and the null model in which all observed variables are assumed as uncorrelated (Hair, et al., 2010). NNFI is an improved version of NFI and also known as Tucker-Lewis Index. It is conceptually similar to the NFI but takes model complexity into account. Desired value for NFI and NNFI is ≥ 0.90 (Hair, et al., 2010; Schreiber, Nora, Stage, Barlow, & King, 2006; Hartwick & Barki, 1994).

Comparative Fit Index (CFI): An improved version of NNFI which examines the differences between the data and the hypothesized model. It is relatively insensitive to model complexity. Desired value for CFI differs ≥ 0.90 (Hair, et al., 2010) to ≥ 0.95 (Schreiber, Nora, Stage, Barlow, & King, 2006).