รูปแบบการจัดการการขนส่ง โดยการประยุกต์ใช้ขั้นตอนวิธีเชิงพันธุกรรม : กรณีศึกษาบริษัทขายวัสดุก่อสร้าง

A Transportation Management Model Using the Application of Genetic Algorithms (GAs): A Case Study of Construction Material Company

พศวีร์ ตรีวิเศษ[1] ชวิศร ปูคะภาค[2] ภาคย์ สธนเสาวภาคย์[3] และศิวดล กัญญาคำ[4]

Podsavee Triviset,[1] Chawisorn Phukapak,[2] Pak Satasaowapak[3] and Siwadol Kanyakam[4]

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์ **ประการแรก** เพื่อศึกษาเส้นทางที่สั้นที่สุดในการขนส่งวัตถุดิบให้กับลูกค้า และ **ประการที่สอง** สร้างรูปแบบการจัดการการขนส่งของกรณีศึกษาที่เป็นบริษัทขายวัสดุก่อสร้าง จากการวิเคราะห์ปัญหาในการขนส่งของกรณีศึกษาด้วยแผนภาพสาเหตุและผล ผลการวิจัยพบว่า

การจัดเส้นทางที่ไม่มีประสิทธิภาพเป็นสาเหตุหลักในการจัดการการขนส่งของกรณีศึกษา ซึ่งปัญหาการจัดเส้นทางการขนส่งดังกล่าวเป็นปัญหาแบบ Traveling Salesman Problem (TSP) โดยในงานวิจัยนี้ได้ทำการเปรียบเทียบประสิทธิภาพของขั้นตอนวิธี (Algorithms) ในการหาเส้นทางที่สั้นที่สุดของปัญหา TSP ทั้งหมด 4 วิธี คือ วิธีแบบละโมบ (Greedy algorithms) วิธี Saving Algorithms วิธี Nearest Algorithms และวิธีเชิงพันธุกรรม (Genetic algorithms, GAs) จากการเปรียบเทียบพบว่า ขั้นตอนวิธีเชิงพันธุกรรมสามารถหาเส้นทางที่สั้นที่สุดได้ โดยมีระยะทางรวมเป็น 61.4 กิโลเมตร ซึ่งลดระยะทางรวมลงจากเดิม 19.8 กิโลเมตร หรือลดลงร้อยละ 24.38 ดังนั้นจึงได้นำวิธีการ GAs มาสร้างเป็นโปรแกรมสำหรับหาเส้นทางที่สั้นที่สุดในการขนส่งวัสดุก่อสร้างของกรณีศึกษา โปรแกรมเขียนด้วยภาษา C+ ที่พัฒนาขึ้นบน Windows application จึงง่ายต่อการใช้งานและช่วยให้พนักงานสามารถจัดเส้นทางการขนส่งได้อย่างมีประสิทธิภาพ

คำสำคัญ : วิธีเชิงพันธุกรรม Traveling salesman problem (TSP) การขนส่ง แผนภาพสาเหตุและผล เส้นทางที่สั้นที่สุด

ABSTRACT

The objectives of this research were to find the shortest path for construction material transportation to the customers and create a transportation management model for the targeted construction material company. According to an analysis of the cause-effect diagram to identify transportation problems in the targeted company, the results revealed as follows:

---

[1] นักศึกษาปริญญาตรี สาขาวิชาการจัดการงานวิศวกรรมและเทคโนโลยี คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏมหาสารคาม

[2] อาจารย์คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏมหาสารคาม

[3] อาจารย์คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏมหาสารคาม

[4] อาจารย์คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏมหาสารคาม

รับต้นฉบับ 14 ตุลาคม 2553 รับลงพิมพ์ 18 พฤศจิกายน 2553

Inefficient routing management problem was the main cause in the transportation problem of this case study which was identified as the Traveling Salesman Problem (TSP). The research was conducted to find out the shortest transportation path by comparing four methods in terms of efficiency and algorithms; namely, Greedy Algorithms, Saving Algorithms, Nearest Algorithms, and Genetic Algorithms (GAs). The result showed that GAs performed the best solution. GAs took the shortest distance of 61.4 kilometers with a reduction of 19.8 kilometers (or 24.38%) from the original distance. Thus, the GAs was selected to create a computer program to find the shortest path for material transportation of the company, using the C+ language program developed for Windows application with simple user interface. The program was an effectient tool for the operators to arrange the transportation routes.

Keywords : Genetic Algorithms (GAs), Traveling Salesman Problem (TSP), Transportation, Cause and Effect Diagrams, Shortest Path

Introduction

Supply chain management is assigned as activities to link customers and suppliers. Supply chain management usually intended in high customer service levels, lower operation cost, and resource utilization. Transportation is an important section of supply chain management responding to the objectives. For construction business, material transportation cost is very influence on the total cost. A case study in this work is a medium size company in construction material business. From the collected data, it shows that transportation cost of this company is too high. Analysis the cost by cause and effect diagram, in figure 2, it shows that the main cause of the cost is poor routing arrangement. The routing problem in this work can be defines as the Traveling Salesman Problem (TSP). The TSP is a classical problem belongs to the class of NP-hard problem (Pedro, 1999). The TSP defined as a task for searching the optimal path in a case of a single vehicle has to visit set of customers (Nodes) exactly once before return to its starting position. The TSP has several applications such as logistics and production planning. The TSP can solving by various optimization techniques such as Genetic Algorithms (GAs), Simulating Annealing (SA) and Ant Colonies (ACO). The GA is an optimization technique based on natural evolution. The basic concepts of GAs were proposed in (Holland, 1975). GAs are operated base on "survival of the fittest" technique. GAs can be applied to many optimization problems, including the NP-hard. From previous research works, the GAs successfully applied to various types of problems. Although a genetic algorithm dose not ensure an optimal solution, it can be obtained an acceptable solution with reasonable time consuming. Thus, the objectives of this work were to study the shortest path of material transportation and created a transportation management model by applied the GA to TSP in a case of construction material transportation problem.

Transportation problems of a case study

A case study in this work is a medium size company in construction material business. From the collected data, transportation cost of this company is very high. Transportation cost of this company is detailed by graphic representation in figure 1.

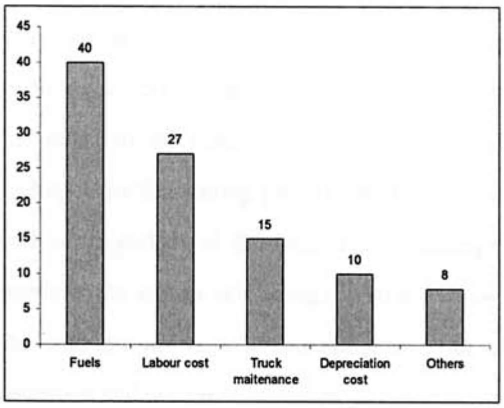


Figure 1 Transportation cost of a case study

The graph shows that the fuel cost is higher than the others costs. So, we used the cause and effect diagrams (Montgomery, 1996) to find the root causes of transportation cost.

From the diagrams, the routing arrangement is a main root cause. The others causes are truck efficiency, scheduling, and supervisor performance. So, we are choosing routing arrangement problem to solve first because the routing arrangement can be solve by immediately.

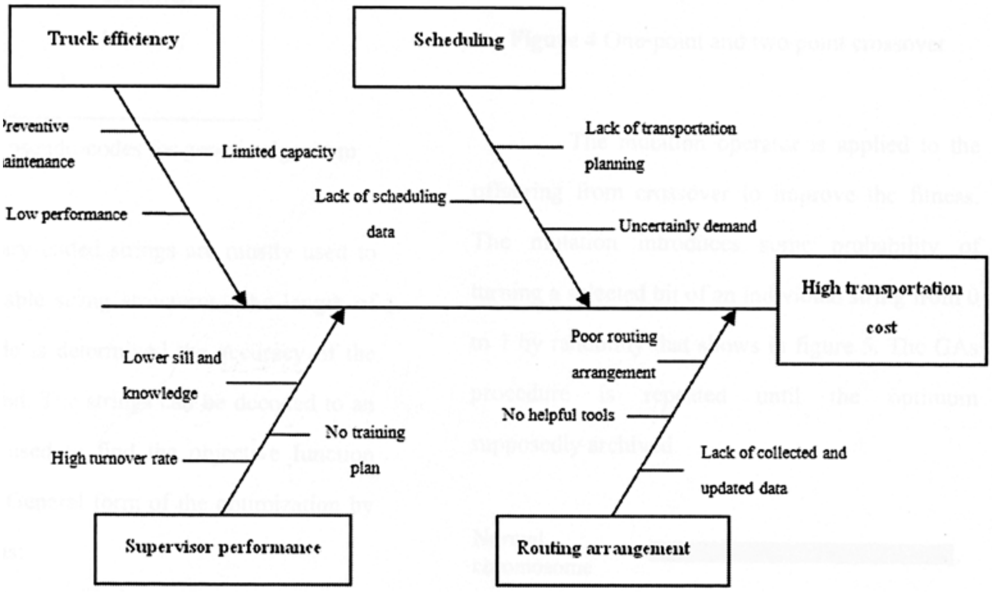


Figure 2 Cause and effect diagram

Genetic algorithms (GAs)

GAs are searching and optimization procedure by motivate the principles of nature genetics and natural selection (Deb, 1998). A GA is different from most of traditional optimization. Advantages of GAs are simplicity, ease of operation, minimal requirements, and global perspective. The basic concepts of GAs can be described by a pseudo-code in figure 3 (Rajendran, 2006).

```
Begin
    Initialize population;
    Evaluate population;
    Repeat
    {
        Reproduction;
        Crossover;
        Mutation;
    }
```

Figure 3 A pseudo-codes for genetic algorithm

Binary coded strings are mostly used to code the variable string structures. The length of the string code is determined the accuracy of the solution desired. The strings can be decoded to an X value that used to find the objective function value $f(\chi)$. General form of the optimization by GAs defined as:

Minimize $f(\chi)$

Variable bound Xmin ≥ X ≥ Xmax

GAs starting from created a population of string structures by randomly. Thereafter, each string (Population) is evaluated. The population is then operated by three main steps as reproduction, crossover, and mutation to find a better solution.

The first operation applied to populations is reproduction. The idea of reproduction is that selects good strings in a population and forms a matting pool. Next step is crossover that applied to the string of the matting pool. Two strings are pickup from the matting pool (Parent) at random and some portion of this strings are exchanged between the strings (Offspring). Figure 4 shows the concepts of crossover operation in cases of one-point and two-point crossover.

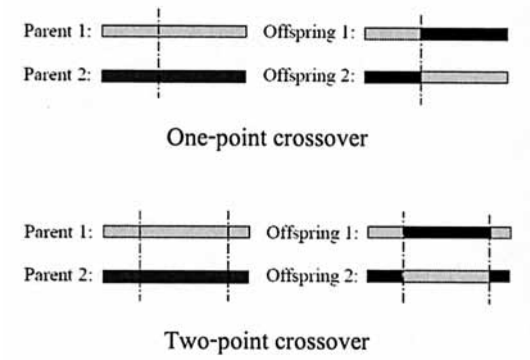


Figure 4 One-point and two point crossover

The mutation operator is applied to the offspring from crossover to improve the fitness. The mutation introduces some probability of turning a selected bit of an individual string from 0 to 1 by randomly that shows in figure 5. The GAs procedure is repeated until the optimum supposedly archived.

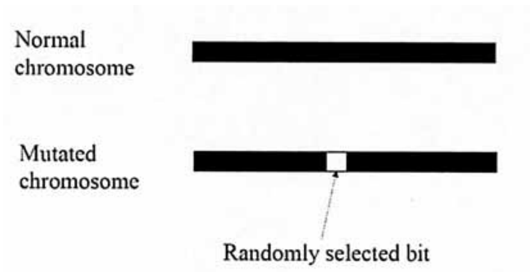


Figure 5 Mutation operations.

Traveling Salesman Problem (TSP)

The TSP is a classical problem belongs to the NP-hard class. The TSP defined as a task for searching the optimal path in a case of a single vehicle has to visit set of customers (Nodes) exactly once before return to its starting position (Calvo, 2000). Figure 6 shows an example of TSP through 8 nodes. Figure 6(a) and figure 6(b) show a feasible path and a better path of the same 8 nodes problem respectively.

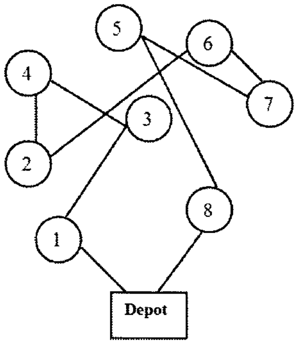


Figure 6 (a) A feasible path through 8 nodes

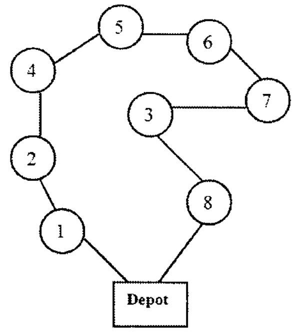


Figure 6 (b) A better path through the same 8 nodes.

Transportation management model and results

There are 10 customers located around the warehouse of a case study that set as a depot (D). The positions of the customers display in figure 7 and the matrix of distances show in table 1.

Table 1 Distance matrix

	Depot	1	2	3	4	5	6	7	8	9	10
Depot	-	9.5	25	19	16	15	16.4	13	7.6	13	9.3
1	9.5	-	11	11	7.9	5.6	5	8.6	5.8	5.9	0.8
2	25	11	-	5.3	8.5	9.8	11	13	14	9	13
3	19	11	5.3	-	3.2	4.5	6	7.5	9	14	10
4	16	7.9	8.5	3.2	-	1.3	2.8	4.3	5.8	14	7.1
5	15	5.6	9.8	4.5	1.3	-	1.4	3.5	4.4	12	4.8
6	16.4	5	11	6	2.8	1.4	-	.1	4.6	11	4.2
7	13	8.6	13	7.5	4.3	3.5	5.1	-	5.5	15	7.8
8	7.6	5.8	14	9	5.8	4.4	4.6	5.5	-	12	5.5
9	13	5.9	9	14	14	12	1	15	12	-	6.8
10	9.3	0.8	13	10	7.1	4.8	4.2	7.8	5.5	6.8	-

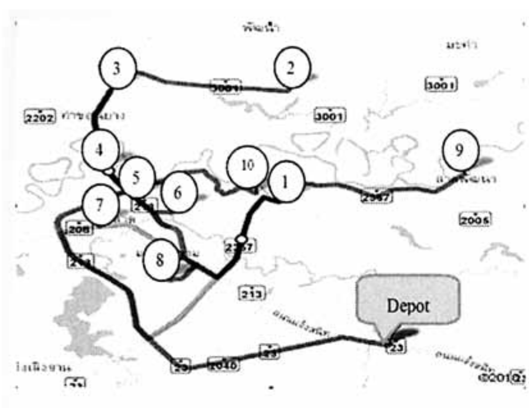


Figure 7 Positions of the customers and a depot

The objective function is aimed to minimize total distance of material transportation.

Constraints of this transportation problem are as follows:

- This problem is TSP with 1 truck. The truck has the dimension of 2.3 × 6 × 2.5 meters (W × L × H). Figure 8 shows a truck used for material transportation.

Figure 8 A truck dimensions

- A truck capacity is not over 7 tons.
- Time windows are not considered.

The present total distance of the case study is 81.2 kilometers (Depot-2-4-3-5-7-8-6-10-9-1-Depot). From previous works, there are many methods to find the shortest path in TSP.

Each method is not proper to all problems. To select the suitable optimal method of this problem, we adopted the popular methods namely greedy algorithms, nearest algorithms, saving algorithms, and genetic algorithms to solve and compare shortest distance of the TSP problem. The comparison of total distance from each method with a present total distance shows in table 2.

Table 2 Comparison of total distance

Method	Total distance (km)	Increase/ decrease (km)	% Increase/ decrease
Greedy Algorithms	121.9	+40.7	+50.12
Nearest Algorithms	61.8	-19.4	-23.89
Saving Algorithms	80.5	-0.7	-0.86
Genetic Algorithms	61.4	-19.8	-24.38

From table 2, a genetic algorithm performed best solution of shortest total distance as 61.4 kilometers. It can be decreases of 19.8 kilometers or 24.38% from present total distance. The second best is a nearest algorithm. Through the genetic algorithm obtained slightly better solutions than a nearest algorithm, the nearest algorithm is lack of flexible and convergence rate to various problems. So, we selected the genetic algorithm to create the computer program to find the shortest transportation routing. To implement the program for the operators, the genetic algorithm was coded by C# language that working on windows application (Cristian, 2005). So, the program is simply to the operators who arrange the routes. The user interface of the program shows in figure 9.

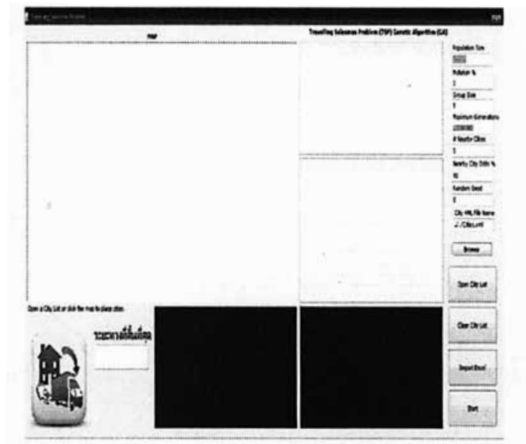


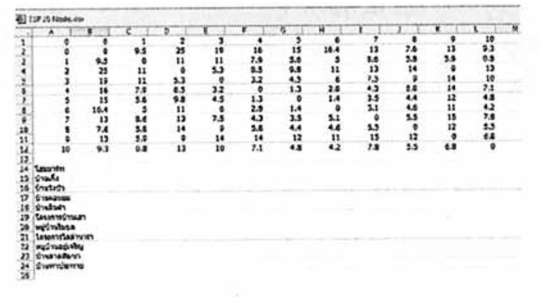
Figure 9 User interface of the program

The GA procedures of the created program can be detailed as follows.

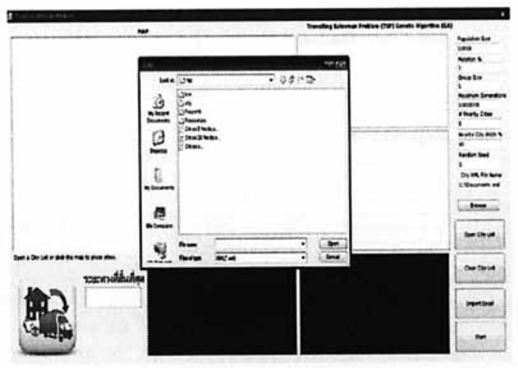
1. Define the positions of the customers by using X-Y co-ordinate.

```
<?xml version="1.0" encoding="utf-8" ?>
- <CityList>
    <City X="450" Y="350" />
    <City X="385" Y="250" />
    <City X="385" Y="100" />
    <City X="285" Y="100" />
    <City X="285" Y="225" />
    <City X="300" Y="240" />
    <City X="340" Y="260" />
    <City X="275" Y="280" />
    <City X="325" Y="325" />
    <City X="525" Y="150" />
    <City X="370" Y="230" />
  </CityList>
```

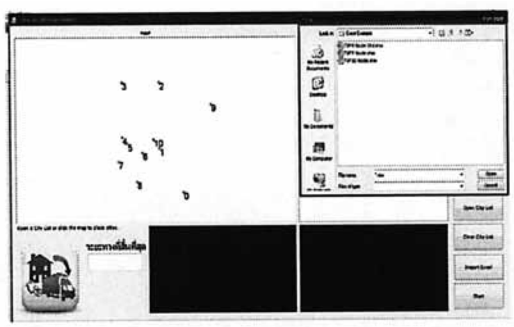
2. Created the matrix distance in Microsoft Excel.



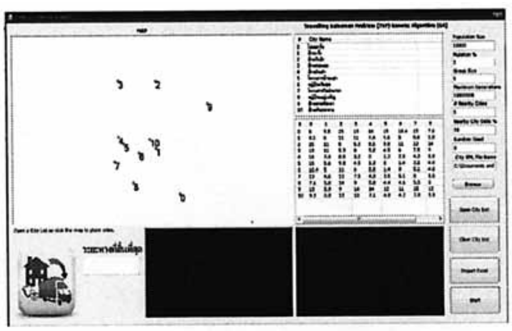
3. Input the customer co-ordinates to the program.



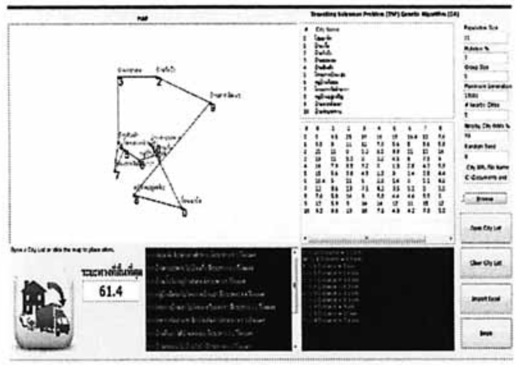
4. Input the distance matrix to the program.



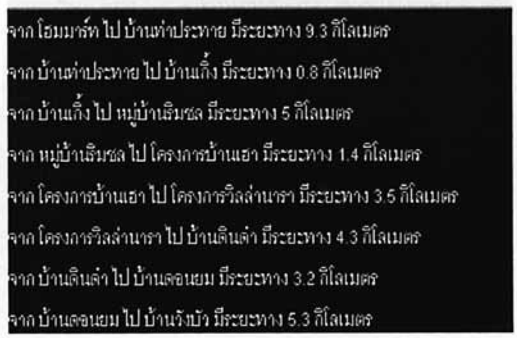
5. The user interface before searching the shortest path by GA.



6. The routes resulted from running GAs.



7. The details of shortest path from the program.



Conclusions

In this work, transportation model of construction material was presented. The model starts from an analysis of transportation root causes by using the cause and effect diagram. From the analysis, the routing arrangement was an influence factor. GAs and other methods namely Greedy Algorithms, Nearest Algorithms, and Saving Algorithms were adopted to find the shortest path of transportation. The result obtained from GAs was better than other methods. It can be reducing 19.8 kilometers or 24.38% of distance from present distance. The computer program for solving the TSP with GAs was created and coded by using C#. The computer program is working on windows application. So, it was an effective tool to help the operators to arrange the shortest path of transportation.

References

Calvo, R.W. (2005). **A new heuristic for traveling salesman problem with time windows.** Transportation Science, (1), 113-124.

Christian Nagel, Bill Evjen, Jay Glynn, Karli Watson, Morgan Skinner., Professional C# 2005 with .NET 3.0. Wrox Press Ltd. Birmingham, UK.

Deb, K., (1998). **Optimization for Engineering Design-Algorithms and Examples,** Prentice Hall of India (Pvt.) Ltd., New Delhi.

John Holland, (1975). “Adaptation in Natural and Artificial Systems: An Introductory analysis with Applications to Biology, Control, and Artificial Intelligence,” **The University of Michigan Press.**

Montgomery D.C., (1996). **Introduction to statistical quality control.** 3^{th} ed. John Wisley&Sons. New York.

Pedro, L., C.M.H. Kuijpers, R.H. Murga, I. (1999), Innza and S.Dizdarevic, “Genetic Algorithms for the Traveling Salesman Problem : Areview Representations and Operators,” 129-170.

Rajendran, S., (2006). “Manufacturing Optimization through Intelligent Techniques” **Taylor & Francis Group.**