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GOAL PROGRAMMING APPROACH FOR CARRYING PEOPLE WITH PHYSICAL DISABILITIES

ABSTRACT

Most of today's optimization efforts aim to reduce costs, time or the number of resources used. However, optimization efforts should consider other factors as important as these, such as facilitating the lives of the disabled, elderly and pregnant and helping them in their daily lives. In this study, the Nuh Naci Yazgan (NNY) University (Kayseri/Turkey) personnel transport problems were discussed. The NNY University provides a shuttle service to bring employees to school at the start of the work and to leave them at home after work. In order to shorten the collection / distribution time and the total distance travelled, the service vehicle does not leave / pick up all employees in front of their homes. Instead, the employees are picked up / dropped at appropriate locations on an intuitively determined route. Since only the time and cost savings are taken into account when determining the service route, some employees have a long walking distance to the service route. This creates a very important problem, especially for the disabled and pregnant workers. In this study, a new mathematical model is proposed which takes into consideration the physical disadvantages and occupational positions of the employees in order to determine the shortest vehicle route. The results show that the proposed model can significantly reduce walking distances of physically disabled people without compromising the total distance travelled by the vehicle.

KEY WORDS

mixed integer programming; goal programming; Analytic Hierarchy Process; humanitarian factors; dial-a-ride problem;

1. INTRODUCTION

This study is inspired by the Nuh Naci Yazgan (NNY) University (Kayseri/Turkey) personnel transportation problem. The NNY University provides a shuttle service to bring the employees to school early in the morning and leave them in the evening after work. In order to save time and cost, the service vehicle does not pick up or leave all the employees in front of their homes but instead collects and distributes them on an intuitively determined route. This requires some employees to walk quite long distances to the service route. The main criterion in determining the route is to minimize the distance travelled by the vehicle. The distances the employees have to walk to the collection point are not much considered. The long walking distance is an important problem, especially for the disabled, pregnant and those older than 65. In such case, shortening the walking distance, especially for the disabled and physically disadvantaged workers, should be as important as reducing costs.

In traditional Vehicle Routing Problems (VRP), the human factor is often ignored when determining the shortest route. Yet, it is also a humanitarian task to take a range of measures that will make the lives of the disabled, pregnant and elderly people easier, rather than just focusing on cost. In this study, an attempt was made to show that human factors such as the situation of physically disadvantaged people can be taken into account as well as the cost in solving problems encountered in daily life through NNY University shuttle user problem. For this purpose, in the first stage, the NNY University shuttle users are divided into classes with a number of factors in mind, such as disability status, pregnancy, age and professional position. Later, weight points were assigned to each group by taking into account the problems that may be encountered in the case of excessive walking distance. A weight point was assigned to each group with the idea that the walking distance of a disabled or pregnant person is not equal to the walking distance of a healthy employee. In the final phase, a goal programming approach was used to simultaneously reduce the sum of weighted walking distances and the vehicle travel distance. The results showed that the lives of people who are physically disadvantaged can be significantly facilitated without deviating too much from the costs.

2. LITERATURE REVIEW

Because it is one of the most common problems in real life, vehicle routing problems attract the attention of researchers. The comprehensive study of Raff [1] is an important resource in terms of the classification of the problem. In the vast majority of VRP studies in the literature, pickup and delivery are handled together (VRPPD). Most of VRPPD studies in the literature have investigated transportation of products, goods and commodities instead of people who live in urban areas. Since what is carried is not usually humans, it is not possible to come across too many studies where physical disadvantages are addressed. However, it is possible to come across some studies in the literature on human factors such as old age and disability. Such problems are often referred to in the literature as Dial-a-Ride (DARP) problems. The DARP consists of designing vehicle routes and schedules for n users who specify pickup and delivery requests between origins and destinations [2]. The aim of DARP is to plan a set of *m* minimum cost vehicle routes capable of accommodating as many users as possible, under a set of constraints. There are several papers that investigated the DARP for handicapped people. The most common example of DARP for handicapped people is door-to-door transportation and DARP may be considered with social services. Psaraftis [3] investigated a single-vehicle, many-to-many dial-a-ride problem for both static and dynamic cases to minimize a weighted combination of the time to service all customers and the total degree of dissatisfaction. He proposed a dynamic programming algorithm for the problem. In another study of Psaraftis [4], he modified his previous dynamic programming algorithm for the same problem where each customer has specified upper and lower bounds for his pickup and delivery times and where the objective is to minimize the time needed to service all customers. Desrosiers et al. [5] proposed a forward dynamic programming algorithm for single-vehicle dial-a-ride problem where the objective is to minimize the total distance with time windows constraints for pickup and delivery locations, and precedence and capacity constraints. Jaw et al. [6] introduced a heuristic algorithm for a time-constrained version of the advance-request, multi-vehicle, many-to-many DARP having a flexible objective function that balances the cost of providing the service with the customers' preferences for pickup and delivery times close to those requested, and for short ride times. Sutcliffe and Board [7] investigated transportation of mentally handicapped adults to an adult training centre and they solved optimally their real-life problem. Toth and Vigo [8] investigated DARP with a fast and effective parallel insertion heuristic algorithm which can determine good solutions for real-world instances of the problem in a few seconds on a personal computer. Furthermore, they present a Tabu Thresholding procedure which can be used to improve the starting solution obtained by the insertion algorithm. Rekiek et al. [9] proposed a method-based genetic algorithm in order to solve the handicapped personal transportation problem. They solved a real-life problem with their proposed method.

The rest of the papers except DARP in the literature investigate the VRPPD considering mostly goods and services. Dumas et al. [10] presented an exact algorithm which solves the pickup and delivery problem when transporting goods. Their algorithm uses a column generation scheme with a constrained shortest path as a sub-problem. Donati et al. [11] investigated a time-dependent VRP with hierarchical objectives: the number of tours and the total travel time. They presented multi ant colony systems for the problem. Fleischmann et al. [12] considered a dynamic routing system that dispatches a fleet of vehicles according to customer orders arriving at random during the planning period. Their system disposes of online communication with all drivers and customers and, in addition, disposes of online information on travel times from a traffic management centre. Masson et al. [13] investigated Pickup and Delivery Problem with Shuttle routes and they proposed three mathematical models for the problem and a branch-and-cut-and-price algorithm to solve it.

Liu et al. [14] investigated the solution algorithms for the multi-criteria multi-modal shortest path problem which belongs to the set of problems known as NP-hard, in urban transit network. They designed an improved exact label-correcting algorithm and exact reverse label-correcting algorithm to solve the problem with transfer delaying and with both of transfer delaying and arriving time-window. Si et al. [15] presented an augmented network model to represent urban transit system. They considered passengers' travel costs including walking time, waiting time, in-vehicle time and transfer time in their system. Furthermore, they presented an equilibrium model for the problem and proposed an algorithm based on an improved shortest path method to solve the problem. Modesti and Sciomachen [16] studied the problem of finding Origin-Destination shortest paths in urban multimodal transportation networks, aiming at minimizing the overall cost, time and users' discommodity associated with the required paths. They presented an approach based on the classical shortest path problem on a network representing the urban multimodal transportation system, i.e. the private, public and pedestrian modalities.

3. PROBLEM DEFINITION AND MATHEMATICAL MODEL

Moving the staff to the workplace is a routine activity that creates significant costs for the companies. Although timing and cost are essentials, some features of the personnel such as disability, old age, pregnancy, status in the workplace, seniority, and other priorities can also be taken into account while planning the personnel carrier path. The main motivation of this study is to show that, in contrast to traditional practices, some human factors as well as costs can be taken into consideration in optimization studies.

The general structure of the problem discussed in the study is as follows. The NNY University offers a shuttle service to its staff to pick them up every morning and to leave in the evening. The shuttle picks up university employees every morning at certain stops and leaves them at the same stops in the evenings. It is not possible to collect the employees in front of their homes, because the distance and time would be too long. For this reason, the employees are required to walk to the nearest stops on the predetermined route. Unfortunately, the physical characteristics and occupational positions of the employees are not taken into consideration in determining the route. This situation causes a number of physical difficulties, especially for the pregnant, disabled and elderly employees.

The mathematical model proposed in this study tries to reduce their weighted walking distances by creating positive discrimination for the pregnant, handicapped and elderly workers. Of course, when doing so, care should be taken to compromise as little as possible from the shortest route. The employees are divided into various classes, such as pregnant, disabled, elderly, senior managers, in order to discriminate positively for those who are supposed to walk shorter distances. The mathematical model proposed for this purpose and the notation used in the model are as follows:

Indices:

i – index of persons who use the personnel carrier $i\in(1,\dots,n)$;

j, k and l – indices of stations that can be preferred by persons $j\in(1,\dots,m)$, $k\in(1,\dots,m)$, $l\in(1,\dots,m)$.

Parameters:

w_i – weight of person i for travelling from their place to any station;

d_{ij} – distance between person i place and station j;

S_{jk} – distance between station j and station k.

Decision variables:

$x_{ij}\in\{0,1\}$ – if person i gets in the vehicle at station j, $x_{ij}=1$. Otherwise $x_{ij}=0$;

$y_{jk}\in\{0,1\}$ – if the vehicle travels from station j to station $k(k\neq j)$, $y_{jk}=1$. Otherwise $y_{jk}=0$;

$u_i\in Z^+$ – decision variable for sub-tour elimination

Objective functions:

$$\min f_1 = \sum_{i=1}^{n}\sum_{j=1}^{m} w_i x_{ij} d_{ij} \tag{1}$$

$$\min f_2 = \sum_{j=1}^{m-1}\sum_{k=2,k\neq j}^{m} y_{jk} S_{jk} \tag{2}$$

Constraints:

$$\sum_{k=2}^{m-1} y_{1k} = 1 \tag{3}$$

$$\sum_{j=2}^{m-1} y_{jm} = 1 \tag{4}$$

$$x_{i1} = 0 \quad \forall i \tag{5}$$

$$x_{im} = 0 \quad \forall i \tag{6}$$

$$\sum_{j=1}^{m} x_{ij} = 1 \quad \forall i \tag{7}$$

$$y_{jj} = 0 \quad \forall j \tag{8}$$

$$\sum_{j=1,j\neq k}^{m-1} y_{jk} = \sum_{l=2,l\neq k}^{m} y_{kl} \quad \forall k < m \tag{9}$$

$$\sum_{j=1}^{m-1} y_{jk} - x_{ik} \geq 0 \quad \forall i,k \text{ and } k > 1 \tag{10}$$

$$y_{jk} + y_{kj} \leq 1 \quad \forall j,k \text{ and } j \neq k \tag{11}$$

$$\sum_{k=2}^{m-1} y_{jk} \leq 1 \quad \forall j \text{ where } j > 1,\ j < m \tag{12}$$

$$u_k - u_j + m \cdot (1 - y_{jk}) \leq m - 1 \quad \forall i,j \text{ where } 1 \leq i \neq j \leq m-1 \tag{13}$$

$$y_{jk} \in \{0,1\} \quad \forall j,k \tag{14}$$

$$x_{ij} \in \{0,1\} \quad \forall i,j \tag{15}$$

$$u_j \in Z^+ \quad \forall j \tag{16}$$

Objective Function 1 is to minimize the total weighted travelling cost of persons to stations. *Objective Function 2* is to minimize the total distance travelled by the shuttle. *Constraint 3* assures that the vehicle must leave from the first station (departure station) for only one station and the vehicle cannot go directly to the last station. *Constraint 4* shows that the vehicle must enter the last station (arrival station). *Constraints 5* and *6* limit people to use the first or last station. *Constraint 7* assures that each person must use only one station to get in the vehicle. *Constraint 8* is a limitation for the vehicle to visit the same station subsequently. *Constraint 9* assures that if the vehicle visits a station, then it must leave from that station to other ones. *Constraint 10* is to assure that if any person uses any station to get in the vehicle, then that station must be visited by the vehicle coming from other stations. *Constraint 11* guarantees that the vehicle cannot go back after visiting a station. *Constraint 12* shows that each station can be visited by the vehicle that comes from only one station. *Constraint 13* is to prohibit sub-tour solutions. *Constraints 14-16* are for the necessary domains of decision variables.

The total distance travelled by a vehicle will increase if the total weighted walking distance decreases as the two objective functions conflict. Both passengers and service vehicles want to cover the shortest distance. One of the methods that can be used to achieve a compromise between the passengers and the vehicle contradictory objectives is the goal programming approach. As a solution approach for the bi-objective optimization problem, goal programming interests in deviations from the desired goals. With the help of goal programming, even if the passengers or service vehicle cannot achieve the shortest distance they desire, a compromise will be achieved by making as little concession as possible to the best solution for them.

The multi-purpose model described above can be transformed into a goal programming problem by solving the model for only one objective function at a time and determining the results as target values. In order to convert the multi-objective model into a goal programming model, the objectives created using the optimum values of the objective functions are defined as follows:

- Optimum value of the weighted walking distance, regardless of the total distance travelled by the shuttle (f_1^*).
- Optimum value of the total distance travelled by the shuttle, regardless of the weighted walking distance (f_2^*).

Since both objectives cannot be optimized at the same time, deviations from these objectives must be defined as shown in *Equations 17* and *18* in order to obtain a conciliatory solution.

$$f_1 + D_1^+ - D_1^- = f_1^* \tag{17}$$

$$f_2 + D_2^+ - D_2^- = f_2^* \tag{18}$$

In *Equation 17*, D_1^- and D_1^+, show respectively how far the solution has exceeded the first target (the minimum weighted travelling distance of passengers) and how far below the first target. In *Equation 18*, D_2^- and D_2^+ indicate respectively how much the solution overachieves and underachieves the second goal (the minimum travelling distance of the vehicle). Since the positive deviations from the targets for this problem are disturbing, the objective function of the goal programming model should be aimed at minimizing the sum of the weighted positive deviation amount as shown below:

Objective function:

$$\min f = h_1 (D_1^+ + D_1^-) + h_2 (D_2^+ + D_2^-) \tag{19}$$

Constraints:

$$D_1^+, D_1^-, D_2^+, D_2^- \geq 0 \tag{20}$$

Constraints 1-16

In *Equation 19*, h_1 represents the weight of the deviation from the first target and h_2 from the second target. The goal programming model created by adding the *Constraints 1-16* defined previously will provide the solution with the least possible deviation from the targets of the passengers and the service vehicle under the existing constraints.

4. APPLICATION

In this study, the personnel transport problem of the NNY University has been discussed. The NNY University is a small campus university outside the city centre of Kayseri/Turkey. The University uses a single vehicle with a carrying capacity of 19 people. There are 19 people using the service vehicle because the majority of employees prefer to use their own vehicles to come to the University. The alternative routes and stops that the vehicle can use are shown in *Figure 1*. As can be seen in *Figure 1*, there are 12 stations used by staff as a pickup/delivery point. Station 1 is the departure station and station 12 is the arrival station.

The personnel using the service can change periodically. The vehicle sets itself a route to minimize the distance and announces this route to service users on a monthly basis. Service users need to walk to the nearest stop on the specified route. The only criterion considered when determining the vehicle route is the minimization of the total route length. While determining the best route, physical characteristics that make it difficult to walk, such as the employees' disabilities, are not taken into account. In our opinion, in determining the best route, apart from the costs, also the special situations of the employees such as physical disabilities should be taken into consideration.

For this purpose, firstly, the workers are divided into seven different classes taking into account their physical condition and occupational position. The specified classes are as follows: disabled, pregnant, over 65 years of age (65^{+}), managers, staff, professors, and assistants. Then, the criterion weight is assigned to the determined classes considering the obstacles that the walking can cause. The Analytic Hierarchy Process (AHP) developed by Saaty [17] was used in determining the class weights. The most important feature of the AHP is that the decision-maker can incorporate both objective and subjective considerations into the decision process [18]. The pairwise comparisons matrix which is established based on the views of the service users to determine the class weights is shown in *Table 1*.

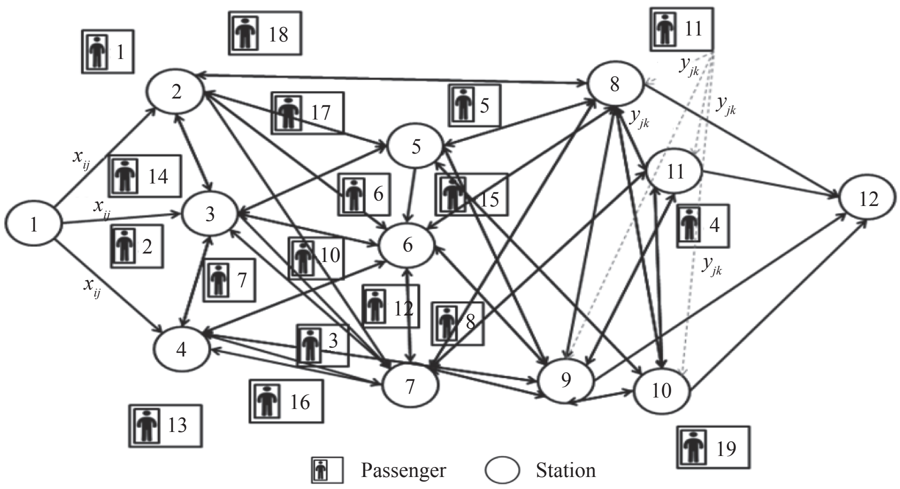

Figure 1 – NNY University transportation network

Table 1 – Pairwise comparisons matrix

PERSONS	Disabled	Pregnant	65 +	Manager	Staff	Professor	Assistant
Disabled	1.00	3.00	4.00	7.00	9.00	8.00	9.00
Pregnant	0.33	1.00	4.00	8.00	9.00	7.00	9.00
65^{+}	0.25	0.25	1.00	5.00	8.00	6.00	9.00
Manager	0.14	0.13	0.20	1.00	7.00	1.00	5.00
Staff	0.11	0.11	0.13	0.14	1.00	0.25	1.00
Professor	0.13	0.14	0.17	1.00	4.00	1.00	5.00
Assistant	0.11	0.11	0.11	0.20	1.00	0.20	1.00

The class weights calculated using the pairwise comparisons matrix in *Table 1* are as in *Table 2*. The rightmost column of *Table 2* shows the codes for passengers, according to which passengers 2 and 9 are disabled and passenger 14 is in the pregnant class. The consistency ratio calculated for the pairwise comparisons matrix is 0.08 indicating that the pairwise comparison matrix is consistent.

Table 2 – Criteria weights

Criteria	Weights	Passenger code
Disabled	0.391243	2, 9
Pregnant	0.285842	14
65^+	0.166046	16
Manager	0.061219	1, 3, 12
Staff	0.0203	5, 7, 8, 18
Professor	0.055062	4, 6, 15, 17
Assistant	0.020288	10, 11, 13, 19

The distances between the passengers to the alternative stations and the distances between the stations are shown in *Table 3* and *Table 4*, respectively. No person has to go to the first station (car parking) or the last station (university) to board the vehicle. So, the distance between any passenger and the first or the last station is given as an arbitrary large number (in this example, it is 50 km) to ban such movements. In *Table 4*, the distances between stations without direct connections are also represented by large numbers.

The proposed mathematical model is solved for each of *Objective functions 1* and *2* to obtain optimal f_1^* and f_2^* using the real data of the NNY University. The routes, walking distances of all passengers and vehicle travelling distances are given in *Table 5* for each objective function. These optimum values are then used in the goal programming model with two sets of weights ($h_1,h_2 \in \{(0.5,0.5);(0.3,0.7)\}$). The detailed results of the goal programming models with different weights are given in *Table 6*.

Table 3 – Travelling distances (m) of passengers to alternative stations

i/j	1	2	3	4	5	6	7	8	9	10	11	12
1	50,000	500	800	1,600	1,500	2,100	6,000	4,500	5,300	10,000	7,000	50,000
2	50,000	300	300	750	300	900	1,600	1,800	2,800	7,000	9,000	50,000
3	50,000	2,200	1,700	1,600	1,200	900	750	900	600	300	1,800	50,000
4	50,000	7,200	6,000	5,600	2,000	1,900	1,800	600	750	5,000	300	50,000
5	50,000	3,250	5,000	6,000	300	750	1,200	400	750	1,950	2,750	50,000
6	50,000	2,350	1,750	1,600	1,200	300	350	1,650	1,100	1,300	6,500	50,000
7	50,000	1,500	200	500	3,250	1,860	1,900	3,950	3,600	3,980	7,000	50,000
8	50,000	7,500	6,000	3,500	1,150	250	1,200	790	350	2,250	2,750	50,000
9	50,000	7,650	3,650	1,750	7,500	5,500	4,500	9,000	9,500	9,750	13,500	50,000
10	50,000	1,150	450	1,500	1,650	600	1,950	3,400	2,700	3,900	5,300	50,000
11	50,000	3,000	4,200	5,600	950	2,250	4,100	800	2,350	4,800	2,750	50,000
12	50,000	5,050	4,100	3,250	2,500	650	850	1,750	1,050	1,300	3,250	50,000
13	50,000	2,050	1,650	750	3,050	2,650	1,250	4,200	3,560	2,900	5,900	50,000
14	50,000	350	650	1,350	1,850	1,950	2,690	3,750	4,200	4,600	5,680	50,000
15	50,000	1,750	1,650	2,630	650	850	1,950	2,360	3,100	4,100	4,600	50,000
16	50,000	2,450	1,250	550	2,250	1,950	950	4,500	4,360	2,250	5,860	50,000
17	50,000	650	1,250	3,500	550	1,350	4,050	2,250	3,050	4,650	5,150	50,000
18	50,000	1,350	3,250	5,650	1,750	3,750	6,650	2,850	5,690	7,995	3,650	50,000
19	50,000	9,650	7,850	6,500	3,250	1,950	650	2,750	1,450	250	3,650	50,000

Table 4 – Distances (m) among stations

j/k	1	2	3	4	5	6	7	8	9	10	11	12
1	50,000	1,750	1,950	1,960	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
2	50,000	50,000	650	50,000	850	3,500	50,000	6,570	50,000	50,000	50,000	50,000
3	50,000	650	50,000	950	1,650	1,250	1,950	50,000	50,000	50,000	50,000	50,000
4	50,000	50,000	950	50,000	50,000	1,850	2,350	50,000	4,200	50,000	50,000	50,000
5	50,000	850	1,650	50,000	50,000	1,050	50,000	1,750	2,750	3,650	50,000	50,000
6	50,000	3,500	1,250	1,850	1,050	50,000	1,350	2,350	1,950	50,000	50,000	50,000
7	50,000	50,000	1,950	2,350	50,000	1,350	50,000	3,260	2,650	50,000	3,150	50,000
8	50,000	6,570	50,000	50,000	1,750	2,350	3,260	50,000	890	1,680	1,050	4,050
9	50,000	50,000	50,000	4,200	2,750	1,950	2,650	890	50,000	650	1,350	4,350
10	50,000	50,000	50,000	50,000	3,650	50,000	50,000	1,680	650	50,000	2,350	5,350
11	50,000	50,000	50,000	50,000	50,000	50,000	3,150	1,050	1,350	2,350	50,000	1,500
12	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000

Table 5 – Walking distances (m) of passengers due to different objectives

Passenger code and criteria	Objective function (f_1)	Objective function (f_2)
1 (Manager)	500	500
2 (Disabled)	300	300
3 (Manager)	300	2,200
4 (Professor)	300	7,200
5 (Staff)	300	3,250
6 (Professor)	300	2,350
7 (Staff)	200	1,500
8 (Staff)	250	7,500
9 (Disabled)	1,750	7,650
10 (Assistant)	450	1,150
11 (Assistant)	800	3,000
12 (Manager)	650	5,050
13 (Assistant)	750	2,050
14 (Pregnant)	350	350
15 (Professor)	650	1,750
16 (65+)	550	2,450
17 (Professor)	550	650
18 (Staff)	1,350	1,350
19 (Assistant)	250	9,650
Total	10,550	59,900
Objective function values	f_1^*=1,269.515 f_2=209,600	f_1=5,347.322 f_2^*=6,900
Routes	{1-6-2-10-11-8-5-4-3-12}	{1-2-5-8-11-12}

As seen from *Table 5*, if we solve the problem with only *Objective function 1*, all passengers board the vehicle from their nearest stations. But the distance covered by the vehicle is greater than the other solutions obtained from solving the model with only *Objective function 2* and the weighted objective functions. The total road taken by the vehicle and the collection time of the passengers are parallel to each other due to the urban speed limits. Thus, the length of the collection / distribution period is one of the important reasons that adversely affect the comfort of the passengers. In the solution obtained by solving the model with only *Objective function 2*, the distance covered by the car (as well as the collection / distribution time) is the shortest. But in this case, the walking distance of the passengers increases considerably. Especially if the walking distances of the disabled or 65^+ passengers represented by numbers 9 and 16 are examined, the disadvantages of this solution are obvious. The same is true for almost all professor passengers. If we solved the model as a goal programming with equal weights, the solution seems to be better than the solution with only *Objective function 2*. However, the walking distances of the disabled or 65^+ passengers represented by numbers 9 and 16 are higher. The total distance travelled by the vehicle is significantly reduced when compared to the solution with only *Objective function 1*. If we solved the proposed goal programming model with different weights (h_1=0.7, h_2=0.3), the solution as seen from *Table 6* would be more satisfactory than the solution with equal weights for the disabled or

Table 6 – Walking distances [m] of passengers obtained by the proposed goal programming model due to different weights

Passenger code and criteria	h_1=0.5, h_2=0.5	h_1=0.7, h_2=0.3
1 (Manager)	500	500
2 (Disabled)	300	300
3 (Manager)	900	900
4 (Professor)	300	300
5 (Staff)	300	300
6 (Professor)	1,200	1,200
7 (Staff)	200	200
8 (Staff)	790	790
9 (Disabled)	3,650	1,750
10 (Assistant)	450	450
11 (Assistant)	950	800
12 (Manager)	1,750	1,750
13 (Assistant)	1,650	750
14 (Pregnant)	350	350
15 (Professor)	650	650
16 (65+)	1,250	550
17 (Professor)	650	550
18 (Staff)	1,350	1,350
19 (Assistant)	2,750	2,750
Total	19,940	16,190
Objective function values	f_1^*=2,371.288 f_2=7,750	f_1=1,484.885 f_2^*=8,710
Routes	{1-3-2-5-8-11-12}	{1-4-3-2-5-11-12}

Table 7 – Summary of the solutions with different weights

h_1	h_2	f_1	f_2	f_1+f_2
1.0	0.0	1,269.515	209,600	210,869.5
0.9	0.1	1,349.346	10,260	11,609.35
0.8	0.2	1,484.885	8,710	10,194.89
0.7	0.3	1,484.885	8,710	10,195.89
0.6	0.4	1,484.885	8,710	10,194.89
0.5	0.5	2,371.288	7,750	10,121.29
0.4	0.6	2,362.739	7,750	10,112.74
0.3	0.7	4,083.777	6,900	10,983.78
0.2	0.8	4,083.777	6,900	10,983.78
0.1	0.9	4,083.777	6,900	10,983.78
0.0	1.0	5,347.322	6,900	12,247.32

65^+ passengers. *Table 7* shows the summary of the solutions of the proposed goal programming model obtained with different weights.

As seen from *Table 7*, the weights for derivation from the best solutions affects the total weighted distance of passengers and total travelled distance of the vehicle. The decision on weights belongs to the decision-maker. The best solution for passengers (the worst solution for the shuttle) is the solution where h_1=1 and h_2=0. While h_1 decreases, f_1 increases and f_2 decreases. For h_1 values between 1 and 0.6, f_1 does not increase so much but there is a significant decrease of f_2. Therefore, the weights marked with bold font in *Table 7* are suggested. Furthermore, in the solution with suggested weights, almost all passengers use the nearest stations to board the vehicle. The results show that the proposed goal programming approach with well-defined weights provides significant benefits to the users and does not create a significant increase in the cost. As a result, the NNY example shows that instead of focusing only on costs, an appropriate solution can be achieved in terms of both cost and employee comfort.

5. CONCLUSION

In traditional routing or path problems, the goal is to find the most cost-effective route. In this study, an attempt was made to show that factors such as disability status of people can be taken into consideration in optimization studies by addressing the shuttle service problem of the NNY University. While the NNY University personnel service route is being determined, the attempt is made to determine the shortest route without considering the physical conditions of the employees in accordance with traditional optimization studies. This situation causes a number of problems especially for people who are disabled, pregnant, over 65 years of age. In this study, a new bi-objective mathematical model was proposed to reduce costs as well as taking into account the physical characteristics of the employees. The proposed problem is to find the best route that minimizes the weighted walking distances of passengers and the total distance covered by the service vehicle. The results show that the lives of people with disabilities can be facilitated to a great extent without sacrificing the costs.

Today's conditions of competition make the organizations active in the production and service sectors obliged to focus on costs first. Most of the time, human factors such as facilitating the daily lives of disabled people and improving working conditions are ignored in order not to compromise the costs.

This study has tried to show that taking some measures that will make people's lives easier instead of focusing on reducing costs does not cause any deviation from the costs. Our hope is that such issues will find more space in the future studies and that success will not be measured only by costs.

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FIZIKSEL DEZAVANTAJLI KIŞILERIN TAŞINMASINDA HEDEF PROGRAMLAMA YAKLAŞIMI

ÖZET

Günümüzün optimizasyon çabalarının çoğu, maliyetleri, zamanı veya kullanılan kaynak sayısını azaltmayı amaçlamaktadır. Bununla birlikte, optimizasyon çabaları, engelli, yaşlı ve hamile insanların hayatlarını kolaylaştırmak ve günlük yaşamlarında onlara yardımcı olmak gibi diğer insani faktörleri de dikkate almalıdır. Bu çalışmada Nuh Naci Yazgan (NNY) Üniversitesi (Kayseri / Türkiye) personel ulaşım problem ele alınmıştır. NNY Üniversitesi, mesai saati başlangıcında çalışanları okula getirmek ve iş çıkışı onları evlerine bırakmak için bir servis hizmeti sunmaktadır. Toplama / dağıtım süresini ve kat edilen toplam mesafeyi kısaltmak için, servis aracı tüm çalışanları evlerinin önünde bırakmaz / almaz. Bunun yerine, çalışanlar sezgisel olarak belirlenmiş bir rotadaki uygun yerlerden alınır / bırakılır. Servis güzergahını belirlerken sadece zaman ve maliyet tasarrufu dikkate alındığından, bazı çalışanların servis güzergahına ulaşabilmek için uzun yürüme mesafelerini katetmeleri gerekmektedir. Bu durum, özellikle engelli ve hamile çalışanlar için çok önemli bir sorun yaratmaktadır. Bu çalışmada, en kısa araç rotasını belirlemek için çalışanların fiziksel dezavantajları ve mesleki pozisyonlarını dikkate alan yeni bir matematiksel model önerilmiştir. Sonuçlar, önerilen modelin, fiziksel olarak dezavantajlı kişilerin yürüme mesafelerini, aracın kat ettiği toplam mesafeden ödün vermeden önemli ölçüde azaltabildiğini göstermektedir.

ANAHTAR KELIMELER

karma tamsayılı programlama; hedef programlama; Analitik Hiyerarşi Süreci; insani faktörler; araç rotalama problemi;

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