Heuristic-Based Hybrid Algorithm for Value Stream Design with Milk-Run Approach

SAFIYE TURGAY, CANBERK ÇOBAN
Department of Industrial Engineering,
Sakarya University,
54187, Esentepe Campus Serdivan-Sakarya,
TURKEY

Abstract: - In this study, a heuristic algorithm has been developed for the Milk-Run related to the vehicle routing problem. It aimed to supply in the right place and at the right time in a short time with the internal logistics system approach. Since the proposed problem formulation is NP-hard, we suggested a heuristic-based hybrid genetic algorithm method to solve the problem. Real life problem is solved with a milk run approach inspired by vehicle routing problems. Firstly the model was developed with mixed integer linear programming then the problem was solved with the proposed hybrid genetic algorithm. The aim reduce the total transportation cost in the network and the number of vehicles required by using an efficient vehicle routing strategy. It explains the change in the existing distribution and collection systems of a logistics service company. The response of variables such as time, weight, volume, and pallet was measured under various scenarios with cost and time savings by applying Milk-Run optimization. The deterministic model and the proposed heuristic algorithm compared the previews and outputs of the paths. Accordingly, 30% and 50% discounts were made on restrictions for six different scenarios.

Key-Words: - Milk-run Systems, Vehicle Routing Problem, Integer Programming; Genetic Algorithm, Stream Design, Optimization, Heuristic Algorithm.

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1 Introduction

The milk-run system provides cyclical deliveries of smaller lot sizes with short lead times and low inventory at points of use, especially during short distance, low inventory, and short time supply processes. It is a repetition event with iterative rounds of short duration. However, the time, the place of delivery, and the product quantity information are uncertain. Our aim formulate and schedule iterative tours in a fixed order and according to a fixed schedule with fixed arrival times. The main goal is for an optimal periodic distribution policy, which determines who will be served, how much will be delivered, and which routes will be repeated regularly to travel with which fleet of vehicles. Milk run routing and timing issues are NP-hard, it can be solved using heuristics. Solutions can be derived, for example, from milk distribution policy when determining whether tours are scheduled cyclically in the Milk-Run approach. Before a product is delivered to the procurement note, it may stop at more than one supplier point. The changing orders may also cause an instant dynamic in the product quantities at the supply points. Before a product is delivered to a customer or a consolidation center, it passes through multiple suppliers. The order-and-repeat system reduces the variability of processes and transport costs with the Milk Run. It allows the transfer of less product with frequent cyclic dispensing, time, and more frequent turnover compared to point-to-point transfer which is another advantage. Field guidance services, shorter transfer times, and a more transparent process until delivery to the customer positively affects quality is the comparable benefits. Which product will be delivered in how much, to which point, and with which vehicle in the Vehicle Routing Problem (VRP). The problem of NP-hard routing and scheduling creates a service plan that specifies how much a given fleet of vehicles should deliver and what cyclical routes vehicles must follow to deliver the required materials on time. A heuristic approach was proposed for solving the VRP, NP-hard vehicle routing and scheduling problem. While low volume and short delivery time cargoes are distributed with the milk run approach, which we call bound logistics, the cargoes collected at the collection centers are shipped with larger vehicles for large volume cargoes. The mixed integer linear programming model and heuristic algorithm are proposed for the optimization process of the problem. To achieve this goal, we are designing a new model that combines low-volume loads through cross-docking and/or dairy logistics and allows high-volume loads to be shipped directly from parts suppliers to assembly plants. In effect, this model decides how to route and consolidate each supplier's load to each assembly facility in the network, minimizing the need for vehicles to perform the transport. Therefore, a proposed integer programming model has been addressed to the problem, but its complexity and NP-complete nature require a combination of heuristic and meta-heuristic optimization algorithms to solve it, which is performed with a hybrid genetic algorithm (GA) in this study.

The stocks of the supply units will be reduced and this may increase the chance of competition among the competitors by affecting the sales prices due to its cost with this method. The main contributions of this study can be summarized as follows:

1) A real milk run problem in Istanbul has been solved by taking into account the milk run approach and vehicle route structure.
2) We proposed a mixed integer linear programming (MILP) model with a hybrid genetic algorithm that discusses the milk run approach in detail.
3) Contrary to generally accepted assumptions, transport processes have a deterministic structure. To evaluate the effectiveness of the variants, the relevant delivery times are taken into account and more realistic results are obtained with the help of the proposed model.
4) We suggested a hybrid genetic algorithm to solve the MilkRun model. The proposed approach has taken into account the structure of large and small truck fleets. While the small trucks perform the rotation process in the cycle consisting of more frequent points, the large trucks perform the product purchase process in order not to interrupt the cycle process at the point where the small truck completes the cycle. A large truck begins and ends its journey at the factory, while a small truck performs the cycle process to perform intermediate stock and distribution operations.

The remainder of the paper is structured as follows: section 2 presents a literature review of relevant milk collection issues. Section 3 gives details about the specific milk transport issue associated with collection centers. Section 4 shows the MILP model and a sequential three-step solution approach. Section 5 illustrates the main components of the ILS approach. Section 6 explains the conclusions. Finally, Chapter 7 demonstrates the results and develops some ideas for future research.

2 Literature Survey

VRPs are combinatorial optimization problems that distribute goods or services to various destinations as a Traveling Salesman Problem. Indeed, in VRPs, a set of vehicles must serve a set of pickup/delivery points and meet predefined constraints that allow the possibility of minimizing various targets such as cost, distance or time. Therefore, VRPs are often NP-hard problems for which no effective solution has been found so far, [1], [2]. In this study, the evaluation of loading and unloading points by time criteria, will provide a solution to the constraint-based vehicle routing and scheduling problem, [3], [4].

In the milk-run system, routes, timetables, and the type and number of parts to be transported are assigned to different logistics trucks. Therefore, trucks can collect orders from different suppliers, [5], [6], [7]. The benefits of using this type of system include increased efficiency of the overall logistics system and significant potential savings in the environment and human resources, as well as significant cost reductions associated with inventory and shipping, [8], [9]. We can give some examples, such as the optimization of routes with the Enhanced C-W algorithm with the Time Windows structure [10]; the collaborative milk run model considering supply and demand situations [11]; simulated in-plant milk run routing model [12]; the time window milk run model with a dynamic structure [13]; the milk run model for a factory supplying high-volume parts [14]; demand situations in the agent-based collaborative milk run model [15]; and the in-factory milk run model. Especially in the automotive industry, they preferred this method in the process of supplying materials between warehouses and the number and variety of parts [16].

There are many approaches to operations research, linear programming, MLP, Integer programming as well as heuristics and artificial intelligence methods for vehicle routing, [17], [18], [19]. In this study, the milk run structure was modeled with Integer linear programming, and a hybrid genetic algorithm structure was developed at the same time. Various studies have been conducted on this subject. As an example, integer programming with local search algorithm was used as a heuristic algorithm for a milk collection system using fleets of different types of trucks, [20], [21]. Which are, a hybrid heuristic algorithm for network optimization with cross-docking and heuristic algorithm, with a harmony algorithm and simulated annealing [22]; the transition strategies in the cross dock structure by aiming to reduce the delivery time with a hybrid metaheuristic algorithm consisting of particle swarm optimization and simulation annealing [23]; to solve the crossdock transportation problem with ant colony algorithm [24]; examined heuristic algorithms used in solving cross dock [25].

During logistics, simultaneous demands can only be met with a good planning system. Analysis of potential deadlock systems prevents bottlenecks in the system. Distribution networks and cyclical realization of transactions and flows can be achieved through the milkrun method, [26], [27]. As a result, suppliers may reduce their safety stocks, which in the long run will affect part price declines. With the effect of this situation, logistics service providers can reduce their transportation costs in the medium term by balancing the empty cycles they have to make. The proposed model contributed to the literature in this study.

3 Milk Run Approach

The Milk-Run serves supplier relations. It has a fixed route, serves at least one supplier, and takes place in circular tours. It preferred to facilitate transportation in daily relations between neighboring suppliers. Volumes are determined daily within an order policy and the Milk-Run system planned by the buyer and delivered to the suppliers. It may involve one or more transfers (Figure 1).

Our mathematical model includes the below assumptions:

(1) The loads to be sent from each supplier to each facility are known and are assumed to be less than the truck capacity. Otherwise, the solution is trivial as the truck would have to go directly from the supplier to the plant for this flow.

(2) Trucks are always available when needed.

(3) Trucks are in two categories, small tucks, and big trucks

(4) The loads shipped have the same cross-sections that can use the entire front section of the truck.

The parameters and definitions used in the model are as follows:

I	distribution point
i	transfer node number, i=1,2,3…,l
L	number of total vehicle, L=1,2,…,n
V_L	L th vehicle volume
f	the volume of the ordered product to be transport
d_{ij}	minimum travel distance between the node i∈ N and the node j∈ N
c_1	i. unit move fee to node
M	set of potential sites to locate depots
F	set of depots
N	set of all nodes of the network: N = M ∪ F ∪ {0}
c_1	i. unit move fee to node
c_2	fixed vehicle usage fee
S_{ij}	flow from i point to j point;
SF ⊆ F	set of small depots
BF ⊆ F	set of big depots
NF⊆ F	set of depots: NF = M ∪ SF.
$L^1 \subseteq$ L	set of big trucks
$L^2 \subseteq$ L	set of small trucks
W_i	L. the amount of load loaded on the vehicle
V_i	i. load volume to be delivered to the node
V'_i	i. volume of cargo to be received from the node
W_i	i. the amount of freight to be delivered to the node
W'_i	i. the amount of freight to be received from the node
V_L	maximum volume that tool k can hold
W_L	maximum payload that vehicle k can take
c_{ij}^1	transportation cost for big trucks with i∈ N, j∈ N
c_{ij}^2	transportation cost for small trucks, i∈ NF, j∈ NF
Q^1	capacity for each truck k∈ K^1
Q^2	capacity for each truck k∈ K^2

Decision Variables

$$u_{ijL} = \begin{cases} 1\ if\ big\ truck\ l \in L^1\ travels\ from\ the\ node\ i\ \in N\ to\ node\ j\ \in N{:}\ j \neq i \\ 0\ otherwise \end{cases}$$

$$r_{ijk} = \begin{cases} 1\ if\ small\ truck\ L \in L^2\ travels\ from\ the\ node\ i\ \in NF\ to\ node\ j\ \in Nf{:}\ j \neq i \\ 0\ otherwise \end{cases}$$

$$y_{ijt} = \begin{cases} 1\ if\ depot\ i \in SF\ with\ t \in T\ is\ assigned\ to\ a\ site\ j\ \in M{:}\ (i,t) \in IT, (j,t) \in MT \\ 0\ otherwise \end{cases}$$

$$y_{ijL=} \begin{cases} 1\quad If\ i.\ task\ performs\ j\ vehicle\ \ L\ arrives\ to\ depots \\ 0\ otherwise \end{cases}$$

$$x_{ijL=} \begin{cases} 1\ If\ customer\ i.s\ vehicle\ L\ leaves\ for\ delivery\ to\ customer\ j. \\ 0\ otherwise \end{cases}$$

$$\min z_1 = \sum_{i=0}^{I} \sum_{j=0}^{J} \sum_{k=0}^{K} x_{ij} d_{ij} u_{ijk}\, c_1 + nc_1 + \sum_{i=0}^{I} \sum_{j=0}^{J} \sum_{L=0}^{L} x_{ij} d_{ij} r_{ijL}\, c_2 + nc_2 \tag{1}$$

$$1 \leq \sum_{L=1}^{L} y_{Li} \leq 2\ i = 1,2, \dots, L \tag{2}$$

$$\sum_{L \in L^1} \sum_{i \in N \setminus \{j\}} x_{ijL} = 1, \forall \mathrm{j} \in BF \tag{3}$$

$$\sum_{L=1}^{n} \sum_{j=0}^{L} x_{ijL} = \sum_{L=1}^{n} y_{Li}\ \ i = 1,2, \dots, l \tag{4}$$

$$\sum_{j=0}^{l} x_{0jL} = \sum_{j=0}^{l} x_{j0L} \leq 1 \tag{5}$$

$$\sum_{i=0}^{n} V'_i \, y_{Li} = \sum_{i=n+1}^{l} V_i \, y_{Li} \leq V_L \tag{6}$$

$$\sum_{i=0}^{n} W'_i \, y_{Li} = \sum_{i=n+1}^{l} W_i \, y_{Li} \leq W_L \tag{7}$$

$$f_{jL} \leq \sum_{i \in N \setminus \{j\}} x_{ijL} Q^1, \forall \mathrm{j} \in M, \mathrm{L} \in L^1 \tag{8}$$

$$\sum_{i \in S^1} \sum_{j \in S^1 \setminus \{j\}} x_{ijL} \leq |S^1| - 1, \forall \mathrm{L} \in L^1, S^1 \subseteq N \ \{0\}; \ |S^1| \geq 2 \tag{9}$$

$$\sum_{i \in S^2} \sum_{j \in S^2 \setminus \{j\}} x_{ijL} \leq |S^2| - 1, \forall \mathrm{L} \in L^2, S^2 \subseteq N \ \{0\}; \ |S^2| \geq 2 \tag{10}$$

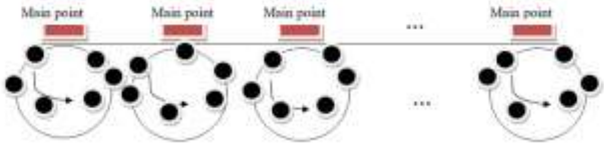


Fig. 1: Milk run concept

The model aims to minimize the overall distance and costs in Eq(1). Eq(2) refers to the calling agent at each node, and a node can be visited by a maximum of one vehicle. Eq.(3) indicates suitable routes for trucks. Eq.(4) expresses vehicle arrivals. It describes the delivery or pick-up of the car that has reached a node. Eq. (5) explains that when a vehicle completes its task, it must return to the distribution point. Eq.(6) and (7) cover quantity and volume restrictions. (8) indicates the maximum capacity for all large trucks. Each node must have an intermediary, but this may change while the model is being solved. Eq. (9,10) undesired sub-tours. The model assumed that each node is serviced by a vehicle. It does not cover the possibility that the service vehicle is not fully loaded or that the load to be loaded is more than its capacity. If the load to be loaded is more than the vehicle's capacity, it causes the vehicle to return to the distribution point. However, in this model, the number of vehicles serving the nodes is not limited to one, [28], [29], [30], [31], [32], [33]. This section is divided into two subsections: the first presents the mathematical model of the three-stage supply chain, while the second delves into the permutation-based genetic algorithm.

The development and application of a heuristic-based hybrid algorithm for Value Stream Design (VSD) with a Milk-Run approach can significantly contribute to and promote research in the field of supply chain management, logistics, and lean manufacturing. Consider a manufacturing facility where various products undergo different processes. The plan targets the main processes including manufacturing and materials supply chain cut off the stressed time and lessen redundant work. The complexity-based hybrid algorithm presents an individual method of evaluating various value stream schemes and determining optimal ones based on factors like production technological processes, materials movement, and customer demand. This provides a way of developing the concept, as well as a means of taking optimization of value chains which is used for achieving higher efficiency and resource utilization. The confusing wholesale industry of multiple suppliers and distribution points in which the shipment can be optimized to cut the transportation costs and improve logistics efficiency through the Milk-Run concept.

The integration of the Milk-Run approach in a heuristic-based algorithm will address the problems associated with the efficient movement of the storage and transportation concerning materials. Besides, it does not only generate savings but also an eco-friendly philosophy which is achieved by minimizing the environmental impact. Scientists will continue to unearth the ability of the algorithm in the Milk-Run route and schedule optimization, consequently driving progress toward a sustainable supply chain. Market demand coupled with production processes causes variations from time to time. The software should enable adjustments in light of fluctuations in demand, production process alterations, or any other input.

According to the research, changes in dynamic adapt organisms by using heuristic-based method. Researchers can study an algorithm's ability to adapt to the ever-changing world and analyze how it holds up and performs in unpredictable conditions serving as a basis for insights on adaptation and consistency. This subtlety increases the chain's agility and resistance to rapid changes in the corporate world of this day. Through lean manufacturing, one of the key objectives is to expedite the lead times and the work-in-progress inventory. The rule requires an algorithm to focus on the procedure speeding and cutting out the useless delay. The scheme moves forward with heuristics while it gives a chance to decrease lead time and optimize work in progress. Regarding the achievement of key findings, researchers may find out how the algorithm relates to the crucial performance measures, such as cycle time and process flow. First and foremost, priorities of stakeholders like cost reduction, service improvements and eco-friendly may differ from one company to another. Such preferences of the algorithm add value to the algorithm while it makes the optimized design of the production sequence. What is involved in the heuristic-based method has both purposes and contraindications The researchers can conduct the fact-finding on the algorithm that is negotiating different stakeholder needs to have frameworks for decision-making in the design of the supply chain that entails a wider range of issues. Besides, they can tie up with business partners to do actual on-ground case studies to apply the heuristic-based hybrid algorithm in reality. Researchers can verify the efficiency of the algorithm on true experiences in real problems by using empirical evidence from real-world applications and experimentations. Case studies contribute to the base of knowledge by showing approaches to the most relevant metrics and shedding light on the institutional factors.

Some of the examples are:

- Dynamic Production Environment

A production site often finds itself in a situation where there's a variety of products and a fluctuation in demand. The algorithm hybrid of heuristics, which is adaptive to changes will dynamically modify the production layout to adjust to different production needs. Such testing can measure the reaction time of the algorithm towards changing demand patterns by the algorithm and also by evaluating its ability to reduce setup times and transition easily between different production setups. This as well allows us to assess the dexterity of the algorithm in the dynamic production areas.

- Multi-Site Manufacturing Network

A company runs several manufacturing sites across the country whereby each site houses different production processes and suppliers. Integrating the MILK-RUN transportation approach to the algorithm is done to optimize the transportation of materials by consolidating deliveries across various sites. The research within this context would concentrate on the algorithm’s fitting degree in harmonizing Milk-Run planning across different manufacturing sites. These insights may help measure better the algorithm's efficiency for the inter-site material flow, the transport costs, and the collaborative practices in the multi-site manufacturing networks.

- Environmental Sustainability

An organization tries to adhere to the green principles and puts a limit on greenhouse gas emissions. The algorithm is sustainability-based, including route optimization features which are to decrease fuel consumption and emission. Research can serve as the key to identifying the role of algorithms in the entire transport system including the environmentally favorable effects. Among such measures are the quantification of carbon emission reductions, assessment of the algorithm’s involvement toward sustainability of the supply chain, and provision of knowledge that can lead businesses to align their operations with environmental goals.

- Supplier Collaboration

An industry comprises interaction including various sub-suppliers which participate at every stage by equipping the production process with different components. The algorithm evaluates suppliers' location in terms of the Milk-Run optimization resulting in a coordinated operation and the smooth flow of material from a supplier to a given manufacturing plant. The studies can deepen into how the algorithms help you create fruitful collaboration with suppliers, lead times optimization and reduction as well as rationalization of material flows. Besides, it might help build awareness of the algorithm in terms of deeper supplier relations and more resilient supply chains.

- Customization and Product Variability

A company offers a configurable product line, through which the products can be ordered with customized options and a selection of different features. The ability of the algorithm to adapt to product demand no matter the variant means the optimization of the value stream can be easily done for all the products regardless of their customizations. Research can approve the algorithm while being customization task considered, it can be evaluated how the algorithm can minimize changeover time and create utilization at best. This therefore helps to realize, the applicability of the algorithm in the industrial setting with high product variation.

- Real-time Decision Support

An industrial setting that faces particular cases of unforeseen disturbance, which requires instantaneous response and apt actions. The heuristic feature inherent in the application makes responses to unforeseen circumstances unmatched in any other app easy and in real time. Therefore, the examination may involve looking at how the algorithm works in a decision support function in real time, or its capability to change just in case any disruptions that occur in the manufacturing or supply fields. It causes the development of interactive and in-motion value mapping practice.

In order, the third party, the heuristic-based hybrid algorithm for Value Stream Design and the Milk-RUN approach is proposed for the application in the production management and supply chain. It directly relates to how value chains can be set up in a changing environment as well as how they can support sustainability practices, and will finally help to create decision-support tools for the industry practitioners. The algorithm's adaptiveness, productivity gains, and ability to address issues relevant to the real world are the main features that make it an imperative instrument in the spectrum of research activities aimed at increasing the effectiveness of modern supply chains.

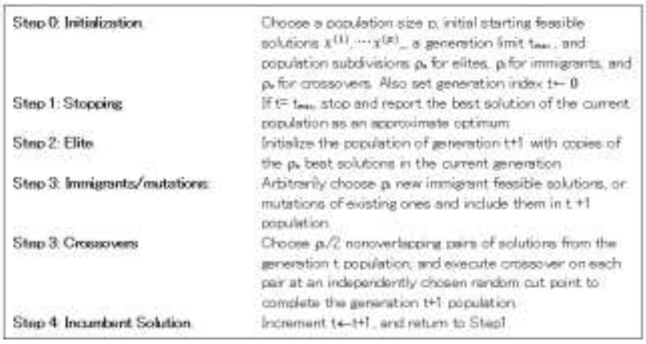
4 Improved Hybrid Fit Genetic Algorithm

The genetic algorithm evaluates the best probability population with the heuristic approach and makes the best use of biological natural selection and randomness. It combines individual solution populations with heuristic optima and leads to the most suitable solution. New solutions are created by combining pairs of individuals in the population. This coupling operation is not centered, and local optima are less frequent totally in the best available solution. In the appropriate harmonic fit genetic algorithm, the inner loop process of the system works in finding the most suitable solution in repetitive operations and in iteration times [34], [35]. Crossover combines a pair of "main" solutions and then produces parent vectors at the same point, a pair of “children” and recombining the first part of a parent solution with the second part of the other and vice versa. The single best solution ever encountered will always be part of the population. (in the variant discussed here), but each generation is also another solution. Ideally, anything will be possible, and some may be nearly as good objective function as best. Others may have rather poor solution values. New solutions are created by combining pairs of individuals in the population. Because this coupling operation is not centered, local optima are less frequent totally in the best available solution. The standard genetic algorithm method for combining population solutions is known as crossover. Many variations on the basic genetic algorithm strategy have been used successfully.

The only requirement is that better solutions have more chances. We consider only one elite population method to manage. Each new generation will be made up of a combination of elite, migratory, mutated, and cross-solutions.

The most outstanding strategy for implementing genetic algorithms creates each new generation as a mix of best solutions from the past. The previous generation was added arbitrarily to migratory solutions to increase diversity, random mutation of other solutions, and children of crossover operations on non-overlapping pairs of solutions in the previous population (Table 1).

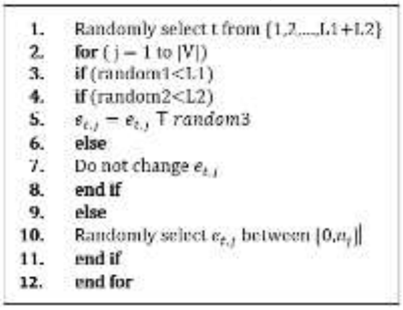
Table 1. Steps of the Genetic Algorithm



Step 0: Initialization	Choose a population size p, initial starting feasible solutions $x^{(1)}, \cdots x^{(p)}$, a generation limit t_{max}, and population subdivisions p_e for elites, p_i for immigrants, and p_c for crossovers. Also set generation index t← 0
Step 1: Stopping	If t= t_{max}, stop and report the best solution of the current population as an approximate optimum
Step 2: Elite	Initialize the population of generation t+1 with copies of the p_e best solutions in the current generation
Step 3: Immigrants/mutations	Arbitrarily choose p_i new immigrant feasible solutions, or mutations of existing ones and include them in t +1 population
Step 3: Crossovers	Choose $p_c/2$ nonoverlapping pairs of solutions from the generation t population, and execute crossover on each pair at an independently chosen random cut point to complete the generation t+1 population
Step 4: Incumbent Solution	Increment t←t+1, and return to Step1

Maintaining the best solutions from the previous generation, the finest known solutions so far will remain in the population and have more opportunities to produce offspring. Adding new migratory solutions and random mutations are existing ones that help maintain equality as solutions combined (Table 2).

Table 2. Steps of the hybrid genetic algorithm



```
Randomly select t from {1,2,...,L1+L2}
for ( j – 1 to |V|)
if (random1<L1)
if (random2<L2)
$e_{t,j} - e_{t,j}$ T random3
else
Do not change $e_{t,j}$
end if
else
Randomly select $e_{t,j}$ between [0,$n_t$]|
end if
end for
```

Collective new solutions are allowed to act as parents, which will be the product of crossovers with elites in the previous population. The hybrid genetic algorithm processing steps above are applied to the following heuristic steps (Table 2 and Figure 2).

5 Case Study

A logistics firm with a warehouse located in Gebze serves nine different locations in Istanbul. It provides collection and delivery services, and wants to change its distribution systems to add one more stop to its current route and save on costs in the locations where the company provides service, which are located in Kartal, Başakşehir, Üsküdar, Kadıköy, Sarıyer,Sultanbeyli,Büyükçekmece, Küçükçekmece, Çekmeköy. The location to be added is a customer located in Beylikdüzü. The company has three vehicles in use and the available ways are in Figure 3 and Table 3.

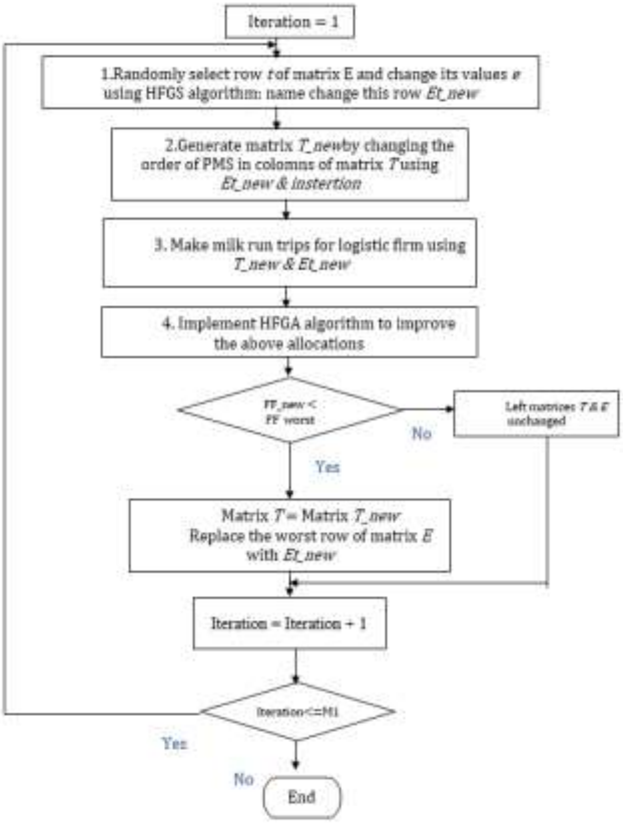


Fig. 2: Illustration of the hybrid fit genetic algorithm steps

The features of the vehicles available to the company are listed in Table 4. It includes the average speed of the cars, the distance they can travel, their maximum capacity on a pallet-volume-weight basis, and various fixed costs.

Fig. 3: Current Route Preview

Stage 1: Inclusion of the New Location in the System

The location planned to be added is located in Beylikdüzü and delivery is planned to this point. The weight of the product to be delivered, its volume, the amount of pallets, the starting and delivery time intervals, and other costs are given in Table 5.

Table 3. Current Route Preview Outputs

Routes	Total Costs	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	420,1828	134,84	163	238	3331	8	11	5:27:00	9:25:00
Green Route	348,0221	91,65	111	191	1328	3	4	5:23:00	8:34:00
Red Route	538,018	203,4	246	326	3011	7	9	4:30:00	9:58:00

Table 4. Vehicle Features

Truck Type	Average Speed	Max Length	Max Duration	Max Weight	Max Volume	Max Pallets	Fixed Costs	Costs Per Stop	Costs Per Distance Unit
Small Tuck	50	450	600	8000	15	30	150	15	1,67
Small Tuck	80	700	800	1300	23	52	225	25	2,85

Table 5. New Location Delivery Information

Weight	Volume	Pallets	Pickup / Delivery	Stop Duration	Start Time Window	End Time Window	External Costs
976	3,74	4	Delivery	15	7:00:00	14:00:00	1500

Stage 2: Implementation of Milk-Run Algorithm

With the new location included in the system, delivery/collection services will be offered to ten different locations, and these points and zip codes are listed in Table 6. Table 7 also includes the details of the planned deliveries.

Table 6. Location Postal Codes

Name	Country	State	Zip	City
TR_34862_Istanbul	TR	Kartal	34862	Istanbul
TR_34494_Istanbul	TR	Başakşehir	34494	Istanbul
TR_34660_Istanbul	TR	Üsküdar	34660	Istanbul
TR_34744_Istanbul	TR	Kadıköy	34744	Istanbul
TR_34396_Istanbul	TR	Sarıyer	34396	Istanbul
TR_34920_Istanbul	TR	Sultanbeyli	34920	Istanbul
TR_34500_Istanbul	TR	Büyükçekmece	34500	Istanbul
TR_34794_Istanbul	TR	Çekmeköy	34794	Istanbul
TR_34290_Istanbul	TR	Küçükçekmece	34290	Istanbul
TR_34520_Istanbul	TR	Beylikdüzü	34520	Istanbul

By transferring the tables containing the location information to the Log-Hub plugin, the outputs in Table 8 are obtained.

Based on the Table 8 information, the vehicle departing from Gebze Warehouse at 05:23 visits the Kartal location, which is the first visit point, at 06:00 and provides collection service. After this process, which takes 20 minutes, it departs for Kadıköy at 06.20, arrives at 06.37, and provides a 30-minute delivery service. The vehicle, which departs for Çekmeköy point at 07.07, arrives at this point at 07.32 and provides a collection service that takes 30 minutes. Leaving the Çekmeköy point at 08.02, the vehicle departs for its fourth planned point, Sarıyer, and arrives at this point at 08.32 and provides a 25-minute delivery service. The vehicle leaves Sarıyer at 08.57, arrives at Başakşehir at 09.32, and provides a delivery service that takes 15 minutes.

Table 7. Delivery/Collection Information of Locations

Weight	Volume	Pallets	Pickup / Delivery	Stop Duration	Start Time Window	End Time Window	External Costs
790	2,22	3	Pickup	20	6:00:00	12:00:00	2000
1297	3,62	4	Delivery	15	7:00:00	13:00:00	1500
828	2,31	3	Pickup	20	6:30:00	14:00:00	2000
1328	3,71	4	Delivery	30	6:00:00	12:00:00	3000
1500	4,75	5	Delivery	25	7:00:00	16:00:00	2500
1218	3,4	4	Pickup	30	6:45:00	18:00:00	3000
1714	4,78	5	Delivery	40	6:45:00	11:00:00	4000
803	2,24	3	Pickup	30	6:15:00	12:00:00	3000
1636	4,57	5	Delivery	25	6:00:00	13:00:00	2500
1339	3,74	4	Pickup	15	7:00:00	18:00:00	1500

Table 8. Route-Time Breakdown

From Location Name	Departure Time	Arrival Location Name	Arrival Time	Arrival Loading Time	Pickup / Delivery
Depot_Gebze	5:23:00	TR_34862_Istanbul	6:00:00	20	Pickup
TR_34862_Istanbul	6:20:00	TR_34744_Istanbul	6:37:00	30	Delivery
TR_34744_Istanbul	7:07:00	TR_34794_Istanbul	7:32:00	30	Pickup
TR_34794_Istanbul	8:02:00	TR_34396_Istanbul	8:32:00	25	Delivery
TR_34396_Istanbul	8:57:00	TR_34494_Istanbul	9:32:00	15	Delivery
TR_34494_Istanbul	9:47:00	TR_34500_Istanbul	10:09:00	40	Delivery
TR_34500_Istanbul	10:49:00	TR_34520_Istanbul	11:10:00	15	Pickup
TR_34520_Istanbul	11:25:00	TR_34290_Istanbul	11:43:00	25	Delivery
TR_34290_Istanbul	12:08:00	TR_34660_Istanbul	12:42:00	20	Pickup
TR_34660_Istanbul	13:02:00	TR_34920_Istanbul	13:31:00	30	Pickup
TR_34920_Istanbul	14:01:00	Depot_Gebze	14:36:00	25	Delivery

The vehicle sets off for Büyükçekmece at 09.47, arrives at this point at 10.09, and makes a delivery that takes 40 minutes. The vehicle, which is ready to depart for the Beylikdüzü point at 10.49, arrives at this point at 11.10 and will provide a 15-minute pick-up service. The vehicle leaves Beylikdüzü at 11.25, arrives at Küçükçekmece at 11.43 and will provide the delivery service that will take 25 minutes. The vehicle, which will be ready to depart at 12.08, will arrive at Üsküdar at 12.42 and will provide a 20-minute pick-up service. The vehicle, which will depart for Sultanbeyli point at 13.02, arrives at this location at 13.31 and will provide a collection service that will take 30 minutes. Having completed its delivery/transport duties at 14.01, the vehicle will depart for the Gebze warehouse and arrive at 14.36 (Figure 4). Figure 5 shows the chart of Time Distribution in Planned Route.

Fig. 4: Route Preview after Milk-Run Application

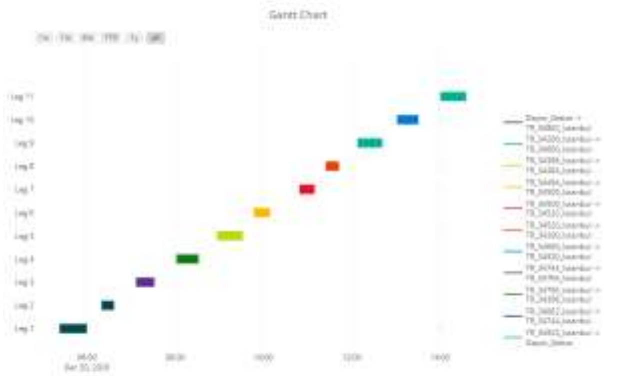


Fig. 5: Gantt Chart with Time Distribution of Planned Route

The "Loading Meter" graphic in the third graphic in Figure 6 is the standard unit of measurement used for transport by truck. It is used as a unit of calculation for goods that need to be transported but cannot be stored. LDM truck length is considered equal to one meter of loading area but may vary between regions.

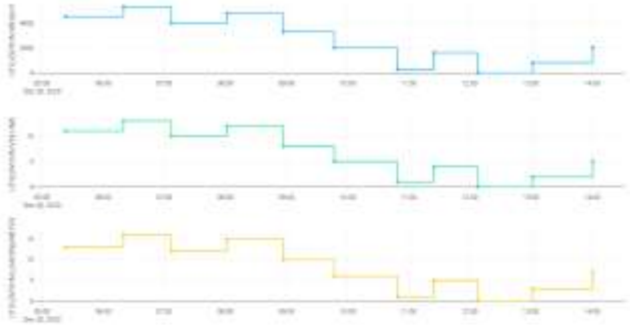


Fig. 6: Changes in Weight, Volume, and Load Size* of the Delivery/Distribution Vehicle over Time

Stage 3: Achieved Results

Table 3 is examined, the total cost is 1306,2229 currency units, the total distance traveled is 431.87 kilometers, the travel time between the points is 520 minutes and the total elapsed time is 755 minutes. The total carried weight was 7670 weight units and 24 pallets were used. The outputs obtained after the Milk-Run application are shown in Table 9. From this point of view, the total cost is 750.6563 currency units, the total distance is 251.89 km, the travel time between points is 303 minutes and the total elapsed time is 553 minutes. The total transported weight is 5333 weight units, and 16 pallets are used.

Table 9. Condition Table After Milk-Run Application

Total Costs-Mathematical Model	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
720,6563	711,4545	251,89	303	553	5333	13	16	5:25:00	14:36:00

Stage 4: Possible Scenario Outcomes When Constraints Change

Scenario 1: Visit Point Constraint Change (30%↓)

As mentioned in the introduction part of the problem, the current vehicle capacities are given in the Table 10. In addition to the given capacities, vehicles can visit 10 different points. Considering a scenario where the visiting point capacity drops by 30%, the outputs are as follows (Figure 7).

Fig. 7: Route Preview after Visit Point Constraint Change (30%↓)

While the outputs for Route 0, the first Blue-colored Milk-Run cycle, are in the first row of Table 10, the outputs for Route 1, that is, the second Milk-Run cycle in green, are in the second row. Based on the table, the total cost is 986,1034 currency units, the total distance is 321.02 kilometers, the travel time between points is 386 minutes and the total elapsed time is 636 minutes. The total transported weight was 6136 weight units and 19 pallets were used.

Table 10. Milk-Run Outputs After Visiting Point Constraint Change (30%↓)

Routes	Total Costs-Mathematical Model	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	348,0221	325,4545	81,85	111	181	1328	7	4	7:23:00	8:34:00
Green Route	638,0813	626,3411	239,18	275	441	4808	12	15	5:27:00	12:12:00

Scenario 2: Visit Point Constraint Change (50%↓)

Considering a situation where the visiting point capacity drops by 50%, the outputs are as follows (Figure 8 and Table 11).

Fig. 8: Route Preview after Visit Point Constraint Change (50%↓)

Table 11. Milk-Run Outputs After the Visitation Point Constraint Change (50%↓)

Routes	Total Costs	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	421,6258	411,4354	117,74	142	272	2849	7	10	6:10:00	10:42:00
Green Route	592,8676	585,3455	220,28	263	383	4808	12	15	5:43:00	12:06:00

While the outputs for Route 0, the first Blue-colored Milk-Run cycle, are in the first row of Table 11, the outputs for Route 1, the green-colored second Milk-Run cycle, are on the second line. Based on the table, the total cost is found to be 1014.4934 currency units, the total distance is 338.02 kilometers, the travel time between points is 405 minutes and the total elapsed time is 655 minutes. The total weight carried was 7657 weight units and 25 pallets were used.

Scenario 3: Transit Time Constraint Change (30%↓)

As shown in Table 12 and Figure 9, each vehicle can travel for a maximum of 600 minutes in each Milk-Run cycle. Considering a scenario where the Transport Time capacity decreases by 30%, the outputs are as follows.

Fig. 9: Route Preview after Move Time Constraint Change (30%↓)

Table 12. Milk-Run Outputs After Transport Time Constraint Change (30%↓)

Routes	Total Costs	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	387,7548	352,4545	106,44	139	229	2046	1	7	6:10:00	9:59:00
Green Route	614,7814	318,4545	224,42	259	421	4808	11	15	4:30:00	11:31:00

Route 0, the first Blue-colored Milk-Run cycle outputs, is in the first row of Table 13, while Route 1, the second Green-colored Milk-Run cycle outputs, is in the second row.

Based on the table, the total cost is found to be 1002,5362 currency units, the total distance is 330,86 kilometers, the travel time between points is 398 minutes and the total elapsed time is 650 minutes. The total transported weight was 6854 weight units and 22 pallets were used.

Scenario 4: Transit Time Constraint Change (50%↓)

Considering a scenario where the Transport Time capacity decreases by 50%, the outputs are as follows (Figure 10 and Table 13).

Fig. 10: Route Preview after Move Time Constraint Change (50%↓)

Route 0, the first Blue-colored Milk-Run cycle outputs, are located in the first line of Table 14, Route 1, that is, the second Milk-Run cycle outputs in green, are located in the second line, and finally Route 2, the third Milk-Run cycle in red. -Run loop is in the last line.

Table 13. Milk-Run Outputs After Transport Time Constraint Change (50%↓)

Routes	Total Costs	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	524,0234	511,3451	197,02	236	351	2797	5	8	5:45:00	10:44:30
Green Route	431,6258	412,3454	117,74	142	272	2846	7	10	6:33:00	10:42:30
Red Route	512,2468		204,94	246	301	2013	7	8	5:10:00	10:20:00

Based on the table, the total cost is 1467,899 currency units, the total distance is 519.7 kilometers, the time between points is 624 minutes and the total elapsed time is 874 minutes. Total transported weight was 7657 weight units and 25 pallets were used.

Scenario 5: Transported Volume Constraint Change (30%↓)

As shown in Table 10, each vehicle can carry a maximum of 15 volumes of cargo. Considering a scenario where the transported volume capacity decreases by 30%, the outputs are as follows (Figure 11 and Table 14).

Fig. 11: Route Preview after Moved Volume Constraint Change (30%↓)

Table 14. Milk-Run Outputs After Conveyed Volume Constraint Change (30%↓)

Routes	Total Costs	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	781,9453	751,5054	288,59	346	596	3980	10	12	5:00:00	15:04:00

As shown in blue in Figure 10, the outputs of the Milk-Run cycle were found to be 781.9453 currency units with total cost, total distance 288.59 kilometers, travel time between points 346 minutes and total elapsed time 596 minutes. While the total transported weight was 3980 weight units, 12 pallets were used.

Scenario 6. Transported Volume Constraint Change (50%↓)

As in the previous scenario, each vehicle can carry a maximum of 15 volumes of cargo. Considering a scenario where the transported volume capacity decreases by 50%, the outputs are as follows (Figure 12 and Table 15).

Fig. 12: Route Preview after Transported Volume Constraint Change (↓50%)

Table 15. Milk-Run Outputs (50%↓) After Transported Volume Constraint Change (%50↓)

Routes	Total Costs	Total Costs-Heuristic Approach	Distance	Driving Duration	Duration	Weight	Volume	Pallets	Departure Time	End Time
Blue Route	516,7621	512,5678	183,69	220	320	2797	7	9	6:18:00	11:30:00
Green Route	597,3132	348,4523	213,96	257	407	2511	8	7	5:08:00	11:55:00

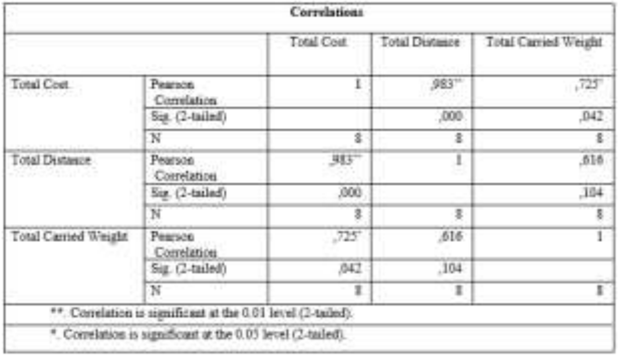
As shown in blue in Figure 11. Route 0 outputs are in the first row of Table 16, and Route 1 outputs, shown in green, are in the second row of the table.

Based on the table, the total cost is 1114.0755 currency units, the total distance is 397.65 kilometers, the travel time between points is 477 minutes and the total elapsed time is 727 minutes. The total transported weight is 5308 weight units and 16 pallets are used.

5.1 Statistical Analysis

Cost is one of the most important criteria in Milk-Run optimization processes and other outputs were compared with Total Cost output and their relationships were investigated. For the analysis, the IBM SPSS program was used and Pearson Correlation measures were used for the analysis to compare significant differences among total cost, total distance, and total carried weight. As stated in Table 16, there is a positive and significant correlation at the level of 0.01 between Total Cost and Total Distance. There is a positive and significant correlation at the level of 0.05 between Total Cost and Total Carried Weight. A sufficient relationship between Total Distance and Total Carried Weight could not be determined.

Table 16. Total Cost, Total Distance, and Total Weight Carried Relationship



Correlations

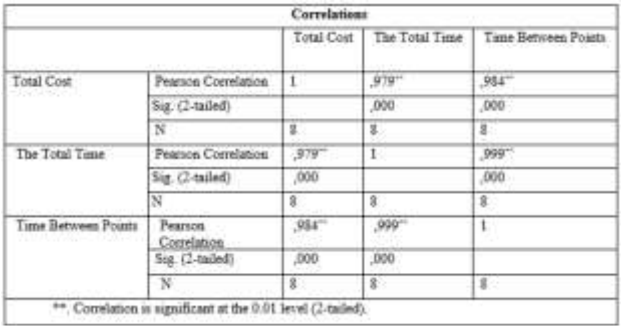
		Total Cost	Total Distance	Total Carried Weight
Total Cost	Pearson Correlation	1	,983**	,725*
	Sig. (2-tailed)		,000	,042
	N	8	8	8
Total Distance	Pearson Correlation	,983**	1	,616
	Sig. (2-tailed)	,000		,104
	N	8	8	8
Total Carried Weight	Pearson Correlation	,725*	,616	1
	Sig. (2-tailed)	,042	,104	
	N	8	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

When Table 17 was analyzed, there was a positive significant correlation at the level of 0.01 between Total Cost and Total Time. A positive significant correlation was found at 0.01 level between Total Cost and Time Between Points. In addition, it was determined that there is a positive and significant correlation at the level of 0.01 between the Total Time and the Time Between Points.

Table 17. Total Cost, Total Time, and Time Between Points Relationship



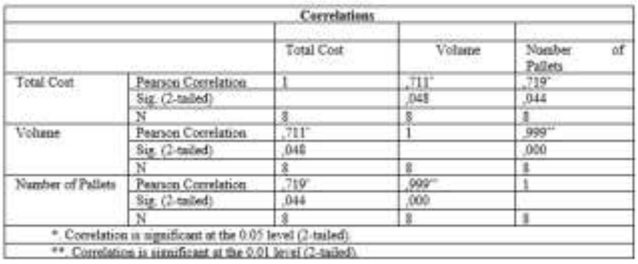
Correlations

		Total Cost	The Total Time	Time Between Points
Total Cost	Pearson Correlation	1	,979**	,984**
	Sig. (2-tailed)		,000	,000
	N	8	8	8
The Total Time	Pearson Correlation	,979**	1	,999**
	Sig. (2-tailed)	,000		,000
	N	8	8	8
Time Between Points	Pearson Correlation	,984**	,999**	1
	Sig. (2-tailed)	,000	,000	
	N	8	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

As stated in Table 18 is a positive correlation of 0.05 levels between Total Cost and Total Volume. A positive correlation of 0.05 levels was found between Total Cost and Total Number of Pallets. There is a positive correlation at the level of 0.01 between the Total Volume and the Total Number of Pallets.

Table 18. Relationship Table between Total Cost, Total Volume, and Total Pallet



Correlations

		Total Cost	Volume	Number of Pallets
Total Cost	Pearson Correlation	1	,711*	,719*
	Sig. (2-tailed)		,048	,044
	N	8	8	8
Volume	Pearson Correlation	,711*	1	,999**
	Sig. (2-tailed)	,048		,000
	N	8	8	8
Number of Pallets	Pearson Correlation	,719*	,999**	1
	Sig. (2-tailed)	,044	,000	
	N	8	8	8

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

6 Conclusion

As a result, of the implementation of Milk-Run optimization, the total cost decreased from 1306.2229 currency units to 720.6563 currency units, the total distance decreased from 431.87 kilometers to 251.89 kilometers and the time between points decreased from 520 minutes to 303 minutes with the inclusion of the new location in the current situation. Afterward, by reducing the vehicle capacities by 30% and 50% has positive effect on the behaviour in the system that observed and obtained the outputs.

The first situation and the optimal state after Milk-Run with the constraint changes and the scenario outputs obtained are compared and illustrated in Figure 13. For each situation and scenario, total cost, total distance, time between points, total elapsed, time, total weight carried, total volume and number of pallets changes are given separately in Figure 14.

	Total Cost	Total Distance	Time Between Points	The total time	Total Carried Weight	Volume	Number of Pallets
● Initial Status	1306,2229	431,87	520	755	7670	18	24
● After Milk-Run	720,6563	251,89	303	563	5333	13	16
● Heuristic Algorithm	986,1034	321,02	386	638	6136	15	19
● Scenario 1	1014,4934	330,02	405	656	7657	19	25
● Scenario 2	1002,5362	330,86	398	650	6854	17	22
● Scenario 3	1467,899	519,7	624	874	7657	19	25
● Scenario 4	781,9463	288,59	346	596	3980	10	12
● Scenario 5	1114,0756	397,65	477	727	5308	13	16
● Scenario 6							

Fig. 13: Table of Changes Due to Scenarios

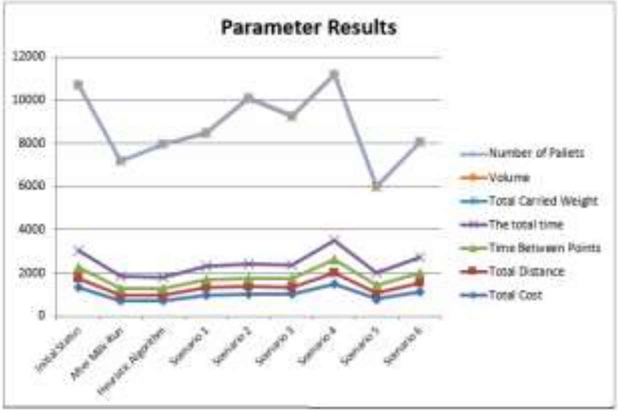


Fig. 14: Parameter Results for different scenarios

The optimization study will save the company a great deal in the short and long term, and it will provide a preview of the actions that can be taken in case the vehicle constraints change due to various reasons. The scenarios created express these possible changes and will protect the company against possible risks. In this way, the company will have efficiency in itself by directing the surplus resources it holds to the necessary areas.

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- C. Coban - validation,
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