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Optimal seat allocation strategy for e-sports gaming center

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Abstract

This paper investigates the seat allocation issues for an e-sports gaming center where people generally visit in groups to play games while eating. According to the data analysis, as the number of customers in a group gets larger, the revenue per person tends to get higher. The data analysis to identify the information, such as revenue and the stay time of customers is conducted, and operations research is applied to derive the optimal seat allocation strategy. Through a numerical experiment with actual data, it is discovered that small groups of customers can also be prioritized in the same way as groups with larger numbers due to the fluctuating revenue generated by each group of customers during every timeslot. Furthermore, the opportunity cost that occurs by blocking customers even if there are available seats to accommodate the larger groups of customers who provide bigger revenue at various timeslots is considered.

Keywords: online games; Internet café; mathematical model; revenue management; group customer; e-sports

1. Introduction

e-Sports can be regarded as the events and activities related to games (Korea Creative Content Agency, 2013). Among the e-sports market of Korea, the size of the PC game market is $4.5 billion, which took 34.6% of the Korean game market in 2018. There are many reasons for promoting the development of the PC game industry, and the increasing number of e-sports gaming centers can be regarded as the major reason (Huhh, 2008). The early stage of e-sports gaming centers in Korea was similar to Internet cafés in other countries, especially the Internet cafés in Turkey, which provided Internet services at an hourly rate and simple snacks and drinks (Gürol and Sevindik, 2007). However, along with the increased attention toward games and the increasing number of users attracted by experienced game players, the current e-sports gaming centers of South Korea provide high-quality computers, fast Internet, 24-hour operation systems, and various types of food. Also,

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these benefits differentiate them from the Internet cafés located in other countries (Korea Creative Content Agency, 2018).

Traditionally, since the corporate structure and regulations of e-sports gaming centers were not defined clearly, they allowed people to smoke, which caused teenagers to avoid visiting the e-sports gaming centers (Kim et al., 2017). However, starting from the early 2000s, regulations that prohibit people from smoking inside buildings and the advent of popular PC games changed the awareness of people about the e-sports gaming centers and allowed more diverse customers, such as women and teenagers to visit e-sports gaming centers (Kim et al., 2010). Moreover, the e-sports gaming centers started to change their interior design, like café, while providing high-quality computers that could accelerate the prosperity of the e-sports gaming centers. Especially, the corporate structure of the e-sports gaming centers that used to sell only snacks, such as chips and sodas, started to sell various foods, which are similar to restaurants. Therefore, the revenue generated by food sales constantly increased, so a few e-sports gaming centers generated higher revenue through food sales than PC use. With these efforts, the number of e-sports gaming centers in Korea rose to 11,349 by 2018, and the size of this business is around \$1.7 billion, which is expected to grow steadily (Korea Creative Content Agency, 2018).

Despite the various efforts, the business environment of the e-sports gaming centers still faces many difficulties, which include pressure on profits due to increased labor costs and demand fluctuation (Baek and Park, 2016). The demand fluctuation occurs because the crowded timeslot and empty timeslot of an e-sports gaming center is divided very clearly based on the characteristics of frequent customers who visit each e-sports gaming center. Teenagers might visit e-sports gaming centers between 15:00 and 18:00 after their school finishes, and the adults might visit between 18:00 and 22:00 after they have finished work. Since the crowded timeslot of e-sports gaming centers generally exists, to keep more customers with higher revenues during the crowded timeslots might be a rational decision to increase the revenue.

Among the many different game genres, the games that people play together account for the largest part of the online gaming business (Lee et al., 2015). People interact with each other through multiplayer games through competitive and cooperative activities (Gong et al., 2019). In addition, it was found that people visit e-sports gaming centers to play games with friends or co-workers according to the statistics from the Ministry of Culture, Sports, and Tourism of Korea in 2018. According to a particular e-sports gaming center, it was found that 35.7% of customers from March 2018 were group customers. Customers who visit in groups prefer to sit beside each other, but sometimes group customers cannot enter the e-sports gaming center because there are not enough seats available to sit together. In this case, they try to find another e-sports gaming center, so they can sit together. Those group customers can be regarded as lost sales. Generally, the seats in an e-sports gaming center are taken on a first-come-first-serve basis. Since the customers want to keep some space between other customers whom they do not know, the first-come-first-serve rule can produce several scattered vacant seats. This phenomenon can make the group customers leave because there are no seats in a row for them to stay together. Therefore, the method to decide the number of seats to be provided for different groups' threshold should be devised for e-sports gaming centers to generate more revenue.

This research suggests an optimal solution to maximize the revenue of e-sports gaming centers by assigning the seats to customers rationally by applying operations research. When seats are allocated to customers, the spending pattern of a single customer and groups of customers, which consists of more than two people, should be considered. For an e-sports gaming center to maximize its revenue, it is important to keep the customers who spend a lot. However, current e-sports gaming centers allocate seats by following the first-come-first-serve rule, so when the customers occupy certain seats, it is difficult to ask them to move to other seats. Therefore, it can occur that the demand block of group customers might be the ones who provided more revenue. Therefore, the solution that can secure group customers by operating the seats for them should be devised. Through the seat allocation strategy, the seats are allocated to secure the customers with high revenue. By considering the seats for group customers, which consist of two, three, or more people, it is expected to fill the e-sports gaming center to capacity. The suggested mathematical model aims to maximize the revenue generated by PC use and food sales.

2. Literature review

The method suggested in this research aims to maximize the revenue of an e-sports gaming center by allocating certain seats for the group customers. Bell (2012) argued that the main object of revenue management is to increase the revenue of the firm by selling less or more fixed quantity of products available for sale. There are five basic tactics that are used in the fields of revenue management, which include overbooking, differential pricing, product protection, trading up, and planned upgrade/short selling. A lot of different research has used these strategies to gain additional revenue. Yang et al. (2017) used dynamic pricing when stock capacity is fixed, and the demand is stochastic. To derive optimal pricing policies, various models were tested in several pricing policies and whether the reference price had an impact on demand. Feng (2019) proposed the inventory management policy and joint dynamic pricing with perishable products. Considering the price-dependent and the time-varying characteristic of the demand rate, they not only decided the product price but also the investment policy to replenish the inventory. Kim and Bell (2019) developed models to derive the optimal quantity and price of products, which considered the shift in demand between products/markets. Considering demand substitution generated by price differences and inventory shortage, the derived result is compared when the total production is restricted or unconstrained. Various studies have proved that revenue management is an effective tool to secure the revenue of firms, and the potential revenue is more important when the items are perishable. However, in case of e-sports gaming centers in Korea, the hourly rent fee of the PCs and the types and prices of the snacks sold are almost same at each center. Also, reservations are not allowed at almost every center. Due to these characteristics of e-sports gaming centers, revenue management through seat allocation can secure more stochastic demands rather than implementing pricing or demand distribution strategies.

Between various businesses, airlines share similar concept with the e-sports gaming centers because both businesses need to manage the seats that are perishable. Cizaire and Belobaba (2013) conducted research about the optimization problem of pricing and seat inventory control for airlines. The model was developed by considering the two-period pricing and seat allocation problem to maximize the revenue, and Monte Carlo simulations were conducted to derive a solution. It was found that 3.4–3.9% of the revenue increased when the seat allocation solution was applied. Li et al. (2008) studied the seat allocation problem of airlines. Competitive seat allocation game theory was applied to compare two different airlines that share a common market demand. An optimal solution to allocate seats into full fare or discount fare was derived. Yoon et al. (2012) investigated seat allocation by considering the multiple fare classes, the demand, and the cancellation rate of an airline. CPLEX was applied to derive the seat allocation and the Monte Carlo simulation technique was adopted to check the increased revenue. Through a numerical experiment and a simulation, it was found that the suggested model worked efficiently with the seat control when cancellations occurred.

Other transportations, such as buses and trains, also consider the seat allocation method. Wang et al. (2016) investigated the seat allocation method for the rail revenue management. The seat allocation method was divided into two models. A single-stage seat allocation model considered one moment of allocating seats, while the multistage seat allocation model considered allocating seats at every time interval. A solution was derived by applying linear programming (LP) and the simulation was conducted. It was found that the suggested seat allocation method could increase the revenue significantly. Macura et al. (2019) suggested a solution for the capacity allocation problem of the railway industry. Linear integer programming and an artificial neural network were applied to derive a solution. The devised model could decide if the new passenger would be accepted or rejected from the berths of the sleeping car on a train. Sumalee et al. (2009) devised the seat allocation model to minimize the congestion of public transportation by considering the transit assignment. To control the congestion of public transportation, the suggested model allocated the vacant seats to passengers with a certain probability to get a seat. It was found that the seat allocation model could handle in-vehicle congestion by reducing the number of people who had to stand.

The seat allocation method is not always applied for transportation, it has also been adopted to allocate seats for indoor spaces. Grimmett (2012) developed a mathematical seat redistribution model for the European Union (EU) Parliament. The model considered the constraints about the minimum and the maximum number of allocated seats for each country. After allocating a fixed minimal number of seats, the remaining seats were allocated following the base + prop method, which considered the degressive proportionality principle. The principle was recommended by the EU Parliament to distribute the seats according to the populations of each country. Serafini (2012) proposed a methodology that considered the proportionality part of the seat allocation process more deeply. A mathematical model was developed based on integer linear programming (ILP) to satisfy the entire complex constraints, which included the need for degressive proportionality recommendations. This research compared the many methods about the assignment of seats, and it emphasized the effort to consider degressive proportionality efficiently through ILP. Łyko and Rudek (2013) proposed a fast and accurate search algorithm called Łyko and Rudek's Search Algorithm (LaRSA) when allocating the seats for the EU Parliament. LaRSA could derive unbiased results by considering all the possible seat allocation cases of the EU Parliament. Through a selective searching process, this algorithm could effectively reduce the computing time used to derive the assigned seats for the EU Parliament. Maclean and Ødegaard (2020) investigated about the seat allocation method for the live entertainment. Authors devised STACK multinomial logit model algorithm and STACK capacity-weighted selection model, and they were solved through heuristic dynamic stochastic knapsack problem. Authors expected that the algorithm devised in this paper may increase the available seats to sell.

This paper suggests the method to maximize the revenue of e-sports gaming centers through seat allocation, and the seat allocation method used in this research shares similar concepts with the table mix problem (TMP) than the seat allocation applied in other industries. This is because the TMP is applied to make a rational decision of a table arrangement to maximize the revenue during the crowded times. Thompson (2003) studied about the configuration of tables in restaurants, which can generate more revenue by serving large groups without an additional investment. By adopting the table mix model, it can derive the number of served and the number of lost guests. The table mix model considered the size of potential group customers and the expected stay time of the customers. This paper explains that the best and the worst configurations generated a $74.48 difference, which means the best configuration can serve three more groups that consist of 2.5 people per each group. Guerriero et al. (2014) devised the new TMP by considering more features that can reflect real settings. By adopting LP, this paper solved the operational problems of restaurant revenue management. The method to serve group customers, which consist of different numbers of customers with a limited number of tables, was suggested. Bertsimas and Shioda (2003) studied a method to allocate restaurant seats to different sizes of incoming parties. The models were tested in two classes, which included when the restaurant does not accept reservations and when the restaurants accept reservations. As a result, testing the algorithms at three demand levels, the approximate dynamic programming algorithm showed a better performance than the stochastic gradient algorithm. Compared with the first-come-first-serve rule, the revenues increased effectively, but the waiting time for the customers did not increase. Kimes and Thompson (2004) developed a simulation model and created an optimal supply mix for an actual upscale restaurant. Based on specific inputs, which included the probability of a group size, the expected value of a group arrival in each time window, and the dining time, tables for two, four, and six people were redesigned. As a result, the revenue of the new table design outperformed the existing one by 5.1%. Among several booking requests, Wang et al. (2017) investigated that receiving a large-sized group did not yield greater profits to restaurants. Therefore, using an average spending per person per minute as a valuation basis, the simulation-based model showed better performance than the traditional first-come-first-serve rule.

Along with the rapidly changing business environment, there are various types of businesses that ask for specific seat allocation methods. e-Sports gaming centers are one of those businesses that provide brand new services. Seat allocation in e-sports gaming centers have a similar concept for the classical seat allocation methods because it allocates seats by accepting more profitable customers. However, compared to the previous research, which focused on designing appropriate seats that considered the physical constraints, the seat allocation method proposed in this research considers more diverse allocation sets that are free from physical constraints at each time interval. By applying the intangible group zones, businesses can accommodate the time-varying customer demands more flexibly. Therefore, the system not only allocates seats to more profitable customers during peak time, it also blocks the less profitable customers by distinguishing the more profitable customers who are expected to visit. In addition, considering the internal structure of e-sports gaming centers, which has many seats that are adjacent to each other, setting a designated group zone at each time interval can have a significant effect on increasing revenue. In order to stimulate qualified research about seat allocation methods, diverse seat allocation methodologies that consider new situations are needed. Therefore, the seat allocation strategy for e-sports gaming centers to maximize revenue will be investigated in this study.

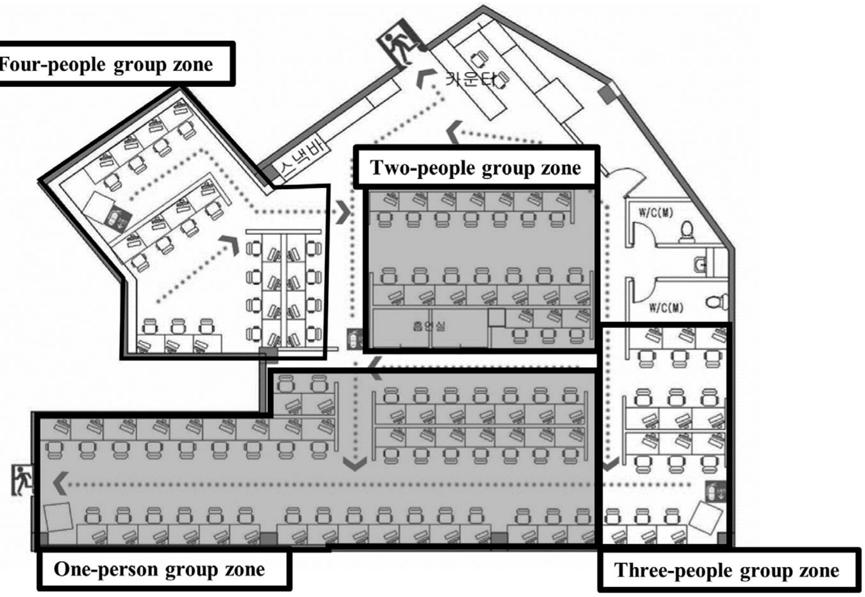

Fig. 1. Configuration of seats for group customers in an e-sports gaming center.

3. Model development

3.1. Problem description

The e-sports gaming center is a place where each seat has a computer for an individual customer to use. Since the customers can also consume food and beverages while using the computers, the PC use and food sales revenue of the customers decide the total revenue of an e-sports gaming center. However, the number of people who visit e-sports gaming centers varies from one person to many people per group. The customers who visit e-sports gaming center take seats following the first-come-first-serve rule. This method can generate many scattered vacant seats because people prefer not to sit beside people whom they do not know. Therefore, the suggested mathematical model assumed that customers can only sit at the designated zone. As can be seen from Fig. 1, the physical space of an e-sports gaming center is divided into four intangible zones for group customers, which considers the expected demand and the profitability of each group customers. For example, if there are no seats left for the one-person group customers, they cannot enter the e-sports gaming center even if there are seats left over from the three-people group customers. By deciding the zones for each of the group customers, the scattered vacant seats that may block group customers can be reduced.

The number of seats that are allocated to each group changes at every time interval. At the beginning of the operation hour, all the seats are vacant. Therefore, the seats for each group are allocated by considering the revenue of the expected group customer's demand at the first time interval. From the second time interval, the vacant seats are calculated based on the seats that are vacant from the first time interval, and the seats that become vacant after the customers leave. The configuration of seats can change, so the seats for one-person group customers can be altered into seats for two, three, or more people group customers. Since the mathematical model aims to maximize the revenue, if the demand of all the group customers exceeds the total vacant seats, the groups that are expected to generate higher revenue get priority with seat allocation. After the vacant seats for each group customers are decided, they are allocated to each of the group customers.

When the customers visit e-sports gaming centers and take seats, they start to use a PC. The stay time of each customer can differ from few minutes to few hours, and it is assumed that the maximum length of hours that each of the group customers can stay at the e-sports gaming center is fixed. Based on the maximum stay time of the group customers, which consists of a different number of people, the particular rate of each group of customers that leaves the e-sports gaming center at every time interval is fixed. The flow, which is the customers who enter and exit an establishment, can occur during every second in an actual e-sports gaming center. However, for the convenience to devise the mathematical model, it is assumed that people enter and leave the e-sports gaming center once during every time interval. While the customers stay at the e-sports gaming center, PC-use revenue and food revenue for the unit customers are generated. The PC-use revenue of each customer can be different based on the age, membership, and the exact time at which they used a PC. However, PC-use revenue that every individual customer generates per unit time is same in the suggested mathematical model. On the other hand, food revenue of each customer is not generated equally at every time interval because the pattern in which customers consume food was observed differently in the actual data.

To sum up, the seat allocation strategy for an e-sports gaming center basically aims to maximize the revenue. At every time interval, the seat allocation for each of the customer groups is determined with several elements, such as the expected demand and revenue generated from each customer group, the customers stay at the e-sports gaming center during the previous time interval, and the customers who enter and leave during each time interval. By applying the seat allocation method devised in this paper, it is expected to prevent the inappropriate allocation that can block the customers with high revenue.

3.2. Notations

3.2.1. Known parameters

This paper derives a solution to allocate seats for groups during every time interval to maximize the revenue. The demand of the groups and the available seats for them are considered. The following notations are composed of the elements that are adopted in seat allocation system for e-sports gaming center businesses.

N : Index for number of customers per group, $n = 1, 2, \ldots, N$
T: Index of time interval, $t = 1, 2, \ldots, T$
d_t^n: Demand of groups consists of n number of people who visit e-sports gaming center at time interval t
p_t^n: PC-use revenue occurred by groups consists of n number of people at time interval t
f_t^n: Food sales revenue occurred by groups consisted of n number of people at time interval t
α^n : Rate of each group consists of n number of people who leave the e-sports gaming center as hour passes
β^n: Maximum stay hour of a group consisting of n number of people
w: Total number of seats
L : A large number

3.2.2. Decision variables

The decision variable set for this mathematical model shows the allocation of seats for groups at certain moments.

x_t^n: Allocation decision variable; it is the number of seats to allocate for groups that consist of n number of people at time interval t

s_t^n : The number of groups consisting of n number of people who entered an e-sports gaming center at time interval t

k_t^n : The number of groups consisting of n number of people who stayed at an e-sports gaming center at time interval t

i_t^n : Inventory of seats for groups that consist of n number of people at time interval t

3.3. Mathematical model

Equation (1) is an objective function to maximize the revenue of the PC use, food sales, and seats for the group customers who consist of one person. By multiplying a large number to the revenue, the effect of allocating seats for one person toward the revenue is restricted. The reason to maximize the seats for a one-person group is to prevent the wastage of seats that are allocated to group customers consisting of more than two people without a specific reason. The mathematical model allocates the seats for group customers consisting of more than two people sitting in a row. In contrast, seats allocated for a one-person group is relatively easy because they can be scattered. However, if the seats for the one-person group customers are not maximized, the seats for the group customers consisting of more than two people can increase even if there is no demand for those seats, such as during off-peak periods. Therefore, except for the crowded time intervals when there are not enough seats for the customers, maximizing the seats for the one-person groups can lift the burden for the e-sports gaming center to allocate the seats for each group.

Maximize

$$\left(\sum_{n=1}^{N}\sum_{t=1}^{T} k_t^n \cdot p_t^n + \sum_{n=1}^{N}\sum_{t=1}^{T} k_t^n \cdot f_t^n\right) \cdot L + \sum_{t=1}^{T} x_t^1. \tag{1}$$

Constraints (2) ensures the number of groups that can stay in the e-sports gaming center at certain moments. If the demand for group customers is smaller than the inventory of seats, an e-sports gaming center can afford all the demand. However, if it is the opposite, an e-sports gaming center can afford group customers only up to the number of seats available. Constraint (3) denotes the change of seats available according to the consecutive time interval. Since the maximum stay hour in which each group can stay is fixed, the inventory at a certain time interval is decided by considering the number of customers who are staying, the people who entered, and the people who left. Constraint (4) shows the number of groups staying at an e-sports gaming center at a certain time interval by considering the rate of people who leave as time passes.

Subject to

$$\min(d_t^n, i_t^n) = s_t^n, \quad n = 1, 2, \ldots N, t = 1, 2, \ldots T \tag{2}$$

$$i^n_{t+1} = i^n_t - (1-\alpha^n)\cdot s^n_t + \left\{\sum_{l=1}^{\beta^n-2}(1-\alpha^n)^l\cdot(\alpha^n)\cdot s^n_{t-l}\right\}$$
$$+(1-\alpha^n)^{(\beta^n-1)}\cdot s^n_{(t-\beta^n)} + (x^n_{(t+1)} - x^n_t), \quad n=1,2,\ldots N, t=1,2,\ldots T \tag{3}$$

$$k^n_t = s^n_t + \left\{\sum_{p=1}^{\beta^n-1}\left(1-\alpha^n\right)^p\cdot s^n_{t-p}\right\}, \qquad n=1,2,\ldots N, t=1,2,\ldots T. \tag{4}$$

Constraint (5) is set to ensure that the allocated seats at every time interval do not exceed the total capacity of the e-sports gaming center. Constraint (6) means that the inventory at an e-sports gaming center at a certain time interval cannot exceed the seats allocated for that time interval. In addition, constraint (7) shows that the groups that are staying at a certain time interval cannot exceed the seats allocated for that time, and constraint (8) expresses the initial operation time of an e-sports gaming center. It shows that before the operation hour, no one can stay at an e-sports gaming center. Lastly, constraint (9) ensures that the variables are not negative.

$$\sum_n n\cdot x^n_t = w, \quad t=1,2,\ldots T \tag{5}$$

$$i^n_t \le x^n_t, \quad n=1,2,\ldots N, t=1,2,\ldots T \tag{6}$$

$$k^n_t \le x^n_t, \quad n=1,2,\ldots N, t=1,2,\ldots T \tag{7}$$

$$s^n_t = 0, \quad t<0,\ n=1,2,\ldots N \tag{8}$$

$$x^n_t, i^n_t, s^n_t, k^n_t \ge 0 \quad n=1,2,\ldots N, t=1,2,\ldots T. \tag{9}$$

4. Numerical experiment

4.1. Data analysis

The mathematical model devised in this research considers many parameters, such as PC-use revenue, food revenue, and the stay time of the customers. In this paper, those parameters are set based on the real data from one e-sports gaming center in Korea. In Section 4.1, the data analysis is conducted to derive the insight and make the data usable as parameters. An example of the raw data that show its attributes is introduced in Table 1.

It is required to check the number of group customers, which consists of one, two, three, and four people, for the data to be applied to the mathematical model. However, because the group customers are not marked in the data, individual customers should be classified into group customers. The criteria used to categorize individual customers into groups include the location of their seats, the start time, and the end time. The people who occupy seats right beside each other and the difference between their start time and end time to use the PCs is less than 10 minutes are considered as the group customers. For example, user C and user E from Table 1 can be considered as a group that consists of two people. The groups that consist of three and four people are categorized similarly.

Table 1
Example of the configuration of actual transaction data

Location of the seat	Customer	Start time	End time	PC-use revenue	Food revenue	Total revenue
3	User A	February 28, 2018; 23:06:18	March 01, 2018; 01:23:58	₩2800	₩4600	₩7400
15	User B	February 28, 2018; 18:29:01	March 01, 2018; 01:38:23	₩3200	₩1300	₩4500
22	User C	February 28, 2018; 23:10:26	March 01, 2018; 01:53:52	₩4200	₩3000	₩7200
54	User D	February 28, 2018; 22:22:42	March 01, 2018; 02:25:58	₩2600	₩3500	₩6100
23	User E	February 28, 2018; 23:07:35	March 01, 2018; 01:50:46	₩4400	₩0	₩4400

Next, the time when people stayed in the e-sports gaming center is calculated hourly. Since the suggested mathematical model assumed that people enter and exit once during every time interval, it is decided to set every time interval as every hour in the numerical example. After calculating the exact time when people stayed, the time they stayed is set by rounding up minutes to hours. For example, a person who stayed at an e-sports gaming center for 2 hours 45 minutes is considered to have stayed for 3 hours. In the process of calculating the time through rounding up, there is an issue about people who stayed less than 30 minutes because they are considered as staying for 0 hours. This is because only 81 customers among 3628 customers stayed less than 30 minutes during March 2018. Therefore, since the number of customers who stayed less than 30 minutes accounts for a very small part of the total customers and has little impact on revenue, these data are handled like they stayed for zero hours. As the time interval is set based on the hour, the PC-use revenue is calculated by multiplying the hourly fee by the stay time.

To check the customer behavior pattern of the customers who visit the e-sports gaming center, the number of people who entered an e-sports gaming center, and the number of people who stayed at an e-sports gaming center are suggested. Figure 2 depicts the number of people who entered an e-sports gaming center during each hour on March 24, 2018. March 24 is selected to check the number of people because that day has the closest value of the average of the daily revenue for March. Throughout the data analysis, it is difficult to find the hour when the number of people who visit exceeds 32 (11:00 a.m.), which is very small compared to an e-sports gaming center that has 94 seats. Even if it is calculated, the sum of the visitors at the hour when each group size is the biggest, only 55 people enter the e-sports gaming center. If the prosperity of an e-sports gaming center is evaluated by the number of people who enter, it can be underestimated by many. This is because customers generally stay more than an hour when they enter a place. Therefore, it is needed to check the number of people who occupy seats at every time interval.

It can be observed from Fig. 3 that 92 out of 94 seats are occupied from 14:00 to 15:00, which indicates that the e-sports gaming center is almost fully occupied. In addition, customers who consist of more than two people account for almost half of the occupied seats from 16:00 to 17:00, which is also one of the most crowded times. Therefore, it can be deduced that the number of customers who stay and not the customers who enter an e-sports gaming center should be considered.

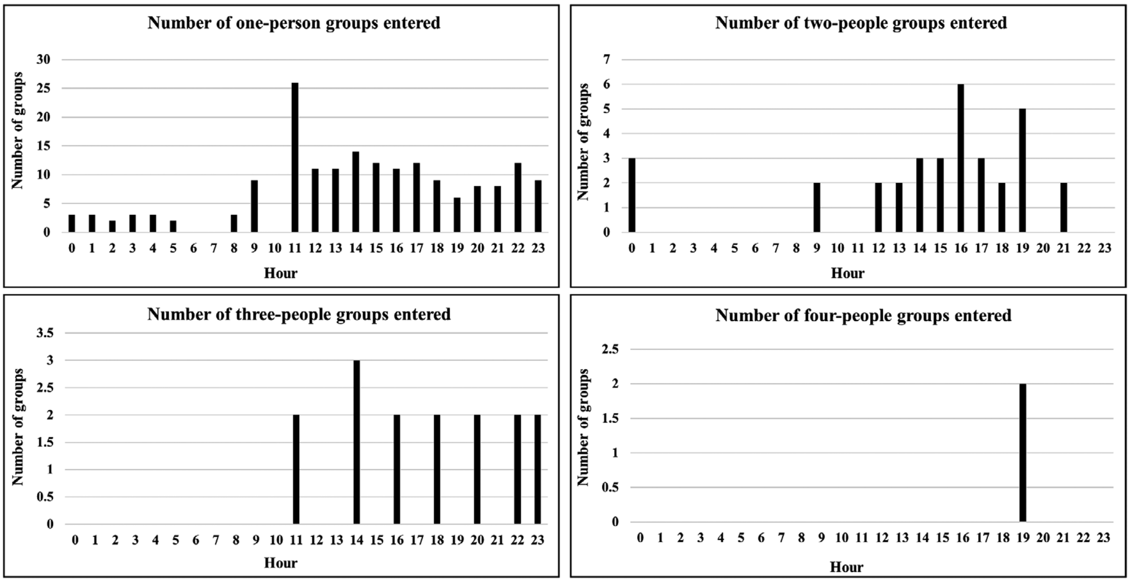

Fig. 2. The number of groups that entered an e-sports gaming center on March 24, 2018.

Fig. 3. The number of people who stayed at an e-sports gaming center hourly on March 24, 2018.

Lastly, Table 2 shows the average food revenue for one person in each group per visit. Through the data analysis about the food revenue, it can be seen that the group customers consisting of more than two people spend more money than the one-person group customers. Since the PC use fee is ₩1000 per hour per person, the average food revenue, which is ₩2273.08 per person, is a big part of a customer's total revenue. Therefore, the data analysis about the food revenue shows that

Table 2
Average food revenue of one person per visit in March 2018

One person (total)	₩2273.08
One person from one-person group	₩2102.78
One person from two-people group	₩2699.68
One person from three-people group	₩2458.97
One person from four-people group	₩2170.98

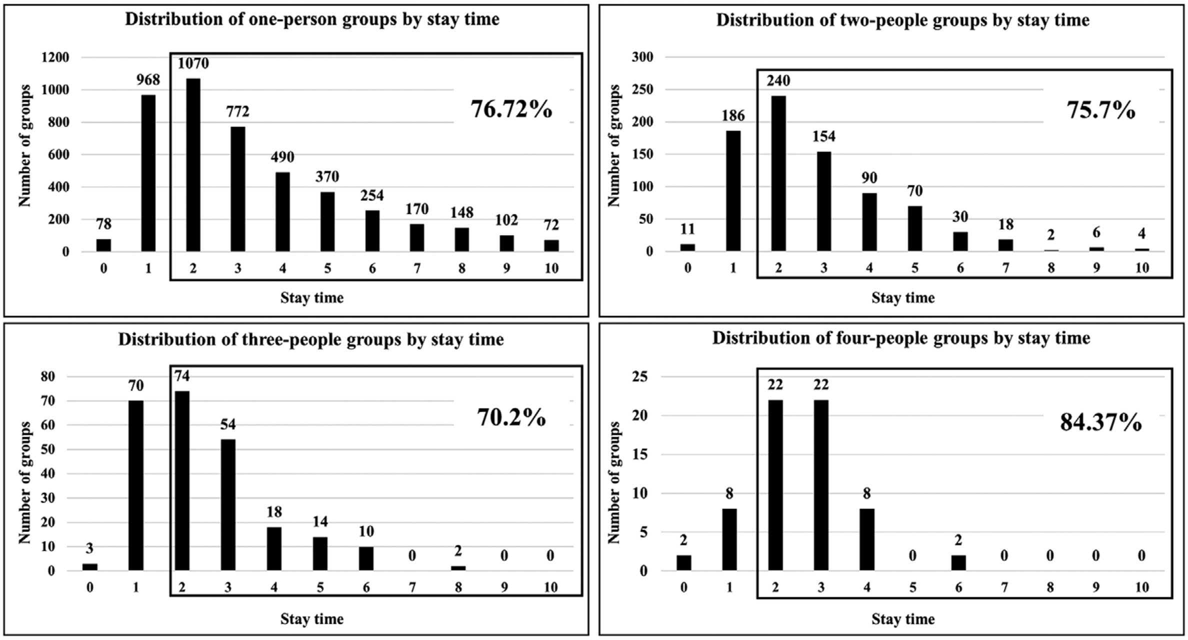

Fig. 4. Distribution of groups by stay time.

an e-sports gaming center may expect high revenue throughout focusing on food sales as much as the PC use sales. Since the food revenue can be generated simultaneously with the PC-use revenue, making the e-sports gaming centers to generate additional food revenue might be helpful from the business operator's point of view.

4.2. Parameters

In this section, the parameters are set based on the results of the data analysis from Section 4.1. The parameters, which include the demand, PC-use revenue, food revenue, the stay time of each group of customers, and the maximum stay hour that each group of customers can stay, are set. Figure 4 is provided to check the influence of the stay time that makes difference between the people who entered and stayed. It depicts the stay time of all the customers for March 2018. In the case of the groups that stayed longer than 10 hours are considered as if they stayed for 10 hours. Figure 4 shows

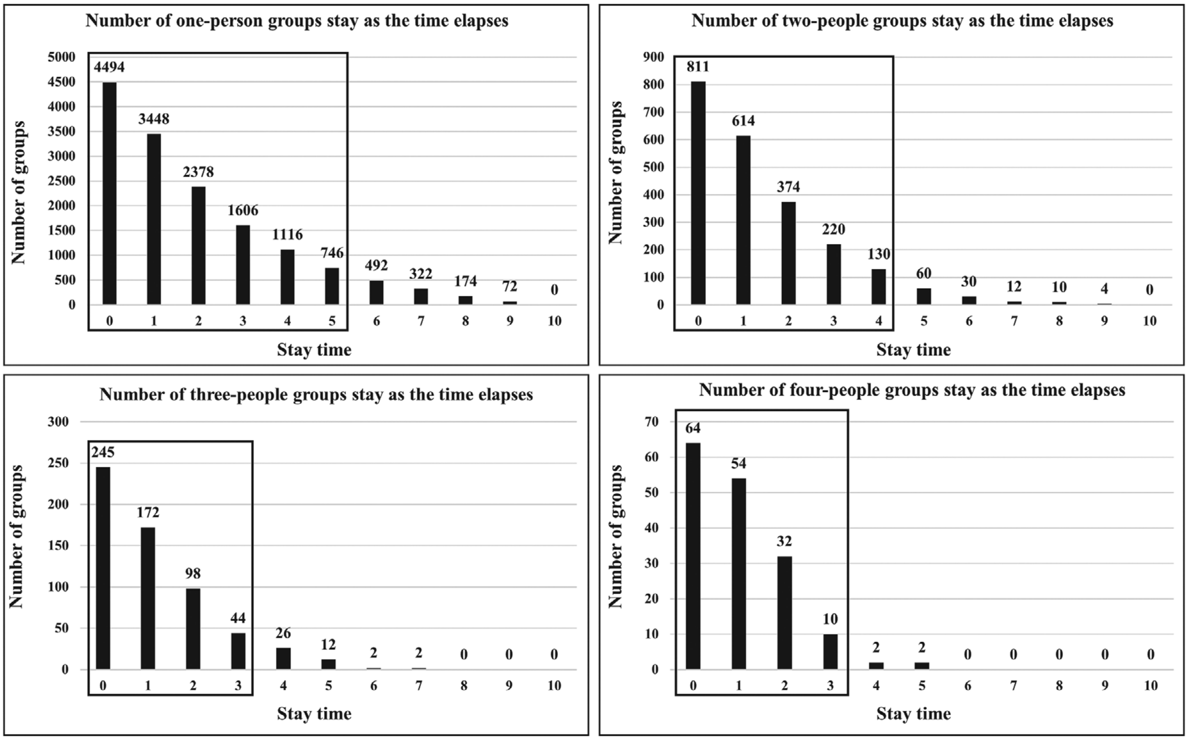

Fig. 5. Maximum stay time of each group.

that more than 70% of the customers in a one-, two-, three-, and four-people group stayed more than two hours.

Since the stay time of each group of customers varies from a few minutes to 10 hours, the maximum stay time of all the groups of customers is set differently. As mentioned in Section 3, the customers who stayed less than an hour account for a really small part, so they were ignored. Not surprisingly, as the stay time gets longer, the number of customers decreases. Therefore, it is assumed that the maximum stay time of each group is set into the time when about 80% of each group leaves the e-sports gaming center. As can be seen in Fig. 5, 83% of the one-person group customers leave an e-sports gaming center after five hours had passed from the time they entered. In the case of two-people group customers, 82% of them left four hours after they entered. Lastly, 83% of three-people group customers and 84% of four-people group customers left three hours after they entered. Therefore, the maximum stay time of one-person groups, two-people groups, three-people groups, and four-people groups is set as five hours, four hours, three hours, and three hours, respectively. By considering the maximum stay time of group customers, α^n, which is the rate of each group that consisted of n number of people who leave the e-sports gaming center is set by considering the maximum stay time of the group customers. This is calculated based on the average value of the rate that the customers leave every hour until the maximum stay time of each group.

The parameter value for the demand, revenue generated by the PC use, and the food sales of each group is set based on the real data of an e-sports gaming center from March 2018. In the case of

Table 3
Demand and food revenue of each group at every time interval

Hour	Demand of each group (number)				Food revenue of each group (₩)			
	One-person group	Two-people group	Three-people group	Four-people group	One-person group	Two-people group	Three-people group	Four-people group
00:00–01:00	6.1	1.1	0.5	0.2	171.5	396.1	488.9	308.1
01:00–02:00	4.9	0.8	0.2	0.0	149.9	369.1	407.5	187.1
02:00–03:00	2.0	0.4	0.1	0.2	122.9	303.6	298.6	493.6
03:00–04:00	3.5	0.4	0.1	0.1	97.7	341.2	231.0	393.6
04:00–05:00	2.0	0.1	0.0	0.0	92.0	85.7	160.8	393.6
05:00–06:00	0.7	0.1	0.1	0.0	63.7	71.9	135.6	0.0
06:00–07:00	0.6	0.2	0.0	0.0	26.2	96.3	97.6	0.0
07:00–08:00	1.2	0.1	0.0	0.0	23.3	72.7	45.5	0.0
08:00–09:00	3.8	0.0	0.0	0.0	24.3	0.0	0.0	0.0
09:00–10:00	8.8	0.5	0.0	0.1	25.6	8.3	0.0	0.0
10:00–11:00	6.7	0.8	0.5	0.1	43.2	157.8	228.3	290.4
11:00–12:00	8.9	1.2	0.3	0.1	105.5	182.3	349.1	571.0
12:00–13:00	10.5	1.7	0.5	0.2	129.1	218.9	550.0	1906.5
13:00–14:00	10.0	1.8	0.2	0.1	119.6	282.3	452.4	590.4
14:00–15:00	16.5	3.0	0.4	0.3	163.3	478.9	380.5	718.6
15:00–16:00	21.4	3.6	1.5	0.5	242.7	565.3	511.4	1265.4
16:00–17:00	17.1	4.8	1.5	0.4	284.3	885.9	483.0	2262.1
17:00–18:00	22.5	5.4	1.2	0.4	253.6	844.6	1091.5	1521.8
18:00–19:00	19.7	3.2	0.7	0.2	182.7	649.4	1205.1	537.1
19:00–20:00	16.2	3.2	0.9	0.3	184.0	559.3	949.9	425.9
20:00–21:00	14.4	3.1	1.2	0.1	146.4	452.5	657.5	459.7
21:00–22:00	14.1	2.0	0.8	0.0	155.6	392.6	565.1	459.7
22:00–23:00	13.7	1.6	0.9	0.0	173.4	365.9	930.2	121.0
23:00–24:00	7.9	1.2	0.2	0.1	174.8	319.5	846.9	121.0

the demand, the number of customers who visited an e-sports gaming center is separated into every time interval. The PC-use fee is set into ₩1000 for every single customer to use the computer per unit time, which follows the same policy with the e-sports gaming center that provided the data. The revenue generated by food sales is calculated by considering the revenue of each customer and their stay time. For example, if a certain customer stayed from 00:00 to 02:00 and spent ₩1200, the food revenue of that customer is considered to be ₩600 from 00:00 to 01:00 and ₩600 from 01:00 to 02:00. The specific value of demand and the food revenue of each group at every time interval is described in Table 3.

5. Results

Based on the set of parameters, the optimal solution is derived by CPLEX 12.8.0, which is a commercial software that can solve mathematical optimization problems. Since the developed mathematical model is made up into mixed integer programming format, CPLEX is adopted to

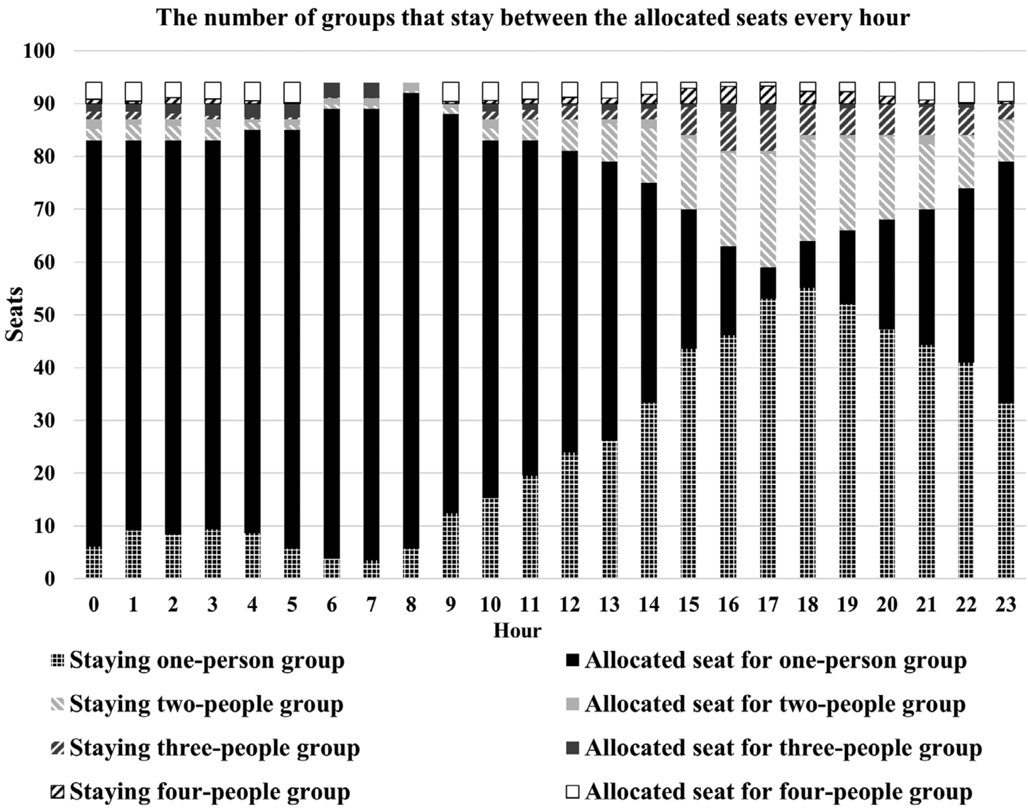

Fig. 6. A result of the allocated seats and the number of groups that stay.

derive a solution. The mathematical model contains an objective function and constraint equations. The value of the objective function is derived within the given constraints that reflect the limitations of the environment. The four decision variables in this research, which include the optimal number of people that entered and stayed at an e-sports gaming center, the inventory of each group zone, and the number of allocated seats, were created to formulate the mathematical model. The value of these decision variables should be decided to maximize the revenue of an e-sports gaming center, which needs to comply with the set of constraints developed. CPLEX is a well-known commercial software that is used to achieve this goal. Since CPLEX is a tool for solving LP problems or mixed integer programming (MIP) problems, the derived results can be guaranteed.

Figure 6 depicts the results of the numerical example. Starting from the bottom, the bar shows the number of each group of customers staying in the e-sports gaming center between the allocated seats for them. It can be found that the seats allocated for the two-people and three-people groups are almost fully occupied by the customers. This results from the objective function to maximize the allocated seats for the one-person groups to prevent the lost sales of the one-person groups, which means that the seats for the two-people groups and the three-people groups are allocated to just accommodate the demand for them. However, according to Fig. 6, it seems that the utilization of the e-sports gaming center is relatively low because the adopted demand data do not have the

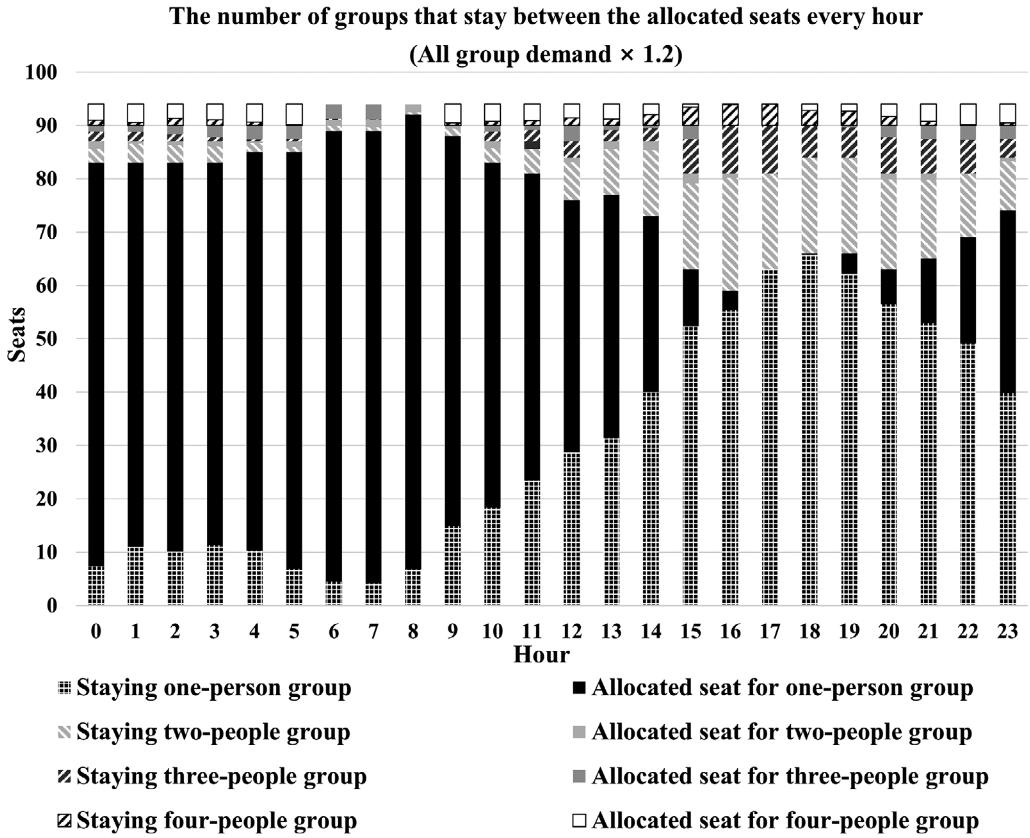

Fig. 7. A result of the allocated seats and the number of groups that stay (lost sales are considered).

information about customers who could not enter the e-sports gaming center for various reasons, such as the lack of available seats for a certain group to sit together. Therefore, it can be considered that the seat allocation method does not have to be applied because there are enough seats. However, even if there are enough vacant seats, group customers who consist of more than two people can be blocked without the seat allocation strategy. Therefore, the seat allocation method needs to be applied to keep the seats in a row for the group customers.

The demand data applied to derive the results of Fig. 6 reflect only the number of customers who entered the e-sports gaming center. However, the potential customers who could not enter the e-sports gaming center should be considered. Therefore, Fig. 7 is added to check the blocked customers by multiplying 1.2 to the demand of the customers, so the demand can represent the customers who enter and the ones who could not enter. As described in Fig. 7, the e-sports gaming center is fully occupied at the time interval from 17:00 to 19:00. From 17:00 to 18:00, a 0.62 one-person group, 3.88 two-people groups, and 0.1 three-people groups are blocked. In addition, from 18:00 to 19:00, 0.22 number of three-people groups are blocked. The result of the numerical experiment shows that the seat allocation method should be applied at least for two hours at the most crowded time interval with the demand block of various group customers. This means that

Table 4
Number of blocked group customers when demand of all groups increases 1.5 times

	Number of blocked customers at each group			
Hour	One-person group	Two-people group	Three-people group	Four-people group
15:00–16:00	4.39	0.12	0.00	0.32
16:00–17:00	14.11	0.36	0.00	0.68
17:00–18:00	9.51	11.94	0.00	0.44
18:00–19:00	0.63	6.90	0.00	0.00
19:00–20:00	0.05	2.78	0.00	0.00

except for two hours, 22 hours per day might not ask for the seat allocation method to be applied. However, if the demand increases, the time interval that needs the seat allocation method might increase with a greater importance. Therefore, in Section 4.4, a sensitivity analysis with a greater demand is conducted.

5.1. Sensitivity analysis

Since the numerical example is conducted based on the real data from an e-sports gaming center, and the demand of the customers is set by considering only the people who entered the e-sports gaming center. This means that the lost sales of the e-sports gaming center could not be considered. Even when the demand increased by 1.2 times to consider the potential demand, the e-sports gaming center is fully occupied only for two hours. The sensitivity analysis is conducted to check if the devised mathematical model can allocate the seats properly when the demand increases sufficiently.

5.1.1. Sensitivity analysis when the demand of all the groups increases

In the first sensitivity analysis, the demand of all the groups is increased 1.5 times more than the numerical experiment. From the results derived when the demand increases 1.5 times, the time interval that needs the seat allocation method to be applied also increases. According to the derived results in Fig. 8, the e-sports gaming center is fully occupied at the time interval from 15:00 to 20:00. Compared to the results of the numerical experiment when demand increases 1.2 times, the time interval when the demand block occurs increases from two hours to five hours. During the time interval from 15:00 to 20:00, a demand block occurs to maximize the revenue. According to Table 4, which depicts the number of groups that are blocked at each time interval, the one-person groups and the two-people groups are blocked mostly. This results from the relatively small revenue generated by the one-person groups and two-people groups compared to three-people and four-people groups. To sum up, through the sensitivity analysis from Section 4.4.1, when the demand of all groups of customers increases 1.5 times, it shows that the time interval to apply the seat allocation increases with the increased demand compared to the numerical experiment. For example, at the time interval between 16:00 and 17:00 when the 14.11 one-person group customers are blocked, the expected food revenue per one person for each group is ₩284.3, ₩442.9, ₩161.0, and ₩565.5 for the one-person groups, two-people groups, three-people groups, and four-people

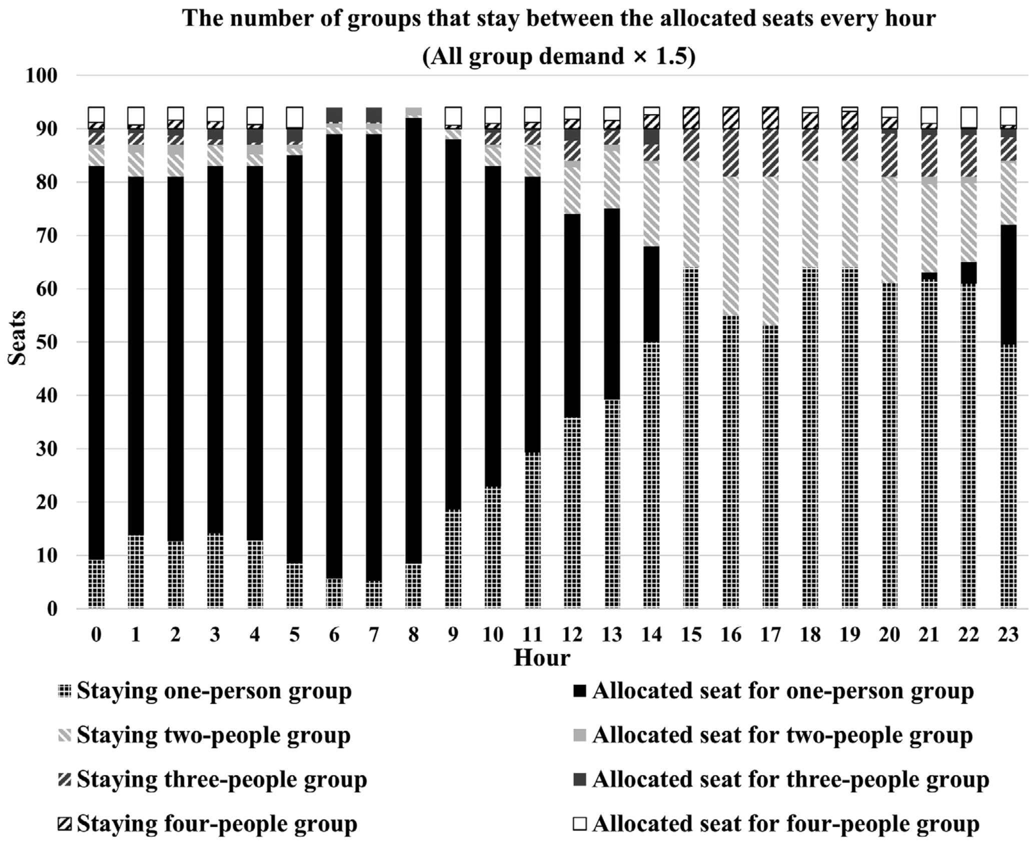

Fig. 8. A result of the allocated seats when the demand of all the groups increases 1.5 times.

groups, respectively. Since the food revenue of the two-people group is relatively large at this time interval, most of the blocked customers consist of the one-person groups. On the other hand, at the time interval between 17:00 to 18:00, when 9.51 one-person group customers and 11.94 two-people group customers are blocked, the expected food revenue per one person for each group is ₩253.6, ₩422.3, ₩363.6, and ₩380.5 for the one-person groups, two-people groups, three-people groups, and four-people groups, respectively. Since the food revenue of one person for each group is similar, the PC-use revenue and the stay time of each group are considered when blocking the customers.

5.1.2. Sensitivity analysis when the demand of the three-people and four-people groups increases

In this section, the sensitivity analysis when the demand of the three-people and four-people groups increased 10 times bigger is conducted, and the results are depicted in Fig. 9. The groups with a larger number of customers can be blocked at the actual e-sports gaming center because of not enough seats for them. However, the data applied in the mathematical model show that the food revenue of an individual customer from the two-people, three-people, and four-people group customers is generally bigger than the one-person group customers. Therefore, the seat allocation strategy of this paper may prioritize the group customers with the higher revenue. According to the derived

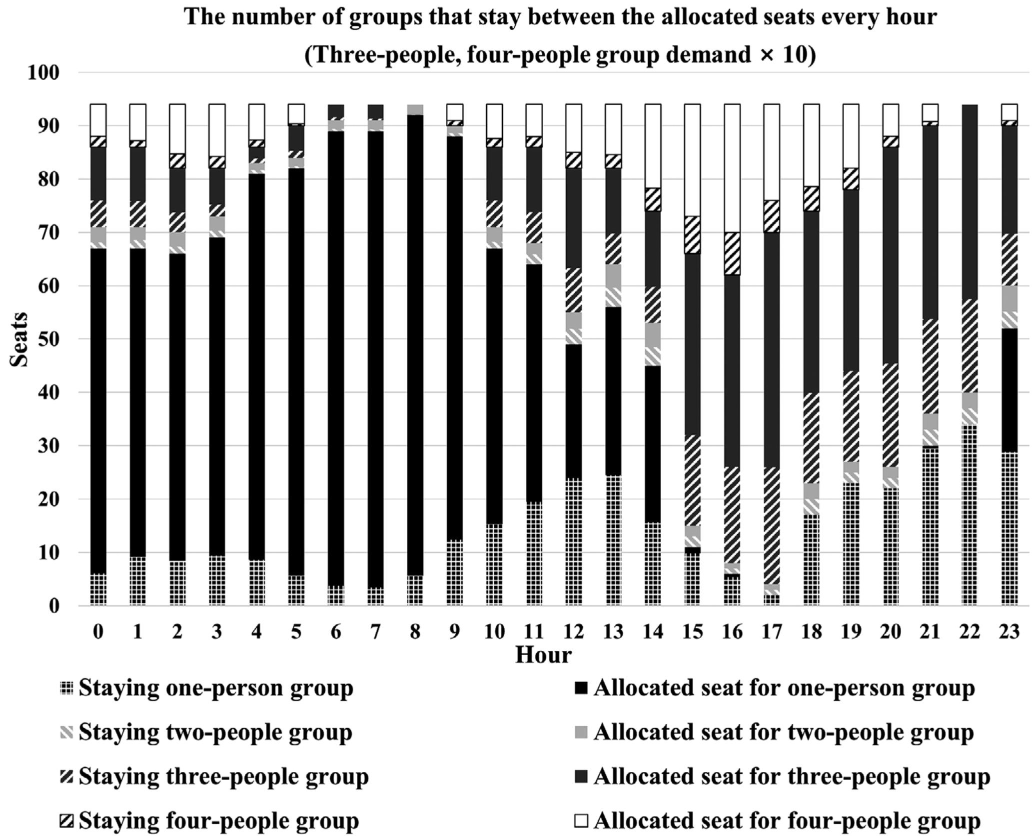

Fig. 9. A result of the allocated seats when the demand of three-people and four-people groups increases.

results, a demand block occurs during the most crowded time intervals. From 13:00 to 23:00, the seats for one-person groups and two-people groups decrease, and the seats for three-people and four-people groups increase. This results from the relatively high food revenue of three-people and four-people groups during most time intervals. From 14:00 to 18:00 when the demand of more than 10 one-person groups are blocked at every hour, the food revenue of two-people and four-people groups are larger than for the one-person groups. Therefore, one-person group customers are mostly blocked. However, at the time interval from 16:00 to 17:00, 6.32 three-people group customers are blocked. This results from the low food revenue for three-people groups during that time interval. The expected food revenue of each person for one-person groups is ₩284.3, two-people groups is ₩443.0, three-people groups is ₩161.0, and four-people groups is ₩565.5. Therefore, three-people groups with relatively low food revenue are blocked. According to Table 5, a demand block of one-person groups and two-people groups starts to occur during the time interval from 13:00 to 15:00 even if there are empty seats allocated for them. This is because when each group enters, they stay until their maximum stay time, so they can block the other groups with higher potential revenue. If the e-sports gaming center allow one one-person group customers, it could block the four-people group customers because of one insufficient seat for them. Therefore, the mathematical

Table 5
Blocked group customers when the demand of three- and four-people groups increases

Hour	Number of blocked customers at each group			
	One-person group	Two-people group	Three-people group	Four-people group
13:00–14:00	1.68	0.00	0.00	0.00
14:00–15:00	16.5	3.46	0.00	0.00
15:00–16:00	21.4	7.20	0.93	0.64
16:00–17:00	17.1	9.60	6.32	0.00
17:00–18:00	22.5	9.48	0.00	8.60
18:00–19:00	2.70	1.26	0.00	0.00
19:00–20:00	5.10	6.24	0.03	3.48
20:00–21:00	8.50	4.76	0.00	4.00
21:00–22:00	0.00	0.34	0.00	0.00
22:00–23:00	0.35	0.18	0.00	0.00

model blocks the one-person groups and the two-people groups to allocate enough seats for the three-people and the four-people groups that will visit a few hours later. To sum up, the groups with the larger number of customers are generally preferred because they generate higher PC-use revenue during the unit time interval, and their food revenue is usually bigger than the group with a relatively small number of customers. However, the sensitivity analysis shows that the mathematical model prioritizes the groups with larger expected revenue.

6. Conclusion

The e-sports gaming center industry in Korea has been prospering along with the growing demand and the increasing number of popular PC games. The increasing interest toward e-sports has led 60 million people to watch the world championships for League of legends, while 20.4 million people watched the basketball world championships in 2017 (Steinkuehler, 2020). As the games became popular among the public, more people got interested in e-sports gaming centers where people can enjoy many different games while eating. Even though the size of e-sports gaming center businesses has gotten bigger, only a few studies related to the effect and the history of public places where people can use computers exist. The studies that investigated the method to help the e-sports gaming center businesses prosper can rarely be found.

The contribution of this study can be explained as the development of a novel seat allocation method that can maximize the revenue by changing the seat zones for many group customers during every time interval. Generally, it is difficult to find a case where customers of an e-sports gaming center change seats except for machine failures. When there are not enough seats, the customers just move to find another location because the e-sports gaming centers are usually located nearby each other, so they can be easily substituted. Therefore, when there are no adjacent seats, the group customers easily move to another location even though there are enough scattered and available seats, so the lost sales can occur. In case of hotels, airlines, and the movie industries where the classical seat allocation models are applied, the service time that is offered to users is fixed or discrete. However, the stay time for an e-sports gaming center is continuous and uncertain, so customers can use the service freely and leave a location like a coffee shop. Therefore, it is hard to find a quantitative method applied for the revenue management of an e-sports gaming center from the previous literature. Since this study developed a mathematical model reflecting these complex constraints, it is expected to positively affect the overall businesses that have customers with continuous stay times.

The model of this research is devised by considering the actual application. First, the suggested model considers the efficiency for the smooth adjustment to the operation system by considering the uncertain situation. Devising a strategy to minimize the lost sales occurred by substitutes is really important for the businesses such as e-sports gaming centers and coffee shops. Throughout applying the strategy suggested in this paper, businesses with customers of continuous and uncertain stay times will be able to reduce the lost sales. Moreover, by leaving the seats unconstrained when there are enough available seats, the owner of an e-sports gaming center will not strictly control the seats during those hours, which can lift the burden for the owner. Moreover, the zones for the group customers who can flexibly change can provide more chances to generate more revenue. If the group zone is designated by applying only the data analysis, excessive seats for group customers who consist of a larger number of people can be allocated. However, it is discovered through the results of the numerical experiment that prioritizing the groups with larger numbers does not always generate a larger profit. The three-people and four-people groups that have a larger number of customers are generally preferred compared to the one-person groups and the two-people groups at the time interval when a certain group with a larger number of customers is expected to spend less money, so many of them are blocked by the numerical experiment. Therefore, by applying the strategy based on the quantitative and scientific method to maximize the customers with higher revenue, the allocation of many seats to groups consisted of many customers.

In the further studies, a simulation method will be applied to check the efficiency of the mathematical model. Moreover, more constraints that can reflect the actual operation system of an e-sports gaming center will be considered. The perception against an e-sports gaming center has continuously changed, and it is now generally considered as one of the places that people spend their leisure time. The success of the e-sports gaming centers in Korea motivated the success of the e-sports gaming centers in China, and it is expected to affect more countries around the world (Jiang and Fung, 2019). In the future, e-sports gaming centers will be recognized as the major part of people's leisure. Therefore, it is expected that this research can accelerate the conduction of additional research about e-sports businesses and consequently assist these businesses to prosper.

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