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Scheduling Nurse Shifts Using Goal Programming Based on Nurse Preferences: A Case Study in an Emergency Department

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ABSTRACT

Nowadays, nurses scheduling is one of the most important challenges with which health care centers are encountered. The significance of nurses' work quality has led researchers to be concerned about scheduling problems, which have an impact on nurses' performance. Observing the interests of hospital and patients, providing their satisfaction, and meeting their needs are among the main objectives of scheduling, which are focused on in this research. For this end, goal programming is used for modeling and problem solving of the nurses scheduling process. Hence, a developed comprehensive model with 7 goals related to management aspects and nurses' interests have been designed considering emergency department characteristics of a large hospital in Tehran as a case study. Finally, the model was solved via GAMS software. The model resulted in an optimal pattern for nurses scheduling in a 28-days horizon. According to the definition presented in the modeling process, 3 goals associated with proportion, sequence, and isolation of working days were fulfilled. However, 4 goals of nurses' interests, number of working days, and isolate off days have illustrated a few deviations due to resource limitation. In addition, a comparison between the results and the current scheduling indicated a higher efficiency of optimal scheduling. Sensitivity analysis of the nurses scheduling also revealed that with an increase in the number of nurses, the goals would improve significantly. Implementation of this scheduling not only improves work justice and performance of the nurses but also increases their satisfaction from the scheduling process.

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NOMENCLATURE

I	Days index	U	The maximum working day for each nurse
J	Working shifts index	d^+	Positive deviation from a goal
K	Nurses index	d^-	Negative deviation from a goal
N	Number of days	Q	Minimum number of night shift for each nurse
$X_{i,j,k}$	Binary decision variable to show *k*th nurse situation in *j*th shift of *i*th day	W	Maximum number of night shift for each nurse
M	Number of nurses	**Greek Symbols**	
$D_{i,j}$	Nurses requirement for *i*th day and *jth* shift	$\alpha_{i,j,k}$	Random variable to show *k*th nurse preference to work in *i*th day and *j*th shift
L	The minimum working day for each nurse	$\beta_{i,k}$	Random variable to show *k*th nurse preference to be off in ith day

1. INTRODUCTION

One of the typical challenges of managers is appropriate scheduling for their employees working shifts. The importance of this issue is highlighted when appropriate scheduling leads in increased satisfaction of the workers, and consequently, increased satisfaction of customers [1]. Hospitals as the major provider of health care services in each country account for a large part of

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resources and credits. Nurses also play a key role in this service as the main hospital workforce, and their satisfaction and high performance contribute to the quality of services [2]. Therefore, one of the most common issues in human resource scheduling is nurses working shifts in hospitals.

Nurses scheduling determines the number of required nurses in each shift and is usually carried out monthly. The scheduling varies in each month based on preferences and conditions. Optimization of this process may improve the nurses' performance, and consequently, the quality of health care services. Nurses scheduling has been taken into consideration as a complex scheduling procedure [3]. In hospitals, supervisors of each ward codify this program and try their best to make it compatible with the requirements and limitations of the nurses and other workers. The schedule should provide the required number of workers with a wide range of skills in each shift. On the other hand, this schedule should include other kinds of limitations, such as rest days, specific conditions of the workers, and their sick leave .

Since many errors occur in manual scheduling, using an appropriate methodology will be guiding in obtaining all scheduling goals. Optimal scheduling improves nurses' performance, and at the same time, saves various hospital resources. On the other hand, appropriate nurses scheduling may have a significant role in the reduction of injustices, and as a result, the satisfaction of nurses [4]. In this study, nurses scheduling of emergency ward in one of the biggest hospitals of Tehran was modeled and solved with a goal programming for a 28-days horizon. The next section of this paper is dedicated to the literature review. Section 3 introduces the methodology and the mathematical model used. The results of the analytical method are presented in Section 4, and Section 5 concludes the paper.

2. LITERATURE REVIEW

Mayer and Wolf conducted the first study on cyclic scheduling of health care centers, which was considered to be primary modeling for single shift scheduling. Their main objective was a minimization of the number of workers [5]. In later studies, it has been stated that scheduling strategies should change since a specific sequence of shifts can have adverse consequences for sleep conditions and heart rhythm of a worker [6]. Therefore, many pieces of researches have been done on ergonomic rules in order to reduce these consequences as much as possible. Cyclic scheduling will be much more complex based on these rules. Different research works has been done on the application of fuzzy hypothesis in nurse scheduling. This study indicated that a fuzzy modeling approach may provide a just schedule for the nurses and maximizes management programs of the hospital [7].

Azaiez and Al Sharif [8] used goal and zero linear programming models to maximize the interests of nurses in nursing scheduling of a hospital in Saudi Arabia. They were able to provide a scheduling design for selecting shifts and distribution of last week shifts among the nurses. Executive results indicated that the researchers were successful in implementing their design and obtaining their goals.

Jafari and Salmasi [9] analyzed nurses scheduling of Milad hospital with a two-week model including working and last week shift preferences of the nurses. Initially, the number of nurses required for scheduling were identified due to a shortage in the number of nurses, and in the next step, the allocation was done based on preferences. A combination of SA and local search algorithms was used in this study. M'Hallah and Alkhabbaz [10] attempted nurses scheduling to minimize the number of nurses. They used integer programming as their study tool. They also compared the optimized scheduling program with traditional manual scheduling in a 4-week practical experience. The resulted schedule not only reduced hospital costs but also increased satisfaction level and quality of nurses' performance. Azimi et al. [11] applied experimental data to introduce a new nurses scheduling model. Their presented model has two simultaneous goals that minimizes the number of nurses and maximizes nurses' interests in their demanded shifts. The results indicated a significant improvement in research goals in comparison with the previous model. Jafari et al. [12] made an effort to solve the scheduling problem by considering the fuzzy mode and with the aim of maximizing nurses preferences. They compared four fuzzy approaches and concluded that fuzzy weighted average method is the best one

Bagheri et al. [13] employed a two-step modeling technique in solving the nurses scheduling problem. They assumed the potential requirement and hospitalization time of patients using the sample mean estimation method (SSA) as well as simulation. Moreover, after the implementation of optimized scheduling, they observed that overtime and normal working hours of the nurses were minimized. Agyei et al. [14] conducted a study on nurses scheduling of internal section of a hospital in Ghana. They used goal programming in their modeling process. Their main objectives were to obtain justice and equity in working days of nurses. They also presented a nurses scheduling program through goal programming technique. Ang et al. [15] developed a software infrastructure and used goal programming for nurses scheduling. Their goal was a minimization of nurse-patient rate (NPR) referring to the number of patients allocated to each nurse.

El Adoly et al. [16] provided new nurses scheduling via linear mathematical modeling and flow network methods. They concluded that the new scheduling not only increases the satisfaction level of nurses, but also reduces their overtime working up to 36%. Di Martinelly and Meskens [17] conducted their study on nurses scheduling of surgery room. They used a multi-objective modeling method to simultaneously increase coordination between nurses during surgery and reduce their inaction time. It should be noted that due to an increasing focus on home care services, many nurse scheduling programs have been conducted in this field. Nasir and Dang [18] led a study on nurse scheduling of home care services. They applied mathematical modeling focused simultaneously on four problems: the patient selection, nurse fare, nurse allocation to each patient, and decision-making scheduling of home care services. Eventually, they solved this model via an innovative method.

The focus of previous studies has been mostly on one goal; and thus, nurses interests were ignored in most of the shift scheduling programs. In the present study, goal and zero linear programming models were used for the first time with seven objectives that provides the most comprehensive model in previous studies. Moreover, the main focus of this research is an observance of nurses' interests in the scheduling process, which results in two goals in increasing their satisfaction. To reach this purpose, Azaiez and Al Sharifs [8] model (as base paper) has been developed by considering Jafari and Salmasi [9] assumptions and directions to maximize nurses satisfaction. Overall, the main contributions of this study are as follows:

- Developing a mathematical model by considering all of the previous related studies and adding 2 new goals to improve nurses satisfaction.
- Adopting a model with a particular case study for the first time; specifically, in the emergency department (before it, the scheduling had been done manually).
- Special sensitive analysis for a number of nurses as a controversial issue for hospital management.

3. METHODOLOGY

An emergency ward in one of the critical public hospitals of Iran was selected as study sample; since emergency wards have the highest number of nurses with more complex nurse scheduling procedures due to their high sensitivity. There are three shifts in this ward, including morning: "M", evening: "E", and night: "N" shifts. Off days are indicated with "V" symbol. There are several approaches to model and solve multi-objective issues. However, goal programming was chosen for this study due to certain characteristics, such as prior situation (specific objective priorities before solving model) and large scale problem (7 goals). Two kinds of limitations are considered in this model; hard limitations that refer to fundamental limits, and soft limitations that refer to unachieved goals. The model tries to minimize these restrictions through the reduction of undesirable deviations [19, 20]. These restrictions are defined below by studying relevant research and direct observations. Occasionally, most limitations exist in literature; however, currently, just hard ones are in the case study rules, It is impossible to execute all the assumptions because of resource limits. Nevertheless, two soft limitations (4 and 5) are assumed for the first time by goal programming. Model symbols are presented in the nomenclature Table on the first page of this article. Moreover, a summary of data and parameters is presented in Table 1. Also, Table 2 shows case study requirements for each shift and day in a random month.

3. 1. Hard Limitations

- Nurses should be allocated based on the needs in each shift.
- None of the nurses should be allocated more than one shift each day.
- None of the nurses should work more than 5 subsequent days.
- Each nurse should use at least three weekends as his or her day off.
- Each nurse should work a minimum of 7 and a maximum of 20 days.
- Each nurse should be allocated with a minimum 4 and maximum 8 shifts at nights .
- Each nurse should have 3 days off after 4 subsequent night shifts.

3. 2. Soft Limitations Objectives in the goal programming method are primarily presented as limitations

TABLE 1. Main parameters and data collection

Parameter name (for emergency department)	Value
Number of nurses	27
Number of shifts in each day	3
Number of days in each scheduling duration	28
Minimum working days for each nurse in each scheduling duration	7
Maximum working days for each nurse in each scheduling duration	20
Minimum number of night shifts for each nurse in each scheduling duration	4
Maximum number of night shifts for each nurse in each scheduling duration	8

TABLE 2. Nurse requirement for each shift and day in a random month

Day number	Type of working shifts		
	Morning	Afternoon	Night
1	5	7	2
2	6	5	3
3	5	8	3
4	5	3	6
5	9	3	4
6	8	4	2
7	7	6	2
8	10	8	6
9	7	5	3
10	5	7	5
11	7	6	6
12	9	3	3
13	5	7	2
14	6	5	3
15	5	5	4
16	10	8	4
17	9	6	6
18	8	5	3
19	6	7	5
20	5	8	6
21	9	7	3
22	6	6	3
23	5	5	3
24	9	5	2
25	5	5	2
26	7	7	6
27	7	3	4
28	10	3	3

due to their undesirable deviations. In this study, 7 goals are as follows:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}(X_{i,j,k})-(d1_k^+ - d1_k^-)=15 \qquad \forall k \qquad (1)$$

The first goal (Equation (1)) states that each nurse works 15 days in one scheduling course (28 days). Positive deviation of this goal is $d1_k^+$, and its negative deviation is $d1_k^-$. Both deviations are undesirable for the issue. Therefore, both of them are placed in the objective function

$$\sum_{i=1}^{n}\sum_{j=1}^{m-1}X_{i,j,k}-\sum_{i=1}^{n}X_{i,3,k}-(d2_k^+ - d2_k^-)=1 \quad \forall k \quad (2)$$

The second goal (Equation (2)) emphasizes that day shifts of each nurse should be more than night shifts in each scheduling course. Positive deviation of this goal is $d2_k^+$, and its negative deviation is $d2_k^-$. $d2_k^+$ is the undesirable deviation of this problem. Thus, it is placed in the objective function.

$$\sum_{j=1}^{m-1}X_{i,j,k}+X_{(i+1),3,k}-(d3_{ik}^+ - d3_{ik}^-)=1 \qquad \forall k, i \le n-1 \quad (3)$$

In the third goal (Equation (3)), a nurse who is present in the morning shift should not be present in the next night shift. According to the previous studies, this will create balance in sleep hours of the nurses and have positive effects on their moods. Positive deviation of this goal is $d3_k^+$, and its negative deviation is $d3_k^-$. $d3_k^+$ is the undesirable deviation of this problem. Hence, it is positioned in the objective function.

$$X_{i,j,k}-\alpha_{i,j,k}-(d4_{i,j,k}{}^+ - d4_{i,j,k}{}^-)=0 \qquad \forall i,j,k \quad (4)$$

The fourth goal (Equation (4)) includes nurses' interests and demands in the allocation of work shifts. According to limitation 4, the model tries to schedule day and night shifts of each nurse based on his or her interests. Positive deviation of the goal is $d4_k^+$, and its negative deviation is $d4_k^-$. Both deviations are undesirable. Therefore, both of them are located in the objective function.

$$V_{i,k}-\beta_{i,k}-(d5_{i,k}{}^+ - d5_{i,k}{}^-)=0 \qquad \forall i,k \qquad (5)$$

The fifth goal (Equation (5)) states that their off days should be scheduled based on their interests and demands. Positive deviation of this goal is $d5_k^+$, and its negative deviation is $d5_k^-$. Both deviations are undesirable. Therefore, both are placed in the objective function.

$$V_{i,k}+\sum_{j=1}^{m}X_{(i+1),j,k}+V_{(i+2),k}-(d6_{ik}^+ - d6_{ik}^-)=2 \qquad \forall k, i \le n-2 \quad (6)$$

The sixth goal (Equation (6)) prevents a working day between two off days. This goal makes the nurses able to plan their off days and have a better mood in their working days. Positive deviation of this goal is $d6_k^+$, and its negative deviation is $d6_k^-$. $d6_k^+$ is the undesirable deviation; thus, it is placed in the objective function.

$$\sum_{j=1}^{m}X_{i,j,k}+V_{(i+1),k}+\sum_{j=1}^{m}X_{(i+2),j,k}-(d7_{ik}^+ - d7_{ik}^-)=2 \qquad \forall k, i \le n-2 \quad (7)$$

The seventh goal (Equation (7)) prevents a day off between two working days. This goal, like the previous one, has many advantages for the nurses. Positive deviation of this goal is $d7_k^+$, and its negative deviation is $d7_k^-$. $d7_k^+$ is the undesirable deviation; hence, it is placed in the objective function.

3. 3. Final Model of the Problem After determining the components, the final model was designed. To complete the objective function (Equation (8)), priority coefficients of the goals are needed, which are obtained using hospital experts' and managers' opinions, as well as previous studies.

$$Min\ z = \sum_{k=1}^{m} d1_k^+ + \sum_{k=1}^{m} d2_k^- + \left[\sum_{i=1}^{n-1}\sum_{k=1}^{m} d3_{i,k}^+\right] + \left[\sum_{i=1}^{n-2}\sum_{j=1}^{3}\sum_{k=1}^{m} d4_{i,j,k}^+ + \sum_{i=1}^{n-2}\sum_{j=1}^{3}\sum_{k=1}^{m} d4_{i,j,k}^-\right] + \left[\sum_{i=1}^{n-2}\sum_{k=1}^{m} d5_{i,k}^+ + \sum_{i=1}^{n-2}\sum_{k=1}^{m} d5_{i,k}^-\right] + \left[\sum_{i=1}^{n-2}\sum_{k=1}^{m} d6_{i,k}^+\right] + \left[\sum_{i=1}^{n-2}\sum_{k=1}^{m} d7_{i,k}^+\right] \quad (8)$$

s.t:

$$\sum_{k=1}^{K} X_{i,j,k} \geq D_{i,j} \qquad \forall i,j \qquad (9)$$

$$\sum_{j} X_{i,j,k} \leq 1 \qquad \forall k,i \qquad (10)$$

$$X_{i+1,1,k} + X_{i,3,k} \leq 1 \qquad \forall k, i \leq n-1 \qquad (11)$$

$$\sum_{j=1}^{m} X_{i,j,k} + \sum_{j=1}^{m} X_{(i+1),j,k} + \sum_{j=1}^{m} X_{(i+2),j,k} + \sum_{j=1}^{m} X_{(i+3),j,k} + \sum_{j=1}^{m} X_{(i+4),j,k} + \sum_{j=1}^{m} X_{(i+5),j,k} \leq 5 \qquad \forall k, i < n-5 \qquad (12)$$

$$V_{6,k} + V_{7,k} + V_{13,k} + V_{14,k} + V_{20,k} + V_{21,k} + V_{27,k} + V_{28,k} \geq 4 \qquad \forall k \qquad (13)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} X_{i,j,k} \geq L \qquad \forall k \qquad (14)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} X_{i,j,k} \leq U \qquad \forall k \qquad (15)$$

$$\sum_{i=1}^{n} X_{i,j,k} \geq Q \qquad \forall k, j=3 \qquad (16)$$

$$\sum_{i=1}^{n} X_{i,j,k} \geq 1 \qquad \forall j,k \qquad (17)$$

$$\sum_{i=1}^{n} X_{i,j,k} \leq W \qquad j=3, \forall k \qquad (18)$$

$$\begin{aligned} &X_{i,j,k} + X_{(i+1),j,k} + X_{(i+2),j,k} \leq V_{(i+3),k} + 2 && \forall k, j=3, i=1,\ldots,n-3 \\ &X_{i,j,k} + X_{(i+1),j,k} + X_{(i+2),j,k} \leq V_{(i+4),k} + 2 && \forall k, j=3, i=1,\ldots,n-4 \\ &X_{i,j,k} + X_{(i+1),j,k} + X_{(i+2),j,k} \leq V_{(i+5),k} + 2 && \forall k, j=3, i=1,\ldots,n-5 \end{aligned} \quad (19)$$

$$\sum_{j} X_{i,j,k} + V_{i,k} = 1 \qquad \forall k,i \qquad (20)$$

Equation (9) ensures that minimum nurse demand of the hospital is met in each day and shift. Equation (10) guarantees that each nurse should not work more than one shift every single day. Equation (11) indicates that a nurse working in a night shift should not work in a morning shift the day after. Equation (12) makes certain that none of the nurses should work more than 5 subsequent days. Equation (13) indicates that each nurse should have at least 4 off days on weekends in a month. Equations (14) and (15) identifies a minimum and maximum working days of each nurse. Equations (16) and (18) determine a minimum and maximum night shifts of each nurse. Equation (17) ensures that each nurse should not work in just a specific shift during a scheduling course (28 days). Further, Equation (19), including three subsequent limitations, states that each nurse should have 3 off days after 4 subsequent night shifts. Finally, Equation (20) creates a balance between the solutions; this limitation indicates that a nurse cannot get both work and be off in one day.

4. RESULTS AND DISCUSSION

27 nurses were selected from an emergency ward. The scheduling was carried out for a 28-days horizon. Minimum daily demand in each shift was determined based on study data for a randomly selected month. Moreover, nurses interests for working shifts and off days were identified through a questionnaire. Finally, goals were prioritized using the opinions of ward managers and nurses respectively, based on the number of previously mentioned goals. The objective function coefficients were also determined according to these priorities. The presented model was embedded in GAMS software after mathematical coding. For this end, an Intel core TM i5 system with 2.3 GH processor and 5 GH internal memory has been applied. In the end, the nurse scheduling table was provided for the emergency ward along with optimized results. These results are obtained based on model parameters and vary for each solution as well as nurse scheduling program. Main computational statistics results have shown in Table 3. In addition, the final results of this scheduling are presented in Table A on the appendix.

4. 1. Goals Analysis The first goal focused on unifying working days of all the nurses. This goal also tried to make a balance between the nurses and minimize the difference in nurses' working days. A significant deviation was observed in this goal after solving the model; it was only achieved successfully in 4 nurses. However, there was only one- or two-days difference between working days of the nurses and the goal. Other nurses work more than 15 days due to a shortage of workforce and obligation of the model to meet minimum demands.

The second goal creates a balance between day and night shifts. This goal increases the satisfaction level of the nurses and meets their demands. According to the

TABLE 3. Computational statistics results

	Value		Value
Total iterations	2112837	z1	58
Execution time	11.34 sec	z2	0
$d1^+$	33	z3	0
$d1^-$	25	z4	222
$d2^+$	0	z5	241
$d2^-$	0	z6	0
$d3^+$	0	z7	3
$d3^-$	0	$d5^+$	104
$d4^+$	126	$d5^-$	137
$d4^-$	96	$d6^+$	0
$d7^+$	3	$d6^-$	0
$d7^-$	0		

interviews with nurses, this goal was identified as one of their main interests. After solving the model, it was observed that the adverse deviation was zero; in other words, the goal was fully achieved. All the nurses in the emergency ward will work in day shifts more than night shifts.

The third goal of nurse scheduling is prevention from a night shift immediately after a day shift. It makes a balance between the working schedules of the nurses and increases their performance as well as vitality. After solving the problem, it was perceived that this goal was fully achieved and its negative deviation was zero.

The fourth goal tries to schedule the shifts based on nurses' interests as much as possible. It is evident that this goal cannot be fully achieved since most of the nurses have similar interests in this regard. However, the goal minimizes the deviation from nurse goals. The results of the goal are indicated in Figure 1. Most of the shifts are scheduled based on nurses' interests. Among 2268 working shifts, which should be scheduled, 2046 ones were scheduled based on nurses' interests. Change in these interests will change the results. Generally, the model was successful in fulfilling this goal.

The fifth goal tries to allocate off days based on nurses' interests. Similar to the former goal, this one also cannot be fully achieved since most of the nurses have similar interests in off days. However, the goal attempts to minimize deviations. After solving the model, it was perceived that most of the off days scheduling was carried out based on nurses' interests. Among 756 decisions for off days, 515 ones were made based on nurses' interests (Figure 2). According to the collected data, most of the nurses wanted their off days to be at the weekend. According to the demands of the emergency ward, deviations from this goal are inevitable.

The sixth goal was fully achieved and removed any isolated working day from the schedule. However, the

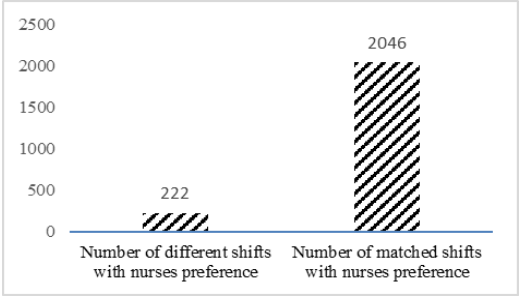

Figure 1. The results of the fourth goal in optimal scheduling

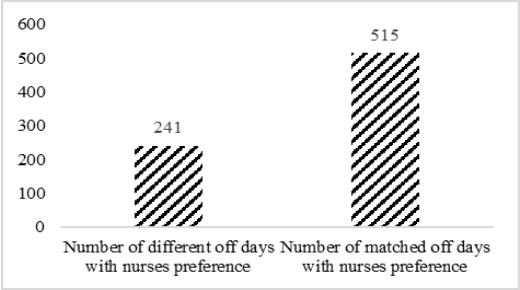

Figure 2. The results of the fifth goal in optimal scheduling

seventh goal had some deviations. This goal was observed in 3 out of 756 decisions due to hard limitations.

In order to have a better evaluation, the results of the optimal scheduling were compared with the current scheduling programs. Some deviations were observed in the first goal. However, generally, a balanced process flows among the nurses. Figure 3 compares the condition of the first goal in optimal scheduling and current scheduling conditions.

According to Figure 3, working day justice and balance have been improved significantly among the nurses in optimal scheduling. The reason for existing deviations is a shortage of nurses, because the minimum demand of the ward should be met. The second goal conditions in the current scheduling are so critical. The third goal also specifies a significant deviation in the current scheduling. Only 42.56% of the goal is observed in the current scheduling. The fourth and fifth goals,

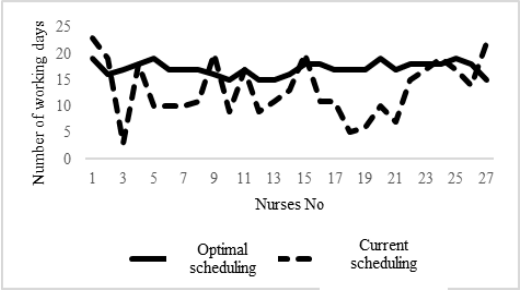

Figure 3. Comparison of optimal scheduling and current scheduling regarding the number of working days

which emphasize on nurses' interests, have critical conditions in the current scheduling.

Figure 4 compares current and optimal nurses scheduling regarding the fourth and fifth goals. The last two goals indicate high deviations in the current scheduling. Figure 5 compares the conditions of these two goals in the current and optimal nurses scheduling. Referring to Figure 5, the proposed scheduling of this research has an absolute superiority in the sixth and seventh goals over the current emergency ward scheduling. In the current scheduling, 95 isolated off days and 129 isolated working days were observed. The presence of isolated working shifts and off days dissatisfied the nurses and had adverse impacts on their performance.

4. 2. Sensitivity Analysis One of the main challenges in the nursing system is the number of nurses. The scheduling model was analyzed in order to make a deep understanding of the effects of the number of working nurses on the research goals. Since the hospitals are currently encountered with a shortage of nurses, it is clear that a reduction in the number of nurses will have negative consequences for them. Moreover, the first goal of the problem indicated that most of the nurses work more than the hours identified by the goal. It indicates that a reduction in the number of nurses will have adverse consequences.

The number of nurses and the change in this number were selected as model parameters to evaluate the efficiency of the proposed model. Therefore, eight new states were defined for the model by increasing the number of nurses from 27 to 35, one by one. Figure 6 indicates the results of changes in the objective function. Changing the number of nurses had significant effects on the first and fifth goals but no significant effect on other goals. These two goals are presented separately in Figures 7 and 8.

By an increase in the number of nurses, the efficiency of the first goal increases so that the rise of the number to 35 nurses, this goal will be fully achieved. This increase provides an opportunity for the model to select the nurses more freely and there will be no need for overtime working.

According to Figure 8, it can be observed that by increasing the number of nurses, deviation from this goal increases as well. As mentioned earlier, the fifth goal tries to schedule off days of each nurse based on

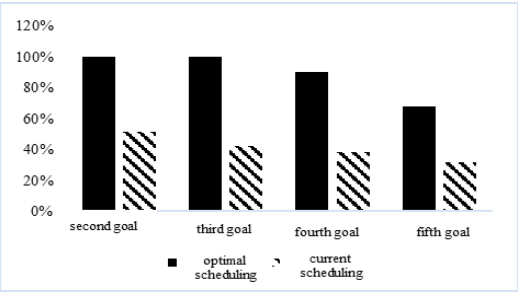

Figure 4. Achievement percentage comparison of the second goal in the optimal and current scheduling.

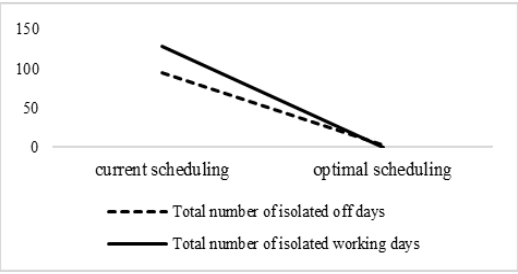

Figure 5. Condition comparison of the sixth and seventh goals in the current and optimal scheduling.

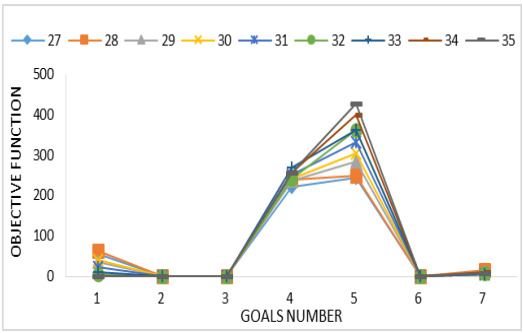

Figure 6. Changes in objective function for changes in the number of nurses

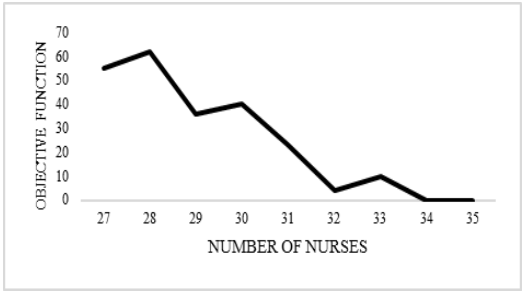

Figure 7. The effects of the number of nurses on deviation from the first goal

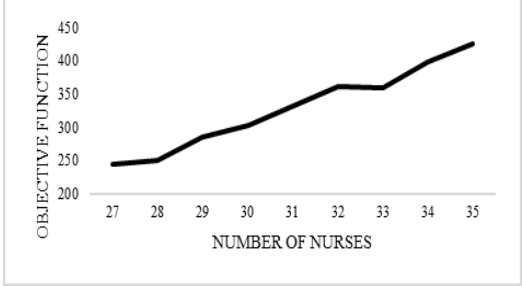

Figure 8. The effects of the number of nurses on the fifth goal

his or her interests. The reason for this increased deviation can be similarities in the interests of the nurses for selecting their off days. As the number of nurses increases, selection of off days based on their interests become harder. Therefore, with an increase in the number of nurses, deviation from this goal increases. It should be noted that although the numerical value of objective function rises with an increase in the number of nurses, the proportion of decisions taken based on the interests of nurses remains almost the same. As each nurse is added to the system, the number of variables added to the model rises exponentially. Therefore, it can be said that the model is still successful in fulfilling the goals.

5. CONCLUSION

Nurse scheduling is one of the most functional issues in the field of health management. In this study, nurse scheduling was carried out via goal programming. For the study sample, an emergency ward was selected from one of the hospitals in Tehran due to its high sensitivity and importance. The mixed mathematical integer model was designed and solved through the goal programming approach. The main contribution of this model is increasing nurse satisfaction. Two new goals, which were considered for the first time in this study aim to schedule working shifts and off days based on nurses' interests. Finally, seven goals were defined in order to have the best scheduling for the emergency ward. The output scheduling of study is the best and optimal scheduling model for working shifts of the nurses. It not only removes manual scheduling techniques but also is so fast and more effective. In sum, the model can increase nurses' satisfaction and performance. For future studies, development of scheduling methods can be more efficient with metaheuristic algorithms and game theories. Designing a scheduling model for human resources of other parts in the hospital and establishing a communication network between these schedules are among the main concerns in improving the function of hospitals, so that move them toward an intelligent health care center.

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APPENDIX

TABLE A. The optimal scheduling of the emergency ward for 4 weeks

Nurse / Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	V	M	E	E	V	M	V	V	M	M	V	V	V	N	V	E	V	V	V	N	V	E	E	E	M	E	V
2	E	V	E	V	V	V	E	N	V	V	V	V	N	E	M	V	M	V	V	N	V	M	E	M	M	M	V
3	E	V	E	V	M	V	M	N	V	V	N	V	E	V	M	V	E	V	M	E	N	E	V	E	E	M	V
4	E	V	V	V	M	N	V	V	N	V	E	N	V	V	M	N	V	N	M	V	N	V	V	M	V	E	M
5	M	V	V	E	M	N	V	V	N	M	M	N	V	V	M	E	V	N	E	V	V	V	M	M	V	M	M
6	V	E	V	M	V	V	N	M	V	E	E	V	V	V	V	M	V	E	M	M	V	M	M	V	N	V	M
7	V	M	N	M	V	V	E	E	V	M	V	V	V	V	V	E	M	M	V	M	N	E	E	V	E	V	M
8	N	E	E	M	M	M	E	M	M	E	V	E	N	N	N	V	E	E	V	M	N	E	M	M	M	N	M
9	N	M	M	V	M	M	V	E	M	V	V	M	N	N	E	V	E	V	V	V	E	V	V	M	V	E	V
10	E	E	M	V	E	E	V	E	M	V	N	M	N	N	E	N	E	V	N	V	M	V	V	V	V	M	V
11	E	V	V	N	E	M	E	V	M	V	N	E	V	V	M	N	E	M	E	N	M	V	M	V	N	M	N
12	M	V	V	E	V	M	M	V	V	M	E	V	V	V	M	V	V	M	M	E	V	V	M	N	N	M	N
13	V	M	N	M	V	V	E	N	V	M	M	V	V	V	V	V	V	M	V	E	V	N	E	N	E	V	E
14	V	M	E	M	N	V	M	E	N	E	M	N	E	E	V	M	N	E	V	M	M	E	M	E	M	V	M
15	N	M	M	V	N	V	E	E	N	E	V	N	M	E	V	E	N	M	N	M	M	M	E	M	M	V	V
16	E	M	M	V	E	M	V	M	E	V	V	E	M	M	N	M	E	V	N	V	V	M	V	V	V	N	V
17	M	M	V	N	E	E	V	E	V	V	E	V	E	M	N	M	M	V	E	V	M	E	V	V	N	N	N
18	M	V	V	N	V	E	N	V	V	N	E	V	M	V	E	E	M	M	E	N	M	V	N	N	E	E	E
19	V	V	M	E	E	E	N	V	E	E	M	M	V	V	E	V	V	M	M	E	M	V	N	N	M	M	M
20	V	N	M	E	M	V	E	V	M	M	V	M	V	E	V	V	V	V	V	E	M	N	E	N	V	E	V
21	E	E	E	V	M	V	V	V	M	V	V	M	E	E	V	N	N	V	V	M	M	N	V	V	V	V	V
22	M	V	M	V	V	M	V	N	M	V	M	M	E	V	M	E	N	E	M	E	V	E	V	V	M	V	V
23	M	V	V	V	V	E	N	N	V	V	M	V	V	V	M	E	E	M	E	V	V	M	V	V	E	V	V
24	E	N	V	N	N	M	E	V	V	N	V	V	V	M	M	M	M	E	E	V	M	M	N	E	E	N	E
25	M	N	V	E	N	V	M	V	V	N	V	V	V	M	V	V	M	V	V	E	M	V	N	M	V	E	M
26	V	N	V	M	E	V	M	M	E	N	N	M	M	M	V	V	V	V	V	M	M	V	E	M	V	M	V
27	V	V	N	M	M	N	V	M	M	V	E	M	M	E	N	M	V	N	N	M	V	N	M	M	E	V	V
28	N	V	N	M	E	N	V	E	V	V	M	V	M	M	E	E	V	N	E	V	V	E	V	V	M	V	N

Scheduling Nurse Shifts Using Goal Programming Based on Nurse Preferences: A Case Study in an Emergency Department

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چکیده

امروزه زمان‌بندی پرستاران یکی از چالش‌های مهم و حساس مراکز درمانی به شمار می‌رود. اهمیت کیفیت کار پرستاران باعث شده تا مسائل مرتبط با زمان‌بندی به دلیل تاثیری که در عملکرد کاری آن‌ها دارد مورد توجه محققان قرار گیرد. حفظ منافع بیماران و بیمارستان و در کنار آن ایجاد رضایت در پرستاران و توجه به خواست آن‌ها در زمان‌بندی از نکات اصلی مسئله است که این تحقیق به آن‌ها توجه ویژه کرده است. برای این کار از برنامه‌ریزی آرمانی به‌منظور مدل‌سازی و حل مسئله‌ی زمان‌بندی پرستاران استفاده شده است. برای این منظور یک مدل ۷ هدفه با توجه به نیازهای مدیریت و در جهت تامین رضایت پرستاران برای بخش اورژانس یکی از بیمارستان‌های شهر تهران توسعه داده شد. در نهایت با استفاده از نرم‌افزار GAMS مدل حل گردید. نتایج مدل یک الگوی بهینه جهت زمان‌بندی ۲۷ پرستار بخش اورژانس بیمارستان بقیه‌الله (عج) در یک افق ۲۸ روزه را نشان داد. طبق تعریفی که در مدل‌سازی مسئله انجام شده بود ۳ آرمانی که مرتبط با سهم، ترتیب و ایزوله بودن شیفت‌های کاری بودند، به صورت کامل برآورده شدند. همچنین، ٤ آرمانی که مربوط به رضایت پرستاران، تعداد روزهای کاری و روزهای تعطیلی ایزوله بودند به علت محدودیت منابع دچار کمی انحراف شدند. مقایسه‌ی نتایج با زمان‌بندی فعلی نشان می‌داد که زمان‌بندی بهینه کاملا برتر و از همه‌ی جهات مناسب‌تر از زمان‌بندی فعلی می‌باشد. تحلیل حساسیتی که بر روی تعداد پرستاران بخش انجام گرفت نشان می‌داد با افزایش تعداد پرستاران شرایط آرمان‌های مسئله به طور کلی بهبود می‌یابد. استفاده از این زمان‌بندی هم باعث ایجاد عدالت کاری و بهبود عملکرد کاری پرستاران می‌شود و هم رضایت آن‌ها را از نحوه زمان‌بندی بیشتر خواهد کرد.

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