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Using self-service technology to reduce customer waiting times☆

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ABSTRACT

An important perceived benefit of self-service technology has been its potential to reduce customer waiting-times. The purpose of this study was therefore to examine under which conditions the introduction of self-service technology in a service delivery process could reduce actual waiting-times and improve service levels. A simulation study showed that waiting-times and service levels in a hotel check-in process were influenced by the number of resources available to customers, the number of customers arriving to receive service, the processing speed of the self-service kiosk and the failure rate of the self-service kiosk. Specifically, results showed that longer self-service kiosk processing times and higher failure rates led to longer waiting-times, especially when customer demand was high. The authors recommend that service providers considering self-service technology implementation pay careful attention to the design and performance of the self-service technology.

1. Introduction

Waiting lines are a common occurrence in many service settings where capacity is fixed as peak-time demand can exceed the available supply. For example, hotel guests arriving in the evening to check-in may encounter a full lobby, while restaurant patrons may have to wait for a table during lunch time. As waiting lines have been associated with reduced service evaluations (Taylor, 1994), negative perceptions of service quality (Dube-Rioux et al., 1989), and reduced satisfaction (Katz et al., 1991), having to wait makes a customer's first experience of a service is a negative one (Baker and Cameron, 1996; Dickson et al., 2005; Maister, 1985). Consequently, waiting-time reduction has been a major objective of service providers.

Service providers have several strategies available to them to reduce customers' waiting-times. In theory, service providers could eliminate waiting lines by setting their capacity to peak demand (Dickson et al., 2005). However, most of this capacity would remain idle and would result in an unsustainable cost structure. Therefore, a more practical approach has been to use queuing theory and other operations management techniques to find the optimal point where the cost of providing service and customers' waiting-time are simultaneously minimized (Dickson et al., 2005; Hwang and Lambert, 2008; Lambert and Cullen, 1987).

A more recent and cost-effective approach to reduce waiting-times has been to introduce self-service technologies (SSTs) into the service delivery process. SSTs have been defined as technological interfaces that allow customers to produce services without a service employee's involvement (Meuter et al., 2000). For example, hotel guests can bypass the front desk and use a self-service kiosk (SSK) to check-in and receive their key cards without the direct contribution of a service employee (Dabholkar, 1996; Weijters et al., 2007). The simultaneous reduction of waiting-times and operating costs has been used by the self-service industry as a selling point for SSKs (Avery, 2008; IBM, 2009). However, there is no empirical evidence that introducing an SST alternative to the existing service delivery process can indeed help firms reduce waiting-times (Oh and Jeong, 2009).

An intuitive application of queuing theory suggests that adding a resource to the existing service delivery system would increase its capacity and therefore reduce waiting-times (Lambert and Cullen, 1987). Nevertheless, the addition of an SST alternative to the existing service delivery process can transform even the simplest system into a complex one with conditional logic and interactions. For example, a customer wanting to check-in will decide whether to use the SSK based on the lengths of the SSK and service employee waiting lines. The next customer arriving will encounter a different system, based on the previous customer's choice. While research on customer usage of SST has examined what influences customers' choice between service delivery alternatives (Weijters et al., 2007),

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the effect of this choice on system waiting-times is unclear. Similarly, previous research has examined the impact of SST failures on customers' satisfaction (Reinders et al., 2008; Weijters et al., 2007), but not their impact on system performance.

The purpose of this study was, therefore, to test if the introduction of SST in a service delivery process could reduce actual waiting-times and improve service levels. This study extends the SST literature by investigating whether a commonly held assumption of SST implementation holds true. This topic is particularly relevant for the hospitality industry. Self-service check-in in hotels has recently received attention in both the academic (Oh and Jeong, 2009) and practitioner literature (Avery, 2008). Furthermore, the 2010 Hospitality Technology SST survey found that 94% of responding hotel managers wanted to implement SST to improve customer satisfaction (Blair, 2010) while 68% of customers believed SST would reduce waiting lines, making this a timely topic for investigation.

2. Background of the study

2.1. Customer waiting-times as a source of dissatisfaction

Waiting-time is a well-documented predictor of perceived service quality and customer satisfaction. Evidence supports relationships between actual waiting-time, perceived waiting-time, perceived service quality and customer satisfaction (Baker and Cameron, 1996; Davis and Maggard, 1990; Hui and Tse, 1996; Katz et al., 1991; Taylor, 1994). However, customer satisfaction and perceived service quality have been found to be most strongly influenced by actual waiting-times (Durrande-Moreau, 1999). These findings were upheld in contexts as diverse as airports (Taylor, 1994) and fast food restaurants (Davis and Vollman, 1990). Consequently, in order to improve customer satisfaction and perceived service quality, service operators have focused their attention on decreasing actual waiting-times through the use of operations management techniques.

2.2. Operations management approaches to waiting-time reduction

While waiting lines mostly occur at peak times, they can appear at any time when the demand for a service exceeds the capacity of the process to provide it (Krajewski et al., 2009; Lambert and Cullen, 1987). Several operations management techniques have been used to examine the relationship between resources and waiting-times. For example, Lambert and Cullen (1987) used queuing theory to determine the number of resources needed to achieve an acceptable waiting-time. In a different context, Hueter and Swart (1998) used simulation-based modeling to determine the optimal labor schedule that will provide a desirable service level.

2.2.1. Queuing theory

Queuing theory is an analytical approach to system performance analysis (Gautam, 2008; Lambert and Cullen, 1987). Queuing models are particularly appropriate when an analyst wants to quickly compare several what-if situations, determine the best course of action for a given set of parameters, or gain insights into the relationship between arrival and processing times (Gautam, 2008). From a practical perspective, service operators can use queuing theory to examine whether the staffing, facilities, and equipment of a service facility are sufficient to serve customers within a reasonable length of time (Lambert and Cullen, 1987). For example, Lambert and Cullen used queuing theory to examine whether including an SSK could help reduce waiting-times in a hotel check-in context and found that adding a SSK could eliminate waiting lines.

While queuing models can be used to study a variety of system configurations (including single station and multi-station settings, single server and multiple server systems, exponential and general arrival and processing distributions, situations where customers are not patient and either balk or renege on service; Gautam, 2008), they have a number of limiting assumptions. For example, queuing models cannot accommodate conditional logic and interactions in a system (Harmonosky, 2008). Also, queuing models only give information about a process when it exhibits steady-state behavior after initialization effects have worn off, an assumption that is untenable for many hotel processes (Kelton et al., 2007). Consequently, in the context of hospitality services, researchers have frequently turned to simulation as a way to investigate the relationships between capacity decisions and waiting-times under a more valid set of assumptions.

2.2.2. Simulation

A simulation is a model of the operation of a real-world system for the purpose of evaluating that system (Goldsman, 2007) and is useful when analyzing systems that are too complex to be analyzed using analytical models such as queuing theory (Law, 2007). Like queuing theory, simulation allows the researcher to experiment quickly and efficiently (Goldsman, 2007) and maintain tighter control over experimental conditions than if experimenting with the system itself (Law, 2007). Simulation also allows experimentation with lower risk and at lower cost (Sanchez, 2007; Thompson and Verma, 2003).

In the context of hospitality services, simulation has been used to examine the impact of changes in staffing, facilities, and equipment on performance measures of interest to service providers. For example, simulation has been used to reduce labor costs by improving schedules at Burger King restaurants (Swart and Donno, 1981) and to analyze parking lots and traffic configuration for Taco Bell sites (Jaynes and Hoffman, 1994). Simulation has also been used to evaluate possible table mixes for restaurants (Kimes and Thompson, 2004; Thompson, 2002), table assignment policies (Thompson and Kwortnik, 2008) and reservations policies in restaurants (Lambert and Lambert, 1988b) as well as hotels (Lambert and Lambert, 1988a; Lambert et al., 1989).

Simulation has also been used extensively to examine the impact of operational changes on customer waiting-times. For instance, simulation was used to examine the impact of changing line configurations and of adding an extra service employee on customer waiting-times in a restaurant (Chou and Liu, 1999), to determine the distance between the drive-thru ordering window and pick-up window that would minimize customer waiting-time at Burger King (Swart and Donno, 1981), to determine the minimum staffing required to meet a pre-specified customer service level at Taco Bell (Godward and Swart, 1994), and to examine the interactions of restaurant resources (tables, servers and cooks) on waiting-times in a multi-stage restaurant (Hwang and Lambert, 2008).

Simulation, like other operations management techniques, has thus allowed service operators to examine the trade-offs between the cost of providing service and customers' waiting-time (Hwang and Lambert, 2008; Paul and Stevens, 1971), effectively helping them balance operational concerns with marketing promises (Kwortnik and Thompson, 2009). Simulation is therefore well suited to examine the assumption that SST can reduce waiting-times, a selling point put forward by the SSK industry (Avery, 2008; IBM, 2009).

2.3. Self-service technologies

Service providers such as hotels, restaurants, and banks, are increasingly using SSTs to supplement or replace their traditional service delivery channels. SSTs provide customers with a greater choice of how and when to receive a service. SSTs such as online retail platforms and ATMs increase the availability of the service beyond traditional store opening hours. SSTs also provide customers with cheaper transactions, opportunities for customization and co-creation, and less heterogeneous service encounters (Weijters et al., 2007).

SSTs have also been assumed to help firms improve their productivity and reduce their operating costs (Lovelock and Young, 1979). SSTs such as SSKs typically provide capacity at a lower cost than the equivalent work force by allowing customers to perform certain production activities (Lovelock and Young, 1979; Mills et al., 1983; Mills and Morris, 1986). Consequently, SSTs have increasingly been seen as a cost-effective way to reduce waiting-times and hence improve satisfaction (Weijters et al., 2007). Nevertheless, there is no empirical evidence that SSTs can indeed help firms reduce waiting-times (Oh and Jeong, 2009).

2.4. Performance measures

There are several objectives that service operators may wish to fulfill through SST implementation. These may include operational objectives such as waiting-time reduction and operating cost reduction; and marketing objectives such as increasing guest choice of service delivery channels, offering guests the possibility to customize their stay, and imitating competitors. However, despite having different objectives and in addition to return-on-investment objectives, service operators will typically be concerned with the impact of implementation on waiting-times.

2.4.1. Waiting-times

Due to the strong link between waiting-time and customer satisfaction (Durrande-Moreau, 1999), waiting-time has often been the focal performance measure when studying service systems (Chou and Liu, 1999; Hueter and Swart, 1998; Hwang and Lambert, 2008; Swart and Donno, 1981). Waiting-time has also been used as a performance measure by studies examining the impact of implementing SST on an existing process. For example, Snowdon et al. (2000) used simulation to examine customer waiting-times for Air Canada's ticketing and check-in operations. The authors identified a one-hour period in the morning where waiting-times for ticketing were excessively high and used simulation to study whether the implementation of SSKs could be used to reduce these waiting-times.

The use of waiting-times as a performance measure has, however, several disadvantages. First, while it is known that increased waiting-times will reduce customer satisfaction, this relationship is not linear. Instead, customers tend to be insensitive to waiting until the waiting-time reaches a particular duration. For instance, Hueter and Swart (1998) found that the balk rate of fast food customers was only 2.5% when the average waiting-time remained under 3 min, but increased exponentially beyond that value. Second, like all statistics based on averages, waiting-times can be influenced by outliers and therefore not give an accurate representation. In the example above, knowing that the average waiting-time is 3.3 min would not have provided any information on the proportion of customers who were likely to be dissatisfied.

2.4.2. Service levels

A useful extension to the use of waiting-times as performance measures is the use of service levels which measure the proportion of customers that wait less than a pre-specified length of time. For example, Hueter and Swart (1998) identified 3 min to be the relevant threshold in the context of their study and defined the service level as the proportion of customers that waited less than 3 min.

Service levels are superior to waiting-times as performance measures, as service levels can be more directly linked to satisfaction. However, one important disadvantage of using service levels as performance measures is the lack of information on how long beyond the pre-specified waiting-time customers have waited. Therefore, average waiting-times and service levels must be used concurrently to provide a more comprehensive picture of process performance.

3. Methods and model development

For this study, a simulation model of a hotel check-in process was developed. The model of the current check-in process was developed after observing the front desk of a 300-room hotel located in Pennsylvania that serves a mix of business and leisure guests. The boundaries of the system to be studied extended from the arrival of the customer to the check-in desk to the departure of the customer to her or his room.

3.1. Model

3.1.1. Current process

The current process starts with a customer arriving at the front desk. If a service employee is available and there is no line, the customer moves directly to the service desk, where the available front desk employee assists him. Once the front desk employee has finished checking the customer in, the customer leaves the service desk. If all three service employees are busy with customers, the arriving customer joins a single line feeding all service employees.

3.1.2. New process

The new process is supplemented by the addition of an SSK served by a separate line. After arriving in the front desk area, each customer decides whether to use the SSK or to be checked-in by a service employee, based on the length of each waiting line. If there is no line, the customer goes directly to the desired service option. If there is a line for the desired service option, the customer joins it. However, if while the customer waits for his desired option, the other service option becomes available, he may decide to jockey and go directly to that service option. Customers checked-in by a service employee leave the service desk. Customers having used the SSK either join the line for the service employee (in case of a service failure), or leave the service area (in case of successful service).

3.2. Definition of study performance measures

Since customers can take different paths through the service system, they may experience waiting-times at different stages of the process. For example, a customer waiting for a service employee may jockey after the SSK becomes available. This customer will have experienced some waiting-time at the service employee and none at the SSK. Similarly, a customer who has waited for the SSK and has encountered an SSK failure will need to wait again for the service employee. This implies that reporting waiting-times for the service employee and for the SSK separately will not provide an accurate measure of the performance of the system. Therefore, the average total waiting-time (TWT) is defined in this study as the average of the total waiting-times experienced by customers. The service employee waiting-time (SEWT) is defined as the average time customers waited for the service employee. The overall service level (SL) is defined as the service level provided to all customers, independently of their chosen service alternative.

3.3. Data collection

In order to accurately model the hotel check-in process, information was collected about customers' behavior at the check-in desk, and what they perceived to be an acceptable waiting-time in this context.

3.3.1. Customer arrivals and employee processing times

Inter-arrival times and service employee processing times were collected by observing the hotel front desk during periods identified by management as representative of high demand periods for front-desk services. These periods consisted of evening hours during which guest regularly check in. Four hours of observation yielded 98 usable inter-arrival times and 96 usable service employee processing times. The ARENA Input Analyzer was used to derive suitable distributions to represent these processes (Hwang and Lambert, 2008). The service employee processing time was represented by the expression 7 + GAMM(109, 1.29). The average processing time by a service employee was, therefore, 147.61 s. The observed inter-arrival time was represented by the expression 4 + EXPO(96.9), equivalent to a mean inter-arrival time of 100 s.

3.3.2. Customer behavior

To model customer choice between the two alternatives, a scenario-based survey (1472 participants) was conducted to estimate a conditional probability that a customer would select to use the SSK based on the number of customers waiting for each alternative (Kokkinou and Cranage, 2011). The resulting estimated conditional probability function calculated that, when both alternatives were available, 25.08% of customers would select to use the SSK, while 18.68% of survey participants indicated that they would select to use the SSK. The estimated conditional probability function calculated that, when both alternatives were busy, and two customers were waiting for a service employee and no other customer was waiting for the SSK, 79.11% would select to way for the SSK. This estimate was very close to the 77.11% of survey participants who indicated they would select to wait for the SSK.

3.3.3. Service level

Participants in the scenario-based survey were asked to indicate what an acceptable waiting-time would be in the study context. In order to reduce modal response effects, participants were presented with possible answers ranging from 0 to more than 11 min in 20 s increments (Seawright and Sampson, 2007). Results based on 1443 responses showed that, to meet the expectations of at least 90% of customers, the wait time should not exceed 120 s.

3.3.4. Self-service technology performance

A review of the practitioner literature yielded estimates of SSK processing times and SSK failure rates. The self-reported industry check-in time estimates for hotel SSKs ranged from as little as 23 s (Carlin, 2008) to 60 s (Sheraton, 2004; Mayock, 2010). Since the distribution of processing is, theoretically, unbounded on the right, a shifted exponential distribution with a lower-bound of 23 s was chosen to represent this process. Estimates of failure rates for similar kiosks in other industries ranged between one in seven and one in nine (Net Resources International, 2007).

3.4. Experimental design

Waiting-times and service levels may be impacted by several factors, including factors common to most check-in contexts and factors specific to the SST in use.

3.4.1. Situational factors

According to traditional queuing theory, waiting-times are directly related to how many customers arrive to receive service and how many customers can be processed in a given time period. While decision-makers should be able to estimate the rate at which customers arrive to receive service, this factor remains outside of the control of decision-makers. For example, if a greater number of guests than anticipated arrive at the front desk, there may not be enough capacity to meet this unexpected demand and waiting-times may increase. Therefore, three levels of guest demand were used in the simulation. These consisted of average inter-arrival rates of 100 s (observed demand), 80 s, and 60 s (denoted respectively as IA = 100, IA = 80, and IA = 60).

Conversely, decision-makers do have control over the number of resources available to serve customers. They can choose to increase the number of service employees (SEs) and/or SSKs. Four different configurations were modeled: the current situation (3 SEs, no SSK), adding an SSK (3 SEs, 1 SSK), replacing one service employee by an SSK (2 SEs, 1 SSK), and removing one service employee without adding an SSK (2 SEs, no SSK).[2]

3.4.2. Self-service technology factors

According to traditional queuing theory, waiting-times are also directly related to how long it takes each server to process customers. Extending this finding to a self-service check-in context, the longer it takes customers to check themselves in, the longer the waiting-times for the self-service check-in kiosk will be. This implies that the impact of SSK implementation on system performance will greatly depend on the accuracy of the hotel SSK industry estimates.

As a comparison, self-service check-in time estimates by the airline industry range from 60 (Edmonton Airports, 2011) to 90 s (NetWorld Alliance, 2004). However, the authors' observation of international travelers at a busy airport during the check-in process suggested actual self-service check-in times were much higher. Access to a dedicated area for frequent travelers was used as a proxy to distinguish between frequent and infrequent travelers. An analysis by type of traveler showed a significant difference between the self-service check-in time of frequent travelers and other travelers ($t(44.689) = 2.386$; $p = 0.021$) with frequent travelers checking in faster ($M = 115.10$, $SD = 59.642$) than other travelers ($M = 161.66$, $SD = 91.985$).

The discrepancies found between industry estimates and observations in the context of airline self-service check-in suggested that hotel self-service check-in times may be similarly underestimated. Therefore, for the purpose of this study, four mean processing times were tested. These included the hotel SSK industry estimate of 60 s (PT = 60), and times that were, 50%, 100%, and 150% higher (PT = 90, PT = 120, and PT = 150 s).

Waiting-times may also be impacted by the failure rate of the SSK. If a failure occurs, customers will need to receive assistance from the front desk employee and will therefore have to wait a second time. Furthermore, their joining the line for the service employee will increase waiting-times for other customers joining the line behind them. For the purpose of this study, two failure rates were tested. The first was based on the industry estimates of

[2] As an anonymous reviewer pointed out, a (2 SEs, no SSK) system can process approximately 49 customers/h. However, under very high demand conditions, the arrivals to the system will exceed this (60 customers/h), leading to an unstable system as the waiting lines in such a system would grow infinitely longer. However, in this particular example, the peak-time (and therefore the simulated period) only lasts 90 min. While very undesirable, the systems such as the one we modeled are used by firms that do not want to (or cannot) staff an 8-h shift for the peak demand that only occurs for 1–2 h of that shift. Instead, they choose to provide a lower service level and reduce costs that way.

between 1 in 7 and 1 in 9 (FR = 12.5%). The second failure rate was chosen as a more pessimistic estimate (FR = 25%).

3.5. Hypothesis development

The purpose of this study was to examine whether SST could be used to reduce waiting-times and whether situational and SSK factors were of influence. Several hypotheses were formulated to examine the impact of either adding an SSK to an existing service process or replacing a service employee by an SSK on waiting-times and service levels.

3.5.1. Implementation objectives

When service operators seek to reduce waiting-times by increasing the number of service delivery channels available to customers, they may decide to implement an SSK. Adding an SSK to an existing service process will result in an increase in resources and hence in an increase of the capacity of the system. Therefore:

Hypothesis 1a. Adding an SSK to a service process will decrease TWT.

Hypothesis 1b. Adding an SSK to a service process will increase the SL.

Furthermore, adding a second service delivery channel will reduce the number of customers that need to be served by the service employees and therefore reduce waiting-time for the service employee. Therefore,

Hypothesis 1c. Adding an SSK to a service process will decrease the SEWT.

When the objective of SST implementation is cost reduction, service operators may elect to replace a service employee by an SSK. While this will result in the same total number of resources, the capacity of the system will change as the time needed by a customer to check in using an SSK may be different than the time needed by a service employee to perform the same task. Specifically, replacing a service employee by an SSK with a faster processing time is likely to decrease TWTs and increase SLs. As the SST check-in times reported by the industry are much faster than the service employee check-in times observed in the current process, we hypothesize that:

Hypothesis 2a. When replacing a service employee by an SSK with a faster processing time, the TWT will decrease.

Hypothesis 2b. When replacing a service employee by an SSK with a faster processing time, the SL will increase.

3.5.2. Influential factors

The impact of SST implementation on system performance will likely depend on the SSK's processing times and failure rates. Longer SST processing times decrease the capacity of the system, and are likely to lead to longer waiting-times. Similarly, a failure of the SSK would lead guests that already waited for the SSK to wait a second time for a service employee, increasing the demand for the service employees and thus increasing waiting-times. Furthermore, the effects of poor SST performance may be compounded by a higher than expected demand on the system as this will increase the utilization of the resources and leave little capacity to absorb the impact of poor SST performance. Therefore,

Hypothesis 3a. When demand is high, slower SSK processing times lead to longer TWT.

Hypothesis 3b. When demand is high, slower SSK processing times lead to lower SLs.

Hypothesis 4a. When demand is high, a higher SSK failure rate leads to longer TWT.

Hypothesis 4b. When demand is high, a higher SSK failure rate leads to lower SLs.

Hypothesis 4c. When demand is high, a higher SSK failure rate leads to longer SEWT.

3.6. Simulation study

A simulation model representing the current situation (IA = 100 s, 3 SE, no SSK) was formulated using the ARENA Simulation Software. The simulation was validated by comparing the output of the simulation model to the observed data. Two performance measures were used to compare the simulated and observed systems: average number of customers arriving and maximum number of customers waiting in line.

A simulation model was formulated for each combination of factor levels. The factors were inter-arrival time (IA = 100, IA = 80, IA = 60), number of service employees (SE = 2, SE = 3), and number of SSKs (no SSK, 1 SSK). Furthermore, for simulation models including an SSK, two more factors were varied. These were the failure rate of the SSK (FR = 12.5% FR = 25%) and the processing time of the SSK (PT = 60, PT = 90, PT = 120, PT = 150). Each model was used to simulate 35 periods of 5400 s (90 min). The performance measures that were collected for each replication included average total waiting-time (TWT), service employee waiting-time (SEWT), three service levels defined as a waiting-time less than 90 s (SL90), a waiting-time less than 120 s (SL120), and a waiting-time less than 150 s (SL150), and the utilization of the service employees. The additional service levels were defined to compensate for people's perceptions of waiting-time, often differing from reality (Taylor, 1994).

4. Results and discussion

This study's hypotheses examined whether SST could result in reduced waiting-times and improved service levels, and which conditions were necessary for this improvement.

4.1. Implementation objectives

Hypotheses 1 and 2 examined the effect of two common SST implementation objectives (increase in service delivery alternatives and cost reduction) on TWT, SEWT, SL90, SL120, and SL150. Two-way ANOVAs were conducted for each of the three demand levels. The main effects of the number of service employees and the number of SSKs as well as their interaction were examined. For all analyses, the main effect of the number of SSK and the main effect of the number of service employees on waiting-times and service levels were significant, and qualified by a statistically significant interaction. The ANOVA results are shown in Table 1. Table 2 shows descriptive statistics.

Under the observed demand conditions (IA = 100), the interaction effects of number of service employees and number of SSKs on overall average waiting-times ($F(1,136) = 8.491$; $p = .004$), service employee average waiting-time, and service levels ($F(1,136) = 28.431$; $p = .000$)[3] were statistically significant. An examination of the means[4] showed that there was no significant difference in TWT between the current setup ($M = 13.603$, $SD = 12.186$) and one where one service employee was replaced by an SSK ($M = 16.236$, $SD = 10.657$). The corresponding service levels (SL120) for these two setups were 95.7% and 95.3%, respectively.

[3] Unless otherwise indicated, service level refers to SL120, defined as a waiting-time of 120 s or less.

[4] All waiting-times are reported in seconds.

Table 1
Summary of Two-Way ANOVA results.

	Normal demand (IA = 100)		High demand (IA = 80)		Very high demand (IA = 60)	
	F	*p*	F	*p*	F	*p*
Average total waiting time						
Servers	$F(1,136) = 15.516$	.000	$F(1,136) = 47.391$	.000	$F(1,136) = 121.61$	.000
SSKs	$F(1,136) = 13.805$	.000	$F(1,136) = 51.864$	.000	$F(1,136) = 155.66$	.000
Servers*SSKs	$F(1,136) = 8.491$	.004	$F(1,136) = 30.489$	.000	$F(1,136) = 85.05$	.000
Adjusted R-Square	.200		.477		.721	
Service employee waiting time						
Servers	$F(1,136) = 17.005$	.000	$F(1,136) = 48.696$	.000	$F(1,136) = 125.645$	.000
SSKs	$F(1,136) = 13.435$	.000	$F(1,136) = 50.571$	.000	$F(1,136) = 156.244$	.000
Servers*SSKs	$F(1,136) = 7.836$	.000	$F(1,136) = 29.255$	.000	$F(1,136) = 86.061$	.000
Adjusted R-Square	.202		.475		.724	
Service level 90 s						
Servers	$F(1,136) = 87.376$	.000	$F(1,136) = 136.785$	.000	$F(1,136) = 232.137$	.000
SSKs	$F(1,136) = 77.889$	.000	$F(1,136) = 158.914$	.000	$F(1,136) = 381.358$	.000
Servers*SSKs	$F(1,136) = 32.409$	.000	$F(1,136) = 58.845$	.000	$F(1,136) = 71.532$	.000
Adjusted R-Square	.583		.717		.831	
Service level 120 s						
Servers	$F(1,136) = 65.515$	.000	$F(1,136) = 113.504$	.000	$F(1,136) = 211.861$	.000
SSKs	$F(1,136) = 61.151$	.000	$F(1,136) = 143.154$	.000	$F(1,136) = 348.351$	.000
Servers*SSKs	$F(1,136) = 28.431$	.000	$F(1,136) = 64.549$	.000	$F(1,136) = 87.122$	.000
Adjusted R-Square	.522		.696		.823	
Service level 150 s						
Servers	$F(1,136) = 52.6$	.000	$F(1,136) = 92.943$	.000	$F(1,136) = 198.779$	.000
SSKs	$F(1,136) = 45.796$	.000	$F(1,136) = 114.385$	.000	$F(1,136) = 328.56$	.000
Servers*SSKs	$F(1,136) = 26.454$	.000	$F(1,136) = 56.951$	.000	$F(1,136) = 100.263$	.000
Adjusted R-Square	.467		.653		0.818	

Adding an SSK to the current setup significantly reduced TWT ($M = 4.163$, $SD = 3.875$), resulting in a service level of 99.3%.

Under very high demand conditions (IA = 60), replacing a service employee by an SSK ($M = 54.556$, $SD = 23.360$) significantly reduced TWT as compared to the current setup ($M = 84.471$, $SD = 75.931$), increasing the service level to 84.3%. Replacing a service employee by an SSK ($M = 58.992$, $SD = 23.557$) similarly reduced SEWT as compared to the current setup ($M = 86.094$, $SD = 78.135$). However, the increase of the service employee utilization that occurred when replacing one service employee by an SSK, from 75.5% to 77.5% was not significant. Adding an SSK to the current setup also reduced TWT ($M = 17.274$, $SD = 15.632$) and improved service levels to 95.8%.

Table 2
Summary of descriptive statistics.

		Normal Demand (IA = 100)		High Demand (IA = 80)		Very High Demand (IA = 60)	
Service Employees	SSKs	Mean	SD	Mean	SD	Mean	SD
Average total waiting time (TWT)							
2	0	94.321	138.367	222.581	174.000	502.633	230.529
	1	16.236	10.657	29.695	17.488	54.556	23.360
3	0	13.603	12.186	34.510	38.737	84.471	75.931
	1	4.163	3.875	9.041	9.663	17.274	15.632
Service employee waiting time (SEWT)							
2	0	95.506	138.393	225.136	175.694	516.288	234.111
	1	19.238	13.098	33.321	17.763	58.992	23.557
3	0	13.831	11.956	35.359	39.367	86.094	78.135
	1	3.612	4.382	9.276	11.273	18.416	16.374
Service level 90 s (SL90)							
2	0	0.710	0.155	0.431	0.212	0.193	0.124
	1	0.930	0.054	0.881	0.073	0.792	0.080
3	0	0.938	0.066	0.861	0.132	0.700	0.194
	1	0.985	0.021	0.971	0.038	0.937	0.069
Service level 120 s (SL120)							
2	0	0.763	0.155	0.482	0.222	0.224	0.150
	1	0.953	0.049	0.922	0.058	0.843	0.071
3	0	0.957	0.051	0.893	0.119	0.752	0.193
	1	0.993	0.014	0.980	0.033	0.958	0.058
Service level 150 s (SL150)							
2	0	0.808	0.150	0.532	0.233	0.252	0.166
	1	0.968	0.035	0.940	0.049	0.882	0.064
3	0	0.975	0.036	0.916	0.112	0.792	0.191
	1	0.996	0.010	0.987	0.028	0.973	0.045
Service employee utilization							
2	0	0.661	0.113	0.821	0.101	0.943	0.039
	1	0.490	0.080	0.620	0.104	0.775	0.075
3	0	0.468	0.096	0.585	0.111	0.755	0.109
	1	0.371	0.064	0.456	0.080	0.597	0.095

Table 3
Four-way ANOVA results for average total waiting time (TWT).

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Corrected Model	2,325,484.480	47	49,478.393	39.942	.000
Intercept	2,331,365.766	1	2,331,365.766	1,882.022	.000
InterArrival	807,380.735	2	403,690.368	325.884	.000
NrServer	736,357.702	1	736,357.702	594.433	.000
ProcessingTime	170,583.955	3	56,861.318	45.902	.000
FailureRate	13,443.283	1	13,443.283	10.852	.001
InterArrival*NrServer	265,701.030	2	132,850.515	107.245	.000
InterArrival*ProcessingTime	127,360.178	6	21,226.696	17.136	.000
InterArrival*FailureRate	11,933.695	2	5,966.847	4.817	.008
NrServer*ProcessingTime	75,358.144	3	25,119.381	20.278	.000
NrServer*FailureRate	8,795.899	1	8,795.899	7.101	.008
ProcessingTime* FailureRate	2,689.551	3	896.517	0.724	.538
InterArrival*NrServer* ProcessingTime	76,530.953	6	12,755.159	10.297	.000
InterArrival*NrServer* FailureRate	9,495.660	2	4,747.830	3.833	.022
InterArrival*ProcessingTime* FailureRate	6,127.085	6	1,021.181	0.824	.551
NrServer*ProcessingTime* FailureRate	5,071.053	3	1,690.351	1.365	.252
InterArrival*NrServer* ProcessingTime*FailureRate	8,655.556	6	1,442.593	1.165	.323
Error	2,021,649.090	1632	1,238.756		
Total	6,678,499.336	1680			
Corrected Total	4,347,133.570	1679			

These findings show that adding an SSK option to the current setup reduced average waiting-times (overall and for the service employee) and improved service levels, providing support for Hypotheses 1a, 1b, and 1c. In other words, an SST implementation meant to provide customers with an additional service delivery option will also result in improved waiting-times and service levels.

The findings also show that replacing a service employee by an SSK with a faster processing time in order to reduce labor costs will always at least maintain the system's current performance. Furthermore, under conditions of high demand, replacing a service employee by an SSK will improve waiting-times and service levels without increasing the service employees' utilization. This finding provided partial support for Hypotheses 2a and 2b.

4.2. Influential factors

While the above findings suggest that the objectives of SST implementation can be achieved, they are based on several assumptions about the SSK performance. The time it takes a customer to check-in using an SSK and the SSK's failure rate, are likely to influence the performance of the system. In order to examine the impact of deviations from these assumptions on TWT, SEWT, and all three service levels tested (SE90, SE120, SE150), four-way ANOVAs were conducted for each of these dependent variables. The four factors were demand conditions (IA = 100, IA = 80, IA = 60), number of service employees (2 or 3), SSK processing time (PT = 60, PT = 90, PT = 100, and PT = 150), and SSK failure rate (FR = 12.5% and FR = 25%).

The results of the four-way ANOVA were similar for all five dependent variables. For TWT, the results showed a significant main effect of demand conditions ($F(2,1632) = 325.884$; $p = .000$), number of service employees ($F(1,1632) = 594.333$; $p = .000$), SSK processing times ($F(3,1632) = 45.902$; $p = .000$), and SSK failure rate ($F(1,1632) = 10.852$; $p = .001$). The significant main effects were qualified by several two-way and three-way interactions. Specifically, the interaction between the demand conditions and the number of service employees ($F(2,1632) = 107.245$; $p = .000$), the interaction between the demand conditions and the processing rate of the SSK ($F(6,1632) = 17.136$; $p = .000$), the interaction between the demand conditions and the failure rate of the SSK ($F(2,1632) = 4.817$; $p = .008$), the interaction between the number of service employees and the processing time of the SSK ($F(3,1632) = 20.278$; $p = .000$), and the interaction between the number of service employees and the failure rate of the SSK ($F(1,1632) = 7.101$; $p = .008$) were all statistically significant. Similarly, the interaction between demand conditions, number of service employees, and processing time of the SSK ($F(6,1632) = 10.297$; $p = .000$), and the interaction between demand

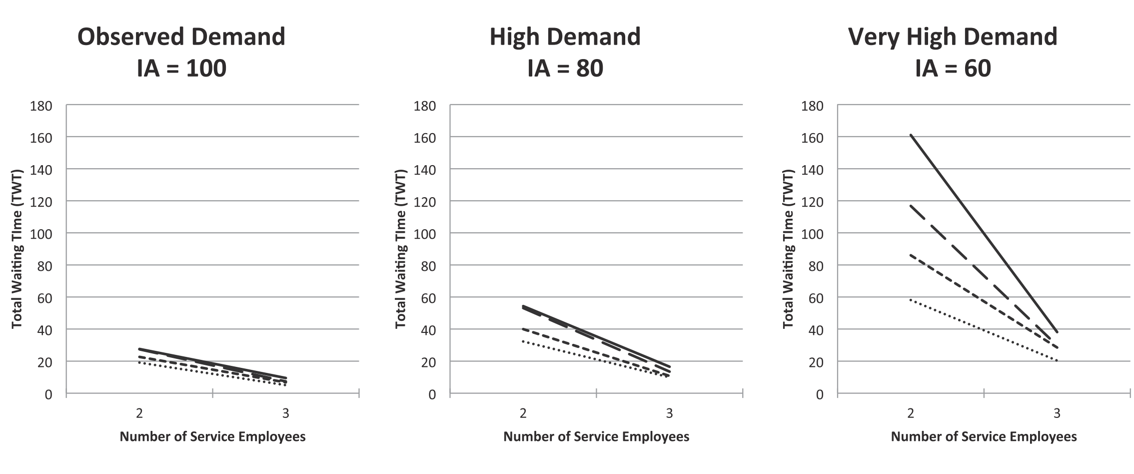

Fig. 1. Effect of interaction between demand, processing time, and number of service employees on average total waiting time (TWT).

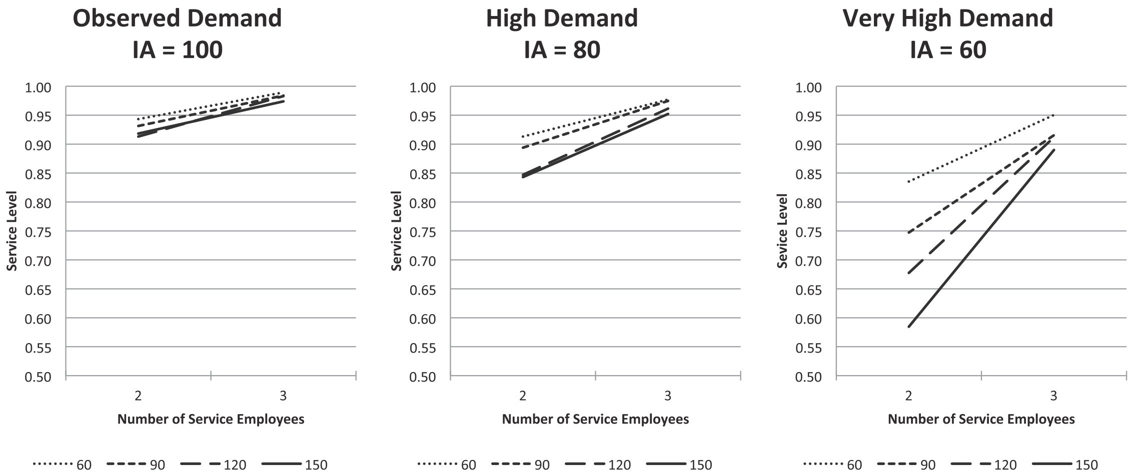

Fig. 2. Effect of interaction between demand, processing time, and number of service employees on average service level (SL120).

conditions, number of service employees and failure of the SSK ($F(2,1632) = 3.833$; $p = .022$) were all statistically significant. As Table 3 shows, the only interaction terms that were not statistically significant were those including both the processing time and failure rate factors.

The means per condition and the interaction plots for the effect of the three way interaction of demand conditions, number of service employees, and SSK processing time, on TWT (Fig. 1) and service levels (Fig. 2) were examined. These show that, when demand conditions are very high (IA = 60), and there are only two service employees available to help customers, slower SSK processing times lead to significantly longer waiting-times and lower service levels. However, when there are more employees available to help customers and/or the demand is lower, the impact

Table 4
Comparison of average total waiting time and service level between current setup and each experimental condition.*

			Normal Demand (IA = 100)		High Demand (IA = 80)		Very High Demand (IA = 60)	
Service Employees	Processing Time	Failure Rate	Mean	SD	Mean	SD	Mean	SD
Average Total Waiting Time (TWT)								
3 (No SSK) (current setup)			13.603	12.186	34.51	38.737	84.471	75.931
2 (1 SSK)	60	12.50%	**16.236**	10.657	29.695	17.488	54.556	23.360
	60	25.00%	**21.964**	15.582	**34.776**	19.489	61.603	29.777
	90	12.50%	**21.957**	13.743	**39.120**	24.138	80.040	51.885
	90	25.00%	**23.310**	15.112	**40.771**	24.565	**92.013**	49.123
	120	12.50%	**26.059**	19.109	**45.039**	33.860	**96.528**	62.002
	120	25.00%	**28.645**	19.649	**61.192**	54.301	**137.080**	95.621
	150	12.50%	**27.012**	17.878	**58.776**	46.532	**141.833**	109.843
	150	25.00%	**28.189**	20.062	**49.897**	26.741	**180.217**	107.761
3 (1 SSK)	60	12.50%	4.163	3.875	9.041	9.663	17.274	15.632
	60	25.00%	5.863	7.749	10.813	11.186	23.328	24.397
	90	12.50%	5.772	5.301	9.767	7.521	27.287	22.474
	90	25.00%	7.751	9.794	11.717	12.589	29.660	24.671
	120	12.50%	7.311	5.679	13.580	13.751	29.301	18.479
	120	25.00%	7.366	5.541	13.330	10.946	30.101	15.991
	150	12.50%	10.188	8.964	16.691	13.567	38.936	24.249
	150	25.00%	8.758	6.243	16.321	12.800	37.276	23.515
	Service Level (TWT < 120 s)							
3 (No SSK) (current setup)			0.957	0.051	0.893	0.119	0.752	0.193
2 (1 SSK)	60	12.50%	**0.953**	0.049	0.922	0.058	0.843	0.071
	60	25.00%	**0.933**	0.057	0.904	0.062	0.828	0.085
	90	12.50%	**0.933**	0.050	0.896	0.074	0.766	0.144
	90	25.00%	**0.930**	0.062	**0.892**	0.083	**0.728**	0.118
	120	12.50%	**0.920**	0.076	**0.866**	0.100	**0.716**	0.165
	120	25.00%	**0.906**	0.077	**0.827**	0.129	**0.639**	0.201
	150	12.50%	**0.921**	0.061	**0.835**	0.123	**0.635**	0.212
	150	25.00%	**0.916**	0.068	**0.851**	0.091	**0.534**	0.210
3 (1 SSK)	60	12.50%	0.993	0.014	0.980	0.033	0.958	0.058
	60	25.00%	0.985	0.029	0.974	0.039	0.942	0.063
	90	12.50%	0.986	0.021	0.977	0.026	0.919	0.077
	90	25.00%	0.982	0.035	0.972	0.038	0.911	0.090
	120	12.50%	0.983	0.020	0.962	0.043	0.910	0.074
	120	25.00%	0.983	0.018	0.961	0.038	0.914	0.057
	150	12.50%	0.971	0.030	0.953	0.041	0.889	0.073
	150	25.00%	0.977	0.022	0.951	0.042	0.891	0.078

* Bold shows setups that perform worse than the current setup.

of the length of the SSK processing time on waiting-times and service levels is much smaller. These findings provided support for Hypotheses 3a and 3b.

Similarly, the SSK failure rate's impact on TWT and service levels is greatest when demand conditions are very high (IA = 60), and there are only two service employees available to help customers. Under these conditions, TWT increased by 24.489 s when the SSK failure rate increased from 12.5% (M = 93.239, SD = 75.508) to 25% (M = 117.728, SD = 89.002). This corresponded to a decrease in service level of 5.8%. The impact of an increase in failure rate of the SSK is not as pronounced when there are more employees available to help customers and/or demand is lower. These findings provide support for Hypotheses 4a and 4b.

The findings above show that the SSK's failure rate and processing time play an important role in the overall performance of the system, especially under high demand conditions. It was therefore necessary to examine under which circumstances poor SST performance could affect the attainment of the implementation objectives. A summary of the overall average waiting-time and service levels for each SSK processing time and failure rate is provided in Table 4.

When the implementation objective was an increase in service delivery alternatives, adding a SSK to the current setup improved, or at least maintained the current performance of the system, independently of the SSK's performance. For example, even adding the worst performing SSK (PT = 150, FR = 25%) to the current setup maintained the service level. Under the observed demand conditions, the service level of the proposed setup (M = 0.977, SD = 0.022) was slightly better than the service level of the current setup (M = 0.957, SD = 0.051), however this difference was not statistically significant.

When the implementation objective was a reduction in labor costs, the impact of replacing a service employee by an SSK on system performance was influenced by the SSK processing time and failure rate. Section 4.1 showed that replacing a service employee by a SSK with a processing time of 60 s and a failure rate of 12.5% maintained the performance of the system under the observed conditions (IA = 100) and improved it under very high demand conditions (IA = 60). Conversely, one-way ANOVAs showed that, replacing a service employee by a SSK with a processing time of 120 s and a failure rate of 25% significantly worsened the performance of the system under all demand conditions. For example, under the observed conditions (IA = 100), TWT was significantly higher ($F(1,68) = 14.814$; $p = .000$), increasing from 13 s (SD = 12.186) to 29 s (SD = 19.649). Service levels were also significantly lower ($F(1,68) = 10.425$; $p = .002$), decreasing from 95.7% (SD = 0.051) to 90.6% (SD = 0.077). Under very high demand conditions (IA = 60), the differences were much more pronounced. TWT increased from 84 s (SD = 75.931) to 137 s (SD = 95.621). Service levels also decreased significantly, from 75.2% (SD = 0.193) to 63.9% (SD = 0.201).

5. Conclusions

SSTs have been presented in the literature as an effective way to reduce waiting-times and hence improve satisfaction (Weijters et al., 2007). This intuitive notion, supported by the application of basic queuing theory (Lambert and Cullen, 1987) is nevertheless contradicted by the study results which showed that SST can only reduce waiting-times under particular conditions of demand and performance.

For the particular system studied, adding an SSK to a check-in process staffed by three service employees only improved waiting-times and service levels when demand was higher than actually observed. This implies that adding an SSK to an existing check-in process will only improve customer waiting-times and service levels if the number of service employees is not sufficient to provide service in a timely manner. This situation can also occur outside of peak demand hours. Therefore, if the purpose of adding an SSK is to reduce waiting-times and improve service levels, decision-makers should ensure there is potential for improvement by not only carefully examining peak demand periods, but also other periods when demand may be high relative to the number of available service employees.

A second implication of the study results is that the speed of checking-in using the SSK and the failure rate of the SSK are important determinants of whether the SST implementation will be successful from a waiting-time reduction perspective. When SST is used to reduce costs, by replacing one service employee with an SSK, the effect of the SSK's performance on waiting-times and service levels is magnified. For the particular system studied, when customer demand is very high, the use of an SSK with a fast processing time will lead to lower waiting-times and higher service levels than the equivalent three employee setup. However, the use of an SSK with slower processing times will lead to much longer waiting-times and lower service levels. Similarly, a higher failure rate will also reduce system performance.

The study findings extend the SST literature in several ways. In addition to dispelling the commonly held belief that SST implementation will inevitably lead to lower waiting-times, the study reinforces the importance of SST performance and reliability (Weijters et al., 2007). Previous research has examined the role that the SST performance plays in customers' attitudes toward the SST. Furthermore, previous research has shown that SST failure has a direct, negative effect on customers' service evaluations (Reinders et al., 2008; Weijters et al., 2007). The present study showed that poor SST performance and failure also have a negative effect on system performance, specifically by increasing waiting-times. The findings of the study also highlight the advantages of simulation over queuing theory when investigating complex, non-steady-state systems subject to conditional logic and interactions.

6. Recommendations

The study findings have several implications for operations managers using waiting-times and/or service levels as performance measures, and contemplating the use of SSKs as either an alternative service delivery method for customers, or as a way of reducing operating costs. First, the impact of SST implementation on system performance will depend on the utilization of the system. Therefore, operations managers need accurate demand information. Furthermore, the disaggregation of this information should allow them to identify peak times as well as other times when the demand may be high relative to the number of service employees available to help customers.

Second, operations managers need to pay close attention to the processing time of the SSK. The processing time of the SSK will be impacted by several factors, including the skills and experiences of customers using the SSK, the design of the interface, and the number of options that will be offered to customers. While operations managers have little control over the skills and experience of customers, they can greatly improve these by making employees available to assist customers during the introduction of the SSK. They can also reduce the time it takes customers to complete the check-in by selecting a well-designed and intuitive interface, as the ease-of-use of the SSK will impact the speed at which customers can go through the check-in process.

Operations managers need to be mindful of the relationship between the number of options customers have to navigate through during check-in and the SSK processing time. The more options customers need to navigate to check in, the longer the check-in process will take. Basic options that customers may be offered when checking-in using an SSK include hotel floor, room type, and bed type. However, hotel SSKs are increasingly being used as a tool for customization. For example, Sheraton's Speed Check kiosks allow guests to receive messages, print additional room keys, and check and print their guest folio (Sheraton, 2004). The present study showed that a longer SSK processing time may, in the best case, result in no waiting-time improvement for customers, and at worst, may result in increased waiting-times. Therefore, implementing SST for the purpose of increasing customization may be incompatible with the use of waiting-times as performance measures. Operations managers need to ensure that they are using performance measures compatible with the objectives of the SST implementation.

7. Limitations and further research

Service providers may have different objectives than waiting-time reduction for implementing SST. For example, they may be appealing to customers' desire for control (Dabholkar, 1994), seeking to provide them with an additional check-in option that does not involve the assistance of a service employee. In that case, waiting-time and service levels are no longer sufficient performance measures. Further research should examine other SST implementation objectives and compatible performance measures.

The present study assumed that an SSK would have its own line, while service employees would be fed by a single line. This is consistent with real-life observations. However, according to queuing theory, single-line, multiple-server waiting line configurations perform better than equivalent multiple-line, multiple-server configurations. Furthermore, single-line, multiple-server waiting line configurations are perceived as more fair by customers. Future research should therefore examine whether the SSK(s) fed by the same line as the service employees are more effective.

The study's findings are based on a particular context, namely a hotel check-in desk staffed by three service employees. While the study did examine the impact of different levels of demand, it did not consider different supply conditions. Future research should therefore examine different base levels of staffing. Also, the present study assumed that introducing SST in this particular context would not influence the service employee's processing times. However, it is plausible that customers with simple needs are more likely to use the SST, and customers with more complex needs are more likely to use the service employee. Further research should therefore examine whether the introduction of SST is thus likely to increase the processing time for service employees.

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