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"MODELING AND SCHEDULING INTELLIGENT METHOD'S APPLICATION IN INCREASING HOSPITALS' EFFICIENCY"

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ABSTRACT

Every human cost of each hospital as the greatest presenter the health care and treatment to all people, the main sources and credits allocated to the health and treatment of a country. Determining the optimal number of employees for each ward of hospital, because of its importance in quality of services offered to customers and costs are among the issues that any clear standard has not been written for it.

In This study, the aim of modeling of hospital and use of intelligent systems to adjust the shift program and to determine optimal number of hospital staff in order to increase efficiency and minimizing its costs.

As, the presence of patient in the hospital and releasing them can be considered as a discrete system with the characteristics of Markov processes, in the first step, using Markov's chain models a good estimate of the system conditions such as the number of beds needed and occupied beds, which can be offered in the optimization of capacity is beneficial. In second step, to develop the model, an approach is stated for minimizing the costs with assist of Petri's network. Finally, to control and optimize the model with using the genetic algorithm is presented for optimal shifting of human resources like nurses. The results show 42% reduction of human resources costs and 87% saving service time for patient.

This study is applicable and it's in group of descriptive-analysis studies, which had been design as the software and the data collection tool was the checklist of Bu Ali Hospital's patients' records, which approved by the related experts and studied after observation, chronoscope and also time of human resources services to several patients and the plan shift of nurses and doctors has been studied with use of intelligent system's designing. Data analysis and planning is carried out with the method of Petri net and Markov and genetic algorithm with use of Matlab and Hpsim software.

Comparison of preparation programs and system design show to patients, improvement of cost reduction about 42% and 87% time saving service.

Research various models in operation, can be used as a suitable tool for scheduling and determination the optimal number of staff needed in several parts of a hospital, which has a vital and significant role. Since the designed system in this study is limited to the obtained data from medical and educational center of Bu Ali department affiliated to Islamic Azad University Tehran medical branch, to extend and optimum use in other hospitals require making changes in programming based on data. Therefore, it is recommended to

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make these systems usable in other hospitals and increasing restrictions, so the prepared program will be closer to the real world, to be done.

Keywords: *Hospital Efficiency, Petri's Network, Markov's Chain Model, Genetic Algorithm, Intelligent Networking*

1. INTRODUCTION

One of the strategic areas of information technology development in the country is health, which acceptance and quick treatment of patients is one of the main components of health care. This center in one side is responsible for the increasing trend and the increasing patients to receive good services, and on the other hand always face limited resources and budgets. Real value human resources needed in the sections of hospital is one of the important concerns of a hospital management . Timetable problems program of different staff of the 1980s had been considered and studied by several researchers. Human resources management policies system can affect on staffs efficiency, care quality, nurses and doctors conscience. Hospitals performance assessment by using modeling and simulation can be propounded as a suitable tool for capacity programming and improve efficiency in providing health care. So it's essential, hospitals with human resource planning and efficient use of labor, time and cost while increasing efficiency reduce planning problem. The basic issues, which can be considered for running optimal hospital systems are including: 1- dimensions of a hospital system 2- understanding the performance and identify system problems such as patient waiting time 3- improving performance 4- study the reaction system against large volume of work.

2. PREVIOUS STUDIES REVIEW

In order to determine the efficiency of hospital and optimizing the staff numbers by using intelligent networks, numerous article based on Markov's chain models or Petri network or genetic algorithm have been presented that in the continuance, some of them are studied.

Whereas the time spent for data processing and planning staff shift work, takes a lot of times from nurse managers, in a research by ANSI and his colleagues in 1996, with use of genetic algorithm they have studied reduction of nurse shifting set time. Implementation of the software was done in 90 seconds.

In 1991, Khan presented a model for minimizing the human resource. The human resource was the nurses whom were supposed to employ in different wards of hospital. They tried to present a model of shifting for the staff of the emergency ward. Yet they could not find a complete model and method for a complex system like emergency wards [3]. In 1996, Mourtou in one of the Greece hospitals made a hospital model by using Petri's network and Hpsim software. In this research, a model was presented for patient services that show the reduction of patient's waiting time up to 23.91%. [7, 12].In 1997, Pitt presented a simulation model which could be applied in different wards of a hospital. The obvious result of this research was a model in which, a hospital was able to have a similar treatment result with fewer budgets but less time

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for patients to stay in hospital. In 1997, Lio and Kao applied the estimation method to determine the number needed for staff based on line programming for optimizing of nurses number In 1998, Isken and Han Cock studied the timing model applicability in different wards of a hospital with different demands during a week, days and a whole day.The intelligent models as a planning and decision making method has been used in health care field increasingly in the last two decays. Genetic algorithm are appropriate for planning and time table problems solving, and a plenty software packages for programming and nurse's shifting problem solving are based on genetic algorithm. This fact is agreeable to the results of Beddoe[28] and Ozcan [25]. The study of researches in this field shows that there are various methods for timing and nurses' shifting problems solutions. In these methods, a simple model or much related to a specific problem in a hospital are generally considered.Gallivan and his colleagues in 2002 studies by offering a model based on Markov's chain were studied the variability in the length of line since it is an important factor in the hospital operations. In this research, reducing patient waiting time in order to get beds for hospitalized patients were studied, and a model was presented for optimizing beds and reducing unused beds.In 2006[30], Ms.Saeedeh Ketabi worked on quantitative optimization in nurse staff in emergency ward of Chamran Hospital with linear programming and they were presented an estimation for reduction in the number of the nurses.In 2008[31], Ms. Asiyeh Darvish presented an intelligent system to set nurses' shift with fewer numbers of them according to fewer working time, nursery ranking and nurses' will with help of genetic algorithm in Koodakane Tehran Hospital. This system presents an optimized shifting schedule in 2 minutes. In this research, the conditions of wards of hospitals is studied according to the discrete event time system (DES) based on Markov and Petri net method, and modeling of hospitals is carried out according to the patients' waiting time and duration of bedridden and then with use of genetic algorithm intelligent system we will study the working time scheduling regulation with less human resources. Rushing and waiting, waiting for a long times for a patient, staff getting tired of working, wasting and etc...All of these are signs of designing a flawed system for the patient matters. Petri nets are mathematical and graphical modeling tools. These models are suitable tools for describing and studying information processing systems which states systems behavior [8]. Markov chain models can be used for appropriate modeling mode choice for estimation of certain models. Markov method is memory-less random discrete events processes. Memory-less means that it is likely to attend a state depend on previous state and it does not depends on state's lifetime. Memory-less is equal to the point that modes counting process has Poason distribution and time of events happening had exponentially distribution. With use of simulation modeling can answer to the qualitative questions [9]. One of the common methods of artificial intelligence is genetic algorithm which is comprehensive searching technique based on natural genetic action. Sub-structural elements of evolution process in GA (genetic algorithm) [10] are including genes

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programs population, age renewal, mutation, competition and selection. Thus nature with gradual elimination of inappropriate species and higher proliferation of optimal species can promote continually each generation in case of different features. In this article, presentation of a model of a hospital and presentation quantitative benchmark for comparison, study of efficiency and extraction of useful variables such as estimated time for ward occupation and presentation shift plan is defined in manner that can minimize costs of uniform alignment of forces.

3. STUDY METHOD

This study is applicable and carried out for software design and achieved according to the extracted data. Samples are chosen from general and specific wards such as emergency and ICU. Data collection tool shifts nursing program during the second 6th month of 1387 and the emergency triage form samples and check lists of time-related services time to patients, that are collected by the wards personnel during two august and September months of 1378 and 200 patients and recommended system based on these data was designed. Analysis of data carried out through review and pre-processing data and calculating mathematic functions and modeling and planning with Petri-net and Markov method and genetic algorithm by using of Hpsim and Matlab 7.1 software.

4. FINDINGS

Being designed intelligent system, after running the designed software, firstly, we entering in to graphical space which is including three icons: nurse shift(algorithm genetic model),manage time(Petri net model) and balance bed(Markov model). Work in process (shown in figure 1). By implementing any of these icons we would enter in to another window which we first receive data and then runs desired application. In this regard, first, we want to study Markov Model (bed balance).

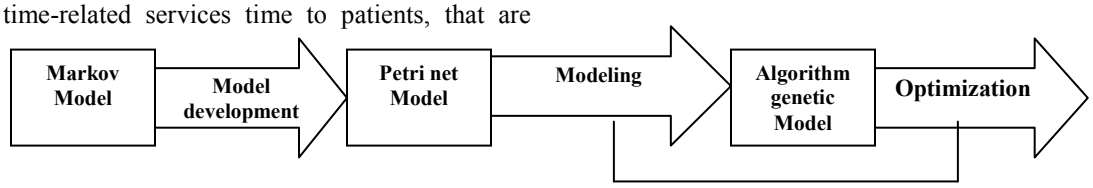

Figure 1: working in process in a view

Markov chain model can be used by choosing the appropriate mode in modeling for estimation of specific models of systems. In this section the time period of hospitalization of patients in wards would analyze and finally the purpose of the analysis would be the used capacity in rooms of ward in order to be able to maximize the usage of existing spaces by re-allocating them for reducing patients waiting time. Achieved findings from hospital records of patients analyzed by using technique based on Markov chain model and then we study the amount of occupied beds with simulated analysis. Accordingly, the proposed scenario for hospital management is introduced and evaluated, (shown in figure 2). This scenario is the usual hospital, in this scenario try to improve understanding of unused space in ward of hospitalization. Accordingly, you can see:

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$$P_{ij} = \begin{cases} k_j / k_i & if \ = j = i + 1 \\ 0 & otherwise \end{cases}$$

(1-1)

Ki* is the percentage of patients who are in hospital after (i) day while Ki is the total percentage of patients who are in hospital after (i) day.

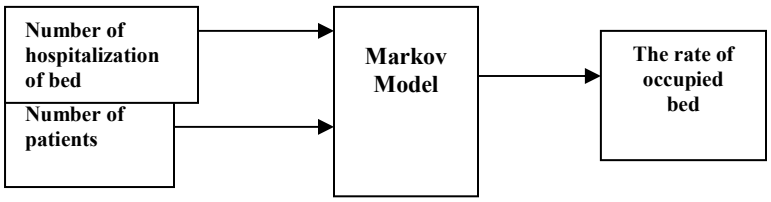

Figure 2: modeling with Markov method

By running of this program we have:

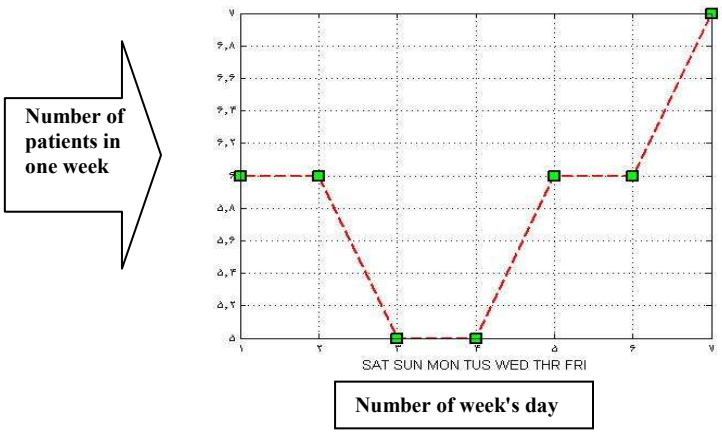

Figure3: graph of patient's bedridden period in ICU May – Jun

The Result of study and rate of occupied bed in ICU"

Table 1: results achieved from markov model analysis of ICU ward

Month	*Saturday*	*Sunday*	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	**Friday**
May-June	76/19%	90/47%	89/51%	90/46%	83/33%	83/33%	76/19%

By observing the achieved results from analysis of beds with Markov method in ICU ward it can be stated that there is no unused bed in this ward and according to the hospital structure we can increase the number of beds in ICU ward. Graph of hospitalized patients shown in figure3 and achieved result shown in table 1The second stage of research, for designing systems and software package we carry out modeling and graphical drawing with modeling Hpsim software, shown In figure5 and we design the manage time program with Matlab software which shows the efficiency computation and waiting time. According to the findings, we would study and analyze the Petri net method. Petri Net can be used to express any field or a system which can be described graphically by a flowchart and use a tool for showing parallel or simultaneous activities. A Petri net is a quintuple set of PN= (P, T, F, W, and M) in which: T= is a finite set of

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transitions, P=is a finite set of places , F: set of arches, W: is a weight function, M: is a primitive marking

,

$$M'(p) = M(p) - I(p,t) + O(p,t) \forall p \in P$$

, M (p) ≥ I (p,t) (1-2)

For stimulation we use queue theory. Our main purpose in queue theory discussion is superficial preparation of facilities which affected by queue theory and finding solution for minimizing related costs. Queue theory, mathematic and statistic science is expanded in a manner that can help managers in analysis of queue or waiting and optimization of systems. Now the Petri net model would study for a queue system [8]. accordingly, for modeling parts of hospital with Petri net, (shown in figure4) first we must examine patient process in a hospital, and then we present a model for this process. For modeling hospitals' wards by Petri net Then a Petri net model would be presented for this process. Table 2 shown several conditioned of ICU in case of doctors and nurses numbers andtable 3 shown results achieved from Petri net analysis of ICU ward with design the manage time program with Matlab.

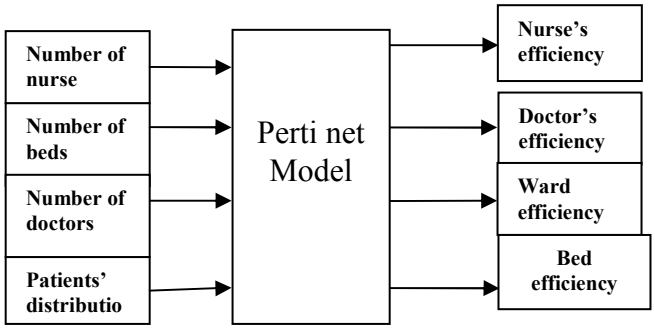

Figure 4: modeling with Petri net

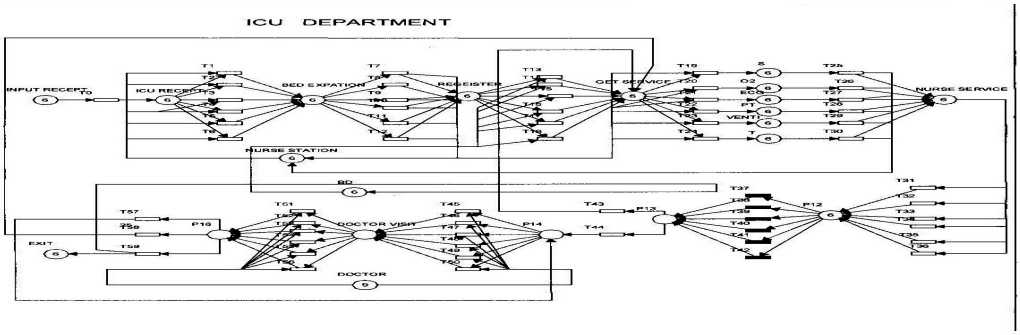

Figure 5: Petri net modeling ICU with Hpsim

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Computations are achieved of the following general relations:

$$Nurse\_Performance=((\sum_{j=2}^{9}((nstep-\sum_{i=1}^{nstep}n(if\ t_j s_i=0\rightarrow n=1))/nstep$$

$$+(\sum_{j=31}^{38}((nstep-\sum_{i=1}^{nstep}n(if\ t_j s_i=0\rightarrow=1))/nstep))\times 100/V_N$$

Nurse efficiency percentage

$$Bed\_Performance=((\sum_{j=10}^{42}((nstep-\sum_{i=1}^{nstep}n(if\ t_j s_i=0\rightarrow n=1))/nstep$$

$$+(\sum_{j=51}^{58}((nstep-\sum_{i=1}^{nstep}n(if\ t_j s_i=0\rightarrow=1))/nstep))\times 100/V_B$$

Bed's efficiency percentage

P= total number of steps,T= time of one step ,5min× n step=T total, PjSi= number of genomes in J position in step I, EjSi= number of output genomes from j in (i) step,TbSi= time of transition activity of b in (i) step,W= number of service presenters in a system, Tz= output transition of system

Table 2: several conditioned of ICU in case of doctors and nurses numbers

Position	*Number of nurses*	Number of beds
1	4	6
2	4	6
3	3	5
4	4	6

Table 3: results achieved from Petri net analysis of ICU ward

condition	*Waiting in reception/min*	*Waiting for bed/min*	*Waiting for nurse/min*	*Nurses' efficiency*	Beds' efficiency
1	2.2	23	1.9	97.16%	54.25%
2	5.6	60	1.8	83.33%	84.32%
3	4.8	123	2.1	85.24%	81.86%
4	3.6	180	2.4	87.11%	81.56%

And finally we will study the intelligent system of genetic algorithm which, in designed program you can notice the title of Nurse Shift genetic algorithm (shown in figure 6), that by choosing this option and running of program we can to optimizing the personnel shift program and regulating the number of work force and eventually we can compute the efficiency.

Initially, the program shift nurse that will be arranged by supervisor in a form of non-

periodically per month. For this issue we consider three shifts working of 7:00 am, 7:00 pm and 12:00 pm. Natural working hours of under-programming forces in this study is 44hours per week. This issue is an optimal multi-criteria issue, because working shifts program should regulate in a way that weekly table

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complete simultaneously by nurses and in a more complex condition a simple model should be considered from nurse distribution in different working shifts. The first criteria of monotonous distribution of work force is in case of arranging and second criteria is distribution of number of staff needed during the week, that by converting program processing, expenditure function would determine as following.

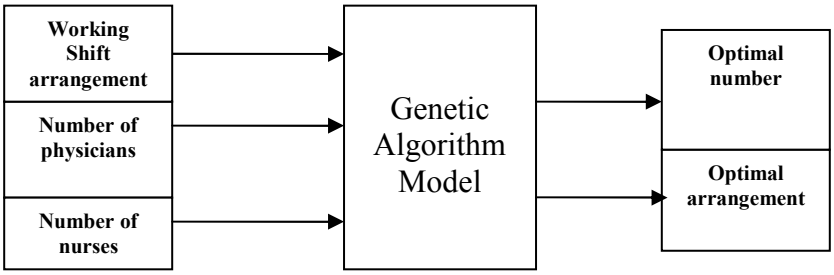

Figure 6: modeling with genetic algorithm method

For each (i) nurse and each (j) working shift we have:

$$a_{jk} = \begin{cases} 1 & \text{shift pattern } j \text{ covers day/night } k \\ 0 & \text{else} \end{cases}$$

Expenditure function of F (i) is the purpose of minimizing expenditure function which is optimal criteria in this stage.

$$P \quad F(i) = \left\{ \begin{array}{ll} \sum_{k-1}^{7} a_{jk} = D_i & \forall j \in days \quad shifts \\ \text{or} & \\ \sum_{k-8}^{14} a_{jk} = N_i & \forall j \in night \quad shifts \\ or & \\ \sum_{k-1}^{14} a_{jk} = B_i & \forall j \in combined \quad shifts \end{array} \right\} \forall i \quad , \sum_{i-1}^{n} \sum_{j \in F(i)}^{m} p_{ij} x_{ij} \rightarrow \min , \sum_{j \in F(i)} x_{ij} = 1 \quad ,$$

$$f1 = \sqrt{\sum_{i=1`}^{numofnurse} (WeekHouri - NormalWorkHour)^2}$$

Minimizing the above formula means decreasing the normal hours.

Suitable coding for stating chromosomes is planned by allocating numbers to nurses. Samples are including 10 nurses for determination chromosomes which has non-periodically program. Length of fibers is equal to the number of week days including three shifts multiply the number of working force needed in each shift which is including 210 genes. Scheduling table is including 210 rows which is completed with arrangement of nurses shift work and less work forces that shown in table 4. Each chromosome which is including genes is a solution for this issue that nurses shift are distributed in rows of table as one and zero.400

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populations of shift pattern and 100 suggestions, 21 genes, 80-85% cross over of chromosome and about 0.01% mutation are designed in this system. In the present study, compared results in the field of different rate, we have the percentage of cost reduction improvement. In regulation of genetic algorithms strategy and parameters to achieve Run time about 3 minutes for optimizing, population size of 400 and stop criteria were considered up to production of 400 generations and for choosing parents we were used rule roulette wheel. Review and implementation of program showed that it is reached to a good convergence. After designing system in order to evaluate its performance, pre-processed data provided to the system and with implementation of system, program was adjusted. Considering the cost function definition and the above description, table 5 shown the results of optimizing the nurse program by genetic algorithm method. Optimizing the arrangement of program by the genetic algorithm is as follows: Nursing program of ICU is adjusted manually by supervisor

Table 4- nursing shift scheduling

nurse	*Sat1*	*Sat2*	*Sat3*	*Sun 1*	*Sun2*	*Sun3*	*Mon1*	*Mon2*	*Mon3*	*Tus1*	*Tus2*	**Tus3**
1	1	1	0	0	1	1	0	1	1	1	0	1
2	0	0	0	1	0	0	0	1	1	1	1	0
3	1	1	0	1	1	1	0	0	0	0	1	1
4	1	1	0	0	0	1	1	1	0	0	1	0
5	0	0	1	0	1	0	0	0	1	0	0	0
6	0	1	0	1	0	0	0	0	1	1	1	0
7	1	0	1	1	1	1	0	1	0	0	0	1
8	1	0	0	0	0	0	0	0	1	1	1	0
9	0	1	0	1	1	1	0	1	0	0	0	1
10	1	0	0	1	1	0	1	0	0	1	0	0

Table 5: results of optimizing the nurse program by genetic algorithm method

Result	*Suggestion*	*Shift (1-21)*	*Manual number*	**Nurse number**
1,4,3,5	32	12	4	1,3,7,9
1,2,3	23	10	5	1,2,6,8,10
5,7	23	3	2	5,7
4,10	98	7	2	4,10
1,6,5,3,4	45	20	6	1,3,6,7,8,10

In this table 6 results had shown the computation of ICU efficiency with manual data of the number of physicians and nurses. At the end the optimized results, we enter the results of genetic algorithm icon in input data of Petri net Icon which can be seen in table 7.

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Table 6: computation ICU efficiency with manual data of physicians and nurses' number

Ward efficiency	*Bed efficiency*	*Physician efficiency*	*Nurse efficiency*	*Number of physicians*	*Number of nurses*	**Shift**
89.1%	91.66%	95.83%	79.54%	3	4	12
90.37%	91.66%	95.83%	83.63%	3	5	10
91.28%	91.66%	95.83%	96.36%	3	6	20
88.31%	91.66%	93.75%	79.54%	2	4	11

Table 7: computation of ICU efficiency with number of physicians and nurses' optimal data

Ward efficiency	*Bed efficiency*	*Physician efficiency*	*Nurse efficiency*	*Number of physicians*	*Number of nurses*	**Shift**
86.04%	91.66%	93.72%	72.72%	2	3	12
89.01%	91.66%	95.83%	78.42%	3	4	10
90.37%	91.66%	95.83%	83.63%	3	5	20
86.04%	91.66%	87.50%	81.63%	2	3	11

Table 8: statistical analysis of average and standard deviation comparison

Title	*Average*	**Standard deviation**
Number of optimized nurse	3025	5
Number of optimized physician	205	58
Efficiency of optimized nurse	83.3%	8.59
Efficiency of optimized physician	95.1%	1.2
Number of nurses	13.3	4.57
Number of physicians	2.75	5
Nurses' efficiency	84.5%	8.45
Physician efficiency	94%	4.49

With observation of all above results (table 8), we can say that, in ICU which is an specific ward by decreasing number of nurses and physicians the physicians and nurses' efficiency will decrease because, moreover the waiting time increase and as a result, transition time increase from one step to another for, the running of ghettos in queue will carry out with delay. The bed efficiency is depending on the number of

patients, that's why we don't observe any change in that. Operations research is in a manner that if patients enter in to system a lot, in case of decreasing the servers, they have to wait for

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services and in contrast if patients enter in to system non-continuous, the service facilities during entering periods would become useless which must remain equilibrium in operation clearly, providing more and better equipments for presenting service lead to reduce waiting time and being in queue and also reduce related costs. By designing intelligent system in this study, this balance was achieved in the operation. According to the achieved results and earlier studies it can point to the issues which calculate manually in hospitals at the end of each month that limited to the cost of occupied bed. about designing intelligent system of nurse shift program we can point to the studies of Ansi and his colleagues, modeling with Markov method in order to estimate the number of unused beds, hospital modeling for estimating of unused beds by studies of Gallivan and his colleagues, hospital modeling with the Petri net model by Mourtou studies, but the system which is introduce in the present article had advantages compared with existing internet services because, at the same time we can calculate the efficiency of ward and offering services to patients, by regulating shifts programs with less staffs and with optimization of system we can reduce main problems of hospitals management center.

5. CONCLUSION

Achieved results from this research shows that despite in health system in country efficiencies such as work force efficiency(doctors and nurses) is not incomputable and percentage of bed occupation and regulating shift work program prepare manually and with paper, this issue results in time consuming of managers and wasting costs and errors in carried out computations. Therefore with technology improvement and automation system there is possibility of making such automatic data is provided. Using of intelligent system consider essentially for preparing optimal program. Studying of Data showed that the present situation of planning and determination of efficiency in Iran Hospitals is not desirable. In this research, Markov methods and Petri net and genetic algorithm as modeling method and developments of model and intelligent optimization for solving problems, reducing costs and planning for work force was used successfully and there is the possibility to generalize it with changes and reforms in programming.

In Achieved results of studies show that, the present research is a suitable base for expanding researches in future in field of system designs in a way that can be used in different wards and can provide more facilities to approach the real world.

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