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Multi-goal Rehabilitation Layout Planning for Total Flow of Staffs and Remoteness of Equipment in Elderly Daytime Care Service

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Abstract

The demand for elderly care services has increased owing to the aging society. Daytime care facilities provide rehabilitation services to the elderly, such as massage and training, which use machines. In these facilities, rehabilitation equipment is used by staff to take care and assist the elderly, particularly in walkable activities. Accordingly, the service productivity of the staffs can be improved by reducing the total flow. The total flow among the staffs can be reduced by placing the equipment closer. However, equipment should be placed separately to avoid injuries caused by tripping on the rehabilitation equipment. Therefore, two goals should be considered for minimizing the total flow of the staff and maximizing the remoteness of equipment. This paper proposes a layout planning business model in a daytime care service for rehabilitation equipment with the two goals for the total flow of the staff and the remoteness of equipment by the quadratic assignment problem (QAP). First, the QAP problem is formulated to integrate the minimization of the total flow and maximization of the value of remoteness by weighting. Next, an actual rehabilitation facility and its staff are surveyed. Finally, numerical experiments are conducted, and the effects of the total flow and remoteness of the equipment are discussed.

Keywords: Elderly Care Service, Quadratic Assignment Problem, Rehabilitation Equipment, Multi-Objective, Healthcare Business

1 Introduction

Japan and other developed countries have serious concerns about an aging society [1]. Almost all Japanese citizens can receive healthcare services, such as medical and rehabilitation services. When they receive these services, they pay only a part of the costs because all Japanese citizens must join the national public insurance, and the government pays the rest of the costs. The government manages financial resources, especially social security costs, to provide healthcare services to citizens at a low cost. Therefore, insurance and government taxes cover a large part of

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the cost. As the number of elderly people increases, the demand for senior care services also increases, thereby increasing the social security costs that fund these services [1]. In Japan, daytime care facilities provide rehabilitation services during the daytime for elderly users [2]. Rehabilitation eases the effects of aging and prevents the worsening of the elderly body functions. In addition, the social security cost can be reduced by providing rehabilitation services because the costs are restrained by maintaining the elderly body functions. As such, these facilities mainly provide rehabilitation services for physical functions. Daytime care facilities play an important role in the elderly population.

In daytime care facilities, care staff have many tasks, such as providing walking assistance and massage for elderly users. However, staff productivity should be improved to prevent security costs increased while maintaining a certain quality of service. Hence, it is necessary to analyze and improve the existing levels of productivity in elderly care services. These facilities have various types of rehabilitation equipment, and their production types are similar to those of job shop production [3]. In the job shop type, multiple machines and process jobs consisting of a series of operations must be performed in a specific order [3]. To improve staff productivity, healthcare facilities, such as hospitals, have been managed. For instance, in the field of industrial engineering (IE), Deb et al. [4][5] performed simulations to reduce resource costs by introducing alarm fatigue [6], scheduled bed demands for patients [7], and proposed plans to minimize either the number of patients' demands or the costs of installing fixed patient rooms [8]. Regarding daytime nursing homes in Japan, Takanokura et al. [9] recorded the staff's tasks and analyzed them in terms of the amount of time required to complete a certain task. The tasks were quantitatively analyzed using an activity meter attached to the care staff to measure the workload of tasks. However, there are a few studies using the IE for healthcare facilities. Moreover, these staffs are not familiar with improving productivity and IE. Therefore, it is difficult to propose the layout that they cannot consider by only their experience.

Regarding layout planning, Karube et al. [10] proposed a survey and analysis method for layout planning that was based on trial and error to reduce the total walking steps of staffs in daytime care facilities. The layout aspect calls to appropriately arrange or rearrange departmental and human resources in the facility while considering the constraints of the facility [11]. Therefore, the productivity of a job shop can be improved by locating related work areas closer because the staff have various tasks to complete. With respect to layout in factories, their objective function is based on minimizing the total cost of moving materials. Yamada et al. [12] proposed a design that considered the aisle structure and interdepartmental material flow. In the design, the transportation cost and size of the aisle area were minimized. Suzuki et al. [13] proposed an aisle design that considered material handling aisles. Karube et al. [14] proposed an elderly care layout design for the quadratic assignment problem (QAP) to minimize the total flow for care staff in elderly care facilities.

For layout planning models, the QAP is used as a mathematical programming method [15]. Heuristic algorithms have also been researched to solve combinatorial optimization problems [16] that combine computer-aided approaches for multi-goal optimization [17] or present a model layout of the user interface components that handle many qualitative factors [18]. Some studies that deal with the QAP handle multiple objectives, such as qualitative and quantitative factors. Fortenberry and Cox [19] focused on the flow cost and closeness relationship rate and minimized the sum of both costs. Urban [20] assigned weights to the closeness relationship rate. Peer and Sharama [21] assigned a weight that divided each relationship value by the sum of all relationship values. To minimize the sum of the flow cost and closeness relationship ratings, the departments may be placed closely. However, these methods are not suitable for applications in healthcare facilities, such as daytime care facilities. This is because equipment is placed away to prevent the risk of injuries due to tripping on the rehabilitation equipment. In addition, it is necessary to separate each rehabilitation equipment as much as possible because elderly users are easy to rehabilitate and feel comfortable when the other users and equipment are far from each other. According to [19][20], the closeness relationship is classified into six types based on importance and value. These studies considered that some equipment should be closer, but equipment in daytime care facilities should not be placed close together because there is a high injury risk for elderly users. The remoteness of equipment is necessary to separate them though Karube et al. [22] proposed an elderly care layout design problem for the QAP to minimize the total flow of staff in elderly care facilities.

This paper proposes a layout planning business model in a daytime care service for rehabilitation equipment with two goals on the total flow of staffs and the remoteness of equipment by a QAP that minimizes the total flow of the staff to maximize the value of remoteness. It also designs a feasible layout for daytime healthcare facilities that considers rehabilitation equipment proximity constraints. The novelty of this paper is that it enables us to reduce the total flow, which is convenience for the staff, and to isolate devices from the viewpoint of safety simultaneously by defining a multi-objective optimization problem. Another novelty is that this study formulates the optimization problem and verifies it using real data. This paper has a great social contribution to these phenomena, because in recent years, aging has occurred in Japan, and a similar trend can also be seen worldwide. The potential of this paper is that the model can be used not only for rehabilitation but also for more general placement problems, and has great academic significance The remaining of this paper is organized as follows: Section 2 explains the proposed model for the two goals, i.e., minimizing the total flow and maximizing the value of remoteness. In addition, the remoteness of the equipment is defined. Section 3 outlines the daytime facility surveyed as an example problem. Section 4 validates the effects of each single objective for the total flow and remoteness by comparing the layouts. After that, the numerical experiments are conducted performed with multi-goal by weighting the total flow and remoteness. Finally, section 5 concludes the paper and proposes future research directions.

2 Methodology

2.1 Notation and Assumptions

This section explains the layout design model focused on minimizing the total flow of staff. The QAP has not been discussed for daytime care facilities in [14]. Figure 1 shows the layout design model used in this study. In the daytime care facility, care staffs assist elderly users and encourage them to walk around the rehabilitation equipment. Some types of rehabilitation equipment include cycles, stretch machines, and mattresses. Elderly users access rehabilitation equipment, and care staffs support them.

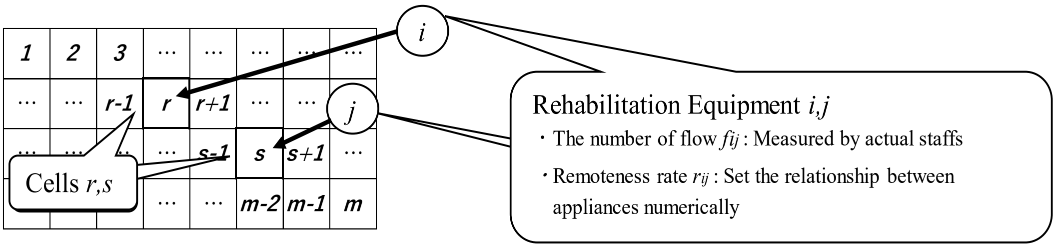

Figure 1: Facility layout model divided with cells

Similar to [14][22], the floor area in this model is divided into cells. Rehabilitation equipment used by elderly users to maintain physical functions is placed in these cells. The set of cells is denoted by M, whereas the set of rehabilitation equipment is defined by N. The cells are denoted by r and s, such that $\forall r, s \in M$, and the rehabilitation equipment are indicated by i and j, such that $\forall i, j \in N$. The work flows between rehabilitation equipment i and j, which indicate the number of movements between the equipment, are shown as r_{ij}. The distance between cells r and s is denoted as a d_{rs} meter. The distance d_{rs} is measured as the Manhattan distance of the facility model.

Furthermore, the assumptions prepare for this model are as follows:

- Though the daytime care facility has a rehabilitation room and an office, this study focuses only on the rehabilitation room.
- The facility can easily rearrange its layout.
- For minimization of total flow by staff, the distance between each rehabilitation equipment is reduced.
- There is no prior relationship when elderly users access rehabilitation equipment in a daytime care facility.
- The number of movements is assumed to be taken and independent of the rehabilitation equipment location.
- The distance between cells is independent of the other cells or equipment. In addition, when equipment is located on a route travelled by care staffs, it does not interfere with or influence the movement.
- The distance between neighboring cells is unity.
- When a diagonal movement is taken, two steps are counted for one vertical and one horizontal one based on the Manhattan distance.
- Dummy rehabilitation equipment with no flow is assumed. This is because all rehabilitation equipment will not be placed in all cells.
- Each cell has as an area of enough space containing the pathway to move to the equipment and to use equipment.

- Some equipment, such as toilets and poles, cannot be moved. This is because this equipment depends on the facility.

A summary of the notation in this study is presented below:

i, j	:	Rehabilitation equipment number to be set in the facility
r, s	:	Cell number where the rehabilitation equipment is placed
f_{ij}	:	The number of flows between rehabilitation equipment *i* and *j*
r_{ij}	:	Remoteness relationship rate between rehabilitation equipment *i* and *j*
d_{rs}	:	Distance from cell *r* to cell *s*
W	:	The weight parameter for total flow and remoteness
M	:	Set of cells $m \in M$
N	:	Set of rehabilitation equipment $n \in N$
N_{move}	:	Set of replacing rehabilitation equipment
N_{static}	:	Set of not replacing rehabilitation equipment $N = \{ N_{\text{move}} \cup N_{\text{static}} \}$, where $N_{\text{move}} \cap N_{\text{static}} = \varphi$
x_{ir}	:	Binary decision variable for the equipment from which the staff depart: 1, if rehabilitation equipment *i* assigned to cell *r* 0, otherwise
x_{js}	:	Binary decision variable for the equipment from which the staff arrival: 1, if rehabilitation equipment *j* assigned to cell *s* 0, otherwise
a_{ir}	:	Parameter of replacing or not replacing cells: 1, if rehabilitation *i* is placed in cell *r* in the default layout 0, otherwise

2.2 Objective Functions

Based on [22], this study proposes a model for two goals rehabilitation equipment layouts in daytime care facilities for minimizing the total flow of staffs to improve productivity, as shown in Eq. (1), and maximizing the total remoteness to prevent the risk of injuries, as shown in Eq. (2). Thus, we define the remoteness relationship rate $r_{i,j}$ between rehabilitation equipment *i* and *j*, which indicates the necessity of separating each piece of equipment.

Objectives:

$$\sum_{i \in N} \sum_{j \in N} \sum_{r \in M} \sum_{s \in M} f_{ij} d_{rs} x_{ir} x_{js} \rightarrow Min \quad (1)$$

$$\sum_{i \in N} \sum_{j \in N} \sum_{r \in M} \sum_{s \in M} r_{ij} d_{rs} x_{ir} x_{js} \rightarrow Max \quad (2)$$

subject to

$$\sum_{i \in N} x_{ir} = 1 \qquad \forall\, r \in M \quad (3)$$

$$\sum_{r \in M} x_{ir} = 1 \qquad \forall\, i \in N \quad (4)$$

$$f_{ij} = 0 \qquad \text{if } m > n \text{ and } \{(i > n) \;\; or \;\; (j > n)\} \quad (5)$$

$$x_{ir} = a_{ir} \qquad \forall\, i \in N_{\text{static}}, \forall\, r \in M \quad (6)$$

$$x_{ir}, x_{js} = \{0, 1\} \qquad \forall\, i, j \in N, \forall r, s \in M \quad (7)$$

Eq. (3) indicates that only rehabilitation equipment can be placed at a cell. In addition, several pieces of equipment cannot be placed in the same cell. Eq. (4) means that the rehabilitation equipment must be placed in any cell. Eq. (5) introduces dummy rehabilitation equipment when the number of candidate cells for the rehabilitation equipment is greater than that of the rehabilitation equipment [23]. The dummy equipment has no work flow with other equipment. Eq. (6) shows some equipment already placed in the initial layout. Therefore, some equipment, such as toilets and poles, cannot be moved. Eq. (7) ensures that x_{ir} and x_{js} are binary decision variables.

To simultaneously satisfy both goals in the layout planning, as well as those in [20][21][24][25], this study defines a multi-goal function as Eq. (8) by combining Eqs. (1) and (2) the weight W is set for the flow and remoteness objective functions in Eq. (9).

$$\sum_{i\in N}\sum_{j\in N}\sum_{r\in M}\sum_{s\in M}\{Wf_{ij}-(1-W)r_{ij}\}d_{rs}x_{ir}x_{js} \rightarrow Min \quad (8)$$

subject to

$$0 \leq W \leq 1 \quad (9)$$

2.3 Remoteness Relationship for Rehabilitation Equipment

The following classification is adapted in this study to apply the remoteness relationship to daytime care facilities.

The removal relationship rate r_{ij} between rehabilitation equipment i and j, and the rate and classification are given as follows:

A (r_{ij} = 5)	:	Absolutely necessary to separate each equipment
E (r_{ij} = 3)	:	Especially important to separate each equipment
I (r_{ij} = 1)	:	Important to separate each equipment
O (r_{ij} = 0)	:	Ordinary remoteness

3 Example of the Layout Problem

3.1 Rehabilitation Facility and Staff Surveyed

This section describes staff data from an actual daytime care facility [10][14] and experimental prerequisite based on the model formulated in Section 2. The surveyed facility, whose information is summarized in Table 1, provides rehabilitation services such as massage and physical training in order to maintain and improve elderly users' physical function. When the elderly users use a machine, or are given massages, the care staff has to assist them. They can receive half-day services. The staff picks up the elderly users by cars and they also return home by cars that care staffs drive.

Table 1 also shows the detailed information of the targeted daytime care facility including the capacity of the facility, service contents and staff breakdown. The services are provided mainly by the staff and the nurse. Each staff is tasked with up to five elderly users.

Table 2 shows the targeted staff information in this analysis. In order to consider different layout designs in terms of staff movement, this study focuses on two functional trainers as the same type of staff in the facility.

Table 3 shows the existing rehabilitation and other equipment in the facility. There are equipment of name, elderly users' purpose and staffs' tasks. Elderly users use equipment for their purpose, and they walk around the facility to access. The staffs also walk between equipment and support the elderly users. It is found that there is no equipment that the elderly users can use it by themselves without the staffs. Therefore, the staff must monitor or assist them during rehabilitation.

Tables 4 and 5 show the from–to charts for staffs A and B, which show the number of movements between the equipment. For example, staff B moved 12 times between the table and counter, as shown in Table 5.

Table 6 shows the remoteness relationship type between the equipment defined in this study. For example, the mattress must be set away from the cycle and machine because of the type A remoteness ($r_{ij} = 5$). The mattress may cause accidents for elderly users particularly when getting up from the mattress.

Table 1: Daytime care facility information

Type of facility	Daytime care facility
Capacity	・A maximum of 25 users and a minimum of 15 users. ・Around 20 users on average.
Services offered	・Rehabilitation equipment, such as stationary bicycles for leg training and other machines for maintaining physical function. ・Massages are serviced on mattresses by functional trainers.
Facility staff	・Care staff (functional trainers) ・Nurse ・Driver (They transport the elderly users.)

Table 2: Staff information

Staff group	Classification	Tasks
Staff A	Manager (Functional trainer)	・His primary tasks are to massage the elderly users and to assist them when they are using the equipment. ・As the facility manager, he is tasked with contacting elderly users and performing emergency duties. ・He also serves as a backup driver.
Staff B	Functional trainer	・Staff B has less urgent tasks than ones by staff A, and he mainly provide massages. ・He also serves as backup drivers.

Table 3: Rehabilitation equipment and others equipment in the facility

Type of equipment	Name of equipment	Purpose for elderly users	Staffs tasks
Rehabilitation	Mattress	Loosening massages. The elderly users' body is stretched by the staff.	Provide massages on mattress.
	Stationary Bicycle	Enhancing lower limb muscles through cycling and range of motion training.	Assist the elderly users by attaching the pedals and managing time.
	Machine	Performing physical functions.	Assist the elderly users by helping them for preparation and by managing time.

	Handicap bars	Aiding elderly users to walk and train.	Assist the elderly users to use the bars.
Others	Counter	No purpose for elderly users.	Perform general office and administration work including contacting elderly users.
	Toilets A and B	Relieving themselves.	Assist elderly users to go to the restrooms and to return.
	Table	Taking a break and talking to other elderly users while awaiting services or equipment.	Talk with the elderly users and help them to go to the mattress.

Table 4: The sum of flow each equipment for staff A

Equipment	Mattress	Cycle	Machine	Table	Counter	Toilet A	Toilet B	Bars
Mattress								
Cycle	0							
Machine	2	0						
Table	2	0	2					
Counter	4	1	3	22				
Toilet A	0	1	3	4	2			
Toilet B	0	0	0	0	0	0		
Bars	1	0	2	4	13	3	0	

Table 5: The sum of flow each equipment for staff B

Equipment	Mattress	Cycle	Machine	Table	Counter	Toilet A	Toilet B	Bars
Mattress								
Cycle	0							
Machine	0	0						
Table	6	0	0					
Counter	0	0	0	12				
Toilet A	0	0	0	8	4			
Toilet B	0	0	0	2	1	2		
Bars	1	0	0	0	0	1	0	

Table 6: Remoteness type of rehabilitation equipment [22]

r_{ij}	Mattress	Cycle	Machine	Table	Counter	Toilet A	Toilet B	Bars
Mattress								
Cycle	A							
Machine	A	O						
Table	O	E	E					
Counter	O	I	I	O				
Toilet A	O	O	O	O	O			
Toilet B	O	O	O	O	O	O		
Bars	O	E	E	O	O	O	O	

3.2 Layout, Equipment, and Staff Environments Analyzed

This study considers possible rearrangement layouts from the current and initial layouts, as shown in Figure 2 [10]. However, certain equipment cannot be moved, such as counters, toilets, and poles. For example, the poles are already set and are not used for rehabilitation. Other equipment, such as the mattress, cycle, machine, table, and bars, can be moved to other cells. Therefore, the number of equipment $n = 5$ and the number of cells $m = 21$ are considered in the experiments. The assumptions in this facility are set as follows:

- Two functional trainers are targeted as staffs in this study.
- Five types of equipment, i.e., mats, machines, cycles, bars, and tables, are shown in Figure 2.
- The daytime care facility is separated by 25 cells and numbered, as shown in Figure 3.

	Cycle			
Mattress		Bar		Machine
Pole				
Toilet A		Table		
Toilet B			Counter	

Figure 2: Current layout in the daytime care facility [10]

#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

Figure 3: Separated and numbered cells in the daytime care facility [14]

4 Results

4.1 Minimizing the Total Flow vs. Maximizing the Value of Remoteness

To discuss the effectiveness of the remoteness objective function, this section compares the results of the layout designed by two conflicting objectives for minimizing the total flow (*W*=1) or maximizing the remoteness (*W*=0). For the comparison, the results of the layout designed by minimizing the total flow only were used in the previous study [14].

Table 7 shows the results for minimizing the total flow of staff and maximizing the value of remoteness. Staff A or B in Table 7 indicates the result for the total work flow or remoteness focused on only the staff to discuss the difference in staff. Staff A and B are the minimization or maximization of the sum of values by staff A and B for each objective function. The results show that the value for minimizing the sum of the total flow for staff A and B reduced by 52.2% compared with the result of staff A and by 36.7% compared with the result of staff B.

Next, in terms of minimizing the sum of multiple staff, the total remoteness is discussed because the number of equipment should be set closer. Regarding the layout for maximizing the total remoteness, the value of remoteness increased by 105% compared with that of the current layout. This layout minimizes the total flow of the staff. However, such a layout is not comfortable for elderly users because the equipment was set closer to the other equipment and was crowded, as shown in Figure 4.

Conversely, the total flow for the coexistence of staff A and B increased by 46.3% as compared to that in the current layout shown in Table 7. The total flow of staff A increased by 50.9% as compared to that in the current layout. In the same case, the value of the total flow increased by 32.1% for staff B. The number of movement of staff A and B have respective 69 or 37 times. higher than that of staff B, because Staff A moved more frequently. Therefore, the layout design deals with multiple staff and is influenced by a staff member who has a large number of movements, which reduces the total flow cost.

Table 7: Results for minimizing the total flow and maximizing the value of remoteness

<table>
<tr><th colspan="2"></th><th colspan="4">Proposed Model</th><th colspan="4">Karube *et.al* (2021)[14]</th><th colspan="2">Karube *et.al* (2017)[10]</th></tr>
<tr><th colspan="2"></th><th colspan="2">Maximizing the value of remoteness</th><th colspan="2">Defference form current layout [%]</th><th colspan="2">Minimizing the total flow of staff</th><th colspan="2">Defference form current layout [%]</th><th colspan="2">Current layout</th></tr>
<tr><th colspan="2"></th><th>Total flow</th><th>Remoteness</th><th>Total flow</th><th>Remoteness</th><th>Total flow</th><th>Remoteness</th><th>Total flow</th><th>Remoteness</th><th>Total flow</th><th>Remoteness</th></tr>
<tr><td colspan="2">Staff A</td><td>341</td><td rowspan="3">312</td><td>-50.9</td><td rowspan="3">105</td><td>108</td><td>116</td><td>52.2</td><td>23.7</td><td>226</td><td rowspan="3">152</td></tr>
<tr><td colspan="2">Staff B</td><td>144</td><td>-32.1</td><td>69</td><td>180</td><td>36.7</td><td>-118</td><td>109</td></tr>
<tr><td>Staff A&B</td><td>Staff A
Staff B</td><td>485</td><td>-33.7</td><td>180</td><td>88</td><td>46.3</td><td>42.1</td><td>335</td></tr>
</table>

Mattress	Table			
Bar				
Pole				
Toilet A				Machine
Toilet B			Counter	Cycle

Figure 4: Results of the layout for maximizing remoteness

4.2 Design Example by Multi-goal with Minimizing the Total Flow and Maximizing Remoteness

This Section 4.2 considers combining the two objective functions of minimizing the total flow and maximizing the remoteness via weighting. Figure 5 shows the designed sample layout by combining the bi-objective functions by weighting for the total flow and remoteness. Rehabilitation equipment were divided for 2 groups, where one has machine and cycle set neighbor and the other has bars, mattress and table set neighbor. Moreover, the mattress was placed near table and bars. The number of movements between the mattress and table is 8 times, which represents 7.55% of total number of movements as shown in Table 8. The elderly users who stay at the table often take a tea and talk with the other elderly users and staffs because they wait for receiving massage and take a break after the rehabilitation. This reason is that the waiting time occurred for the receiving massage because a staff has to serve one by one for massage. Additionally, the table was placed near bars. The number of movements between the bar and table is 7 times, which represents 3.77% of total number of movements. In rehabilitation at the bar, multiple users train at the same time. When the elderly users rehabilitate at the bar, the staffs call for the elderly users to encourage starting the training. Therefore, it is effective to place the table and bar closer.

Table 8 shows a comparison for the results of the current sample layout and the maximized remoteness layout. The layout for the two objective functions increased by 103% in terms of the remoteness as compared to the current layout and decreased by 27.5% in terms of the total flow for staff B. In addition, the total flow reduced by 31.5% as compared to the results of the layout that maximizes the remoteness. However, the remoteness decreased by only 1.28%. Therefore, the layout was considered with the total flow and remoteness by considering the bi-objective functions.

Cycle				
Machine				
Pole				
Toilet A			Bar	
Toilet B		Table	Counter	Mattress

Figure 5: Designed sample layout by combining the bi-objective functions in weighting the total flow and remoteness

Table 8: Comparison of the results of the current sample layout and maximized remoteness layout

		The sample layout for bi-objective function		Defference form current layout [%]		Current layout		Diiference from the result of maximizing remoteness [%]		Maximizing the remoteness	
		Total flow	Remoteness	Total flow	Remoteness	Total flow	Remoteness	Total flow	Remoteness	Total flow	Remoteness
Staff A		150	308	33.6	103	226	152	33.7	-1.28	341	312
Staff B		78		27.5		109		24.3		144	
Staff A&B	Staff A Staff B	228		31.5		335		30.9		485	

4.3 Result of layout with multi-goal by the flow of staffs and remoteness of equipment

In order to integrate the both objective functions for minimizing the total flow and maximizing the remoteness, this section explains the result of multi-goal consisting of the total flow and the value of remoteness as Eq. (8) given in Section 2.2. The result focuses on the staff A, B and both of them by changing the weight W.

(1) The result of the sum of the total flow and remoteness for both staffs considered multi-goal by changing the weight W: staff A and B

To treat the multi-goal with the flow of staffs and remoteness of equipment, the weight W is introduced based on [21][24]. The trend of changing the weight W between the total flow and the total remoteness for equipment is considered to decide the weight W when the layout is designed. Figure 6 shows the total value of bi-objective function for the total flow and value of remoteness by each weight W. When the weight W becomes higher, the total value of bi-objective function is monotonically increased. When the value of bi-objective function becomes higher, it is found that the priority between the objective functions is given to minimize total flow in the experiments.

Figure 7 shows the result of the total flow for the weight W for staff A and B. In the Figure 7, the line graph shows the total flow of staffs by each weight W. When the weight W becomes higher, the value of total flow becomes also higher. By comparing with the W=0.2 and W=0.4, the value of total flow is reduced by 47.0% because lowering the value of total flow brings higher priority in this range of the weight W. The values of flow and remoteness become 106 and 48, respectively. The inverse ratio of these values is 0.31 and 0.69. Therefore, when the weight sets the inverse ratio, W = 0.31, the value of total flow is reduced.

On the other hand, the line graph means the values of the remoteness equipment for the weight W as shown in Figure 8. When the flow weight W becomes higher, the value of the remoteness equipment becomes lower because the equipment is set neighbor. When the weight W is changed from 0.6 to 0.8, the value of remoteness equipment is reduced by 31.2%. When the value W is changed from 0.8 to 0.10, the remoteness was reduced by 58.5%. However, when the weight W was between 0 and 0.6, the remoteness was reduced by only 1.1%. In considering the result of the total flow and remoteness equipment, the weight W range should be set between 0.4 and 0.6 in this case.

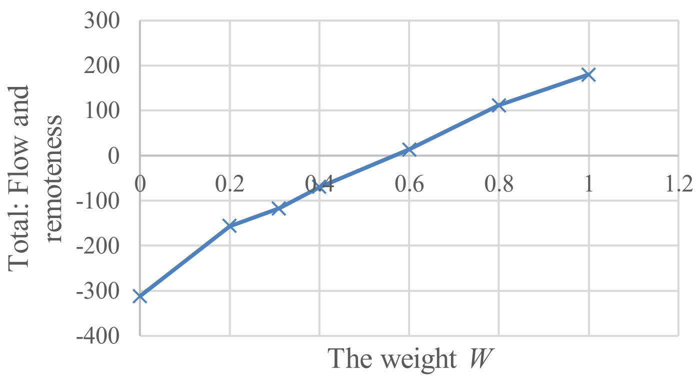

Figure 6: The result of the total flow and remoteness for the weight W: staff A and B

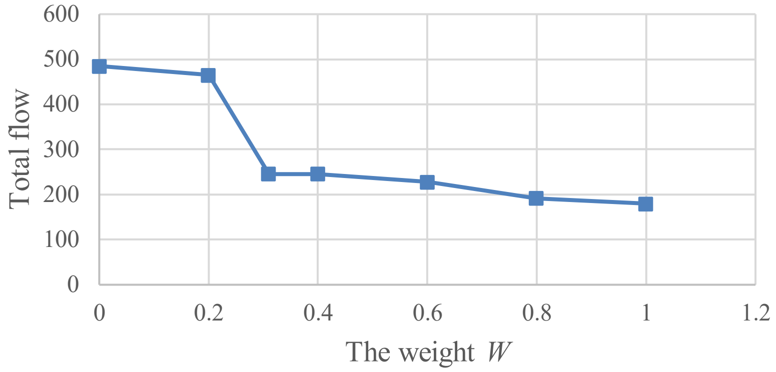

Figure 7: The result of the total flow for the weight *W*: staff A and B

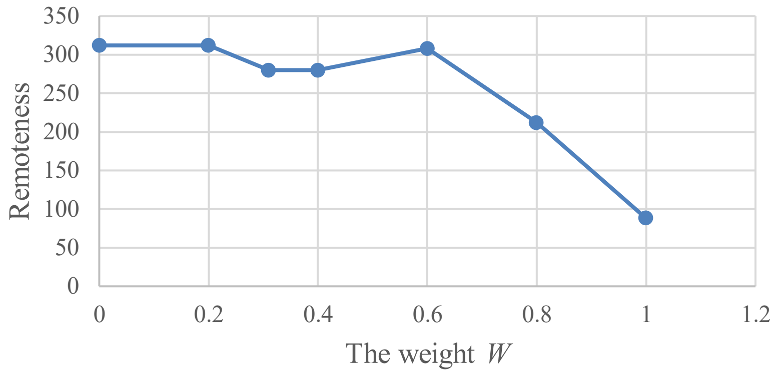

Figure 8: The result of the value of remoteness for the weight *W*: staff A and B

(2) The result of layout for both staffs considered multi-goal by changing the weight *W*: staff A and B

In this section, the result of layout with considering multi-goal for both staffs is discussed. Figures 9, 10, 11, 12 and 13 show the result of the layouts for each weight *W*, respectively. In these layouts, rehabilitation equipment are divided for 2 groups, where one has machine and cycle set neighbor and the other has bars, mattress and table set neighbor. One of the reasons is that this equipment have remoteness rate O whose value is $r_{ij} = 0$. It is said that the value is not affected for the value of total remoteness. However, these equipment in the group are placed away since the machine and mattress have remoteness rate A as $r_{ij} = 5$. Additionally, this equipment have higher frequencies flows to reach the table such as 2 and 8 times. Therefore, the equipment are set closer by that the counter was changed, so that it was affected for the value of total flow.

The number of movements between the machine, cycle and counter is 4 times while the number of movements between the table, bar and counter is 51 times. When the weight *W* is 0.2, the value of total flow becomes 317. On the other hand, when the weight *W* is 0.4, the total flow became 98 so that the value is reduced by 69.1%. In compared the resulted layout with the weight *W* from 0.2 to 0.4, the equipment placed near the counter was changed from the machine and cycles to the table and bar. This reason is that the equipment near the counter, which had the highest number of movements, was changed.

All the equipment were placed next to the counter to minimize the total flow. However, not all the equipment can be placed close together because the layout considered for the bi-objective functions. Therefore, the layout was changed by gathering some equipment. These groups were separated to reduce the total flow. Hence, it is considered that the specific equipment was placed neighbor the equipment that have a much greater number of movements to manage the bi-objective functions for minimizing the total flow and the maximizing the remoteness. When the weight *W* becomes higher, the group which contained mattress, table and bar set neighbor the counter because this group has more number of movements than one in the other group which contained machine and cycle.

In the Figure 9, the value of remoteness was reduced for between the weight $W = 0.2$ and 0.4, then the value were increased for the weight $W = 0.6$. One of the reasons is the location of the groups of equipment changed. In particular, the group which contained cycle and machine was changed from upper right to upper left coordinates in the facility model as shown in Figures 10 and 11. Since the distance of cycle-counter and machine-counter are 5 and 4 in the weight W=0.4, the distance were changed to respective 7 and 6 in the weight W=0.6. Therefore, the value of remoteness was increased by 2.3%.

Mattress	Bar			
Table				
Pole				
Toilet A				Machine
Toilet B			Counter	Cycle

Figure 9: The result of the layout for the weight $W = 0.2$: Staff A and B

				Cycle
				Machine
Pole				
Toilet A	Bar			
Toilet B	Mattress	Table	Counter	

Figure 10: The result of the layout for the weight $W = 0.4$: Staff A and B

Cycle				
Machine				
Pole				
Toilet A			Bar	
Toilet B		Table	Counter	Mattress

Figure 11: The result of the layout for the weight $W = 0.6$: Staff A and B

Cycle				
Pole				
Toilet A		Machine	Bar	
Toilet B		Table	Counter	Mattress

Figure 12: The result of the layout for the weight $W = 0.8$: Staff A and B

Pole				
Toilet A	Machine	Mattress	Bar	
Toilet B	Cycle	Table	Counter	

Figure 13: The result of the layout for the weight $W = 1.0$: Staff A and B

5 Summary and Future Studies

This study proposed a method to minimize the total flow of the staff and maximize the value of remoteness using the QAP. Then, it designed a feasible layout for daytime healthcare facilities that considered rehabilitation equipment proximity constraints. A summary of this study is as follows:

- Minimizing the total flow of staff and maximizing the value of remoteness have a trade-off relationship because it is desirable for the equipment to be set closer to minimize the total flow, and it should be set separately to maximize the value of remoteness.
- Considering the multi-goal, the rehabilitation equipment has a low remoteness rating when placed together.
- Regarding the layout design for multiple staffs, it was similar to the layout design that a targeted staff who had a greater number of movements. This is because the staff who has greater number of movements are mainly reduced in terms of the total flow.
- When the staffs had small number of movements, the value of remoteness was improved by placing separately some rehabilitation equipment that had less number of movements.
- The facility model has to separate equipment each other for the elderly users to move easily.
- The cells should be defined as the different scale because each equipment have different size.

Further studies should consider the feasibility of the layout as follows:

- This model was not considered for the pathway between equipment. Therefore, it is difficult for the staff and users to move without a pathway in an actual facility. It makes the determination of the location for the equipment difficult.
- In actual cases, the staff movements between equipment have a dependent relationship. For example, the staff pass through the table when moving from the counter to the mattress because the staff also interact with the elderly. Thus, the equipment which have a dependent relationship should be considered.
- It is necessary to increase the number of numerical experiments in other cases such as more facilities, staff and equipment.

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