EPiC Series in Computing
Volume 81, 2022, Pages 385–394
Proceedings of 11th International Congress on Advanced Applied Informatics

Rehabilitation Layout Planning for Elderly Daytime Care Service for Total Flow of Staffs and Remoteness of Equipment

Koki Karube[1*], Hiromasa Ijuin[2], Masato Takanokura[3], Munenori Kakehi[4] and Tetsuo Yamada[5*]
[1] The University of Electro-Communications, Tokyo, Japan
k2140017@edu.cc.uec.ac.jp
[2] The University of Electro-Communications, Tokyo, Japan
hju1n@yahoo.co.jp
[3] Kanagawa University, Kanagawa, Japan
takanokura@kanagawa-u.ac.jp
[4] Fukushima University, Fukushima, Japan
kakehi@sss.fukushima-u.ac.jp
[5] The University of Electro-Communications, Tokyo, Japan
tyamada@uec.ac.jp

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. Two goals are 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.

Key words: Elderly Care Service, Quadratic Assignment Problem, Rehabilitation Equipment, Multi-Goal, Healthcare Business

[*] Corresponding author

1 Introduction

Japan and other developed countries have serious concerns about an aging society (Takanokura et al., 2015). 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 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 (Takanokura et al., 2015). In Japan, daytime care facilities provide rehabilitation services during the daytime for elderly users (Karube et al., 2016). 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 (Salvendy , 1982). In the job shop type, multiple machines and process jobs consisting of a series of operations must be performed in a specific order (Salvendy, 1982). To improve staff productivity, healthcare facilities, such as hospitals, have been managed. For instance, in the field of industrial engineering (IE), Shuchisnigdha and David (2015) and Harper (2002) performed simulations to reduce resource costs by introducing alarm fatigue (Ma & Erik, 2013), scheduled bed demands for patients (Rene & Paulien, 2011), and proposed plans to minimize either the number of patients' demands or the costs of installing fixed patient rooms (Ines & Nickel, 2013). Regarding daytime nursing homes in Japan, Takanokura et al. (2016) 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. It is difficult to propose the layout that they cannot consider by only their experience.

Regarding layout planning, Karube et al. (2017) 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 (James & Alcorn, 1991). 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. (2004) 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. (2007) proposed an aisle design that considered material handling aisles. Karube et al. (2021a) 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 (Francis et al., 1992). Heuristic algorithms have also been researched to solve combinatorial optimization problems (Peng et al., 1996) that combine computer-aided approaches for multi-goal optimization (Khare et al., 2004) or present a model layout of the user interface components that handle many qualitative factors (Peer et al., 2004). Some studies that deal with the QAP handle multiple objectives, such as qualitative and quantitative factors. Fortenberry and Cox (1985) focused on the flow cost and closeness relationship rate and minimized the sum of both costs. Urban (1987) assigned weights to the closeness relationship rate. Peer and Sharama (2008) 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 Urban (1987) and Fortenberry and Cox (1985), 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. Karube et al. (2021b) 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 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 Karube et al. (2021a). 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.

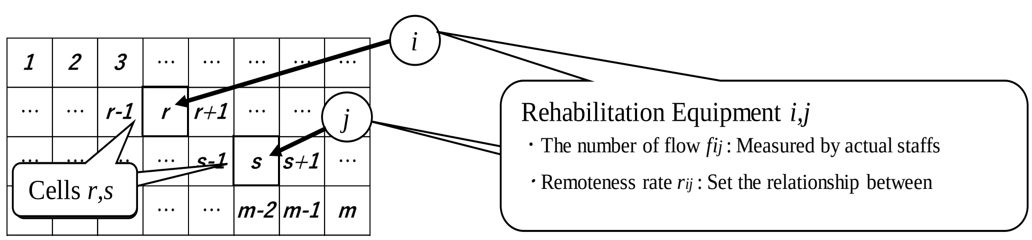

Figure 1: Facility layout model divided with cells

Similar to Karube et al. (2021a, 2021b), 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.
- 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.
- To solve these problems, dummy rehabilitation equipment with no flow is assumed.
- 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 these equipment depend 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 flow 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
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: 1, if rehabilitation equipment i assigned to cell r 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 Function

Based on Karube et al. (2021b), 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.

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

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

subject to

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

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

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

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

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

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. Some equipment, such as toilets and poles, cannot be moved. Eq. (5) introduces dummy rehabilitation equipment when the number of candidate cells for the rehabilitation equipment is greater than that of the rehabilitation equipment (Hillier & Connors, 1966). The dummy equipment has no work flow with other equipment. Eq. (6) shows some equipment already placed in the initial layout. Eq. (7) ensures that x_{ir} is a binary decision variable.

To simultaneously satisfy both goals in the layout planning, as well as those in Rosenblatt (1979), Urban (1987), and Peer and Sharama (2008), 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).

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

subject to

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

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 discusses an experiment conducted based on the model formulated in Section 2 with staff data from an actual daytime care facility. This facility, whose information is summarized in Table 1, provides rehabilitation services, such as massage and physical training, to maintain and improve the elderly's physical functions. When the elderly use a machine or are given massages, the care staff must assist them. This facility provides half-day services. The staff pick up the elderly by car, and they also drive them back home.

Table 1 shows the from–to charts for staff 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 1.

Table 2 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: 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 2: Remoteness type of rehabilitation equipment (Karube et al., 2021b)

r_{ij}	Mattress	Cycle	Machine	Table	Counter	Toilet A	Toilet B	Bars
Mattress		A	A	O	O	O	O	O
Cycle	A		O	E	I	O	O	E
Machine	A	O		E	I	O	O	E
Table	O	E	E		O	O	O	O
Counter	O	I	I	O		O	O	O
Toilet A	O	O	O	O	O		O	O
Toilet B	O	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 (Karube et al., 2017). 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 (Karube et al., 2017)

4 Results

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

To discuss the effectiveness of the new remoteness objective functions, 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 (Karube et al., 2017).

Table 3 shows the results of minimizing the total flow of staff and maximizing the value of remoteness. Staff A or B in Table 3 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, as shown in Figure 3.

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 3. 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 flow of staff A and B was 69 or 37 times higher than that of staff B, respectively. 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 3: Results of minimizing the total flow and maximizing the value of remoteness

	Proposed Model				Karube *et.al* (2017)				Karube *et.al* (2017)	
	Maximizing the value of remoteness		Defference form current layout [%]		Minimizing the total flow of staff		Defference form current layout [%]		Current layout	
	Total flow	Remoteness	Total flow	Remoteness	Total flow	Remoteness	Total flow	Remoteness	Total flow	Remoteness
Staff A	341		-50.9		108	116	52.2	23.7	226	
Staff B	144	312	-32.1	105	69	180	36.7	-118	109	152
Staff A&B (Staff A, Staff B)	485		-33.7		180	88	46.3	42.1	335	

Mattress	Table			
Bar				
Pole				
Toilet A				Machine
Toilet B			Counter	Cycle

Figure 3: Results of the layout for maximizing remoteness

4.2 Design Example by Bi-objective 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. Table 4 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 4: Designed sample layout by combining the bi-objective functions in weighting the total flow and remoteness

Table 4: 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		Diifference 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		33.6		226		33.7		341	
Staff B		78	308	27.5	103	109	152	24.3	-1.28	144	312
Staff A&B	Staff A Staff B	228		31.5		335		30.9		485	

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.

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, making 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 and equipment.

Acknowledgement

The authors would like to express their appreciation to the elderly and healthcare workers at the daytime care facility for their cooperative support and to Dr. Yuki Kinoshita and Mr. Shota Hasegawa for their helpful suggestions in this study. This research was supported by the Japan Society for the Promotion Science (JSPS), Grants-in-Aid for Scientific Research (C), JP19K04915.

References

Bekker, R., Koeleman, P. K. (2011) Scheduling admissions and reducing variability in bed demand. *Health Care Management Science* 14(3): (pp. 1-13).

Deb, S., Claudio D. (2015) Alarm fatigue and its influence on staff performance. *IIE Transactions on Healthcare Systems Engineering* 5(3): (pp. 183-196).

Fortenberry, J. C., Cox, J. F. (1985) Multiple criteria approach to the facilities layout problem. *International Journal of Production Research* 23(4): (pp. 773-782).

Francis, R. L., McGinnis, L. F., White, J. A. (1992) Facility Layout and Location: An Analytical Approach. Pearson(2nd Edition). Prentice Hall: pp. 553-560

Guoxuan, M., Erik, D. (2013) A multilevel integrative approach to hospital case mix and capacity planning. *Compuers & Operations Research* 40(9): (pp. 2198-2207).

Harmonosky, C. M., Tothero G. K. (1992) A multi-factor plant layout methodology. *International Journal of Production Research* 30(8): (pp. 1773-1789).

Harper, P. (2002) A framework for operational modelling of hospital resources. *Health Care Management Science* 5(3): (pp. 165-173).

Hillier, F. S., Connors, M. M. (1966) Quadratic assignment problem algorithms and the location of indivisible facilities. *Management Science* 13(1): (pp. 42-57).

Ines, A. V., Nickel, S. (2013) Multi-period layout planning for hospital wards. *Socio-Economic Planning Sciences* 47: (pp. 220-237).

James, R. W., Alcorn, P. A. (1991) A guide to facilities planning. Prentice Hall

Karube, K., Yamada, T., Takanokura, M., Kakehi, M. (2021a) Layout design of rehabilitation equipment in daytime care facility with observing by staffs, *Journal of Society of Plant Engineers Japan* 32(4):1-11(2021) (in Japanese)

Karube, K., Yamada, T., Takanokura, M., Kakehi, M. (2021b) Rehabilitation layout design problem of remoteness and total flow of staffs in daytime care facilities for elderly people. *In Proceeedings of the Japan Industrial Management Association*, Osaka, Japan (pp. 124-127)

Karube, K., Yamada, T., Takanokura, M., Kakehi, M. (2017) Layout study and analysis method of elderly day care facilities. *Journal of Society of Plant Engineers Japan* 29(3): (pp. 1-13). (in Japanese)

Karube, K., Yamada, T., Takanokura, M., Kakehi, M., Taki, S. (2016) Analysis and improvement plans for rehabilitation schedule and service times: a day care nursing home. In *Proceeedings of the 13th International Conference on Industrial Management*, Hiroshima, Japan: (pp. 382-390).

Khare, V. K., Khare, M. K., Neema, M. L. (2004) Combined computer-aided approach for the facilities design problem and estimation of the distribution parameter in the case of multigoal optimization. *Computers & Industrial Engineering* 14(4): (pp. 465-476).

Peer, S. K., Sharama, D. K. (2008) Human–computer interaction design with multi-goal facilities layout model. *Computers and Mathematics with Applications* 56: (pp. 2164-2174).

Peer, S. K., Sharma, D. K., Ravindranath, K., Naidu, M. M. (2004) Layout design of user interface components with multiple objectives. *Yugoslav Journal of Operations Research* 14: (pp. 171-192).

Peng, T., Huanchen, W., Dongme, Z. (1996) Simulated annealing for the quadratic assignment problem: A further study. *Computers & Industrial Engineering* 31(3/4): (pp. 925-928).

Rosenblatt, M. J. (1979) The facilities layout problem: a multi-goal approach. *International Journal of Production Research* 17(4): (pp. 323-332).

Salvendy, G. (Editor) (1982) Handbook of Industrial Engineering. A Wiley-Interscience Publication: 11.2.8 – 11

Suzuki, H., Tokita, S., Sorimachi, T., Yoshimoto, K. (2007) A layout technique considering material handling aisles. *Journal of the Japan Society of Mechanical Engineers* (C) 73(728): (pp. 1259-1264). (in Japanese)

Takanokura, M., Yamada, T., Kawakami, M., Ishiguro, K., Kakei, M., Muto, T., Taki, S. (2015, March) Issues with healthcare delivery systems in Japan: insurance, services, and facilities for elderly care. In *Proceeedings of Northeast Decision Sciences Institute 2015 Annual Conference*, Cambridge, USA

Takanokura, M., Yamada, T., Kawakami, M., Taki, S., Kakehi, M. (2016) Visualization of a healthcare service by physical activity of workers' tasks at a long-term care nursing home. *Innovation and Supply Chain* 10(2): (pp. 71-77).

Urban, T. L. (1987) A multiple criteria model for the facilities layout problem. *International Journal of Production Research* 25(12): (pp. 1805-1812).

Yamada, T., Irohara, T., Fujikawa, H. (2004) Design methodology for the facility layout problem to consider the aisle structure and intra-department material flow. *Journal of Japan Industrial Management Association* 55(3): (pp. 111-120). (in Japanese)