Modeling and Analysis of the Customer Checkout Process with Flexible Servers for a Retail Store

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Abstract – **Staff should perform several jobs beside checkout operations during working hours in a retail store. To maintain a high service level, those who are performing other jobs may switch to serve customers when there is a customer waiting queue. In this study, a simulation model of the checkout process with the staff who are cross-trained is constructed to examine the server switching policy. Different scenarios compare system performance under various customer arrival conditions and queuing modes. The simulation model provides a potential decision support tool resolving staffing and queuing arrangement problems in a retail store.**

Keywords – **Simulation modelling, checkout process**

I. INTRODUCTION

In retail, competitiveness depends heavily on the ability to reduce costs and increase customer satisfaction. Waiting in a checkout line in the store is a necessary but undesirable activity that customers must undertake to complete their purchase. The customer may be dissatisfied with a long queue or a long waiting time, and these are considered important indicators for measuring store service quality [1] [2]. In Japan, the convenience store is a common retail format that meets customers' daily needs. Products and services include food, drink, magazines, stationery items, household commodities, bill payment, even ATM and delivery services. However, because of high labour costs, staffing is limited. Therefore, staff members must perform several operations during the work hours besides serving at the checkout counter such as receiving, checking and displaying goods, preparing the Oden and deep-fried food, cleaning the floor, and others [3]. Deciding when to open a new checkout counter and switch from other work is important to the shop manager during the staff training period for maintaining service levels with a limited workforce. In this study, a simulation model is constructed to study the staff switching policy to meet different queuing problems in a retail store. Experiments with different scenarios compare system performance under various customer arrival patterns.

II. CUSTOMER SERVICE AND STAFFING PROBLEMS IN THE RETAIL INDUSTRY

Problems related to retail store operations and workforce management such as shop layout, customer flow, and staffing schedules have been studied extensively. As a powerful analyzing and design tool, several studies have adopted simulation techniques to solve the problems. Miwa and Takakuwa (2008) presented a procedure for simulation modelling in-store merchandizing to examine customer flow and goods layout in a retail store [4]. Miwa and Takakuwa (2010) also presented a simulation analysis for optimization of staffing problems at the retail store considering operation types and frequency [3]. Liu (2009) discussed a simulation IP-based approach to optimize the retail store personnel planning [5]. A discrete event modelling method was used to construct a simulation model of the store checkout process and input customer shopping information from POS data as in [3] [4] [5]. To more naturally describe and simulate system behaviour [6], recently, agent-based modelling (ABM) method has been used to examine customer flow and the checkout process of retail industries. Terano et al. (2009) developed an agent-based in-store simulator to examine the effects of changes to operations through a detailed simulation setting. A supermarket was simulated, and the effect of a layout change and promotions was evaluated in their study [7]. Yamane et al. (2012) built a model for analysing checkout layout design and discussed experimental results with the stakeholders of a specific supermarket [8]. ABM methods in [7] [8] focus on customer behaviour and movement patterns. Siebers et al. (2007) simulated management practices such as training and empowerment in regard to worker behaviour. Their study sought to determine the department where customers usually seek help before purchase [9]. The input data and parameters in [7] [8] [9] were collected from POS terminals or manager experience to reflect system characteristics.

The problem of the staff switching policy for retail services having both front and back room operations was studied in [10] [11] [12]. In these studies, the front room serves customers, and the back room focuses on restocking shelves or other less time-sensitive and interruptible work. The queuing and staffing cost model was constructed, and the optimal switching number was found by the OR method.

Register layout and operation planning of the checkout process were described in several studies using a simulation method [7] [8] [13], but few simulation studies considered the staff switching policy. In this study, simulation of the switching policy using different scenarios is used to compare service level and remaining work time

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at other jobs using various customer arrival levels and queuing modes.

III. SIMULATION MODEL

A. Problem Definition

In a retail store, customers move around the shop to pick up the goods that they want to purchase. When customers finish shopping, they walk to the checkout area, and then stand in line waiting to pay the bill to complete the purchase. Meanwhile, the shop staff who are working other jobs frequently check the queue to decide whether to open a new register to shorten customer waiting time.

The outline of the staff switching problem in the study is defined as follows:

1) Number of staff and severs:

N_r =total number of registers in the shop ($N_r > 0$)

S = total number of staff working in the shop ($S > 0$),

S_r= number of staff who are fixed at the checkout counter ($N_r \geqq S_r \geqq 0$),

2) Switching points (Threshold):

The switching point to decide when to open a new register with current staff is denoted as T_0.

The number of customers waiting is used to set the threshold, which means if the waiting number of the queue is more than T_0, and there still has any available staff, he or she will open a new register to serve the customer.

3) Queuing mode:

The queuing mode: (1) customers standing in front of each register (QM_1) and (2) customers standing in a line (QM_2) are examined in the simulation model.

In the case of QM_1, the customer will try to pick a lane with the shortest wait time. We assume that once a customer picks a lane, they remain in the lane. In the case of QM_2, the customer will go to the end of the queue.

4) Output Data:

Customer average waiting time (W_a) and remaining free time for staff to do other jobs (T_f) are used as output data to evaluate system performance.

B. General Description of the Retail-Store

The store in the study is a franchise retail store located at a university campus in Japan. The shop is open from 7AM to 11PM. Sale items are goods that are commonly sold at Japanese convenience stores, such as basic grocery items, magazines, cup noodles, soft drinks, and snack foods, among others. A shop layout with areas is shown in Fig. 1. Most of the customers in the store are university students. Customer arrival rates vary depending on the timetable of the university. Peak time at the store is mid-day lunchtime (12:00 pm-1:00 pm) and during class breaks (approximately 8:30 am-8:45 am; 10:15 am-10:30 am; 2:30 pm-2:45 pm; 4:15 pm-4:30 pm; 6:00 pm-6:15 pm) [4] [5]. If the customer waiting queue is long, store staff will help work at checkout. Occasionally, a customer will take a long time at a register, to pay a bill, deliver services or buy several items. In this case, other staff will check the queue frequently, or the staff who operate the registers will ask for help. The server switching policy of the store staff at the checkout process and other operations is analysed by the simulation modeling method.

C. Model Construction

The simulation model of this study focuses on store checkout out processes, from the point when the customer finishes picking up goods. The flow reflecting customer and staff behaviour is shown in Fig. 2.

The model is developed using Simio™ software [14] that provides independently acting intelligent objects to model system behaviour. The threshold to switching the servers in the model is set through the Monitor Element and Event-driven Process [15].

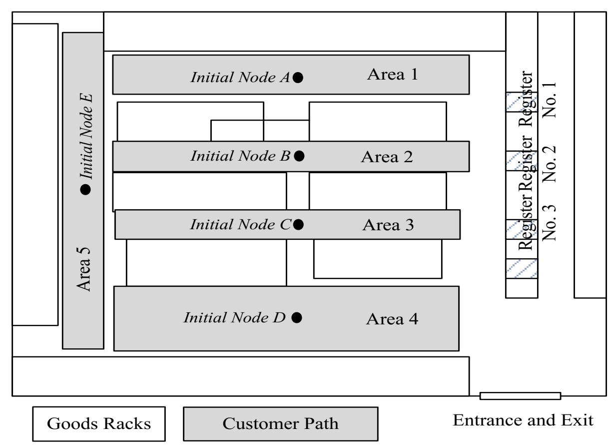


Fig. 1. Facility layout of the store.

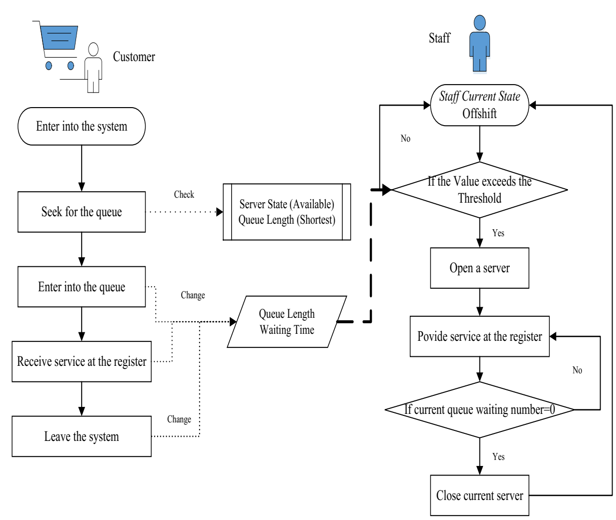


Fig. 2. Logic flow of the customer and store staff.

TABLE I. PARAMETERS FOR PERFORMING SIMULATION

Input Data	**Customer**	
	Initial Node (%)	Node (A,B,C,D,E) =(33,11,3,18,35)
	Buying Items Number (n)	Discrete(1,0.449,2,0.754, 3, 0.904, 4, 0.963, 5, 0.983, 6, 0.991, 7, 0.994, 8, 0.997, 9, 0.999, 10, 1)
	Select Time(seconds)	[0.999+EXPO(23.40)]n
	Staff	
	Nr	3
	S	3
	Sr	1 (Register No. 2)
	Priority of the register open	No.1, No.3
	Processing Time (seconds)	
	Scan	TRIA(n, 2.43*n+0.03, 2.43*n+0.03+3*3.17)
	Transaction	TRIA(7, 6.76*n+14.76, 6.76*n+3*9.31)
Output Data	**Time**	*Wa*
		Tf

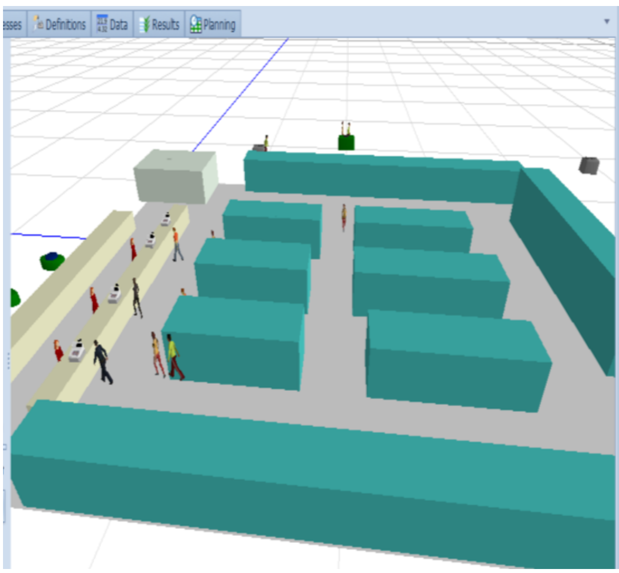


Fig. 3. A screen shot of the simulation model.

Because this is a collaborative study project between the university and the retail company, POS data are provided by the store. One month's weekday data (June, 2014) was used for analysis. After analysing the POS data, the period 1:00 pm~5:00 pm, with three staff is selected to study the server switching problem. After the lunch-time peak, customer arrival rates tend to be stable except for two 15-minute class-break peaks. Preliminary analysis of the POS data indicated that the average number of customers varied from 110 to 160 during normal time and rose to 300 during the class-break peaks. Therefore, four levels of customer arrival rates are used for the experiments: 110 (a_1), 130 (a_2), 160 (a_3), and 300 (a_4) customers per hour. The input data obtained from the POS data and selected simulation parameters are given in Table I.

The model constructed by Simio™ can be confirmed dynamically and visually. Part of the screen image for the simulation model is shown in Fig. 3.

IV. APPLICATIONS

A. Scenarios Constriction

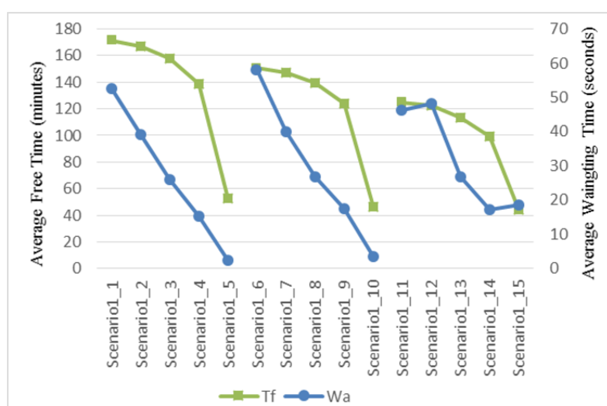
The application examines the staff switching policy in the store. The scenarios are designed to examine the switching points and queue mode under the different arrival rates. Detail of the scenario construction is shown in Table II.

B. Results Comparison among Scenarios

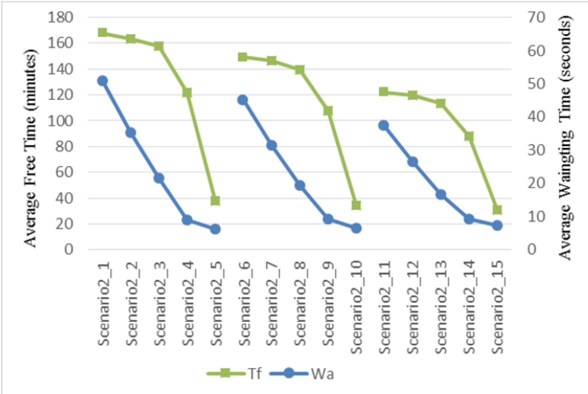
Run length of the experiments is set to 30 minutes for case arrival rates a_4, and 1.5 hours for the other cases. The warm-up period is selected as fifteen minutes before output statistic collection. Simulation experiments of corresponding models are executed with 20 replications. The results of the scenarios using different customer arrival rates are shown in Fig. 4.

TABLE II. SCENARIOS

Customer Arrival Rates	T_0 (person)	QM_1 Scenario 1 _#	QM_2 Scenario2 _#
a_1	4	1_1	2_1
	3	1_2	2_2
	2	1_3	2_3
	1	1_4	2_4
	0	1_5	2_5
a_2	4	1_6	2_6
	3	1_7	2_7
	2	1_8	2_8
	1	1_9	2_9
	0	1_10	2_10
a_3	4	1_11	2_11
	3	1_12	2_12
	2	1_13	2_13
	1	1_14	2_14
	0	1_15	2_15
a_4	4	1_16	2_16
	3	1_17	2_17
	2	1_18	2_18
	1	1_19	2_19
	0	1_20	2_20



(1)



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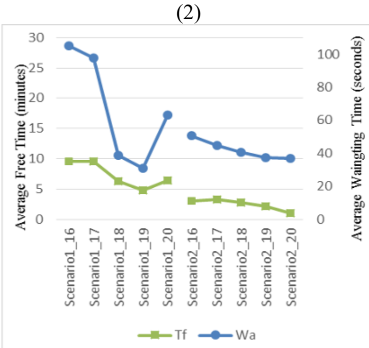

(3)

Fig. 4. Results comparison among the scenarios.

From Fig. 4, it is found that the W_a is shorten significantly with a smaller T_0 by using T_f in the case arrival rates a_1, a_2 for both two queue modes and the case a_3 for QM_2. However, in the busy time period case (arrival rates a_4), the W_a is not improved effectively when the T_0 little than two among the scenarios for QM_1 and varied little among the scenarios for QM_2. In the peak time, if a register is open, it is rarely closed until there is no one waiting for service. The switching policy should be adopted in the normal time period for effectively keeping customer service level and also ensuring enough time for staff completing other operations.

V. CONCLUSIONS

In this study, a simulation model that focused on the customer checkout process was used to examine the staff switching rules of a retail store. The model provides a potential decision support tool s on the store staffs' work assignments and customer checkout queuing patterns. Because the assumption that the customer would wait in the chosen line, some customers may wait for a long time if those ahead take too much time, further model improvements will consider the case where customers may change a queue when a new register opens and the processing time for staff performing other operations.

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