Rehabilitation staff scheduling in senior daytime care facility with feeling of physical/mental workloads and movements

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Abstract
Demand for nursing care facilities such as senior daycares has increased in Japan because of an aging population. In these facilities, multiple staff members offer nursing care services to the elderly such as physical therapy and exercise using machines, according to a staff schedule planned manually. These staff members face some issues regarding heavy workloads, limited human resources, etc. Therefore, it is necessary to plan the staff schedules by distributing the workloads among all the staff members. Additionally, it is observed that staff members are stressed because of physical as well as mental stress when providing services since they also need to vigilant to prevent user accidents. A previous study proposed a scheduling model considering the feeling of physical and mental workloads separately. Thus, the differences for either of the workloads may become very large in planned schedules. This study proposes a scheduling model considering both physical and mental workloads, and produces a balancing schedule considering both types of workloads simultaneously. Additionally, the impact of a movement constraint that is added to the model to reduce the inefficient movement of staff is also discussed. Lastly, to analyze actual cases of the surveyed facility, we conducted numerical experiments with practical scenarios such as increasing the number of staff members, and changing the staff role according to actual staff shifts in the facility.

Keywords: Staff scheduling, Workloads leveling, Nursing care service, Case study, Service assignments

1. Introduction
Japan is facing a demographic issue due to an increase in its aging population, the percentage of elderly people in Japan is expected to reach 36.1% by 2040. There is an increased importance for preventative care with an objective to prolong the healthy life of the people, keeping up with the social trends of an aging population (Cabinet Office in Japanese Government, 2018) (Takanokura et al., 2015). Senior daycare facilities offer nursing care services for the elderly, including the above mentioned preventative care; thus, these facilities will play an important role in the near future. In these facilities, nursing care services such as physical therapy by licensed staff, exercise using machines, meal services, etc., are offered to users in order to maintain or improve their body functions (Karube et al., 2017). The users visit these facilities travelling from their homes by utilizing transportation services to avail the offered daycare services.

Facility staff members offer nursing care services according to a predetermined schedule for each staff member. Presently, this staff schedule is planned manually in most of the facilities (Yih, 2011). Manual planning is considered a time burden for schedule planners, and suggesting a solution is also difficult with multiple constraints (Matsumoto et al., 2020).

In addition, the facility staff members face some critical issues such as heavy workloads and limited human resources due to high turnover rates (Taniguchi, 2014) and (Matsumoto et al., 2018). Further, all these problems are expected to be
exacerbated in the future. Thus, it is very important to consider the staff workloads while planning the staff schedule to balance it among multiple staff members, as found from the facility staff comments (Matsumoto et al., 2020).

As described above, the facility staff members deal with physical as well as mental workloads when providing nursing services to elderly users. This is because the staff is required to be vigilant to prevent user accidents, and offer a suitable service with respect to the physical condition of each user. Further, nursing services include restroom usage (Matsumoto et al., 2018). Thus, mental workloads may heavily impact staff. Therefore, both physical and mental workloads should be considered and balanced in staff schedules in senior daycare facilities.

In addition, reducing the number of staff movements on schedule is also recognized as an important aspect (Matsumoto et al., 2020); it increases service time with the elderly users, and the staff members can offer the same service for a longer time. Thus, although staff movements should be considered in planning the schedule, while physical/mental workloads are balanced, the relationship between balancing workloads and reducing staff movements may have a tradeoff.

In previous studies similar to the ones described above, Matsumoto et al. (2018) and Matsumoto et al. (2019) proposed a rehabilitation staff scheduling model considering the physical and mental workloads of staff separately, and planned a balancing schedule. Thus, the differences for either physical or mental feeling of workloads may become large among staff members, although one of the feeling is achieved a good balance. However, occurrence of variation in either workload for staff is undesirable in the facility, thus, we need to consider the stress of both types of workloads simultaneously when planning the balancing schedules.

On the other hand, since the relationship between balancing the physical/mental stress of workloads and reducing staff movements may come with a tradeoff, the schedule planner should find a solution that satisfies each demand. In Matsumoto et al. (2019), although they planned a balancing schedule for both types of workloads, it was planned considering staff movements of two staff members. Further, discussions were not carried out to find the satisfying points in the tradeoff relationship between the two types of workloads and staff movements using weight parameters.

This study proposes a staff schedule model considering the physical and mental feeling of workloads and staff movements, simultaneously, based on the workloads survey. Further, schedules balancing both types of workloads are planned and compared with the previous schedules to illustrate the advantages of our model. Additionally, satisfying solutions among tradeoff relationships are found and discussed by using weight parameters for the objective function.

The rest of this paper is as follows. First of all, literatures are reviewed in section 2. In section 3, formulation of staff scheduling is conducted considering the physical/mental feeling of workloads and staff movements with weight parameters. After that, the facility information and the results of the workloads survey conducted by Matsumoto et al. (2020) are described in section 4. Section 5 includes analysis of numerical experiments in a two functional training expert case. Here, the balancing schedule for both physical and mental feeling of workloads are planned and the obtained results are compared with the current schedule and previous studies. Moreover, in order to find satisfying points for each component with some scenarios, an effect of weight parameters is discussed. In section 6, another case is considered according to actual surveyed shifts. Lastly, we conclude in section 7 with a summary and a brief description of future works.

2. Literature review

The staff scheduling problem has been noted in several fields (Ernst et al., 2004; Suwa and Sandoh, 2013). Thus, this study surveyed the staff scheduling, especially in the service and health care settings and divided the scheduling problem into four categories: service staff scheduling, healthcare staff scheduling, nursing facility staff scheduling, and rehabilitation staff scheduling. Service staff scheduling includes research to reduce the staff movement across multiple locations, healthcare staff scheduling considers the workloads in the long term, and nursing staff scheduling is similar to the subject of our study. Thus, the following studies were surveyed:

- Service staff scheduling
  Anbil et al. (1998) addressed the scheduling problem of an airline crew. Bard et al. (2003) proposed a full-scale model for the tour scheduling problems for the United States Postal Service. Additionally, Kuo et al. (2014) suggested a scheduling model for airline customer service agents considering the staff’s skill level and movement across multiple locations. Tokunaga et al. (2015) proposed a shift scheduling model for restaurants to ensure a specific number of skilled
staff members for each time slot, which means a detailed daily staff schedule. Cheng and Kuo (2015) considered different preferences for work shifts by the staff for the food safety inspector scheduling problem and tried to balance the dissimilarities in workers.

- **Healthcare staff scheduling**
  The major rostering focus in health care systems has been in nurse scheduling (Ernst et al., 2004). Maier-Rothe and Wolfe (1973) addressed the nurse scheduling problem considering staff levels and skills. Ikegami and Niwa (2003) considered the workloads on nurses during the scheduling by balancing the number of night shifts. Ito et al. (2016, 2018) proposed scheduling systems whose targets are residents in an operation room, with the case study of an actual hospital. He et al. (2019) integrated the nurse staffing and scheduling models considering individual preferences for the shift and the personnel cost under patient demand uncertainty.

- **Nursing facility staff scheduling**
  Issues concerning home care routing and staff scheduling in a nursing care facility are focused upon. There are related research papers about routing and scheduling problems (Paraskevopoulos et al., 2017), especially in a home care setting (Cissé et al., 2017; Fikar and Hirsch, 2017). Cappanera and Scutella (2015) proposed an integrated approach for a scheduling and routing model for home care in a weekly planning horizon, which attempted to balance the operator workload. Cappanera et al. (2018) addressed the scheduling and routing decisions taken jointly under the uncertainty of patient demands.

- **Rehabilitation staff scheduling**
  Although significant research on staff scheduling regarding the routing problem has already been conducted, there are only a few specific studies regarding senior daycare facilities for rehabilitation. Moreover, there are few studies considering the physical and mental feelings workloads and the staff movements while offering the nursing services based on an analysis using by Industrial Engineering (IE) method in a daily schedule of a daytime care facility. Matsumoto et al. (2020) proposed a rehabilitation staff scheduling model considering physical feeling workloads for the staff based on the workloads survey for the actual facility staff members. However, the mental feeling workloads are not considered. Additionally, their study minimizes only total excessed physical workloads from upper bounds. Matsumoto et al. (2018) surveyed mental workloads and took it into account in the rehabilitation staff scheduling model. However, their study did not plan the schedule to consider both of physical and mental workloads at the same time.
  Matsumoto et al. (2019) addressed a staff scheduling in the senior daytime care facility considering the physical and mental feeling workloads simultaneously. Since numerical experiments were limited to the small case study with only two functional training experts, a practical schedule based on actual staff shifts was not implemented. Moreover, detailed discussions were not conducted in the relationships among physical/mental workloads and staff movements since the model was formulated without weight parameters for multiple criteria in the objective function.

3. **Methodology**

3.1 **Notation and Assumptions**

In this section, modeling a schedule for a senior daycare facility is conducted to consider the physical and mental workloads of staff based on the staff scheduling problem (Mingozzi et al., 1999; Ernst et al., 2004; Eveborn et al., 2006). This model assigns a service \( k \) to a staff member \( i \) in a time slot \( t \). Here, a time slot indicates the minimum unit time of the staff schedule (Tokunaga et al., 2015). There are no predetermined sequences and timing for providing the services in the facility, unlike production schedules in factories. Thus, all the services can be offered at any time slot with flexible sequences.

This study uses the average physical and mental workloads, \( p_k \) and \( s_k \) based on the questionnaire survey. This is because, in the actual facility, staff schedule is sometimes changed due to absences of staff. For example, some staff go out to help the other facility and become sick, etc. Thus, if schedule planners consider the individual differences into the schedule planning, the staff has to reschedule to treat the urgent situation. Therefore, this study used the average of physical and mental workloads which are shown by \( p_k \) and \( s_k \), respectively, to avoid reschedule for the staff absence.
A summary of notation in this study is as follows.

\[
\begin{align*}
I & : \text{Set of facility staff } \quad i \in I \\
T & : \text{Set of time slots } \quad t \in T \\
K & : \text{Set of nursing care services } \quad k \in K \\
z_k & : \text{Required total time to offer for service } k \\
p_k & : \text{Average physical feeling of workload value at service } k \\
s_k & : \text{Average mental feeling of workload value at service } k \\
up_i & : \text{Upper limits of total physical feeling of workload for staff } i \\
us_i & : \text{Upper limits of total mental feeling of workload for staff } i \\
r_{ik} & : 1 \text{ if staff } i \text{ can serve for service } k, 0 \text{ otherwise} \\
f_{ik} & : \text{Number of facilities for service } k \\
S & : \text{Time length for one-time slot} \\
\alpha_i^-, \alpha_i^+ & : \text{Negative and positive deviation variable from } \up_i \\
\beta_i^-, \beta_i^+ & : \text{Negative and positive deviation variable from } \us_i \\
P_{\text{max}}, S_{\text{max}} & : \text{Maximum value of } \alpha_i^+, \beta_i^+ \text{ in all staff members} \\
x_{ikt} & : 1 \text{ if staff } i \text{ is offering a service } k \text{ in time slot } t, 0 \text{ otherwise} \\
m_{ikt} & : 1 \text{ if staff } i \text{ change the offering service } k \text{ from time slot } t \text{ to } t+1, 0 \text{ otherwise} \\
w_1, w_2, w_3 & : \text{Weight of physical, mental feeling of workloads and movement of staff in the objective function}
\end{align*}
\]

3.2 Formulation

In this case study, the schedule planner in the senior daytime care facility needs to take into account total physical/mental workloads for each staff and total movements for all staff to plan balanced schedules. Thus, this study attempts to balance the physical and mental workloads among multiple staff members and to reduce the total number of movements based on Matsumoto et al. (2019) and Kuo et al. (2014). It is noted that total physical/mental workloads in the schedule cannot be reduced in the senior daytime care facility since the offering time for each service are predetermined and fixed to recover body functionality for users. In the situation, it is important to preferentially reduce the highest total physical/mental workloads on a certain staff who is assigned to the services with higher workloads for a long time. Therefore, the objective function of our study is minimizing the maximum total of physical/mental workloads exceeded from the upper limit in all staff members, \( P_{\text{max}} \) and \( S_{\text{max}} \), and the total number of movements for a staff member between locations of the facility, \( m_{ikt} \).

Each component in the objective function is weighed by \( w_1, w_2 \) and \( w_3 \) to coordinate a balance among the physical/mental workloads and staff movements.

Objective function:

\[
\begin{align*}
\min & \quad w_1 P_{\text{max}} + w_2 S_{\text{max}} + w_3 \sum_{i \in I} \sum_{k \in K} \sum_{t \in T} m_{ikt} \\
\text{Subject to:} & \\
\sum_{k \in K} \sum_{t \in T} p_k x_{ikt} \times S + \alpha_i^- - \alpha_i^+ = \up_i & \forall i \in I \quad (2) \\
\sum_{k \in K} \sum_{t \in T} s_k x_{ikt} \times S + \beta_i^- - \beta_i^+ = \us_i & \forall i \in I \quad (3) \\
x_{ikt} \leq 1 & \forall i \in I, \forall t \in T \quad (4) \\
\sum_{i \in I} \sum_{t \in T} x_{ikt} \times S = Z_k & \forall k \in K \quad (5)
\end{align*}
\]
Equations (2) and (3) calculate the values of physical and mental feeling of workloads with an excess or shortage from the limit value of both types of workloads of staff $i$. Equation (4) ensures that all staff members can offer only one service in a time slot, which means that multiple services cannot be assigned to the staff in a single time slot. Equation (5) represents the predetermined working time for each service, $Z_k$, is definitely offered by multiple staff members. Equation (6) ensures that an assigned service $k$ to staff $i$ is not carried out if the staff $i$ cannot offer the service $k$ if unqualified. Equations (7) and (8) set maximum physical and mental workloads values excessed from the upper limit among all staff members by $P_{\text{max}}$ and $S_{\text{max}}$, respectively. Equation (9) states that movement is required when transiting to another location. Equation (10) ensures that the numbers of staff, who offer the same service in each time slot, is less than or equal to the upper bounds for the numbers of facilities for each service. Equation (11) shows that $\alpha_i^-, \alpha_i^+, \beta_i^-, \beta_i^+$ are non-negative.

### 3.3 Method of physical and mental workloads survey

In this section, the method of workload survey, conducted in a previous study is explained (Matsumoto et al., 2018). In order to evaluate the physical and mental workloads of staff quantitatively, the survey consisted of two parts: a questionnaire and an interview survey. The questionnaire survey required staff members to rate the physical and mental workloads for each service using a five point evaluation system, inspired by NASA-TLX (Miyake, 2015). In the interview survey, in order to clarify the reasons for the answered points for each service, an interview for the staff members based on the answered sheets was conducted. Using this survey, we try to quantitatively grasp the physical and mental workloads of staff.

Although NASA-TLX can evaluate workloads based on six parameters, mental demand, physical demand, temporal demand, performance, effort, and frustration, using a 100 point evaluation system, it may be difficult for actual staff members to answer the survey. The reason is that several evaluation points are included, and the staff members are not familiar with such complicated surveys. Thus, in order to enable the staff to answer the survey with ease, Matsumoto et al. (2019) used a simplified method of NASA-TLX by reducing the evaluation points from 100 to 5. Results of the workload survey for the physical and mental workloads are explained in section 4.2.

Additionally, we did not evaluate the reliability and validity of the workload survey since it was simplified from a previous method of NASA-TLX. This is because in-depth discussions were conducted in NASA-TLX (Miyake, 2015). In addition, staff members said the following regarding the results of our workload survey in a staff feedback, “Results of workloads survey were almost confirmed.” Thus, the reliability and validity of the workload survey are confirmed from the staff members’ perspective.

### 4. Facility information and results of workload survey

#### 4.1 Information about the daytime care facility

Information regarding the surveyed daytime care facility, such as contents of services offered and roles of staff members, is explained in this section. An overview of the surveyed facility in this study follows.
Multiple staff members offer nursing care services to elderly users for purposes such as strength training and joint rage exercise. The staff mainly offer nine types of nursing care services that require the following equipment: Mattress, Cycle, Machine, Pulley, Table, Bars, Counter and Toilet. Elderly users can also get meal services if the users request.

The facility staff members have four roles: functional training experts, care workers, nurses, and drivers. The services a staff member can offer depends on the staff role. For example, the mattress services are offered only by functional training experts since this service requires a specific qualification.

The surveyed facility is very small, and the number of users who visit the facility depends on the day; however, approximately 16-23 elderly people visit on an average day. Further, the number of staff members are 4-7, depending on the number of users in a day.

4.2 Results of physical and mental workload survey for facility staff

This section describes the results of the survey for the physical and mental workloads conducted by Matsumoto et al. (2019). At first, the states of both types of workloads when providing the service are scored using a 5 point evaluation system in a questionnaire survey. Second, in order to clarify the reasons for workload results for each service, an interview survey was carried out. This study mainly focuses on the results of the questionnaire since they are used in the numerical experiment to calculate the physical and mental workloads for each staff member.

Fig. 1 shows the values of the physical and mental workloads for each service in the questionnaire. Results indicate that the value of both types of workloads depended on the types of service provided. For example, toilet service indicated a high workload in both the physical and mental elements, and its values are more than 4. Conversely, services involving a pulley or table apparently have a lower impact on workloads by staff members, for which values are less than 2. Differences in workloads occurred between these services because of the diversity of the service contents in the facility. For instance, although the toilet service requires significant support in a delicate situation, a pulley service does not since the task simply requires setting up tools in the beginning of the user’s exercise.

Thus, because of the large diversity of these services, the schedule planner needs to consider the differences in the types of workloads. Moreover, from the viewpoint of differences between physical and mental workloads in services, some services, excluding the cycle and pulley, had a few differences. The counter service has a difference of more than 1 point between physical and mental workloads. Staff comments in the interview survey indicate that there are staff members who are unfamiliar with office work; therefore, mental workload is higher than physical. These results indicate that there are quantitative differences between physical and mental workloads when providing services. Moreover, one of our contributions is that staff members can recognize both types of workloads for each service quantitatively and manage themselves.
5. Effect of physical/mental workloads and assignments

5.1 Assumptions and evaluation

To clarify the effects of consideration for both physical and mental workloads, this section conducts a numerical experiment for an actual case in the surveyed facility. Our proposed schedules are compared with the current schedule and previous studies (Matsumoto et al., 2018, 2020) to illustrate the advantages of our methods. The current schedule data surveyed by Karube et al. (2017) has two functional training experts (FT) because FT is qualified to offer all services; therefore, FT is very important for the assignments. Thus, cases with two staff members with functional training expertise are considered here to compare with a current schedule, and to analyze how the assignments are changed by considering the workloads of staff.

Each obtained result is one of the optimal solutions in this experiment. In addition, another case for the actual facility will be considered subsequently, section 6, by increasing the number of staff members and changing their role. Assumptions of the scheduling model and the input data from the current schedule are based on (Matsumoto et al., 2018), as follows:

- Assumptions of the model;
  - The time slot is set to 10 min, which is the maximum time unit that staff members have to offer each service continuously. In the surveyed facility, each service is offered within 10 min, and it means that there are no services across two (or more) time slots. Thus, a time slot is set by 10 min as the case study.
  - Toilet service is not considered in planning schedules because of unpredictability.
  - All services can be offered at any time slots with flexible sequences since these timing and sequence are not predetermined in the facility, unlike a factory.
  - The number of facilities for service \( k, f_1, \ldots, f_7 \) was assumed as 10 for mattress, cycle, machine, pulley, bars, table, and counter, respectively.

- Assumptions of input data;
  - A case with two staff members is considered here, both staff members are functional training experts; functional training expert is qualified to offer all the services in the facility.
  - The average result of the workload survey shown in Fig. 1 is used after rounding off in the experiment, to calculate the physical and mental workloads for each staff member.
  - Required offering times of each service are obtained by rounding up the sum of offering service time between the staff in the current schedule to the nearest 1; this is because the time slot was set to 10 min, so it was necessary to assign all services by units of 10 min. Thus, the total service provision time increased from the current schedule in our assumptions.
  - The weights of each parameter \( w_1, w_2, w_3 \) are set by one in this experiment in section 5.2 while effects of these weight parameters are discussed in section 5.3 by changing these parameters.

The numerical experiment based on the assumptions in section 5.1 was conducted, and the results are discussed in this section. Further, in order to illustrate advantages of our proposed model, the proposed staff schedule (1) is compared with the three other planned schedules (2)-(4) as follows:

(1) Balancing schedule for the physical and mental feeling of workloads simultaneously (proposed schedule)
(2) Current schedule (baseline) surveyed by Karube et al. (2018):
  - The current schedule is manually planned by a manager in the surveyed facility, it means by trial and error methods which is not considering physical and mental feeling workloads.
(3) Balancing schedule for physical workloads by Matsumoto et al. (2020)
(4) Balancing schedule for mental workloads by Matsumoto et al. (2018)

First, the schedule that balances both physical and mental workloads is planned based on the assumption in section 5.1. Next, the planned schedule is compared with (2) the current schedule. Finally, the proposed schedule is compared with the balancing schedule for either of the (3) physical or (4) mental workloads.

In each comparison, the results of each schedule are evaluated by differences [%] in physical and mental feeling
workloads between two staff members (A and B), which is shown by equations (12) and (13), respectively. These differences are calculated by dividing the absolute value of differences in physical/mental feeling workloads between staff A and B by the sum value of physical/mental workloads on both staff members and shown as ratio [%].

\[
D_{PW_{AB}} = \left\{ \frac{\sum_{k \in K} \sum_{t \in T} p_k x_{ikt}(i=A) - \sum_{k \in K} \sum_{t \in T} p_k x_{ikt}(i=B)}{\sum_{k \in K} \sum_{t \in T} p_k x_{ikt}(i=A,B)} \right\} \times 100 \% \tag{12}
\]

\[
D_{MW_{AB}} = \left\{ \frac{\sum_{k \in K} \sum_{t \in T} s_k x_{ikt}(i=A) - \sum_{k \in K} \sum_{t \in T} s_k x_{ikt}(i=B)}{\sum_{k \in K} \sum_{t \in T} s_k x_{ikt}(i=A,B)} \right\} \times 100 \% \tag{13}
\]

\[
p_k: \text{ The value of physical workloads} \]
\[
s_k: \text{ The value of mental workloads} \]
\[
x_{ikt}: 1 \text{ if staff } i \text{ offer a service } k \text{ in time slot } t, \text{ otherwise } 0
\]
\[
D_{PW_{AB}}: \text{ Differences in physical workloads between staff A and B} \]
\[
D_{MW_{AB}}: \text{ Differences in mental workloads between staff A and B}
\]

The solution and related results are calculated on a personal computer with Windows 7, Intel® Core TM I7-2600 CPU operating at 3.40GHz, and a commercially available optimization solver, Numerical Optimizer, provided by NTT DATA Mathematical Systems Inc. The computation time was just a second at each numerical experiment.

5.2 Results of physical/mental workloads and assignments in the planned schedules

A) Effects of a balancing schedule for physical and mental workloads

The effects of a balancing schedule for physical/mental workloads are explained in this section. Table 1 shows the effects of a balancing schedule for physical/mental workloads and the current schedule; the difference in physical/mental workloads for staff A and B becomes 0.0% and 1.1%, respectively, which indicates that the balancing of physical and mental workloads is achieved. Additionally, the total workloads are the sum of physical/mental workloads that are balanced, where the difference is only 0.7%.

As shown in Table 1, the working time of staff A and B are 120 and 130 min, respectively, and as shown in Table 2, differences in working time between staff A and B are only 4.0%. These results indicate that the balancing of working time is also accomplished in the proposed schedule, although the schedule only aimed to balance the physical and mental workloads in the experiments.

B) Comparison of (1) proposed schedule with (2) current schedule

The advantages of our balancing schedule for physical/mental workloads are shown by comparing it with the current schedule planned manually. As shown in Table 1, the differences in mental workloads between the staff members are the same, 1.1%, in both the current and our proposed schedules. On the other hand, our proposed schedule could decrease the difference in physical workloads from 4.7 to 0.0% when compared with the current schedule, indicating that the results of balancing workloads were improved in the planned schedule.

In order to balance the physical/mental workloads, assignments of services recognized as high workload services including mattress and bars were considered as important. Table 2 shows the breakdown of the working time for each staff member. In the current schedule, the mattress service, in which physical and mental workload values are 3 and 4 points, is assigned to staff A and B for 34 and 76 min, respectively. Conversely, in the proposed schedule, staff A and B are assigned to the mattress service for 60 and 50 min, respectively. Therefore, the differences in the working time of the mattress service between staff A and B was brought down from 42 to 10 min. Thus, it was found that the differences in physical and mental and total workloads were improved compared to the current schedule by making changes in the assignment of high workload services.

Since the differences in mental workloads were the same between the (1) proposed and (2) current schedules, the schedule planned by the current method is comparable. However, difficulties with the current method existed, such as time burden for a schedule planner, unclear schedule satisfying constraints, and variation of the results in balancing workloads. Our scheduling procedure has the potential to reduce difficulties.
Table 1 Results of the balancing schedule for the physical, mental workloads, current schedule \((w_1, w_2, w_3 = 1)\)

| Staff | Physical | Mental | Total workload (Physical and Mental) | Working time [min] |
|-------|----------|--------|-------------------------------------|-------------------|
|       | Value    | Value  | Difference between baseline [%]     | Value             |
|       |          |        |                                     | Difference between baseline [%] |
|       |          |        |                                     | Difference between baseline [%] |
| Staff A | 300 | 5.2% | 440 | 14.5% | 440 | 0.2% | 740 | 12.0% | 120 | - |
| Staff B | 300 | 5.2% | 400 | 10.2% | 400 | 0.2% | 700 | 5.9% | 120 | - |
| Difference between staff [%] | 0.0% | - | 1.1% | - | 0.7% | - | 4.0% | - | 8.1% | - | 4.0% |

Table 2 Breakdown of the working time by allocated service for each staff \((w_1, w_2, w_3 = 1)\)

| Service | Staff A | Staff B | Staff A | Staff B | Staff A | Staff B | Staff A | Staff B | Staff A | Staff B | Staff A | Staff B |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Mattress | 60 | 50 | 34 | 34 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Cycle | 0 | 10 | 1 | 10 | 0 | 0 | 10 | 0 | 10 | 0 | 10 |
| Machine | 10 | 0 | 8 | 0 | 0 | 10 | 0 | 0 | 10 |
| Pulley | 10 | 0 | 2 | 0 | 0 | 10 | 0 | 0 | 10 |
| Table | 0 | 40 | 5 | 20 | 0 | 20 | 0 | 20 | 0 |
| Bars | 0 | 10 | 7 | 0 | 0 | 10 | 0 | 0 | 10 |
| Counter | 40 | 20 | 40 | 0 | 60 | 0 | 60 | 0 |
| Sum | 120 | 130 | 106 | 114 | 130 | 130 | 120 | 130 | 120 | 130 | 120 | 130 |
C) Comparison of (1) proposed schedule with either (3) physical or (4) mental workloads balanced schedule

Lastly, the proposed schedule is compared with the balancing schedule for either physical or mental workloads by Matsumoto et al. (2018, 2020).

In the previous study (Matsumoto et al., 2018, 2020), the difference in either one workload which is not considered becomes very large between staff members. For example, in Table 1, the difference in the mental workloads between staff A and B is 8.1% in the previous schedule which aimed to balance only the physical workload. Additionally, the difference in physical workloads was 6.7% between staff A and B in the balancing schedule for only the physical feeling of workloads. Thus, the difference in either one workload was very large in the previous study’s planned schedule.

On the other hand, both types of workloads were balanced simultaneously between staff members in our proposed schedule, as mentioned in the previous section (B) comparison of (1) proposed schedule with the (2) current schedule. This indicates that among the planned schedules, our proposed result is more practical for actual staff members.

5.3 Effect of prioritizing physical/mental feeling of workloads and staff movement

The previous section 5.2 planned schedules without prioritizing physical/mental workloads and staff movement. However, the staff movement could be further reduced if the weight value is increased. Reducing the staff movement is also recognized as an important requirement as well as workload balancing since many staff movements also reduce the duration of service provided to users. Additionally, the impact may be significant in a large facility like a hospital, whereas the surveyed daycare facility is relatively small. Thus, this section focuses on providing the model with a higher priority to reduce staff movements by increasing the weight of staff movements. However, excessive reduction of staff movement is not good when both workloads are not considered. Therefore, we need to find satisfying points among these components in the objective function; to achieve that, two scenarios considering the reduction of staff movements are set for the schedules in the facility.

● Scenario A: Reduction of staff movement

Scenario A analyzes how the number of staff movements is reduced by increasing the weight parameter, $w_3$. Then, a case with an increased parameter of staff movements, $w_3$, from 10 to 80 is prepared to determine the impact. Differences in the two types of workloads among staff members are also analyzed along with the number of staff movements.

● Scenario B: Reduction of physical workloads

Scenario B attempts to plan a balancing schedule for both, physical and mental workloads simultaneously by keeping the lower times of staff movements which is revealed in scenario A. It is observed that the difference in physical workloads between both staff members tends to be larger compared to mental workloads. By using the obtained parameter of staff movements, $w_3$, in scenario A, the weight parameter of physical workloads, $w_1$, is increased to find the satisfying points in tradeoff relationships between the two types of workloads.

![Fig. 2 Results of physical/mental workloads and number of movements as increasing for the parameter of staff movements, $w_3$, from 1 to 80 ($w_1 = w_2 = 1$): Scenario A](image)
Fig. 2 shows the results for physical/mental feeling of workloads and number of movements by changing the weight parameter of staff movements, \( w_3 \). In the figure, for each weight of staff movement, the total number of movements in staff A and B are shown by a bar graph and the differences in workloads between both staff members are shown by a line graph. For these results, a lower number of staff movements, and minimal differences in workloads is preferred. The results could be classified into three cases: case 1) baseline \( (w_3 = 1) \), case 2) low priority \( (w_3 = 10-40) \), and case 3) high priority \( (w_3 = 50-80) \).

It was found that the relationship between staff workloads and movements has a tradeoff. For case 1) baseline \( (w_3 = 1) \), the difference for the physical and mental feeling of workloads is 0.0% and 1.1%, respectively. This shows that workload balancing between staff A and B is achieved, as in the previous section 5.2. However, the total movement of staff is 7 times higher among the three cases. The movements of staff members gradually decreased with the weight of movements, \( w_3 \), in cases 2 and 3. On the other hand, the difference in the physical and mental workloads between the staff members gradually increases as the weight value of staff movements, \( w_3 \), increases, indicating that workloads and movement of staff have a tradeoff relationship.

One explanation as to why the relationships between both the feelings of workloads and movements has a tradeoff is that the assignment of services is perfectly separated by the types of service and the locations for each staff member. For example, in the case 3) \( (w_3 = 50) \), all services of the mattress and pulley are assigned to staff A for 110 and 10 min, respectively. On the other hand, staff B is assigned to all the other services such as machine and table. Thus, the perfectly separated assignments by types of service and locations are important to reduce the movements of staff. However, these assignments often bring the larger difference for feeling of workloads between the staff. This is because the high feeling workloads service such as mattress are assigned to a specific staff for all the service offering time.

Considering the tradeoff relationship, case 2 \( (w_3 = 10-40) \) delivers one of the practical results for the actual surveyed facility. In this case, the total movements between staff A and B are 6 times higher, which could be reduced compared to case 1) baseline \( (w_3 = 1) \), and the current schedule. Additionally, the difference for mental workloads is only 1.1%, which is maintained from case 1 \( (w_3 = 1) \), and shows perfect balancing. Although the difference for physical workloads increased from 0.0 to 3.3% when compared with case 1 \( (w_3 = 1) \), the differences are smaller compared to the results from the current schedule, by 4.7%. Thus, the results of case 2 \( (w_3 = 10-40) \) is practical for the actual facility since the difference for mental workloads is maintained from the results of case 1 \( (w_3 = 1) \), and the physical workload becomes smaller than the one in the current schedule.

As a result of the analysis above, the schedule planner should set the weight parameter of staff movement ranging from 10-40 if the facility intend to reduce it, keeping both of the workloads balanced in the experiment. Moreover, since the planned schedule is classified into only 3 patterns in the scenario, the schedule planner does not need to set the weight parameter of movements in detail in our scheduling procedures. Our scheduling model can obtain each schedule by setting an approximate weight parameter of movements such as 1, 30, and 70, respectively.
Results of Scenario B: Balance for the feeling of physical/mental workloads

Previously, scenario A revealed that the parameter of staff movements was practical in case 2 by taking the staff movements into consideration. However, considering physical workloads, there was a 3.3% difference between staff members. Thus, to find a better solution that satisfies the balance between the physical and mental workloads simultaneously, the parameter of physical workloads,  \( w_1 \), by limiting the weight parameter of movements,  \( w_3 \), to 40, and the parameter of mental workloads,  \( w_2 \), is set to 1.

Fig. 4 shows the results of the balancing schedule upon increasing the weight parameter of physical workloads,  \( w_1 \), from 1 to 60 (\( w_2 = 1, w_3 = 40 \)): Scenario B

Fig. 5 Results of assignment for each service as increasing weight parameter of physical feeling workloads,  \( w_1 \), from 1 to 60 (\( w_2 = 1, w_3 = 40 \)): Scenario B

- Results of Scenario B: Balance for the feeling of physical/mental workloads

Previously, scenario A revealed that the parameter of staff movements was practical in case 2 by taking the staff movements into consideration. However, considering physical workloads, there was a 3.3% difference between staff members. Thus, to find a better solution that satisfies the balance between the physical and mental workloads simultaneously, the parameter of physical workloads was increased,  \( w_1 \), by limiting the weight parameter of movements,  \( w_3 \), to 40, and the parameter of mental workloads,  \( w_2 \), is set to 1.

Fig. 4 shows the results of the balancing schedule upon increasing the weight parameter of physical workloads,  \( w_1 \), from 1 to 60. Further, results of assignments for each service are described in Fig. 5. As shown in Figs. 4 and 5, it was found that the differences of results for both types of workloads and service assignments are changed when setting  \( w_1 \) to 10. These obtained schedules have two classified patterns, and the cases after  \( w_1 = 20 \) show that the differences for physical workloads were reduced from 3.3% to 0.0% by increasing the weight of physical workloads, whereas the differences for the mental workloads were increased from 1.1% to 5.7%. Thus, by limiting the number of staff movements to 6 times, two balancing schedules which satisfy the physical and mental workloads are obtained, respectively.

On the other hand, a balancing schedule for physical/mental workloads simultaneously was not found since the relationship between physical and mental workloads has a tradeoff, as the case between the workloads and staff movement revealed in scenario A.
In the actual facility, it is considered that the importance of physical and mental workloads is different for each staff member, and also depends on the day. This means that individual staff members may have differences in perceptions depending on how they feel regarding physical or mental workloads. Thus, a schedule planner in the facility can use two options for different purposes each day. If the schedule planner wants to reduce the differences in physical workloads among staff members, the weight parameter of physical workloads should be set to more than 20. On the other hand, the weight parameter should be set to less than 10 if the reduction of differences in mental workloads is recognized as important by the facility staff members.

6. Designs for actual staff shift patterns in the surveyed facility

6.1 Input data according to survey for actual staff shifts

In the previous section 5, the impacts of considering physical/mental workloads simultaneously were discussed for a small instance involving two functional training experts to valid prioritizing each weight parameter in the objective function. This also exists for other shift types with an increased number of staff members and for different staff roles in the surveyed facility. Thus, this section plans a larger case based on the actual staff shifts in the surveyed daytime care facility for one month (Table 3).

Table 3 shows the actual shift in the surveyed daytime care facility for one month (20 working days). These actual shifts for 20 days were obtained by visiting and surveying the actual facility. Twenty working days of staff shifts are classified into three patterns. It is observed that the difference among the shift patterns are only a number of care workers (CW), and the number of other roles is the same. Moreover, the sum of pattern 1 (6 staff) and pattern 2 (5 staff) was 19 days, and it occupied 95% of all staff shifts. Thus, the three patterns of the actual shift described in Table 3 are considered here to obtain practical schedules based on the actual cases. It was assumed that the duration for each service, $z_k$, was doubled with respect to the current schedule, since the number of staff members increased. Moreover, to determine whether the workload results of the schedules among multiple staff members were balanced or not, standard deviation (SD) for workloads and working time was used here.

| Role                  | Pattern 1 (6 staff) | Pattern 2 (5 staff) | Pattern 3 (4 staff) | Total |
|-----------------------|---------------------|---------------------|---------------------|-------|
| Functional training expert (FT) | 1                   | 1                   | 1                   |       |
| Nurse (Ns)            | 1                   | 1                   | 1                   |       |
| Care worker (CW)      | 4                   | 3                   | 2                   |       |
| Number of observed shift pattern | 10 days             | 9 days              | 1 day               | 20 days |
| Observed ratio for each shift pattern | 50%                 | 45%                 | 5%                  | 100%  |

6.2 Analysis of workloads and offering time for each staff

Figures 6-8 show the results of physical and mental workloads in the planned schedules with three shift patterns. Each figure indicates both types of workloads and service provision time for each staff member, and the differences among them by SD. Low values are preferred for SD of differences in both types of workloads, and service provisioning time, which indicates balancing. The balancing schedules are obtained for both types of workloads, even the actual cases. On the other hand, considering Figs. 6 to 8, the SD of total workloads is the highest at pattern 1, with 6 staff members, where the number of staff members is the largest among all the patterns. Regarding physical and mental workloads, it was noted that it might be difficult to balance the workloads for large number of staff because it will be more complex to plan the staff schedule considering the workloads and working time simultaneously.
Fig. 6 Results of workloads and SD of differences in both workloads among staff in pattern 1: 6 staff

Fig. 7 Results of workloads and SD of differences in both workloads among staff in pattern 2: 5 staff

Fig. 8 Results of workloads and SD of differences in both workloads among staff in pattern 3: 4 staff

Note: FT, CW and Ns means a functional training expert, a care worker and a nurse, respectively.
Pattern 1 (6 staff)

Staff A (FT)  Staff B (CW)  Staff C (CW)  Staff D (CW)  Staff E (CW)  Staff F (Ns)

Fig. 9 Results of working time for each staff in pattern 1: 6 staff

Pattern 2 (5 staff)

Staff A (FT)  Staff B (CW)  Staff C (CW)  Staff D (CW)  Staff E (Ns)

Fig. 10 Results of working time for each staff in pattern 2: 5 staff

Pattern 3 (4 staff)

Staff A (FT)  Staff B (CW)  Staff C (CW)  Staff D (Ns)

Fig. 11 Results of working time for each staff in pattern 3: 4 staff

Note: FT, CW and Ns means a functional training expert, a care worker and a nurse, respectively.
Figures 9-11 show the results of working time for each staff with three shift patterns. The SD of working time in pattern 3 is more than 9, which can be explained from the detailed results of the working time for each staff member (Fig. 9). In this experiment, nurses cannot offer the mattress service because they do not have the required qualifications. The physical and mental workloads of the mattress service are higher than the average points of all services according to the workloads survey in section 4.2 (Fig. 1). Thus, to balance the two types of workloads among multiple staff members, assignments of low workloads such as table or pulley service with a longer time for nurses are needed in pattern 3. As the results indicate, the SD of working time became significantly large but workload balancing was achieved in pattern 3. Moreover, the bars service, which has the highest workload among all services, excluding the mattress, was assigned to nurses in all patterns.

As the characteristic of FT and CW, both types of staff can offer all services, including mattress, in the facility because of their qualifications. However, in the results of pattern 1 with 6 staff members in Fig. 6, staff B (CW) was assigned to a mattress service for only 10 min. These assignments revealed that the role of CW is not required for Staff B if the mattress assignment is moved to other staff members. Accordingly, although the balance of workloads may be biased towards other staff, staff shifts can decrease the number of qualified staff while workloads are almost balanced. Therefore, replacing qualified and normal staff helps the facility since most of the facility is facing limited human resources.

On the other hand, we could illustrate that balancing physical and mental workloads was approximately achieved, even in cases with increased staff members. This is because all the SDs of workloads are less than 8.0 for all patterns. Moreover, although these cases considered multiple staff roles, such as functional training experts, care workers, and nurses in the planned schedule, the balancing workloads were conducted as described above. Thus, the proposed scheduling procedure is useful and practical for the facility schedule since it could be adapted not only to small instance cases, but also to actual shift patterns in the daytime facility.

7. Conclusions

This study proposed the staff scheduling model considering physical and mental workloads, as well as staff movement. To illustrate the usefulness of the proposed model, numerical experiments were conducted to plan the balancing schedule for both types of workloads, and were compared with other planned schedules including current ones. Moreover, additional experiments were conducted with some scenarios and a larger case based on an actual shift surveyed. The main conclusions are as follows:

- One of our contributions is that staff members can recognize both types of workloads for each service quantitatively and manage themselves based on the results. The workloads survey including the questionnaire and interview revealed that there were differences between the physical and mental workloads for the services provided, except for the pulley. Thus, the schedule planner should consider both types of workloads simultaneously, otherwise, differences between either staff workload may become very large in the planned schedule.

- In the numerical experiment with two functional training experts, the physical and mental workload balancing was achieved at the same time. Moreover, the number of staff movements were reduced by adding the movements constraint proposed by this study. The benefit of our model is illustrated in these results compared to the previous studies by Matsumoto et al. (2018, 2019, 2020).

- To observe the relationship between both types of workloads and staff movements, and also to obtain more practical results which satisfy all the demands of these components, a sensitivity analysis by the weight parameters among physical/mental workloads and staff movements were conducted in the experiment. It was considered that the two obtained schedules could be practical for different purposes in the actual facility by coordinating the weight parameters.

- The staff schedules were designed based on the actual shift in the surveyed daytime care facility. This experiment showed that the differences of all SDs in workloads were smaller in all shift cases. Our model could be adapted to an actual case with multiple staff members and staff roles. Thus, our model can bring contributions above even in the actual shifts.

In the future works, the usefulness of our model should be discussed by conducting numerical experiments with other input data on the duration of service. In this study, section 4.2 revealed that physical/mental workloads depended on not
only service types but also staff members. Thus, the individual differences should be considered by using $p_{ik}$ and $s_{ik}$ instead of $p_k$ and $s_k$. If this scheduling procedure is adopted into the facility where there are differences in consecutive offering time for each service, it would need to be considered by setting a different time slot for each service.

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