From Shopping Aids to Fully Autonomous Mobile Self-checkouts – A Field Study in Retail

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Abstract. Self-checkout terminals allow integrating customers as active co-producers into a retailer's business processes. They have enjoyed increasing popularity in the past years since they allow saving costs and increasing customer satisfaction. Yet, they cannot be implemented in many retail settings, as the technology relies on retailer provided terminals and does not yet fully utilize the possibilities provided by mobile smartphones, which until recently have mostly served as decision or shopping aids. This paper presents steps towards and results from a field study of a purely mobile self-checkout solution that provides a more time efficient shopping experience to time-constrained users. We show that the time performance of app users is independent of store rush and that the time for a transaction is significantly lower for app users compared to regular shoppers during peak periods.

Keywords: shopping aids, mobile payments, self service technologies, retail, lost sales

1 Introduction

Recent implementations of self-service technologies (SST) such as self-checkout terminals enable users to scan and pay groceries without interaction with the store personal [1]. By skipping the waiting queues of regular registers, SST have been effective at increasing consumers' satisfaction and convenience [2, 3]. Self-checkout solutions today are usually implemented through large physical terminals that include barcode scanners and payment facilities [4]. Some solutions also provide the ability to scan items already during the shopping journey with dedicated handheld scanning devices or the user's mobile phones. However, even in these scenarios the digital shopping basket is transferred to a self-checkout terminal where the actual payment and integration of transaction data take place, creating new, unnecessary bottlenecks. As a consequence, capacity constraints remain during peak times [2]. While current self-checkout solutions are well suited for the digital transformation of regular grocery stores and have become well adopted among these [4], they are not easily applicable to

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a convenience store context. Unlike regular grocery stores, convenience formats typically have a high share of customers that only purchase very few items. In Europe, convenience stores are often located at train stations where space is highly constrained and expensive [5] and train schedules often generate significant peak loads of customers. During these high peak hours, convenience stores often experience a high share of lost sales as customers not willing or able to wait decide to abort their purchase or frequent competing stores [6, 7]. Due to the space requirements of traditional self-checkout solutions, it is often not feasible to dedicate the space needed to physical terminals to handle these peak loads more efficiently. While retailers have historically differentiated from competitors mainly through price, assortment and location [8], recent technologic advancements enable increasing differentiation through the use of interactive technologies [9]. We therefore develop a fully autonomous self-checkout solution suited for the fast-paced environment that combines self-scanning and mobile payments. We report findings from a digital transformation project including a field study conducted jointly with one of Europe's leading convenience store operators. Our contributions include a thorough analysis of the pre-transformation situation, critical aspects of the design and implementation of such an information system and results from an evaluation in a real-world pilot deployment with 46 buying users and 129 transactions in a period of 12 weeks. Our results provide valuable insights that are potentially applicable to other cases of digital transformation where end-users are involved in core business processes with own mobile devices. In addition to mitigating the lost sales problem, we open possibilities for forming a digital relationship between consumers and retailers.

The paper is structured as follows. We first study and summarize the relevant literature and illustrate our research context, questions and methodology. We illustrate the current situation and based on this we design a target shopping process adapted to our research context and provide an overview of our system architecture. We then discuss results from our field study and finish with a conclusion and outlook.

2 Related Work

2.1 Shopping aids

Many retailers have deployed technology solutions traditionally known as shopping or decision aids to assist shoppers in their shopping journey [11]. Common shopping aids, both online and in-store, can either help screen and narrow down available products or allow for the in-depth comparison of selected products [12]. While shopping aids in the form of in-store kiosks have been around in physical retail for a longer time [10], they have been used and studied much more in detail in online settings [11–13]. Online shopping aids have been shown to reduce search costs and increase convenience and the quality of purchase decisions [11, 12]. They can help enhance store loyalty but can also increase consumers' price and promotion sensitivity [13]. Furthermore, implementations of shopping aids in physical retailing besides in-store kiosks, such as smart shopping carts, can increase spending and re-patronage intentions as well as

satisfaction and loyalty of users [14, 15]. Yet, such solutions require high up-front investments. However, the increasing ubiquity of smartphones paired with their mobile and personal nature, has made the operationalization of personalized shopping aids economically and technologically feasible in physical retailing on a much greater scale [16]. Thus, consumers are beginning to increasingly utilize mobile phones in the shopping process–currently mostly for information search in the pre-purchase phase and less for actual purchase transactions [17]. However, research has also shown that consumers shop differently online compared to offline [13] and that mobile shopping aids are overwhelming shoppers with information instead of providing key functionalities [18].

2.2 Mobile Payments

Mobile payments can be defined as all transactions in which consumers use a mobile phone to transfer money or funds from one party to another in exchange for goods or services [19–22]. In general, one can distinguish between *remote mobile payment applications*, in which transactions are made independently of the location of the user and *proximity mobile payment applications* in which a user's mobile phone communicates locally with the point-of-sales (PoS) [20]. While the former resemble online payment systems known from e-commerce settings, the latter require a solution to link the digital and physical economy [23]. Such solutions include utilization of short-range wireless communication protocols such as the Bluetooth protocol or near frequency communication (NFC) technology [23] or the scanning of a 2D barcode [24]. Mobile payments are frequently considered the "killer" application of mobile communication networks [25] and seen as the most critical driver for the success of mobile commerce [21]. Yet, the adoption and usage of mobile payments remains sobering and below expectations [20, 26–28]. Nevertheless, expectations are currently rising again due to increasing penetration of the NFC technology [26].
Several studies have highlighted the security and trust as prerequisites for the adoption of mobile payments [22, 27]. Research on mobile ticketing systems, where the transaction itself happens remotely and independently of the location, yet the ticket verification happens locally, show that convenience and speed have a big impact on perceived usefulness and the use of mobile ticketing systems [29, 30]. In such manner, people are willing to use even more complex ticketing systems when they are in a hurry or try to avoid queues [30]. Hence, the relative advantage of mobile payments is among others driven by possible queue avoidance and situational factors such as the presence of queues, support the adoption of mobile payment solutions [19]. Yet, current mobile payment solutions require mobile devices to interact with the same established PoS [20, 28] and thus require users to queue at the same register, offsetting potential advantages.

2.3 Self-service technologies

Self-service technologies (SST) can be defined as technological interfaces that allow customers to coproduce a service without employee interaction [1, 31–33]. Retailers mainly offer SST to reduce costs and improve customer experience [3]. The most

frequently mentioned advantages of SST are convenience and speed [2]. Negative experiences include forced experiences of self-checkout uses, instances when self-checkout terminals have been closed at certain times of the day (i.e. night) and the fact that these terminals happen to be slower when there is a queue [2]. In accordance with this, researchers find complementary reasons for the use of self-checkout terminals and traditional checkouts at traditional retailers and advice practitioners to offer both in addition to another [34]: With respect to this, researchers have found evidence that SST customers tend to use self-checkout terminals for smaller baskets and might avoid items that require additional steps in the checkout process (e.g. fruits, vegetables etc.) [32]. In fact, small shopping baskets turn out to be a key reason for self-checkout usage and are only topped by long lines at traditional PoS [35].
The service quality of SST is mainly determined by functionality, enjoyment, design, assurance and convenience and has a positive impact on customer loyalty through customer satisfaction [3]. However, while the first trial and adoption of SST constitutes the most prominent obstacle since it usually involves significant behavior change [36], actual waiting time at regular checkout terminals acts as an important determinant for actual use [37]. From an industry perspective the main concern regarding self-checkout solutions is the potential increased risk of theft. While there is little evidence regarding the impact on retail shrinkage, the studies available suggest that there is no increase [38, 39]. To the best of our knowledge, there exists no implementation or analysis of a fully mobile self-checkout solution in grocery retailing.

3 Research Framework

3.1 Research Context

Our study is carried out in collaboration with a leading European convenience store retailer with a physical store network of over 1000 stores–most of them located at public transport transit points such as train stations. For a pilot study, we have selected three stores at Zurich main station. None of the stores currently have a self-checkout solution in place. In fact, traditional self-checkout solutions have been evaluated as unprofitable due to high place requirements and investment needs. Also, there is no mobile application or shopping aid offered by the retailer at the time of the pilot start and mobile payment support was introduced just shortly before the pilot start. Due to the fast paced nature of the business at the pilot store locations, there is no loyalty card system in place either. The retailer suspects and has anecdotal evidence that a high share of sales is lost due to long queues and time pressure of customers during peak hours.

3.2 Research Question and Methodology

The key challenge is to enable a self-checkout system that allows consumers to fully autonomously purchase products in a grocery store even under time pressure. To address this complex problem, we follow a design science approach [40]. First, we aim to leverage insights from store workers and managers as well as quantitative data from

the three existing stores to get a better understanding of the extent and nature of the problem. Second, we translate the learnings in an iterative system design and implement a corresponding artefact consisting of a mobile application, an instore feedback component, and a backend system. Our development process focuses on previously outlined constructs from SST and mobile payments research, namely functionality, relative advantage, complexity and convenience [3, 36] and perceived risk, assurance, security and trust [3, 22, 27, 36]. We optimize these constructs over multiple test phases and iterations with various users. Finally, we evaluate the artifact in a 12 week pilot deployment. The corresponding research question we hereby aim to address is whether such an implemented artifact provides added benefit to users. We operationalize this by ultimately measuring its repeated use [41] and quantifying time performance during more and less busy periods of the day [42], as well as the difference to the regular shopping time during busy periods, as waiting time has been revealed to be a key issue for our industry partner and was shown to impact the satisfaction-loyalty relationship of retailers [6, 7].

4 Design and Evaluation

4.1 Analysis of Status Quo

The following analysis is based on one year transaction data for two stores and half a year for one of the three pilot stores with more than 1.2 Million receipts in total. The highest frequented store has on average about 2,300 transactions per day, followed by 1,500 transactions by the second and about 700 from the smallest of the three stores.

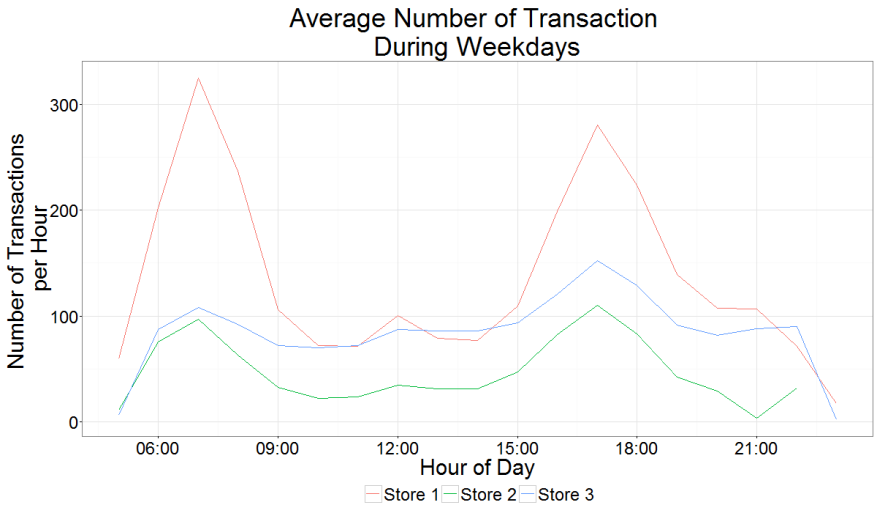

Figure 1. Distribution of average number of transactions per hour throughout weekdays

All of the three stores are characterized by very small shopping baskets with on average 1.5 to 1.8 items per transaction and an average basket value between 6 and 10 CHF. None of the stores currently have a self-checkout solution in place. The share of baskets that include alcohol, tobacco or services (ultimately, products that cannot be purchased through the mobile application), lies between 18 and 36%. The most popular products include soft drinks, beer, (self-service) coffee, tobacco, newspapers, magazines and bread and pastries. Our research partner does not offer a loyalty program and has thus no clear insight into consumption patterns of consumers. Due to the central location of our pilot stores and the high share of commuters, two of the three stores are characterized by high peak demand before and after working hours. Figure 1 illustrates the average daily pattern during weekdays for the three different stores. All of the three stores have their highest number of transactions either between 7 a.m. and 9 a.m. or between 5 p.m. and 7 p.m. Store 1, also the biggest in size, is characterized by the highest increase during peak hours of more than three times the average demand during. Especially this store exhibits very long queues during rush hours and customers are faced with long waiting times. We therefore argue that it is critical that a mobile self-checkout application minimizes the required time and effort for customers even during peak hours in the presence of long queues. Furthermore, it is important to mention that all the stores in our pilot are part of a chain and thus not stand alone stores, yet the mobile self-checkout application is only supported in the respective pilot stores.

4.2 Target shopping process

The key functionality of our mobile application is to buy physical products from a brick-and-mortar retailer without interaction with the PoS. The shopping process is composed of four main operations: A user has to check into the respective store before choosing products in order to see the correct price information. Users then select products by scanning the barcode printed on the product or shelf. After scanning the barcode, the user can adjust the desired quantity and then add the product to his (virtual) shopping basket. The user can then review his basket and start the checkout and payment process. The process is completed once the user confirms his transaction and the due amount is charged to the credit card information stored on the user's mobile device (Figure 2).

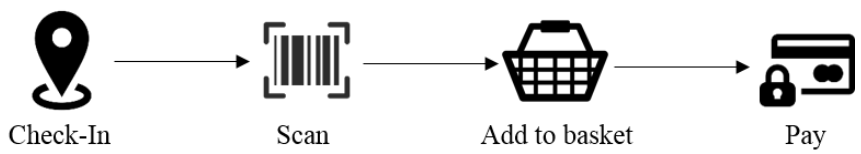

Figure 2. Illustration of target shopping process

The system was developed in several design iterations. The first iteration was conducted together with store workers and managers in order to come up with a first initial implementation which also allows store workers to track and identify valid transactions of users and thus emerged as a key requirement. The second design

iteration took place in a lab setting where students used a first proof of concept and were faced with a typical shopping assignment. Based on feedback from seven testers, the design was refined. Eventually, it emerged that the testers favored a version of the self-checkout application that included a physical touch point (a QR code) within the retail store. The third design iteration took place in a real store setting where eight testers used the mobile self-checkout application executing real transactions in order to buy a product of their choice in one of the pilot stores. We again collected user feedback and use this to improve the mobile application's usability, mainly focusing on in app communication and the in-store feedback system.

4.3 System Design

Our system illustrated in Figure 3 consists of three components, the backend, an iOS application which allows users to self-scan and pay products with their smartphone and an in-store information system which provides feedback for successful transactions.

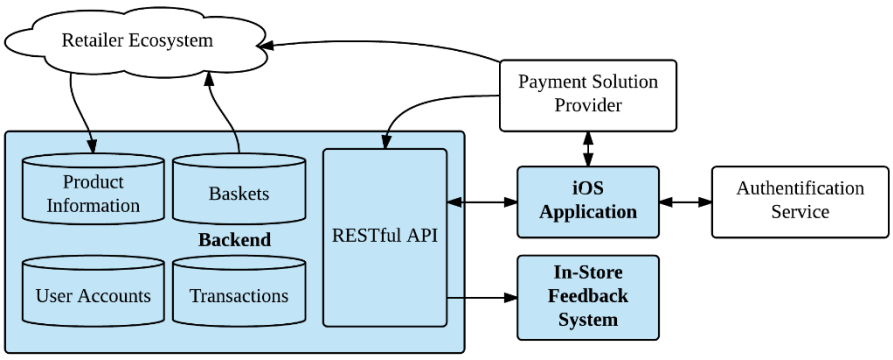

Figure 3. Overview of system architecture, developed artefact marked blue

The backend is responsible for storing all the information and communicating with the two clients. As our research partner's infrastructure relies highly on information systems that currently do not support application programming interfaces (APIs) that would allow the mobile application and the in-store feedback system to retrieve and store information, we mirror the retailer's product database and build our own backend. Product information is exported daily from our industry partner in order to account for changing prices. By predefining a specific data format we ensure a frictionless and correct re-integration of all transactions back into the retailer's information systems. The mobile self-checkout application "Scan&Go" is implemented for iOS systems and can be downloaded freely from the Apple App Store. The app features a short optional tutorial that outlines the steps to be performed in order to purchase a product. After registering with a phone number, a user has to fill out a short screening survey (six questions). Among others, users are asked about their motivation, demographics and average train station frequency. Since the service provided by our mobile application is highly location based, only at least multiple times per month at Zurich train station can

participate in our pilot study[1]. Once registered and screened, a customer can use the mobile self-checkout application–if eligible.

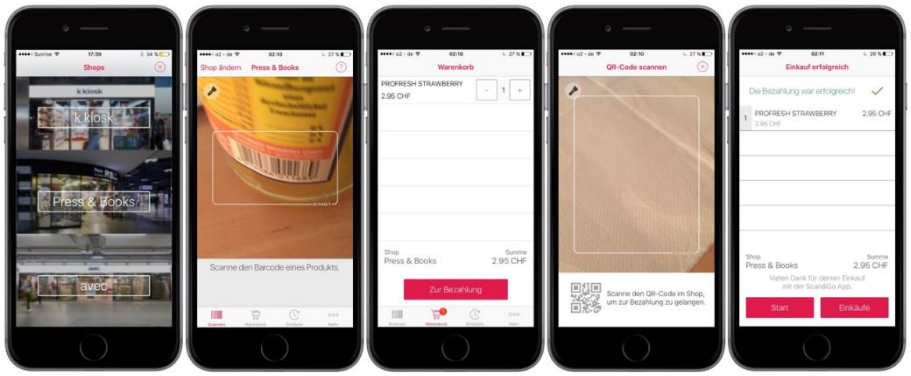

Figure 4. Screenshots of in-app view of 1) check-in, 2) barcode scanning, 3) virtual shopping basket summary, 4) QR-code scan and 5) confirmation and digital receipt

The in-store feedback system serves two purposes, theft prevention and public information signaling for successful purchases. It consists of a tablet that is mounted to a chipboard and features a poster with the QR which the user has to scan to confirm his payment. Although from a technologic perspective not required, the QR code serves three purposes: 1) it ensures that the user is in a pilot store, 2) it ensures that the user is in the right pilot store and did not accidentally check-into a wrong one and 3) guarantees that the user is located right in front of the tablet and store workers and other shoppers are able to match transaction feedback with a user[2]. The tablet constantly checks against the backend's API whether a transaction was successfully executed and approved by the payment service provider. In this case, the tablet, which is also visible from further away, turns green, features a confirmatory message and plays a positive, *cashregisterlike* sound. Based on user feedback, we believe, that a well designed and implemented in-store feedback system is key to support adoption and usage of such a purely mobile self-checkout application.

[1] Since this train station is relatively big and features many stores of the same banner, even on several levels, this allows us to confirm a user's eligibility only to some extent.

[2] While the first two purposes can be replaced with beacon technology the last cannot without compromising easy matching and/ or usability.

5 Results

5.1 User Recruitment

Users are recruited through three distinct channels. First, we email about 60 colleagues and friends. Furthermore, we distribute flyers to current customers either through the cashier or a dedicated student. Finally, we launch a small Facebook campaign targeted at people at the train station during the illustrated commuting hours.

5.2 User Statistics

The evaluation study ran in all three stores during 12 weeks from July to September 2016. We recruit 200 eligible users of our mobile application (out of 229 total registrations). 29 registered users were not eligible for participation either due to no supported payment method (11), age (11) and/ or a too low train station frequency (20). Users involved in the development of the mobile application are already excluded from this sample. 81% of all registered users are male and the majority is between 25 and 34 years old (35%) followed by 35 to 44 years (27%) and 18 to 24 years (22%). The majority (45%) of registered users states curiosity as their main motivation, followed by 38% that state time saving as the most important driver behind trying the mobile self-checkout application (convenience, 11%). 39% of all users are multiple times per week at the train station while slightly less, 36% of all registered users, visit the train station daily. 13% each state to be once a week or multiple times per month at the train station. In order to illustrate the consequences of long queues and waiting times during peak hours and quantify the previously hypothesized lost sales problem, we additionally ask users how often on average they have aborted or not even started a purchase due to long waiting times. In total, almost half of our sample state that this happens on average at least once a week, with about 10% claiming that this is even a daily problem. These statistics support our initial hypothesis and anecdotal evidence from store workers and managers. Although there is obviously self-selection involved in the acquisition of users for such a mobile self-checkout application, we conclude that there is great benefit for users and opportunity for retailers to differentiate – with a potentially highly lucrative business case for retailers able to address this issue by providing a faster shopping experience.

5.3 Conversion and Usage

Out of 200 eligible users 83 have scanned at least one product, either playing around with random products of other retailers or testing the app's functionality with actual products from our research partner. The detailed user funnel is illustrated in Figure 5. No financial incentive for using the app has been given to users. In total 46 users (23% of all eligible users) have carried out at least one transaction through the app and in total 26 users have used the self-checkout application more than once for a product purchase. Thus, about 56% of all buying users have made more than one transaction.

While these numbers itself are above industry benchmarks of similar e- and m-commerce implementations [43, 44], conversion and usage numbers are even greater when accounting for the recruitment channel of customers. We distinguish between proximity recruitment (in-store through flyers) or distance recruitment (Email to colleagues and friends and Facebook campaign). The cohort type can be assigned to users based on the date of their respective registration. All of the relative conversion numbers of proximity recruited users are higher than for distance recruited ones.

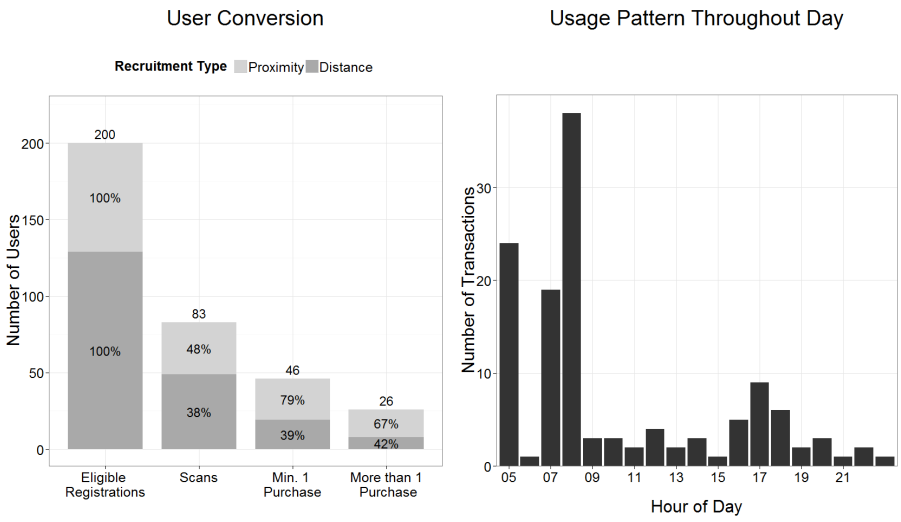

Figure 5. User conversion with number of users per action for proximity (flyer) and distance (Email, Facebook) recruited users (percentage numbers illustrating share of users relative to previous action for same recruitment type) and number of total transactions per hour

Out of all proximity recruited users, 48% have scanned an item using the app and 79% of these have ultimately also purchased something. In fact, about 38% of all proximity recruited users have made a purchase using the app, compared to 15% in the distance recruited group. Even more impressively, 46% of proximity recruited users stating "time saving" as their main motivation have made a purchase, and if stating to be at the train station "daily", the share of users making a purchase with the app is even 57% - with all of these (8) making at least one more purchase through the app. We report a total of 129 transactions issued through the mobile application with about 85% of all transactions made in Store 1. The most active user has a total number of transactions of 23, followed by one user with 16 and one with eight transactions. Figure 5 shows that most of the transactions through the app are made in the morning hours, specifically between 8 a.m. and 9 a.m. Compared to the overall sample, relative app usage is even greater during the morning peak.

5.4 Time Performance

In order to analyze the impact of increasing store rush and queues on the mobile app users, we measure the time required from 1) opening the app and 2) a first product scan to a successful transaction and its respective distribution throughout time and during peak and non-peak hours for all of the 129 transactions. For the first metric, 12 transactions (4 morning peak, 6 nonpeak, 2 afternoon peak) had to be excluded, as an instance of opening the app was either not reported or the app was obviously already opened much prior to entering the store (more than 10 minutes before the purchase). We find that the mean purchase time from app opening is about 99 seconds (st. deviation 86 seconds) with a median of 64 seconds. While our first metric has a relatively wide distribution, the purchasing time from a first scan is on average 40 seconds (st. deviation 38 seconds) with a median of 28 seconds and is thus more concentrated.

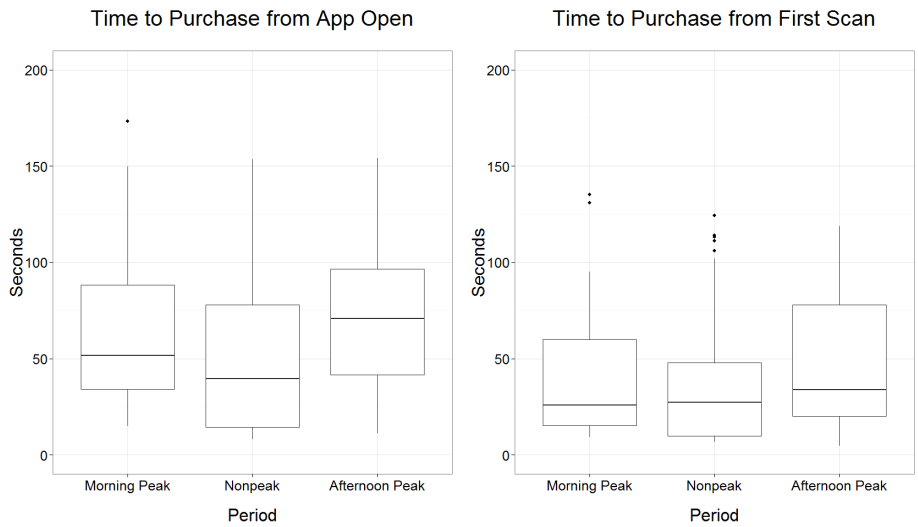

Figure 6. Standard boxplots (1st, 2nd and 3rd Quartile) of time to purchase from app open and first scan during peak (morning and afternoon) and nonpeak periods ($N_{morning\ peak} = 57$, $N_{nonpeak} = 57$, $N_{afternoon\ peak} = 15$)

In order to compare our two measures throughout the day, we categorize the transactions into three different time intervals according to regular transaction data from the three pilot stores, with a morning peak period from 7 a.m. to 9 a.m., an afternoon peak period from 5 p.m. to 7 p.m. and a remaining nonpeak period. Our results in Figure 6 show almost equal or equal means and medians for both measures between the different periods of the day. We hypothesize that the somewhat higher median shopping time during the afternoon and evening period is due to less time pressure and more of a “strolling” shopping behavior of users. We attribute the wider distribution of our first metric to the differences in time needed to buy certain products (i.e. coffee from a self-service coffee machine – users could scan the barcodes before,

after or while making the coffee) and also to the fact that some people already open the app before entering the target store. Due to the noisier distribution of the first metric, we argue that the purchase time from first scan is a more accurate measure of the actual shopping time required, as products bought have to be scanned in store whereas an instance of opening the app can occur outside of the store. In order to evaluate the performance of app users we derive a baseline by taking the shopping time for all regular shoppers during the morning peak period and compare this to app users during the same morning hours. For each users we measure the time from picking a first product from the shelf as this should correspond to a first scan of a product within the app. We collect a sample of 95 observations. The mean purchasing time for regular shoppers is 99 seconds (st. deviation 46 seconds) compared to 39 seconds (st. deviation 31 seconds) for app users during the morning peak.

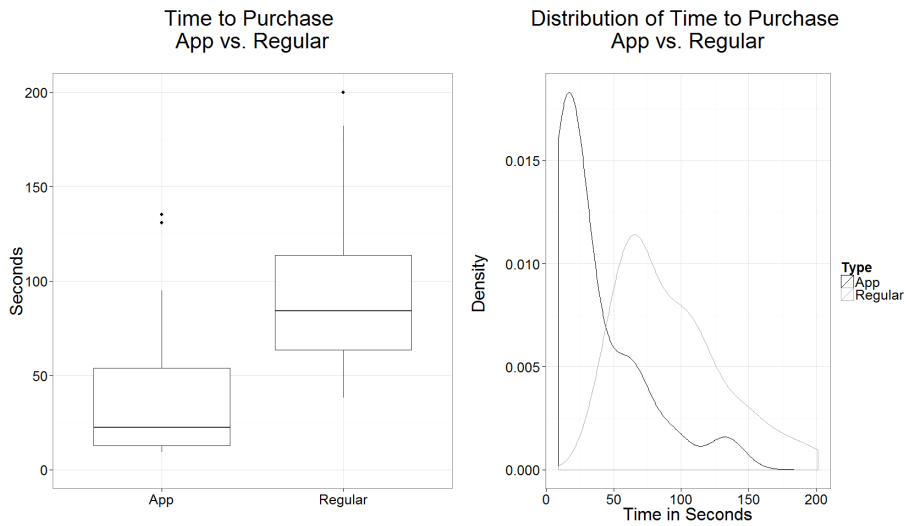

Figure 7. Standard boxplots (1st, 2nd and 3rd Quartile) and kernel density plots of purchase times for app users and regular shoppers during peak hours (N_{App} = 57, $N_{Regular}$ = 95)

Figure 7 shows the distribution of purchasing times for both app users and regular shoppers during the morning peak. We conduct a Wilcoxon-Mann-Whitney-Test [45] for non-normally distributed data and find statistically significant evidence that the time to purchase is smaller for app users (p = 8.56e-12).

6 Conclusion and Outlook

We have designed and implemented a mobile self-checkout application and tested its acceptance and usage in a first pilot at three stores at the central train station in Zurich. Learnings from the usage logs of 46 purchasing users, of which 26 are repeated purchasing users, illustrate positive value and consumer acceptance from such an

application. An onboarding survey has provided additional insights into the demographics and motivation of our study participants and illustrated that almost half of all users regularly (at least once a week) fail to make purchases because of time pressure and long queues. With respect to this, we compare with the baseline time performance of regular shoppers during peak hours and show that app users on average save 60 seconds. Furthermore, we are able to show that the required purchasing time for app users is stable throughout the day, even in the presence of queues during morning and afternoon rush hours. Our study is a first step in understanding how to design a fully autonomous mobile self-checkout solution and transition from stationary to mobile retailing. In order to gain more insights into app adoption and usage and learn more about general consumption patterns of mobile app users, we aim to extend our study further with more participants over a longer time period and collect additional data on satisfaction of mobile app users. Furthermore, besides technical obstacles one obvious reason for retailers not implementing a purely mobile self-checkout solution is easier control of actual product purchases when using self-checkout terminals. Consequently, we aim to measure changes in inventory shrinkage at the end of our extended study in order to evaluate the impact of such an application on theft and inventory shrinkage. A self-checkout application as presented in our study allows retailers to offer valuable information systems based services to consumers beyond only the provisioning of additional product information and allows retailers to pursue new digital business models. It can help retailers differentiate from competitors in an increasingly crowded market place. Thereby, consumers profit from a faster and more convenient shopping experience. Furthermore, in the absence of existing loyalty programs, such a mobile app provides more sophisticated insights into individual shopping patterns.

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