An analysis of the various factors related to the establishment of optimum cash register numbers

Bin Fang (Department of Economics, Kanazawa Seiryo University, fan@seiryo-u.ac.jp)
Takuya Tajima (Department of Information Engineering, Fukuoka Institute of Technology University, t-tajima@fit.ac.jp)
Takehiko Abe (Department of Economics, Aichi University, abet@vega.aichi-u.ac.jp)
Shinichi Shibata (Department of Information department, Daido University, shibatas@daido-it.ac.jp)
Hidetaka Nambo (Graduate school of Natural Science & Technology, Kanazawa University, nambo@blitz.ec.t.kanazawa-u.ac.jp)
Akinori Ono (Department of commerce, Keio University, akinori@keio.jp)
Haruhiko Kimura (Graduate school of Natural Science & Technology, Kanazawa University, kimura@blitz.ec.t.kanazawa-u.ac.jp)

Abstract

The supermarket industry is constantly examining how to reduce waste and improve net profit in difficult circumstances. To date, many prediction methods have been developed for reviewing the allocation of employees and part-timers by predicting the number of store visitors. However, the number of store visitors generally also includes accompanying visitors, and does not only consist of people making payments at cash registers. The present study proposes a system that, based on live POS data provided by an actual supermarket chain and examining rental cash registers, predicts the optimal number of cash registers in operation for each time band several weeks after introducing register operation rates and numbers of visitors leaving per unit time. The present paper proposed a method to obtain data including the optimal number of cash registers in operation from the POS data. It also investigated the factors in fluctuating customer numbers in concrete terms. Moreover, it evidenced that the optimal number of cash registers in operation hardly changes after 1-2 weeks. This allows for the appropriate planning of cash register staff numbers per time unit. Furthermore, it enables stores to obtain the optimal number of cash registers. The store whose POS data were used had 7 cash registers, but it was ascertained that when the optimal operation rates were 80 %, 70 %, and 60 %, sufficient cash register numbers were 4, 5, and 6, respectively. Opening hours for this store were between the 7 am and 10 am time bands. Virtually no customers visited the store in the 7 am, 8 am, and 10 pm time bands regardless of the day of the week, and it was concluded that the opening hours should be changed to the 9 am - 9 pm time bands.

Key words

POS data, registers number, optimal number, registers in operation, rate of operation

1. Introduction

The supermarket industry is constantly examining how to reduce waste and improve net profit in difficult circumstances. To date, many prediction methods have been developed for reviewing the allocation of employees and part-timers by predicting the number of store visitors (Ueda, 2001; Ueda Data Mining Laboratory, 2014). However, the number of store visitors generally also includes accompanying visitors, and does not only consist of people making payments at cash registers.

Furthermore, regarding the question as to how supermarkets and other stores decide how many cash registers to install or how many cash register operators to depute, some make this decision in reference to the situation in other existing supermarkets, some make rough estimates based on the number of store visitors they anticipate, and some also take the number of neighboring stores, including supermarkets as well as population, into account. Moreover, once decided, these details are usually not reviewed because of work pressures or the effort required, or, even if they are reviewed, visitor forecasts are per day and hardly ever per hour (Anat, 1989). There is, therefore, the potential to reduce ineffectual deployment of the number of cash registers in new establishments and of numbers of cash registers in operation (numbers of cash register operators) in the various time bands. However, obtaining accurate cash register and operator numbers necessitates data on customer arrival distribution and service time distribution, which is currently not included in POS data. The present study proposes a system that, based on live POS data provided by an actual supermarket chain and examining rental cash registers, predicts the optimal number of cash registers in operation for each time band several weeks after introducing register operation rates and numbers of visitors leaving per unit time. The system thus obtains the optimal numbers of employees and part-timers to be allocated to cash registers, keeps down wasteful personnel costs, and prevents the loss of customers to other stores because of insufficient numbers of cash registers in operation. With regard to the control of the number of cash registers, it further calculates the number of cash registers for the following month based on predicted numbers of cash registers in operation.

In related research, results of a survey on the supermarket industry in 2020 predict that the introduction of self-service checkouts will not progress significantly, but supermarkets with annual sales of JPY 100 billion or more are expected to introduce self-service checkouts and are thought to further cut back staff numbers (Kijima, 2012). However, in the present circumstances, staff operated cash registers process more customers per unit time. Since many customers also do not know how to operate a self-service checkout or think it is complicated, operation of self-service checkouts needs to be simple. Furthermore, as several employees or part-timers need to be allocated to deal with questions or errors or to support customers, introduction of expensive self-service checkouts is not as effective as thought. Beyond that, systems exist where customers entering a store are counted using a sensor placed at the store entrance, with sensors similarly placed at cash registers counting customers queuing at cash registers, thus calculating cash register operation rates per time band depending on cash registers' operation status, etc. This system is called IQ Lane, a well-known checkout management system using infrared sensors developed by the UK company Irisys (InfraRed Integrated Systems Ltd., 2015). This is currently extremely expensive, however, and whether it is profitable in future is open to question. There are also studies that employ POS data association analysis to reveal customer purchasing behavior and retail store properties, and examine means to improve POS productivity and efficiency (Murata et al., 2013; Tajima et al., 2013).

2. Optimal number of cash registers in operation on a given day

2.1 Definitions

2.1.1 Cash registers

The installed cash registers are rentals under monthly contracts. The number of rented cash registers shall be communicated one week in advance.

2.1.2 Number of visitors leaving per unit time

Total number of customers *S* for whom account processing was completed over all cash registers per hour. In other words,

$$S_t = \Sigma_{i=1}^{r} C_{t,i} \tag{1}$$

where C_i is the number of customers who have completed their account processing at cash register number *i* per 1 hour, and *r* is the number of cash registers installed.

2.1.3 Average number of cash registers in operation

Average value *AR* for the number of cash registers operating simultaneously, checked at 1 minute increments during 1 hour. In other words,

$$AR_t = \frac{\Sigma_{t=1}^{60} \; \Sigma_{i=1}^{r} R_{t,l,i}}{60} \tag{2}$$

where R_t,I is 1 if cash register number *i* is operating after *t* minutes, and 0 if not.

2.1.4 Average number of people successively served

The average number of customers AM_j whose accounts are processed in succession at a single cash register per 1 hour. In other words,

$$AM_{t,j} = \Sigma_{k=0}^{m_{t,j}} k \cdot P_{t,j,k} \tag{3}$$

$$P_{t,j,k} = \Sigma_{i=1}^{d_{t,j,k}} \frac{T_{t,j,k,i}}{3600} \tag{4}$$

where AM_j is the number of successively served customers at register number *j*, and $P_{j,k}$ is the probability that the number of customers having their accounts processed successively at cash register number *j* is *k*. Furthermore, m_j is the maximum number of customers having their accounts processed successively at cash register number *j*. $T_{j,k,l}$ is the period of time, in seconds, that *k* people in a queue at cash register number *i* have their accounts processed successively at cash register number *j*. $d_{j,k}$ is the number of occurrences per 1 hour of queues, where the number of customers who have their accounts processed successively at cash register number *j* is *k*.

2.1.5 Cash register operation rate

Ratio $H_{j,}$ where 1 cash register is in operation per 1 hour. In other words,

$$H_{t,j} = \Sigma_{i=1}^{e_{t,j}} \frac{U_{t,j,i}}{3600} \tag{5}$$

where H_j is the operation rate of cash register number *j*, and $U_{j,l}$ is the account processing time (unit: seconds) for customer number *i* at cash register number *j*. Furthermore, e_j is the number of customers having their accounts processed at cash register number *j*.

2.1.6 Average cash register operation rate

The average cash register operation rate for cash registers actually in operation per 1 hour. In other words,

$$AH_t = \sum_{j=1}^{r} \frac{H_{t,j}}{W_t} \tag{6}$$

where *w* is the number of cash registers actually in operation.

2.1.7 Optimal number of cash registers in operation

The minimum number of cash registers in operation when the cash register operation rate for each cash register and the average number of people successively served are below the ratio and lesser than the number of people set by the proprietor or manager. All optimal numbers of cash registers in operation are estimated for the month the cash registers are studied, and are obtained from its maximum values.

2.2 Obtaining the optimal cash registers in operation on a given day from the POS data

The number of visitors leaving per unit time and the average number of cash registers in operation can be simply obtained from the POS data. These POS data are the receipts received by buyers when payments are made. Below follows the explanation of the processing at the core of the acquisition of the average number of people successively served, the cash register operation rate, and the optimal number of cash registers in operation. As the average cash register operation rate can be simply obtained from the cash register operation rate, its explanation is omitted here.

2.2.1 Average number of people successively served

The question asked in the definition of the average number of people successively served is to evaluate whether customers have their accounts processed in succession. In the present article, customer *i* and customer *i* + 1 are deemed to have their accounts processed in succession when the following condition is met.

$$B_{t,j,i} \leqq N_{t,j,i+1} \times \alpha + \beta + \gamma \tag{7}$$

where

B: The time interval in the POS data between customer number *i* + 1 and customer number *i*

N: Total number of goods purchased in POS data for customer *i* + 1

α: Access time to enter product code for one product. This is the time required to read a barcode with a barcode scanner, and includes the time spent on looking for the barcode.

β: The time to convey the price for the total amount of goods to the customer, to receive the money from the customer, and put it into the cash register. It also includes the time needed to return any change.

γ: Allowable error

Moreover, as customers tend to line up at the cash register along the shortest queue, all AM_j for cash registers in operation are virtually equal.

2.2.2 Cash register operation rate

The problem in defining the cash register operation rate is how to obtain $U_{j,i}$. In this article, it is obtained as follows.

$$U_{t,j,i} = N_{t,j,i} \times \alpha + \beta \tag{8}$$

where $N_{j,i}$ is the total of all goods purchased by customer number *i*, queuing at cash register *j*.

2.2.3 Optimal number of cash registers in operation

The optimal number of cash registers in operation is the minimum number of cash registers in operation required when allotting the number of customers leaving per unit time, to cash registers in sequence of receipt times, starting at the earliest, so that the cash register operation rates and the average number of people successively served, as set by the proprietor or manager, are not exceeded. If the average number of people successively served, as set by the proprietor, for example, is exceeded, the allocation of those customers to a cash register is temporarily delayed (*LT* seconds), thus halting the extension of the number of customers served in succession. However, when the total accounts processing for the number of visitors leaving per unit time (including *LT*) exceeds one hour, a cash register is added and customer allocation starts anew. In concrete terms, the minimum number of cash registers in operation that meets the cash register operation rate and the average number of people successively served is obtained, while the number of cash registers in operation is increased incrementally by one cash register at a time.

2.3 Shaping POS data and database generation

Figure 1 shows the list of extracted items required for analysis.

POS data included per transaction are shown in Figure 2.

1. Number of visitors leaving per unit time
2. Average number of cash registers in operation
3. Average number of people successively served
4. Cash register operation rate
5. Average cash register operation rate
6. Optimal number of cash registers in operation
7. Difference between POS data receipt times for customer i and customer i+1 queueing at the same cash register
8. Total number of goods purchases in POS data
9. Day of the week
10. Seasonal variation
11. Weather
12. Temperature

Figure 1: Items required for analysis

- Receipt code
- Purchased article name
- Store code
- Article price
- Purchased article code (JAN code)
- Cash register No.
- Date
- Total number of purchases
- Time
- Total purchase price
- Staff code
- Purchased article dept. ID

Figure 2: POS data

To obtain items 1 to 8 in Figure 1, first, data are prepared by adding (date (year/month/day), time, cash register number, and day of the week) to (date (combined with time), receipt code, product dept. ID, product name, JAN code, price). A program was created to shape these data, as one store generates POS receipt data for over 400,000 transactions a month.

These data were then entered into a database (Access). A year's database was created by dividing data into 12 monthly database files, but it is also possible to generate a single database from a year's worth of data. This allows for the analysis of cash register operation rates and time bands or seasonal variation just by creating queries, including the equations for the proposed analysis method.

Data regarding the weather and temperature were not included in the receipt data, but were obtained from the Kanazawa Meteorological Office. Fields can also be easily added to manage data in the database.

2.4 Experiment–Obtaining the optimal number of cash registers in operation on a given day

2.4.1 Experiment 1

The following data were obtained for the opening hours on a specified day, based on live POS data provided by an actual supermarket chain: number of visitors leaving per unit time, where the unit time was 1 hour; average number of cash registers in operation; average number of people successively served for all cash registers; cash register operation rate; average cash register operation rate; optimal number of cash registers in operation.

2.4.2 Results

Tables 1-6 show the results calculated from POS data for March 2, 2008 (Monday) for one store. Table 1 shows the number of customers leaving after having processed their accounts in each unit time in opening hours from the 7 am time band to the 10 pm time band. Table 2 lists the number of cash registers that were in operation simultaneously for each minute in the 9 am time band, omitting instances when none were in operation. Data have been totaled per day. Substituting these data in the definitional equation for the average number of cash registers in operation results in $AR = 26/60 = 0.433$. Table 3 shows part of the aggregate results for the number of customers served in succession when α = 1 second, β = 30 seconds, and γ = 30 seconds. The average number of people successively served for each cash register can be calculated from the aggregate results for the number of customers served in succession. For instance, based on Table 3, the average number of people successively served at cash register 1 in the 5 pm time band is $AM_1 = 3 \times ((120 + 120) / 3600) + 4 \times (180 / 3600) = 0.4$ people. However, this assumes that cash register 1 was in operation between 5 pm and 6 pm. Table 4 shows the aggregate results for cash register operation rates for all cash registers, for all unit times in the opening hours from the 7 am time band to the 10 pm time band. However, α = 1 second, β = 30 seconds. Furthermore, the figures following the underscore (_) in the header row indicate the cash register number. Table 5 lists the average cash register operation rate calculated from Table 4, the number of visitors leaving per unit time (total number of customers), the total number of products purchased over all cash registers per unit time (total number of bought items), the total operation time over all registers per unit time (total

Table 1: Number of visitors leaving per hour

Date	Time	visitors per hour
2008/3/2	7	0
2008/3/2	8	0
2008/3/2	9	77
2008/3/2	10	124
2008/3/2	11	188
2008/3/2	12	140
2008/3/2	13	131
2008/3/2	14	126
2008/3/2	15	139
2008/3/2	16	144
2008/3/2	17	157
2008/3/2	18	111
2008/3/2	19	49
2008/3/2	20	31
2008/3/2	21	13
2008/3/2	22	0

Table 2: Number of registers working at the same time

Date	Time	Number of registers	Cash register No.
2008/3/2	9:03:00	1	3,
2008/3/2	9:08:00	2	5,3,
2008/3/2	9:16:00	2	5,3,
2008/3/2	9:18:00	2	5,3,
2008/3/2	9:22:00	1	3,
2008/3/2	9:23:00	2	5,3,
2008/3/2	9:27:00	3	5,4,3,
2008/3/2	9:31:00	1	3,
2008/3/2	9:36:00	1	4,
2008/3/2	9:39:00	1	4,
2008/3/2	9:41:00	3	5,4,3,
2008/3/2	9:45:00	2	4,3,
2008/3/2	9:48:00	2	4,3,
2008/3/2	9:49:00	2	4,3,
2008/3/2	9:51:00	3	5,4,3,
2008/3/2	9:52:00	3	5,4,3,
2008/3/2	9:53:00	3	5,4,3,
2008/3/2	9:54:00	3	5,4,3,
2008/3/2	9:55:00	1	5,
2008/3/2	9:56:00	3	5,4,3,
2008/3/2	9:57:00	1	4,
2008/3/2	9:58:00	3	5,4,3,
2008/3/2	9:59:00	1	3,

Table 3: Average number of people successively served

Date	Time	Cash register No.	Number of visitors successively served	Total number of purchases	ID of continuous visitor
2008/3/2	11:33-11:33	2	2	8	1227-1228
2008/3/2	11:37-11:38	2	2	57	1230-1231
2008/3/2	11:52-11:52	2	2	12	1242-1243
2008/3/2	10:34-10:34	3	2	33	1570-1571
2008/3/2	10:39-10:39	3	2	5	1575-1576
2008/3/2	10:51-10:51	4	2	18	2025-2026
2008/3/2	11:32-11:33	4	2	57	2053-2054
2008/3/2	12:21-12:21	5	2	36	2437-2438
2008/3/2	17:52-17:52	5	2	6	2584-2585
2008/3/2	11:30-11:30	6	2	26	2611-2612
2008/3/2	11:40-11:41	6	2	46	2617-2618

Note: $\alpha = 1$sec., $\beta = 30$sec., $\gamma = 30$ sec.

Table 4: Result of cash register operation rate

Date	Time	Operation rate 1	Operation rate 2	Operation rate 3	Operation rate 4	Operation rate 5	Operation rate 6	Operation rate 7
2008/3/2	7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2008/3/2	8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2008/3/2	9	0.00%	0.00%	35.81%	21.94%	26.58%	0.00%	0.00%
2008/3/2	10	0.00%	6.39%	41.17%	44.14%	39.19%	6.36%	0.00%
2008/3/2	11	0.00%	52.00%	50.22%	49.22%	45.14%	16.36%	0.00%
2008/3/2	12	0.00%	37.58%	42.33%	41.14%	33.08%	0.00%	0.00%
2008/3/2	13	0.00%	50.89%	43.94%	44.94%	0.00%	1.61%	0.00%
2008/3/2	14	0.00%	38.00%	39.56%	35.36%	22.69%	0.00%	0.00%
2008/3/2	15	1.14%	22.72%	46.14%	43.44%	48.39%	0.00%	0.00%
2008/3/2	16	0.00%	36.86%	43.64%	41.81%	39.11%	0.00%	0.00%
2008/3/2	17	0.00%	36.44%	41.11%	45.94%	44.36%	0.00%	0.00%
2008/3/2	18	0.89%	40.56%	45.14%	18.28%	15.53%	0.00%	0.00%
2008/3/2	19	0.00%	19.81%	34.53%	0.00%	0.00%	0.00%	0.00%
2008/3/2	20	0.00%	3.33%	27.08%	0.86%	0.00%	0.00%	0.00%
2008/3/2	21	0.00%	0.00%	13.47%	0.00%	0.00%	0.00%	0.00%
2008/3/2	22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Note: $\alpha = 1$ sec., $\beta = 30$ sec.

Table 5: Result of average cash register operation rate

Date	Time	Total number of visitors	Total number of purchases	Total operation time	Optimal number of cash registers	Average cash register operation rate
2008/3/2	7	0	0	0	0	0.00%
2008/3/2	8	0	0	0	0	0.00%
2008/3/2	9	77	726	3036	3	28.11%
2008/3/2	10	124	1221	4941	5	27.45%
2008/3/2	11	188	2026	7666	5	42.59%
2008/3/2	12	140	1349	5549	4	38.53%
2008/3/2	13	131	1160	5090	4	35.35%
2008/3/2	14	126	1102	4882	4	33.90%
2008/3/2	15	139	1656	5826	5	32.37%
2008/3/2	16	144	1491	5811	4	40.35%
2008/3/2	17	157	1333	6043	4	41.97%
2008/3/2	18	111	1004	4334	5	24.08%
2008/3/2	19	49	486	1956	2	27.17%
2008/3/2	20	31	196	1126	3	10.43%
2008/3/2	21	13	95	485	1	13.47%
2008/3/2	22	0	0	0	0	0.00%

Note: $\alpha = 1$ sec., $\beta = 30$ sec.

Table 6: Optimal number of cash registers in operation

Date	Time	Number of working registers	Optimal number of cash registers in operation
2008/3/2	7	0	0
2008/3/2	8	0	0
2008/3/2	9	3	1
2008/3/2	10	5	2
2008/3/2	11	5	2
2008/3/2	12	4	2
2008/3/2	13	4	2
2008/3/2	14	4	1
2008/3/2	15	5	2
2008/3/2	16	4	2
2008/3/2	17	4	2
2008/3/2	18	5	2
2008/3/2	19	2	1
2008/3/2	20	3	1
2008/3/2	21	1	1
2008/3/2	22	0	0

Note: at a rate of 80 %

operation time), and the maximum number of cash registers that were in operation per unit time (number of cash registers in operation). Lastly, Table 6 shows the optimal number of cash registers in operation for an optimal operation rate of 80 %.

Elaborating further on the calculation methods for Experiment 1, the number of visitors leaving per unit time and the average number of cash registers in operation were calculated according to the definitions in section 2.1, and the optimal number of cash registers in operation was calculated according to the definition in section 2.2.3. The average number of people successively served and cash register operation rate are not provided in seconds in the POS data, and were, therefore, obtained through the following approximate calculation.

Viewed from management's perspective, the cash register operation rates set by the proprietor or manager are never greatly exceeded, but if they do, waiting lines grow longer, customers are lost to other stores, and the frequency of mistakes in operating the cash registers increases. Therefore, as the actual register operation rates, as observed in the POS data, were 0-80 %, register operation rates determined by the proprietor or manager were set to three different rates, namely 60 %, 70 %, and 80 %. Moreover, the average number of people successively served was set to 3. Next, it is shown how the cash register operation rate H_j is calculated from the POS data. Using the definition, it is required to calculate for each cash register in operation in each hour (e.g., the 9 am time band): (total number of customer goods purchases x α) plus (number of customers x β.) Here $\alpha = 1$ second, $\beta = 30$ seconds/customer. These values were obtained through the observation of cash registers. As these calculation results are totaled every hour, the operation rate for each cash register in operation was calculated by dividing it by 3,600 (seconds) and arranging the units in seconds. For the calculation of $T_{k,i}$ in obtaining the average number of people successively served, $\gamma = 30$ seconds and equation (1) were used.

The optimal number of cash registers in operation varies depending on time bands and whether it is a week day/holiday. The difference was made evident by comparing the obtained actual numbers of cash registers in operation and the optimal number of cash registers in operation. For instance, in Table 6, the optimal number of cash registers in operation is approximately half the actual number of cash registers in operation. Moreover, a comparison of the total for the actual number of cash registers in operation and the total for the optimal number of cash registers in operation per unit time showed them to be 48 and 23, respectively. This is due to wastefulness in personnel and equipment costs, and emphasizes the necessity of the present study.

3. Factors in fluctuating customer numbers

3.1 Effect of the day of the week

3.1.1 Experiment 2

To clarify whether customer numbers fluctuate depending on the day of the week, a year's worth of average data were obtained for the number of visitors leaving per unit time and the average cash register operation rate for each day of the week. However, the number of visitors leaving per unit time was obtained for the opening hours between the 7 am and 10 pm time bands, whereas the average cash register operation rate was obtained per day for the purpose of saving space. This average cash register operation rate per day is the average cash register operation rate in the opening hours between the 7 am and 10 pm time bands.

3.1.2 Results

The results are presented in Tables 7 and 8. The calculation method is as follows. Calculation for Table 8 comprises: for each time band on each day, the total of customers leaving in 1 year divided by the number of days (person/day) for each time band on each day. For instance, the year average for the 8 am time band on Sundays is 3.94 visitors/day. Furthermore, once the average cash register operation rate is obtained for each time band on each day, the average value per day can be obtained.

It is clear from Table 7 that the number of customers is high on Sundays and Thursdays and low on Mondays and Wednesdays. The reason for this could be that people go out shopping on Sundays when the family is together, and refrain from shopping the next day, a Monday. Furthermore, the high number of customers on Thursdays might be because of store-specific characteristics such as bargain days (yet to be confirmed as unfortunately the business has shut down.) It is unclear why the number of customers is slightly reduced on

Table 7: Number of visitors leaving per hour on each day and time based on one year's data

Time	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
7	0.08	0.03	0.00	0.00	0.00	0.00	0.02
8	3.94	0.34	0.04	0.06	0.17	0.10	0.26
9	86.48	4.48	3.61	3.45	3.03	3.99	49.17
10	154.25	125.27	130.96	128.08	149.98	135.81	133.34
11	192.54	170.86	193.84	177.49	215.80	189.38	185.82
12	137.34	126.88	145.92	133.23	156.14	138.43	134.42
13	109.98	100.66	103.35	105.39	114.75	104.70	106.21
14	123.79	111.22	115.32	113.98	128.93	113.32	109.26
15	152.76	121.43	124.99	123.33	140.53	123.39	123.71
16	169.56	134.30	143.98	139.17	155.05	138.10	140.64
17	183.77	165.44	172.64	161.94	194.34	185.57	159.20
18	123.89	123.63	126.20	121.19	131.14	124.98	118.15
19	69.33	70.19	76.48	75.59	79.20	70.59	70.55
20	39.66	38.14	40.23	39.33	43.83	41.11	38.67
21	24.53	22.10	25.10	24.50	26.99	24.24	24.63
22	1.01	0.86	1.13	1.03	1.05	0.98	1.18
Total	1572.91	1315.83	1403.80	1347.77	1540.91	1394.68	1395.21

Table 8: Average cash register operation rate for each day based on one year's data

Date	Average cash register operation rate
Sunday	23.81%
Monday	21.40%
Tuesday	22.88%
Wednesday	22.78%
Thursday	23.62%
Friday	22.74%
Saturday	22.26%

Wednesdays, but it could be that people refrain from shopping because it is in the middle of the week, and the following day is a Thursday (bargain day?). Table 8 shows that the average cash register operation rate is almost proportional to the number of customers, but that it is a little lower on Saturdays whereas the values for Wednesday are the same as for Tuesdays and Fridays. This shows that it is possible that the number of cash registers temporarily increased somewhat on Saturdays, whereas it temporarily dipped slightly on Wednesdays.

These results reveal that customer numbers fluctuate depending on the day of the week.

3.2 Effect of seasonal variation

3.2.1 Experiment 3

To confirm whether customer numbers are affected by seasonal variation, the average seasonal values were obtained for the number of visitors leaving per unit time and average cash register operation rate, for all four seasons. In order to save space, however, they were obtained for the number of visitors leaving per unit time per 1 day and average cash register operation rate per 1 day. This number of visitors leaving per unit time per 1 day is the total number of visitors leaving per unit time during opening hours between the 7 am time band and the 10 pm time band.

3.2.2 Results

The results are shown in Tables 9 and 10. Values for both were obtained from average data for each season (3 months each). Table 9 shows the number of visitors leaving per unit time per 1 day, and Table 10 shows the average cash register operation rate per 1 day.

Table 9: For each season the number of visitors leaving per hour

Season	Number of visitors leaving per unit time
Spring	1437.03
Summer	1515.49
Autumn	1446.44
Winter	1300.72

Table 10: Average cash register operation rate for one day for four seasons

Season	Average
Spring	23.13%
Summer	23.00%
Autumn	23.38%
Winter	21.61%

Table 9 shows that customer numbers are high in summer and low in winter, and Table 10 shows that average cash register operation rates are high in autumn and low in winter.

It can be estimated from this finding that the number of cash registers in operation either temporarily increased marginally in the summer season, or temporarily dipped to some extent in the autumn.

These results reveal that customer numbers fluctuate due to seasonal variation.

3.3 Effect of weather

3.3.1 Experiment 4

To confirm whether customer numbers are affected by weather, average values were obtained for the number of visitors leaving per unit time and average cash register operation rate, for each of the following weather types throughout 1 year: Sunny, cloudy, rain, snow. In order to save space, however, they were obtained for the number of visitors leaving per unit time per 1 day and average cash register operation rate per 1 day.

3.3.2 Results

The results are shown in Tables 11 and 12. Values for both were obtained from average data for each weather type over 1 year. For Table 11, the average number of visitors leaving per unit time per 1 day was obtained by adding the numbers of visitors leaving per unit time per 1 day for each weather type during 1 year, and dividing it by the number of days for each weather type. For Table 12, the average for the cash register operation rates per 1 day was obtained in the same way.

Table 11: Number of visitors leaving per hour for all weathers

Weather	Number of visitors leaving per unit time
Sunny	1455.88
Cloudy	1480.09
Rain	1313.73
Snow	1159.00

Table 12: Average cash register operation rate per day for all weathers

Weather	Average cash register operation rate
Sunny	23.25%
Cloudy	22.83%
Rain	21.94%
Snow	21.35%

Table 11 shows that customer numbers are highest when it is cloudy and lowest at times of snow. Table 12 shows that the average cash register operation rate is high when it is sunny, and low at times of snow. Based on the order reversal of sunny and cloudy weather, it can be estimated that the number of cash registers in operation is either temporarily increased slightly during cloudy weather, or temporarily dipped to some extent during sunny weather.

These results reveal that the number of customers is affected by weather.

3.4 Effect of temperature

3.4.1 Experiment 5

To confirm whether customer numbers are affected by temperature, average values were obtained from 1 year's worth of data for the number of visitors leaving per unit time and average cash register operation rate, when the maximum temperature changed by 5 °C or more compared with the previous day. In order to save space, however, they were obtained for the number of visitors leaving per unit time per 1 day and average cash register operation rate per 1 day.

3.4.2 Results

The results are shown in Table 13. The number of visitors leaving per unit time was slightly higher when the temperature changed by 5 °C or more, but the average cash register operation rate remained virtually the same.

Table 13: Number of visitors leaving per hour by average cash register operation rate in the case of change over 5 degrees centigrade compared to the previous day

	Number of visitors leaving per unit time	Average cash register operation rate
Change over 5 degrees centigrade	1452.87	22.80%
Average of 1 year	1424.59	22.78%

For reference, Table 14 shows the average cash register operate rates at ±5 °C for the year and for each season. This reveals no extreme differences, although it shows that the average cash register operation rate is on the lower side when the temperature drops below zero in spring and winter, and on the higher side when it is above zero in winter. Assuming that there are no temporary changes in the number of cash registers in operation, this generally aligns with human behavior where people get more active when it is warmer.

Table 14: Average cash register operation rate of ±5 °C for each year and season

	+5℃	-5℃
Yearly	23.38℃	22.56℃
Spring	23.02℃	21.97℃
Summer	23.13℃	22.79℃
Autumn	23.72℃	23.47℃
Winter	24.43℃	21.70℃

4. Estimation of optimal number of cash registers in operation after several weeks

4.1 Experiment 6

Variations in the optimal number of cash registers in operation per time unit, after 1, 2, 3, and 4 weeks for each day of the week in spring, summer, autumn, and winter were ob-

Table 15: Number of operating cash registers at optional rate of 80 %

Day, month/time	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
29 Apr.	1	1	2	3	3	2	2	2	3	3	3	2	2	1	1	1
22 Apr.	1	1	2	3	3	3	2	2	2	3	3	2	1	1	1	1
15 Apr.	1	1	2	3	3	2	2	2	3	3	3	2	2	1	1	1
8 Apr.	1	1	1	3	3	2	2	2	3	3	3	2	2	1	1	1
1 Apr.	1	1	1	2	3	2	2	2	3	3	3	3	2	1	1	1

Table 16: Number of operating cash registers at optional rate of 70 %

Day, month/time	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
29 Apr.	1	1	2	3	3	3	2	3	3	3	3	3	2	1	1	1
22 Apr.	1	1	2	3	4	3	2	2	3	3	3	3	1	1	1	1
15 Apr.	1	1	2	3	3	3	2	3	3	3	4	3	2	1	1	1
8 Apr.	1	1	2	3	4	2	2	3	3	4	3	2	2	1	1	1
1 Apr.	1	1	1	3	3	2	2	3	3	3	3	3	2	1	1	1

Table 17: Number of operating cash registers at optional rate of 60 %

Day, month/time	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
29 Apr.	1	1	2	3	4	3	2	3	3	3	4	3	2	1	1	1
22 Apr.	1	1	2	4	4	4	3	3	3	3	4	3	2	1	1	1
15 Apr.	1	1	2	3	4	3	2	3	4	4	4	3	2	1	1	1
8 Apr.	1	1	2	4	4	3	2	3	3	4	4	3	2	1	1	1
1 Apr.	1	1	2	3	4	3	2	3	4	4	4	3	2	1	1	1

tained. They were calculated for the opening hours between the 7 am and 10 pm time bands.

4.2 Results

Changes in the optimal number of cash register in operation were examined for optimal operation rates set at 80 %, 70 %, and 60 %. The results showed that the variations in the optimal number of cash registers in operation per time unit, after 1, 2, 3, and 4 weeks for each day of the week in spring, summer, autumn, and winter were not that large. For instance, the variation for Sundays in April, in mid spring, is shown in Tables 15, 16, and 17, respectively. It must be noted that these numbers are shown as rounded up whole numbers. Moreover, a minimum requirement of 1 cash register has been set even if the actual operation rate is 0 %. The calculation results showed the following differences. Differences after 1 week: 2 (2 cash registers) between April 1 and 8 at 10 am and 6 pm, 1 (1 cash register) between April 8 and 15 at 9 am, 3 (3 cash registers) between April 15 and 22 at 12 pm, 3 pm, and 7 pm, 3 (3 cash registers) between April 22 and 29 at 12 pm, 3 pm, and 7 pm. The average difference was 2.25. Differences after 2 weeks: 3 (3 cash registers) between April 1 and 15 at 9 am, 10 am, and 6 pm, 4 (4 cash registers) between April 8 and 22 at 9 am, 12 pm, 3 pm, and 7 pm, none (no cash registers) between April 15 and 29. The average difference was 2.33. Differences after 3 weeks: 6 (6 cash registers) between April 1 and 22 at 9 am, 10 am, 12 pm, 3 pm, 6 pm, and 7 pm, 1 (1 cash register) between April 8 and 29 at 9 am. The average difference was 3.5. Difference after 4 weeks: 3 (3 cash registers) between April 1 and 29, at 9 am, 10 am, and 6 pm. Out of the 16 in the 7 am and 10 pm time bands, only about 2 occur after 1 or 2 weeks. This showed that when the number of student part-timers or employees manning the cash registers 1 or 2 weeks previously are obtained per time unit, it can be approximated by the optimal number of cash registers in operation of that day.

5. Conclusion

The present paper proposed a method to obtain data including the optimal number of cash registers in operation from the POS data. It also investigated the factors in fluctuating customer numbers in concrete terms. Moreover, it evidenced that the optimal number of cash registers in operation hardly changes after 1-2 weeks. This allows for the appropriate planning of cash register staff numbers per time unit. Furthermore, it enables stores to obtain the optimal number of cash registers.

The store whose POS data were used had 7 cash registers, but it was ascertained that when the optimal operation rates were 80 %, 70 %, and 60 %, sufficient cash register numbers were 4, 5, and 6, respectively. Opening hours for this store were between the 7 am and 10 am time bands. Virtually no customers visited the store in the 7 am, 8 am, and 10 pm time bands regardless of the day of the week, and it was concluded that the opening hours should be changed to the 9 am-9 pm time bands.

References

Anat, R. (1989). When cashiers meet customers: An analysis of the role of supermarket cashiers. *Academy of Management Journal*. Vol. 32, No. 2, 245-273.

InfraRed Integrated Systems Ltd. (2015). http://www.irisys.co.uk.

Kijima, T. (2012). Research on problems and prospects of 2020 with the supermarket industry. *Distribution Information*, Vol. 43, No. 5, 40-58.

Murata, H., Kajiwara, Y., Nakamura, M. and Kimura, H. (2013). Development of customer purchasing behavior simulator that takes into account the distance to goods. *Japan Facility Management Journal*, Vol. 24, No. 4, 88-94.

Tajima, T., Abe, T. and Kimura, H. (2013). A study on the POS data analysis and department productivity improvement. *Production Management*, Vol. 19, No. 2, 91-98.

Ueda Data Mining Laboratory (2014). Prediction introduction to predict the super of customer traffic. http://www.datamining.jp/uedaken/pc_10.html.

Ueda, T. (2001). Data Mining Practice Collection. Kyouritsu Press.

(Received: June 10, 2015; Accepted: June 29, 2015)