APPLICATION AND POTENTIALS OF WIRELESS COMMUNICATION TECHNOLOGIES IN PASSENGER AIR TRANSPORT FROM AN AVIATION SECURITY STANDPOINT

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Abstract

The paper discusses the effects of the integration of wireless communication technologies into the passenger air transport process. As the guiding example, Near Field Communication is introduced as the transmittal form for security relevant data. The integration has been evaluated by a passenger acceptance study, designed by using systems modeling language and will be validated in stochastic passenger flow simulations.

1 Introduction

Growth rates in air transportation are expected at 4.8% p.a. based on revenue passenger kilometers worldwide [1]. Current practices in process transactions for commercial and especially for aviation security purposes are at the limits of practicability. New regulations are increasing the amount of data that is required to be submitted. At the same time passengers are asking for seamless processes and would favor a consistent, easy to use method for identification and information exchange across different process stakeholders. The existing capacity constraints at airport infrastructures require the in-depth analysis of efficiency gains. The optimization of passenger processes within the terminal plays a key role in this context. Principles of automation and self-service at check-in and boarding are gaining further momentum and require alongside the technical development a consideration of the passenger's viewpoint. The identification of acceptance factors and the incorporation into the system design at an early stage are necessary for a successful adaptation of processes to new technological developments. To realize the projected growth rates and reach the aspired profitability levels while keeping the costs in reasonable boundaries the research into new applications of technologies and the individual analysis of their potentials could provide the needed solutions. By the use of wisely chosen technologies incentives can be created, which besides cost savings result in new advantages and service opportunities. Besides their procedural interrelation the commercial services and the security related processes have not yet been aligned towards the use of a compatible technology platform.

Hence the objective of this paper is to discuss the effects in the process flow in passenger air transport by the application of wireless communication technologies. With a focus on the aviation security strategy, the overall process will be re-designed with regard to simplifying transactions and providing relevant process information. The following section 2 describes the developments of the process design in passenger air transportation with its technological and systematic changes. In section 3 a brief introduction into the characteristics of wireless communication technologies and a description of existing and possible future applications will be given. For the central research part, the introduction of an NFC enabled device will be described on a system-wide level in section 4. In section 5 the research environment will be described with a focus on the results from the passenger acceptance study. The paper concludes in section 6 with the discussion of results and a future outlook.

2 Developments in Passenger Air Transportation Process Design

The process design in air transportation has changed tremendously in the last decades. For passenger handling operations, technological advancements, such as the introduction of the e-ticket, have made new procedures possible. Furthermore, technology enabled the principle of automation in most of the air transport process steps from check-in to boarding. Passengers are nowadays more or less forced to use self-service methods. However, the trend towards self-control and individualization of processes might be seen more positively by the majority of passengers in the future.

New regulations in aviation security policies have been introduced worldwide that lead to sensor technology installations and the set-up of databases for passenger pre-screening. Over the last decades explosive detection systems have been further refined and used to cover the 100% screening of checked baggage obligation. Advanced imaging technology came to publicity after the failed bombing of the Northwest Airlines flight 253, after which new sensor technology was asked for. Besides the introduction of new sensor technology also the security procedures have been adapted over the years to changing threat scenarios and risk assessments by the authorities. From the requirement of checked-baggage and the passenger-bag matching starting in the 1980s, the computer assisted pre-screening (CAPPS), the introduction of the Advance Passenger Information System (APIS) in 2005 to the TSA's Secure Flight Program - the provision of security data has been ever more increased. Intensive data gathering and assessments of passenger records are used to determine a passenger's risk status.

In recent years, a paradigm change can be seen in the trend towards diversification among passengers based on their risk. Searching for "bad people" instead of "bad objects" might be more efficient as sensor technology will reach its limits of practicability with high false rejection rates and increasing technology costs. Whether it is called profiling technique or in a more moderate term risk based grouping, aviation practitioners and leading industry associations [2] are increasingly favoring some kind of defined distinction between passengers, as for example in IATA's *Checkpoint of the Future* [3].

Trusted or registered traveler programs have been introduced since 2005 and tested in several pilots. The basic principle of trusted traveler programs is to register a passenger in advance with certain information and biometrical data, e.g. fingerprint or iris scan, and if granted assign him with a lower risk status, dependent on his background information [4]. This status will be valid for a defined time period and enable the passenger to access facilitated security control lines and automated border control gates. Although none of the trials has been a sustaining success, registering passengers will eventually be a central element in future aviation security, since it provides a reasonable method to cope with rising passenger numbers and increasing efficiency losses at security and immigration checkpoints.

Some technologies failed to deliver the anticipated results due to a lack of acceptance or malfunctions. The advanced imaging or body scanners for instance are not accepted in several countries as they are seen as being too intrusive and their effectiveness is criticized as well. Other technologies however still provide a great potential. E.g. in 2009 automated gates were installed for the immigration at Frankfurt Airport's border control in a pilot program and have been successfully transferred to real operation since 2010.

3 Wireless Communication Technologies in Passenger Air Transportation

In the following, several common characteristics of wireless communication technologies are described, existing applications are introduced and the technology is then confronted with likely future process design requirements.

3.1 Fundamental Characteristics of Wireless Communication Technologies

The term wireless communication technology can be defined as any form of data transmittal that does not require a cabling infrastructure instead the transmittal method works by modulation of radio signals. WLAN and Bluetooth are commonly used in personal devices for large communication data transfer and require a configuration of connectivity. Radio Frequency Identification (RFID) and Near Field Communication (NFC) can be used for automatic identification procedures without any configuration setting. All methods give the flexibility of contactless data transfer, which facilitates seamless processes. However, they vary in terms of frequency, range, and transmittal procedure as highlighted in table 1.

NFC is similar to RFID since it uses amplitude load modulation for the transmittal of data and allows to read and re-write RFID tags, but since it requires inductive coupling of electromagnetic fields it works over much shorter distances up to a few centimeters [5]. NFC interfaces can work in two different modes:

- active mode, transferring data between two NFC devices,
- passive mode, in which one NFC device emulates a reader, the other a smartcard and vice versa.

It is thus compatible to most smartcard systems (ISO14443). Besides short read ranges, NFC is more secure than RFID due to its capabilities of active-active mode in which considerable cryptographic measures can be run. More importantly, NFC is utilizing a secure element, either a hardware embedded chip, the SIM card, or a MicroSD, and could incorporate biometric applications on the mobile phone.

3.2 Past and Existing Applications

WLAN access points have been installed in most international airports for passenger use and are seen as a basic attractiveness factor. Operational aspects from the airline or airport

	NFC	RFID	Bluetooth	WLAN
Frequency	13.56 MHz	30kHz -13.56 MHz (inductive coupling) 400 MHz-2.5 GHz (propagation coupling)	2.4 GHz	2.4 & 5.15 GHz
Set-up time and manner	less than 0.1ms, automatic detection, touch or wave	less than 0.1ms, automatic detection	approx 6 sec. activation necessary	usually up to 30s considerable configuration needed
Range	up to 10cm	dependent on the use case, typically 3-5m,	5m, 10m, 100m dependent on classes	approx. 20m
Data transmittal rate	up to 424kbit/s	dependent on frequency, 5kbit/s to 424kbit/s	up to 3Mbit/s	up to 54 Mbit/s
Usability	human centric, easy	item centric, easy	data centric, moderate	data and application centric, moderate
RFID compatibility	yes, ISO 18000-3	n.a.	only active tags	only active tags

Table 1. Typical key characteristics of selected wireless communication technologies.

view, e.g. by using Bluetooth or WLAN network signals of passengers' devices for flow and wait time analysis, have been implemented only recently and similar applications are very likely to be introduced in the future.

RFID has proven its capabilities in automatic identification of objects in supply chain logistics. The first utilization field of RFID in air transport has been for baggage tagging to replace regular barcodes, which has been implemented in a first trial by British Airways in 1996. In 2005 the IATA has released the Recommended Practice (RP) 1740C document, in which the use of UHF tags and readers compliant with the ISO 18000-6C protocol for baggage tags is defined. The benefits and use of RFID has been explored by IATA in its Simplifying the Business program. According to IATA approx. 21% of baggage mishandling reasons, which are erroneous read rates (9.7%) and missing sorting information (10.9%), can be eliminated through the use of RFID tags [6]. Several further pilot projects have been carried out by airlines and airports around the world, i.a. AirFrance/KLM at Paris CDG, Amsterdam Schiphol, and Beijing Airport, and been introduced in real operations, i.a. at McCarran Int. Airport Las Vegas or Hong Kong. The achieved read ranges averaged 99% and were a clear improvement to the 85-90% of barcode systems. With regard to aviation security matters the FAA has studied the application of RFID focusing on controls over checked baggage handling and possible relation between high-risk passengers and their baggage [7]. After the 9/11 terrorist attacks the Department of Homeland Security has also focused on the use of RFID for baggage and people tracking and implementations of baggage tagging were realized at Las Vegas Airport with funding by the TSA. The expectations were to increase the security of baggage handling by enabling better tracking of screened baggage. Nevertheless RFID systems in air transport have not yet realized the expected potential and remain in isolated solutions without an integrative implementation between various infrastructures or services. Despite its apparent logistical advantages the RFID technology is still not implemented widely in the baggage logistics sector due to the uncertainty of return on investment and the disproportionate allocation of financial burden and operational advantages. Airports will bear considerable infrastructure investments whereas the airlines would realize the benefits of fewer mishandling baggage cases.

NFC has been in trials only recently around the world. Several consortiums have piloted the introduction of NFC for the transmittal of boarding cards and frequent traveler authorization. In 2009 the trial "Pass-and-Fly" by i.a. Air France and the airport Nice Côte d'Azur has been the first to demonstrate the capabilities of NFC [8]. Within a six-month period members of the Club Airport Premier and frequent flyer had the possibility to test NFC on the Nice-Paris-Orly route for the transmittal of the boarding card. Processes of passenger identification, boarding and crediting of bonus points could be simplified and the trial results were generally positive. In a similar trial SAS Scandinavian Airlines has tested NFC in 2011 for their frequent flyer. Traditional mobile phones could also be used in the trial by attaching an NFC sticker to them. The so called SAS Smart Pass was used for check-in, access to fast track lanes at security control, and to enter the lounge area. The latest trial has been at the Airport of Toulouse-Blagnac, which started in 2012. Although several activities of introducing NFC in other transport sectors and payment services in the retail and banking sector have been started, the introduction of NFC in the aviation sector is open.

3.3 Future needs in process design

The developments in passenger process design and the changing aviation security regulations show that there is a clear need for substantial provision of information that determines how a passenger can be identified and checked throughout the process chain. The requirements to submit passenger data and security related information has been increased, nevertheless the method and quality of the data provision itself has not been adapted to the technical possibilities of a consistent digital platform. Since the presentation of the ideal process flow by IATA and others in 2006 mobile technology has evolved tremendously starting with the introduction of the iPhone in 2007 and other smartphones together with a variety of application software. Approx. 60% of passengers from the survey explained afterwards used self-service options and 65% carried a smartphone. These technological developments have to be considered in the future passenger process design.

The efficient use of technology can prove to support new strategies in aviation security, such as the risk based grouping of passengers. With increasing data-centric automation, self-service, and data provisioning the need for efficient and easy to use communication methods is prevalent. In addition to that passengers are asking for real-time information and a more interactive exchange of data. Wireless communication methods and especially NFC are facilitating self-service automation in a seamless way and thus showing great potential for efficiency gains.

4 Process design with NFC

The general concept of a digital process key for passengers is described by God et al.[9], in which the digitization of processes for a consistently harmonized security and service concept in air transportation is described. The implementation was outlined using NFC as the primary data transmittal method in process transactions. Aligning commercial services, such as ticketing or payment, and security related processes enables seamless processes. Furthermore, NFC creates frictionless linkages between transactions that are covered by the underlying technology, thus enabling the passenger to benefit from network effects by using the same device for multiple services without the need to re-learn a technological interaction. Using NFC technology three key benefits can be achieved:

- Simplification of transactions: due to shorter processing times and the usability in touch and go manner automation is facilitated. Process data can be exchanged in a seamless way without the need for passengers to configure connection details or even selecting application tasks in the menu.
- Secure data exchange: using the secure element of the NFC device, the data trustworthiness and integrity of e-documents will be tremendously improved in contrast to existing paper documents. Secure access to data can be incorporated using PIN and biometrical systems that are beginning to be incorporated into smartphones such as facial or voice recognition. The inherent characteristics of NFC to only work over short ranges of a few centimeters contribute to the secure data transfer.
- Facilitated collection and integration of status data along the process steps: NFC will contribute to a comprehensive provision of security and process related information at the authority or airport/airline level.

At each process step, current status information is added and the passenger’s attributes in terms of process advancement and security control are enriched. On one hand this information can be used for the optimization of passenger handling processes, knowing process locations and destinations of passengers in advance. On the other hand the interactive data exchange at each process step allows for a constant monitoring of the passenger status. Responsible stakeholders can thus improve the awareness of critical situations and refine the risk assessment methods. In turn more accurate information can be used to grant passengers access to security fast lanes or modify procedures in the security control, e.g. in adjusting sensor sensitivity. The fusion with related background information regarding flight and threat situation complete the actual risk assessment. Figure 1 shows the integration of exemplary security information that is transmitted over the NFC interface. Although not required, the system intends to facilitate the implementation of registered traveler programs and their automation principle, providing an easy method for secure automatic identification of passengers.

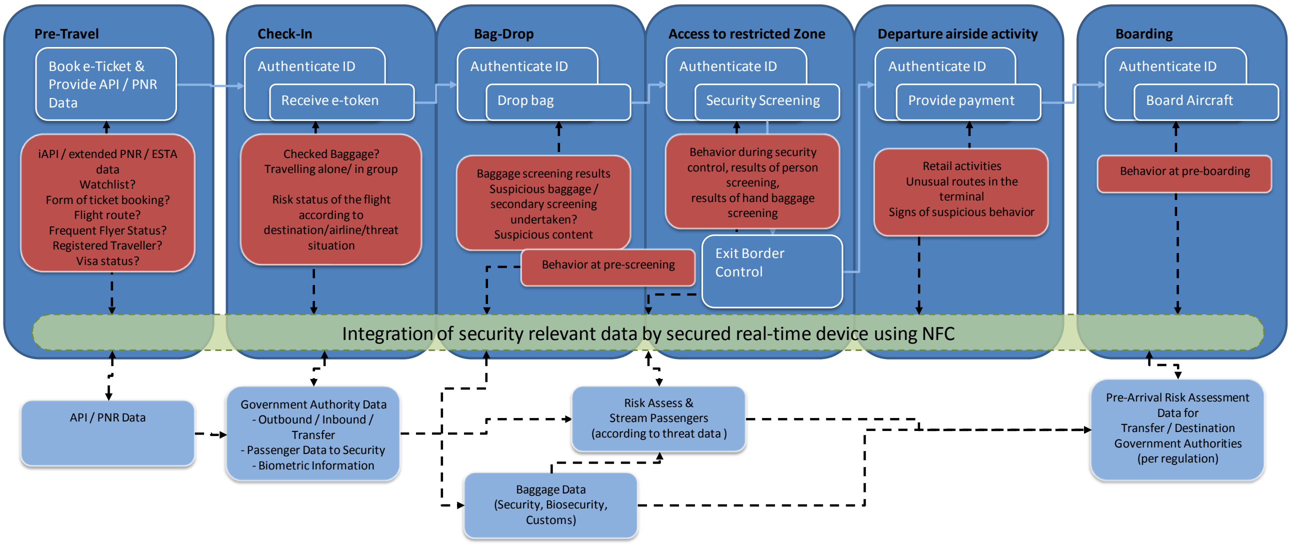

Fig. 1. Integration of selected security aspects to the passenger process flow (excerpt of departure process based on the ideal process flow[10]).

Using the system to gather and exchange security relevant data, a qualitative security process measure can be developed, which factors information and security level according to the related process status of a passenger. Distinction in risk assessment between passengers could be supported due to the information status they provide:

- passengers with no information,
- normal information,
- e-docs,
- e-docs & biometrical,
- being a registered passenger and the like.

The integrity of data varies between passengers, if more information of a certain kind is provided the assessment becomes more reliable. A quantitative security metric has been defined by Chawdhry as the permeability of combined procedures and technologies in aviation security processes [11]. In this context a qualitative measure based on the time period of availability of data and the integrity of the security relevant information is a necessary addition. The proposed NFC system delivers the suitable implementation form for such a qualitative measure.

5 Research Environment

In order to analyze the integration of NFC and enable reasonable assessments of its effects the research methodology consists of three areas:

- empirical study by undertaking a passenger acceptance survey
- conceptual system modeling to cover the requirements and describe the system design in a formal way
- simulation to obtain experimental results with variation of parameters in the system model.

These methods are interlinked with validation and verification steps and follow a reciprocal progress as shown in figure 2.

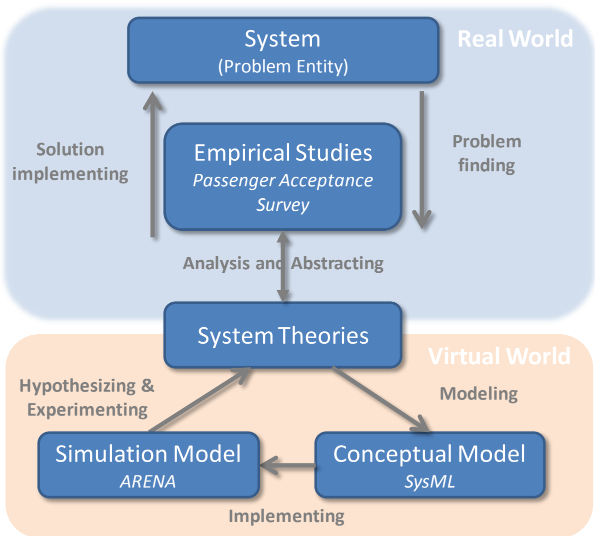

Fig. 2. Layout of the research environment and the modeling process (adapted from [12]).

5.1 Acceptance Analysis

The analysis of the passenger acceptance plays a key role in the assessment of the future NFC implementation possibilities. On one hand the acceptance study supports the analysis of the current process design and the problem finding, since passengers' perception of the technology and the requirements in its use can be directly identified. Albeit the results have to be deliberately interpreted, an empirical study delivers valuable aspects for potentials that can be considered for the abstraction of problematic system characteristics and thus be the starting point for optimization. On the other hand the empirical study can be used to validate proposed system changes and the introduction of innovative services and technologies.

To be a successful solution it is essential to consider the relevant acceptance aspects by passengers and to incorporate those into the system development. The full potential of the NFC integration can only be realized if a high usage rate among passengers will be achieved, because investments in infrastructure have to be outweighed by the benefits of cost savings, network effects, and revenue opportunities. This in turn depends on a wide acceptance of the technology. However, a large share of a defined passenger group, e.g. frequent flyers, could be the first step towards acceptance by the majority of passengers to utilize the technology. What factors are determining the overall acceptance of a technology?

The intention of using a technology can be fundamentally explained and described by cognitive reasoning theories. Based on the theory of reasoned action by Fishbein and Ajzen [13] and the theory of planned behavior by Ajzen [14], Davis has developed the *Technology Acceptance Model* [15] focusing on the adoption of technologies in services and products. Two key factors lead to the intentional use: the perceived ease of use, which is the subjective assessment of the effort to use or learn a technology, and the perceived usefulness, which represents the subjectively assessed probability of realizing a benefit by using the technology. Venkatesh et al. have developed this theory and combined several aspects from acceptance models into a *Unified Theory of Acceptance and Use of Technology* [16], which is shown in figure Fig. 3. In this model the performance and effort expectancy together with the social influence and facilitating conditions constitute the key acceptance factors, which are influenced by gender, age, experience, and voluntariness of use.

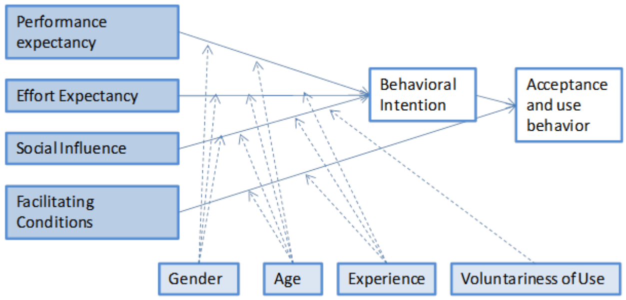

Fig. 3. Technology acceptance factors [16].

To obtain empirical evidences regarding the acceptance of mobile technology in passenger air transport processes, a passenger survey has been undertaken at the German airports Cologne/Bonn and Berlin/Tegel in short interviews among a sample of 970 passengers. The questionnaire was divided into two major parts. One set of questions asked to evaluate past behavior in air travel and existing technology affinity together with general passenger demographics and characteristics. The other part addressed the passengers' performance and effort expectancy towards the use of an NFC enabled smartphone and the introduction of services via this wireless communication technology. The questionnaire represented the theoretical framework and allowed to prove several hypotheses.

The survey sample consisted of 39% female and 61% male passengers from all age groups (18-65+) with 45% business and 54% privately related trip purposes (1% even). In general a large majority of passengers was in favor of the mobile technology and the integration of NFC. Flexibility was seen by 67% as high or very high, followed by the integration of capabilities in a single device by 63% of the respondents. Figure 4 depicts the distribution of passengers' performance and effort expectancy towards the different aspects.

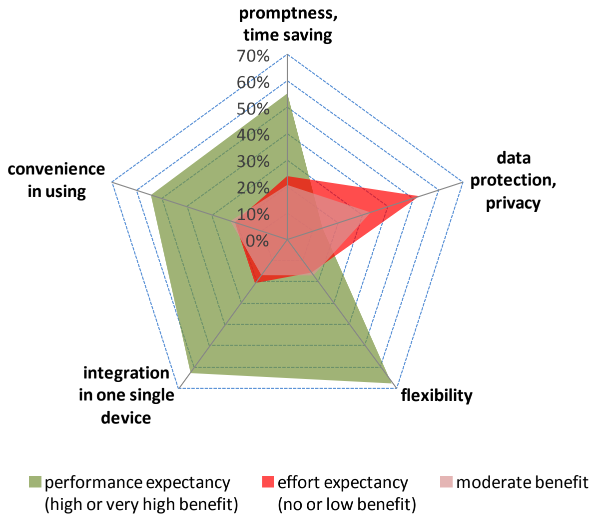

Fig. 4. Performance and effort expectancy of mobile technology by passengers.

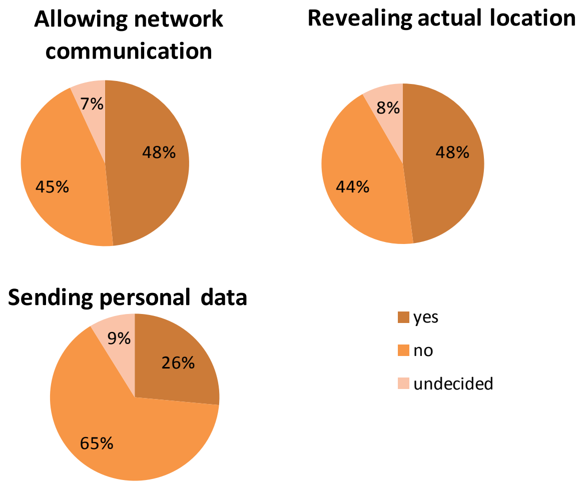

Fig. 5. Passengers' viewpoint regarding access rights via mobile technology.

The data privacy aspect was critically perceived as a disadvantage and mentioned as the reason for reservation towards the use of mobile technology. 65% of the respondents were neglecting the transmittal of personal data, whereas almost half of them allowed the network communication and would reveal their actual location for operational purposes, as can be seen in fig. 5. In the second part passengers were asked about their view regarding new or future services via smartphones and respectively wireless communication technologies. As shown in fig. 6, passengers are in favor of some services, whereas commercial applications that would enable new revenue strategies are less likely to be accepted.

However these results reflect the status of passengers that are uncertain of the actual implementation, which could lead to higher and respectively lower acceptance rates once these services are realized in an application. In our survey we could confirm the moderating factors of age, gender, and experience from the acceptance theory for the views regarding new services via smartphone. Respondents from a younger age, with more flights per year were more favorable of the usage of the mobile phone and valued the performance in usage as considerably higher than respondents from older age or with less experience. If the flights per year are taken into account, the approval rates to use a smartphone for identification increase. At least 55% of frequent flyers with 6 or more flights p.a. are in favor of the use of mobile phones in security relevant identification procedures as shown in figure 7.

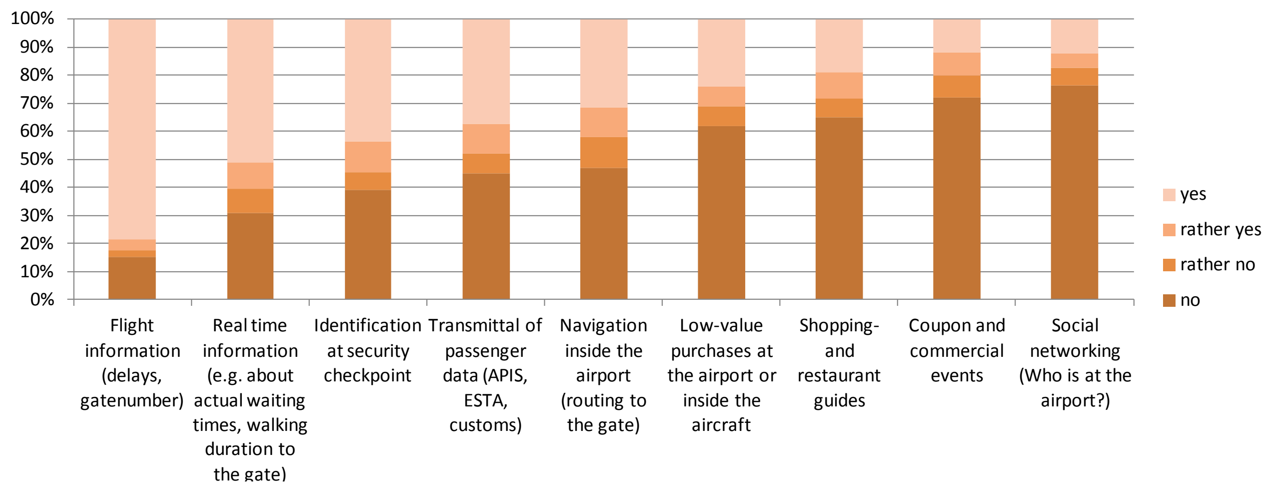

Fig. 6. Passengers' viewpoint regarding new services via mobile technology.

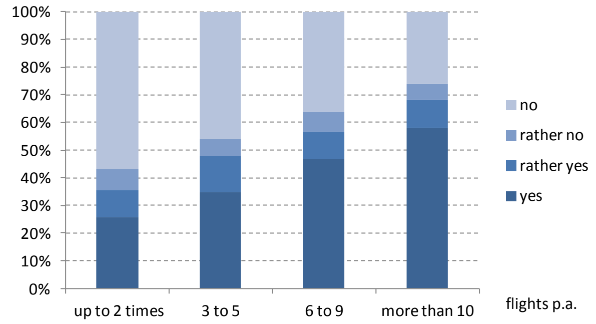

Fig. 7. Distribution of passenger approval regarding identification at security checkpoint via mobile phone in relation to flights p.a.

5.2 System Modeling

SysML is a graphical modeling language to model systems [17], [18]. It supports the analysis, specification and design of systems, which include hardware and software elements. It is suitable to model functional and non-functional relations among elements from different perspectives such as requirements, static and dynamic system architecture and sequence of events. The purpose to use SysML is to enable a consistent and formal concept model generation that helps to describe the activities and system structures on different detail level. Instead of a text based approach the modeling ensures the explicit definition of elements, interfaces, and interrelations such as requirements or entity attributes.

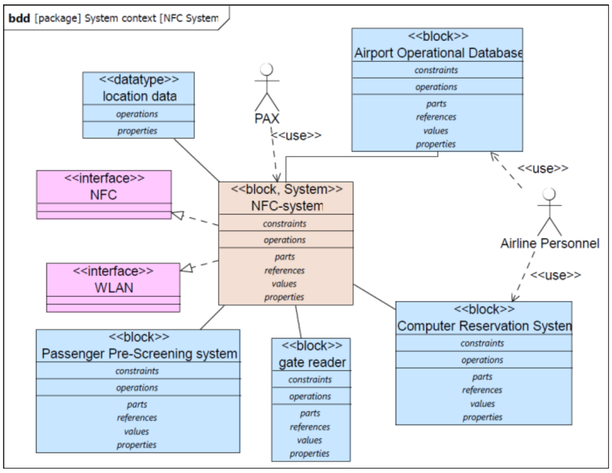

Fig. 8. SysML diagram of the system context (excerpt).

Figure 8 shows an example of a SysML diagram that describes elements of the system context of the NFC device. Furthermore, the SysML model is used as the foundation for the model generation in the simulation software Arena. Although there are some recent works on the direct transfer of SysML models to simulation software [19], [20], it is a rather unproven method. Therefore the SysML model will be converted into the domain specific simulation language of Arena.

5.3 Simulation

The simulation of the concept model is the third part of the research methodology. The objective is to develop a discrete event simulation of the complete passenger air transport process. This simulation allows to analyze the inefficiencies of the current system and test new approaches with regard to operations research statistic data like e.g. processing times, wait times, and utilization rates. Furthermore the simulation is designed to represent aviation security and operational aspects such as the quality of information provision and the time of its availability to the relevant process owners. The simulation reflects the dynamic complexity of queuing theory due to its stochastic (random) distribution input of processing times. This fact enables a dynamic analysis of the existing process design and the effects of technology integration. The simulation model will be used to study what-if scenarios by variation of critical parameters, such as utilization rate of the technology, infrastructural ramifications, or revenue per service. Therefore the simulation model serves as the basis for the evaluation of the technology’s potential with regard to operational and financial results. Arena simulation software has been selected due to its proven capabilities in process flow simulation. On the basis of the SysML concept model the different processes of passenger air transportation are then modeled in Arena. Figure 9 shows an exemplary layout of steps from the departure process.

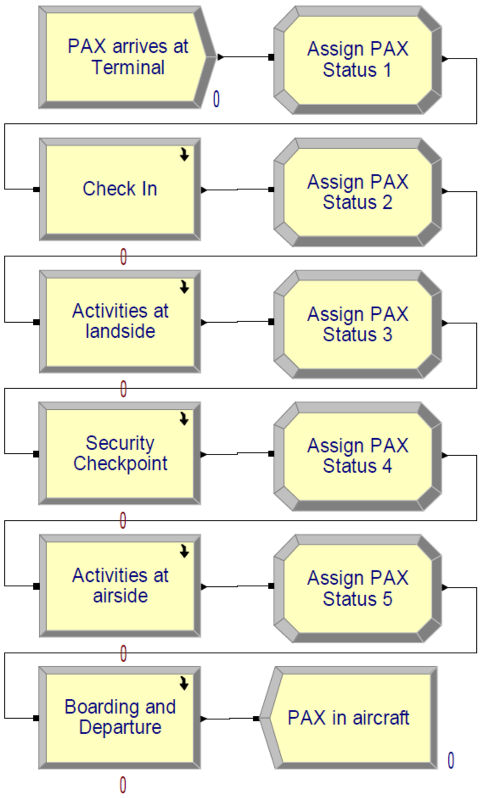

Fig. 9. Exemplary departure process modeled in Arena simulation software.

6 Conclusion

The proposed approach to use wireless communication technology and specifically an NFC enabled device to cover currently necessary information exchanges in the passenger process steps simplifies and eases the transaction efforts for passengers. Based on the research results from the acceptance study and the model generation, there seems to be a great potential of NFC for air transportation process improvement. Mobile phones are becoming increasingly accepted by passengers to be utilized as the digital boarding card and when NFC enabled smartphones will be used in other sectors and critical applications, it would be possible for the air transportation stakeholders to utilize this facilitating communication form. NFC seems to be a suitable solution to fulfill current requirements more efficiently and provide the capabilities to cover future needs. The inclusion into aviation security matters furthermore paves the way for NFC to be used in more comprehensive ways to establish the needed integration of security relevant information that would otherwise be lost along the process steps. Aviation security could thus well benefit from the possibilities of NFC, since it provides the needed characteristics of usability, data security and informational capabilities.

Besides the beneficial technical solution that NFC could provide, the successful introduction depends on the collaborative exchange of information among stakeholders. An NFC device could comply with this requirement since it could replace the need to set up an extensive database containing all information, instead passengers are keeping the necessary information in the palm of their hands and allowing access to relevant information by simply tapping it to a reader.

However, the question remains as to whether NFC is a solution that can compete in the long term against other upcoming technologies and be successfully implemented under consideration of financial and operational limitations. Since passenger characteristics differ, suitable customer groups have to be identified according to the needs in services and experience. The presented comprehensive approach of empirical study, concept modeling and simulation covers process details in a holistic study to provide a valuable analysis of the technology. The simulation environment furthermore enables the inclusion of scenarios of future technological developments.

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