Application of a Two-stage Multi- item Fuzzy Transportation Model for Medical Resources during the (covid-19) Pandemic in Baghdad

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Abstract:

The spread of the Corona virus (covid-19) poses a major challenge to the ability of our health systems to respond to the enormous needs of medicines and medical supplies for people infected with this virus all over the world, as well as its negative effects on tourism, trade, production and other activities. This pandemic has created dynamic and complex scenarios, including governments taking strict measures to slow the spread of the virus and thus reduce the burden and excessive pressure on health institutions and systems, Since the pandemic is witnessing epidemic waves from time to time, this leads us to the fact that it may be long-term and witness the spread and development of strains of other coronaviruses that may be more dangerous.

This makes us search for a logistical system that makes the process of transportation and distributing multiple medical resources (therapeutic protocol and medical supplies) balanced and effective in light of a fuzzy environment and the lack of knowledge of the problem data specifically and accuracy, such as delay times resulting from the transport and distribution of medical resources from warehouses to distribution centers and then To the consumption centers as well as the required quantities of those resources during the peak period of the pandemic in the capital, Baghdad, so it was relied on to formulate a multi-item, two-stage fuzzy transportation model, starting from the central warehouses of (Kimadia) Company to the Baghdad health departments and then to the beneficiary hospitals. Researchers have relied on medicines and special medical supplies to prevent a pandemic (covid-19), as well as in formulating the mathematical model.
Keywords: Fuzzy multi-item two-stage transportation model, (covid-19) pandemic, therapeutic protocol and medical supplies, membership function

1. Introduction

The Corona Virus Pandemic or (COVID-19) is a global pandemic that continues until now. This disease first broke out in the Chinese city (Wuhan) at the beginning of the month (December 2019), and the World Health Organization declared a state of emergency and turned this disease into a pandemic on (March 11, 2020). The number of confirmed infections as a result of this virus has reached more than (537) million, including 6.3 million deaths around the world until (June 2022), when the United States of America is considered the most affected by this pandemic.

With the beginning of the discovery of the first cases in Iraq (February 2020), the Iraqi government began to adopt many measures to follow up and limit the spread of this virus, including restricting businesses, closing schools and universities, and suspending air travel in light of the exacerbation of the effects of the pandemic as a result of the collapse in oil prices in global markets and the decline in financial capacity. For Iraq, whose oil export revenues constitute more than (92%) of the total public revenues in the annual budgets, which led to a double crisis (the spread of the Corona virus and the collapse of oil prices), not to mention the weakness and deterioration of the infrastructure of health systems as a result of conflicts, international sanctions, corruption and economic neglect made the country and its system The health sector was more vulnerable when it faced a severe shortage of medical supplies and the number of health workers, and was unable to confront the epidemic, despite the immediate financial and security support for the Ministry of Health’s purchases of medicines and basic medical supplies. In addition, the majority of the population did not follow the health guidelines for wearing masks and adhering to social distancing this was enough to spread the virus in all governorates of Iraq.

The Iraqi capital, Baghdad, has surpassed the most recorded cases of infection and deaths by more than (40%) out of (18) Iraqi governorates, due to its population density compared to the rest of the governorates. The Ministry of Health has divided the capital, Baghdad, into three health departments (Al-Rusafa, Al-Karkh, and Medical City), which are linked from an administrative and technical point of view by a group of government and private hospitals, as well as specialized centers and laboratories.

2. Literature review

The topic of the use and application of mathematical methods in addressing and limiting the spread of the pandemic (covid-19) is one of the new and vital topics. The most relevant studies can be summarized as follows :

(Pandian & Kavitha, 2016) The researchers in this study propose a new method to solve the two-stage transportation problem, which is based on the zero point method. This method is very simple, easy to understand and apply, and also provides more than one solution to the two-stage transportation problem. The proposed method helps in taking the decision of the issues related to logistics by helping them in the decision-making process and providing the optimum solution in a simple and effective way.(Sanchez & Herrera, 2016) In this research, the optimal solution for a group of products was obtained in the general formulation of the transportation model by using a linear programming model, where the researchers combined all products in one linear model that includes the available and required quantities of each product with the identification of the units in the store as well as the costs For each product, this proposed model overcomes the complexity of similar solutions proposals with its simplicity and model was solved using (Excel Solver). (Rodrigo & Rjapaksha, 2018) This research sheds light on the problem of locating (distribution centers) as one of the most important issues in the design of supply chains, and the design of the distribution system is an important issue for almost every company, so the focus is on designing a multi-commodity and shipping distribution system that starts from the factory to the customer through the distribution center and provides This research is a realistic distribution problem that lies in determining the distribution centers that should be used so that all customer demands are met, provided that production capacities are not exceeded, and in order to reduce the total distribution cost, which is the cost of operating the distribution center and the cost of transportation . In order to obtain the optimal solution, (Software R) was developed.(Jayakumar & Raghunayagan, 2018) This research discussed the method of re-shipment of goods or containers to an intermediate destination, and then from there to another destination, due to the reasons for changing the means of transport during the journey (for example, transport by ships and then to land transport) another reason is the integration of small shipments into a large shipment (unifying them). Usually the recharging process takes place in the transport centers, and the researchers presented a simple two-stage transport problem that was formulated in a linear programming style through a hypothetical numerical example consisting of three factories and two intermediate stores in addition to three demand centers in order to reduce the cost of transportation and distribution. Finally, the model was solved using a program (LINGO). (Cosma et al., 2019) In this research, the problem of two-stage transportation with fixed fees for opening distribution centers is dealt with, which is an extension of the traditional transportation problem. The problem is a model of a two-stage transportation and distribution network that includes: manufacturers, distribution centers and customers, and its main characteristics are the presence of a fixed fee for opening distribution centers as well as a variable transportation cost that is proportional to the quantity of goods shipped. The research presented a new solution method to reduce the total distribution costs, which is a heuristic algorithm that is characterized by speed and effectiveness and reduces the search space for the solution, and the results obtained from examples and random experiments show that the solution method is very competitive compared to the current methods from the literature.(Bera & Mondal, 2020) This study deals with the problem of multi-objective transportation in two stages to transport products from the production site to some retailers through some distributors in order to reduce the total transportation cost for retailers and maximize the total profits of distributors at one time. The research also indicated that the displayed quantities are subject to the fuzzy, which were classified into linear and non-linear memberships. functions. Two numerical examples were also adopted to illustrate the model, one natural and the other fuzzy, as well as a sensitivity analysis for the parameters of the problem model. Based on the results, a relatively better result was obtained for the linear case other than the non-linear case through the use of a multi-objective genetic algorithm to find the optimal solution.

3. Methodology

In this aspect, the methodology of the current study has been clarified, which includes modeling the processes of transportation and distributing the available medical resources (therapeutic protocol and medical supplies) in an optimal manner between central warehouses and between hospitals, passing through health departments located within the administrative borders of the capital, Baghdad, and achieving optimal utilization of those medical resources through a quantitative method It is known as the two-stage multi-item fuzzy transportation model, thus achieving a balance between the required quantities and the available quantities, as well as reducing the delay times for the arrival of those resources to the designated authorities. Figure (1) illustrates the methodology of this study.

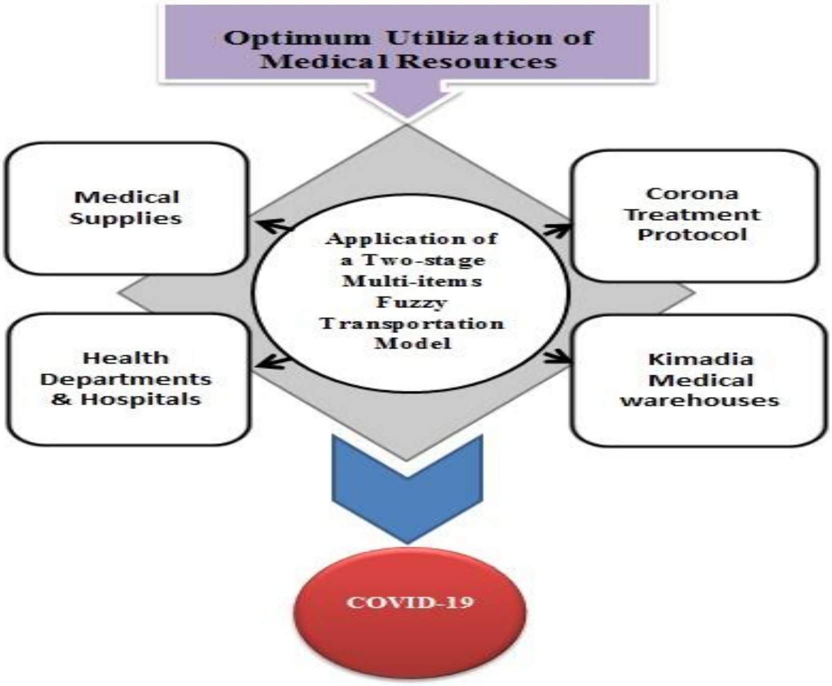


Figure 1: Study Methodology

4. Transportion and Distribution problems

The problems of transportation and distribution are one of the important applications of linear programming, where the idea of transportation and distribution is based on reducing the cost of transporting a commodity available in the sources of processing (production areas) to distribute it to demand sites (consumption areas), and that the first to put this method is the scientist (F.L.Hitchock) to address the problems of transporting products and goods from sources of supply to sites of demand (Destinations) at the lowest possible cost. The transportation problem is expressed in a two-dimensional matrix (m x n) of rows and columns. This matrix can be solved in many ways and methods, the most important of which is linear programming. (Mubashiru, 2012)

4.1.The mathematical formula of Transportation problems

The general model of the transportation problem consists of a number of (sources) symbolized by (m) and a number of demand or consumption sites (Destinations) symbolized by (n), as each supply source has a total supply energy known as (a_i) representing the quantities (Supply) (i=1,2,…,m) . As well as for each site, a total absorption capacity demanded by (b_i) represents the required quantities (Demand) (j=1,2,…,n), and the cost of transporting one unit from the source (i) to the Destinations (j) is (Cij).(Ghazali et al., 2012)

The transportation problem can be expressed in the form of linear programming, that is, determining the optimal number of units (X_{ij}) that will be transport from source (i) to Destinations (j) at a cost (C_{ij}) and thus we will get the lowest possible cost, which is (Z), and from this basis we can Formulate the equivalent linear programming model of the General Transportation model as follows:(GUPTA & HIRA, 2008) (Vanderbei, 2008)

$$Minimize\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}\ X_{ij}$$

Subject to constraints

$$\sum_{j=1}^{n} X_{ij} \leq a_i \qquad , i = 1,2, \ldots , m \qquad \ldots (1)$$

$$\sum_{i=1}^{m} X_{ij} \geq b_j \qquad , j = 1,2, \ldots , n$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

$$X_{ij} \geq 0 \qquad \text{for all } i,j$$

5. Multi-item Transportation Problems

In the previous classic transportation problems, we assumed that there is only one type of item, product or commodity and also homogeneous in terms of quality in the processes of transport and distribution, but on the ground it is difficult to have a problem of this type. Most of the production institutions and logistic activities produce and deal with many different item, and therefore the demand of customers (Destinations) is usually a variety of units available by the factory (sources). So when dealing with the transportation model, it must take into account many of these possibilities so that this model acquires the required dynamism in the face of all problems and in turn determines the transmission and distribution channels that will be adopted, taking into account that (cost, time or distance) varies according to the type of transported unit.

The problem of multi-item transportation aims to transfer a group of units or products from the sources of supply to the demand Destinations to meet the actual needs of those units so as not to exceed the capacity of the sources of supply, and Figure (2) shows the network diagram of the process of transportation multi-item at one time.(Sanchez & Herrera, 2016)

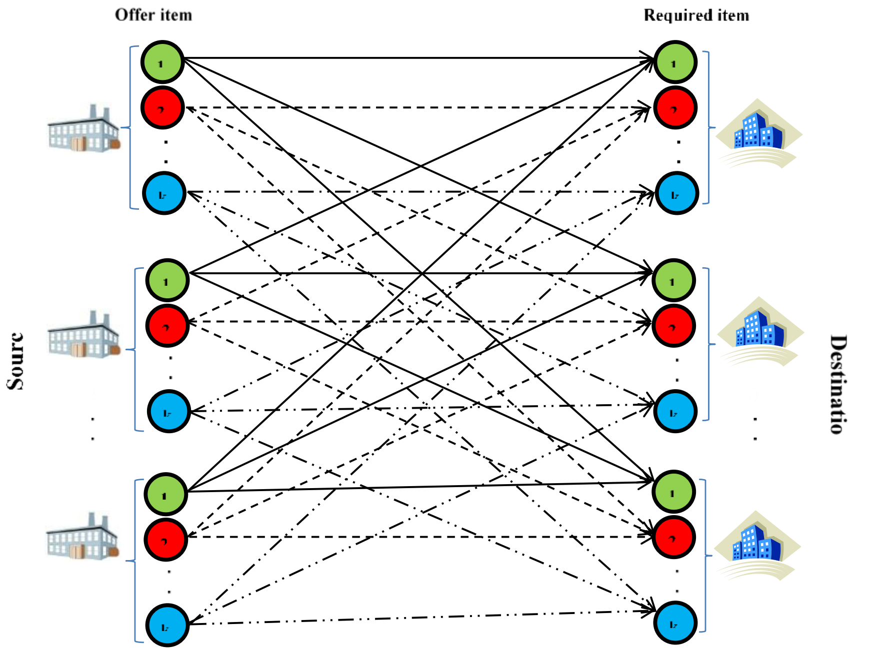


Figure (2) Diagram of the multi-item transportation problem

In Table (1), the form of the multi-item transportation matrix is shown, where the rows represent the sources of distribution or processing, as well as the quantities supplied from each type of item, and the columns represent the locations of demand or consumption and also represent the quantities required of each type of item, and these rows and columns permeate the unit cost Single and decision variables (quantity transported).(HERNÁNDEZ R & GARCÍA G., 2003)

Table (1) Matrix Multi-item Transportation Problem

	items	D_1	D_2	...	D_n	Supply for items
S_1	K_1	C_{11K1} X_{11K1}	C_{12K1} X_{12K1}	...	C_{1nK1} X_{1nK1}	a_1k_1
	K_2	C_{11K2} X_{11K2}	C_{12K2} X_{12K2}	...	C_{1nK2} X_{1nK2}	a_1k_2
	⋮	⋮	⋮	⋮	⋮	⋮
	K_k	C_{11KK} X_{11KK}	C_{12KK} X_{12KK}	...	C_{1nKk} X_{1nKk}	a_1k_k
S_2	K_1	C_{21K1} X_{21K1}	C_{22K1} X_{22K1}	...	C_{2nK1} X_{2nK1}	a_2k_1
	K_2	C_{21K2} X_{21K2}	C_{22K2} X_{22K2}	...	C_{2nK2} X_{2nK2}	a_2k_2
	⋮	⋮	⋮	⋮	⋮	⋮
	K_k	C_{21KK} X_{21KK}	C_{22KK} X_{22KK}	...	C_{2nKk} X_{2nKk}	a_2k_k
⋮	⋮	⋮	⋮	⋮	⋮	⋮
S_m	K_1	C_{m1K1} X_{m1K1}	C_{m2K1} X_{m2K1}	...	C_{mnK1} X_{mnK1}	a_mk_1
	K_2	C_{m1K2} X_{m1K2}	C_{m2K2} X_{m2K2}	...	C_{mnK2} X_{mnK2}	a_mk_2
	⋮	⋮	⋮	⋮	⋮	⋮
	K_k	C_{m1KK} X_{m1KK}	C_{m2KK} X_{m2KK}	...	C_{mnKK} X_{mnKK}	a_mk_k
Demand for items	K_1	b_1k_1	b_2k_1	...	b_nk_1	
	K_2	b_1k_2	b_2k_2	...	b_nk_2	
	⋮	⋮	⋮	⋮	⋮	
	K_k	b_1k_k	b_2k_k	...	b_nk_k	

A linear mathematical model can be built using decision variables (X_{ijk}) that reflects the state of the multi-item transport matrix, where (i) represents the source of supply (factory), (j) the receiving Destinations (consumer) and (k) the type of product (unit) thus:

X_{ijk}: the number of units transported from the supply source (i) to the receiving Destinations (j) of the product type (k).(Rodrigo & Rjapaksha, 2018)

$$Min\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{k} C_{ijk}\ X_{ijk}$$

S.to

$$\sum_{j=1}^{n}\sum_{k=1}^{k} X_{ijk} \leq a_m\, k_k \quad ,i = 1,2,\dots,m$$

$$\sum_{i=1}^{m}\sum_{k=1}^{k} X_{ijk} \geq b_n\, k_k \quad ,j = 1,2,\dots,n \qquad \dots (9)$$

$$\sum_{i=1}^{m} a_m\, k_k = \sum_{j=1}^{n} b_n\, k_k \quad ,k = 1,2,\dots,k$$

$$X_{ijk} \geq 0$$

Reflects the objective function in Form No. (9) is to determine the minimum value of units transported from multiple supply sources to multiple receiving Destinations, in addition to that the first constraint expresses the number of supply sources for each type of offered product, and the second constraint represents the number of Destinations that will be Distribute different products to it. And finally, the equilibrium constraint, which indicates that the quantities supplied must be equal to the quantities demanded.(Pirkul & Jayaraman, 1996)(Sanchez & Herrera, 2016)

6. Two-Stage Transportation Problems

In some cases and circumstances, and due to the presence of storage operations, the demand Destinations are not able to receive the quantities they need directly from the supply sources, and therefore these quantities are shipped to other destinations in two stages.

At first, the required quantity is transported from the point of origin (factory) to the distribution centers (warehouse) and then to the receiving point (consumer). This type of transportation problem is known as two-stage transportation problems, as shown in Figure (3) . The main objective of the two-stage transport problem is to transport the quantities from the sources of supply to the demand Destinations through the distribution centers so that the total (costs / time) of transport in the two stages is at a minimum.(Pandian & Kavitha, 2016)

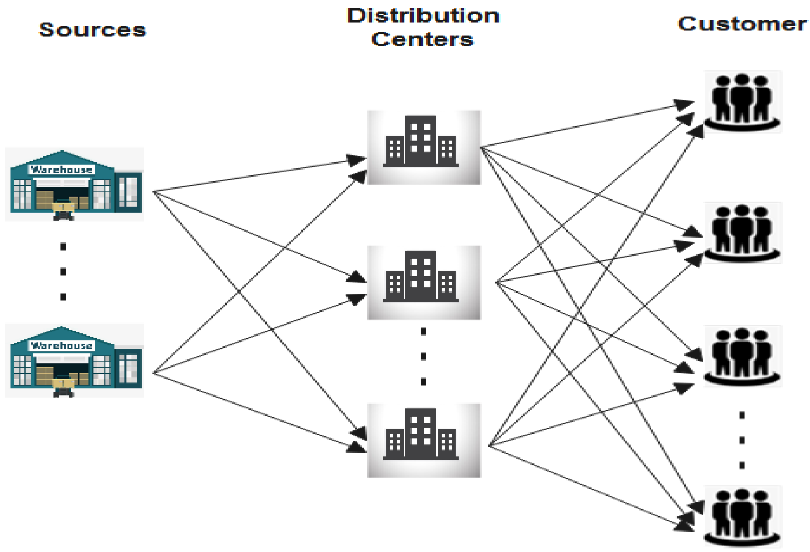


Figure (3) Two-stage transportation problems

Suppose we have a two-stage transportation problem, which includes the process of transporting production units from a specific factory to intermediate stores and then to consumers. In this case, the transport process takes place in two stages, the first of which is the transport of units from the factory (i) to intermediate stores (j), and then the transport process to the second stage through intermediate stores (j) to consumers (k), and this can be represented by the mathematical model below (Jayakumar & Raghunayagan, 2018)

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}\ X_{ij} + \sum_{j=1}^{n}\sum_{k=1}^{k} C_{jk}\ Y_{jk}$$

Subject to constraints

$$\sum_{j=1}^{n} X_{ij} \le a_i \qquad , i = 1,2,\dots,m \qquad \dots(4)$$

$$\sum_{i=1}^{m} X_{ij} \ge \sum_{k=1}^{k} Y_{jk} \qquad , j = 1,2,\dots,n$$

$$\sum_{k=1}^{k} Y_{jk} \ge b_k \qquad , k = 1,2,\dots,k$$

X_{ij} , $Y_{jk} \ge 0$ for all i,j,k

X_{ij} = Quantity supplied from factory (i) to warehouse (j)

Y_{jk} = Quantity transported from warehouse (j) to consumer (k)

C_{ij} = Cost of one unit transported from factory (i) to warehouse (j)

C_{jk} = Cost of one unit transported from the warehouse (j) to the consumer (k)

a_i = Quantities available of units in the factory (i)

b_k = Quantities of units demanded by the consumer (k)

7. Fuzzy Logic

It is one of the forms of logic used in expert systems and artificial intelligence. Fuzzy logic was originated by the mathematician (Lotfi Zadeh). There are many motives that prompted a group of scientists and researchers to develop the science of Fuzzy. With the development of computers and software, the desire to deal or program systems that can deal with inaccurate or clear data arose. On the other hand, this case caused a problem with the inability of the computer to deal with inaccurate and specific data. Which resulted in a trend towards the use of artificial intelligence algorithms. (Ghanbari et al., 2020)

So, Fuzziness is a logic that reflects people's thinking about describing the quantities of things or concepts that are ambiguous and somewhat similar. It gives a model for expressing the words we exchange and gives a closer picture of representing these things in computer programs, which enables us to take the optimal decision.

Finally, it can be said that Fuzziness is a degree that expresses the extent to which the subordinate description of the same thing belongs between perfect true and perfect false. (Effati & Abbasiyan, 2010)

7.1.The Traditional set and The Fuzzy set

The element in the traditional group is either a member of the group or not a member of it, while in the fuzzy group the element has degrees of affiliation and membership to that group, for example in the traditional group if (U) was a group and ($\tilde{a}$) a subgroup of (U) and it was ($\mu\tilde{a}$) is a function that gives each element of the set (U) the degree to which it belongs to the set ($\tilde{a}$). If, for example, the element (X) belongs to the set ($\tilde{a}$), then ($\mu\tilde{a} = 1$), but if the element (X) does not belong to the group ($\tilde{a}$), then ($\mu\tilde{a} = 0$) and the membership function in this case is defined as follows: (Peraei et al., 2001)

$$\mu\tilde{a} : U \rightarrow [0,1] \qquad \dots (5)$$

The membership function must fulfill the following conditions:

1- The fuzzy group $\tilde{a}$ is convex
2- The set $\mu\tilde{\tilde{a}}$ is defined within the interval [0,1]

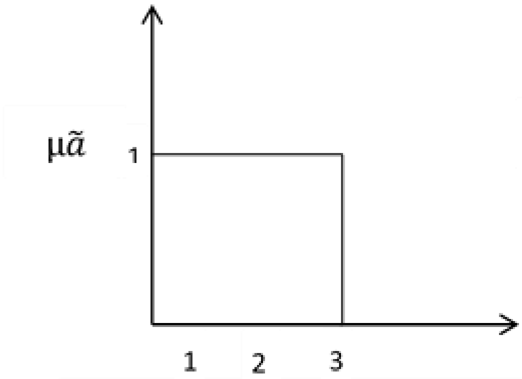


Figure (4) Traditional set

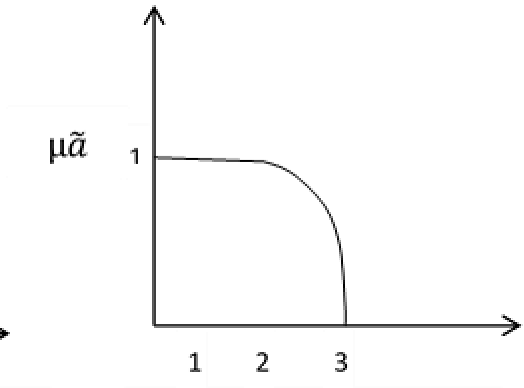


Figure (5) Fuzzy set

source:(Peraei et al., 2001)

7.2. Triangular Fuzzy Numbers

It is a subset of the fuzzy group that has properties that make it very suitable for programming and designing activities on the ground, and it is called by this name because it has a triangular shape, meaning that the fuzzy numbers consist of three real numbers, let $\tilde{a}$ be a triangular fuzzy number (three-valued). (Dinagar & Kamalanathan, 2017)

$$\tilde{a} = [a_1, a_2, a_3] \qquad \dots (6)$$

Where the lowest possible value is (a_1) and the middle value is (a_2) and the largest possible value is (a_3) all belong to the membership function $\mu\tilde{a}$ (x) and it is graphically represented in Figure (6). (Gani, 2012)

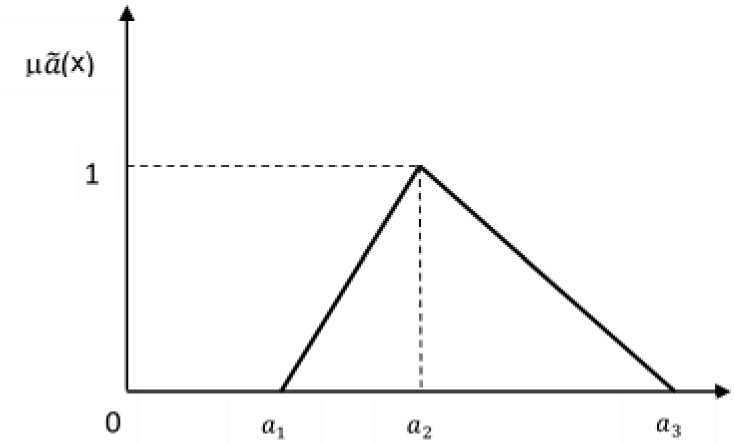


Figure (6) Fuzzy Triangular

Thus, the membership function $\mu\tilde{a}(x)$ for the fuzzy number $\tilde{a}$ can be expressed in the following form: (Nasrabadi et al., 2005)

$$\mu\tilde{a}(x) = \begin{cases} 0 & for\ x \le a_1 \\ \dfrac{x-a_1}{a_2-a_1} & for\ a_1 < x < a_2 \\ 1 & for\ x = a_2 \\ \dfrac{a_3-x}{a_3-a_2} & for\ a_2 < x < a_3 \\ 0 & for\ x \ge a_3 \end{cases} \quad \ldots (7)$$

7.3. Fuzzy Transportation Problem

In all problems in general that require finding the optimal solution to them, and transportation problems in particular, the decision maker is supposed to be sure of the exact values for the availability of means of transportation, the cost and quantities of demand and supply of the product or commodity, but on the ground, it is possible that the data of the problem is unknown Specifically due to several factors and variables that cannot be controlled and precisely defined. Therefore, there is a need for a method that addresses these problems in light of the fuzzy of the data (uncertain), and to express the ambiguous transport problems through the following model: (Das et al., 2016)

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{C}_{ij}\ \tilde{X}_{ij}$$

Subject to constraints

$$\sum_{j=1}^{n} \tilde{X}_{ij} \le \tilde{a}_i \quad , i = 1,2,\ldots,m \qquad \ldots (8)$$

$$\sum_{i=1}^{m} \tilde{X}_{ij} \ge \tilde{b}_j \quad , j = 1,2,\ldots,n$$

$X_{ij} \ge 0$ for all

Where as:

$\tilde{a}_i$ = fuzzy Quantities supplied per unit in supply sources (i)

$\tilde{b}_j$ = fuzzy Quantities required in receiving centers (j)

$\tilde{C}_{ij}$ = cost of fuzzy transportation per unit per unit from supply sources (i) to receiving centers (j)

$\tilde{X}_{ij}$ = fuzzy quantity of the unit that must be transferred from supply sources (i) to receiving centers (j)

Assuming that the model is balanced, that is: (Hassan, 2015)

$$\sum_{i=1}^{m} \tilde{a}_i = \sum_{j=1}^{n} \tilde{b}_j \qquad \dots (9)$$

Thus, the fuzzy transportation problem above can be expressed in the following fuzzy transportation table:

Table (2) transportation model in fuzzy form

	D1	D2	…	Dn	supply
S1	$\tilde{c}_{11}$ $\tilde{x}_{11}$	$\tilde{c}_{12}$ $\tilde{x}_{12}$	…	$\tilde{c}_{1n}$ $\tilde{x}_{1n}$	$\tilde{b}_1$
S2	$\tilde{c}_{21}$ $\tilde{x}_{21}$	$\tilde{c}_{22}$ $\tilde{x}_{22}$	…	$\tilde{c}_{2n}$ $\tilde{x}_{2n}$	$\tilde{b}_2$
⋮	⋮	⋮	⋮	⋮	⋮
Sm	$\tilde{c}_{m1}$ $\tilde{x}_{m1}$	$\tilde{c}_{m2}$ $\tilde{x}_{m2}$	…	$\tilde{c}_{mn}$ $\tilde{x}_{mn}$	$\tilde{b}_m$
demand	$\tilde{a}_1$	$\tilde{a}_2$	…	$\tilde{a}_n$	$\sum_{j=1}^{m} \tilde{b}_j = \sum_{i=1}^{n} \tilde{a}_i$

7.4. Methods to Remove Fuzzy

There are many ways to remove Fuzzy from data, including:

- Pascal Method

Pascal's method is considered closer to reality in removing states of confusion from data and coefficients of mathematical models, and the general formula of Pascal's method is as follows: (Babu et al., 2013)

$$\mathrm{P(A)} = \frac{a_1 + 2a_2 + a_3}{4} \qquad \dots (10)$$

Where as:

$a_1 =$ Is the least fuzzy number in the triangular fuzzy group

$a_2 =$ The fuzzy middle number within the fuzzy trigonometric group

$a_3 =$ The largest fuzzy number within the triangular fuzzy group

8. Case Study –Model Application

With the beginning of the discovery of the first cases in Iraq (February 2020), the Iraqi government began to adopt many measures to follow up and limit the spread of this virus, including restricting businesses, closing schools and universities, and suspending air travel, in light of the exacerbation of the effects of the pandemic as a result of the collapse in oil prices in global markets and the decline in financial capacity. For Iraq, which accounts for oil export revenues more than (92%) of the total public revenues in the annual budgets, which led to a double crisis (the spread of the Corona virus and the collapse of oil prices), not to mention the weakness and deterioration of the infrastructure of health systems as a result of conflicts, international sanctions, corruption and economic neglect made the country and its system The health sector was more vulnerable when it faced a severe shortage of medical supplies and the number of health workers, and was unable to confront the epidemic, despite the immediate financial and security support for the Ministry of Health’s purchases of medicines and basic medical supplies. In addition, the majority of the population did not follow the health guidelines for wearing masks and adhering to social distancing This was enough to spread the virus in all governorates of Iraq.

8.1. Analysis of the health and epidemiological situation during the covid-19 pandemic in Iraq

The virus (COVID-19) pandemic has spread in Iraq by recording the first case (February 24, 2020) in Najaf Governorate, and the total number of confirmed infections has reached (2329662) infected since the beginning of the pandemic, while the total deaths have reached (25,222) cases since the beginning of the pandemic until (June 2022).

The returnees from neighboring countries to Iraq were the main reason for the spread of the virus, especially since the quarantine was not yet implemented. Figure (7) and Figure (8) show the number of daily infections and deaths during the period from (February 2020) to (June 2022).

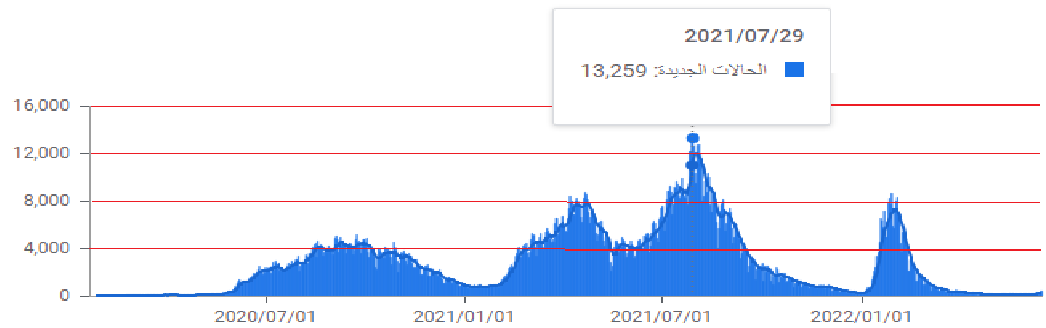


Figure (7) the number of daily injuries recorded in Iraq, according to the World Health Organization

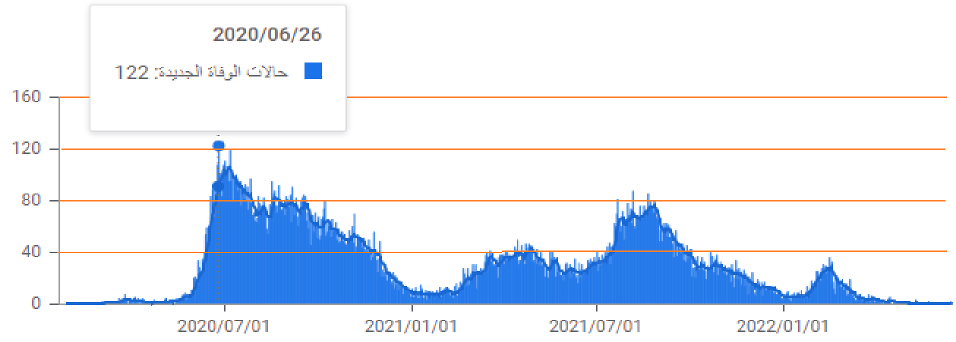


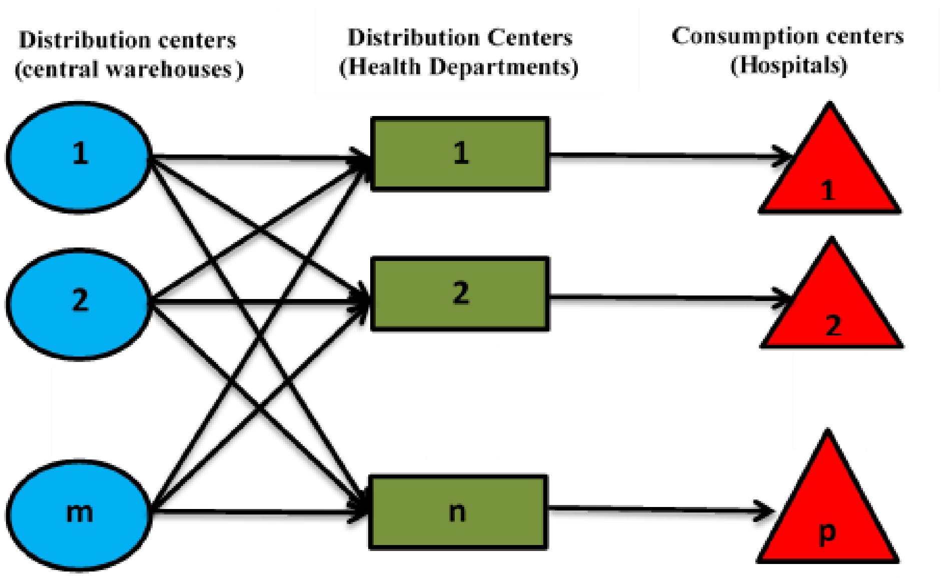
Figure (8) shows the number of daily deaths recorded in Iraq, according to the World Health Organization

The Iraqi capital, Baghdad, has surpassed the most recorded cases of infection and deaths by more than (40%) out of (18) Iraqi governorates, due to its population density compared to the rest of the governorates. The Ministry of Health has divided the capital, Baghdad, into three health departments: (Al-Rusafa, Al-Karkh, and Medical City), which are linked from an administrative and technical point of view by a group of governmental and private hospitals, as well as specialized centers and laboratories.

It should be noted that the period from (February 2021) to (September 2021) was chosen in our study because it represents the peak period of the pandemic in Iraq in general and in Baghdad in particular.

8.2. Fuzzy Two- Stage Multi-commodity Mathematical Model

The fuzzy mathematical model will be adopted for the distribution and transportation of a variety of medical goods (medicines and medical supplies) through a two-stage process, which includes transportation from central warehouses (kimadia warehouses) to distribution centers (Baghdad health departments) and then finally to consumer centers (hospitals).



Figure(9) A two-phase multi-commodity distribution network

8.2.1. Model Indicators

M = number of Kimadia's central warehouses
N = number of distribution centers affiliated with the Baghdad Health Departments
P = Number of consumption centers (hospitals)
Q = number of medicines and medical supplies
I = represents the number of Kimadia central warehouses (the ID of the warehouses) $i \in \{1,2,\ldots,m\}$
J = represents Baghdad health departments (identifier of health departments) $j \in \{1,2,\ldots,n\}$
K = number of hospitals (hospital identifier) $k \in \{1,2,\ldots,p\}$
T = number of types of drugs and medical supplies (identifier of drugs and medical supplies) $t \in \{1,2,\ldots,q\}$

8.2.2. Parameters of the model

a_{it} = quantities available in Kimadia Central warehouses (i) of the treatment protocol and medical supplies (t)
$\tilde{b}_{kt}$ = fuzzy hospital requirements (k) of treatment protocol and medical supplies (t).
$\tilde{D}_{ijt}$ = fuzzy delay time caused by the processing process from Kimadia central warehouses (i) to the health departments (j) for the treatment protocol and medical supplies (t).
$\tilde{D}_{jkt}$ = fuzzy delay time caused by the transportation process from health departments (j) to hospitals (k) for the treatment protocol and medical supplies (t).

8.2.3. Model Variables

$\tilde{X}_{ijt}$ = fuzzy quantity supplied from Kimadia central warehouses (i) to Baghdad health departments (j) of the therapeutic protocol and medical supplies (t)
$\tilde{Y}_{jkt}$ = fuzzy quantity transferred from the Baghdad health departments (j) to its affiliated hospitals (k) of the treatment protocol and medical supplies (t).

8.2.4. Assumptions of the model

- Each central (kimadia) warehouse $i \in \{1,2,\ldots,m\}$ has (a_i) units available from the treatment protocol and various medical supplies.
- Each distribution center in Baghdad health departments $j \in \{1,2,\ldots,n\}$ has the ability and ability to distribute the treatment protocol and medical supplies, each according to its administratively affiliated hospitals.
- Each hospital $k \in \{1,2,\ldots,p\}$ has (b_k) the demand for its needs from the treatment protocol and medical supplies.
- Each of the central (kimadia) warehouses can transfer and distribute the treatment protocol and medical supplies to any distribution center in the Baghdad health departments without exception based on a time calculated called the delay time (D_{ijt}) resulting from the delay in the arrival of the treatment protocol and medical supplies from the warehouse Central to distribution center.
- Each distribution center in the Baghdad health departments can distribute the treatment protocol and medical supplies to its administratively affiliated hospitals only, based on a

time calculated called the delay time (D_{jkt}) resulting from the delay in the arrival of the treatment protocol and medical supplies from the distribution center to the hospital.

8.2.5. Mathematical model data

Table (3) The treatment protocol adopted in the (covd-19) pandemic

No.	medicament name	Type
1	Remdesivir 100mg	Vial
2	Azithromycin 500mg	Tablet
3	Tamiflu 75mg	Capsule
4	Kaletra 200mg/50mg	Tablet
5	Hydroxychloroquine 200mg	Tablet
6	Decadron 2ml	Ampoule
7	Actemra 400mg	Vial
8	Favipiravir 200mg	Tablet
9	Zinc 50mg	Tablet
10	Vitamin D 50000mg	Capsule
11	Vitamin C 1000mg	Tablet

Source: Ministry of Health/Kimadia Company

Table (4) Approved medical supplies in the (covid-19) pandemic

No.	Supplies name	Type
1	Face mask (various colors)	Piece
2	Face mask N95	Piece
3	Theater face mask	Piece
4	Face shield	Piece
5	Head cap (various types)	Piece
6	Theater head cap	Piece
7	Gloves (various sizes)	Piece
8	Gown (various sizes)	Piece
9	Protective glasses	Piece
10	Bed sheet	Piece
11	Shoes cover	Piece

Source: Ministry of Health/Kimadia Company

Table (5) Kimadia Central warehouses Coding

No.	warehouses	code
1	Al-Adl warehouses	W1
2	Al-Iskan warehouses	W2
3	Al-Dabash warehouses	W3
4	Al-Husua warehouses	W4

Table (6) Coding of distribution centers in Baghdad health departments

No.	warehouses	code
1	Rusafa Health Department	RH
2	Karkh Health Department	KH
3	Medical City Health Department	MH

Table (7) coding of consumption centers (hospitals) of the Rusafa Health Department

No.	Hospital name	code
1	Al-Kindi Teaching Hospital	H1R
2	Ibn Al-Khatib Hospital	H2R
3	Sheikh Zayed Hospital	H3R
4	Al-Atta Hospital	H4R
5	Imam Ali Hospital	H5R
6	Ibn Zohr Hospital	H6R
7	Al-Sadr General Hospital	H7R

Table (8) coding of consumption centers (hospitals) of the Karkh Health Department

No.	Hospital name	code
1	Yarmouk Teaching Hospital	H1K
2	Al Furat General Hospital	H2K
3	Al Karkh General Hospital	H3K
4	Al-Hakim Hospital	H4K
5	Imam Kadhimin Medical City Hospital	H5K
6	Al Karama Teaching Hospital	H6K

Table (9) coding of consumption centers (hospitals) of the Medical City Health Department

No.	Hospital name	code
1	Baghdad Teaching Hospital	H1M
2	Al-Shifa Hospital	H2M

After applying the data and data related to the research problem, we get the following Model:

$$Min\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{q}\widetilde{D}_{ijt}\ \widetilde{X}_{ijt} + \sum_{j=1}^{n}\sum_{k=1}^{p}\sum_{t=1}^{q}\widetilde{D}_{jkt}\ \widetilde{Y}_{jkt}$$

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$$\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{q}\tilde{X}_{ijt} \leq a_{it}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{q}\tilde{X}_{ijt} \geq \sum_{j=1}^{n}\sum_{k=1}^{p}\sum_{t=1}^{q}\tilde{Y}_{jkt} \qquad \ldots (11)$$

$$\sum_{j=1}^{n}\sum_{k=1}^{p}\sum_{t=1}^{q}\tilde{Y}_{jkt} \geq b_{kt}$$

$$\sum_{i=1}^{m}\sum_{t=1}^{q}a_{it} = \sum_{k=1}^{p}\sum_{t=1}^{q}b_{kt}$$

$$\tilde{X}_{ijt}, \tilde{Y}_{jkt} \geq 0 \qquad \forall\, i,j,k,t$$

- Fuzzy objective function: The objective function of the model consists of two parts, the first is to reduce the delay time as a result of transferring the treatment protocol and medical supplies from the central warehouses to the distribution centers in the Baghdad health departments, and the second part is to reduce the delay time as a result of distributing the therapeutic protocol and medical supplies from centers Distribution of Baghdad health departments to consumption centers in their affiliated hospitals.
- Constraints: The first constraint represents the quantities available in Kimadia central warehouses, the second constraint represents the process of processing and transporting medicines and medical supplies, starting from the central warehouses to the health departments and then from the health departments to hospitals, the third constraint represents the Fuzzy quantities required in the hospitals of Baghdad health departments, and the fourth constraint represents Balance the available quantities with the required quantities.

In order to find the optimal solution to the above mathematical model, the Fuzzy must be removed from the values of the objective function, as well as from the constraints of the required quantities. Therefore, the Pacal Method , will be used to treat and remove fuzzy from the model data, as follows:

- Removing the fuzzy of delay times in the objective function

(12,5,4) $\tilde{X}_{W1,RH,1}$ $\Rightarrow$ $P = \frac{a+2b+c}{4}$ $\Rightarrow$ 6.5 $X_{W1,RH,1}$ $\approx$ 7 $X_{W1,RH,1}$

(6,3,2) $\tilde{X}_{W1,RH,2}$ $\Rightarrow$ $P = \frac{a+2b+c}{4}$ $\Rightarrow$ 3.5 $X_{W1,RH,2}$ $\approx$ 4 $X_{W1,RH,2}$

(11,6,5) $\tilde{X}_{W1,RH,3}$ $\Rightarrow$ $P = \frac{a+2b+c}{4}$ $\Rightarrow$ 7 $X_{W1,RH,3}$

(8,5,2) $\tilde{X}_{W1,RH,4}$ $\Rightarrow$ $P = \frac{a+2b+c}{4}$ $\Rightarrow$ 5 $\tilde{X}_{W1,RH,4}$

(7,4,2) $\tilde{X}_{W1,RH,5}$ $\Rightarrow$ $P = \frac{a+2b+c}{4}$ $\Rightarrow$ 4.25 $\tilde{X}_{W1,RH,5} \approx$ 4 $\tilde{X}_{W1,RH,5}$

In the same way, the fuzzy is removed from the rest of the delay times in the objective function

- Removing the fuzzy of the required quantities in the model constraints

$\tilde{Y}_{RH,H1R,1} \geq (50000,100000,250000)$ $\quad P \Rightarrow \frac{a+2b+c}{4} \quad Y_{RH,H1R,1} \geq 125000$

$\tilde{Y}_{RH,H2R,1} \geq (70000,150000,350000)$ $\quad P \Rightarrow \frac{a+2b+c}{4} \quad \Rightarrow Y_{RH,H2R,1} \geq 180000$

$\tilde{Y}_{RH,H3R,1} \geq (40000,80000,100000)$ $\quad P \Rightarrow \frac{a+2b+c}{4} \quad Y_{RH,H3R,1} \geq 75000$

In the same way, the fuzzy is removed from the rest of the constraints on the required quantities, and then the mathematical model is tested and the imbalance of the model is addressed by comparing the required quantities of the therapeutic protocol and medical supplies with the available quantities as follows:

$$\sum_{i=1}^{m}\sum_{t=1}^{q} 35990221 \neq \sum_{k=1}^{p}\sum_{t=1}^{q} 39284000$$

9. Analyze Results of the Model

Linear Program Solver (LiPS V.1.11.1) was used to find the optimal solution and analyze the results of the model Through the results, we note that the model was effective in the process of transport and distributing the therapeutic protocol and medical supplies in two phases and achieving the optimum utilization of those resources, as they were transported in varying quantities through neglecting some warehouses in transferring part of the medical resources and relying on another warehouses in the process of transportation and processing because It has the advantage in reducing delay times from the four central warehouses of Kimadia to the three health departments in Baghdad under the name ($X_{Wi,RH,t}$), ($X_{Wi,KH,t}$), ($X_{Wi,MH,t}$) and then distribute them in an optimal way from the departments Health care to the hospitals, each according to its affiliated department under the name ($Y_{RH,\ HkR,\ t}$), ($Y_{KH,\ HkK,\ t}$), ($Y_{MH,\ HkM,\ t}$), taking into account and also differentiating between the delay times in the distribution process and according to the needs of those hospitals. Determining the total amounts of deficit in the hospitals of the Baghdad Health Departments from these materials according to the following table:(10)

Table (10) represents the total amounts of deficit in the hospitals of the Baghdad Health Departments

Therapeutic protocol and medical supplies (t)	deficit quantities
Remdesivir 100mg	-1336127
Azithromycin 500mg	-2849183
Tamiflu 75mg	-676543

Zinc 50mg	-1819333
Vitamin D 50000mg	-948671
Vitamin C 1000mg	-230489
Face mask N95	-394676
Gloves (various sizes)	-1129584
Protective glasses	-37778

Therefore, a dummy central Warehouse was added under the name (WD) to compensate for the shortage of some medicines and medical materials in the hospitals of the Baghdad Health Departments. The results of the sensitivity analysis of the mathematical model, indicated the surplus quantities of medical resources, which are as shown in the table (11) and their percentages in the figure (10) as follows:

Table (11) represents the total surplus quantities of the treatment protocol and medical supplies in Kimadia Warehouses

Therapeutic protocol and medical supplies (t)	surplus quantities
Kaletra 200mg/50mg	168985
Hydroxychloroquine 200mg	147965
Decadron 2ml	77421
Actemra 400mg	251847
Favipiravir 200mg	23690
Face mask (various colors)	358473
Theater face mask	17650
Face shield	15465
Head cap (various types)	22700
Theater head cap	365643
Gown (various sizes)	84930
Bed sheet	59778
Shoes cover	487550

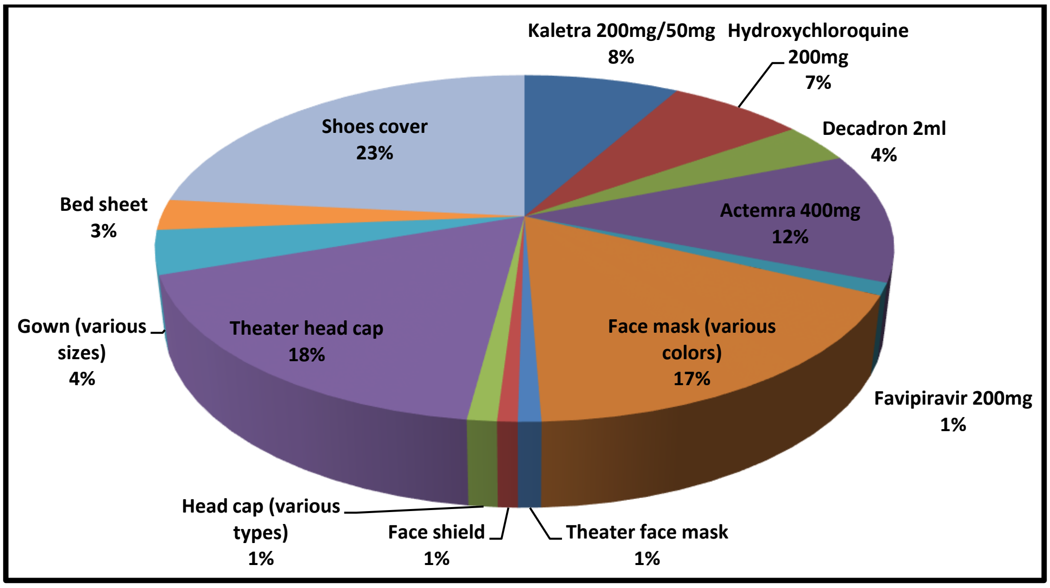

Figure (10) shows the percentages of surplus medical resources in Kimadia warehouses after the transportation and distribution Modeling

Conclusion

This study presented the formulation of a two-stage multi-item fuzzy transportation model for a realistic problem during the spread of the (covid-19) in Baghdad with the aim of achieving optimal utilization of medical resources such as (therapeutic protocol and medical supplies) in light of the high demand for those materials, as well as reducing the delay time resulting from the transportation and distribution process Between the company's warehouses and health departments, the results of the model indicated the achievement of a logistical system that makes the process of transferring and distributing medical resources balanced and effective in meeting the requirements of hospitals and diagnosing and treating weaknesses in a fuzzy environment during the height of the pandemic in the capital, Baghdad, and finally the model was resolved and the results analyzed Using Linear Program Solver (LiPS V.1.11.1).

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