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| RESEARCH ARTICLE

Optimizing the Medical Resource Supply Chain During the Covid-19 Pandemic in Baghdad Hospitals using the Fuzzy Inference System (FIS)

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| ABSTRACT

The importance of using scientific and quantitative methods in addressing contemporary problems, including the (Covid-19) pandemic, as these challenges and problems require everyone, especially those working in educational institutions and researchers, to support international and local efforts to reduce the impact of this pandemic by achieving optimal use of medical resources, for the supply chain of medical resources that includes (therapeutic protocol and medical supplies) ; Thus, providing solutions, alternatives and logistical support that would absorb the significant increases in the number of injuries in light of the limited resources in the face of this pandemic .Hence, this research came to contribute to the local and international efforts to address this problem by presenting a package of ideas and solutions for how to achieve the optimal utilization of medical resources. In light of the inaccuracy and discrepancy in the available data by distributing those resources in a quantitative and thoughtful manner to achieve the goal for which it was set, as well as evaluating alternatives on the ground and ways to improve them with an indication of the future prospects for this problem is by applying one of the artificial intelligence techniques called the fuzzy inference system (FIS).

| KEYWORDS

Artificial intelligence techniques, fuzzy inference system, supply chain, medical resources

| ARTICLE INFORMATION

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1. Introduction

Operations research deals, in general, with the problems of the optimal use of available resources, and the science of operations research is based on linking these resources with optimal uses through the formulation of clear and specific mathematical models that reflect the reality of those problems; a quantitative method for optimization. The focus of this research will be on the types of one of those models and the requirements for their application, as well as the logistical activities and the supply chain that can be achieved as a result of the application of these models, thus achieving the optimal exploitation of limited (scarce) resources through the concept of optimization, which all institutions seek to reach to solve their problems, and from the most prominent of these problems (supply chain operations), which are considered one of the most important models of operations research in helping to transport and distribute goods and services to production and service institutions and others.

2. Supply Chain (SCM)

Transportation and logistics are among the applications of operations research, which have contributed greatly to improving the efficiency of operations and providing support for decision-making at different stages of the decision-making process. The concept of (logistics) differs from (supply chain management), where logistics refers to the planning, implementation, and control of the movement of goods and purchases to achieve the objectives of the approved project or strategy, while supply chain management

(SCM) is a wide range of activities necessary to plan and implement the transportation and distribution of goods starting from materials Primary and ultimately to the customer. (Stadtler and Kilger 2008).

Transportation and distribution are one of the most important elements in the supply chain work system. Thus, the supply chain is defined as a sequential network of production processes that carry out the process of (transfer/transfer) materials in order to meet consumer demands. It also includes procurement, manufacturing, storage, transportation, and distribution. (Koberg and Longoni 2019).

2.1 Concept of Supply Chain

The emergence of the term supply chain was due to the need to integrate business operations from the main supplier to the final consumer by providing goods, services, and information (Abdul, Khan, and Yu, 2019) and the first to touch on the concept of the supply chain was the management consultant (Keith Oliver) in the eighties of the last century, then several different concepts and points of view followed by writers and researchers in Logistics Management. It is worth noting that supplies are part of the supply chain that shares the flow of goods and services (Ivanov and Tsipoulanidis, 2019). Figure (1) shows the content of the supply chain process.

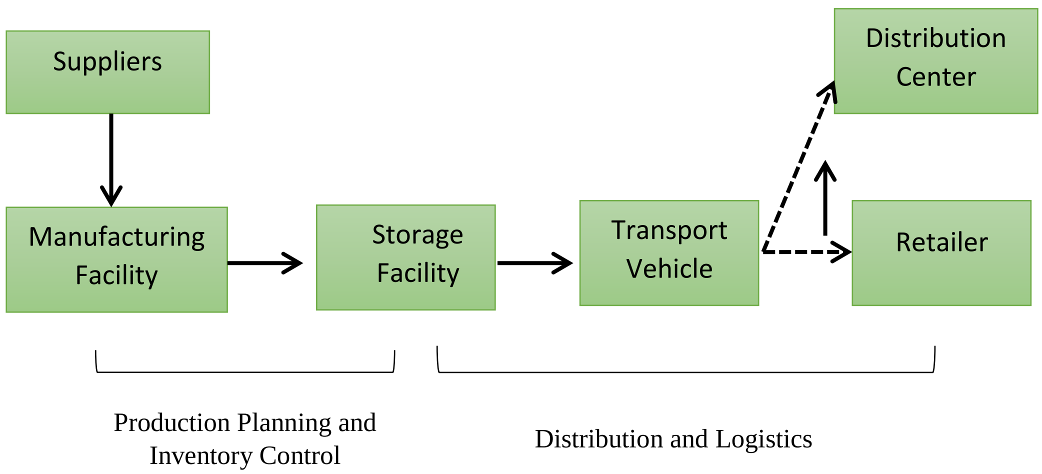

Figure (1) shows the process of supply chain (SCM)

Source: (Beamon 1998)

2.2 Supply Chain Components

Researchers differed in defining the components of the supply chain, some put them in groups and secondary components, and some of them relied on the departments and activities carried out by Supply Chain Management (SCM) in determining those components where (Krajewski and Malhotra 2016) identified three main components For supply chain:

1- Purchasing: It is a process that includes selecting and identifying suppliers
2- Production: It is the management of the processes of transforming raw materials (raw) into goods or services.
3- Distribution: It is the management of the process of the flow of goods and services from the factory to the consumer, whether from the factory directly or a third party carrying out the distribution process.

While (Li p.) put the components of the supply chain based on the activities carried out by the chain, which are as follows:(Speranza 2018).

1- Demand Management: It is the main component of (SCM) that includes satisfying consumers' needs for goods and services, which are determined through the planning process, after which the required needs for materials should be evaluated and purchasing methods determined.
2- Acquisition Management: This includes purchasing management and evaluating bids through specialized committees.
3- Logistics Management: It includes the movement and storage of goods and materials and ensuring the effective flow from the main sources to the consumption sites.

4- Disposal Management: It gives attention to planning the obsolescence of materials, establishing a database of surplus materials, determining what is good for them, and disposing of surplus materials.
5- Risk Management: managing the consequences of unexpected decisions and considering and avoiding risks while providing coverage for the remaining risks.
6- Supply Chain Performance: Monitoring the progress of operations through a retrospective analysis to determine whether the operations have achieved the desired goals. Figure (2) illustrates the general concept of the supply chain model, which includes all the central activities of enterprises as they are combined, starting from raw materials to final consumption through the flow and flow of goods, raw materials, and services that make up the entire supply chain. Figure (2) shows the continuous flow of and the flow of goods from the beginning of processing to the end of receiving, while the dashed arrows show the progress and flow of the main information from the issuance of requisition orders and so on (Takai 2009)(Ivanov et al. 2018)

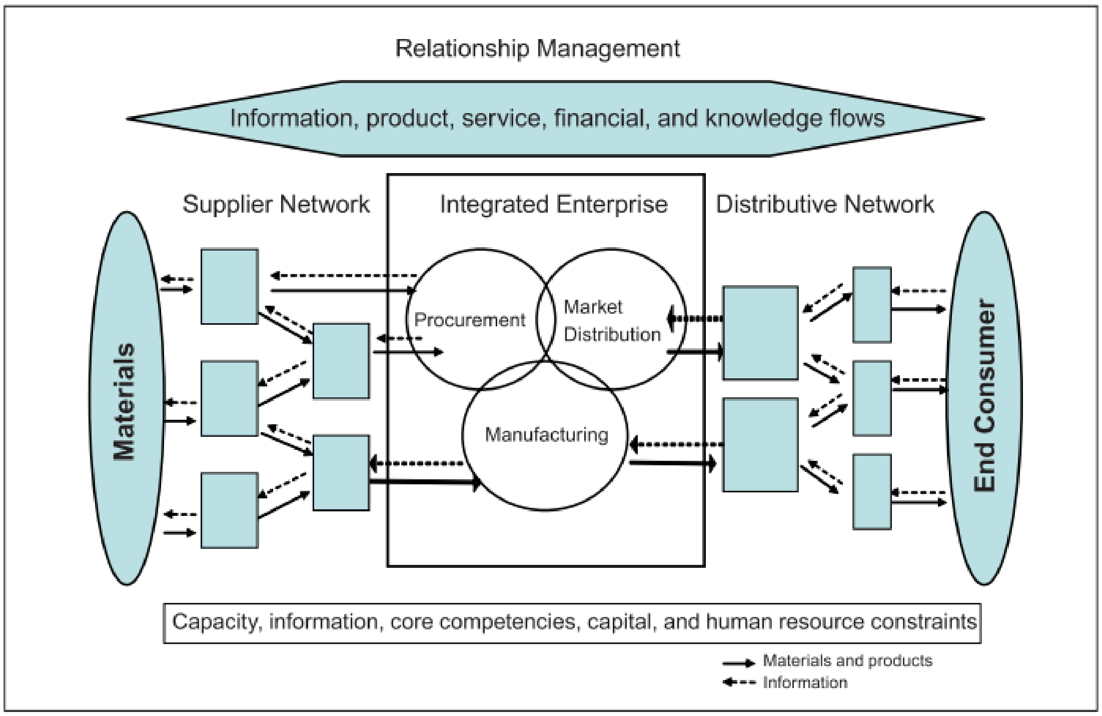

Figure (2) shows the general supply chain model (SCM Model)

3. The relationship of the supply chain with other fields

The supply chain is linked to several applied fields and is looked at according to the field or specialization to which it is related. Table (1) shows a comparison between the supply chain with other applied fields (Chibba 2017).

Table (1) Comparison of the supply chain with the applied fields

fields	Focus on	definition	Branch of the supply chain	Relationship
Logistics/Transportation	transportation and distribution	The process of planning, implementing, and controlling the flow and storage of goods and services from sources of origin to consumption sites to meet customer requirements	Yes	**Some researchers have pointed out that the supply chain is the same concept as logistics, and others say there are some differences**

Marketing	distribution centers	Activities aimed at meeting needs through exchange channels	Yes	**There is a close link between marketing and logistics**
Operations Management	production operations	Managing resources in an organization specialized in producing goods and providing services	Yes	**Having a strong connection with some components of the supply chain**
Quality Management	customer satisfaction	Seeking to adopt the quality of goods as a strategy to achieve sustainable success	Yes	**Quality management is based on making improvements within the organization, while the supply chain focuses on improvements between organizations**
Information Systems Management	Hardware and software	Managing information technology between and within organizations	Yes	**For efficient supply chain, modern information technology is required**

4. Supply Chain Modeling Techniques

To perform the supply chain modeling process, the method (method) to be used in modeling must initially be chosen, and here, modeling is meant building a mathematical model of the supply chain; then, its results are analyzed and tested according to the data available on the ground. The modeling process of the supply chain varies depending on the supply chains themselves and the aspects that are taken into account when building the mathematical model. The researchers presented several applications of the methods used in modeling, and they can be classified into: (Shukla et al. 2017)

1- Optimization method: It is an analysis method that determines the best possible way to model the supply chain using one of the operations research models, such as linear programming, transportation models, and others. This method aims to build a mathematical model that seeks to maximize profits or reduce costs. In addition, the construction process requires real data and information about the problem at hand. Despite the difficulty of building an accurate, applicable, uncomplicated model that includes all the elements and variables in the supply chain, in the end, it will reflect the best results in solving the problems facing the supply chain. (Chandra 2008).

2- Simulation method: The idea of simulation is summarized in imitating and simulating the current situation of the supply chain in reality, but in a purely mathematical way, then the operational characteristics of the model are studied, and finally, decisions are made that are based on the results of the simulation model. Probabilistic simulation models allow the supply chain to be represented in a more comprehensive and flexible manner and thus provide the ability to study detailed or complex problems compared to the optimization method. However, in the modeling process, the decision maker seeks to focus on the strategic and fundamental effects, and therefore this is considered a relative advantage of the simulation method (Şehitoğlu 2019).

3- Heuristics method: It is a method that refers to the methods used to solve different problems by resorting to experiments or technical expertise, The analysis process is carried out according to (artificial intelligence algorithms) prepared for this purpose, and it must be fed with some information about the problem so that it can work and reach the optimal solution (Ghadimi, Wang, and Lim 2019).

Figure (3) shows the methods adopted in operations research to assist in the supply chain modeling process in line with the nature and assumptions of the problem.

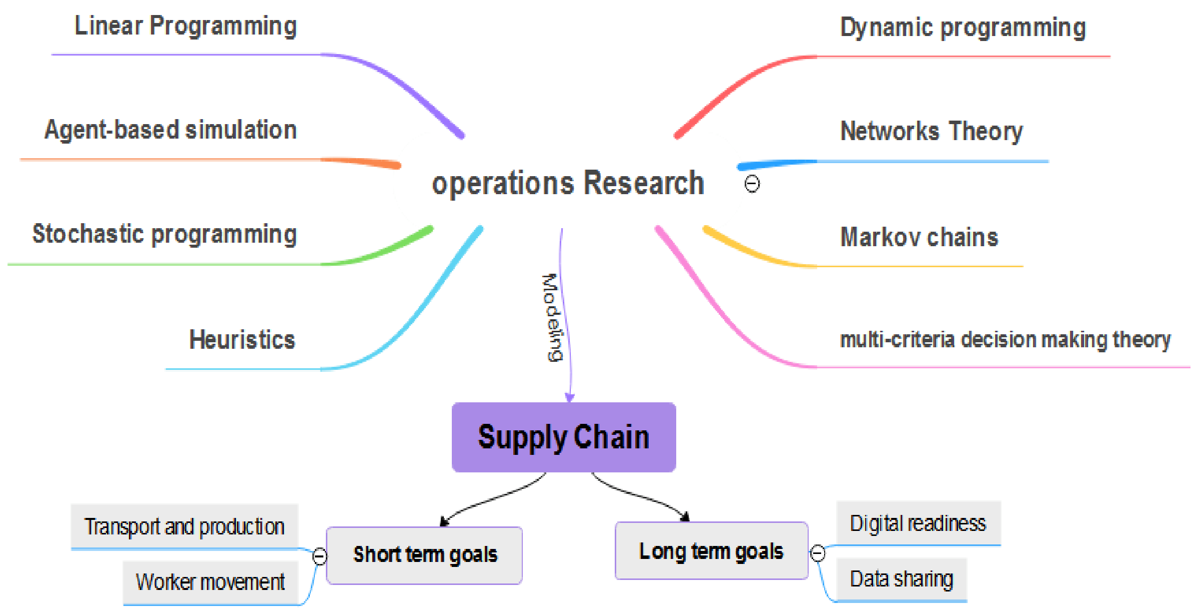

Figure (3) shows the methods of operations research in the modeling of supply chains

5. Artificial Intelligence (AI)

Many scientists and researchers have known "artificial intelligence" according to its specialization. There are those who knew it from the point of view of mathematics, astronomy, engineering, etc. (Ian Rich) defined it as "a science that investigates how to make computers perform the tasks that humans perform in a better way." We can define artificial intelligence as "a method aimed at designing expert systems that give characteristics similar to human behavior for problems using coding (Son, Viet, and Hai, 2016).

As it is known that computers process data through logical algorithms from a specific and known beginning to a specific and known end, while in operations that require mental thinking in humans, artificial intelligence depends on processing it on the acquisition and accumulation of experience from a specific experience or based on experimental behavior (Legg and Hutter 2007).

- **Techniques of (AI)**

After the remarkable development currently in the information age for processing big data and integrating it with artificial intelligence, which with time began to take a trend to invent new technologies from technical sciences, the following are some of these sciences and technologies within the field of artificial intelligence (Dalal, Kanoria, and Beriwal 2018).

5.1 Expert Systems

1. Artificial Neural Networks
2. Logic Rules
3. Genetic Algorithms
4. Game Theory
5. Heuristic

6. **Fuzzy Inference System (FIS)**

It is one of the techniques of artificial intelligence that is compatible with expert systems because it allows the processing of foggy data that lacks accuracy in the way it is processed and the decision is taken regarding it. The fuzzy inference system is built according to a mathematical model in order to model complex systems that help in solving problems characterized by Fuzzy and inaccuracy of data around them.

The fuzzy inference system relies on fuzzy groups to devise models that are processed using computer programs through an automatic dialogue between the human expert and the computer to process the fuzzy data. The control unit is based on rules that draw the best decision-making policy. (Cherkassky 1998).

One of the most important and most common, and widely used fuzzy inference systems is the fuzzy inference system (mamdani), which was suggested by the scientist (mamdani) based on what was presented by the scientist Lutfi Zadeh (L.Zadeh) about fuzzy concepts and decision-making processes, This expert system shows a set of inputs and outputs, and the management of relationships between them through rules of thumb (Rules) and (Membership Function) in order to remove the Fuzzy and reach the final result. (Ocampo-duque et al. 2006)(Rejeesh 2019).

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The main objective of using the fuzzy inference system is to control complex processes by relying on strategies of sequential analysis based on knowledge, experience, and expertise. Therefore, the fuzzy inference system can be defined as the process of drawing diagrams from a specific input to a specific output using fuzzy logic (Sivanandam, Sumathi, and Deepa, 2007).

The expert system (fuzzy inference), like the rest of the expert systems, consists of a knowledge base called the (Knowledge base), which is also called the Database.

It contains general knowledge about the problem under study that is represented and formulated through a set of conditional rules (IF) that link the fuzzy groups with conditions and conclusions, and the process of evaluating these rules is carried out according to an inferential engine and optimum decision-making. Figure (4) shows the model of fuzzy inference operations (Chaudhari and Patil, 2014) (Sivanandam et al., 2007).

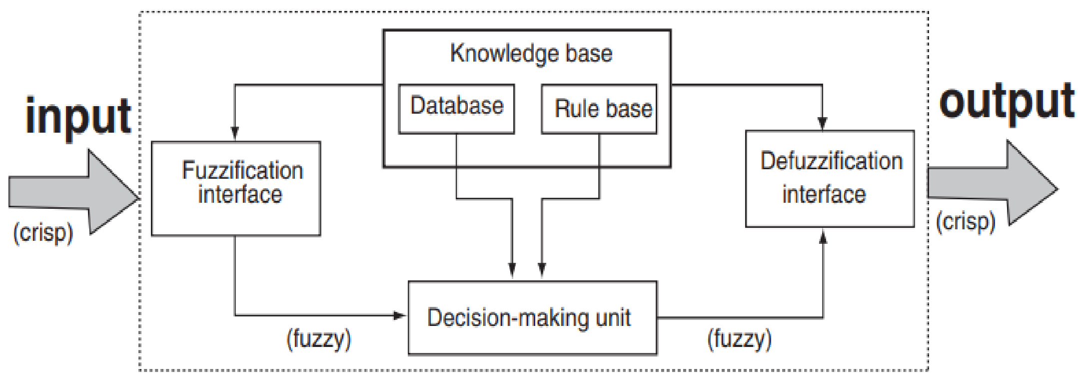

Figure (4) Fuzzy Inference Model (FIS)

The fuzzy inference model above shows that there are four main and proxy stages: (Kumar and Singh 2012)

- **Fuzzification**

It is considered the first stage in building the fuzzy inference model, as the traditional inputs (Crisp inputs) are converted into (fuzzy inputs) through the Membership Function, which is either of the types of triangular or trapezoidal numbers, meaning that the linguistic inputs are converted into digital.

- **Knowledge base**

The knowledge base defines a set of conditional rules (IF-Then) as follows:

IF x is A Then y is B

Where x is the input variable and y is the output variable, A and B are language variables that are defined by fuzzy sets.(Kazeminezhad and Mousavi 2005).

- **Decision-making unit**

It includes the rules obtained from the individual results to which each of the rules contributed, meaning that one fuzzy group that represents the outputs will be obtained. Upon completion of the aggregation strategy, the final output is determined through two cases. Either there is a common system of rules or a separate system of rules, so the judgment is linked to the logical operations represented by (and), (or) (Kasabov, Member, and Song 2002)

- **Defuzzification**

It is considered the last stage in fuzzy inference modeling, in which the fuzzy set of outputs is converted to specific values, depending on one of the methods of removing fuzziness. (Ojha, Abraham, and Snášel 2019)

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It is worth noting that the fuzzy inference system has been successfully applied within (Matlab) programming and in many fields such as (automated control, decision analysis, expert systems, etc.), The fuzzy problem is addressed using (Matlab) programming, where the graphic interface (GUI) consists of five main tools for building the fuzzy inference system (FIS), which are as follows: (Bystrov and Westin 2015)

1. (FIS Editor) is concerned with determining the number of inputs and outputs for variables and their names for the fuzzy problems under study.
2. (MF Editor) is used to determine the forms of the Membership Function (trigonometric or trapezoidal, etc.) and associated with each variable.
3. (Rule Editor) is used to add rules that define the behavior of system variables
4. (Rule Viewer) is used to display the problem in the form of a fuzzy inference scheme
5. (Surface Viewer) displays how one of the variables depends on one or more of the inputs and maps the outputs of the system. Figure (5) shows the system diagram

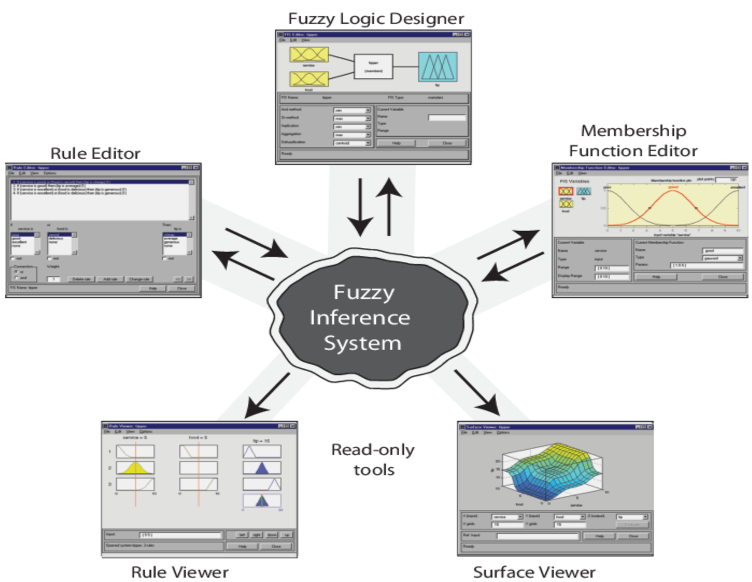

Figure (5) Scheme of the fuzzy inference system in Matlab

6.1 IF-Then Rules

They are tools in the programming language (Matlab) that make fuzzy logic useful and, in a sentence, understandable and explain the rules of the condition, and the result is a process consisting of three parts: (Pourjavad and Shahin 2018).

- Fuzzy Inputs
- Apply Fuzzy Operator
- Apply Implication Method

6.2 Managing Fuzzy Classification

It is an analogue of fuzzy control systems and can be represented in the form of a matrix consisting of a number of rows and columns representing linguistic variables used to formulate the rules of condition and outcome (IF-Then) within the fuzzy inference system (FIS), and as shown in the table (2) below ,The conditional element (IF) is expressed in fuzzy groups, and the result (Then) takes the probabilistic values (the conclusion) that represent the rows of the matrix, and then the result of the rule is determined from the corresponding columns. (Hudec 2016) (Jang 1993).

Table (2) IF-Then Matrix

		The second premise of the conditional element (IF)		
		linguistic variable first A	**linguistic variable second A**	**linguistic variable Third A**
The first premise of the conditional element (IF)	**linguistic variable first A**	**Then Conclusion B**	**Then Conclusion B**	**Then Conclusion B**
	linguistic variable second A	**Then Conclusion B**	**Then Conclusion B**	**Then Conclusion B**
	linguistic variable Third A	**Then Conclusion B**	**Then Conclusion B**	**Then Conclusion B**

7. Case study

This aspect aims to define and describe the sample that includes the sites of conducting this study (from places visited and experienced, as well as the people who were interviewed and collected data for this study). The medical resources that represent the treatment protocol and medical supplies, such as medicines and vitamins, as well as masks, paws, covers, and others, have been identified. As for the sample, it represents the health departments in Baghdad and its affiliated hospitals, which were designated to treat patients with the Corona pandemic, and in which the percentage of infections reached a peak during the period from (February 2021) to (September 2021) to record the highest percentage of monthly injuries and deaths, so it will be adopted in this sample The study is as shown in Table (3) below.

Table (3) represents the number of monthly infections with the (Covid-19) pandemic for the year 2021, distributed according to Baghdad health departments

No	Months	Rusafa Health Department	Karkh Health Department	Medical City Health Department	Total
1	January	1789	6493	510	**8792**
2	February	8024	14668	1666	**24358**
3	March	24462	25701	3762	**53925**
4	April	36561	37890	4170	**78621**
5	mayo	19922	26964	2039	**48925**
6	June	12726	27762	1786	**42274**
7	July	31373	37707	3264	**72344**
8	August	19120	34054	2712	**55886**
9	September	5864	11438	898	**18200**
10	October	1497	3452	331	**5280**
11	November	954	1884	136	**2974**
12	Dec	692	1064	92	**1848**
Total		**162984**	**229077**	**21366**	**413427**

Source: Ministry of Health/Public Health Department

8. **The reality of the supply chain for medical resources in Baghdad**

The demand for medicines and medical supplies related to the Corona pandemic is increasing with the rapid increase in the number of infections, and with this increase, attention is directed to the mechanism of transporting and distributing these medical resources and delivering them to hospitals in the required quantity and speed, In order to get acquainted with the reality of the chain of supplying medicines and medical supplies related to the (Covid-19) pandemic, it is necessary to see the progress of this chain, which was prepared by the researcher in transferring those resources from the central warehouses of the Kimadia company in Baghdad to the stores of its health departments from In Figure (6) below:

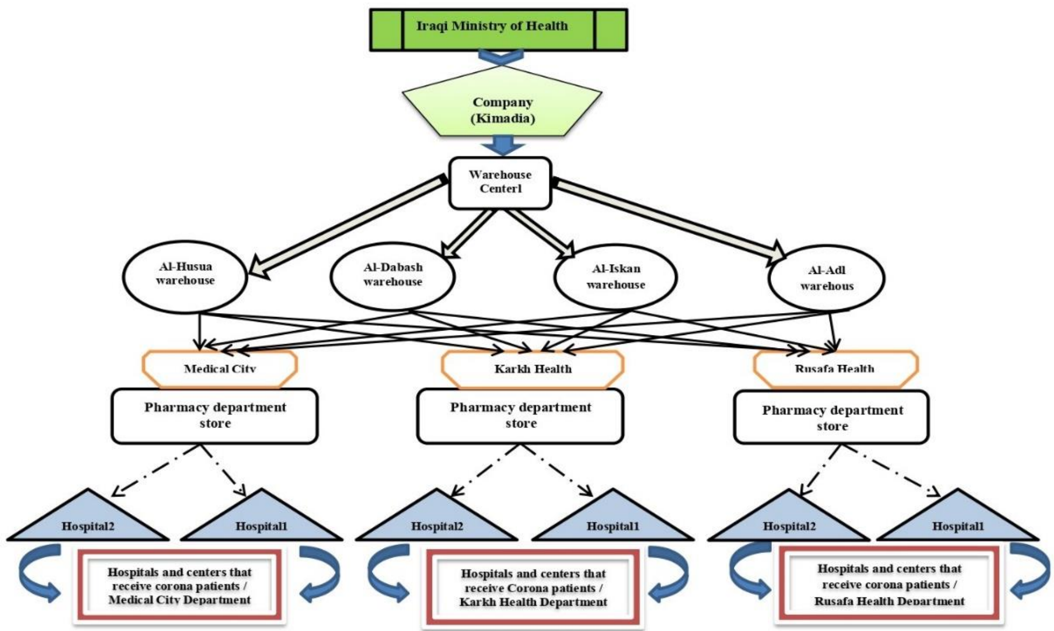

Figure (6) Diagram of the supply chain of medicines and medical supplies for the hospitals of the Baghdad Health Departments

9. Application of the Fuzzy Inference System (FIS)

The theoretical aspect was addressed with regard to (FIS) which requires defining the inputs and outputs at the beginning to address the ambiguity of the data and thus reached the optimal decision for the treatment protocol and medical supplies (medical resources). Therefore, the fuzzy (quantities required) for each resource were approved in each hospital of the Baghdad Health Departments (Al-Rusafa, Al-Karkh, Medical City) to represent the first inputs ,as the second input represents the ambiguous delay time, which was collected from (Kimadia stores to Baghdad health departments) and from (Baghdad health departments to its affiliated hospitals), which became standardized delay times for each medical resource in each hospital.

As for the outputs, they are of two types as well. The first represents medical resources (therapeutic protocol and medical supplies) whose goal is to achieve optimal use of them and prevent disability, and the second is the processing time, which is planned to achieve a time commensurate with the aspirations of hospitals to obtain those resources with the least possible delay. In order to implement the fuzzy inference system (FIS), the program (Matlab R2021b) will be relied on to process the fuzzy data for each hospital, as shown in Table (3).

Table (3) Medical Resources and Hospitals to be Treated in (FIS)

medical resources (therapeutic protocol and medical supplies)	**Baghdad Health Departments Hospitals**		
	Al-Rusafa	Al-Karkh	Medical City
1. Remdesivir 100mg **2. Azithromycin 500mg** **3. Tamiflu 75mg** **4. Kaletra 200mg/50mg** **5. Hydroxychloroquine 200mg** **6. Decadron 2ml** **7. Actemra 400mg** **8. Favipiravir 200mg** **9. Zinc 50mg** **10. Vitamin D 50000mg** **11. Vitamin C 1000mg** **12. Face mask (various colors)** **13. Face mask N95**	1. Al-Kindi Teaching Hospital 2. Ibn Al-Khatib Hospital 3. Sheikh Zayed Hospital 4. Al-Atta Hospital 5. Imam Ali Hospital 6. Ibn Zohr Hospital 7. Al-Sadr General Hospital	1. Yarmouk Teaching Hospital 2. Al Furat General Hospital 3. Al Karkh General Hospital 4. Al-Hakim Hospital 5. Imam Kadhimin Medical City Hospital 6. Al Karama Teaching Hospital	1. Baghdad Teaching Hospital 2. Al-Shifa Hospital

14. Theater face mask **15. Face shield** **16. Head cap (various types)** **17. Theater head cap** **18. Gloves (various sizes)** **19. Gown (various sizes)** **20. Protective glasses** **21. Bed sheet** **22. Shoes cover**			

Thus, the implementation of the (FIS) system can be started by choosing the first department and the first hospital and treating all medical resources one by one, and so on for all departments and hospitals affiliated with it, as is clear in Figure (7), and the implementation process can be summarized through the following steps:

Figure (7) shows the selection of the first medical supplier (Remdesivir 100mg) in (FIS)

9.1 ***Create (FIS)***

You start by creating a fuzzy inference system (FIS) for the first supplier (Remdesivir 100mg) at (Al Kindi Teaching Hospital) through the (Matlab R2021b) API. Where the FIS Editor window appears in Figure (8)

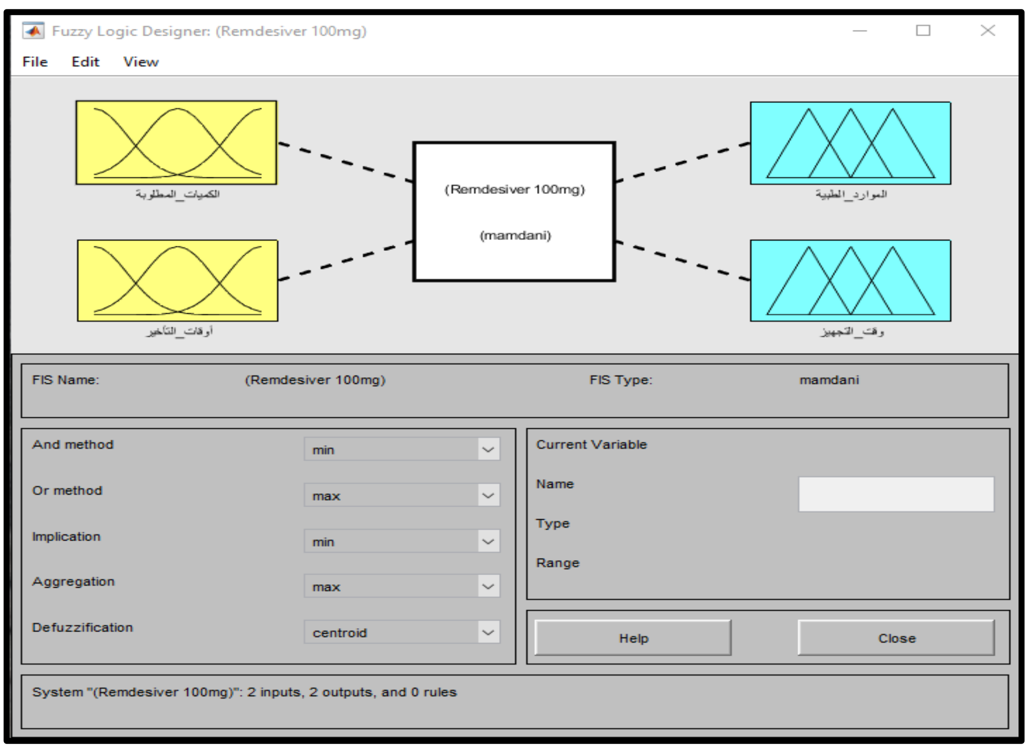

Figure (8) window (FIS Editor) for the medical resource (Remdesivir 100mg) in Al-Kindi Teaching Hospital

9.2 Determine the type of membership function (MF)

It is determined through which the type of belonging function (Membership Function) associated with the form of the available data, and certainly the type of the Membership Function will be triangular, since all the data of the problem (three fuzzy numbers), then the inputs and outputs of the system are defined, which includes the following:

- **Input** : Through it, the medical resources (therapeutic protocol and medical supplies) that will be applied (FIS) are entered and identified, and the optimum utilization of them is achieved in each hospital. The process of entering the fuzzy data that was previously touched upon for the supplier (Remdesivir 100mg) is carried out in two types (order quantities) and (delay times). Figures (9) and (10) show the Membership Function of each of the fuzzy demand quantities and fuzzy delay times, respectively. For (Remdesivir 100mg)

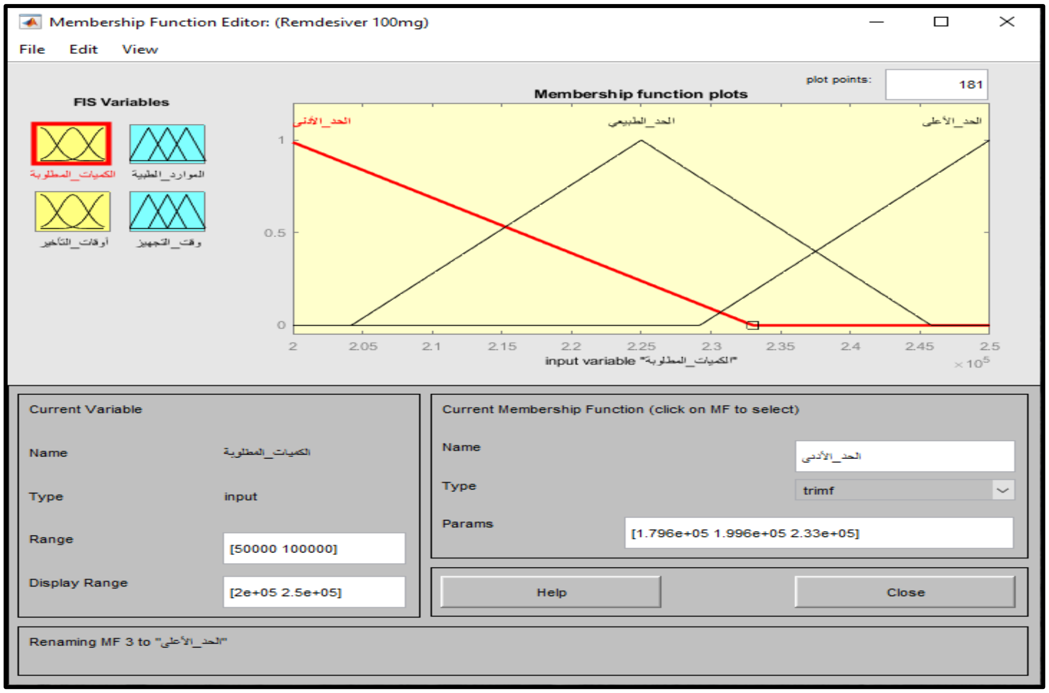

Figure (9) Trigonometric Membership Function of Demand Quantities for a Medical Supplier (Remdesivir 100mg) in Al Kindi Teaching Hospital

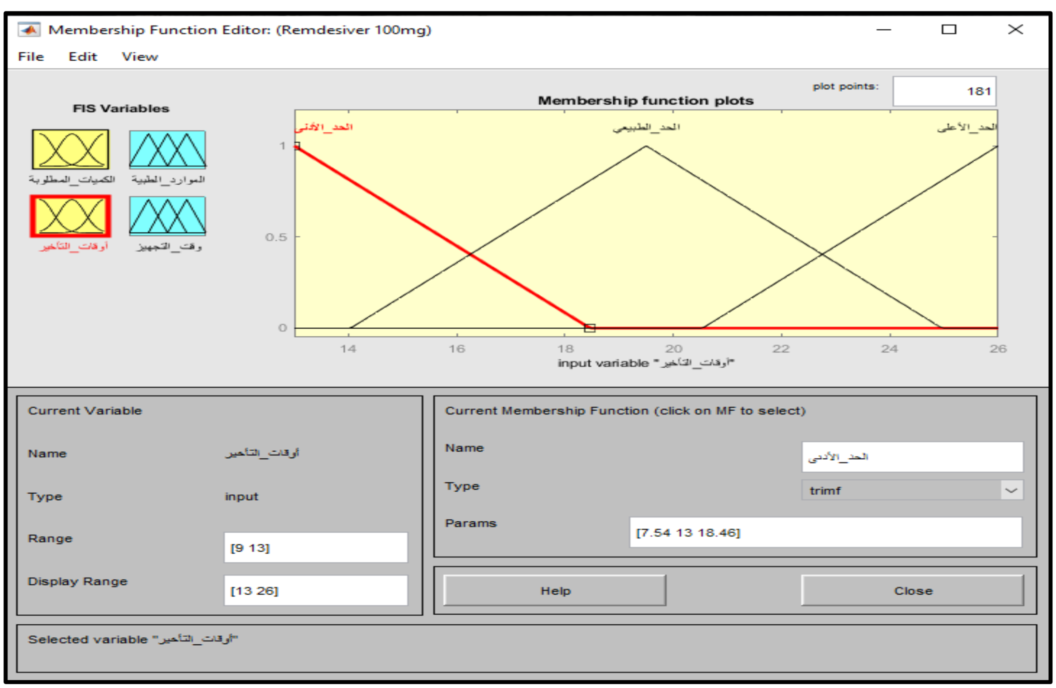

Figure (10) Trigonometric Membership Function of delay times for the medical resource (Remdesivir 100mg) in Al Kindi Teaching Hospital

- **Output** :It represents the outputs of (FIS) after processing the data using the logical operations of the system and achieving the desired goal, which is the optimal utilization of medical resources at the best processing time; before that, the outputs must be defined in the light of which the decision will be taken. They are of two types, the first (medical resources) and the second (processing time).

  Where the first output (medical resources) is subject to the conclusions of the rules of the condition and the outcome (IF-Then Rules), if the condition is met, the result will have three possibilities (surplus, natural, deficit), while the second output (processing time) also carries three possibilities (good, normal, bad). Figure (11) shows the triangular Membership Function of medical resources, and Figure (12) shows the triangular affiliation function of the processing time.

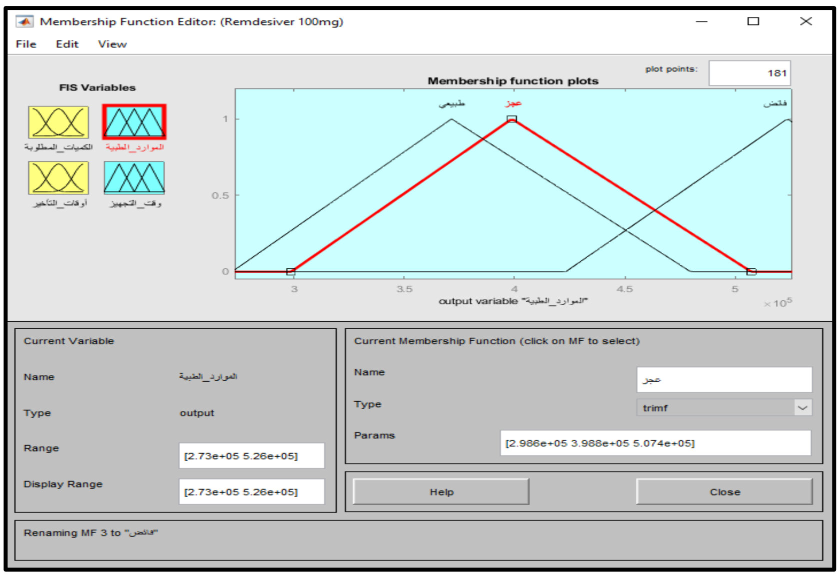

Figure (11) Trigonometric Membership Function of medical resources for (Remdesivir 100mg) in Al-Kindi Teaching Hospital

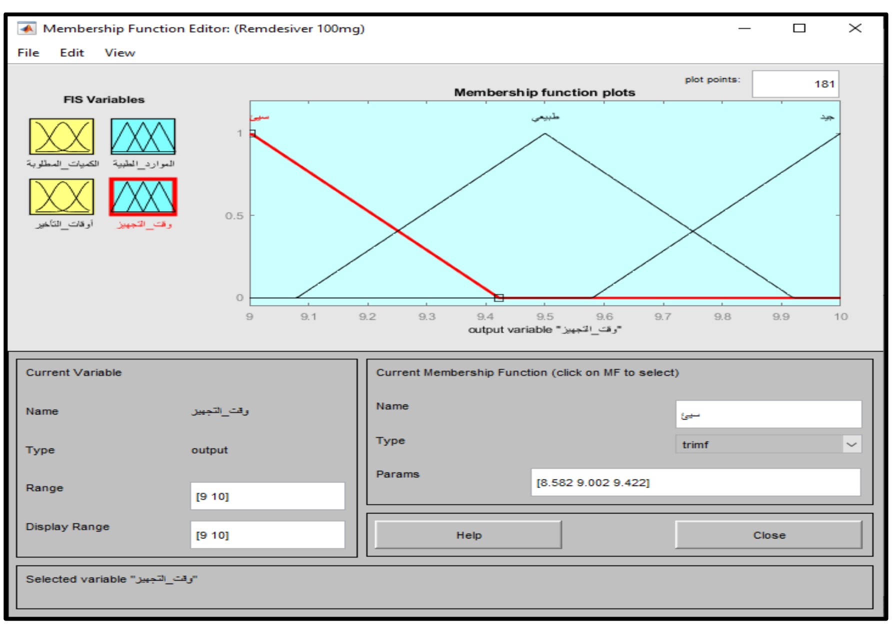

Figure (12) Trigonometric Membership Function of processing time for (Remdesivir 100mg) in Al Kindi Teaching Hospital

9.3 Programming (FIS)

At this stage, the FIS is programmed by defining the IF-Then rules for all the problem elements through the Rule Editor window . In the beginning, the conditional rules and their results are set for the hypotheses and variables of the study, where table (4) shows the matrix of the condition rules and the result of the hypotheses of the study, which are the quantities of demand and delay times, which were developed based on logic and the discussion of stakeholders in all hospitals of Baghdad health departments.

Table (4) Condition and result rules matrix for order quantities and delay times

		Delay times					
		Lower limit		*normal limit*		*upper limit*	
		medical resources	*processing time*	*medical resources*	*processing time*	*medical resources*	*processing time*
Quantities required	*Lower limit*	Normal	Good	Normal	Good	Normal	Normal
	normal limit	surplus	Good	Normal	Normal	deficit	Bad
	upper limit	surplus	Normal	deficit	Bad	deficit	Bad

It is worth noting that the formulation of rules for medical resources in hospitals is done depending on the quantities of demand and times of delay, so the results affect the number of medical resources that must be provided in the hospital, which is either surplus or natural quantities, or there is a deficit, on the other hand, there is also an effect achieved in the processing time, which includes the case that the processing time is (good, normal or bad.) Then we need to express table (4) in text form for each of the nine rules, so the rules are written as follows:

First Rule: If the request is at the lower limit and the delay time is the lower limit, then the medical resources are in a normal situation and the processing time is good.

Second Rule: If the demand is at the lower limit and the delay time is at the normal limit, then the medical resources are in a normal situation, and the processing time is good.

Third Rule: If the request is at the lower limit and the delay time is at the upper limit, then the medical resources are in a normal situation, and the processing time is normal.

Fourth Rule: If the demand is within the normal limit and the delay time is at the lower limit, then the medical resources are in surplus and the processing time is good.

Fifth Rule: If the demand is within the normal limit and the delay time is within the normal limit, then the medical resources are in a normal situation, and the processing time is normal.

Sixth Rule: If the demand is within the normal limit and the delay time is at the upper limit, then the medical resources are in deficit, and the processing time is bad.

Seventh Rule: If the demand is at the upper limit and the delay time is at the lower limit, then the medical resources in the situation are in surplus and the processing time is normal.

Eighth Rule: If the demand is at the upper level and the delay time is at the normal limit, then the medical resources are in deficit, and the processing time is bad.

Ninth Rule: If the demand is at the upper limit and the delay time is at the upper limit, then the medical resources are in deficit, and the processing time is bad.

And Figure (12) shows the Rule Editor window for the supplier (Remdesivir 100mg) in Al-Kindi Teaching Hospital, which was programmed in (FIS) through (Matlab R2021b)

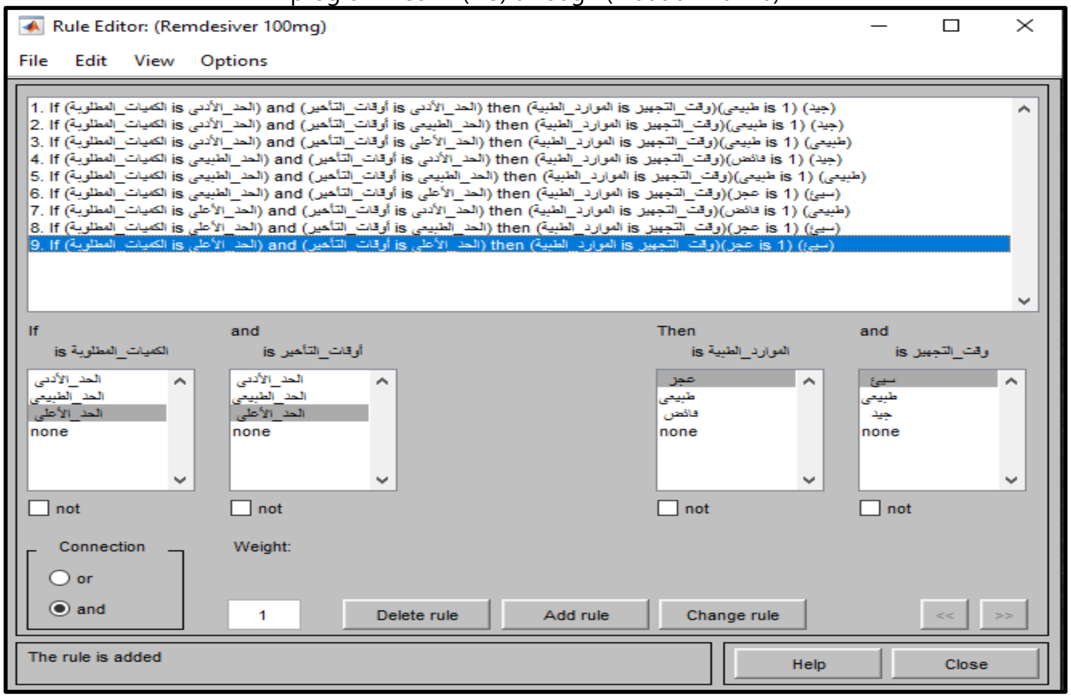

Figure (12) Rule Editor window in (FIS) for the resource (Remdesivir 100mg)

10. Output analysis (FIS)

The process of fuzzy processing and showing the outputs in FIS technology is carried out by instructing (Centroid) within the (Defuzzification) list, where the results show a normal value (non-fuzzy) for each fuzzy group within the previously defined variables.

Among the outputs of the system, we get to know the fuzzy inference scheme of the medical resource (Remdesivir 100mg) in Figure (13), which is a list of all the bases of the variables and displays them together (Rule Viewer), which is considered a traffic map in (FIS), Where each rule of the condition and result is expressed in a row, as well as for each of the variables (input and output) in a column.

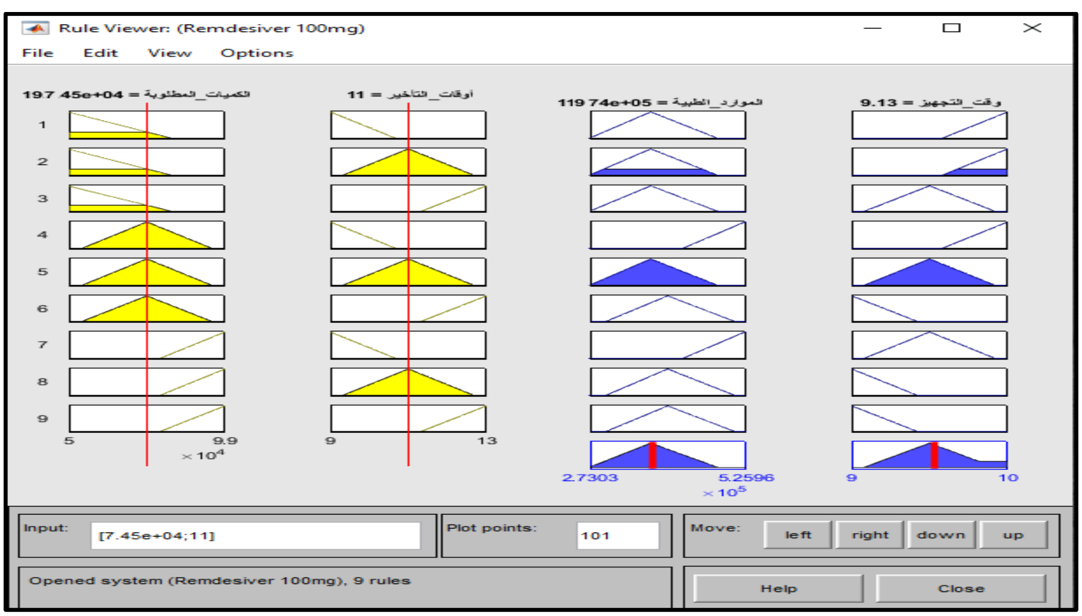

Figure (13) Rule Viewer window in (FIS) for the supplier (Remdesivir 100mg) at Al Kindi Hospital

It is clear from Figure (13) above that the first and second columns represent the inputs, namely (quantities of demand) and (delay times); As for the third and fourth columns, they represent (medical resources) and (processing time), where the diagrams of the rules show the approach of each variable in each rule within three levels (lower limit, normal, upper limit) that is, the state of rise, stability and decrease in quantities and time.

The results of the medical resource (Remdesivir 100mg) in Al-Kindi Teaching Hospital after addressing the foggy problem with (FIS) technology were also shown, where the amount of medical resources reached (Vial 119740), and the processing time was (9) days. That is, the level of the resource above was within the normal limits at Al-Kindi Teaching Hospital, and there was no surplus or deficit; in other words, the quantity of the medical resource (Remdesivir 100mg) in the Al-Kindi Teaching Hospital should not be less than the scope of (Medical Resources), which is (Vial 119740) so that there is no shortage of the resource and therefore so as not to affect the (processing time), which is (9) days.

The outputs (medical resources) and (processing time) were also shown in Figures (14) and (15), respectively, in the form of three-dimensional models to express the shape of each variable of high and low as a result of its influence with the values of the rest of the variables.

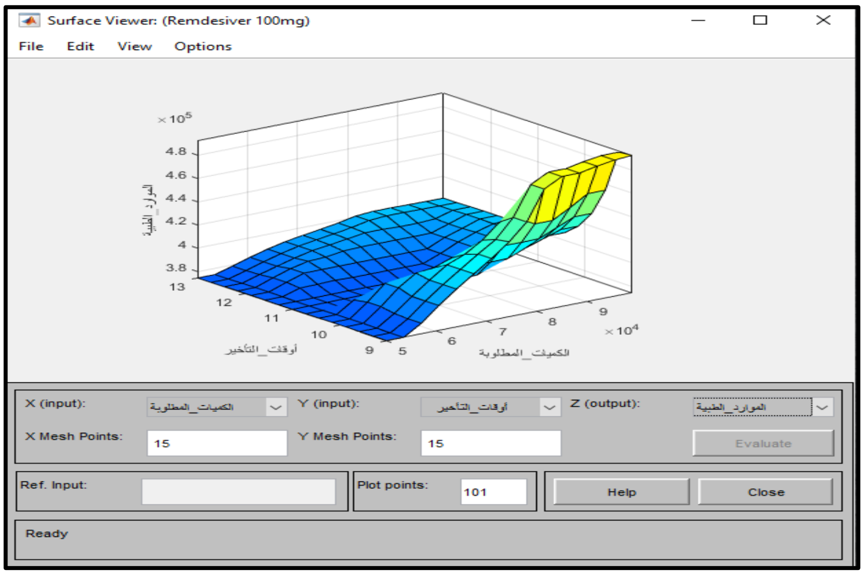

Figure (14) A three-dimensional model of the medical resource variable in (FIS) for the resource (Remdesivir 100mg)

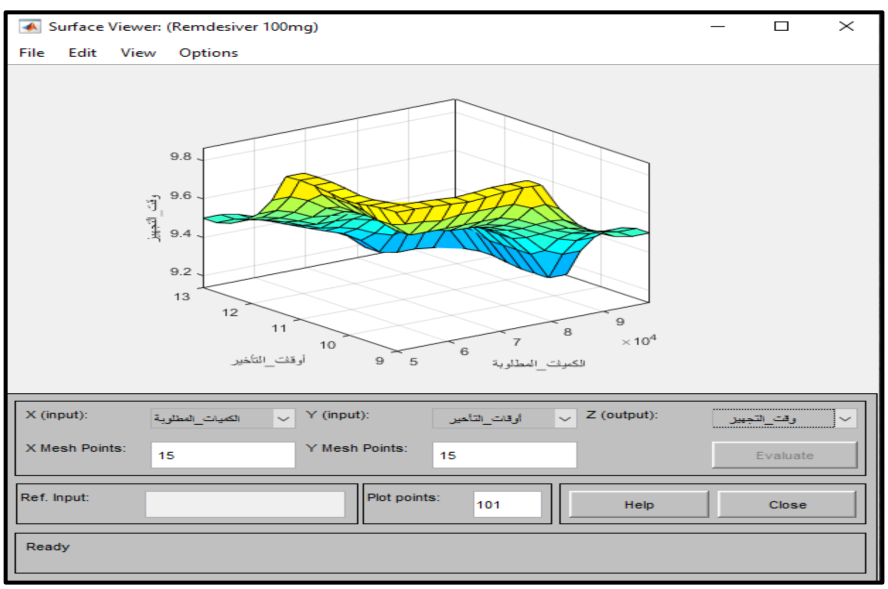

Figure (15) a three-dimensional model of the processing time variable in (FIS) for the supplier (Remdesivir 100mg)

In the same way as the previous steps, the fuzzy inference system (FIS) will be applied to all medical resources (therapeutic protocol and medical supplies) in each of the Baghdad health departments and its affiliated hospitals.

11. Conclusion

This research, the first of its kind, aims to find a balanced and effective logistical system that makes the process of transporting and distributing multiple medical resources (therapeutic protocol and medical supplies) In light of a Fuzzy environment and the lack of knowledge of the problem data specifically and accurately, such as the delay times resulting from the transportation and distribution of medical resources from central warehouses to distribution centers and then to consumption centers, as well as the required quantities of those resources during the peak period of the pandemic (Covid-19) in the capital, Baghdad, One of the artificial intelligence techniques (FIS) was used to process the fuzzy data of the problem and to determine the optimal quantities and processing times for medical resources.

Where the successful representation and application of the (medical resources) supply chain allowed achieving priorities (time, flexibility, and response) that make it in a state of continuity and optimal service delivery ,artificial intelligence technology (FIS) is one of the important scientific and mathematical methods that have proven its worth in finding the best solutions in the presence of Fuzzy in the data of the problem. Because of the positive results of using the fuzzy inference system (FIS) and its ability to address the fuzziness of problem data and to determine the optimal quantities and processing times for medical resources, we recommend its adoption and development.

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