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Medical Supply Transportation Scheduling in Pandemic

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ABSTRACT

The Covid-19 pandemic has brought the world to its knees, with healthcare systems struggling to cope with the surge in demand for medical supplies. One of the major challenges faced by healthcare providers has been the transportation of essential medical supplies from manufacturers to hospitals and clinics. The pandemic has exposed the weaknesses in our supply chain systems and has highlighted the need for a more resilient and efficient transportation network. This project aims to investigate the medical supply problem during the pandemic, with a focus on transportation. It uses the Simple Heuristic Method and C programming language. The data generated using exponential distribution. The result shows that the application of the Simple Heuristic Method can minimize and optimize transportation time, providing a solution to the medical supply problem during pandemics. This project examine the challenges faced by healthcare providers in sourcing and transporting essential medical supplies and the impact of the pandemic on transportation networks. The results of this research provide valuable insights into the medical supply problem during pandemics and help inform the development of more effective transportation systems for the healthcare industry.

Keywords: Emergency Centre, Medical Supply Problem, Scheduling, Simple Heuristic Method,Transportation Scheduling.

1 INTRODUCTION

In both hospital and health care systems, medical supplies (MD) are very crucial in other to treat patients. MDs are medical items that are consumable, disposable and that are used for patient treatment like medicine, hypodermic needle and vaccine. Each risk or crisis with the shortage of MD can instantly have an impact on the entire MD chain. This issue not only wastes a ton of money but also poses a risk to patients' lives by hindering their ability to access MDs. In 2019 when Covid-19 was discovered in Wuhan, China, the virus quickly spread worldwide. During the early stages of the pandemic, there was a shortage of MDs, leading to overcrowding in the hospitals and major patient cross-infection. The same goes for our country, not many hospitals in Malaysia are being used to treat the Covid-19 patient in order to maximize the utilization efficiency of the extremely limited MDs.

Significant issues, such as inefficient supply distribution and untimely transportation, led to the reported senseless deaths of infected cases. The supply distribution in Malaysia is also inefficient according to The Malaysian Reserve. They make a statement in 2021 that the distribution of Covid-19 vaccinations to the state, according to our Sultan of Selangor Sultan Idris Shah, is unfair because the quantity is out of proportion to Selangor's population.Sultan Sharafuddin's private secretary Datuk Mohamad Munir Bani stated in a statement on 9 June 2021 that His Majesty was taken aback that Selangor had only received 615,210 doses of the Covid-19 vaccination as opposed to the 2.9 million doses that the federal government had first claimed. This also means that Malaysia had poorly handled the distribution of medical supplies.

There are actually many reasons that cause the inefficient of MDs such as unreasonable distributions, cost of transportations, natural disasters and uneven allocations of MDs. All of these problems will create a shortage of MDs and instantly reduce the efficiency of the chain for the MDs in response to the pandemic. Although the problems mentioned above are crucial, the lack of timely transportation of MDs is the most crucial.

In this project, we decide to choose transportation as our main focus, how to schedule medical supplies transportation from the manufacturing centre of MDs until it arrives at the hospital. The Transportation Scheduling of Medical Supplies (TSMS) must be created in other to increase patient survival rates during the incidents like Covid-19. In this research, we intend to test the stability of the model by applying algorithms for the transportation of medical supplies. The models and algorithms can be utilized to determine the optimal scheduling scheme of the MDs with the shortest transportation time.

2 LITERATURE REVIEW

The Covid-19 pandemic's supply and demand disruptions have a substantial impact on the supply chain network, which can also lower the effectiveness of the pandemic's medical supplies supply [1],[2]. By taking into account customer incentives, Weraikat et al. [3] expanded the reverse medical supply chain network. In their research, a coordination mechanism for logistics and pharmaceutical makers has been defined. Distributors send medications directly to customers, and in the opposite direction, a third party sends perishable medications to a burial facility. Martins et al. [4] suggest a hybrid simulation-optimization technique to build the medical equipment and medicine distribution network. For decisions at the strategic level, a mixed-integer linear programming model was employed, while decisions at the operational stage were taken into account using a discrete event simulation model. The main goals of their suggested model are to reduce operating costs, inventory keeping, and transportation costs. The findings indicate that as demand rises, system costs do as well.

Despite the fact that the number of medical supplies had drastically increased, the medical system was in such disarray that the supplies were not effectively scheduled. There were significant issues, such as inefficient supply distribution and late supply delivery, which resulted in unnecessary deaths of infected people and were highlighted or criticized by the media [5]. Some studies aim to improve the preparation, supplementation, and timing of the entire system of MDs [6]. For example, in order to determine the effect factors of the supply of MDs, Jia et al. [7] proposed a workflow simulation system based on the Petri network for the preparation and scheduling of the emergency materials. In contrast, more academics concentrate on a single area of emergency supplement or material preparation.

Mehrotra et al. [8] proposed in the event of a pandemic, a stochastic optimization model for resource allocation and sharing a critical resource was put forth. Corominas [9] proposed a perpetual reserve model that can rapidly meet equipment demand at the start of and throughout a pandemic. Additionally, because of the government's strict controls, the transportation scenario during the Covid-19 pandemic is very different from typical settings [10]. Therefore, creating the MDs transportation schedule for the MD to arrive at the hospital from the manufacturing centre is a new type of research question.

The scheduling of transportation is essentially vehicle transportation or allocation problem. This kind of problem is frequently solved using heuristic algorithms, such as the ant colony algorithm. In the aspect of emergency materials scheduling, Zhang et al. [11] established an adaptively mutate genetic algorithm to solve the problem. Liu and Xie [12] established an emergency materials scheduling model and its solution method-based ant colony algorithm considering the continual alteration of material demand and vehicle amount. However, the algorithm complexity proposed by the research is high. While solving the problems with many demand areas and vehicles, the application of heuristic algorithms may save time.

The research paper from Goodarzian et al. [13] was used as the main reference during the research of this paper. This is because the model used in the research paper is focused on minimising the total cost of transportation and minimising the total transportation time taken for MD to arrive at the hospital. In this paper, we are going to focus on transportation schedules, so it is aligned with our research study. Besides, the method that has been used is Ant Colony Optimization. Forozandeh et al. [14] stated that this algorithm is based on the natural behaviour of the ant colonies and the working ant of workers. The process of finding nutrients in the ant colony is highly optimized. When ants begin their exploration to find food sources, they will naturally find an "optimal" and "logical" route from their nest to food sources. In other words, the ant population is always able to find an optimal route to supply the required food. This is undoubted be one of the most interesting algorithms to study.

3 METHODOLOGY

In this section, the methodology used for solving the problem will be discuss.

3.1 Heuristic Method

It is a technique for obtaining good solutions but not optimal solutions because it provides near-optimal solutions. Near-optimal solutions are also beneficial for NP-hard problems. It is also suitable for beginners that just learning about algorithms because it is easier compared with other algorithms such as Tabu Search or Genetic Algorithms. Furthermore, the solution was produced within a reasonable time space. This procedure is commonly used in service management and transportation. For example, Fu et al. identified the main features of different heuristic strategies in transportation applications [15].

3.2 Generating Data Using Exponential Distribution

Exponential distribution is a commonly used probability distribution that models the time between events in a Poisson process. It is used to model the amount of time between two consecutive occurrences of an event, such as the time between arrivals of customers at a service counter or the time between failures of a machine.

The exponential distribution has a single parameter, called the rate parameter, which is denoted by λ (lambda). The rate parameter is a positive value that represents the average rate at which events occur in the process. The larger the value of λ, the more frequent the events will be, and vice versa.

To generate data that follows an exponential distribution, one can use a random number generator to produce a series of random numbers between 0 and 1. These random numbers can then be transformed into the exponential distribution by applying the inverse cumulative distribution function (ICDF) of the exponential distribution.

The algorithm below shows the example of generating data using exponential distribution. The data range was extracted from Goodarzian et al. [13].

Table 1 : Data Range Extracted from Goodarzian et al.[13]

Parameters	Value (Units)
Demand from Hospital 1 and Hospital 2	~U (1 000, 10 000)
Remaining medical supplies in inventory	~U (3 000, 14 000)

Algorithm 1 Generate Random Values

Set the rate parameter, λ, to 1.0.
Set the minimum value, MIN, to x.
Set the maximum value, MAX, to y.
for z months **do**
    Generate a random number x between MIN and MAX.
    Generate another random number between 0 and 1.
    Calculate the exponential distribution value using the formula: $r = -\ln(1.0 - \text{random number})/\lambda$.
    Calculate the final result y as $y = \lfloor x + r \rfloor$.
    Output the month number and the result y.
end for

3.2.1 Data

The data below was generated by exponential distribution using C Programming. The data range was extracted from Goodarzian et al. [13]. We utilize this data in our research in order to produce the result. The following tables indicate fixed and varied data, respectively.

Table 2 : Fixed Data

MC	**Manufacturing Centre**
DC	**Distribution Centre**

Place	Distance from MC to DC (Km)	Distance from DC to Hospital (Km)	Distance from Hospital 1 to Hospital 2 (Km)	Transportations Storage Capacity (Units)	DC Storage Capacity (Units)	Time Taken for MDs to Arrive at DC from MC (Hours)	Time Taken for MDs to Arrive at Hospital from DC (Hours)	Time Taken for MDs to Arrive at Hospital 2 from Hospital 1 (Hours)
Hospital 1	500	280	320	10 000	20 000	5	4	3
Hospital 2		430					5	

Place	Distance from MC to Emergency Centre (Km)	Distance from DC to Emergency Centre (Km)	Distance to Hospital 1 (Km)	Distance to Hospital 2 (Km)	Emergency Storage Capacities (Units)	Time Taken for MDs to Arrive from DC (Hours)	Time Taken from Hospital to Emergency Centre (Hours)
Emergency Centre	721	340	320	250	5 000	7	Hospital 1 = 4 Hospital 2 = 2

Table 2 shows fixed data of hospital 1 and hospital 2. These data are applicable for all 12 months. The table contains the distance from MC to DC, DC to hospitals and also Hospital 1 to Hospital 2. It also composed of transportation storage capacity, DC storage capacity and time taken to arrive at designated area. Furthermore, there is a new fixed table that comprised of distance from MC to emergency centre, DC to emergency centre, distance to Hospital 1 and 2, emergency centre storage capacities and time taken for emergency centre to arrive at designated area.

Table 3 : Varied Data

Month	Demand from Hospital 1 (Units)	Demand from Hospital 2 (Units)	Previous Period Remaining Medical Supply in Inventory (Units)
1	5 096	9 904	6 124
2	5 773	3 727	12 500
3	7 340	5 660	3 000
4	6 401	8 599	6 000
5	8 291	1 209	13 401
6	5 696	7 304	3 201
7	7 842	7 158	7 010
8	6 215	3 285	13 410
9	5 365	7 635	3 218
10	5 589	9 411	6 919
11	6 954	2 546	13 204
12	5 476	7 524	3 701

Meanwhile Table 3 indicates a set of data for 12 months. The table consist of demands from Hospital 1 and 2 together with previous period remaining medical supply in inventory.

4 MEDICAL SUPPLY PROBLEM USING NORMAL TRANSPORTATION CHANNELS

Throughout this section, we will explain more in detail about medical supply problem. We will find a schedule of medical supply that will obtain the shortest transportation time.

4.1 Problem

In a pandemic situation, hospitals may face a shortage of medical supplies (MDs) due to delays in the transportation process. Normally, MDs are first transferred to a local distribution centre (LDC) before being delivered to the hospital. However, this can take too much time during an emergency. To solve this problem, a transportation schedule using the Simple Heuristic Method will be implemented to minimize the time needed to transport the MDs directly to the hospital.

4.2 Normal Transportation Channels Model (NTChannels Model)

4.2.1 Indices

m : Index for manufacturing centres $m \in \{1, 2, ..., M\}$.
i : Index for distribution centres $i \in \{1, 2, ..., I\}$.
j : Index for emergency distribution centres $i \in \{1, 2, ..., J\}$.
c : Index for hospital $c \in \{1, 2, ..., C\}$.
n : Index for capacity levels possible for distribution centres $n \in \{1, 2, ..., N\}$.
p : Index for medical supply $p \in \{1, 2, ..., P\}$.
t : Index for time period $t \in \{1, 2, ..., T\}$.

M : Number of medical supplies produced by the manufacturing centres.
I : Number of medical supplies receive by distribution centres.
J : Number of medical supplies receive by emergency distribution centres.
C : Number of medical supplies receive by hospital.
N : Number of capacity levels possible for distribution centres to store the medical supplies.
P : Number of medical supplies to distribute.
T : Number of time taken for transporting medical supplies.

4.2.2 Parameters

d^t_{cp}	: Hospital demand c for medical supply p at period t.
ϖ_p	: Transportation storage capacity for medical supply p.
Y_{in}	: Storage capacity of DC i with capacity level n.
a_i	: Available storage capacity in the DC i.
ψ_{pmi}	: Transportation time of per unit medical supply p from manufacturing centre m to DC i.
ψ_{pij}	: Transportation time of per unit medical supply p from DC i to Emergency DC j.
ψ_{pic}	: Transportation time of per unit medical supply from DC i to hospital c.
Ω^{pict}	: The quantity of shipped medical supply p form main DC i to hospital c at the end of the period t.
Ω^{tpi}	: The quantity of produced medical supply p and shipped to the DC i at period t.
N^t_{pi}	: Inventory level of medical supply p in the DC i at the end of the period t.

4.2.3 Decision variables

$$\pi_{pmi}=\begin{cases}1, \; if \; medical \; supply \; p \; from \; manufacturing \; centre \; m \; to \; DC \; i \; is \; transported.\\ 0, \; if \; otherwise.\end{cases}$$

$$\pi_{pij}=\begin{cases}1, \; if \; medical \; supply \; p \; from \; DC \; i \; to \; emergency \; DC \; j \; is \; transported.\\ 0, \; if \; otherwise.\end{cases}$$

$$\pi_{pic}=\begin{cases}1, \; if \; medical \; supply \; p \; from \; DC \; i \; to \; hospital \; c \; is \; transported.\\ 0, \; if \; otherwise.\end{cases}$$

4.2.4 The Model

$$\min\ z = \min \textstyle\sum_p \sum_m \sum_i \sum_c (\psi_{pmi}\pi_{pmi} + \psi_{pic}\pi_{pic})$$

s.t

$$\sum_p N_{pi}^{t-1} + \sum_m \Omega^{tpi} \leq \sum_n Y_{in} \tag{1}$$

$$\sum_i \pi_{pmi} \geq 1 \tag{2}$$

$$\sum_c \pi_{pic} \geq 1 \tag{3}$$

$$\varpi_p \geq \sum_i \Omega^{pict} \tag{4}$$

$$d_{cp}^t = \sum_i \Omega^{pict} \tag{5}$$

$$d_{cp}^t, \varpi_p, Y_{in}, a_i, \Omega^{pict}, \Omega^{tpi}, N_{pi}^t, \varpi_p, \psi_{pmi}, \psi_{pic} \in \{0,1\} \tag{6}$$

$$\pi_{pmi}, \pi_{pic} \in \{0,1\} \tag{7}$$

The objective function is to minimize the total of transportation time during the distribution of medical supply. For the constraint, constraint (1) is the sum of the remaining medical supply from the previous period plus the total of newly received medical supply in the DC in each period cannot exceed the relevant storage capacity. The set of constraints (2) and (3) are to guarantee that the medical supply must be moved between main levels of the chain including manufacturing centres, distribution centres and hospital to satisfy hospital demand. Furthermore, constraint (4) is the quantity of shipped medical supply cannot exceed the transportation storage. Constraint (5) is the demand medical supply must be equal to quantity of shipped medical supply. Finally, constraints (6) and (7) is the sign restrictions that indicate the type of decision variables.

4.3 Simple Heuristic Method for NTChannels Problem

In this section, we will present a concise explanation of the transportation method for medical supplies, along with the corresponding algorithm.

4.3.1 Method of transporting MDs

Method 1

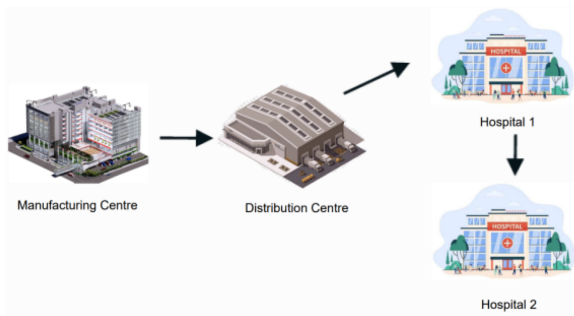

Figure 1 : Method 1 for NTChannels

Figure 1 illustrates the first method for transporting MDs from a Manufacturing Centre (MC) to hospitals. The process involves transporting the MDs from MC to a Distribution Centre (DC), which then distributes the MDs to Hospital 1 and Hospital 2.

Method 2

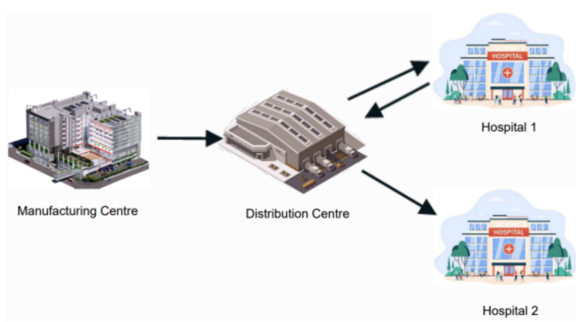

Figure 2 : Method 2 for NTChannels

Figure 2 show the second method for transporting MDs from MC to hospitals. The process involves transporting the MDs from MC to a DC, which then distributes the MDs to Hospital 1. The transportation then goes back from Hospital 1 to DC to pick up any remaining MDs, before continuing on to Hospital 2 for distribution.

4.3.2 Pseudocode for Heuristic NTChannels Algorithm

Algorithm 2 Heuristic NTChannels Algorithm

```
for each month do
    for each hospital demand p do
        if p < a_i then
            Receive MDs from manufacturing centre
            if ϖ_p > d^t_cp then
                if Method 1 passes all constraints then
                    Transport MDs to hospitals all at once
                else if Method 2 passes all constraints then
                    Transport MDs to hospitals in multiple trips
                end if
            end if
        end if
    end for
    Choose shortest transportation time for the month
end for
Repeat for next month
```

The algorithm described outlines a process for the transportation of medical supplies (MDs) from a manufacturing centre to a hospital. The process begins with the hospital placing a demand for the medical supplies with the manufacturing centre.

The distribution centre then receives the information about the demand and checks if the total amount to be stored is less than the available inventory. If it is, the process of receiving the MDs from the manufacturing centre continues. If not, the process of receiving the MDs stops.

Next, the algorithm checks if the total MDs need to transport to hospitals are greater than the transportation storage. If it is, the algorithm considers two transportation methods.

Method 1 involves either transporting all the MDs to the hospital at once or transporting the MDs multiple times. In either case, the algorithm selects the closest hospital, chooses the shortest transportation time and calculates the total transportation times.

Method 2 involves checking all the constraints and if they are met, selecting the shortest distance hospital, transport to the nearest hospital first, going back to distribution centre to collect remaining MD, proceed to transfer to next hospital and calculating the transportation times. The algorithm then calculates all transportation times and chooses the shortest time.

4.4 Result and Discussion

In this section, we will analyze into the results obtained through the use of Simple Heuristics Method for the medical supply problem, as shown in Tables 2 and 3. By calculating the total transportation times for each month, we will gain a clearer understanding of the effectiveness of this approach.

Table 4 : Total time taken to transport MDs for 12 months for NTChannel

Month	Demand from Hospital 1 (Units)	Demand from Hospital 2 (Units)	Previous Period Remaining Medical Supply in Inventory (Units)	Total Transportation Time for Each Month (Hours)
1	5 096	9 904	6 124	18
2	5 773	3 727	12 500	12
3	7 340	5 660	3 000	18
4	6 401	8 599	6 000	18
5	8 291	1 209	13 401	12
6	5 696	7 304	3 201	18
7	7 842	7 158	7 010	18
8	6 215	3 285	13 410	12
9	5 365	7 635	3 218	18
10	5 589	9 411	6 919	18
11	6 954	2 546	13 204	12
12	5 476	7 524	3 701	18
Total Time Taken to Transport MDs for 12 Months				**192**

A review of Table 4 reveals that the total time taken to transport medical supplies to Hospitals 1 and 2 over a period of 12 months was 192 hours. It is important to note that the monthly transportation times varied as a result of the varying demands from each hospital throughout the year.

The demand from Hospitals 1 and 2, as well as the remaining medical supplies in inventory, were crucial factors in determining the optimal route for transportation. The transportation time of 18 hours was due to the high demand from the hospital exceeding the available transportation storage capacity. This necessitated multiple trips for transportation, which led to longer transportation times.

In contrast, the transportation time of 12 hours was a result of lower demand from the hospital and the availability of sufficient transportation storage. This allowed for the transportation of all medical supplies in one trip, resulting in shorter transportation times.

These findings highlight the importance of considering demand and transportation storage in determining the optimal route for medical supply transportation. By ensuring that transportation is efficiently managed, it is possible to minimize transportation times and ensure that hospitals receive the medical supplies they need in a timely manner.

As demonstrated in Table 2, it has been revealed that the transportation storage capacity is only capable of accommodating 10,000 units of medical supplies. This limitation could result in significant consequences if the transportation of medical supplies is not properly managed and scheduled.

To reduce this potential issue, a Simple Heuristic Method was employed and implemented through the use of C programming language in the study to optimize transportation time and meet the objective function of minimizing it. As a result, it was successfully demonstrated that efficient scheduling can help to ensure that the transportation storage capacity is utilized to its fullest potential.

It is evident that by utilizing this method and programming language, medical supplies can be transported with efficiency, ensuring that hospitals receive the necessary supplies in a prompt manner. By carefully considering factors such as demand and transportation storage, the study highlights the importance of implementing a thorough and well-planned approach to medical supply transportation.

5 MEDICAL SUPPLY PROBLEM USING EMERGENCY CENTRE

Throughout this section, we will explain more in detail about medical supply problem by using emergency centre as our support. We will find a schedule of medical supply that will obtain the shortest transportation time.

5.1 Problem

Our problem is when we transport MDs using normal distribution channels, it still take a lot of time for the MDs to arrive at the hospital during pandemic. A lot of unexpected things occur during transporting the MDs, like supply chain disruptions, logistic issues and challenges in tracking medical supplies. These problems create a lot of variables that will undoubtedly affect the arrival of MDs to hospitals that are in need of MDs. It will affect the hospitals like delayed or canceled surgeries, increased risk of infections and also reducing the hospitals' patient capacities. Therefore, we are planning to create an emergency centre, designed specifically to tackle this issue head-on. This centre will act as a support system to transport medical supplies to hospitals, with the goal of reducing the time taken for MDs to arrive at their destination. Furthermore, we will conduct a comparison between utilizing one versus two transportations to optimize transportation times and ensure that medical supplies reach hospitals in a timely and efficient manner.

5.2 Emergency Centre Transportation (ECT Model)

$$\pi_{pij}=\begin{cases}1, \; if\ medical\ supply\ p\ from\ DC\ i\ to\ emergency\ DC\ j\ is\ transported.\\ 0, \; if\ otherwise.\end{cases}$$

$$\min\ z = \min \textstyle\sum_p \sum_m \sum_i \sum_c \sum_j (\psi_{pmi}\pi_{pmi} + \psi_{pic}\pi_{pic} + \psi_{pij}\pi_{pij})$$

s.t

$$\sum_p N_{pi}^{t-1} + \sum_m \Omega^{tpi} \leq \sum_n Y_{in} \tag{8}$$

$$\sum_i \pi_{pmi} \geq 1 \tag{9}$$

$$\sum_c \pi_{pic} \geq 1 \tag{10}$$

$$\sum_j \pi_{pij} \geq 1 \tag{11}$$

$$\varpi_p \geq \sum_i \Omega^{pict} \tag{12}$$

$$d_{cp}^t = \sum_i \Omega^{pict} \tag{13}$$

$$d_{cp}^t, \varpi_p, Y_{in}, a_i, \Omega^{pict}, \Omega^{tpi}, N_{pi}^t, \varpi_p, \psi_{pmi}, \psi_{pic}, \psi_{pij} \in \{0,1\} \tag{14}$$

$$\pi_{pmi}, \pi_{pic}, \pi_{pij} \in \{0,1\} \tag{15}$$

The objective function is to minimize the total of transportation time during the distribution of medical supply. For the constraint (8) is the sum of the remaining medical supply from the previous period plus the total of newly received medical supply in the DC in each period cannot exceed the relevant storage capacity. The set of constraints (9), (10) and (11) are to guarantee that the medical supply must be moved between main levels of the chain including manufacturing centres, distribution centres, emergency centre and hospital to satisfy hospital demand. Furthermore, constraint (12) is the quantity of shipped medical supply cannot exceed the transportation storage. Constraint (13) is the demand medical supply must be equal to quantity of shipped medical supply. Finally, constraints (14) and (15) is the sign restrictions that indicate the type of decision variables. The highlighted parameter in the objective function and the constraint is a new addition to ECT Model.

5.3 Simple Heuristic Method for ECT Problem

In this section, we will present a concise explanation of the transportation method for medical supplies, along with the corresponding algorithm. The Method 1 and 2 in this ECT Problem are the same from Figure 1 and 2, respectively.

5.3.1 Method of transporting MDs with one transport

Method 3

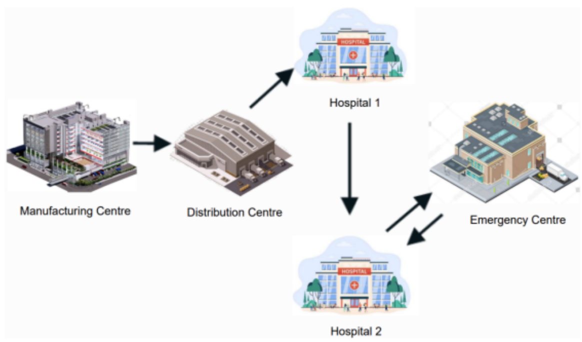

Figure 3 : Method 3 for ECOneT

Figure 3 illustrates the third transportation method for moving MDs from MC to hospitals. The process involves transporting the MDs from MC to DC, which then distributes them to Hospital 1 and Hospital 2. If the MDs at Hospital 2 are insufficient, the transport will pick up additional MDs from the Emergency Centre (EM) and then return to Hospital 2 to complete the transportation.

Method 4

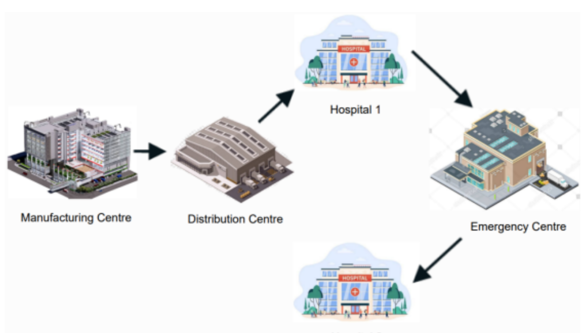

Figure 4 : Method 4 for ECOneT

Figure 4 shows the fourth transportation method for moving MDs from MC to hospitals. The process involves transporting the MDs from MC to DC, which then distributes them to Hospital 1. The transport will then pick up any remaining MDs from the EM due to insufficient MDs in transportation storage to deliver to Hospital 2, before completing the delivery to Hospital 2.

5.3.2 Pseudocode for Heuristic ECOneT Algorithm

Algorithm 3 Heuristic ECOneT Algorithm

```
Receive hospital demand p
if p ≤ a_i then
    Receive MDs from manufacturing centre
else if ϖ_p ≥ d_t c_p then
    Choose method 1 or 3
else
    Choose method 2 or 4
end if
if chosen method involves transporting all MDs at once then
    Select shortest distance hospital and move to next
else
    Select shortest distance hospital and return to distribution centre to collect MDs if method 3
and 4 involve return to emergency centre
end if
Transport to next hospital
Calculate transportation times
Choose shortest transportation time
Repeat for next month
Calculate total transportation times for x months
```

This is a procedural algorithm for solving the medical supply problem in a pandemic. The algorithm starts with the hospital placing a demand for medical supplies (MDs) from the manufacturing centre. The distribution centre then receives the information and checks its available inventory. If the demand is less than or equal to the available inventory, the distribution centre proceeds to receive the MDs from the manufacturing centre.

If the transportation storage is greater than the hospital demand, two methods are considered: Method 1 and Method 2. Both methods undergo constraint checking and the method with the shortest transportation time is selected. If neither method works, the MDs are received using an emergency centre through Methods 3 and 4, again undergoing constraint checking and choosing the method with the shortest transportation time.

The algorithm repeats this process for each month and calculates the total transportation times for each month. The algorithm ends after all months have been calculated.

5.4 Method of transporting MDs with two transports

Method 3

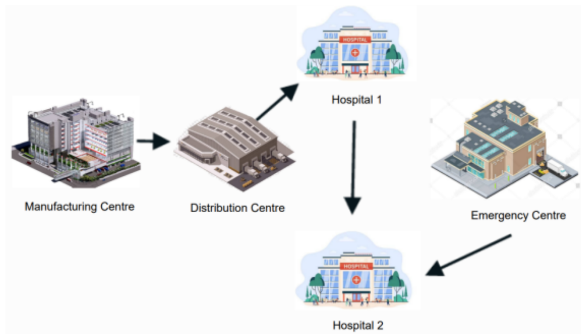

Figure 5 : Method 3 for ECTwoT

Figure 5 illustrates the third transportation method for moving MDs from MC to hospitals. The process involves transporting the MDs from MC to DC, which then distributes them to Hospital 1 and Hospital 2. If the MDs at Hospital 2 are insufficient, the transport stationed at the EM will deliver the remaining MDs to Hospital 2 to complete the transportation.

Method 4

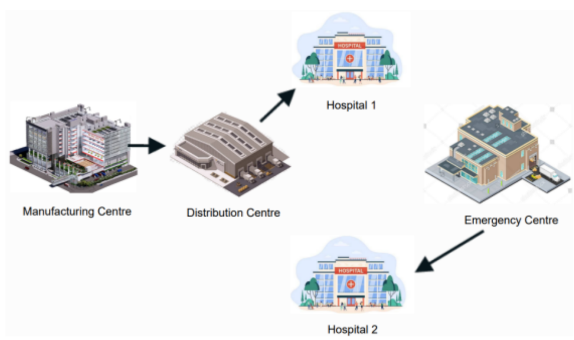

Figure 6 : Method 4 for ECTwoT

Figure 6 shows the fourth transportation method for moving MDs from MC to hospitals. The process involves transporting the MDs from MC to DC, which then distributes them to Hospital 1. If the MD demand at Hospital 2 is smaller than the amount of MDs stored at the Emergency Centre, the transport stationed at the EM will be responsible for delivering the MDs to Hospital 2.

5.4.1 Pseudocode for Heuristic ECTwoT Algorithm

The given algorithm outlines a procedure for the distribution of medical supplies (MDs) from a manufacturing centre to various hospitals. The algorithm begins with the hospital demanding a certain amount of medical supplies (MDs) from the manufacturing centre. Upon receiving the information, the distribution centre checks if the total medical supplies to be stored are less than or equal to the available inventory. If the transportation storage is greater than or equal to the demand for medical supplies, the algorithm proceeds with the next steps.

Algorithm 4 Heuristic ECTwoT Algorithm

Receive hospital demand p
if $p \leq a_i$ **then**
  Receive MDs from manufacturing centre
else if $\varpi_p \geq d_t c_p$ **then**
  Choose method 1 or 3
else
  Choose method 2 or 4
end if
if chosen method involves transporting all MDs at once **then**
  Select shortest distance hospital and move to next
else
  Select shortest distance hospital and return to distribution centre to collect MDs if method 3 and 4 involve emergency centre will help transfer it
end if
Transport to next hospital
Calculate transportation times
Choose shortest transportation time
Repeat for next month
Calculate total transportation times for x months

There are two methods of transportation that the algorithm considers: Method 1 and Method 2. In Method 1, the distribution centre transports the medical supplies all at once to the hospital. The algorithm selects the hospital closest to the distribution centre, moves to the next hospital, and calculates the total transportation time. Alternatively, in Method 2, the distribution centre may choose to transport medical supplies multiple times. The algorithm selects the shortest distance hospital, goes back to the distribution centre to collect the medical supplies, and then transports them to the next hospital. The total transportation time is calculated and the method with the shortest transportation time is chosen.

If the transportation storage is not greater than or equal to the demand for medical supplies, the algorithm proceeds with the next steps. There are two methods of transportation that the algorithm considers: Method 3 and Method 4. In Method 3, the distribution centre transports the medical supplies all at once to the hospital, with the assistance of the emergency centre. The algorithm selects the shortest distance hospital, moves to the next hospital, and calculates the total transportation time. Alternatively, in Method 4, the emergency centre transports the medical supplies to the hospital. The algorithm selects the shortest distance hospital and calculates the total transportation time. The method with the shortest transportation time is chosen.

The algorithm stops after the medical supplies have been distributed to the hospitals. The total transportation time for x months is calculated, and the algorithm is repeated for the next month. The given algorithm outlines a comprehensive procedure for the efficient and effective distribution of medical supplies from a manufacturing centre to various hospitals, considering all necessary constraints and factors to minimize transportation time and cost.

6 RESULT AND DISCUSSION

In this section, we explore into the findings obtained from the application of Simple Heuristics Method to the medical supply transportation problem. Through a comprehensive analysis of the transportation times calculated for each month, by using Tables 2 and 3, we aim to gauge the efficiency of this method. In this analysis, we will compare the results of the three transportation options discussed in this chapter. Ultimately, we hope to determine the minimum transportation time through this research. By the end of this section, we will have a clear understanding of the viability and effectiveness of Simple Heuristics Method as a solution to the medical supply transportation problem.

Table 5 : Total time take to transport MDs for 12 months for ECT

Month	**Total Transportation Time for Each Month (Emergency Centre 1 Transportation) (Hours)**	**Total Transportation Time for Each Month (Emergency Centre 2 Transportation) (Hours)**
1	15	12
2	12	12
3	15	12
4	15	12
5	12	12
6	15	12
7	15	12
8	12	12
9	15	12
10	15	12
11	12	12
12	15	12
Total Time Taken to Transport MDs for 12 Months	**168**	**144**

A comprehensive analysis of Table 5 reveals that the use of the emergency centre as a transportation method can greatly impact the total transportation time for medical supplies. By comparing the use of one transportation and two transportation over a 12-month period, we can see that the latter results in a more efficient transportation time of 144 hours, compared to 168 hours for one transportation.

The reason for this difference lies in the manner in which the transportation is carried out. With 2 transportation, the medical supplies can be transported in one trip, reducing the time required for multiple pick-ups at the distribution centre or emergency centre. In comparison, 1 transportation requires multiple trips, leading to longer transportation times and the potential for hospitals to receive medical supplies later than required.

In determining the optimal route for transportation, it is essential to take into consideration the demand from Hospitals 1 and 2, as well as any remaining medical supplies in inventory. This highlights the importance of efficiently managing transportation, in order to minimize transportation times and ensure that hospitals receive the necessary medical supplies in a timely and efficient manner.

By using an approach such as Simple Heuristics Method, it is possible to make informed decisions about the optimal number of transportation to be used, ultimately leading to a more efficient and effective transportation system. By carefully considering all factors, it is possible to create a transportation model that meets the needs of hospitals, while reducing transportation times and ensuring the timely delivery of medical supplies.

As demonstrated in Table 2, it is evident that the transportation storage capacity for medical supplies is limited to only 10,000 units. This can prove to be a critical constraint if the transportation of medical supplies is not properly managed and optimized.

In the scenario of using a single transportation, if the demand from hospitals exceeds the storage capacity of transportation, only a portion of the demand can be fulfilled. This is because some hospitals may require a substantial amount of medical supplies, and in such cases, the transportation must pick up the remaining supplies from emergency centres near the hospitals. Although this process helps to reduce the transportation time, it still takes a considerable amount of time for the medical supplies to reach the hospitals.

However, utilizing two transportation with the aid of emergency centres can greatly minimize the total transportation time. This is because even if the demand from hospitals exceeds the transportation storage capacity, emergency centres can promptly transport the critical supplies to the hospitals. Moreover, transportation from the distribution centre can also efficiently transfer the medical supplies, which could result in the hospitals not having to wait for their supplies from the distribution centre.

To overcome this issue, a Simple Heuristic Method was employed in the study to optimize the transportation time and achieve the objective of minimizing it, with the assistance of emergency centres. As a result, it was effectively demonstrated that efficient scheduling of transportation, along with the utilization of emergency centres, can help to maximize the utilization of transportation storage capacity and ensure that the hospitals receive their medical supplies in a timely manner.

6.1 Comparison

Table 6 : Total time take to transport MDs for 12 months

Month	Demand from Hospital 1 (Units)	Demand from Hospital 2 (Units)	Previous Period Remaining Medical Supply in Inventory (Units)	Total Transportation Time for Each Month (Normal Transportation Channel) (Hours)	Total Transportation Time for Each Month (Emergency Centre 1 Transportation) (Hours)	Total Transportation Time for Each Month (Emergency Centre 2 Transportation) (Hours)
1	5 096	9 904	6 124	18	15	12
2	5 773	3 727	12 500	12	12	12
3	7 340	5 660	3 000	18	15	12
4	6 401	8 599	6 000	18	15	12
5	8 291	1 209	13 401	12	12	12
6	5 696	7 304	3 201	18	15	12
7	7 842	7 158	7 010	18	15	12
8	6 215	3 285	13 410	12	12	12
9	5 365	7 635	3 218	18	15	12
10	5 589	9 411	6 919	18	15	12
11	6 954	2 546	13 204	12	12	12
12	5 476	7 524	3 701	18	15	12
Total Time Taken to Transport MDs for 12 Months (Hours)				**192**	**168**	**144**

The analysis in Table 6 unveils a remarkable conclusion regarding the transportation of medical supplies to hospitals. It is evident that utilizing the emergency centre as support significantly minimizes the transportation time, thereby achieving the objective of reducing the transportation time to a minimum.

Undoubtedly, the use of the emergency centre as support expedites the transportation process, reducing the total transportation time from 192 hours with normal transportation to a mere 168 hours. This represents a remarkable 12.5% reduction in transportation time, clearly illustrating the impact of the emergency centre in hastening the delivery of medical supplies to hospitals.

Furthermore, the comparison between the use of one transportation and two transportation with the aid of the emergency centre showcases a remarkable difference in the total transportation time. The use of 2 transportation methods is a strategic move, with one transportation bringing medical supplies from the distribution centre, while the other from the emergency centre. In times of urgent need, the emergency centre can act as an additional distribution centre, further reducing the transportation time to a mere 144 hours with 2 transportation methods, as opposed to 168 hours with 1 transportation method.

In conclusion, it is irrefutable that the utilization of the emergency centre as support greatly contributes to reducing the transportation time and ensuring the timely delivery of medical supplies to hospitals. This highlights the significance of having a well-equipped and efficient emergency centre as an integral part of our medical supply chain.

7 CONCLUSIONS

This project analyzed the findings obtained from the application of the Simple Heuristics Method to the medical supply transportation problem. Through a comprehensive analysis of transportation times calculated for each month, the efficiency of this method was gauged. The analysis compared the results of three transportation options discussed in the chapter, with the aim of determining the minimum transportation time. The data from Table 5 was solved using the C programming language.

A comprehensive analysis of Table 5 revealed that the use of the emergency centre as a transportation method greatly impacts the total transportation time for medical supplies. Comparing the use of one transportation and two transportation methods over a 12-month period, it was found that the latter resulted in a more efficient transportation time of 144 hours, compared to 168 hours for one transportation.

The difference in transportation time stems from the manner in which the transportation is carried out. With two transportation methods, medical supplies can be transported in one trip, reducing the time required for multiple pick-ups at the distribution centre or emergency centre. On the other hand, one transportation method requires multiple trips, leading to longer transportation times and the potential for hospitals to receive medical supplies later than required.

Efficiently managing transportation is essential in determining the optimal route and minimizing transportation times. It is crucial to consider the demand from hospitals, any remaining inventory of medical supplies, and effectively schedule transportation to ensure timely and efficient delivery to hospitals.

The analysis further revealed that the transportation storage capacity for medical supplies is limited to 10,000 units, which can prove to be a critical constraint if not properly managed and optimized. If demand exceeds the storage capacity, utilizing two transportation methods with the aid of emergency centres can greatly minimize transportation time. Emergency centres can promptly transport critical supplies to hospitals, reducing waiting time and ensuring timely delivery.

To optimize the transportation time, a Simple Heuristic Method was employed in the study, in conjunction with the assistance of emergency centres. The results effectively demonstrated that efficient scheduling of transportation, along with the utilization of emergency centres, maximizes the utilization of transportation storage capacity and ensures timely delivery of medical supplies to hospitals.

The analysis of Table 6 revealed a remarkable conclusion regarding the transportation of medical supplies to hospitals. The utilization of the emergency centre as support significantly reduces transportation time, achieving the objective of reducing it to a minimum. Comparisons between different transportation methods highlighted the impact of the emergency centre in hastening the delivery of medical supplies.

In conclusion, the findings of this analysis highlight the effectiveness of the Simple Heuristics Method and the importance of utilizing emergency centres in reducing transportation time and ensuring timely delivery of medical supplies to hospitals. Efficient transportation management, considering factors such as demand, inventory, and optimal routes, is crucial for minimizing transportation time and improving the overall efficiency of the medical supply chain.

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