

ISSN: 1672 - 6553

JOURNAL OF DYNAMICS
AND CONTROL

VOLUME 9 ISSUE 6: 25 - 40

OPTIMIZATION OF MULTI-
CAPACITATED CLOSED-LOOP
SUPPLY CHAIN NETWORK PROBLEM
WITH MULTI-PRODUCTS AND M
ULTI-TIME PERIOD USING SMA

Guman Singh¹, Mohammad
Rizwanullah^{2*}, Jay Chandra Yadav³

^{1,2,3}Department of Mathematics and Statistics
Manipal University Jaipur, Jaipur, Rajasthan,
India.

OPTIMIZATION OF MULTI-CAPACITATED CLOSED-LOOP SUPPLY CHAIN NETWORK PROBLEM WITH MULTI-PRODUCTS AND MULTI-TIME PERIOD USING SMA

Guman Singh¹, Mohammad Rizwanullah^{2*}, Jay Chandra Yadav³

^{1,2,3}Department of Mathematics and Statistics Manipal University Jaipur, Jaipur, Rajasthan, India.

*Corresponding Author: mohd.rizwanullah@jaipur.manipal.edu

Abstract: Now a days, the Closed-loop Supply Chain Networks Problem (CLSCNP) is a most popular optimization problem. We examine closed-loop supply chains that are multi-capacitated and multi-time period, involving producers, distributors, and recyclers in an unpredictable setting. Examining the retail costs of new products and rewards given to customers for returning their used goods is the main objective. In this study, possibility theory is used to enable Saving Matrix Approach (SMA) to find the best answers in uncertain situations. The primary goal of the study is to reduce the overall cost of closed-loop supply chain network by determining the total number of facilities that will be opened and by maximizing the cost of all forward and reverse flow between the various CLSC network levels. Lastly, sample data is used to analyze theoretical results. To demonstrate the benefits of the suggested strategy, the outcomes.

Keywords: Closed Loop Supply Chain, Network Problem, Saving Matrix Approach, Route, Distance

1. Introduction

Vehicle routing problems (VRPs) are difficulties pertaining to the distribution of products between warehouses and clients. In a supply chain, distribution is the process of moving goods from a supplier to a customer. Because it directly affects customer needs and supply chain costs, distribution is a crucial component that can benefit the business [4] [11]. The most crucial factor to consider when deciding on distribution management is the delivery timetable and path from a starting point to a few target locations. The business is still limited in its ability to address the issue of goods distribution, particularly with regard to the choice of shipping routes. When shipping items to consumers, a vehicle must travel a greater distance, which results in increased costs.

The closed-loop supply chain network problem (CLSCNP) has a lot of literature written about it. The most popular SCM techniques simply take into account the logistical processes involved in the physical chain; they do not take into account its financial components. The Multi-Capacitated CLSCNP with Multi-Products and Multi-Time Period is presented in this study, building on the research done by Bhuranda and Rizwanullah [5]. This article will discuss distribution route optimisation using the saving matrix approach. By calculating the distribution routes that must be travelled and the number of vehicles based on vehicle capacity to get the shortest route and lowest possible transportation costs, the Savings Matrix Method is a technique used to identify the product distribution route to the marketing region. Additionally, Matrix Savings Method.

You, Z., et al. [31] presented the integration of the Milk-Run schema into express distribution logistics. Through a feasibility analysis, the authors explore the application of cyclic goods-taking methods in the express industry. They aim to optimize distribution routes to achieve full vehicle loads, thereby improving efficiency and reducing costs. Sarjono, H. et al. [25] effectively demonstrates the potential of the Nearest Neighbor Procedure in minimizing transportation costs through route optimization. The simplicity and practicality of NNP make it a valuable tool for logistics professionals seeking quick and efficient solutions. However, for more complex and large-scale routing problems, more advanced algorithms or hybrid approaches might be necessary to achieve optimal results. Putranto, R. et al. [21] examined the optimization of LPG distribution routes for PT. Limas Raga Inti, an authorized distributor of PT. Pertamina LPG products, in response to

increasing consumer demand following the government's policy shift from kerosene to LPG. The study utilizes the Saving Matrix method to enhance the efficiency and effectiveness of the distribution process, aiming to provide superior service to customers.

Saputra, I. W. et al. [24] explores the optimization of vehicle routing problems (VRP) with time windows in the newspaper distribution industry using the Differential Evolution (DE) algorithm. The goal is to enhance the efficiency of the distribution channels, ensuring timely deliveries while minimizing costs. Tan, S. Y., et al. [28] reviewed recent literature on Vehicle Routing Problems (VRPs) published between 2019 and August 2021, using a taxonomic framework. It categorizes VRP models into vehicle-related, customer-related, and depot-related models, and classifies solution algorithms into exact, meta-heuristic algorithms and heuristic. The study provides classification table available online, aiming to aid future researchers in navigating the extensive body of literature and understanding current trends and methodologies in VRP research [7]. Tunnisaki, F. [29] aimed to establish a mathematical model for the Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) for the distribution of 3 kg LPG gas and solve it using the Clarke and Wright Savings method [8]. Feng, Y., et al. [13] addressed the limitations of conventional vehicle routing problems (VRP) that assume fixed or time-dependent travel speeds. It proposes a mathematical model to calculate expected fuel consumption and fixed vehicle costs by considering average speeds that follow a normal distribution, accounting for uncertainties such as weather and traffic conditions.

Problem identification: Using matrix saving techniques to process the available data, calculate the optimal route to minimize transportation expenses and the best way to go between nearest neighbor, the farthest insert, and the insert nearest. as well as the study's scientific goal. The goal is to use matrix saving to find the optimal distribution route that will minimize transportation costs.

Transportation activities can be defined as the movement of goods from one place to another to reach the customer. This is because the manufactured goods are used in the same location. Transport is a routine process aimed at reducing a business's expenses. Choosing the timetable and shipping route between locations is one of the most crucial factors in product distribution. Once the delivery location is determined, the trucks will be allocated in a highly meaningful way, with each truck going to a certain site or store. This process is called the saving matrix method, and it begins with the computation of savings [27].

El Fahmi (2013) defines the saving matrix approach as a matrix that holds the lists of savings obtained by integrating two agents into a single vehicle, in this case a truck. By considering the current constraints, the savings matrix approach minimizes time, expenses, or distance. This method's goal is to select the optimal routing and vehicle assignment.

1.1 Supply Chain Network

Supply-chain networks (SCNs) are an advancement above traditional supply chain. A supply-chain network is created when a company with a basic supply chain expands it into a more complex structure with a higher degree of interdependence and connectivity with other organizations, thanks to the rapid growth of technology. Supply networks and supply chains connect businesses to better serve the end user by describing the flow and movement of information and products. A supply chain network illustrates the connections between businesses and the movement of products and information between specific connections [2]. The movement of information and resources between organizations may be demonstrated, as well as the relationships between them, using a supply-chain network. These days, supply-chain networks are often organized around five main components: transportation assets, manufacturing centers, demand zones, external suppliers, and distribution centers (DCs) [10].

1.2 Closed Loop Supply Chain Network (CLSCN)

Closed-loop supply chain (CLSC) has received tremendous academic and business attention in recent years as social responsibility, environmental concerns and strict international regulations increased [5]. The CLSC combines forward and reversing supply chains to wholly cover the product life cycle from cradle to grave. Forward supply chain includes the logistic activities all the way from the raw material suppliers to the consumer and the reverse supply chain includes collecting, reproducing, recycling and disposal activities. When closed-loop logistic management adheres to conservation regulations throughout the materials' life cycle, it may ensure the least amount of material waste [14], [22]. The realization that the forward and reverse supply chains must be handled collaboratively has led to a widespread interest in the notion of CLSC. The way forward and reverse supply chain networks are configured to affect each other's performance significantly [19].

1.3 Saving Matrix Approach (SMA)

The saving matrix method is a method used to determine the best route by considering the distance, the number of vehicles to be used, and the number of products that can be loaded by vehicles in product delivery to consumers so that the distribution process is optimal.

The CLSCNP is a most well-researched problem including the problems of combinatorial optimization. CLSCNPs are generally regarded as a problem with static routing. This work studies the problem of Multi-Capacitated CLSCN Problem [2], [15], [16]. With minimum cost and time, every customer wants to get any product through online mode, so the company also keeps the same effort that the products reach the customer in the minimum possible time. The CLSCNP consists of optimizing the sum of total cost of the scheduled possible paths and expected failures[1].

The rest of this literature is designed as follows: section 2 gives some literature review; section 3 describes the problem description including the mathematic model; section 4 introduces Methodology; section 5 provides the solution process to find the optimal solution through feasible solutions; section 6 mentions verification test with MRC, while the conclusion is given in section 7.

2. Review of Literature

In an unpredictable context, Fallah, H. et al. [12] investigated the rivalry between two closed-loop supply chains that comprised producers, merchants, and recyclers. This paper's main objective is to examine how two closed-loop supply chains' profitability, demands, and returns are affected by simultaneous and Stackelberg contests. The best answers are found under uncertain conditions by using a game theoretical strategy strengthened by possibility theory.

A stochastic robust optimization model was given by Jabbar Zadeh, A. et al. [16] for the purpose of designing a CLSCN that can withstand disturbances and still function well. Lateral transshipment is a reactive method that the suggested model may consider managing operational and interruption concerns. The goal is to identify lateral transshipment amounts and facility locations that minimize the overall cost of the supply chain under various interruption scenarios. Some reviews based on recent SCM are given in [Table 1]

Authors name	Network Problem	Optimization technique	Objective	Area
Bhuranda, L. K. Rizwanullah [5]	multi-capacitated vehicle routing problem	Revised Saving Matrix approach	Min. cost and max. profit	Transportation

Rosanti, A. A. et al. [23]	delivery problem in courier service company in Surakarta	Saving matrix approach	Minimize total distribution cost	courier services industry
Jabbarzadeh, A. et al. [16]	CLSCN	Lagrangian relaxation algorithm	minimize the total supply chain cost	A case study of glass the industry
Ramezani, M. et al. [22]	CLSCN	financial approach	myopic performance indicators (as profit or cost)	Logistics
Fallah, H. et al. [12]	CLSCN design under uncertainty	game theoretic approach	investigate the impact between two supply chains	A real industrial case

A financial method to modelling a CLSC architecture that explicitly considers financial components as exogenous variables was provided by Ramezani, M. et al. [22]. In addition to making tactical judgements, the model also makes strategic ones. This work primarily adds value to the supply chain planning literature by including the financial components (current and fixed assets and liabilities) together with a set of budgetary limitations that reflect cash balances, debt, securities, payment delays, and discounts.

Rosanti, A. et al. [23] have found solutions to delivery issues for courier services, allowing a minimal distribution cost to be calculated by considering the vehicle's capacity, service duration, and cargo arrangement. Savings of 3–25% were gained in the distribution cost calculation process by employing the saving matrix approach. Using a range of alternatives, Singh, G. et al. [26] created a desired method for selecting an electric car. This study aims to develop a testing procedure that is correlated with the analytical hierarchy process (AHP) and a technique for ranking performance by similarity to ideal solution (TOPSIS). These tools will be helpful to vehicle company employees in their selection of the best electric vehicle in unclear environments.

A robust optimisation approach was presented by Pishvae, M. S. et al. [19] to address the intrinsic uncertainty of input data in a CLSCN design problem. Initially, a CLSCN design model is created using deterministic mixed-integer linear programming. Subsequently, utilising the latest developments in robust optimisation theory, the robust equivalent of the suggested mixed-integer linear programming model is introduced [6].

3. Problem Description Including Mathematical Model

There are so many reputable businesses that have a great number of customers. Any kind of company is an unbelievably disruptive model of social e-commerce aimed at reinventing retail for the next billion generations to generation. The pick-up and delivery of products at the minimum waiting time is therefore the most important issue for the company. This paper discusses the company that supplies customers in certain areas with almost all goods with minimum time and cost. It is an online buying platform for purchasing products of daily real-life. It has 120 vehicles used in the minimum time to pick up and deliver the products to their homes. For the route of the respective vehicle, the number of pick-up and delivery stations are different [30]. The company's platform offers cheaper rates than wholesale and makes purchases easy with just a couple of clicks on its application, thereby enabling its customers to find the best deals for daily use items. Each vehicle has a distinct capacity that is finite. A reasonable way to enforce this restriction is to require that vehicle capacity is not exceeded by the expected demand for the route.

Given a network which has certain weight value, let us assume that the vertices be $\{1, 2, n\}$ where node 1 represents the source point of the company and set $V = \{2, 3, n\}$ indicates the collections of customer's locations. The travelled length $d(i, j)$ is symmetric, and they fulfill the triangle inequality [5], [9]:

$$d(i, j) \leq d(i, k) + d(k, j)$$

Let us assume that vehicle's capacity is Q which is an integer. Let C_i and D_i , $i = 2, 3, n$ be the stochastic variables that define the customer 'i' and demand of the client 'i'. Let us consider that the probabilistic distributions of D_i are non-fuzzy and know [3].

Let $p_i(k) = Pr\{D_i = k\}$, $i = 2, 3, n$ and $k = 1, 2, K$

Furthermore, let us assume that $K \leq Q$, i.e., no single place has demand that exceeds Q capacity. We further assume that the requirements are autonomous. There are $(K+1)^n$ possible realizations of the demands and the customers have also possible realizations $(K+1)^n$. Therefore, $(K+1)^{2n}$ possible instances of the issue. If we solve the underlying VRP optimally at every problem instance. i.e., we find the route that minimizes the total distance travelled, $RVRP(D_2, D_3, D_n)$ be the optimal route length if the demand is D_2, D_3, D_n . Note that since the demand and customer are stochastic these are random variables [3].

4. Method of Research

The research method used in this research is the data collection stage and followed by data processing. The activities of data collection and processing are discussed below.

4.1. Data Collection

Data collection methods used are direct observation in the form of data collection and interviews to the freight forwarding industry, for this case study, the PT KAI Kalog branch office is in the city of Surakarta and then some data will be used in this study, including number of nodes, vehicle number, demand amount, route, delivery time and service time.

4.2. Data Processing

The Saving Matrix approach is utilized for data processing to find out the optimal cost for delivery services. The Saving Matrix method has 3 steps [23]:

- a) First step: Identify the distance matrix, at this stage the data needed is distance data from the distribution center to each consumer and distance between consumers. The data is the output data from Google Maps Earth software with input in the form of addresses of each consumer and distribution center.
- b) Second step: Determine the Saving Matrix if a merger is made for distribution to many locations, savings will be realized at this point. The following equation shows the formula for calculating the amount of savings:

$$S(x, y) = J(DC, x) + J(DC, y) - J(x, y)$$

Here,

$$S(x, y) = \text{Distance Saving}$$

$$J = \text{Distance}$$

$$DC = \text{Distribution Center}$$

$$x = \text{First consumer}$$

y = Second consumer

After obtaining a savings matrix, then sort results of saving the distance from the largest to the smallest. Through the stages of sequencing the amount of savings is then generated by the sequence of consumers. Determination of the sequence in one route is to use the Nearest Neighbor procedure which is a route made by adding the nearest customer from the last point visited by the vehicle. Iteration starts from DC, then the journey goes to the customer closest to DC, and so on.

- c) Third step: Allocate consumers to vehicles, at this stage the division of the route is carried out with restrictions in the form of vehicle capacity, service time and vehicle capacity layout. After obtaining travel routes, the next step is to calculate the total cost of all shipping combinations and compare them with the actual situation.

5. Solution Progress

The algorithm for optimizing the route is Revised Savings Matrix Algorithm. The steps of Savings Matrix Method are following [Table 2]:

Table 2. Capacities and number of vehicles with quantities of products

S. No.	Name of the vehicle	Quantity of product 1	Quantity of product 2	Quantity of product 3	Capacity of each vehicle	No. of the vehicle
1.	Bike	150	280	120	600	20
2.	Pick-up	300	800	300	1500	22
3.	Cargo Truck	500	900	400	2000	08
4.	TATA-407	600	400	800	1800	25
5.	Magic	200	500	200	1000	14
6.	Tempo	400	600	600	1600	31
						Total = 120

Table 3. Coordinates of customer wise place

S. No.	Cust wise place	X COORDINATES	Y COORDINATES	Demand for Each Place
	DC	00	00	000
1.	Cust 1	04	-05	420
2.	Cust 2	-02	03	340
3.	Cust 3	05	12	510
4.	Cust 4	13	16	120
5.	Cust 5	-09	10	260
6.	Cust 6	12	-01	730
7.	Cust 7	01	08	910
8.	Cust 8	-12	-07	810
9.	Cust 9	-11	05	450
10.	Cust 10	08	15	320

11.	Cust 11	03	11	460
12.	Cust 12	-11	12	840

5.1. Identify distance matrix

For the twelve delivery centers, the distance matrix is calculated using eqn.1, as shown above in [Table 3]. Table one is obtained from a drawing based on distance and the area's road map. The first stage in determining the best possible distribution path should be to get the company's warehouse position and location across to the customers' businesses. The business is not used separately, so the location of the company's warehouse is the company it's self's location. Clients in this study were used as a sample, amounting to 12 consumers. The position of each location is gained using the map. The position of each location shown on the X and Y axis scale can be obtained from existing maps with center co-ordinates (0.0), which is the location of the company.

The distance between two several places, that is the location of A (X_1, Y_1) and B (X_2, Y_2), to be evaluated by the general distance formula:

$$D(A, B) = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \tag{1}$$

The possible travel length from cust.1 to cust.2 is D (1,2). Therefore

$$D(1,2) = \sqrt{(36 + 64)} = 10 \quad D(2,3) = \sqrt{(49 + 81)} = 11.40$$

Next, the distance between cust.7 and cust.9 is D (7,9)

$$D(7,9) = \sqrt{(144 + 09)} = 12.36 \quad D(5,10) = \sqrt{(289 + 25)} = 17.72$$

Here are a few values of possible travelled length (1 to 12) in [Table 4] were calculated by the general distance formula. Further we consider the average velocity 40 km/h for each vehicle and find a period using distance matrix [Table 5].

Table 4: Distance Matrix

	DC 0	cust 1	cust 2	cust 3	cust 4	cust 5	cust 6	cust 7	cust 8	cust 9	cust 10	cust 11	cust 12
DC 0	00	6.40	3.60	13.00	19.79	13.45	12.04	8.05	13.89	12.08	17.00	11.40	16.27
cust 1	6.40	00	10.00	17.02	22.84	19.84	8.94	13.34	16.12	18.02	20.39	16.03	22.67
cust 2	3.60	10.00	00	11.40	19.84	9.89	14.56	5.83	14.14	9.21	15.62	9.43	12.72
cust 3	13.00	17.02	11.40	00	8.94	14.14	14.76	5.65	25.49	17.46	4.24	6.32	16.00
cust 4	19.79	22.84	19.84	8.94	00	22.80	17.02	14.42	33.97	26.41	5.09	11.18	24.33
cust 5	13.45	19.84	9.89	14.14	22.80	00	23.70	10.19	17.26	5.38	17.72	12.04	2.82
cust 6	12.04	8.94	14.56	14.76	17.02	23.70	00	13.03	25.29	23.76	16.49	15.00	26.41
cust 7	8.05	13.34	5.83	5.65	14.42	10.19	13.03	00	19.84	12.36	9.89	3.60	12.64
cust 8	13.89	16.12	14.14	25.49	33.97	17.26	25.29	19.84	00	12.04	29.73	23.43	19.02
cust 9	12.08	18.02	9.21	17.46	26.41	5.38	23.76	12.36	12.04	00	21.47	15.23	7.00
cust 10	17.00	20.39	15.62	4.24	5.09	17.72	16.49	9.89	29.73	21.47	00	6.40	16.23
cust 11	11.40	16.03	9.43	6.32	11.18	12.04	15.00	3.60	23.43	15.23	6.40	00	14.03
cust 12	16.27	22.67	12.72	16.00	24.33	2.82	26.41	12.64	19.02	7.00	16.23	14.03	00

Table 5: Time Period (in minutes) Matrix (Velocity-40 km/h)

	DC 0	cust 1	cust 2	cust 3	cust 4	cust 5	cust 6	cust 7	cust 8	cust 9	cust 10	cust 11	cust 12
DC 0	00	9.60	5.40	19.50	29.68	20.17	18.06	12.07	20.83	18.12	25.50	17.10	24.40
cust 1		00	15.00	25.53	34.26	29.76	13.41	20.01	24.18	27.03	30.58	24.04	34.00
cust 2			00	17.10	29.76	14.83	21.84	8.74	21.21	13.81	23.43	14.14	19.08
cust 3				00	13.41	21.21	22.14	8.47	38.23	26.19	6.36	9.48	24.00
cust 4					00	34.20	25.53	21.63	50.95	39.61	7.63	16.77	36.49
cust 5						00	35.55	15.85	25.89	8.07	26.58	18.06	4.23
cust 6							00	19.54	37.93	35.59	24.73	22.50	39.61
cust 7								00	29.76	18.54	14.83	5.40	18.96
cust 8									00	18.06	44.59	35.14	28.53
cust 9										00	32.20	22.84	10.50
cust 10											00	9.60	24.34
cust 11												00	21.04
cust 12													00

5.2. Identify distance matrix

There have been transport facilities in the form of 120 vehicles classified into six vehicles, such as Bike, Pick-up, Magic, Cargo Truck, Tempo. Each conveyance has a different capacity in which Magic has capability of 1000 Kg. The initial path of the company has 12 routes. The initial path for the company is depot-client-depot [Table 6]. The data on the average path of product distribution along with path length data on each path are following:

Table 6: Initial and distance route of the Company

S. No.	Consumer	Distance
1.	0-1-0	6.40
2.	0-2-0	3.60
3.	0-3-0	13.00
4.	0-4-0	19.79
5.	0-5-0	13.45
6.	0-6-0	12.04
7.	0-7-0	8.05
8.	0-8-0	13.89
9.	0-9-0	12.08
10.	0-10-0	17.00
11.	0-11-0	11.40
12.	0-12-0	16.27

5.3 Identify savings Matrix

We'll determine the sum of the saving matrix from the distance matrix calculation that was done before. Every single delivery of the goods is consumed by visiting some. In [Table 7] we will obtain the value of the savings by the formula which are following [20]:

$$S(x, y) = D(0, x) + D(0, y) - D(x, y) \tag{2}$$

Table 7: Saving Matrix

	cust 1	cust 2	cust 3	cust 4	cust 5	cust 6	cust 7	cust 8	cust 9	cust 10	cust 11	cust 12
cust 1	0											
cust 2	00	0										
cust 3	2.38	5.20	0									
cust 4	3.35	3.55	23.85	0								
cust 5	0.01	7.16	12.31	10.44	0							
cust 6	9.50	1.08	10.28	14.81	2.42	0						
cust 7	1.11	5.82	15.40	13.42	11.31	7.06	0					
cust 8	4.17	3.35	1.40	2.29	10.08	0.64	2.10	0				
cust 9	0.46	6.47	7.62	5.46	20.15	0.36	7.77	13.93	0			
cust 10	3.01	4.98	25.76	29.70	12.73	12.55	15.16	1.16	7.61	0		
cust 11	1.77	5.57	18.08	18.01	12.81	8.44	15.85	1.86	8.25	22.00	0	
cust 12	00	7.15	13.27	9.73	26.90	1.90	11.68	11.14	21.35	17.04	13.64	0

5.4. Rank Savings

Ranking the savings is the next step. The concept is to combine the two customers into the same vehicle, the combination of which provides the highest savings [18].

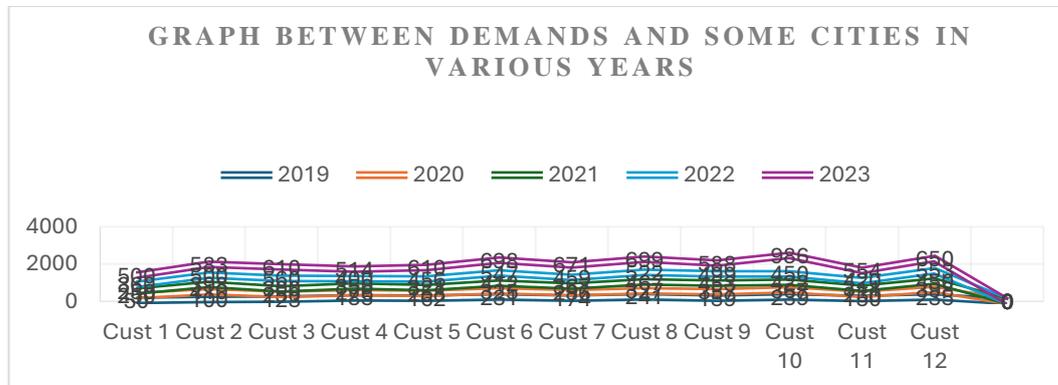
- We are ranked as the savings in order from high to low. The values of 29.70 and 7.63 are the highest saving and time which are obtained from the savings matrix and period matrix shown on the previous slides by combining cust 4 and cust 10 with the same vehicle in [Table 8].
- The next highest savings of 26.90 will be achieved by merging cust 5 and cust 12 customers with the same vehicle.
- Similarly, we are ranked as the other savings with respective time periods and displayed on the next slide.

Table 8: Rank Matrix

S. No.	Time Period	Cost of Saving Matrix	Pairs of Places corresponding to the cost	S. No.	Time Period	Cost of Saving Matrix	Pairs of Places corresponding to the cost
1.	7.63	29.70	(cust 4, cust 10)	35.	32.20	7.61	(cust 9, cust 10)
2.	4.23	26.90	(cust 5, cust 12)	36.	14.83	7.16	(cust 2, cust 5)
3.	6.36	25.76	(cust 3, cust 10)	37.	19.08	7.15	(cust 2, cust 12)
4.	13.41	23.85	(cust 3, cust 4)	38.	19.54	7.06	(cust 6, cust 7)
5.	9.60	22.00	(cust 10, cust 11)	39.	13.81	6.47	(cust 2, cust 9)
6.	10.50	21.35	(cust 9, cust 12)	40.	8.74	5.82	(cust 2, cust 7)
7.	8.07	20.15	(cust 5, cust 9)	41.	14.14	5.57	(cust 2, cust 11)
8.	9.48	18.08	(cust 3, cust 11)	42.	39.61	5.46	(cust 4, cust 9)
9.	16.77	18.01	(cust 4, cust 11)	43.	17.10	5.20	(cust 2, cust 3)
10.	24.34	17.04	(cust 10, cust 12)	44.	23.43	4.98	(cust 2, cust 10)
11.	5.40	15.85	(cust 7, cust 11)	45.	20.83	4.17	(cust 1, cust 8)
12.	8.47	15.40	(cust 3, cust 7)	46.	29.76	3.55	(cust 2, cust 4)
13.	14.83	15.16	(cust 7, cust 10)	47.	29.68	3.35	(cust 1, cust 4)
14.	25.53	14.81	(cust 4, cust 6)	48.	21.21	3.35	(cust 2, cust 8)
15.	18.06	13.93	(cust 8, cust 9)	49.	25.50	3.01	(cust 1, cust 10)
16.	21.04	13.64	(cust 11, cust 12)	50.	35.55	2.42	(cust 5, cust 6)
17.	21.63	13.42	(cust 4, cust 7)	51.	19.50	2.38	(cust 1, cust 3)
18.	24.00	13.27	(cust 3, cust 12)	52.	50.95	2.29	(cust 4, cust 8)
19.	18.06	12.81	(cust 5, cust 11)	53.	29.76	2.10	(cust 7, cust 8)
20.	26.58	12.73	(cust 5, cust 10)	54.	39.61	1.90	(cust 6, cust 12)
21.	24.73	12.55	(cust 6, cust 10)	55.	35.14	1.86	(cust 8, cust 11)
22.	21.21	12.31	(cust 3, cust 5)	56.	17.10	1.77	(cust 1, cust 11)
23.	18.96	11.68	(cust 7, cust 12)	57.	38.23	1.40	(cust 3, cust 8)
24.	15.85	11.31	(cust 5, cust 7)	58.	44.59	1.16	(cust 8, cust 10)
25.	28.53	11.14	(cust 8, cust 12)	59.	12.07	1.11	(cust 1, cust 7)
26.	34.20	10.44	(cust 4, cust 5)	60.	21.84	1.08	(cust 2, cust 6)
27.	22.14	10.28	(cust 3, cust 6)	61.	37.93	0.64	(cust 6, cust 8)
28.	25.89	10.08	(cust 5, cust 8)	62.	18.12	0.46	(cust 1, cust 9)
29.	36.49	9.73	(cust 4, cust 12)	63.	35.59	0.36	(cust 6, cust 9)
30.	18.06	9.50	(cust 1, cust 6)	64.	20.17	0.01	(cust 1, cust 5)
31.	22.50	8.44	(cust 6, cust 11)	65.	24.40	0.00	(cust 1, cust 12)
32.	22.84	8.25	(cust 9, cust 11)				
33.	18.54	7.77	(cust 7, cust 9)				
34.	26.19	7.62	(cust 3, cust 9)				

6. Verification Test with MRC (Moving Range Chart)

To determine if the forecasting technique being employed is indicative of the data, verification tests for forecasting results are required. Furthermore, the value of the actual data collection should be compared with the predicted values of an application, the Moving Range Chart is used [Graph 1].



Graph 1: Comparison of demands in various places

The graph above makes it clear that neither the top control limit nor the lower control limit really contains any data. Thus, it can be said that the Linear Regression method is appropriate or representative of this research [17].

It is possible to perform customer allocation processes by referring to the table of the savings matrix. The allocation of each client could be merged into one route, up to the limit of the transport capability of the firm. The combiner starts with the greatest value for savings. We will start with the 29.70 savings cost, which is the savings from the merger of cust.4 client and cust.10 client. The value of each client's burden is 120 Kg and 320 Kg, while the total load is 600 Kg. The total is still lower than the optimum transport capacity limit, which is 1500 kg. Consumer 4 and consumer 10 join Route 1, and so on, so the merger is feasible. Next is to sort customers along a defined path. The aim of this sorting is, in principle, to optimize the travel length of the conveyance. The possible best path determination is performed using the Nearest Insert process. The Nearest Insert method is done by selecting clients who produce additional minimum distances if inserted into an existing route. At first, it had only a zero-distance journey from the warehouse to the warehouse, then by adding each consumer to the current route, it was seen how much distance took place.

The results are as follows:

0-4-0 → 19.79
 0-10-0 → 17.00

Because the minimum distance generated from both is 17.00 kilometers, the consumers visited are 10 consumers. 0-10-4-0 is the route formed, and so on.

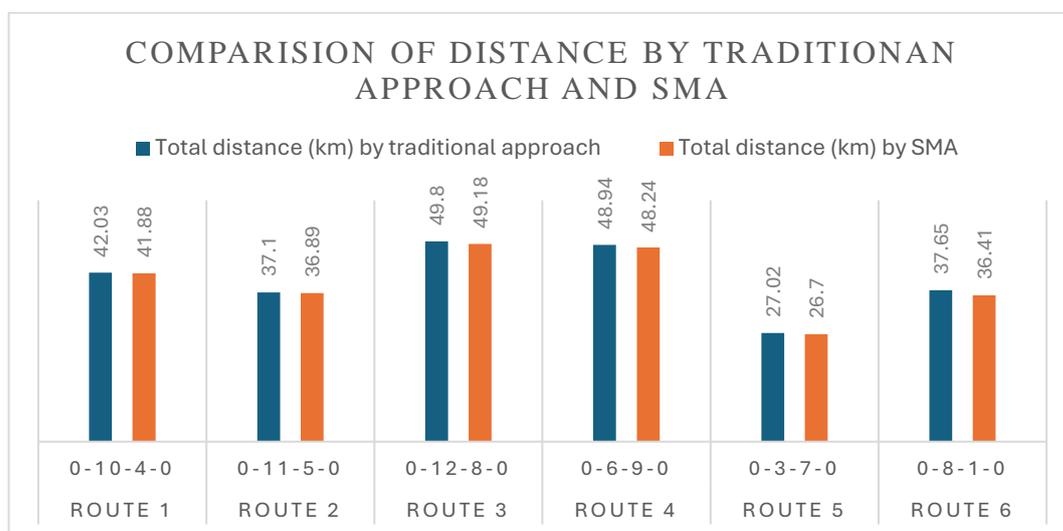
6.1. Proposed Product Distribution Routes

There are 6 routes, limited by the number of routes to be taken by the company, from the results of the processing and analysis of the above data. Over the next year, to distribute its products. Using the Revised Saving Matrix method, the path is grouped according to data processing results. Furthermore, the shorter the total distance travelled, the shorter the time spent [Graph 2, 3].

The suggested analysis of the company's product distribution route is as follows in [Table 9, 10]:

Table 9: Comparison of optimal results (distance) with total order load

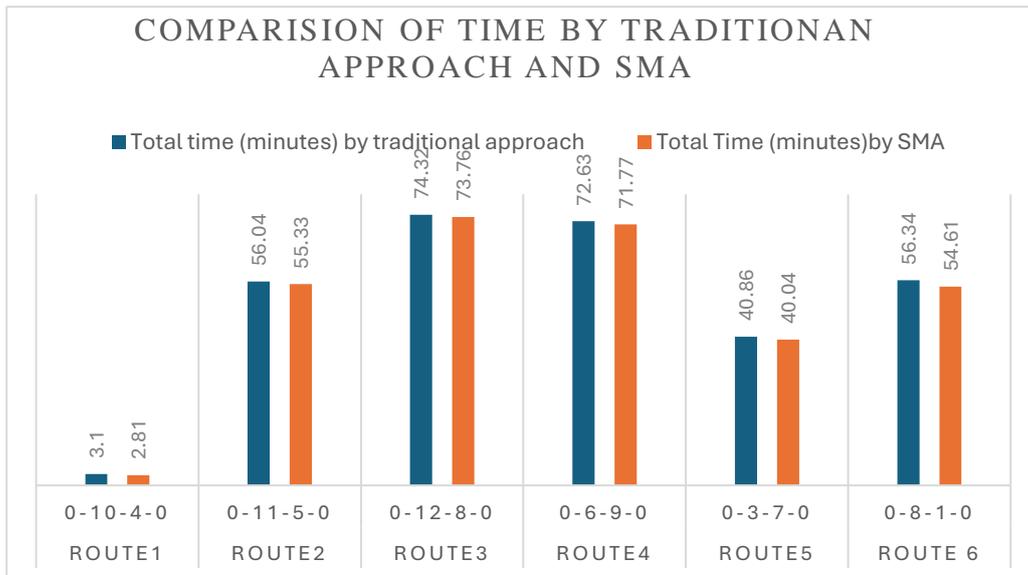
S. No.	Route	Delivery Schedule	Total distance (km) by traditional approach	Total distance (km) by SMA	Total order Load (Kg.)	Conveyance
1.	ROUTE 1	0-10-4-0	42.03	41.88	550	Bike
2.	ROUTE 2	0-11-5-0	37.10	36.89	1150	Pick-up
3.	ROUTE 3	0-12-8-0	49.80	49.18	1315	Cargo Truck
4.	ROUTE 4	0-6-9-0	48.94	48.24	1070	TATA-407
5.	ROUTE 5	0-3-7-0	27.02	26.70	720	Magic
6.	ROUTE 6	0-8-1-0	37.65	36.41	1310	Tempo



Graph 2: Comparison of distance by traditional approach and SMA

Table 10: Comparison of optimal results (time-period)

S. No.	Route	Delivery Schedule	Total time (minutes) by traditional approach	Total Time (minutes) by SMA	Percentage of returned products (%)
1.	ROUTE1	0-10-4-0	3.10	2.81	1.00 %
2.	ROUTE2	0-11-5-0	56.04	55.33	1.75%
3.	ROUTE3	0-12-8-0	74.32	73.76	2%
4.	ROUTE4	0-6-9-0	72.63	71.77	1.20%
5.	ROUTE5	0-3-7-0	40.86	40.04	2.00%
6.	ROUTE 6	0-8-1-0	56.34	54.61	1.89%

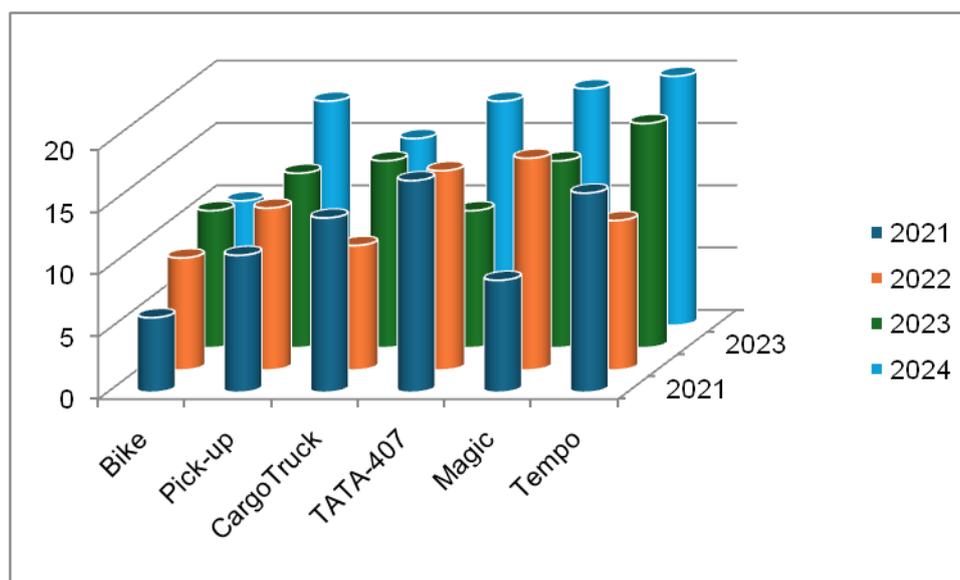


Graph 3: Comparison of time by traditional approach and SMA

In various years returned products from costumers to collection centers are given in Table 11 and Graph 4.

Table 11: Variation of returned products in various years

S. No.	Name of the vehicle	Quantity of product 1+2+3			
		Year of returned products			
		2021	2022	2023	2024
1	Bike	6	9	11	10
2	Pick-up	11	13	14	18
3	Cargo Truck	14	10	15	15
4	TATA-407	17	16	11	18
5	Magic	9	17	15	19
6	Tempo	16	12	18	20



Graph 4: Variation of returned products in various years

7. Conclusion

This study aims to solve delivery problems so that a minimum distribution cost is obtained by considering the vehicle capacity, service time and layout of goods in the vehicle. These research results can be applied to many industries which have closed-loop supply chain structures such as electrical, plastic, petrochemical, medical instruments, etc. Our findings indicate that our approach (SMA) performs better than our traditional approach. However, the models proposed in this paper can be also extended for future research by making improvements in different aspects. For example, we considered a linear price sensitive demand and return in this paper; other types of demand and return functions such as non-linear ones, can be considered based on the marketing expenditures, recycling costs, etc.

Author contributions: Guman Singh: Conceptualization, Writing of original draft, Methodology, , Formal analysis, Data curation, Validation and writing–original draft preparation. Mohammad Rizwanullah (M.R.): Formal analysis, software application, Writing–review and editing, Supervision, Project administration. Jay Chnadra Yadav: Writing–review, editing and analysis.

Acknowledgments

Data availability All the data utilized for analysis is available in manuscript.

Declarations:

Ethics approval and consent to participate: No human/animal was used in the study and not based on any clinical trial

Competing interests: The authors declare no competing interests.

Conflicts of Interest: The authors claim to have no conflict of interest.

References

- [1] N. A. F. P. Adam, I. P. Sari, A. Tasya, and W. Sutopo, “Determination of Routes for Daily Newspaper Product Distribution with Saving Matrix Methods”, *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 943, no. 1, (2020), pp. 012040. DOI: 10.1088/1757-899X/943/1/012040.
- [2] M. Afshar, S. Y. Hadji Molana, and B. Rahmani Parchicolaie, “A multi objective optimization model for multi-commodity closed-loop supply chain network considering disruption risk”, *Int. J. Eng.*, vol. 37, no. 4, (2024), pp. 646–661. DOI: 10.5829/ije.2024.37.04a.07.
- [3] M. A. H. Akhand, T. Sultana, M. I. Shuvo, and Al-Mahmud, “Constructive and Clustering Methods to Solve Vehicle Routing Problem”, *Orient. J. Comput. Sci. Technol.*, vol. 10, no. 3, (2017), pp. 549–562.
- [4] M. Altabeeb, A. M. Mohsen, L. Abualigah, and A. Ghallab, “Solving Capacitated Vehicle Routing Problem Using Cooperative Firefly Algorithm”, *Appl. Soft Comput.*, vol. 108, (2021), pp. 107403. <https://doi.org/10.1016/j.asoc.2021.107403>
- [5] L. K. Bhuranda, M. Rizwanullah, A. K. Sharma, K. Gautam, and Y. Chawla, “Stochastic optimization of multi-capacitated vehicle routing problem with pickup and delivery using saving matrix algorithm”, *J. Inf. Optim. Sci.*, vol. 44, no. 3, (2023), pp. 541–552.

- [6] H. M. Bidhandi, R. M. Yusuff, M. M. H. M. Ahmad, and M. R. A. Bakar, "Development of a new approach for deterministic supply chain network design", *Eur. J. Oper. Res.*, vol. 198, no. 1, (2009), pp. 121–128. <https://doi.org/10.1016/j.ejor.2008.07.034>
- [7] O. Braysy and M. Gendreau, "Vehicle Routing Problem with Time Windows, Part 1: Construction and local Route Search Algorithm", *Inform. Syst. Oper. Res.*, vol. 39, (2005), pp. 104–118.
- [8] C. Do, L. Martins, P. Hirsch, and A. A. Juan, "Agile Optimization of a Two-Echelon Vehicle Routing Problem with Pickup and Delivery", *Int. Trans. Oper. Res.*, vol. 28, (2021), pp. 201–221. <https://doi.org/10.1111/itor.12796>
- [9] G. Easwaran and H. Üster, "A closed-loop supply chain network design problem with integrated forward and reverse channel decisions", *IIE Trans.*, vol. 42, no. 11, (2010), pp. 779–792. <https://doi.org/10.1080/0740817X.2010.504689>
- [10] S. Ebrahimi, M. Fathian, and S. M. Hosseini-Motlagh, "Coordinating Location Information Sharing Strategy in a Sustainable Dual-Channel Closed-Loop Supply Chain", *IEEE Trans. Syst. Man Cybern. Syst.*, vol. 54, no. 6, (2024), pp. 3525–3533. <https://doi.org/10.1109/TSMC.2024.336243>
- [11] E. F. F. El Fahmi, "Studi Komparasi Penyelesaian Capacitated Vehicle Routing Problem (CVRP) dengan Metode Saving Matrix dan Generalized Assignment", *J. Mahasiswa Mat.*, vol. 1, no. 4, (2013). <http://repository.ub.ac.id/id/eprint/153484>
- [12] H. Fallah, H. Eskandari, and M. S. Pishvae, "Competitive closed-loop supply chain network design under uncertainty", *J. Manuf. Syst.*, vol. 37, (2015), pp. 649–661. <https://doi.org/10.1016/j.jmsy.2015.01.005>
- [13] Y. Feng, R. Q. Zhang, and G. Jia, "Vehicle routing problems with fuel consumption and stochastic travel speeds", *Math. Probl. Eng.*, vol. 2017, no. 1, (2017), p. 6329203. <https://doi.org/10.1155/2017/6329203>
- [14] Y. Gao, S. Lu, H. Cheng, and X. Liu, "Data-driven robust optimization of dual-channel closed-loop supply chain network design considering uncertain demand and carbon cap-and-trade policy", *Comput. Ind. Eng.*, vol. 187, (2024), p. 109811. <https://doi.org/10.1016/j.cie.2023.109811>
- [15] M. Gmira, M. Gendreau, A. Lodi, and J.-Y. Potvin, "Tabu Search for the Time-Dependent Vehicle Routing Problem with Time Windows on a Road Network", *Eur. J. Oper. Res.*, vol. 288, (2021), pp. 129–140. <https://doi.org/10.1016/j.ejor.2020.05.041>
- [16] Jabbarzadeh, M. Haughton, and A. Khosrojerdi, "Closed-loop supply chain network design under disruption risks: A robust approach with real world application", *Comput. Ind. Eng.*, vol. 116, (2018), pp. 178–191. <https://doi.org/10.1016/j.cie.2017.12.025>
- [17] F. Mohammed, S. Z. Selim, A. Hassan, and M. N. Syed, "Multi-period planning of closed-loop supply chain with carbon policies under uncertainty", *Transp. Res. D: Transp. Environ.*, vol. 51, (2017), pp. 146–172. <https://doi.org/10.1016/j.trd.2016.10.033>
- [18] E. Ozceylan, "Simultaneous optimization of closed-and open-loop supply chain networks with common components", *J. Manuf. Syst.*, vol. 41, (2016), pp. 143–156. <https://doi.org/10.1016/j.jmsy.2016.08.008>

- [19] M. S. Pishvae, M. Rabbani, and S. A. Torabi, "A robust optimization approach to closed-loop supply chain network design under uncertainty", *Appl. Math. Model.*, vol. 35, no. 2, (2011), pp. 637–649. <https://doi.org/10.1016/j.apm.2010.07.013>
- [20] F. Pulansari, I. Nugraha, and S. Dewi, "Determining the shortest route of distribution to reduce environmental emissions using saving matrix and nearest neighbor methods", *Nusant. Sci. Technol. Proc.*, (2021), pp. 218–225. <https://doi.org/10.11594/nstp.2021.1435>
- [21] R. Putranto and R. Hendayani, "Distribution route optimization by utilizing saving matrix: case study in Limas Raga Inti Bandung", *J. Corp. Gov. Insur. Risk Manag.*, vol. 1, no. 2, (2014), pp. 162–180.
- [22] M. Ramezani, A. M. Kimiagari, and B. Karimi, "Closed-loop supply chain network design: A financial approach", *Appl. Math. Model.*, vol. 38, no. 15–16, (2014), pp. 4099–4119. <https://doi.org/10.1016/j.apm.2014.02.004>.
- [23] A. Rosanti, W. Sutopo, and M. Hisjam, "Implementation of saving matrix to determine distribution route of Kalog Express Surakarta", *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 495, no. 1, (2019), p. 012025. DOI: 10.1088/1757-899X/495/1/012025.
- [24] W. Saputra, W. Sutopo, and M. Hisjam, "Optimization of distribution channel vehicle routing problem with time windows using differential evolution algorithm: A case study in newspaper industry", *Asia-Pac. Manag. Bus. Appl.*, vol. 10, (2017), pp. 1–10.
- [25] H. Sarjono, "Determination of best route to minimize transportation costs using nearest neighbor procedure", *Appl. Math. Sci.*, vol. 8, no. 62, (2014), pp. 3063–3074. <https://doi.org/10.12988/ams.2014.43225>
- [26] G. Singh and M. Rizwanullah, "A sustainable supplier selection in green supply chain framework using fuzzy TOPSIS method", *Glob. Stoch. Anal.*, vol. 11, no. 1, (2024), pp. 15–25.
- [27] S. Chopra and P. Meindl, *Supply Chain Management: Strategy, Planning, and Operation*, New Jersey, USA: Pearson Prentice Hall, (2010). DOI: <https://10.1016/j.pursup.2008.08.001>
- [28] S. Y. Tan and W. C. Yeh, "The vehicle routing problem: State-of-the-art classification and review", *Appl. Sci.*, vol. 11, no. 21, (2021), pp. 10295. <https://doi.org/10.3390/app112110295>
- [29] F. Tunnisaki, "Clarke and Wright Savings algorithm as solutions vehicle routing problem with simultaneous pickup delivery (VRPSPD)", *J. Phys.: Conf. Ser.*, vol. 2421, no. 1, (2023), pp. 012045. DOI: <https://10.1088/1742-6596/2421/1/012045>
- [30] N. A. Wassn and G. Nagy, "Vehicle Routing Problem with Deliveries and Pickups: Modeling Issues and Meta-Heuristics Solution Approaches", *Int. J. Transp.*, vol. 1, (2014), pp. 95–110. <http://dx.doi.org/10.14257/ijt.2014.2.1.06>
- [31] Z. You and Y. Jiao, "Development and Application of Milk-Run Distribution Systems in the Express Industry Based on Saving Algorithm", *Math. Probl. Eng.*, vol. 2014, no. 1, (2014), pp. 536459. <https://doi.org/10.1155/2014/536459>