

## **Scheduling workers using genetic algorithm: A comparative study between scheduling nurses with two shifts and scheduling doctors with three shifts. A case study at Nasiriyah Heart Hospital**

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**Abstract :** The study aims to compare the scheduling of nurses at work on dual shifts and the scheduling of doctors at work with triple shifts, Where Good scheduling contributes to increasing the well-being of workers and achieving their satisfaction, thus focusing their interests in providing services, where Organizations today invest their resources optimally through the scheduling process, which is the process of allocating those resources in a certain period of time by achieving a set of constraints , as it has an important role in achieving the goals of organizations and increasing their efficiency, as the service production system in most service organizations, especially Nasiriyah Heart Hospital, suffers from a large momentum in the numbers of patients and the Hospital providing health services to all governorates and working to improve the service provided to customers (patients). Nasiriyah Heart Hospital was chosen to represent the study population, while the sample was chosen by the number of doctors (Senior resident) in all departments of the hospital, and the number of nurses in the children's lobby. the study problem was formulated in the MILP method (mixed integer liner programming) and solved it using the GA genetic algorithm, which is one of the advanced modern quantitative methods that have efficiency and speed in solving the scheduling problem and was implemented through the MATLAB 2023b program. where the problem of scheduling staff, including doctors (senior residents) in the hospital and nurses who work in the children's lobby, has been solved and a comparison. As this, the study found that the genetic algorithm has efficiency and speed in solving the problem of scheduling workers and reaching the optimal solution very quickly, and the constraints imposed on the scheduling of nurses are more flexible compared to the scheduling of doctors because of the large number of nurses

**Keywords - Scheduling, Scheduling Nurses, Scheduling Doctors, Genetic Algorithm.**

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**Introduction:** Good scheduling contributes to increasing the well-being of workers and achieving their satisfaction, thus focusing their interests in providing services where organizations work to constantly improve their business through advance planning and effective scheduling. the decision-making process in various service systems may depend on scheduling in how to make optimal use of the organization's resources, especially the human resources required to provide services and ensure the availability of specialized human resources at work. Scheduling is used heavily because it works to link improvement and feasibility to each of the problems facing organizations, and it has a major role in achieving the goals and success of organizations and increasing their efficiency. Scheduling is the process of allocating resources in a certain period to meet the constraints presented by achieving as many of these constraints as possible, and there are many types of scheduling such as scheduling sports events, scheduling workers, scheduling a training course, scheduling customer appointments, etc. scheduling problems are represented as a built-in optimization problem commonly referred to as NP-hard. Therefore, scheduling workers is one of the most effective ways to match demand with supply, thus ensuring the availability of a sufficient number of workers to provide health services to patients. and in this study the constraints imposed on doctors are more difficult compared to nurses who work in the children's lobby due to the small number of doctors compared to nurses, and the work of doctors is in the entire hospital compared to the work of nurses, which is only in the children's lobby.

The genetic algorithm (GA) has emerged as a useful tool of Meta-Heuristic algorithms to solve complex optimization problems, including scheduling, due to its high efficiency, comprehensiveness, and ability to find solutions. as the genetic algorithm GA is an effective and ideal technique in solving scheduling problems, in which a set of random solutions is formed by determining the size of the community and the number of possible generations chromosomes being based on the principles of natural genetics and natural selection as the Genetic Algorithm implements a copy Simplified from the Darwinian evolution that occurs in nature. The genetic algorithm contributes to achieving justice and fairness, increasing employee satisfaction, and reaching the optimal solution quickly. The Study included four sections. The first section was devoted to the study methodology. The second section included the theoretical framework. The third section included the practical framework for the study. The fourth section included recommendations and conclusions.

## **I. FIRST SECTION: STUDY METHODOLOGY**

### **FIRST: STUDY PROBLEM**

The success of service organizations depends on the satisfaction of their customers as well as on the material and intangible resources that the organization possesses, especially human resources, which are considered the most important resources of the organization and the reason for its survival.

Recently, the demand for health services has increased due to the large population growth, environmental pollution, and other problems, which has led to an increase in the number of patients significantly, and this has exacerbated the contradiction between the limited medical resources available and the rapidly growing demand for health services, as health services are critical services and services must be provided efficiently and effectively, Especially at Nasiriyah Heart Hospital, where there is a clear increase in the number of patients over previous years

Therefore, the many numbers of customers must be organized and work to balance the organization's capacity and demand for services to ensure that everyone gets the right service at the right time and work to provide the required numbers of workers, and fair distribution of the required staff, Those who find that there is favoritism in work .as well as lack of conviction in the duration of the workers ' holiday, for example, the morning shift works daily and has a holiday period of only two days, while the night shift has more days off and fewer working days, and therefore there are those who want to switch between work patterns ( from morning to evening, for example) but it is not allowed because the required numbers do not allow him to do so, also, the problem of tribal custom, which does not accept women working at night, and therefore there are many pressures in preparing the scheduling of workers, especially since most women prefer the morning shift, and therefore may be There is favoritism and unfairness in the numbers of scheduling workers, including facilitating the task of one worker at the expense of another , Where The constraints imposed on doctors are more difficult compared to nurses who work in the children's lobby due to the small number of doctors compared to nurses, and the work of doctors is in the entire hospital compared to the work of nurses, which is only in the children's lobby.

Therefore, scheduling workers is considered one of the difficult problems (Np-Hard) and dealing with it manually will lead to a large waste of time and money. It will also lead to more waiting time for customers (patients) due to not appointing enough individuals to work. It will also drain energy and effort for the purpose of organization. Failure to schedule workers may also lead to in a fair manner, this will lead to the dissatisfaction of the working individuals, and thus it will affect the performance of their work, as the working individuals represent the organization's internal brand ambassadors and its image in front of its customers, and therefore they must be given attention to provide the best services.

### **Second: Study significance**

The importance of the study is derived from the importance of the topic it deals with and the goals that the study seeks to achieve. This significance could be summarized in the following points:

1. Trying to draw the attention of senior management to how it contributes to achieving justice and fairness, and not showing favoritism to the staff working at Nasiriyah Heart Hospital, and determining the appropriate number of staff to achieve the required level of service through the use of scientific methods.
2. Focusing on how to achieve optimal investment of the time of doctors and health personnel and reduce waste to the maximum possible extent, taking into account the resources possessed by the organization and ensuring the availability of sufficient numbers to provide the service.
3. Demonstrate the importance of scheduling workers in improving the quality of services provided to customers.
4. Clarifying how to achieve the satisfaction of all stakeholders, including doctors, health staff, patients, and senior management, by using staff scheduling and finding a schedule that takes into account the wishes and preferences of workers, as well as scheduling operations through quantitative methods and modern scientific methods.

### **Third: Study objectives**

The objectives of the study are represented by the purpose that the study wants to achieve and are as follows:

1. Scheduling workers and achieving a schedule that meets the wishes of working individuals and their preferences to achieve justice and fairness and ensure that there are sufficient staff to provide health services to customers at the appropriate time.
2. Improve the use of the resources that the organization has and work on knowing the required inputs to ensure the provision of services that suit all customers and at the required Times.
3. How to use evolutionary research algorithms, including the genetic algorithm, to find the optimal solution to the problem of scheduling workers, as it is one of the self-guided algorithms (Heuristic Meta) that can be used to Scheduling workers.

#### Fourth: The general formulation of the issue of scheduling workers:

One of the most common and most famous methods in the method of solving the scheduling of workers is the Formula Mix Integer Linear Programming or what is called MILP, which is one of the methods of numerical linear programming, through which the solution takes only integers, and the mixed ones take two values, either the value of 0 or the value of 1 in addition to integers, the mathematical model of this method may be formulated as follows:

$$\text{Min } Z = \sum_{j=1}^m \sum_{i=1}^n X_{ij} \cdot Y_{ij}$$

$$\sum_{i=1}^n X_{ij} = 1$$

$$\sum_{j=1}^m \sum_{i=1}^n Z_{jx} \cdot B_{ik} \cdot X_{ij} \geq D_{k,s}$$

The equations represent the following:

Equation No. 1: represents the sum of the target function (cost function), which requires to be reduced to the lowest possible value, which represents the sum of the penalty costs of the penalty costs for allocating nurse  $j$  to work within the Shift  $k$

Amendment No. 2: represents the first limitation of the issue, which includes that each of the hospital workers works within one shift per day, whether that shift is (morning, evening) or (Morning, Evening, night).

Equation No. 3: represents the second limitation of the issue, which includes that the demand for the service is met by the workers who work in the hospital and their various job titles (a doctor, a nurse, etc.). The numbers must be available within the minimum and maximum limits and according to the shifts that exist at work.

#### Fifth: Population and sample size:

The Nasiriyah Heart Hospital was chosen to represent the study population. In previous years, the Nasiriyah Heart Hospital was called the Nasiriyah Heart Center, as this center was established in the year 10/7/2007 in Dhi Qar Governorate in the name of the Nasiriyah Center for Cardiac Surgery, where the journey of this center began, which it carries within it. Ingredients for success, The Dhi Qar Health Department celebrated the first private open-heart surgery on Tuesday, 28/4 2009, which was carried out in partnership with the medical staff from Ibn Al-Bitar Hospital. After that, the Nasiriyah Heart Hospital was opened, which consists of three floors that include many departments such as the surgical department, the internal department, the administrative department, the scientific department, and the technical department, in addition to operating theaters and a hall for scientific conferences and seminars. Today, the Nasiriyah Heart Hospital is considered one of the most important specialized hospitals in the heart. Which includes many specialized cardiologists, skilled heart surgeons, and many qualified and distinguished medical staff, in which many complex and large operations are performed, such as open-heart surgeries, valve implantation operations via catheter, catheterization operations, and balloon operations for men and children, as many patients flock to it from various governorates.

The study sample was chosen by the number of doctors (Senior resident) in all departments of the hospital, and their number was 6 doctors, and the number of nurses in the children's lobby was chosen, and their number was 12, to represent study sample.

#### sixth: hard constraints and easy constraints:

The problem of scheduling hospital staff is basically the problem of preparing a schedule that suits the staff and the organization in light of a set of constraints, which are of two types, which are difficult constraints and easy constraints, as difficult constraints must be met in any work schedule for hospital staff, and therefore the presence of any violations of those constraints will be scheduling is not possible, but the easy constraints can be achieved, but at the lowest possible value, as they can be bypassed, and work scheduling is established, as there are many difficult constraints and easy constraints that are determined according to the work of the organization and the scheduling that you want, as those constraints vary from one organization and from one department to another, and the limitations in the current study problem are divided into two types The seizures are bilateral (morning, evening) and triple seizures (Morning, Evening, night) as each type has specific limitations and as follows:

- A. Two shifts: it includes two types of shifts, namely morning shift and evening shift, as there are two types of constraints for these shifts, including:

1.Hard constraints: these are constraints that cannot be overcome and must be achieved in order for the scheduling process to be possible and achievable and include two types of constraints:

A.Hard constraints of the first type: these constraints include the number of workers required per day for each work shift, whether it is a morning shift or an evening shift, as the number of workers must be within these constraints, and each specific department has a certain number required for each shift, as these numbers vary from department to department and from job to job, and these constraints include the following:

- The number of workers for each working day within the morning shift should be between the minimum number of workers and the maximum number of workers

Max-number-shift-Morning - Min-number-shift-Morning.

- The number of workers for each working day within the evening shift should be between the minimum number of workers and the maximum number of workers

Max-number-shift-Evening - Min-number-shift-Evening.

b.Hard constraints of the second type: these constraints include avoiding working within the prohibited modes of work, namely:

- ❖ It should not be a morning work pattern for every working individual after an evening work pattern.
- ❖ There should be no three working hours in a row.

2.Easy constraints: these are constraints that can be exceeded or achieved with the lowest possible value, as they can be achieved or not, and therefore their achievement does not affect the choice of the optimal solution for scheduling work, but the quality of the solution depends on it and includes a number of constraints, namely:

- ❖ The total number of holidays for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of holidays and the minimum number of holidays.

- ❖ Determine the total number of Morning Shift days for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of Morning Shift days and the minimum number of Morning Shift days.

- ❖ Determine the total number of evening shift days for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of evening shift days and the minimum number of evening shift days.

B. Three shifts: it includes three types of shifts, namely morning shift, evening shift and night shift, as there are two types of constraints for these shifts, including:

1.Hard constraints: these are constraints that cannot be overcome and must be achieved in order for the scheduling process to be possible and achievable and include two types of constraints:

A. Hard constraints of the first type: these constraints include the number of workers required per day for each work shift, whether it is a morning work shift, evening work shift and night work shift, as the number of workers must be within these constraints, and each specific department has a certain number required for each shift, as these numbers vary from department to department and from job to job, and these constraints include the following:

- ❖ The number of workers for each working day within the morning shift should be between the minimum number of workers and the maximum number of workers

Max-number-shift-Morning - Min-number-shift-Morning.

- ❖ The number of workers for each working day within the evening shift should be between the minimum number of workers and the maximum number of workers

Max-number-shift-Evening - Min-number-shift-Evening.

- ❖ The number of workers for each working day within the night shift should be between the minimum number of workers and the maximum number of workers

Max-number-shift-Night - Min-number-shift-Night.

B. Hard constraints of the second type: these constraints include avoiding working within the prohibited modes of work, namely:

- ❖ It should not be a morning work pattern for every working individual after an evening work pattern.

- ❖ There should be no three working hours in a row.

- ❖ It should not be a morning work pattern for each individual worker after a night work pattern.

2.Easy constraints: these are constraints that can be exceeded or achieved with the lowest possible value, as they can be achieved or not, and therefore their achievement does not affect the choice of the optimal solution for scheduling work, but the quality of the solution depends on it and includes a number of constraints, namely:

- ❖ The total number of holidays for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of holidays and the minimum number of holidays.

- ❖ Determine the total number of Morning Shift days for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of Morning Shift days and the minimum number of Morning Shift days.
- ❖ Determine the total number of evening shift days for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of evening shift days and the minimum number of evening shift days.
- ❖ Determine the total number of Night Shift days for each worker within the work scheduling days, whether weekly or monthly, between the maximum number of Night Shift days and the minimum number of Night Shift days.

The generation of work scheduling depends on ensuring the achievement of a set of constraints that have been mentioned above, as the difficult constraints must be achieved, and the achievement of easy constraints can be achieved to the extent possible and can be bypassed.

### **Seventh: the goal function and cost calculation:**

The goal function that has been formed depends on achieving a set of difficult constraints and easy constraints that can be achieved, as there are three costs to be determined and the total cost of scheduling represents the sum of these three costs, as the goal function for scheduling work represents:

$$F = C1.W1 + C2.W2 + C3.W3$$

Where F represents the total cost of scheduling work, which is calculated based on hard constraints and easy constraints.

The W value represents the weight value that is calculated for both hard and easy constraints as follows:

The value W1 = 100 represents the weight of exceeding the hard constraint of the first type.

The value W2 = 100 represents the weight of exceeding the hard constraint of the second type.

The value W3 = 1 represents the weight of exceeding the easy constraints.

The value of C represents the cost calculation value for both hard and easy constraints as follows:

1.The first cost is C1: the cost of the penalty for violating the Hard constraints of the first type, where the total number of the number of mornings, evening and night shifts must be within the upper and lower limits, and each violation of these constraints will increase the value of C1 by 1.

2.The second Cost C2: represents the cost of the penalty for violating the Hard constraints of the second type, where there should not be three consecutive night shifts for each worker and the absence of a morning shift after an evening shift for each worker for two shifts, in addition to the absence of a morning shift after a night shift for each worker for triple shifts and that each violation of these constraints will increase the value of C2 by 1.

3.The third cost C3: represents the cost of the penalty for violating the easy constraints, where the total number of days off for each worker must be within the upper and lower limit, the number of days of morning shifts for each worker within the upper and lower limit, and the number of days of evening shifts for each worker within the upper and lower limit for double shifts and add the number of days of night shifts for each worker within the upper and lower limit for triple shifts and each violation of these constraints will increase the value of C3 by 1.

### **SECOND SECTION: THEORETICAL FORMWORK**

Scheduling plays an important role in achieving the goals and success of organizations by increasing their efficiency, ensuring optimal use of resources, making the most of their energy, achieving outstanding performance and speed of completion, achieving customer requirements and satisfaction through timely execution of work and reducing waiting times to the extent possible.

#### **First: Historical development of scheduling:**

Scheduling is one of the important ancient terms that was used in the old days, as Sun Tzu spoke about scheduling and strategy from a military perspective 2500 years ago in the seventeenth century (Ali et al.,2018: 164), pyramids, inner-city trans-city railways have been built for 200 years and others for which none of these activities could have been accomplished without some form of scheduling and understanding of activities and their sequences (Patrick.et al.,2014:2)

Frederick Taylor is the founding father of the concept of production scheduling in 1911 with his idea of creating a planning office for efficient manufacturing. This separation of planning and implementation was the beginning of scheduling (Kumar,2017:174). Taylor proposed an office in which production planning is carried out around the time of the first World War through the creation of plans, inventory management and process control by several individuals (Herrmann,2006:4, the widespread adoption of Taylor's approach reflects the importance of perspective

it also reflects the importance of system-wide scheduling, which is part of the complex flow of information and decision-making that forms the manufacturing planning and control system (Herrmann, 2010:246).

Then, as early as 1912, some graphic scheduling tools appeared, including the bar chart method, called the Gantt chart, which is the most practical and widespread technique at the time (Wang, 2018:20), as Henry Gantt is the man who is uniquely characterized by scheduling production, he created innovative control charts in production and the Gantt chart is the first and most famous type of control charts designed specifically to show the relationship between planned performance and actual performance graphically (Herrmann, 2006:4). Gantt has designed his blueprints so that foremen or other supervisors can quickly tell if production is on schedule, ahead of schedule, or behind schedule. His schemes were therefore improvements on the models developed by Taylor for the planning office (Herrmann, 2007:7).

And in 1954 there was a pioneering work of the researcher S.M. Johnson, who analyzed the characteristics of the optimal solution and introduced the Johnson algorithm, which adopted the optimal solution to the problem of scheduling a workflow in two stages and also looked at problems with three or more stages, seeing scheduling as solutions to an optimization problem to be solved and creating optimal production schedules (Herrmann, 2010:247).

### **Second. Scheduling concept**

To begin with, the concept of schedule (Schedule)) is a plan for performing a series of specific tasks within a certain time frame (Bamford & Forrester, 2010:84), since the schedule is what determines when a particular activity occurs and what resources are used (cunha, 2021:2), and Production Scheduling includes activities for setting a production schedule in time stages, developing short-term production schedules and managing the production of works in progress (WIP) (Khan & Yu, 2019:8), since production scheduling concerns the allocation of limited resources such as manpower, equipment and tools to perform a set of tasks while optimizing one or more goals (Singh, 2014:15), the function of If production scheduling is not good, the level of energy use and input will be less efficient (Septiana et al., 2021:39).

While scheduling means meeting different performance criteria or factors by allocating available production resources over time (Chawla & Singari, 2022: 198), scheduling is also about allocating limited resources to activities in order to improve performance measures depending on the situation as resources and activities can take many different forms (Ramkumar et al., 2011: 282), whereas, (Ansari & Saubari, 2020:1) pointed out that scheduling is the activity of allocating existing resources to perform a set of tasks during a certain period of time, as scheduling has two meanings, namely:

A. Scheduling as a decision-making function: scheduling is defined as the process of scheduling.

B. Scheduling as a theory: scheduling is defined as a set of principles, models, techniques and logical conclusions in decision-making.

Table (1) shows the definition of scheduling from the point of view of a number of researchers, as follows:

**Table (1) the concept of Scheduling**

Source	Definition
<b>Russell &amp; Taylor, 2019:751</b>	Determining the time of need for labor, equipment and material facilities to produce a product or provide a service, as it represents the last stage of planning before production occurs.
<b>Santisteban, 2019:15</b>	Allocating scarce resources to tasks over time, it is part of any process that requires time and resources, as Schedule design involves allocating activities or operations at a specific place and time.
<b>Mazda &amp; Kurniawati, 2020:2</b>	The process of organizing, selecting and timing the use of existing resources to produce the expected outputs and also during the expected time
<b>Stevenson, 2021:693</b>	Determining the timing of the use of equipment, physical facilities and human activities in the organization as scheduling takes the resource plan and translates it into specific operational tasks on a detailed basis as schedules for physical facilities can be developed by allocating activities and making use of them efficiently
<b>Groleaz, 2021:23</b>	Describe activities that attempt to adjust the order and time of planned events depending on the context, as events are sometimes defined by business terms, processes, or activities.
<b>Anwar et al., 2021:404</b>	A method used to allocate limited resources to complete a set of works at a predetermined time, as the scheduling function is to make adjustments between the number of works and the limited number of resources that the organization has.
<b>Krajewski &amp; Malhotra, 2022:420</b>	The introduction of the resource plan and its translation into specific operational tasks on a detailed basis, as the schedules of production facilities can be developed by allocating activities to them and making use of them efficiently

From the above, the researcher believes that scheduling concerns short-term plans, in which the control process is very high in the follow-up of works, which is more detailed than the main production schedule, which is within the medium-term plans, and therefore the production schedule must be followed continuously to ensure the implementation of the required work and to ensure the optimal use of available resources to Prioritize the production of these works, follow up and arrange them to complete them on time.

### **THIRD. Scheduling in Health organizations.**

Effective human resources management is an important factor that helps to achieve the quality of service provided by organizations Significant improvements in labor management and The Associated cost are directly proportional to reducing the organization's expenses and increasing the productivity of its daily operations (Arora,2021). therefore, resource planning in health services is very important by properly managing human and material resources to avoid progress or flow in poor efficiency and medical delays as well as low-quality service (Du et al.,2017), efficient scheduling systems aim to match the demand with the energy that health systems have, work to use resources optimally and work to reduce the time of Waiting for patients (Medeiros, 2022), as well as the second main goal of scheduling is to ensure the availability of medical personnel in the workplace in order to serve patients at the time of need without risking the lives of others (Sivasankaran, 2020).Medical service scheduling aims to effectively allocate medical resources (medical staffing, hospital beds, operating rooms, medical equipment, etc.) to patients to improve performance standards (Zhu et al.,2021:), scheduling problems in health organizations are divided into two types, namely:

#### **a. Scheduling of Worker.**

Medical staffing scheduling refers to the design of the shift for each medical staffing worker in accordance with the regulations and policies of health organizations as medical staffing works around the clock, usually divided into three to four shifts per day (Pahlevanzadeh et al.,2021:3317). Problems of scheduling medical staffing are a big problem for the health sector due to the work structure of health organizations and various constraints (Sulak & Bayhan,2016:755). one of the main challenges in improving the efficiency of Health Services is the shortage of medical staffing (Akhavizadegan et al.,2015:2), Medical Staffing is one of the resources that plays an important role in determining the performance and quality of health organizations because they are directly responsible for meeting the patient's needs 24 hours a day to increase patient satisfaction however, there are often cases when the number of available personnel is insufficient due to the large number of patients that can lead to fatigue, therefore the performance Undesirable mistakes in dealing with patients, as the working hours of medical staff must be properly organized (Ariyani et al.,2021:1).

Scheduling problems often require a combination of several elements, which is very confusing due to various constraints such as orientation and assignment (Asif et al., 2022:306). the appointment of medical staff at the right place and time to do the right work is a major concern for health organizations. these organizations are usually divided into specialized units, which include many job positions, each of which requires a specific set of skills, and this leads to a large number of possible work schedules when combined with demand and changing situation (Lim et al.,2016:35), as health organizations are under increasing pressure to reduce service costs as these expenses account for more than 40% of their total budget and thus help Providing effective and customized scheduling for workers such as doctors and nurses in relieving this pressure (Hamid et al.,2020: 279), and see (Rosocha et al.,2015:2) that the performance of medical staff is an important factor in determining the quality of the public health service, in connection with the pressure to reduce the cost, as a small number of working doctors and nurses negatively affect their work-life balance, which leads to a decrease in the quality of services required, as they often have to take consecutive shifts , or they cannot take a day off, as well as there are many doctors and medical staff working in private health organizations in order to reach higher salaries, which caused this trend In the occurrence of a critical problem in the preferences of medical owners and therefore when senior doctors often have more than one professional obligations they add additional constraints to. Scheduling appropriate work is one of the ways to increase the satisfaction of medical staff, in addition to the composition of the work team, as the shortage of medical staff is a major problem in health organizations (Youssef & Senbel, 2018:72)

As the performance of the medical staff is the most important factor in determining the quality of the health service, there is a great pressure to reduce the cost, which negatively affects the work-life balance and often leads to a decrease in the quality of the required services (Simić et al.,2020:226), and therefore scheduling must take into account many limitations such as medical staff requests and preferences, Health Organization policies and work regulations as poorly established shift schedules can lead to fatigue, errors and affect the quality of Service (Abd-El-Aziz & Wahab, 2019:147), as scheduling is usually done on a weekly or monthly basis and is a very difficult task if performed manually It is not accepted (Ernst et al.,2004:3), since scheduling is largely used on a regular basis, it combines optimization and feasibility with each of the specific problems that occur to management that does not

schedule, as scheduling problems are one of the complex problems that must be dealt with to optimize business execution tasks (Sarfaraj et al.,2021:46). According to (Brunner et al., 2009:285) the scheduling of workers requires the following:

A. Shift: it is a set of consecutive periods during the day whose length represents the total time you cut.

P. Lists: they are a set of shifts and holiday day assignments that cover a specific period of time.

T. Flexibility: flexible handling of the scheduling of each worker, the ability to set the necessary shift lengths, shift start times and break periods, the ability to accept preferences, requests and constraints that meet the wishes of workers.

**b. patient scheduling:**

Patient scheduling is concerned with the optimal allocation of medical resources for patients, and the process by which the organization of how to receive treatment is of great importance for the efficiency of Patient Flow and therefore strongly affects the overall performance of Health Systems (Conforti,2008:264), as scheduling plays the main role in the performance of the health service system by reducing patient waiting time as well as facilitating the provision of consecutive treatments without interruption (Azadeh et al, 2014:4), and since hospitals require continuous work unlike most other organizations, an effective approach is needed for scheduling in order to save time and resources in the process of scheduling and conducting service delivery operations (Paramathevan & Daundasekera, 2013: 1), in recent years, the patient's point of view regarding hospital services has gained great importance in order to improve health service systems both at the individual level and at the administrative level (Safdar et al.,2020:8961), and see (Schimmelpfeng et al.,2012:2) that the scheduling task is usually performed manually on a patient-by-patient basis, continuously and with different time intervals, and therefore the scheduling effort of this kind may be large, it may require many clerks to find empty time intervals in the resource calendar in order to book an appointment for a patient, and therefore this work may lead to very strict schedules that are difficult to change if They are indicated due to changes in the patient's state of Health.

**Fourth: Genetic Algorithm**

Many scientists in the last century have developed evolutionary-inspired algorithms for optimization and machine learning (Mitchell,1996:2). in the Fifties and sixties of the last century, many computer scientists independently studied evolutionary systems taking into account the idea of using evolution as a tool to improve engineering problems. the idea in all these systems was to develop a set of candidate solutions to a particular problem, using factors inspired by natural genetic variation and natural selection (Mitchell, 1999:2), the history of genetic algorithms dates back to Turing is called machine learning machine) in which it simulates the way of using the principles of evolution (drachal & Pawłowski,2021:5), machine learning is synonymous with advanced computing, the complex or incomprehensible nature of many problem areas, such as data mining or process control, has led to the need for technologies that can adapt to the task they face (IBull, 2004:), the genetic algorithm was proposed and developed in the Sixties by John Holland, his students and colleagues at the University of Michigan (Avin et al.,2012: 257), and the beginning of GA research in general was marked by the publication of Holland's book in 1975 ( Roeva et al.,2021:1)), in his book adaptation in natural and artificial systems, he presented the genetic algorithm as an idea of biological evolution and provided a theoretical framework for adaptation under GA, which is a method of transition from one set of chromosomes such as (1,0, or bits) to a new set of society using a kind of natural selection along with genetic factors inspired by exchange factors Mutation and recombination and then the selection factor selects those chromosomes in the population that will allow them to reproduce (Mitchell, 1998:2), the original goal of which was to create a research method that was more powerful than the traditional methods of that time. inspiration was taken from nature and Darwin's theory of evolution and survival of the fittest. since then, it has been proven both theoretically and experimentally to be a powerful algorithm even in complex problems (Bengtars & Våljamets, 2014:7).

The genetic algorithm GA is defined as a class of randomized population-based search methods within evolutionary algorithms (EAs) (Wang,2006:17), and is one of the classes of evolutionary algorithms inspired by evolutionary genetics (Karakaya & Soykasap,2009:478). evolutionary algorithms are defined as optimization procedures that search for a solution that improves a particular function in a specific search space (Karimi & Jahanian, 2012:81) and is one of the most commonly used algorithms of all evolutionary algorithms (Helal et al.,2012: 2).

GA works on a set of possible solutions that apply the principle of survival of the fittest to produce better approximations of a solution and in each generation of GA ,A new set of approximations is created through a process of individual selection (Chipperfield & Fleming, 1995:1), initially several individual solutions are randomly generated to form an initial set(Lamini et al.,2018: 181), and individual solutions are selected in a random way and according to their trade-off values which are calculated from the trade-off function of the specific problem and which carry genetic factors (hybridization and mutation) to produce a new generation (Rooki et al.,2012:164), and at each step, individuals are selected from a group Current solutions and consider them as parents for the application of



genetic processes to produce individuals for the next generation and over successive generations, " society evolves and the optimal solution is reached (Mudduluru, & Chizari,2021:3) .

Table (2) shows the definition of scheduling from the point of view of a number of researchers, as follows:

**Table (2) the concept of GA**

Source	Definition
Sheppard,2016:2	One of the tools that we can use to apply machine learning to find good, and sometimes ideal, solutions to problems that have zero potential solutions is through the use of biological processes in programs to find answers to problems that have large search spaces through the continuous generation of candidate solutions, evaluating the extent to which Solutions trade-off for desired results, and optimizing the best
Murthy <i>et al.</i> ,2017:127	It is a random process that searches a complex and multimedia space, as it is a random method in that it uses domain-specific knowledge, in the form of a target function, to conduct a random directed search.
Fouad <i>et al.</i> ,2018:1062	A research method that uses a random choice to guide a highly exploitative search, by maintaining a balance between exploring the area of feasible research and exploiting good solutions.
Mudduluru & Chizari,2021:2	It is an evolutionary optimization technique that simulates the process of natural selection to solve constrained and unrestricted optimization problems as the algorithm iteratively modifies the initial set of individual solutions.
Baghalzadeh <i>et al.</i> ,2022:1445	A set of computational models that encode possible solutions or possible hypotheses of a particular problem in a chromosome-like data structure

### Third Section: Practical framework

The solution method used through the genetic algorithm based on the genetic algorithm, where the problem will be solved first for binary work shifts (morning, evening) and then solve the scheduling problem using the genetic algorithm for Triple work shifts (morning, evening, night), as the steps of the genetic algorithm to solve work scheduling are as follows:

1. Initialization: it is done by generating the initial matrices, as the initial data is initialized to generate matrices consisting of the number of workers  $n$  multiplied by the number of days  $D$  and the elements of the Matrix contain the types of lips  $S$  for the workers where:

In binary shifts there are Morning lips, evening lips and a lip that represents the holiday for each worker.

In triple shifts there are three lips, morning lip, evening lip, night lip and a lip that represents the holiday for each worker.

2. Determination of the parameters of the work of the genetic algorithm: the determination includes the following:

❖ The size of the population: represents the population required to be generated for the solution, as the size of the population here is represented by 1000 tables.

❖ Number of generations: represents the number of possible generations achievable for the solution.

❖ Stop condition: stop generating random solutions when the value of the objective function is equal to zero, that is, the total cost of the hard and easy constraints has been exceeded and all those constraints have been achieved.

3. Creating a random population: a random population is formed that represents the possible solutions and according to the parameters that have been formed, represented by the size of the population.

4. Calculation of the goal function (cost function): the goal function is calculated for the difficult and easy constraints that have been configured for all the tables created in the population, which are randomly configured, where the creation of solutions is stopped if the value of the goal function is equal to zero, where it represents the optimal solution, but if the difficult constraints are not met, the steps of the genetic algorithm will be continued.

5. Selection: the selection process mimics the concept of the selection process in nature, which is the survival of the fittest. In our study, two selection methods were selected based on the number of seizures in the hospital, as follows:

a. The roulette wheel method: This method may be similar to how to use the roulette wheel and how to allocate a part of the wheel to each individual commensurate with the value of his trade-off, and when rotating the wheel, the probabilities of choosing each individual are proportional to the size of the part of the wheel that it occupies, and the genetic algorithm will select the best individuals and abandon the worst, and in our study we used this method to schedule work with two shifts ( morning, evening), as we choose the value of the trade-off based on the calculated cost of each a table where the first table with the lowest cost for the target function is chosen to be the first parent (P1), and then the second table is chosen, which represents the second The least cost is calculated for the target function to be the second father ( P2) and then carry out the exchange process for the formation of new offspring (new offspring).

b. Tournament method: this method depends on the value of the individual's trade-off, as the selection of a tournament requires determining the size of the tournament, which determines the number of individuals from the population who must be selected to compete in a tournament and entails randomly selecting individuals from the

chromosome set to participate in the tournament, as the winner of each tournament is selected to reproduce for selection, and weaker individuals in society have less chance to be selected to reproduce if the tournament size is large. In our study, we used this method to schedule work with three shifts ( morning, evening, night) and the size of the tournament was determined by three, we choose the value of the trade-off based on the calculated cost of each table, the first table is chosen at the lowest cost of the target function to be the first Father (P1) and then choose the second table, which represents the second lowest cost calculated for the target function to be the second father (P2) and then choose the third table, which represents the third lowest cost calculated for the target function to be the third father (P3) and then the process of exchange for the formation of new offspring (new offspring).

6. Crossover: It is the process of replacing some genes in one parent with the corresponding genes in the other parent. Two chromosomes may be randomly selected from the population and combined to form a new offspring. This newly created chromosome may carry better parameters and trade-off values for each parent.:

7. Mutation: it is a genetic factor used to maintain genetic diversity from one generation of the chromosome set to the next generation and its procedure begins by determining which of the individuals from the community that were created from the process of substitution interference to be mutated based on the percentage of mutation specified in the input data. Mutation leads to random differences in the community as the mutation rate is part of the bits or values within the community. this process occurs at each position in the bit string with a specific probability and this specific probability is generally determined between 0.1 or less according to the length of the community.

8. Termination: in which the work of the genetic algorithm is completed, where the final solution is the total cost calculated for the target function, depending on the hard constraints and easy constraints created to configure the scheduling of work and according to the number of binary and triple shifts.

A comparison will be made between the scheduling of nurses with two shifts and doctors with three shifts, as nurses work in various departments, while doctors work throughout the hospital.

### 1. Scheduling Nurses.

The work of nurses is to provide health services and follow up on the health conditions of patients in the children's lobby. The Hard and easy constraints to solve the problem of scheduling workers for this job description are represented by the following, according to Table (3):

Table (3) The Hard and easy constraints

Type of constraints	constraints	Minimum	Maximum
<b>hard constraints1</b>	Number of workers in the morning shift	4	6
	Number of workers in the evening shift	3	5
<b>hard constraints2</b>	nonexistence of three consecutive shifts night No morning shift after an evening shift		
<b>easy constraints</b>	The total number of holiday days for each worker	2	2
	Number of days of morning work shifts for each worker	2	3
	Number of days of evening work shifts for each worker	1	2

As the number of patients working in children's lobby is (12), they must be distributed into bilateral shifts in a way that ensures achieving the lowest possible cost by calculating the costs for the Hard and easy constraints and achieving the optimal solution, which includes the value of the Hard constraints of the first type being zero and the constraints of the first type The second is zero. As for the easy constraints, they can be achieved as little as possible, as all the constraints achieved through the genetic algorithm were zero. Table (4) shows the scheduling of nurses through the genetic algorithm.

Table (4) scheduling Nurses by GA

Source	Day1	Day2	Day3	Day4	Day5	Day6	Day7
Nurse1	M	OFF	N	M	M	OFF	N
Nurse2	N	N	OFF	N	M	M	OFF
Nurse3	M	OFF	N	OFF	N	M	M
Nurse4	OFF	N	M	M	OFF	N	N

Nurse5	OFF	M	M	OFF	N	N	M
Nurse6	M	M	OFF	N	N	OFF	M
Nurse7	N	M	M	M	OFF	N	OFF
Nurse8	N	OFF	OFF	N	M	M	M
Nurse9	M	OFF	N	N	OFF	M	M
Nurse10	M	M	M	OFF	N	N	OFF
Nurse11	M	N	OFF	N	M	OFF	M
Nurse12	OFF	M	M	M	OFF	N	N

## 2. Scheduling Doctors.

Doctors provide medical and advisory services to patients and visitors, as they are available 24 hours a day, and therefore they require scheduling them throughout that period, as the presence of doctors is sensitive and very important for patients, and thus the lack or absence of their presence affects the health and safety of patients, and a delay in their presence may lead to the exacerbation of cases. health for patients. The Hard and easy constraints to solve the problem of scheduling workers for this job description are represented by the following, according to Table (5):

Table (5) The Hard and easy constraints

Type of constraints	constraints	Minimum	Maximum
<b>hard constraints1</b>	Number of workers in the morning shift	2	3
	Number of workers in the evening shift	1	2
	Number of workers in the Night shift	1	2
<b>hard constraints2</b>	nonexistence of three consecutive shifts night No morning shift after an evening shift No morning shift after a Night shift		
<b>easy constraints</b>	The total number of holiday days for each worker	1	1
	Number of days of morning work shifts for each worker	2	3
	Number of days of evening work shifts for each worker	1	2
	Number of days of Night work shifts for each worker	1	2

As the number of doctors working in Hospital is (6), they must be distributed into bilateral shifts in a way that ensures achieving the lowest possible cost by calculating the costs for the Hard and easy constraints and achieving the optimal solution, which includes the value of the Hard constraints of the first type being zero and the constraints of the first type The second is zero. As for the easy constraints, they can be achieved as little as possible, as all the constraints achieved through the genetic algorithm were zero. Table (6) shows the scheduling of nurses through the genetic algorithm.

Table (6) scheduling Doctors by GA

Source	Day1	Day2	Day3	Day4	Day5	Day6	Day7
Doctor1	M	OFF	E	N	N	M	M
Doctor2	M	E	OFF	E	N	N	M
Doctor3	N	M	M	M	OFF	N	E
Doctor4	M	N	N	E	M	OFF	N

Doctor5	N	M	M	OFF	E	E	N
Doctor6	E	N	N	M	M	M	OFF

#### FOURTH SECTION. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of the study are presented as follows

##### First: Conclusions

1. There is a high efficiency of the genetic algorithm in solving the problem of scheduling workers in terms of speed and time and reaching the optimal solution as quickly as possible and in an ideal time. The genetic algorithm can prepare more than 1000 schedules in a very short time not exceeding a minute and thus the optimal solution can be reached easily.
2. The scheduling of nurses is more flexible than the scheduling of doctors due to the greater flexibility in the available numbers. Also, the restrictions imposed on doctors are difficult and their work requires more working hours than nurses, as their Holiday days are only one day, While Holiday days for nurses are two days.
3. The use of genetic algorithm contributes to improving the quality of the service system provided in the hospital, as it works to achieve the presence of a sufficient number of workers for the purpose of providing service to patients with various job titles who work within the different departments.
4. The use of the genetic algorithm contributes to achieving justice, fairness and impartiality among health personnel in terms of the number of shifts each worker works, as the genetic algorithm is the one that prepares this scheduling and therefore it will be fair for everyone.
5. There is a shortage in the number of doctors (Senior resident ), and there is a clear increase in the number of nurses, as the number of doctors is 6 in all hospital departments, while the number of nurses varies from one department to another and is in very large numbers. The number of nurses in the children's lobby that has been scheduled is 12, and the rest of the departments have many nurses in very large numbers.
6. Nurses work in two shifts, while doctors (Senior resident ), work in three shifts. Therefore, using a genetic algorithm enables us to know the shortage in a particular department, as well as the increase in numbers, and thus contributes to achieving balance between departments.

##### Second: Recommendations

1. It is necessary to invest in the shortage in the number of doctors and work to attract doctors to fill the shortage in the hospital. As for nurses, they can be transferred from double shift to triple shift and exploit the increase in their numbers by providing better services.
2. The need to pay attention to algorithms, including the genetic algorithm, in solving the problem of scheduling workers with different job titles, and working to invest them in facilitating the process of providing service to clients and ensuring the presence of sufficient staffing of workers.
3. The need to pay more attention to achieving the satisfaction of working individuals by investing in their abilities and encouraging them, and making it easy to determine the work shifts they want that meet their needs and desires.
4. The necessity of investing in personnel and providing them with adequate training before working in the hospital, especially for newly appointed staff with various job titles, as the hospital requires individuals with experience, high competence, and skills as it deals with difficult cases, especially for patients with heart and blood vessels.
5. It is necessary to direct the Ministry of Education and the Ministry of Health to provide the hospital with the largest possible number of doctors in the specializations of cardiology and cardiac surgery and to work to increase these specializations in medical colleges, as there is a shortage of health personnel of doctors specializing in cardiology and cardiac surgery, with the noticeable increase in the number of patients and visitors in the hospital. the heart.

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