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An Effective Staff Scheduling for Shift Workers in Social Welfare Facilities for the Disabled

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Abstract: The efficient management of social worker personnel is important since it involves a huge portion in its operations. However, the burnout and turnover rates of social workers are very high, which is due to dissatisfaction with the irregular and unequal schedules, despite the continuous improvement in the treatment of social workers and the enactment of work-related legislation in Korea. This means that changes in policy do not significantly contribute to improving worker satisfaction, which shows the necessity of the strategies to prevent the turnover of workers. Therefore, this study aims to propose a strategy for the staff scheduling of workers that considers the fairness in the shift distribution among workers and the individual preference for shift work by using the linear programming. A survey about the preferences for shift work is conducted that targeted the employees of a welfare facility in Korea to enhance the practicality of the model. The effectiveness and applicability of the developed mathematical model are verified by deriving a deterministic schedule for a worker via the system parameters that were obtained based on the survey and the rules of the welfare facility in the numerical experiment. Compared to the conventional schedule, the derived schedule shows an improvement in the deviations in the number of shifts workers and a reflection of the personal preferences. This can raise the social worker's satisfaction, which will decrease intention on burnouts and turnover. It will consequently facilitate on managing human resources in welfare facilities.

Keywords: social worker; job satisfaction; staff scheduling; mathematical model; operations research; optimization

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1. Introduction

Social welfare is a service for people who need help in regards of welfare, health, medical treatment, education, and living to ensure people's humane life [1]. A social worker is a one who provides these crucial services. Social workers require a high level of personal commitment compared to other professions to provide services, so the working conditions and the environments are the factors that directly affect the service quality [2]. Therefore, an improvement of these factors leads to satisfactory services [3]. The Korean Ministry of Health and Welfare has annually revised and promulgated the implementing rules that limit the number of clients that are handled by one welfare worker to 2.5 to maintain the quality of the services [4]. However, Figure 1 illustrates that the number of the elderly and disabled residents that are allocated to one social worker in Korea is still too excessive compared with the standard, even though the number of residents that are allocated to each social worker in Korea continues to decrease. This implies that an excessive amount of work is still distributed to one social worker in Korea. In addition, social workers in Korea have low salaries and unstable hiring systems, so their working environmental level and job satisfaction level are very low. According to a survey that was conducted by the Korean Ministry of Health and Welfare in 2011 [5], it was shown that 2479 social workers had job satisfaction levels that ranged from 2.38 to 3.51 out of 5 points. It was regarded as a low level of job satisfaction. To improve social workers' job satisfaction, the Korean government has continuously legislated a law for increasing their treatment and dignity since 2012 [6].

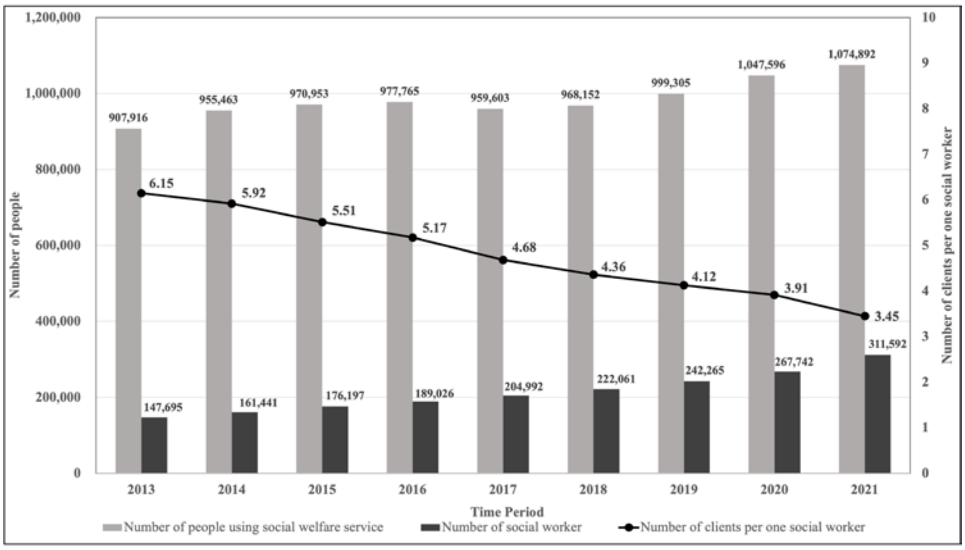


Figure 1. Number of clients per one social worker.

However, that change didn't have any effect on the working environment and the conditions of social workers. According to 2020 social worker statistics [7], 3951 social workers replied that the degree of improvements in labor conditions after the legislation was 4.23 out of 10. In addition, the rate of social workers who work overtime for more than 5 h is about 42.8%, which is very high. This shows that the job satisfaction of social workers is still at a low level. This low job satisfaction eventually leads to burnout, a long-term phenomenon that is derived from chronic stress at work. It can cause exhaustion, mental fatigue, and deterioration of the job performance. In addition, high burnout contributes to high turnover since they are correlated [8]. Turnover is caused by low salary, heavy workload, and low level of organizational justice, which are also factors that decrease the job satisfaction [9,10]. In short, low job satisfaction causes high burnout and turnover.

High burnout and turnover can also negatively affect the service quality or job performance. This is prominent in the case of shift workers that have irregular routines and long work times, such as social workers, firefighters, and policemen [11,12]. In the case of a nurse who is a shift worker, high burnout, and turnover lead to deterioration of the safety and quality of treatment and a decrease in the satisfaction of patients [13]. Likewise, in the case of a policeman, it is not only decreasing service quality and performance but also preventing their conduct of efficient performance [14]. There are many ways to prevent these negative situations, but the most basic way is to increase the job satisfaction of workers. An organization should provide appropriate payment and promotion opportunities suitable for the workers' performance as well as ensure their job autonomy to improve job satisfaction. It is also very important to make clear the fairness of the process, which include various factors such as how salaries, schedules, evaluations, and promotions are determined [15].

This study intends to draft a schedule to improve the job satisfaction of shift workers. This is because a schedule has a high level of correlation with job satisfaction [16]. Many studies that demonstrate it have progressed until now. Elisabeth et al. [17] intended to confirm if a schedule in improving police officers' health can have an influence on their job satisfaction. The average job satisfaction of the conventional schedule was 65.904, but average job satisfaction of the new schedule increased to 70.677. This proved that shift schedules that consider workers' health can make a meaningful influence on workers' job satisfaction. In other research, Frederick et al. [18] intended to draw up a schedule that considers residents' shift preferences and improves the perception of fairness. The newly derived schedule scored 4.0 and 4.2 out of 5 in the level of satisfaction and equity, while the schedule using conventional method scored 3.3 in both levels. This showed that shift schedules that consider fairness can have a positive effect on job satisfaction. It is therefore important to draw up a schedule that considers various factors.

Various measures have been taken, which include the enactment of laws, to increase the job satisfaction of social workers who are shift workers in Korea. However, the situation has still not improved. Low job satisfaction not only results in high burnout and turnover intention as well as causes a decrease in the quality of services that are provided by social workers and inefficient management of human resources in an organization. This study therefore aims to increase the workers' job satisfaction via scheduling to prevent these problems. This study derives a decisive worker management schedule by using linear programming, which considers the workers' work preferences and fairness among the workers. Conventional schedules and the welfare facility rules were received via interviews before conducting this study. The individual preferences for shifts and requirements of the welfare facility were additionally also investigated. In conclusion, this study will help to solve the problems that are derived from it by increasing the job satisfaction of shift workers.

The remainder of this paper is organized as follows. Section 2 summarizes the previous research of scheduling in labor-intensive industries that need shift workers, and the welfare, medical and nursing industry. Section 3 describes the mathematical formulation and problem procedure. In Section 4, a numerical example is provided to validate the applicability and efficiency of the proposed schedule using mathematical model. In Section 5, the contribution of this paper and future study is described.

2. Literature Review

The method that is suggested in this study considers the employees' preferences, fairness, and the situation of each employee when deriving an optimal schedule. Human resource management in highly labor-dependent industries is crucial in operational and cost-related perspectives. Scheduling is a key supportive decision-making system that is used by organizations to effectively manage human resources [19]. Thus, numerous studies about staff management that have diverse objectives have been conducted in various industries. Taylor and Huxley [20] presented a study that considers the problem of assigning police officer shifts in minimizing the under-covers. The proposed optimization-based decision support system forecasts hourly needs, drafts schedules to maximize coverage, and allows fine-tuning to meet human needs. The results, which used an integer search procedure, generated a solution that makes 25% more patrols available in the times of need, which also saved $11 million per year. Yang et al. [21] suggested flexible management strategies for airline crew scheduling problems. They developed a model that makes an airline effectively manages its maintenance of employee supply. A schedule that minimizes the total maintenance of employee supply is derived to satisfy all the requirements and the demand in each time slot. Xu and Wang [22] conducted a study about the fairness problem of the weekend-off-schedule in a call center. They proposed the Enhanced Artificial Bee Colony (EABC) algorithm to manage a combination structure that complicates the procedure of optimization. The results showed that the algorithm offers a solution that is suitable for maximizing fairness about large-scale problems by applying it. Alsheddy and Tsang [23] proposed an optimal schedule that assigns the right worker to the right position in the field workforce, which also considers the workers' preference for shifts and fairness. An empowerment scheduling model that provides flexibility by authorizing the employees to express their preference on shifts and participate in the scheduling process was proposed. This made a big regression on variability in employees' individual satisfaction levels. Park and Ko [24] presented a mathematical model in minimizing the total labor cost of a construction company, that considered irregular employee's average absence rate in the process of reinforcement. Linear Programming was utilized to derive a deterministic staff schedule that considered the irregular employee's average absent rate. As a result, it was able to reduce unneeded employees from about 46.6 to 45 a day on average.

Van den Bergh et al. [25] defined three main staff scheduling parts, which included shift scheduling, days off scheduling, and tour scheduling. Shift scheduling involves scheduling across a daily planning horizon, which one worker has just one shift a day. The shift scheduling problem (SSP) needs to comply with certain labor regulations and the organization's rules and policies. Therefore, the studies for SSP in various industries have been conducted and introduced. Mabert [26] conducted a study about the shift scheduling procedure of a commercial bank's encoder workforce with daily workload uncertainty. The study presented a chance constraint model to meet varying volume demands when forecast errors are present. As a result, this model provided solutions with the schedules obtaining the lowest labor costs. Özder et al. [27] indicated the worker's scheduling problems by considering the personnel abilities in a natural gas combined cycle power plant. They tried to create an adequate monthly shift schedule that maximizes the fairness level of the personnel workload by using integer programming. As a result, the new shift schedule has decreased the shutdown time from 53 to 4 h, which means $83,790,000 worth of costs were saved. Shuib and Kamarudin [28] devised work shift schedules to identify main criteria and conditions in a power station. This study intended to formulate a Binary Integer Goal Programming (BGP) model. This model considered the worker's day-off preference as its main feature. The MATLAB was used to solve this model, which generated an optimal schedule that was based on the required number and the composition of shifts as well as the workers' day-off preferences. As a result, workers' satisfaction with the day-off preference increased by 37.21%, which is up from 43.02% based on the existing prepared schedule to 80.23%. Dahmen et al. [29] designed a model minimizing under-coverage, over-coverage, transfer, and labor costs while scheduling for various departments. An integer programming model with a two-stage solution approach and three heuristics, IH, TDH, and TSDH, were proposed to solve the disaggregated problem in the process. The proposed scheduling tool derived a schedule by considering coverage, transfer, and labor costs. Soukour et al. [30] tried to solve staff scheduling problems in airport security services. This research focused on staff assignment, by providing a greedy algorithm and a global assignment algorithm that provides an initial solution. Under coverage, overtime, and dissatisfaction were minimized with the solutions that were derived.

The welfare, medical, and nursing industry are interested in SSP research to assign employees better. Trivedi [31] conducted a study for optimizing the expense budgeting in a hospital nursing department. The objectives of this study involved matching nursing staff to the random nature of the patient loads to meet the personnel's requirements. These were conducted by using a mixed-integer goal programming model that utilized hospital financial data, staffing standards, and user institutional norms. The proposed model was proven to be efficient in cost setting for the hospital by minimizing the deficit in the budget, understaffing, and the number of part-time employees. Becker et al. [32] presented a shift scheduling model that considered unpredictable employee absences in emergency medical services. Set covering-based integer programming formulation was proposed for cyclic stint-based staff scheduling with on-call duties. The employee preferences such as fairness, less work on weekends and longer recovery times were the items that were mainly considered. Baum et al. [33] derived a shift schedule to fix the unfair allocation of individual revenue that occurred in an academic hospital. They proposed a simple unified optimization formulation of this scheduling problem using mixed-integer optimization. The revenue increased by 8.2% over previous operating revenue as well as strictly adhered to codified fairness and objectivity. Huang et al. [34] constructed two mathematical models that increased the efficiency of a nurse's shift and the day-off scheduling to improve the quality of the nurses' lives at a hospital. They proposed a two-step nurse scheduling model to sequentially solve the shift and day-off problem. The model was able to satisfy the maximum preferences of a shift for the nurses as well as provide an optimal day-off assignment which was based on the given shift scheduling table. Proano and Agarwal [35] selected a schedule that was decided by multiple criteria in a hospital, which compared the fairer schedule and the schedule that was good to facilitate.

They used constraints called the Analytical Hierarchy Process (AHP) to make the selecting easier. This helped the decision-maker to select a more executable schedule, which is one of the high-quality alternative schedules in terms of their workload balance, educational experience, satisfaction, and ability to deal with patients. Recently, Rerkjirattikal et al. [36] presented methods of devising a schedule for nurses' job satisfaction. They received data on the operations of the institution and the shift preferences, which they then utilized them in the Normalized Goal Programming Technique model. They created an optimal schedule that shows sufficient improvement in terms of job satisfaction, compared with the former schedules. Hidri et al. [37] presented shifts scheduling that minimizes overtime for physicians in the ICU. The problem was mathematically formulated as an integer linear program and solved using a state-of-the-art software. The model created a reduction of overtime work by 69.23%, and the under-load was eliminated. Abadi et al. [38] improved scheduling by eliminating unbalanced workloads or excessive stress, which could lead to decreasing the nurse's performance and potential human errors. They suggested a novel model of the Hybrid Salp Swarm Algorithm and Genetic Algorithm (HSSAGA) to solve the nurses' scheduling. In addition, the proposed algorithm assigned the nurse's shifts, which also considered the individual's situation is considered.

This study suggests an optimized shift strategy using integer programming that aims at maximizing the worker's job satisfaction within limited human resources of a Korean welfare facility. The shift scheduling problem (SSP) is a complex NP-hard integer programming problem, especially when many shifts and a large number of workers of various ranks and multi-skills are involved. A welfare facility is a complex workplace that has numerous variables, considering the worker's job satisfaction is crucial. Thus, fairness in the shift distribution, worker's preferences on shifts, and individual situations should be considered. These requirements are based on an interview with a welfare facility. The previously mentioned requirements included 2-days off after the night shifts, senior and leader worker's presence in the dayshifts, inhibiting only 1 new worker to work on each shift, and shift patterns to be specific. A shift pattern can have a negative impact on scheduling if it is applied as a hard constraint due to the clash with other constraints that ensures fairness. Therefore, the shift pattern is applied as soft-constraint to the model. In addition, it satisfies all the requirements without any recruitment, so it is different with other research and provides validity to the study.

3. Mathematical Formulation

Adopting an optimization technique is based on mathematical modeling maximizing satisfaction on a monthly schedule for social workers. A monthly schedule should be developed and announced on the last week of the preceding month. The overall procedure is presented in Figure 2.

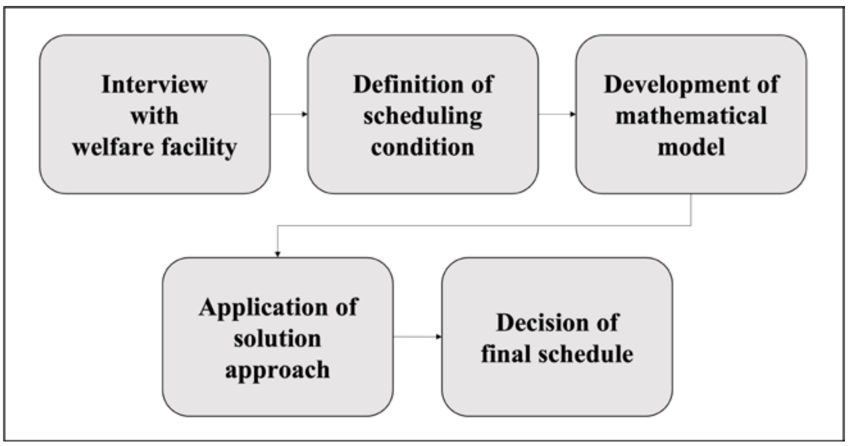


Figure 2. Overall procedure for development of a social workers' schedule.

3.1. Problem Description

This study developed a monthly schedule to maximize the workers' job satisfaction of workers in a welfare facility, located in Korea. The welfare facility drafts shift schedules for a month. There are 13 workers in the welfare facility, with 4 positions, which include senior workers, team leader workers, normal workers, and new workers. In addition, there are 4 types of shifts, which are mainly divided into 2 kinds of shifts that start to work in the morning and at night. There are three shifts that start in the morning, which include D1, DA, and DAY. Each shift starts at 7 a.m., 8 a.m., and 9 a.m., and the shifts last for 9, 10, and 9 h, respectively. There is also a NIGHT shift, which starts at 6 p.m. and lasts for 13 h. The head worker of the facility drafts the schedule by hand based on these factors. However, the schedule that was derived from the facility's conventional method has large variances in the total working hours, the number of night shifts, and the number of shifts on holidays for each worker. In addition, consideration of each worker's preferred shift has not been reflected in the schedule. This can lead to an increase in the workers' job dissatisfaction and turnover intention. Thus, this study conducts an interview of the workers in the welfare facility, investigates the preferred shifts during the daytime for each worker and the working environments that can increase their satisfaction, and then designs a schedule that aims for maximizing satisfaction of workers. In detail, working environments that increase workers' job satisfaction of workers include avoiding working patterns that work between off days and reflecting each worker's preferred shifts of each worker on the schedule. Furthermore, the conditions for fairness and the Korean labor law are considered as well as the conditions for workers' satisfaction from the interview when draw the schedule in this study. To sum up, this research derives a schedule that simultaneously fulfills the facility worker's requirements, practicality, and applicability.

3.2. Notation

3.2.1. Known Parameters

This paper derives a conservative and deterministic solution for a social worker's schedule that can maximize the total workers' satisfaction by considering the fairness of the work distribution and the workers' preference for daytime shifts. The following notations in Table 1 are composed of elements that regard the fairness of the work distribution and the facility's rules.

3.2.2. Decision Variables

The decision variables in Table 2 for this mathematical model show the allocation of the social worker to a specific shift which included off and vacation on a certain day.

3.3. Mathematical Model

Considering the required scheduling conditions from the facility, a mathematical model with the form of 0–1 Integer Linear Programming is developed. The decision variable, which is about whether the certain worker is assigned to certain shift on a designated day or not is defined as a binary 0–1 variable. The objective function aims at maximizing the satisfaction of workers, which is consist of multiplication of parameter and decision variable. Several conditions for scheduling defined through the interview with the facility are described by one or more mathematical formulations using decision variable and several parameters to consider specific meanings.

Table 1. Known parameters.

Variables	Meaning
N	Set for all workers, $n \in N$
SN	Set for senior workers, $sn \in SN$
CN	Set for team leader workers, $cn \in CN$
NN	Set for new workers, $nn \in NN$
D	Set for days, $d \in D$
$DM3$	Set for days of month, last 3 days excluded, $d \in DM3$
$DM6$	Set for days of month, last 6 days excluded, $d \in DM6$
HD	Set for holidays, $hd \in HD$
W_t	Set for days of the tth week, $w = \{7t-6,\ 7t-5,\ \ldots,\ 7t\}$
S	Set for all shifts, including off and vacation, $s \in S$
RS	Set for working shifts only, $rs \in RS$
DS	Set for shifts on daytime, $ds \in DS$
O	Set for off and vacation
$C_{s,n}$	Set for contentment of worker n when assigned to shift s
LCD	Maximum number of consecutive workdays
NV_n	The number of employee's vacations
V_n	Set for dates of vacations for worker, $n \in N$
$SNLB_d$	Minimum number of senior workers on daytime
$CNLB_d$	Minimum number of team leaders on daytime
$NNUB_s$	Maximum number of new workers per shift
ST_{rs}	Worktime for each shift, $rs \in RS$
LH	Maximum total working hours a week, established by law
$DTLB$	Minimum number of workers for shifts on daytime
$DTUB_d$	Maximum number of workers for shifts on daytime
$needS1_d$	Least number of workers for D1 shift a day
$S2LB_d$	Minimum number of workers for DA shift a day
$S2UB_d$	Maximum number of workers for DA shift a day
$needS4_d$	Number of workers for night shift a day
$DDEV$	Gap between maximum and minimum number of total workers a day
$HDDEV$	Gap between maximum and minimum number of workdays by workers
$S4DEV$	Gap between maximum and minimum number of workdays on holidays by workers
$NDEV$	Gap between maximum and minimum number of night shifts by workers

Table 2. Decision variables.

Variables	Meaning
$X_{d,s,n}$	It becomes 1, if social worker n is assigned to shift s on day d, otherwise 0
P_n	It refers to penalty, which becomes larger if working schedule of worker n is not assigned consecutively

Equation (1) is an objective function that maximizes the workers' satisfaction when a worker is assigned to specific shift. It is based on the preference for the shifts of each worker. The penalty for limiting scattered work patterns that greatly affect job satisfaction is deducted from the objective function. Equation (2) means the penalty. It is a constraint to reflect the results of the interview that job satisfaction decreases if a work shift is between the off shift or vacation. In general, the pattern of working days is to work 4 or 5 consecutive days a week and take a break, and in case of shift workers, they also prefer to have the above pattern rather than mixing working days and off-duty days. Therefore, it is additionally assigned the penalty to the value of objective function when certain workers are assigned to work less than 3 consecutive days.

$$15 \cdot \sum_{d \in D} \sum_{s \in S} \sum_{n \in N} X_{d,s,n} \cdot C_{s,n} - \sum_{n \in N} P_n \tag{1}$$

$$\begin{aligned} P_n = {} & 10 \cdot \sum_{d \in DM3} \sum_{s \in O} X_{d,s,n} + 10 \cdot \sum_{d \in DM3} \sum_{s \in O} X_{d+3,s,n} \\ & + \sum_{d \in DM3} \sum_{s \in DS} X_{d+1,s,n} + \sum_{d \in DM3} \sum_{s \in RS} X_{d+2,s,n} \end{aligned} \tag{2}$$

3.3.1. Constraints for Compliance with Labor Laws

Equation (3) represents that all workers cannot work more than the 52 h a week, which is established by the labor law in South Korea. Working hours per week is the sum of the value that each working shift, which is multiplied by each working time.

$$\sum_{d\in W_t}(ST_1\cdot X_{d,1,n}+ST_2\cdot X_{d,2,n}+ST_3\cdot X_{d,3,n}+ST_4\cdot X_{d,4,n}) \leq LH, \forall t\in T, \forall n\in N \quad (3)$$

3.3.2. Constraints for Reality

Equation (4) means a worker should be unconditionally assigned to one of the shifts. Equation (5) shows that a worker can only be assigned to only one of the three shifts during the daytime. Equation (6) guarantees that if a worker is allocated to the shifts on the daytime, the same worker cannot be allocated again to the night shift on that day. Equation (7) indicates that a worker cannot be assigned to the shifts during the daytime after the night shift.

$$\sum_{d\in D}X_{d,s,n}=1, \forall s\in S, \forall n\in N \quad (4)$$

$$X_{d,1,n}+X_{d,2,n}+X_{d,3,n}\leq 1, \forall n\in N, \forall d\in D \quad (5)$$

$$X_{d,s,n}+X_{d,4,n}\leq 1,\ \forall d\in D, \forall s\in DS, \forall n\in N \quad (6)$$

$$X_{d,4,n}+X_{d+1,s,n}\leq 1,\ \forall d\in D, \forall s\in DS, \forall n\in N \quad (7)$$

3.3.3. Constraints for Rules and Requirements of the Welfare Facility

Equations (8) and (9) indicate that the minimum number of the senior and team leader workers that should be included in the shifts during the daytime. Equation (10) is used to limit the number of the new workers that can be assigned in each shift. Equation (11) guarantees the minimum number of workers that should be allocated to the night shift. Equations (12) and (13) guarantee the days of rest after the night shift. Equation (14) indicates the vacation of each worker that was received before constructing the schedule.

$$\sum_{s\in ds}\sum_{n\in sn}X_{d,s,n}\geq SNLB_d, \forall d\in D \quad (8)$$

$$\sum_{s\in ds}\sum_{n\in cn}X_{d,s,n}\geq CNLB_D, \forall d\in D \quad (9)$$

$$\sum_{n\in nn}X_{d,s,n}\leq NNUB_s,\ \forall d\in D, \forall s\in S \quad (10)$$

$$\sum_{n\in N}X_{d,4,n}\geq needS4_d,\ \forall d\in D \quad (11)$$

$$\sum_{s\in O}X_{d+1,s,n}+\sum_{s\in O}X_{d+2,s,n}\leq 2\cdot X_{d,4,n},\ \forall d\in D, \forall n\in N \quad (12)$$

$$X_{30,4,n}\leq\sum_{s\in O}X_{31,s,n}, \forall n\in N \quad (13)$$

$$\sum_{d\in V_n}X_{d,6,n}=NV_n, \forall n\in N \quad (14)$$

3.3.4. Constraints for Fairness of Work Distribution

Equation (15) limits the gap of the number of the total workers a day. Equations (16) and (17) are used to limit the gap of the number of working days among the workers, which include holidays. Equation (18) means the difference in the number of the night shifts among the workers is limited.

$$\sum_{n\in N}\sum_{s\in RS}X_{d,s,n}-\sum_{n\in N}\sum_{s\in RS}X_{d',s,n}\leq NDEV,\ \forall d,d'\in D(d\neq d') \quad (15)$$

$$\sum_{d\in D}X_{d,s,n}-\sum_{d\in D}X_{d,s,n'}\leq DDEV,\ \forall s\in RS, \forall n,n'\in N(n\neq n') \quad (16)$$

$$\sum_{d\in HD}X_{d,s,n}-\sum_{d\in HD}X_{d,s,n'}\leq HDDEV,\ \forall s\in RS, \forall n,n'\in N(n\neq n') \quad (17)$$

$$\sum_{d\in D}X_{d,4,n}-\sum_{d\in D}X_{d,4,n'}\leq S4DEV, \forall n,n'\in N(n\neq n') \quad (18)$$

3.3.5. Constraints for Compliance with Labor Laws

Equations (19)–(23) reflect the conventional schedule condition that is reflected with the on-site situation. The equations constrain the number of workers assigned to each work shift in a day. Equations (19) and (20) constrain the number of workers that can be assigned during the daytime, whereas Equations (21) and (22) are to limit the number of workers in a DA shift. Equation (22) describes the number of workers for a D1 shift.

$$\sum_{n \in N} \sum_{s \in DS} X_{d,s,n} \le DTUB_d,\ \forall d \in D \tag{19}$$

$$\sum_{n \in N} \sum_{s \in DS} X_{d,s,n} \ge DTLB_d,\ \forall d \in D \tag{20}$$

$$\sum_{n \in N} X_{d,2,n} \le S2UB_d,\ \forall d \in D \tag{21}$$

$$\sum_{n \in N} X_{d,2,n} \ge S2LB_d,\ \forall d \in D \tag{22}$$

$$\sum_{n \in N} X_{d,1,n} = needS1_d,\ \forall d \in D \tag{23}$$

3.3.6. Constraints for Compliance with Labor Laws

Equation (24) prohibits workers from working consecutively for 7 days. It makes workers work only for 5 days maximum in a week. It also guarantees 2-days off a week.

$$\begin{aligned} &\sum_{s \in RS} X_{d,s,n} + \sum_{s \in RS} X_{d+1,s,n} + \sum_{s \in RS} X_{d+2,s,n} + \sum_{s \in RS} X_{d+3,s,n} + \sum_{s \in RS} X_{d+4,s,n} \\ &+ \sum_{s \in RS} X_{d+5,s,n} + \sum_{s \in RS} X_{d+6,s,n} \le LCD, \forall n \in N,\ \forall d \in DM6 \end{aligned} \tag{24}$$

3.3.7. Constraints for the Binary Decision Variable and Nonnegative Parameter

Equation (25) means the decision variable is binary.

$$X_{d,s,n} \in \{0,\ 1\},\ \forall d, s, n \tag{25}$$

3.4. Solution Procedure

CPLEX version 12.10 was adopted to find an appropriate staff schedule that can maximize the sum of the workers' satisfaction via the proposed mathematical model. The number of decision variable, $X_{d,s,n}$ is 31 × 13 × 5 = 2015 and various constraints should be considered, so it is difficult to find an optimal or near-optimal solution via heuristic approaches. Obtaining feasible solutions that reflect all the required schedule conditions that are based on penalty-function-based improvement algorithms is challenging even with metaheuristics, such as genetic algorithms, tabu search, and simulation annealing. Therefore, the mathematical model is developed as a form of integer programming to adopt CPLEX in this study, and an optimal staff schedule for the facility can be generated.

4. Numerical Experiment

4.1. Parameter Setting

The welfare facility has 13 social workers, which consisted of 3 senior workers, 3 team leaders, 4 normal workers, and 3 new workers. There are also 4 types of shifts, which include D1, DA, DAY, and NIGHT. Other known parameters are set to specific values, which are illustrated in Table 3. The number of workers that are in need for a specific shift, the number of new workers that can be allocated in shifts, and the known parameters to making the optimal schedule for the numerical experiment are shown in Table 3.

Table 3. System parameters.

Parameter	Value
LDM	31
LCD	5
LH	52
$SNLB_d$	1
$CNLB_d$	1
$NNUB_s$	1
$DTLB_d$	5
$DTUB_d$	7
$needS1_d$	3
$S2LB_d$	0
$S2UB_d$	1
$needS4_d$	2
$DDEV$	2
$HDDEV$	2
$S4DEV$	1
$NDEV$	1

4.2. Result

4.2.1. Schedule Using the Conventional Method

The conventional schedule is generated by the head manager of the facility by hand via the trial-and-error method, which takes almost one week to draft a single schedule. However, the derived schedule could not meet the workers' need for equity and shift preferences. A worker's schedule in Figure 3 is drafted based on the record of the workers' shifts. The way to see the schedule is explained before the results are analyzed. Figure 3 illustrates that the row number signify each worker and the column number represents the dates. The number in each cell represents the assigned shift, the cells with black circle mean a day off, and cells with 2 circles means vacation.

		Index for Dates																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Senior workers	1	N	●	D1	●	N	●	D1	●	DAY	D1	N	●	◎	●	D1	D1	N	N	●	DA	◎	DA	DAY	N	●	●	D1	DA	DA	●	DA
	7	●	D1	N	N	●	◎	D1	DAY	N	●	DA	DA	DAY	DAY	DA	DAY	●	●	D1	●	D1	●	D1	●	D1	●	N	●	D1	N	●
	10	D1	●	DAY	D1	●	DAY	N	●	D1	DAY	DAY	D1	N	●	●	DAY	DAY	N	●	◎	D1	DAY	◎	N	●	●	D1	◎	DAY	N	●
Team leader workers	6	●	D1	DA	D1	●	D1	N	N	●	DAY	◎	●	DAY	N	●	DA	D1	D1	◎	◎	N	●	D1	DAY	●	●	DA	N	●	●	D1
	8	D1	●	DAY	●	●	D1	◎	DA	DA	●	●	DAY	D1	D1	N	●	●	DAY	DA	DAY	DA	N	●	●	D1	DAY	N	●	●	D1	◎
	11	N	●	D1	●	D1	●	●	D1	DAY	D1	N	●	●	D1	D1	N	N	●	●	D1	DAY	●	◎	D1	N	●	◎	D1	D1	DAY	●
Normal workers	2	●	●	●	DA	D1	DAY	◎	●	●	●	D1	DAY	DA	D1	●	●	◎	D1	DAY	DAY	●	D1	●	D1	DAY	DA	DAY	D1	●	●	D1
	9	DAY	DA	◎	◎	◎	◎	◎	D1	D1	N	●	◎	D1	DA	N	N	●	●	D1	D1	●	D1	N	●	●	D1	●	DAY	●	D1	N
	12	●	N	●	N	●	D1	DAY	◎	●	D1	DAY	N	●	●	DAY	D1	◎	●	D1	N	●	D1	N	●	D1	N	●	D1	D1	DAY	●
	13	●	◎	●	DAY	N	●	D1	N	●	●	D1	DAY	D1	N	●	●	D1	D1	N	●	●	DAY	D1	DAY	●	D1	●	●	●	D1	●
New workers	3	DA	N	●	D1	D1	N	●	●	D1	DAY	D1	N	●	●	D1	◎	D1	◎	N	●	D1	●	◎	DA	N	N	●	●	D1	DA	●
	4	D1	●	D1	●	DAY	DA	DA	●	N	●	◎	D1	N	●	●	D1	DA	DAY	DAY	N	●	N	●	D1	DA	●	D1	D1	N	●	●
	5	●	D1	N	●	D1	N	●	D1	N	●	●	D1	◎	◎	◎	◎	◎	DA	●	D1	N	●	DA	DAY	●	D1	DAY	N	●	●	DAY

Type of shifts working in daytime		Type of shift working in night		Type of shifts not assigned to work	
D1	D1 (07:00 ~ 17:00)	N	Night (18:00 ~ 07:00)	◎	Vacation
DA	Da (08:00 ~ 18:00)			●	OFF
DAY	DAY (09:00 ~ 18:00)				

Figure 3. A staff scheduling using conventional method.

Many cases failed to comply with the welfare facility's rules and requirements for the workers. For example, as shown on day 5 in Figure 3, shows that senior workers aren't allocated to the daytime shifts. This is a failure of complying with the welfare facility's rule. This also happens on day 18, 24, 26, and 30. In addition, cases of days 7, 11, 22, and 29 violate the rule that team leader workers should be allocated to daytime shifts. Moreover, the case of ensuring 2-days off after a night shift is violated 33 times.

4.2.2. Derived Schedule Using the Mathematical Model

Figure 4 shows that the derived schedule complies with the welfare facility's rule perfectly, unlike the one before the mathematical model is applied. There were originally 5 cases that a senior worker isn't allocated to shifts during the daytime. There is no case of senior workers absent on daytime in the new schedule. This is an aspect similar to that of leader workers. The case that a leader worker is absent during daytime shifts occurred 4 times in the conventional schedule, but no cases occurred in the new schedule. Moreover, the case with more than 2 new workers allocated in the same shift occurred 5 times in the conventional schedule. However, only 1 new worker is allocated per shift in the new schedule. Furthermore, ensuring 2-days off after the night shift, a requirement of the welfare facility, was violated 33 times in the conventional schedule, but none of these occurred in the new schedule. In addition, the standard deviation of the number of employees working per day decreased from 0.81 to 0.61.

		Index for Dates																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Senior workers	1	D1	N	●	●	D1	D1	DAY	D1	DAY	●	●	D1	◎	DA	N	●	●	D1	DA	N	◎	●	DAY	N	●	●	D1	D1	D1	●	●
	7	●	DAY	D1	DA	N	◎	●	D1	N	●	●	DA	D1	●	●	DA	N	●	●	D1	D1	DAY	●	DA	DA	●	N	●	●	D1	DA
	10	●	D1	D1	DAY	DAY	N	●	●	DAY	D1	D1	N	●	●	DAY	D1	DAY	N	●	◎	DAY	N	◎	●	D1	D1	●	◎	●	N	●
Team leader workers	6	DAY	●	●	N	●	●	D1	DAY	DAY	N	◎	●	DAY	D1	D1	D1	N	●	◎	◎	N	●	●	D1	●	DAY	DA	DAY	●	DA	D1
	8	●	●	DAY	D1	DA	D1	◎	N	●	●	D1	DAY	N	●	●	●	D1	D1	N	●	●	DA	D1	D1	D1	N	●	●	DA	N	◎
	11	●	D1	N	●	●	D1	N	●	●	D1	DA	D1	D1	N	●	●	D1	●	DAY	DAY	D1	N	◎	●	N	●	◎	DA	D1	D1	●
Normal workers	2	●	●	D1	DAY	N	●	◎	DA	DA	DA	●	DAY	DA	●	D1	N	◎	●	D1	D1	DA	●	N	●	●	DA	D1	N	●	●	D1
	9	D1	N	◎	◎	◎	◎	◎	DAY	D1	DAY	N	◎	●	D1	N	●	●	D1	D1	D1	DAY	D1	●	●	DAY	D1	DAY	N	●	●	N
	12	N	●	●	D1	DAY	DAY	D1	◎	D1	●	●	D1	D1	DAY	D1	N	◎	●	DAY	N	●	●	DAY	N	●	●	D1	DAY	N	●	●
	13	N	◎	●	●	D1	DAY	N	●	●	D1	DAY	●	●	D1	DAY	DAY	DAY	N	●	●	D1	D1	D1	DAY	N	●	◎	D1	N	●	●
New workers	3	D1	D1	N	●	●	●	D1	D1	DAY	●	N	●	●	N	●	◎	D1	◎	DAY	DAY	N	●	◎	D1	D1	DAY	N	●	●	DAY	DAY
	4	●	●	●	D1	D1	N	●	●	D1	N	◎	●	N	●	●	D1	DAY	DAY	N	●	●	DAY	D1	DAY	DAY	N	●	●	DAY	D1	D1
	5	DA	DAY	DA	N	●	●	DA	N	●	●	D1	N	◎	◎	◎	◎	◎	DA	D1	DA	●	D1	N	●	●	D1	DAY	D1	D1	●	N

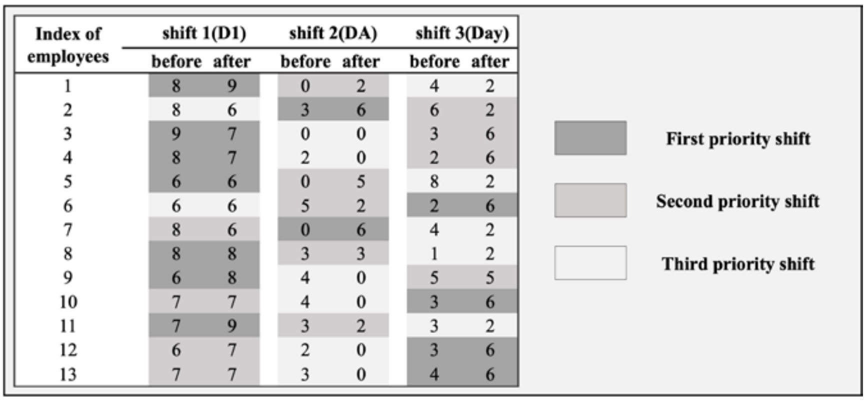
Type of shifts working in daytime
D1 — D1 (07:00 ~ 17:00)
DA — Da (08:00 ~ 18:00)
DAY — DAY (09:00 ~ 18:00)

Type of shift working in night
N — Night (18:00 ~ 07:00)

Type of shifts not assigned to work
◎ — Vacation
● — OFF

Figure 4. Optimal staff schedule using mathematical model.

Figure 5 shows the information in terms of how many times each worker is allocated to each preferred shift. Allocating to the first preferred shift ranged from 0 to 9 days before adopting the mathematical modeling, and its average is 5.15. In addition, in the case of the second preferred shift, the allocating range is 0 to 8 days, and its average is 4.33. The allocating range is 0 to 8 days in the case of the third preferred shift, and its average is 3.76. Allocating to the first preferred shift ranged from 6 to 9 days after adopting, and its average is 6.92. The allocating range is 2 to 7 days in the case of the second preferred shift, and its average is 4.61, whereas the allocating range is 1 to 8 days, and the average is 1.69 in the case of the third preferred shift. It describes the gap in the new schedule generally increases compared to the conventional schedule, and it means an increase in the case that workers are assigned to their preferred shifts.



Index of employees	shift 1(D1)		shift 2(DA)		shift 3(Day)	
	before	after	before	after	before	after
1	8	9	0	2	4	2
2	8	6	3	6	6	2
3	9	7	0	0	3	6
4	8	7	2	0	2	6
5	6	6	0	5	8	2
6	6	6	5	2	2	6
7	8	6	0	6	4	2
8	8	8	3	3	1	2
9	6	8	4	0	5	5
10	7	7	4	0	3	6
11	7	9	3	2	3	2
12	6	7	2	0	3	6
13	7	7	3	0	4	6

Figure 5. Change in preferred shift placement number for each worker.

The average is very low in the case of the third preferred shift in the new schedule, which is 1.69, but it widely ranges from 0 to 6. This means there are some cases away from the average, in which most of the values are 0 or 2. According to the rules of the welfare facility, shift D1 needs 3 workers, shift DA needs 0 to 1 worker, and shift DAY needs 1 to 4 workers. The workers who are excessively allocated to the third preferred shift have shift D1 in common in the third priority. This is the result that they choose shift D1 as the third priority, which is not flexible. It happens because the demand, which is the workers' preference for shifts, is inconsistent with the supply, which is a rule of the facility for needed workers per shift. The new schedule is improved compared to the conventional schedule despite the limitation.

4.3. Evaluation of a Derived Staff Schedule

This paper presents an equitable schedule that maximizes workers' job satisfaction by considering work distribution fairness and workers' preference for shifts. In addition, the welfare facility can manage workers' burnout and turnover by using optimized scheduling. The study also makes it possible for the head worker to draft the schedule easily and quickly, which reduces the time from about 6 h to 5 min. In addition, it considers reality, such as field situations and vacations. Therefore, this schedule is useful enough that it improves fairness numerically, and it fully complies with the welfare facility rules and requirements regardless of the manager's ability and feelings.

Table 4 shows the improvement of the new schedule compared to the conventional schedule. The average and standard deviation (S.D) of the newly derived schedule generally decrease. The standard deviation of working hours a month reduces from 12.1 to 1.8. The working days in the new schedule are the same as the conventional schedule, but its standard deviation decreases from 0.96 to 0. The standard deviation of the night shift and working on holidays reduces about 1 and 2. This means the new schedule makes the existing unfairness of work distribution fair.

Table 4. Comparison between the original schedule and the proposed schedule.

	Original Schedule	Proposed Schedule
Average working hours	184	183.08
S.D of working hours	12.1	1.8
Average working days	18	18
S.D of working days	0.96	0
S.D of working days in night shift	1.51	0.42
S.D of working days on holidays	2.34	0.57

In addition, one of the requirements from the facility is to prevent work structures, such as OFF-ON-OFF or OFF-ON-ON-OFF, so the mathematical model includes the constraint to work consecutively for at least 3 days. However, if it is applied as a hard-constraint, it can be too excessive for the program to work, so it should be applied as a soft-constraint, which penalizes the objective function. The inconsecutive work pattern in the conventional schedule is 43 cases for a day and 32 for 2 days. However, the inconsecutive work pattern in the new schedule is 19 cases for a day and 27 for 2 days. It consecutively reduces all the inconsecutive patterns up to 9 cases, which is less than 3. It demonstrates that the penalty is applied to the mathematical model well, and the new schedule improves in terms of consecutive work patterns compared to the conventional schedule.

5. Conclusions

This research proposed a scheduling strategy that maximizes job satisfaction by considering work distribution fairness and workers' preference for work shifts to solve burnout and turnover problems of social workers. Contributions of this paper are as follows. First, this paper suggested a mathematical model that can reflects the employee's preferred working day and shift to maximize job satisfaction. As shown in the numerical experiment, a mathematical model increased the percentage of each worker assigned to their preferred shift by about 10 percent. In addition, the difference in the number of preferred shift assignments between workers decreased by about 30 percent. This can contribute significantly to improving worker satisfaction. Second, this paper suggested a mathematical model that simultaneously considers the factors that each prior study considers as an optimizing objective. This model maximized the workers' job satisfaction by reflecting the preference of a shift for a worker on the objective function. It also pursued work distribution fairness by reducing the gap of the factors that have an impact on job satisfaction, such as the total working hours, the number of night shifts, and the number of days working on holidays via constraints. In addition, it is close to reality by considering personal situations, such as each worker's position and vacations in the model. Third, this study solved a social problem that is related to social workers using mathematical model-based optimization algorithm. The background of the study is that the government made efforts, such as enacting laws to improve the working environment of social workers. Job satisfaction did not dramatically improve despite these efforts. However, this study can improve this problem from an operational point of view. The mathematical model, which focuses on increasing the workers' job satisfaction, provided the workers with a more satisfactory schedule than before, which can improve the treatment of social workers. Finally, this study efficiently derived an optimized schedule without increasing the number of workers. This paper presented an effective schedule that can increase the workers' job satisfaction without the additional cost of the welfare facility. In addition, the time that is required to derive a schedule reduced drastically from more than 6 h to about 5 min with the program. The model in this paper can reduce both the effort and the time required to create a schedule. Moreover, this study can provide workers with an increase in satisfaction, propose the welfare facility with effective worker-management by decreasing the workers' burnout and turnover intention without additional costs, and help the head worker who drafted the schedule by hand with convenience and speed.

This paper can be expanded to further worker scheduling research that increases job satisfaction and considers the fairness of work distribution more than the current model. First, the model can be a better study if additional factors that are related to fairness are considered. For example, the research reflects the workers' shift preferences, but there is no constraint for fairness in the number of assignments of the workers' preferred shifts. It is difficult to apply constraints to the model due to the strict rules of the welfare facility. However, it will be possible to maximize the job satisfaction of the workers by increasing the additional work distribution fairness. Second, designing the long-term study will make a better schedule. The suggested model in this study drafts a schedule, which restricts its size to a month. In other words, the previous month and the next month are not considered in the model. There is the constraint of assuring 2-days off after the night shift in this study, but it is not reflected in the month's schedule even if a worker works on the night shift on the last day of the previous month. Further research in deriving a schedule for the long term will result in a more realistic model. The research about deriving a schedule that considers the preferences of work patterns by workers is needed in terms of improving job satisfaction. Conducting this research improves the workers' fatigue by providing a regular routine and it contributes to increase satisfaction with a new schedule. In conclusion, various factors that influence the workers' satisfaction in several ways should be considered in deriving a better schedule to improve the shift workers' high burnout and high turnover.

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