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## Solving an Extended Logistic Model by Hybrid Genetic Algorithm

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**Abstract** - In recent decade, there have been intensive research works on logistics design system because of its great use in public distribution. Huge research efforts have been devoted to studying many variants of logistic problems. The common objective is to determine overall production strategy, inventory strategy and flow of products through some facilities in order to minimize cost or maximize profit. In this paper, we introduce a more realistic logistics model that includes transportation model and multi-depot Vehicle Routing Model. By assuming that the plant capacities and the customer demand are known in advance from past statistical data, we examine how the distribution centers should be designed and how the product should be produced and transported. We propose a genetic algorithm approach which is hybridized with a local search method to solve the problem. We report several numerical experiment results to show the effectiveness of the proposed method.

**Keywords:** Logistics, Vehicle Routing Problem, Genetic Algorithm, and Local Search.

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### 1. INTRODUCTION

The logistic problem is known as one of important combinatorial optimization problems that has taken great interest of the researchers. Huge research efforts have been devoted to studying logistic problems since 1941 where Hitchcock described the problem as Transportation Problem (TP). Thousands of papers have been written on many variants of logistics problems such as Traveling Salesman Problem (TSP), Vehicle Routing Problems (VRP), Production Distribution and Inventory Problem (PDI), Supply Chain Management (SCM) and so on (Geoffrion and Graves, 1974); Gen and Cheng, 1997).

For the real-world applications, it is often represented as an integrated multi-stage problem (Das and Heragu, 1988; Heragu, 1997). The common objective is to determine overall production strategy, inventory strategy and flow of products through some facilities in order to

minimize cost or maximize profit (Syarif, Yun and Gen, 2002).

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Since it was introduced by Holland (1975), GA has been intensively used for solving various combinatorial optimization problems including TP, VRP, TSP, Scheduling and so on (Gen and Cheng, 2000). It has been shown that GA can give good solutions within reasonable time. In order to increase the performance of GA, some researchers hybridize GA with local search method.

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In this paper, we introduce a more realistic logistics model (tsLP) that combines transportation model and multi-depot Vehicle Routing Problem (mdVRP) Model. By assuming that the plant capacities and the customer demand are known in advance from past statistical data, we examine how the distribution centers should be designed and how the product should be produced and transported. It is clear that this problem is NP-complete because of NP-completeness of mdVRP (Toth and Vigo, 2001). Thus, it is

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unlikely that exact polynomial time algorithm exist to solve this problem. To solve this problem, we develop a GA approach hybridized with 2-opt.

The rest of this paper is organized as follows: The design of this problem is given in Section 2. In Section 3, we describe the design of our algorithm proposed in this paper including the chromosome representation, genetic operators and the selection methods. In Section 4, numerical experiment results are presented to demonstrate the efficiency of the proposed method. Finally, some concluding remarks are given in Section 5.

## 2. PROBLEM STATEMENT

As stated earlier, in this paper, we concern with a logistics model that combines transportation problem (TP) model and multi-depot Vehicle Routing Problem (mdVRP) Model. Here, we assume that sets of customers, DCs and Plants within a certain coordinate location are known in advance. We associate a non-negative customer demand and plant capacities from past statistical data. We define the travel cost corresponding to *travel distance*. This model is restricted to logistics problems for which travel distances are symmetric. There are enough identical vehicles of capacity to serve customer demand.

Our purpose is to determine the transportation network to satisfy the DC demand and vehicle routing with minimum distance in such a way that:

- 1) Each customer is serviced by a DC,
- 2) Each route starts and ends at the same DC,
- 3) Each customer is visited exactly once by a vehicle,
- 4) Total customer demand for each route does not exceed the vehicle capacity,
- 5) Total product transported to each DC is equal to the DC demand,
- 6) Total product shipped from each plant does not exceed its capacity.

From the above explanation, this model can give the answers for the following questions:

- 1) From which DC a is serviced,
- 2) On which route a customer served.
- 3) The sequence of customers on the route
- 4) Transportation pattern to serve DC from each plant.

## 3. DESIGN OF ALGORITHM

In this Section, we shall propose our basic concepts

and searching procedures for the proposed method. Basically our proposed method includes an integrated two mains (mdVRP and TP ) GA solvers.

### 3.1 Representation

To determine the vehicle route from each DC, we adopt two stages procedure that assign custom the closest DC and then solve a VRP from each DC as illustrated in the following Figure.

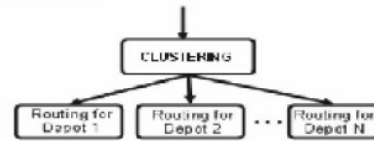


Figure 1. Two stage procedure for routing

To represent the chromosome, we use permutation-based representation. Initially all customers are clustered to their nearest DC in terms of Euclidean distance. This strategy is simple, fast and viable since no capacity limit is imposed on each DC (Ombuki and Hanshar, 2004). The clustering phase is done to determine a list of customer number assigned to each DC. We show the illustration of the chromosome representation for this phase in the following Figure 2 when the logistics system is consisting of 4 DCs and 38 customers:

DC (1)	21	30	30	17	27	4	13	22					
DC (2)	1	11	12	25	14	24	23	0	7	1	31	29	28
DC (3)	31	23	7	21	11	17	22	2	2	2	2		
DC (4)	27	8	10	34	3	7							

Figure 2. Chromosome for Routing Phase

To determine the vehicle route, the customer is assigned to the vehicle with *left-to-right scan* procedure (Gen and Cheng, 1997). It is a sequential adding procedure which assigns customers to vehicles. When adding a new customer to a current vehicle, it is necessary to check the capacity feasibility for the customer. If it is feasible, the customer is assigned to current vehicle; otherwise, the customer is assigned to a new vehicle.

We also adopt permutation-based representation to determine the transportation graph from the plant to DC with minimum cost. Based on the information on the previous phase, we can determine the necessary demand of each DC. The decoding procedure for this phase is done by the following procedure:

**Procedure: decoding**

**Input: Permutation-based chromosome**

**For**  $l = 1$  to  $mn$

- Let  $k$  be the content of  $l$ -th digit in the chromosome;
- Determine of the plant index ( $i$ ) and DC index ( $j$ )

$$i \leftarrow \frac{(k-1)}{n} + 1$$

$$j \leftarrow (k-1) \bmod n + 1$$

- The number of product shipped from plant  $i$  to DC  $j$  is determined as follows:

$$x_{ij} \leftarrow \min(a_i, b_j)$$

- Update the plant capacity and DC demand

$$a_i \leftarrow a_i - x_{ij}$$

$$b_j \leftarrow b_j - x_{ij}$$

**next**  $i$

**Output: Number of product transported from each Plant to each DC**

**3.2 Genetic Operator**

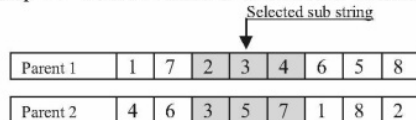
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**Crossover:**

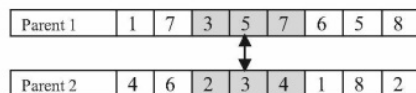
Crossover is known as the most important recombination operator in GA. Here we adopt, PMX (Partial Mapped Crossover) introduced by Goldberg and Lingle (1985). This method can be viewed as a development of two-point crossover method for binary representation of chromosomes and subsequently be repaired. PMX crossover process is done as follows:

**Procedure : PMX**

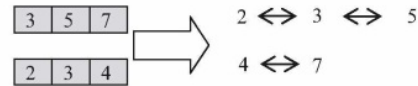
**Step 1 :** Select a section of chromosome randomly



**Step 2 :** Exchanged each sub string



**Step 3 :** Determine the mapping of genes in each substring



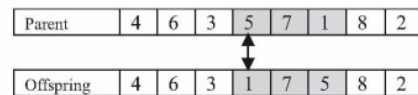
**Step 4 :** Update chromosome with information on Step. 3



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**Mutation :**

Mutation is usually used to prevent premature lost of information. It is done by exchanging the information within a chromosome. In this paper, we use the inversion mutation that selects two positions within a chromosome at random and then inverts the sub-string between these two positions.



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**Evaluation :**

As in nature, it is necessary to provide driving mechanism for better individuals to survive. Evaluation is to associate each chromosome with a fitness value that shows how good it is based on its achievement of the objective function. The higher fitness value of an individual, the higher its chances for survival for the next generation. So the evaluation plays a very important role in the evolutionary process. For this problem, we used the objective function (total travel distance) as the fitness value

**Selection :**

In the genetic algorithm, the role of selection is to determine the set of chromosome that will go for the next generation. For the selection methods, we use elitist strategy to enforce the best chromosome into the next generation.

**3.3 Local Search**

It is easy to understand that a tour is said to be good if there is no cross in it. Therefore, finding an algorithm to eliminate those crosses would increase the quality of the



solutions. Here, we include 2-Opt algorithm in our GA approach. This method is often used in repairing the tour. The principle of this method is to remove the two sides so that the outlines tour into two paths and then connect back the other way.

The algorithm can be elaborated as follows: Select the customer for each  $i$  ( $i = 1, 2, \dots, n$ ) where  $n$  is the number of customers. Suppose  $A$  is the customer that was selected, check whether there is a cross between  $A$  trajectory formed from customer to customer  $B$  where,  $B$  is the customer that arrived after the customer  $A$  with arbitrary trajectories. Parameters of a tour that includes crossing can be described as follows: assumed customer  $A$  is the customer that was selected,  $next(A)$  is the customer came after customer  $A$  tour in the sequence, and  $B$  any different from the customer  $next(A)$  and customer  $A$ . Tour can now be corrected if only if:

$$d(A,next(A))+d(B,next(B)) > d(next(A), next(B))+d(A,B)$$

To illustrate the above algorithm, consider Figure 3. Suppose that the customer now selected is the third customer, and customer 4 is the next city selected arbitrary.

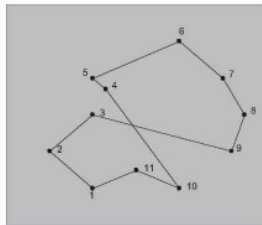


Figure 3. Tour with a cross tour

Obviously, that distance  $d(3,9)+d(4,10) > d(9,10)+d(3,4)$ . Therefore, 2-opt algorithm can be implemented to improve the tour so the tour generated depicted Figure 4 the following:

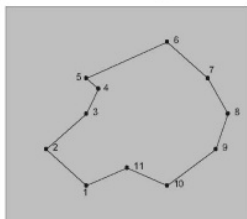


Figure 4. Result of 2-opt algorithm

#### 4. NUMERICAL EXPERIMENTS

To confirm its effectiveness, the proposed method was implemented in PHP and run on PC Core to Duo. As the test problems, we modify the benchmark problems of mdVRP as follows:

Table 1. Design of test problems

Test Problem	Case Problem		
	Plant	DC	Customers
mod p01	3	4	50
mod p03	6	5	75
mod p07	7	4	100

Other necessary data including coordinate and capacity of the plants are randomly generated. The traveling cost is assumed to be depending on the distance. We run our proposed GA with  $p_C = 0,4$  and  $p_M = 0,2$ . For all test problems, the proposed algorithm was run 10 times. We note its best, average and worst results for each test problem. The convergence of generation is shown in Figure 5 and the computational result is shown in Figure 6.

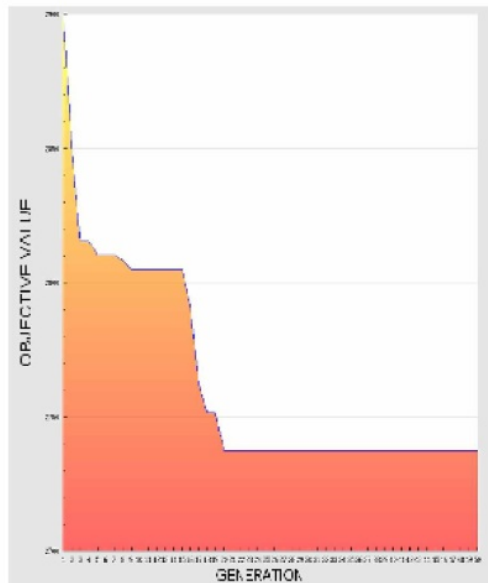


Figure 5. Objective values in generation

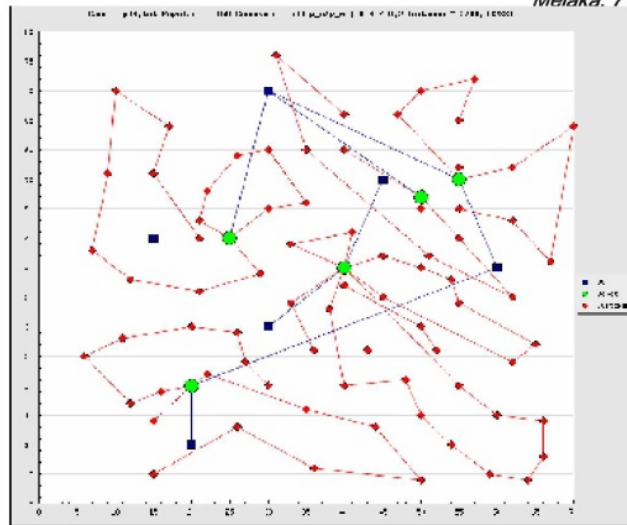


Figure 6. Computational result for mod\_p03

Table 2: Computational Result

Test Problem	Parameter GA		Computational Result		
	Pop Size	Max Gen	Best	Worst	Average
mod p01	100	500	1303,634262	1325,214491	1312,061944
mod p03	150	500	2736,902881	2799,240190	2768,485920
mod p07	200	500	3348,854060	3390,518180	3366,211420

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## 5. CONCLUSION

In this paper, we developed a realistic logistics model that includes the determination of vehicle routing with time window. As this is an NP-hard problem, we proposed a hybridized Genetic Algorithm approach to determine the best heuristic solutions to the problem in real time. In order to increase the performance of our algorithm, we hybridized GA with local search method. To demonstrate the effectiveness of the proposed GA approach, we have carried out the numerical experiments after modifying the benchmark problems of mdVRP. It was shown that the proposed method could give good heuristic solutions.

## ACKNOWLEDGMENT

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