Scheduling Computerized System for Nurses: Change the Traditional Method to the Electronic Method

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Abstract: Nurses working shift scheduling is known as a challenging task for nursing managers. In this study a nursing scheduler computerized system is designed to prepare justice schedules in less time. Data is gathered from shift schedules and nursing manager's interview in a big educational and governmental hospital in Iran. The expert entity planning procedure transformed to mathematical functions and system was designed based on Genetic Algorithms programming. Comparison between expert and system designed schedules resulted in 57% reducing of uniform arrangement cost and 93% time saving for nursing manager. Further investigations on designing a system which can be applied in various nursing wards with more constraints and flexibility are recommended.
[Asieh Darvish, Farzad Towhidkhah, Rasoul Khayati, Sina Keyhanian. **Scheduling Computerized System for Nurses: Change the Traditional Method to the Electronic Method.** *Biomedicine and Nursing* 2018;4(3): 22-30]. ISSN 2379-8211 (print); ISSN 2379-8203 (online). http://www.nbmedicine.org. 3. doi:10.7537/marsbnj040318.03.

Key words: Computerized system; Working shifts; Scheduling; Nursing; Genetic Algorithms

1. Introduction

In health care facilities, nursing administrators should arrange high quality timetables considering the constraints provided by nurses, patients and nursing wards requirements; so they find staffing and scheduling to be critical and a major operational challenge [].

Nursing schedules usually are generated in 3 methods intervals included periodical, rotational and self-scheduling. Self-scheduling has numerous organizational and individualistic advantages; for instance, saving nurse manager's time, reducing staff absenteeism and turnover; and improving cooperative atmosphere and team working spirit. But sometimes staffs prefer their requirements rather than the health care setting affiliated needs. So it may interfere with making an accurate schedule to meet all the management policies [].

Some of the Iranian private hospitals, where personnel shifts are mostly fixed, utilize the periodical scheduling. Nevertheless periodical scheduling or permanent shift for a specific period of time may decrease flexibility. Since the rotation program has more flexibility and off days differ from week to week programme; it can cover both personnel preferences and hospital requirements as well as producing better and effective schedules []. Hence there is more complexity in preparing rotation pattern [].

Arrangement of nursing schedules in educational hospitals is usually rotational in Iran; so the rotational nursing scheduling scheme is considered in the present study. Taking into account employee's individual superiorities, personnel requests as well as producing uniform schedules are a time-consuming and challenging task for nursing administrators [3]. On the other hand, studies have shown that nursing working shift scheduling issues have significant impact on nurse's health and quality of care [„"]. Although some studies have shown that scheduling influences not only health service costs but also nurse's job satisfaction [3,], but it is rarely considered. It seems that nursing managers must take on new dimensions to facilitate scheduling by the use of automated systems in order to improve nurse's job satisfaction and patient care outcomes and reach other strategic objectives. To bring this goal into reality the aim of this study was to design a nursing scheduler computerized system to prepare justice schedules in less time to give opportunity of presenting better services to patients.

1.1. Why designing a computerized system?

Producing adjusted schedules in traditional and manual method to meet nurses, patients and hospital's requirements is a time consuming and challenging task for nursing managers. An automated computer-based scheduling system can prepare schedules. Some benefits of implementing such a system can be as following: [3].

- Cost-effectiveness due to reduction of clerical staff and better use of professional nurses by decreasing the time spent on indirect patient care activities
- Unbiased, consistent scheduling

- Developing an easy-to read working schedule in advance; so employees know what their schedules are, also they can plan their personal lives accordingly
- Availability of data and integrating them with clinical information systems, for monitoring the effect of staff size and composition, quality of care and cost
- Improving nurses job satisfaction by producing adjusted schedules
- Improving nurses health by decreasing work time
- Promotion of the care quality by arranging schedules depending on nursing wards requirements and patients needs

Ultimately it has been found that automated staff scheduling is one of the most desirable components of management information systems.

1.2. Why Genetic Algorithms?

Nurse scheduling problems have been widely studied in recent years due to managerial and organizational constraints; and felt to be so hard to deal with. Therefore a lot of researches have been done to solve it heuristically or meta-heuristically [,,,]. Genetic Algorithms are searching techniques based on selection and recombination of solutions; and have been used to solve difficult scheduling problems successfully in recent years as an important class of meta-heuristics. Even it is used in nursing scheduling problem studies. Aickelin 1996, in his diploma thesis designed a nursing scheduler system based on GA in Germany []. Tanomaru used GA for weekly staff scheduling with a flexible starting work time in 1995 [] and Ozcan has used a set of mimetic algorithms, combining genetic operators and hill climbing method to solve rotational nursing schedules problem in two shifts included day and night in 2005 [].

Main application of genetic algorithms is its use in the problems with a huge solution space as our problem. So it is not possible for experts to find best solution in a real life time. GA can find better solution in the field of artificial intelligent. It is blind searches modeled on the idea of evolution in nature and has the "survival of the fittest" idea. The main GA elements are gene and chromosome or a string of solution. Solutions should be coded in a way that GA operators as selection, crossover, mutation and replacements can be applied. Better solutions through evaluation by fitness function will be improved [,].

In our study schedules should have been generated rotationally, so GAs which are known as suitable intelligent methods for producing optimized solution in scheduling problems are used to design a scheduler system.

1.3. Scheduling and timetabling

Timetabling is a specific type of scheduling problem and consists of assigning a number of events into a limited number of slots while minimizing the violations of a set of constraints.

The constraints of timetabling can be divided into two categories: hard and soft. Hard constraint can not be violated. Soft constraints are not essential but their satisfaction is highly desirable in order to produce a good quality timetable []. In this study, two common timetabling hard constraints were violated in order to produce feasible timetable.

A- Two same events can not be schedules at the same working shift in the same day.

B- There must be sufficient resources available for all the events scheduled for each timeslot.

1.4. Study Background

Regarding to other investigations and experiences, it is determined that implementing IT in nursing different aspects has become an important trend in health care [,,]. Ting-Ting Lee et al (2008) for smoothing the beginning stage of implementing nursing information systems, recommended nurses early involvement in the system design. They found that the use of nursing information system decreases nurses spending time on indirect care and ward related activities [].

As the basic infrastructures for implementing information technology in nursing care management are available; there is huge potential for system designing based on our problems in health care organizations. Working shift is one of the health care worker's oldest problems and is known to have important implications on nurses' health [5, 8, 9]. Nursing scheduling process is still done manually and prepare on papers in most hospitals. Studies resulted that the schedules have impacts on nurses health and satisfaction and also patients care quality [6, 7, , ,].

Studies in different countries, tried to solve problem based on a specific hospital with their own problem definition. In this investigation we tried to change the traditional method to electronic method by designing a system based on our health care setting problem definition in an educational hospital.

In our hospital, there were three shift periods per day: morning, evening, and night. The hospital nursing managers produced a monthly schedule and fixed it weekly. In Iran, BSN [1] degree is being awarded to registered nurses[2] after going through an academic educational period for 4 years. After that they are being employed for two years in educational hospitals to be experienced in real health care settings. During two years they may work in different wards and shifts. After two years they can fix their interested work area and would be employed in a private hospital. So educational hospitals would change their

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routine nursing resources and practice on rotation schedules.

2. Methodology

In this applied research samples were all the nursing wards schedules in hospital. Our week start day is Saturday & the last day is Friday, which is a holiday.

The purpose of this study was to design a system capable of generating weekly work schedule for at most 20 nurses working in three shifts; where would have minimized the cost of uniform arrangement. Features such as taking into account staff working shift preferences and their grades are also considered.

Data gathered through analyzing the paper schedules in 9 months. It was consisted of 63 papers data totally 252 weekly schedules. Then, two wards of the hospital bearing the utmost number of personnel and the most complicated planning procedure selected using convenient sampling method for designing system. Also structured interviews with 6 experienced and knowledgeable nursing managers were conducted to reach data saturation. The major focus of interview questions was on the number of shifts per day and each time accounting, nurses grades, normal work hour per week, required number of nursing personnel per day & per shift, scheduling method, time spend for preparing weekly schedules and introduction of the ward with the most complicated scheduling. Their expert entity planning procedure was transformed to mathematic function. Then our system was designed with Genetic Algorithms programming via MATLAB software. Finally we compared the schedule produced in the selected ward by expert nurse and our system for 6 months.

All participants were informed about the purposes and the method of the study. Before starting the interview process, they were informed that participation in the study was voluntary and they could refuse to participate or withdraw from the study at any time without penalty. Also the data they present to the researcher would be kept confidential and would be used just in the research framework. However they cooperated with keen interest.

Data collection was done in following 5 stages:

1. Getting introductory information from officials affiliated to nursing management office. They helped the researchers to choose a suitable research environment with this criterion: having the most complicated nursing scheduling process.

2. Gathering the written schedules on paper generated by nursing managers during three months from all nursing wards of the hospital with respecting to the ethical issues. Then required data were extracted and analyzed.

3. Conducting structured interviews with the hospital nursing managers and wards head nurses to confirm accuracy of the analyzed data. The gathered data were saved on paper.

4. Selecting the ward with the most rotation schedules and most number of active beds (30 beds) and nurses (20 people).

5. Extracting required data from schedules of the selected ward for designing the system.

Finally expert scheduling procedure was converted to a mathematical cost function model. Then the system was designed based on our data, in continue chromosome, GA parameters and strategies were defined. In the last step we evaluated the designed system by comparing the schedules generated by the system with expert generated ones during 6 months scheduling in the selected ward.

3. Results

Here the study findings step by step are mentioned:

Step1: Analyzing data

- Shifts: There were three shifts as morning (7 hours), evening (7 hours) and night (12 hours)
- Grades: A- Registered nurses with less than two years experience B- Registered nurses+ with between two and twenty years experience C- Associate nurses with working experience varies from less than two years up to more than twenty years experience.
- Normal work hour: 44 hours per week
- Scheduling method: rotational
- Time spend for preparation of weekly schedules by expert: at least 30 minutes

Step2: Determining cost function

The important parameters of the problem have been modeled to determine cost function. Our problem was a multifunctional problem. Scheduling timetable should be completed by nurses in an adjusted manner. In complicated condition; a simple model of nurse's preferences to work on different shifts should be taken into account. One function for each is determined.

First function will account fitness of uniform distribution:

$$f_1 = \sqrt{\sum_{i=1}^{Numof\ Nurses} (WeekHour_i - NormalWorkHour)^2}$$

Parameters describe as follow:

Number of Nurses Nurse number i

$WeekHour_i$	Work hour per week for nurse number i
Normal WorkHours	Normal work hour per week

Minimizing f_1 will minimize the difference of Normal work hour per week and Work hour per week for each nurse.

For the $WeekHour_i$ we have:

$$WeekHour_i = H_{Night} \times NNightSh_i + H_{Evening} \times NEveningSh_i + H_{Morning} \times NMorningSh_i;$$

Where:

$Num\ of\ Night\ Shifts_i$	Number of night shifts for nurse number i
$Num\ of\ Evening\ Shifts_i$	Number of evening shifts for nurse number i
$Num\ of\ Morning\ Shifts_i$	Number of morning shifts for nurse number i
H_{Night}	work hour of night shift =12
$H_{Evening}$	work hour of evening shift =7
$H_{Morning}$	work hour of morning shift =7
$WeekHour_i$	Sum of work hour per week for nurse number i

Second function will account fitness of nurse's preferences to work on different shifts. Nursing services are needed for 24 hours, when nurses and their family members are used to arrange their living programs based on 8 hours work and five days per week. So it is very important for some nurses to have less variant schedules. Since we should not only arrange adjusted schedule, but also meet nurse's requests at least.

$$f_2 = \sum_{i=1}^{Num\ of\ Nurses} \frac{\sum_{j=1}^{Num\ of\ Unfavorite\ Shifts_i} WorkHourShift_j}{\sum_{k=1}^{Num\ of\ Shifts_i} WorkHourShift_k}$$

Parameters describe as follow:

Num of Nurses	Number of nurses
$Num\ of\ Shifts_i$	Number of shifts
$Num\ of\ favorite\ Shifts_i$	Number of favorite shifts for nurse number i
$Work\ Hour\ Shift_i$	Work hour in shift number i
$\sum_{j=1}^{Num\ of\ Unfavorite\ Shifts_i} WorkHourShift_j$	Number of unfavorite shifts for nurse number i
$Work\ Hour\ Shift_i$	Sum of work hour for nurse number i

In fact, minimizing f_2 means minimizing the ratio of un-favorite work hour to the sum of work hour per week for all nurses. So it will make work shifts schedule closer to nurse's interest shifts.

For determining total function, f_1 and f_2 should be optimized together. In this way we convert a multi functional problem to one functional and assign weight 20 to W_2 to normalize total function.

$$f_{Total} = w_1 \times f_1 + w_2 \times f_2$$

To give more importance to each function 1 or 2, we can assign a weight.

Step3: Coding and chromosome determining

Numbers were assigned to nurses. From 20 personnel, two were head nurse and unit clerk with fixed five or six morning work schedule who was left out from the study. In this stage, 18 nurses should be scheduled. Chromosome determined based on table1 with the length of 94.

Initially, we determined the required number of nurses is sufficient to assign the slots to violate first common hard constraint in timetabling problems on (table 1).

Table 1: The required number of nurses per week

wards	Holidays Morning Evening Night	No holidays Morning Evening Night
First ward	2 1 1	3 2 2
Second Ward	4 3 3	6 4 4

In related to the second hard constraint; programming has been arranged "for loop" to circle the timetable slots and replace each repeated number per shift with the other number to prevent of repeated numbers in slots per shift in the same day.

Grades also have been taken into account and increased complexity. In hospital, nurses have different experiences and skills. Registered nurse+ with more than two years experienced are more professional rather than registered nurses who have completed their college 4 years education recently (with less than two years experience). Both should do their tasks including special tasks such as oral and injection therapy, visit, wound dressing and suture care. Associated nurses help nurses in providing patient care such as vital signs. Suitable distribution of these grades is important for quality of care in nursing management. In this study designing system with three grades were examined.

Grade1: Seven registered nurses

Grade2: Seven unregistered nurses

Grade3: Four associated nurses

Chromosome determined based on table2 which is extracted in data gathering stage. We designed chromosomes for each grade separately.

Table 2- Required grades per shift

Grades	Holidays Morning Evening Night	No holidays Morning Evening Night
Registered Nurses	1 1 1	3 1 1
Unregistered nurses	2 1 1	2 2 2
Associated nurses	1 1 1	1 1 1
Total	4 3 3	6 4 4

Step 4: GA Strategy and Parameter determining

Bellow GA strategies and parameters gave the best results in consequents runs and kept for future experiments.

Strategy	**Optimized setting**
Population size	100
Parent selection	Rolette weal
Crossover percentage in population (pc)	60
Mutation percentage in population (pm)	25
Recombination percentage in population	100-pc-pm = 15
Stopping Criteria	100 generation

Step 5: Simulations implementing

First simulation: Distribution of 18 nurses **by first function**, convergence diagram has shown the decreases cost from 42.7 to 11.3 in last generation.

Second simulation: Distribution of 18 nurses with three grades **by first function**, convergence diagram has shown that our recommended algorithm can generate schedules effectively.

Third simulation: Distribution of 18 nurses **by total function**, it is supposed nurse 1 to 6 are interested to morning shift, 7 to 12 are interested to evening shift and the others are interested to night shift. Convergence diagram has shown the decreases cost from 255.8 in first generation to 178.8 in last generation. Cost function results showed f_1= 30.28 and f_2= 7.42 means the cost of uniform distribution some increased but nurses schedules are more closed to their interests.

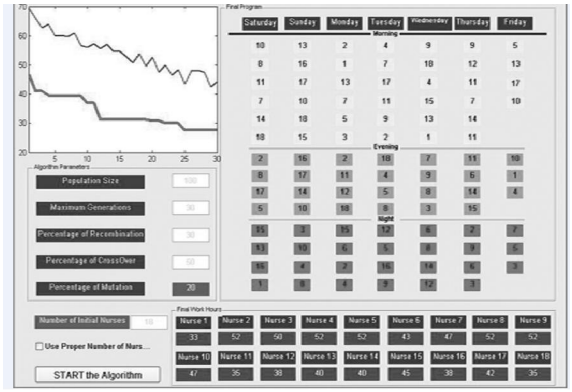

Figure 1- system graphical environment

Step 6: Graphical environment

For evaluation of the system we designed a graphical user-friendly environment (Figure1) to be able to distribute 18 nurses in a weekly schedule uniformly; based on 2nd simulation and 1st function.

This graphical interface has below features:

- Setting and changing GA parameters
- Determining number of nurses we want to generate schedule for
- Generating schedules for less than 18 nursing resources
- Generating artificial nurses in the case of lack of nursing resources
- Viewing the progress of scheduling process and convergence diagram
- Viewing the population minimum and mean cost
- Viewing the weekly schedule timetable generated
- Viewing the sum of work hour per nurse in the schedule timetable generated

If our nurses are less than 18 (which is set by default in the system), we have two situations:

1- Selecting "Use proper Number of Nurses" will automatically make artificial nurses instead of absent people and continue to generate schedule for 18 nurses.

2- Not selecting " Use proper Number of Nurses", will generate adjusted schedule for which number of nurses you entered and distribute the work hour of the absent nurses among others uniformly.

Step 7: Evaluation of the system

In the last step for comprising schedules produced by expert and our designed system; 6 months schedules produced on papers are compared. In the way that extracted data were analyzed and pre-processed, then fed into the first function and check out its cost results which shows fitness. In expert schedules, 17 nurses out of 18 were considered in scheduling, due to the leave law. Also we extracted data from those weeks, which had only one holiday, because our system designed for such weeks. It included 16 weeks. So we produced 16 schedules with 17 nurses by designed system. The cost comparison results can be seen in Figure 2.

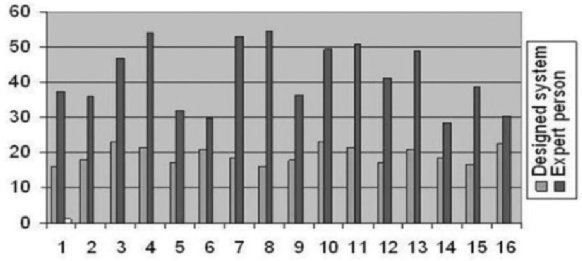

Figure 2- Compare cost results in expert and our system schedules in 16 weeks with 17 nursing resource and uniform distribution

Time spend comparison

Our system produced schedules in around 2 minutes; versus the expert time spent on producing schedules for one week was around 30 minutes. It shows our system can save nursing manager's time by 93%.

Uniform distribution cost comparison

Finding on comparison of total Variance, total mean cost, and Standard Deviation resulted on more efficiency in our system than expert (table3). Mean comparison shows our system has 57% improvement in distributing uniform schedules than expert.

Table 3- Uniform distribution cost comparisons

Comparison	First ward Variance Mean SD	Second ward Variance Mean SD
Expert schedules	28.6 35.5 5.3	86.3 41.6 9.2
Designed system schedules	0.8 8.5 0.9	4.4 17.7 2.1

Deciding in lack of human resource

In our problem, when recently graduated nurses complete their two years work experience, they may leave the ward. Also they may experience working in different wards during these two years. In this situation or some others like illness of personnel, nursing managers should arrange schedule with reminding people. So there will be load on some personnel. Here an adjusted distributing schedule can overcome long time work load on some nurses, which our system is capable to produce. It results on more nurses' satisfaction and improvement on care outcome. But an expert may not be able to consider complete justice based distribution of the absent people work times between all others.

4. Discussion

Timetabling & scheduling problems are generally suitable to be solved by GA. This investigation determines the efficiency of GA to design nurse scheduling system. It is mentioned the same in the other investigations [4, 15, ,]. Various

studies on nurse scheduling problem defined their problem based on the data of a specified hospital, so we could not use their method in this problem. In our study, problem to be solved is defined locally. Accordingly, cost function was designed based on our data extracted from expert made schedules and some constraints in the model were entered. It is supposed to enter more constraints in future research to be more similar to the real world.

Nursing managers spend a lot of time to arrange staff scheduling. But our system is expected to save time by 93% which results in manager's efficiency promotion. Studies with variant strategies and methods, reported much more reduction in the time spent on scheduling by computerized system than expert. The time for producing schedule was reported to be less than 15 minutes by Isken et al 1990 [], and more than 90 seconds by Anzi et al 1987 [].

Notarantonio (2006), the nursing manager of Arizona Hospital, reported decrease in mangers time spent on scheduling by half an hour and 25% savings by the use of internet based staff scheduling system. She reported the nurse managers were already spending about 60 percent of their time each week creating paper lists and telephoning staff to fill vacant shifts. Also they were increasingly using costly external agencies to fill open shifts at a rate of nearly 20 percent more per hour than they paid their internal staff already [].

Staff scheduling internet based system is mostly based on self scheduling. So it may satisfy nurses and save managers time; but may need to be refined to reach a uniform distribution and take into account the preference requirements in distribution [].

Nursing management studies recommended consideration of nurse's preferences as well as hospital requirements in schedule designing [,], which our system tried to consider. It is difficult to pick up a nursing journal today that does not have at least one article that speaks to the relationship between nursing care hours, staffing mix, and quality of care []. Considering grades, in our system has attention to staff mix also.

On the other hand, our system can produce uniform and satisfactory schedules as well as decrease in nurses work time load on some personnel and promote caring outcome and nurse's health.

Also our system prepares a uniform schedule; as it can distribute the absent personnel work hours among all present ones, or it can produce a schedule for a new personnel instead of absent one. We defined normal work hour per week to be 44 hours for 18 nurses. Our system is considered about 47 hours for 17 nurses automatically by calculation based on table 1 data. The most work hour in the highest cost results varied from 71 to 55 hours per week for 17 nurses distributed in the timetable slots respectively in expert and system produced schedules. So this system is capable to produce better schedule with less work time for personnel.

Conclusion

Designing staff scheduling traditionally on the papers has many disadvantages such as being time consuming, paper and documents protection (in A2 size) cost, defect on management decision making and error in manual calculations. Now a day, there are equipments available to automate these processes. In this study we found that in our educational hospitals, schedules are mostly flexible rotational, which try to satisfy management policies and can consider nurses preferences also. In our study, Genetic Algorithms were utilized successfully. It is feasible to generalize it to other ward of the hospital by making modifications in programming, based on unit's data such as the quantity of the required staff in each shift as well as the working priority of the nurses. Considering the complexities of the nursing scheduling and other constraints based on the rules such as confining work to two diurnal shifts per 24 hours; and further investigations on the effect of such a system on nurse's effectiveness is proposed. Designed system can be use in the wards with same condition according to our data. The same way can also be use to design system for the other wards with different conditions in the entire world.

Acknowledgements

This article is outcome of the dissertation in the postgraduate degree in the medical information technology management field in 2008. Here we wish to acknowledge nursing managers and all those who contributed in any way to the completion of this research.

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References

1. Tomey Ann Marriner, Nursing Management & Leadership, seventh Edition, U.S.A.: Mosby, Elsevier, 2004; 716 -723.
2. Hosseini M., Fundamentals of Nursing Management, Tehran, Iran: Boshra Publications; 2006: 170.

3. Huber Diane L., Leadership & nursing care management, 3rd Ed., Philadelphia: Saunders Elsevier; 2006: 387-394.
4. Aickelin U., Genetic Algorithms for Multiple Choice Optimization Problems, University of Wales, 1999. PhD Thesis. Available at http://www.cs.nott.ac.uk/~uxa/papers/Thesis.pdf
5. Soleimany M.A., Nasiri Ziba F., Kermani A., Hoseini F., A comparative study of the general health among staff nurses with fixed or rotating working shift, Iran Journal of Nursing, 2007; 20(50).
6. Kiekkas P., Brokalaki H., Manolis E., Samios A., Skartsani C., Baltopoulos G., Patient severity as an indicator of nursing workload in the intensive care unit, Journal of Nursing in critical care, England, 2007;12 (1): 34-41. Available at http://www3.interscience.wiley.com/journal/118515180/abstract?CRETRY=1 & SRETRY=0
7. Montgomery V.L., Effect of fatigue, workload, and environment on patient safety in the pediatric intensive care unit, Journal of Pediatric critical care medicine, published in United States, 2007; 8 (2): 6-11.
8. Anosheh M., Ahmadi F., Faghihzadeh S., Vaismoradi M., Survey of predisposing causes of working errors in nursing cares from perspective of nurses and their managers perspectives, Iran Journal of Nursing, 2007; 20(51):25-36.
9. Shu-Fen N; Min-Huey Ch; Chiung-Hua Ch; Desley H; Anthony O; Kuei-Ru Ch, The Effect of Shift Rotation on Employee Cortisol Profile, Sleep Quality, Fatigue, and Attention Level: A Systematic Review, Journal of Nursing Research, 2011; 19(1).
10. Ruggiero Jeanne S., Health, Work Variables, and Job Satisfaction among Nurses, Journal of Nursing Administration, 2005; 35(5): 254-263.
11. Aickelin U., Dowsland K. A., An indirect Genetic algorithm for Nurse Scheduling Problem, Computers and Operations Research, 2003; 31(5): 761-778. Available at http://eprints.nottingham.ac.uk/661/1/04cor_indirect.pdf
12. Aickelin U., Paul W., Building Better Nurse Scheduling Algorithms, Annals of Operations Research, 2004; 128: 159- 177.
13. Bellanti F., Carello G., Croce F.D., Tadei, A greedy-based neighborhood search approach to a nurse rostering problem, Europian Journal of Operational research, 2004; 153(1): 28-40.
14. Burke, E.,P. De Causmaecker, S. Petrovic, and G. Vanden Berghe, Metaheuristics for Handling Time Interval Coverage Constraints in Nurse Scheduling. Applied Artificial Intelligence, 2006; 20(3).
15. Aickelin U., Dienstplanerstellung in Krankenhausern mittels genetischer Algorithmen, Business Science, University of Mannheim,1996. Diploma Thesis. Available at http://www.cs.nott.ac.uk/~uxa/papers/diplom.pdf
16. Tanomaru J., Staff Scheduling by a Genetic Algorithm with Heuristic Operators, Proceedings of the IEEE Reference on Evolutionary Computation. 1995; p. 456- 461.
17. Ozcan E., Memetic Algorithms for Nurse Rostering, 20th International Symposium on Computer and Information Sciences, Springer-Verlag, 2005; p.482-492.
18. Holland J., Adoption in Natural and Artificial Systems. Ann Arbor: University of Michigan Press.1976.
19. Mitchell M., An Introduction to Genetic Algorithms, MIT Press, 1998; 209 p., Available at http://www.esnips.com/doc/8eb3ad27-db6a-47a1-91d5-03112c60296a/An-Introduction-to-Genetic-Algorithms---Melanie-Mitchell
20. Abdullah Salwani, Heuristic approaches for university timetabling problems, The school of computer science and information technology, University of Nottingham, 2006. PhD Thesis. Available at http://www.asap.cs.nott.ac.uk/publications/pdf/sqa-thesisFinal.pdf
21. Gary L. Gaumer, Rebecca Koenigerk-Donohue, Christina Friel, Mary Beth Sudbay, Use of Information Technology by Advanced Practice Nurses, CIN: Computers, Informatics, Nursing. 2007; 25(6):344-352.
22. Susan P. Kossman, Sandra L. Scheidenhelm, Nurses' Perceptions of the Impact of Electronic Health Records on Work and Patient Outcomes. CIN: Computers, Informatics, Nursing. 2008; 26(2): 69 -77.
23. Jane A. Anderson, Pamela Willson, Clinical Decision Support Systems in Nursing: Synthesis of the Science for Evidence-Based Practice. CIN: Computers, Informatics, Nursing. 2008; 26(3): 151-158.
24. Ting-Ting Lee, Mary Etta Mills, Ming-Huei LU, Impact of a Nursing Information System on Practice Patterns in Taiwan. CIN: Computers, Informatics, Nursing. 2008; 26(4):207-214.
25. Kilpatrick Kelley, Lavoie-Tremblay Melanie, Shiftwork: What Health Care Managers Need to Know. Health Care Manager. 2006; 25(2): 160-166.
26. Movahhed M., Haghighi Moghaddam Y., Survey of job satisfaction and the factors affecting it, with employed nurses in the educational and curative centers of Urmia University of Medical

Sciences, Journal of Urmia Nursing & Midwifery Faculty, Iran, 2004; 2(2): 91-86.
27. Mahmoodi H., Ebrahimian A., Solynmani M., Ebadi A., Hafezi S., Fayazi F., Sadeghi M., The study of job motivation factors in critical care nurses, Journal of Behavioral Sciences, Iran, 2008;1(2): 171-178.
28. Beddoe, G. R. and S. Petrovic, Selecting and Weighting Features Using a Genetic Algorithm in a Case- Based Reasoning Approach to personnel Rostering. European Journal of Operational Research, 2006;175(2): 649-671.
29. Puente J, Gómez A, Fernández L, Priore P, Medical doctor rostering problem in a hospital emergency department by means of genetic algorithms, Computers & Industrial Engineering, 2009; 56(4): 1232-1242.
30. Isken M., Hancock W., A Heuristic Approach to Nurse Scheduling in Hospital Units with Non-Stationary: Urgent Demand and a Fixed Staff Size, Journal of the Society for Health Systems, 1990; 2(2): 24- 41.
31. Anzai M., Miura Y., Computer Program for Quick Work Scheduling of Nursing Staff, Medical Informatics,1987: 43-52.
32. Notarantonio R, Arizona hospital online shift bidding and staffing system Report, 2006. Available at http://archive.healthmgttech.com/archives/0206/0206going_once.htm
33. Darvish A., Towhidkhah F., Khayati R., Keyhanian S., Designing nursing schedules through internet: a new approach in nursing management, Quarterly Journal of Yasuj, Faculty of Nursing & Midwifery, Kohgilluye & Boierahmad University of Medical Sciences, Iran, 2008; 2(1): 121.
34. Moosavi S.A., Foroughi S., Zakavati R., H. Abbasi N., Haggigi S., Mehdiyan nasab S.Moosavi Z., Fundamentals and Principles of Management in Nursing, 1st ed., Tehran, Iran: Khosravi Publications; 2005:62-63.
35. Šimunić A & Gregov L, Conflict Between Work and Family Roles and Satisfaction among Nurses in Different Shift Systems in Croatia: a Questionnaire Survey, Archives of Industrial Hygiene and Toxicology, 2012; 63(2): 189–197.
36. Bessie L. Marquis & Carol J. Huston, Leadership roles & management functions associated with staffing and scheduling, 5th ed., Lippincott-Wilkin; 2006: 429.

9/25/2018