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Reverse Supply Chain and Pharmaceutical Waste Collection Management Utilizing Location-Routing Model

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ABSTRACT

Nowadays, the increased amount and variety of waste, and the health risks caused by them are considered among the substantial issues of human societies today. Pharmaceutical wastes are among the most dangerous polluting wastes of the environment in the world. They include expired products and unused medicines. This study aims to investigate pharmaceutical waste collection management utilizing the location-routing model in a reverse supply chain. To do so, pharmaceutical waste from pharmacies and hospitals is collected and then transfer to collection centers, where waste classification and future decisions are planned. This process is done in two stages, the first includes pharmacies and hospitals, and collection centers, and the second stage includes collection centers, disposal centers, and airports. In the first stage, pharmaceutical waste is collected, and in the second level, this waste is either safely disposed of or recycled, or medicines that can be reused are sent to third-world countries. Finally, by creating an optimization model, the transportation costs, the construction cost of collection centers, disposal costs, and the cost of producing carbon dioxide will be minimized. Reducing carbon dioxide production helps make this chain greener.

1. INTRODUCTION

Contamination of surface, underground, and drinking waters with pharmaceutical wastes can have serious environmental implications. The amount of pharmaceutical waste a population produces is correlated with the amount of pharmaceutical products it consumes, which can be influenced by the pharmaceutical industry as well as the size of the elderly section of the population. Besides the environmental hazards, expired or unused medicine not only comprises wasted healthcare resources, but also pose a probable public health hazard of intentional or accidental misuse and poisoning in case extracted from waste bins [1]. Pharmaceutical wastes include distributed and undistributed products that have remained unused and eventually expired. When patients receive a drug for an acute or chronic condition, they rarely consume the entire package and often discard the remains. When disposed of along with other wastes, these pharmaceutical wastes can seep into water streams and contaminate aquatic habitats, recreational lakes, or even purification facilities that produce drinking water [2, 3]. Every year, large amounts of human drugs such as antibiotics, acetines, and cytotoxins used in cancer treatment and veterinary drugs such as antibacterial and anti-fungi medicines and disinfectants reach the environment through various mechanisms [4-6], polluting the soil, surface waters, and agricultural lands. In a study conducted in seven Asian countries (China, Indonesia, Taiwan, Malaysia, Singapore, Bangladesh, Philippines), 679 areas were identified as being contaminated with pharmaceutical and chemical waste [7]. According to another study [8], almost 90% of American households discard their unused/unwanted drugs in waste or wastewater. Since sewage systems are not equipped with any mechanism to filter out these substances, they can easily find their way back into water supplies, causing issues that may not be immediately visible but still negatively affect public health [9]. Researchers have identified a wide range of adverse effects for pharmaceutical wastes including physiological effects, growth inhibition or stimulation of aquatic plant and algae species, and change in the fertility and growth rates of fish, reptiles, and aquatic invertebrates [10]. Even if these wastes are collected and burned properly under strict supervision, the resulting ash can be toxic and may contaminate water streams, which will ultimately affect humans, aquatic life, and the entire environment. Meanwhile, not discarding unused painkillers, antibiotics and other drugs may lead to improper use or over-medication, especially in young people [11]. Unlike many other products, unused or spoiled drugs have no value that makes them worthy of returning or collection. Thus, they should just be inspected and sorted before proper disposal [12]. The typical disposal methods for these wastes include burning, deep burial, landfilling, and release in sewage [13]. The most recyclable and reusable part of these wastes is their packages and containers [14]. For proper waste management in this field, the collection procedure needs to be optimized for cost minimization as well as other objectives such as minimizing carbon dioxide emissions [15]. Route optimization is a common problem in the field of waste collection, which can greatly affect the efficiency, costs, and environmental impacts of the collection process. This optimization problem can also be defined as a Vehicle Routing Problem (VRP), which involves minimizing the cost of transporting goods between customers and warehouses by a fleet of vehicles. Route optimization is regarded an efficient returns on investment a waste service is able to make. As other engineering systems, the place to discover main effectiveness in a system is in the design phase, as opposed to during operations. The effective and proper operation of rounds is crucial, and other innovations and technological means, such as In-Cab can assist here. Nonetheless, in case the design isn't proper in the first place, effectiveness and performance would be compromised [16].

To prevent the implications of improper disposal or home storage of pharmaceutical waste, this paper presents a model for pharmaceutical waste collection. For efficient pharmaceutical waste management, the process of gathering those wastes requires to be optimized for cost minimization and also sustainability objectives. Thus, this study aims to reduce the environmental impacts of pharmaceutical waste by facilitating proper disposal through the determination of optimal waste collection routes that minimize the entire cost of the operation.

The last decade has seen growing interest in the subject of waste collection and other similar green supply chains and VRPs. In the following, we review the literature on this subject. According to the research [17], in cases where the environmental impacts of a waste or unused product are believed to be more important than the resources spent on the collection process, it is crucial to take the necessary actions to collect it to prevent ensuing damages. In Hannan et al. [18] researchers developed a waste collection route optimization model that tries to maximize efficiency and cost-saving and minimize the carbon dioxide emission of the urban waste collection process. This study reported that implementing this model in a test resulted in 26.08% efficiency improvement, 44.44% cost-saving, and a 70% decrease in carbon dioxide emission. In Benjamin and Beasley [19] and Kim et al. [20] the waste collection problem was formulated as a VRP with time windows (VRPTW) where drivers are given rest times and can drive to multiple disposal centers. The objective of this problem was to minimize the number of vehicles as well as the total travel time. Ultimately, this problem was solved by Solomon's Insertion algorithm. In Jabir et al. [21] and Huang et al. [22], a green vehicle routing model was constructed by converting carbon dioxide emissions into a cost term to build a single-objective function. In Buhrkal et al. [23] and Osaba et al. [24], the problem of waste collection in an urban environment was modeled as a VRP with time windows where the objective is to optimize the routes of waste trucks so that they can empty all trash containers and move the waste to disposal sites. To demonstrate its performance, the model was implemented in a Danish waste collection company. In Hannan et al. [25], researchers developed a Capacitated Vehicle Routing Problem (CVRP) to minimize the total cost of waste collection subject to the following constraints: all vehicles start from a depot and ultimately return to the same depot; each trash container is visited by only one vehicle; the entire amount of waste collected by a vehicle should not exceed its capacity, and each trash container should be emptied as soon as it is filled to a certain level.

From the above literature review, it can be concluded that previous articles in this field generally fall into one of two categories: 1- the works focused on cost and time optimization of the waste collection process, which have mostly attempted to minimize the operating costs and the total travel time, and 2- the works focused on the environmental impacts of waste collection, where the main objective has been to minimize the total amount of pollution emitted as a result of the operation. This paper tries to take a combination of these two approaches, i.e. develop a model for reducing the amount of carbon dioxide emitted by vehicles as well as the total cost of operation so that both environmental and economic aspects of the discussion receive due attention. Another innovation of this article is that it considers the possibility of collecting expensive drugs that meet certain reusability requirements and sending them to poor countries at much lower prices.

2. MATERIALS AND METHODS

2.1. Problem definition

The drug supply chain considered in this study consists of a set of customer points including pharmacies and hospitals, a set of collection centers, a set of disposal centers, and a set of recycling centers/transit hubs (e.g. airports). All drugs expiring in under 6 months and all unused drugs that have been returned by patients are deemed to be expired and shall be transferred to disposal centers. Unused drugs that won't expire in the following 6 months are transferred to a transit hub near the collection center so that they can be transferred to developing countries. The expiration dates are checked by the collection centers that receive the drugs from pharmacies and hospitals. The model has two different levels of tours: a lower level consisting of the tours between pharmacies, hospitals, and collection centers, and an upper level comprised of the tours between collection centers, disposal/recycling centers, and transit hubs. In addition to reducing the environmental impact of drug collection, the model decides how many collection centers should be established and where they should be located. More specifically, it checks a series of candidate sites and decides whether or not to establish a collection center at a given site based on cost analyses. The second stage involves modeling a vehicle routing problem for the established collection centers with the objective of minimizing carbon dioxide emissions (Figure 1).

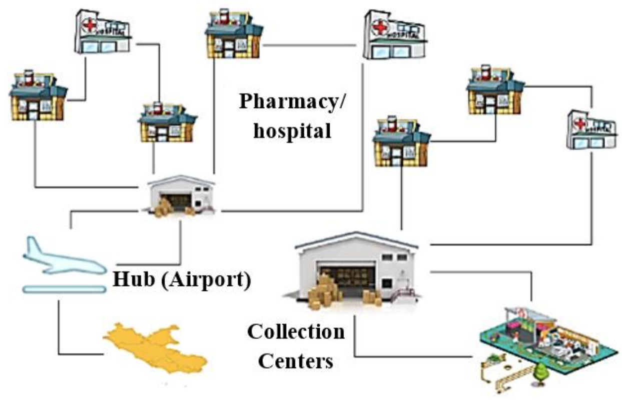

Figure 1. Schematic diagram of the defined problem

2.2 Mathematical model and assumptions

The assumptions considered in the modelling are as follows:

- All drugs that will expire in less than 6 months and all unused drugs that have been returned by patients are considered expired.
- The cost of shipping out reusable drugs and the cost of transportation from collection centers to transit hubs and the consequent carbon dioxide emissions are borne by the destination country (the model only assigns a nearby transit hub to each collection center).
- Each drug has a limited shelf life and a known expiration date.
- The capacity of vehicles is known.
- Each point is visited by only one vehicle.
- The amount of pharmaceutical waste in each pharmacy does not exceed the vehicle capacity.
- The loading of pharmaceutical waste to vehicles is immediate.
- Disposal centers and customer centers (pharmacies and hospitals) have fixed locations, but there are several candidate locations for collection centers.
- The cost of establishing a collection center is constant (does not change with location).
- The cost of transportation between each two points is known.

2.3 Sets

R: set of collection centers
L: set of vehicles on the disposal routes
B: set of destination countries
F: set of transit hubs (airports)
I: set of pharmacy/hospital nodes
N: intersection set of pharmacies and collection centers
K: set of vehicles on the collection routes
A: set of disposal centers
H: intersection set of disposal centers and collection centers

2.4 Indices

$h \in H,\ h' \in H$: elements of the intersection set of disposal centers and collection centers
$l \in L$: elements of the set of vehicles on the disposal routes
$b \in B$: elements of the set of destination countries
$f \in F$: elements of the set of transit hubs (airports)
UU_l: elements of the set R to which vehicle L belongs.
$i \in P,\ p \in P$: elements of the set of pharmacy/hospital nodes
$r \in R$: elements of the set of collection centers
$n \in N,\ n_1 \in N$: elements of the intersection set of pharmacies and collection centers
$k \in K$: elements of the set of vehicles on the collection routes
$a \in A,\ a' \in A$: elements of the set of disposal centers

2.5 Parameters

c'_{rfl}: cost of transportation between collection centers and transit hubs
dis_{nn_1} : distance between collection centers and pharmacy/hospital nodes
$dis_{hh'}$: distance between collection centers and disposal/recycling centers
$treabove_r$: the number of vehicles available for the disposal process
$Price_r$: cost of establishing a collection center
V_f: the amount of carbon dioxide emitted by a vehicle per unit weight tranported over unit distance
P_{CO_2}: unit cost of carbon dioxide emission
$Apercent_r$: percentage of pharmaceutical waste that is disposed
vc_k: variable cost of vehicle per unit distance traveled on the lower level
MM: a very large number
dem_i: the amount of pharmaceutical waste in node i
$capV_k$: capacity of vehicle k
$capD_r$: capacity of collection center r
$capA_a$: capacity of disposal/recycling center a
RRr: coverage radius of collection center r
$dd(r,f)$: distance between transit hub f and collection center r
cs_a: disposal/recycling cost
$C_{hh'l}$: cost of transportation between collection centers and disposal/recycling center
$trebellow_r$: the number of vehicles available for the collection process

2.6 Variables

u_{al}: a variable for removing sub-tours on the disposal routes
$w_{hh'l}$: the amount of drug transported from node h to node h' by vehicle l for disposal
s_{ral}: the amount of pharmaceutical waste that is offloaded at disposal center a by vehicle l belonging to collection center r
$y_{hh'l}$: =1 if there is a route from node h to node h' for vehicle l, =0 otherwise
yy_{rbf}: the amount of drug shipped from collection point r to country r via transit hub f.
zz_r: =1 if collection location r is selected, =0 otherwise
x_{nn_1k}: =1 if there is a route from node n to node n_1 for vehicle k, =0 otherwise
aa_{rk}: =1 if pharmacy/hospital nodes are assigned to collection point r, =0 otherwise
E_{arl}: =1 if vehicle l belonging to collection point r is assigned to disposal center a, =0 otherwise
yy'_{rbf}: =1 if the drug shipped from collection site r to country b goes through transit hub f, =0 otherwise
ww_{nn_1k}: the amount of drug transported from node n to node n_1 with vehicle k

2.7 Objective function

$$\sum_{r\in R} zz_r\,.\,price_r \tag{1}$$

Cost of establishing collection centers:

$$\sum_{n\in N}\sum_{n_1\in N}\sum_{k\in K} vc_k\,.\,dis_{n_1 n}.\,x_{n_1 nk} \tag{2}$$

Variable cost of transportation from collection centers to pharmacy/hospital nodes:

$$\sum_{h\in H}\sum_{h\prime\in H}\sum_{l\in L} c_{hh'l}\,.\,dis_{hh'}.\,y_{hh'l} \tag{3}$$

Variable cost of transportation from collection centers to disposal centers:

$$\sum_{a\in A}\sum_{r\in R}\sum_{l\in L} Cs_a\,.\,s_{ral} \tag{4}$$

Cost of disposal/recycling of pharmaceutical waste:

$$\sum_{n\in N}\sum_{n_1\in N}\sum_{k\in K} dis_{n_1 n}\,.\,ww_{n_1 nk}.\,vf\,.\,p_{co_2} \tag{5}$$

Cost of carbon dioxide emitted during transportation from collection centers to pharmacy/hospital nodes:

$$\sum_{h\in H}\sum_{h'\in H}\sum_{l\in L} dis_{hh'}\,.\,w_{hh'l}.\,vf\,.\,p_{co_2} \tag{6}$$

Cost of carbon dioxide emitted during transportation from collection centers to recycling/disposal centers.

Total objective function: (1) + (2) + (3) + (4) + (5) + (6)

2.8 Constraints

$$\textstyle\sum_{n\in N}\sum_{k\in K} x_{pnk} = 1 \quad \forall p\in P \tag{7}$$

$$\textstyle\sum_{n\in N}\sum_{k\in K} x_{npk} = 1 \quad \forall p\in P \tag{8}$$

These determine the routes that can be taken from each node (previous and next nodes). They also ensure that each node can be visited by only one vehicle (in these constraints, the vehicle going out of a node may not be the same as the vehicle going into that node).

$$\textstyle\sum_{n_1\in N} x_{n_1 nk} = \sum_{n_1\in N} x_{nn_1 k} \quad \forall \mathrm{n}\in \mathrm{N}, \mathrm{p}\in \mathrm{P} \tag{9}$$

This ensures that the vehicle r going out of a node is the same as the vehicle going into that node.

$$\textstyle\sum_{n\in N} x_{rnk} + \sum_{n\in N} x_{npk} \le 1 + aa_{pr} \quad \forall p\in P, r\in R, k\in K \tag{10}$$

This ensures that each node is connected to either another node or a collection center, depending on the collection center to which it is assigned.

$$\textstyle\sum_{r} aa_{pr} = 1 \quad \forall p\in P \tag{11}$$

Each node can be assigned to only one collection center.

$$w_{rpk} = 0 \quad \forall p\in P, r\in R, k\in K \tag{12}$$

Vehicle k transports nothing from the collection center to the first node.

$$w_{ipk} \ge \textstyle\sum_{n_1\in N} ww_{n_1 ik} + dem_i - MM.(1 - x_{ipk}) \quad \forall p, i\in P, k\in K \tag{13}$$

This computes the amount of drug that vehicle k carries from node p to its collection center.

$$\textstyle\sum_{p\in P} aa_{pr}\,.\,dem_p \le capD_r.\,zz_r \quad \forall r\in R \tag{14}$$

This determines the capacity of each collection center based on its site.

$$\textstyle\sum_{p\in P} aa_{pr}\,.\,dem_p \ge zz_r \quad \forall r\in R \tag{15}$$

This ensures aa_{pr} = 1 only when collection center r is selected.

$$ww_{npk} \le capV_k \quad \forall p, i\in P, k\in K \tag{16}$$

This ensures that the amount of pharmaceutical waste collected by a vehicle does not exceed its capacity.

$$\sum_{p\in P}\sum_{k\in K} x_{rpk} \le trebellow_r.\,zz_r \quad \forall r\in R \tag{17}$$

This determines the optimal number of lower-level vehicles for each collection center.

$$\sum_{h\in H} y_{ahl} = E_{arl} \quad \forall a\in A, r\in UU_l, l\in L \tag{18}$$

$$\sum_{h\in H} y_{hal} = E_{arl} \quad \forall a\in A, r\in UU_l, l\in L \tag{19}$$

This determines the ingoing and outgoing routes of each node for each vehicle based on the nodes assigned to the collection center.

$$u_{a'l} - u_{al} + |A| y_{a'al} \le |A| - 1 \ \forall a, a'\in A, r\in R, l\in L \tag{20}$$

This constraint removes sub-tours.

$$\sum_{h'\in H} y_{h'hl} = \sum_{h'\in H} y_{hh'l} \quad \forall n\in N, p\in P \tag{21}$$

This ensures that the vehicle l going out of a node is the same as the vehicle going into that node.

$$\sum_{h\in H} y_{rhl} + \sum_{h\in H} y_{hal} \le 1 + E_{arl} \quad \forall a\in A, r\in UU_l, l\in L \tag{22}$$

This ensures that each node is connected to either another node or a collection center, depending on the collection center to which it is assigned.

$$\sum_{a \in A} y_{rhl} . MM \geq \sum_{a \in A} E_{arl} \quad \forall r \in UU_l, l \in L \tag{23}$$

This ensures that vehicle *l* moves from collection center *r* to the next node only if that vehicle and that node are selected.

$$w_{ral} \geq \sum_{n_1 \in N} \sum_{k \in K} (ww_{n_1 rk} . Apercent_r) - MM.(1 - y_{ral}) \quad \forall r \in UU_l, a \in A, l \in L \tag{24}$$

$$w_{ahl} \geq \sum_{h' \in H} w_{ah'l} - \sum_{r \in UU_l} S_{ral} - MM.(1 - y_{ral}) \quad \forall a \in A, h \in H, l \in L \tag{25}$$

This determines the amount of drug that each vehicle carries from one node to another.

$$\sum_{a \in A} \sum_{l \in UU_r} S_{ral} \leq \sum_{n_1 \in N} \sum_{k \in K} ww_{n_1 rk} . Apercent_r \quad \forall r \in R \tag{26}$$

This determines the amount of drug that each vehicle offloads at nodes based on the percentage of waste.

$$S_{ral} \leq E_{arl}.MM \quad \forall r \in UU_l, a \in A, l \in L \tag{27}$$

$$S_{ral} \geq E_{arl} \quad \forall r \in UU_l, a \in A, l \in L \tag{28}$$

This ensures that s_{ral} takes value only when E_{arl}=1.

$$\sum_{l \in L} \sum_{r \in UU_l} S_{ral} \leq capA_a \quad \forall a \in A \tag{29}$$

This determines the assignment capacity of each node.

$$\sum_{a \in A} \sum_{l \in UU_r} y_{ral} \leq treabove_r . zz_r \quad \forall a \in A \tag{30}$$

This determines the number of vehicles available at each collection center for waste collection routing.

$$\sum_{b \in B} \sum_{f \in F} yy_{rbf} \leq \sum_{n_1 \in N} \sum_{k \in K} ww_{n_1 rk} . (1 - Apercent_r) \quad \forall r \in R \tag{31}$$

This determines the amount of drug transported to transit hubs for shipping out.

$$RR_r . yy'_{rbf} \geq dd_{rf} \quad \forall r \in R, b \in B, f \in F \tag{32}$$

This ensures that drugs can be transported from a collection center to a transit hub only when that transit hub is located within the coverage range of that collection center.

$$yy'_{rbf} . MM \geq yy_{rbf} \quad \forall r \in R, b \in B, f \in F \tag{33}$$

$$yy'_{rbf} \leq yy_{rbf} \quad \forall r \in R, b \in B, f \in F \tag{34}$$

This governs the relationships between the binary variable yy'_{rbf} and the size of shipment yy_{rbf}.

$$x_{n_1 nk}, zz_r, aa_{rk}, E_{arl}, yy'_{rbf}, y_{hh'l} \in \{0,1\} \tag{35}$$

This ensures that these variables only take binary values.

$$ww_{nn_1 k}, w_{hh'l}, S_{ral}, yy_{rbf} \geq 0 \tag{36}$$

This ensures that these variables only take non-negative values.

3. RESULTS AND DISCUSSION

The software GAMS 24.7.3 was used to implement the proposed model for a small problem with two collection centers, 6 pharmacy/hospital points, 4 disposal/recycling centers, 3 countries, and 4 transit hubs. The values obtained for model parameters and the results obtained for this problem are provided in the Table 1.

Table 1. Parameter values and results obtained by solving the model

Value	Parameter	Value	Parameter	Value	Parameter
0.8	vc_{k_1}	0.7	$Apercent_{r_1}$	16	RR_{r_1}
0.5	vc_{k_2}	0.8	$Apercent_{r_2}$	15	RR_{r_2}
0.6	c'_{rfl}	1	$trebellow_{r_1}$	30	$capA_{a_1}$
1000	$price_r$	2	$trebellow_{r_2}$	30	$capA_{a_2}$
20	dem_{p_1}	1	$treabove_{r_1}$	20	$capA_{a_3}$
15	dem_{p_2}	1	$treabove_{r_2}$	20	$capA_{a_4}$
30	dem_{p_3}	uniform (100,400)	$c'_{hh'l}$	100	$capV_{k_1}$
28	dem_{p_4}	uniform (150,350)	Cs_a	110	$capV_{k_2}$
25	dem_{p_5}	uniform (6,10)	dd_{rf}	90	$capD_{k_1}$
10	dem_{p_6}			85	$capD_{k_2}$
		26123.083448			Objective function value

Table 2. Distances considered for collection centers and pharmacy/hospital nodes

	r_1	r_2	p_1	p_2	p_3	p_4	p_5	p_6
r_1	0	0.5	0.8	0.6	0.3	0.9	0.7	0.3
r_2	0.5	0	0.65	0.55	0.2	0.7	0.6	0.2
p_1	0.8	0.65	0	0.65	0.5	0.3	0.5	0.4
p_2	0.6	0.55	0.65	0	0.1	0.7	0.3	0.6
p_3	0.3	0.2	0.5	0.1	0	0.15	0.4	0.5
p_4	0.9	0.7	0.3	0.7	0.15	0	0.6	0.3
p_5	0.7	0.6	0.5	0.3	0.4	0.6		0.4
p_6	0.3	0.2	0.4	0.6	0.5	0.3	0.4	0

Table 3. Sensitivity analysis for the capacity of node a1

Parameter	Change in the capacity of the disposal center	Cost of disposal at node a1	Objective function value
	+50%	8121.353	19355.958
	+20%	6497.083	20742.663
$capA_{a1}$	0	5414.236	21597.359
	-20%	4331.389	22630.488
	-35%	3519.253	23327.044

An example of the distances considered in the model is given in the Table 2.

The sensitivity analysis was performed for the capacity of disposal nodes as it is one of the factors that determine whether the model will be feasible or not.

As Figure 2 shows, increasing $capA_{a1}$ lowers the cost of disposal at that node compared to other nodes, which encourages the model to send more work toward that node (while taking into account other costs). As a result, the cost related to this node becomes increasingly larger than other costs of the objective function. This reduces other cost items including transport costs and environmental costs, which reduce the total cost of the objective function. As shown in Table 3, the model behavior matches the analysis (Maximum error < 6%).

Following the approach taken in researches [26-30], a similar sensitivity analysis was performed for demand, the results of which are presented in Figure 3.

In Figure 3, it can be seen that as demand increases, so does the total system cost. The response to rising demand is completely non-linear and cannot be accurately predicted. It is interesting that the cost changes with a gentle slope at negative values, but this slope is noticeably steeper at positive values. Therefore, it can be concluded that rising demand can increase the system costs at an extremely high rate and need to be adjusted with great care.

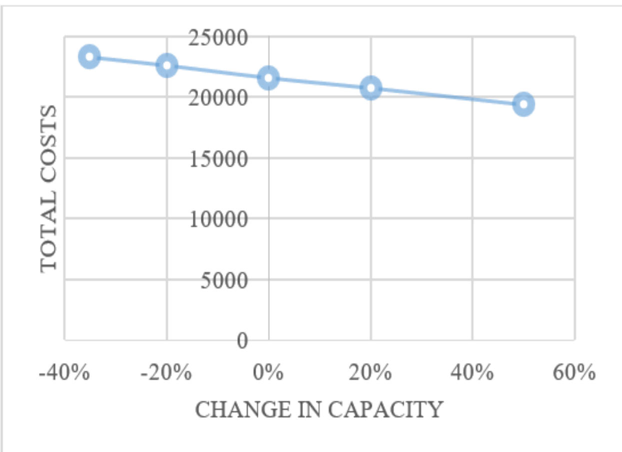

Figure 2. Results of sensitivity analysis for $capA_{a1}$

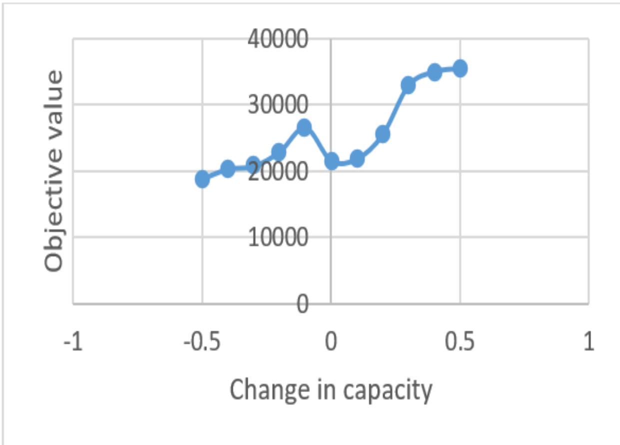

Figure 3. Results of sensitivity analysis for demand

4. CONCLUSION

Recent decades have seen a sharp rise in the use of pharmaceutical products, which can be attributed to the growth of the pharmaceutical industry as well as the growth of the elderly population. This trend has resulted in an increase in the amount of pharmaceutical wastes produced across the developed world, as patients rarely consume all of the drugs they receive for acute or chronic conditions and keep or discard the remains. Most wastes can become a source of disease as well as environmental damage if not properly managed. This also applies to pharmaceutical wastes, which can be even more dangerous than other waste. If not properly disposed of, these wastes can find their way into water streams and contaminate aquatic habitats, recreational lakes, or even purification facilities that produce our drinking water. Also, since many pharmaceutical wastes do not degrade quickly or completely, they can easily return to our water supplies, causing issues that may not be immediately visible but still negatively affect public health. Rising concerns about contamination with pharmaceutical waste have increased the importance of addressing this issue. For proper pharmaceutical waste management, the process of collecting these wastes needs to be optimized for cost minimization as well as sustainability objectives. This article tried to develop an efficient model for collecting unused pharmaceutical products and pharmaceutical waste and transferring them to recycling/disposal centers in order to prevent the aforementioned hazards.

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