Dispatching of Container Trucks using Genetic Algorithm

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Abstract

The dispatching problems in container transportation field are classified as the pickup and delivery problems, which are highly complex issues that consider various conditions in the work-site operations. Therefore, this study suggests the automated dispatching based on genetic algorithm. To achieve this, diverse constraints considered in work-site operations are established. Besides, dispatching rules and phases for generating initial solution are suggested. In this study, it is meaningful that it could solve the problem which considered various assumptions and constraints. In the future study, performance evaluation of genetic algorithm compare to optimization model is presented. At the same time, applicability in real container transportation field is identified through experiment based on work-site operations’ data.

Keywords: Vehicle Allocation, Genetic Algorithm

1. Introduction

The container cargo is carried by railway transportation, coastal transportation, airway transportation, and inland transportation in Korea. Reviewing the proportion of each transportation means, however, inland transportation keeps 90% from 2006 till 2010, which takes over a large proportion of the domestic container transportation [1]. This implies that the container transportation company must secure the pricing competitiveness, while providing the shippers with high-quality services, through efficient vehicle operation. It is required to set up the dispatching that can minimize unnecessary empty carriage distance and the number of return trucks in order to save the transportation cost which occupies 40% of total logistics cost. However, the empty carriage distance ratio of container transportation vehicle in the past 5 years has been repeating up and down in a narrow range based on the 25%. It shows that the research is insufficient which is reflecting working-level constraints considered at the operating site to minimize the empty carriage distance.

A lot of researchers have accomplished extensive studies for a long period to solve such a problem in the dispatching. The dispatching algorithm and system suggested in the previous researches had been able to obtain the optimal solution or near optimal solution, however, it was not easy to apply to the actual dispatching process because it was not reflected with the working-level constraints considered at the operating site.

This study proposes the genetic algorithm, therefore, that can set up the dispatching for the minimum transportation cost by minimizing the empty carriage distance and the number of rented truck. The size of problem in the practical viewpoint has been deduced for this objective through the interview with the container transportation company. The problem dealt with in this study has been defined based on it. And various constraints and presumptions considered in this problem have been established. This study also has presented the genetic algorithm to solve the defined problem and the experiment method to evaluate the performance of the algorithm.
2. Previous Studies

Dispatching problem had been researched in the type of vehicle scheduling or vehicle routing of the visiting order or visiting time to carry out the service for the customer. Vehicle scheduling problem (VSP) is the planning of vehicle operation schedules for the service to customers, of which goal is minimizing the total travel distance (expense or time) of vehicles as well as satisfying the constraints such as the upper limit of vehicle travel distance and the time zone that customer is requesting [2]. Waters [3] had dealt with vehicle schedule problem to minimize total travel distance of multiple vehicles in the single depot satisfying fixed orders from customers. Park and Song [4] had presented the model to calculate the average speed in the vehicle scheduling problem between two points by assuming the average speed of vehicles for each of the territories and for each time zone, as vehicle speed is changing according to the travelling territory and time zone. Such a vehicle scheduling problem is distinguished from the general vehicle routing problem as time-related constraints are added up on the vehicle movement [2]. On the other hand, vehicle routing problem (VRP) is the problem to determine the vehicle's route for minimum transportation cost while satisfying the request at the same time of all the customers or shippers [5]. The vehicle routing problem was arisen by Danzig and Ramser for the first time in 1958 [6], which is being studied in the types of CVRP (Capacitated Vehicle Routing Problem), HVRP (Heterogeneous Vehicle Routing Problem), VRPTW (Vehicle Routing Problem with Time Window), VRPM (Vehicle Routing Problem with Multiple Trips), and VRPPD (Vehicle Routing Problem with Pickup and Delivery) with the addition of various constraints on the conventional VRP.

The dispatching problem of container truck is the problem, on the contrary, that the container cargo located in fixed pickup/delivery depots should be carried by a certain number of vehicles differently from the general dispatching problems [7]. Various constraints also should be considered due to the characteristics of container transportation trucks. To combine the header and chassis, which may be located in different depots with each other, minimum empty carriage distance should be calculated from header depot to chassis depot. So, the previous researches dealing with dispatching problem of container truck had been processed in the type which is considering the combination of each VRP problem mentioned above. Accordingly, Ko et al. [8] processed the research considering VRPPD and HVRP altogether. They dealt with the container transportation problem of different capacities between the pickup depot and delivery depot. Yoon et al. [9] processed the research considering VRPPD and VRPTW simultaneously as a problem to allocate travel limit time to each group after establishment of the group against each transportation request. As a study considering VRPPD and VRPTM, Yun et al. [10] dealt with the dispatching problem to minimize the empty vehicle operation and empty container travel time under the assumption that the circulation of same vehicle is allowed more than one time. Furthermore, Lee et al. [11] had processed the research considering HVRP and VRPTW together with the VRPPD type, and Goel et al. [12] had researched the vehicle route planning problem for the cargo transportation of multiple vehicles dispersed in different depots within the set time limit. In the meantime, this study has dealt with the dispatching problem that is more suitable for the actual circumstance by processing the research reflected with HVRP, the capacity constraint of container vehicle, VRPTW, the transportation priority constraint for time, VRPM, the vehicle's multiple trip constraint, and VRPPD, the container pickup and delivery constraint, altogether.
As is shown in Table 1, dispatching problem of container truck should consider various constraints according to the characteristics of container transportation. So it is differentiated from the dispatching problem of general vehicles in the viewpoint of problem types. That is why there have been relatively less researches on the container vehicle dispatching problem, differently from the dispatching problem of general vehicles, as of the complexity of the problem. Based on the descriptions as above, this study has schematized the problem types dealt with in this research as is shown in Figure 1 to verify the difference from other problem types dealt with in the previous researched.

This study is dealing with the problem how to set up the dispatching of container truck using the genetic algorithm, one of meta heuristic methods.

The genetic algorithm has not been applied much in the research related to dispatching problem of container truck, while the genetic algorithm technique has been applied widely to the conventional vehicle routing problems. That is because it is not easy to express the dispatching problem of container truck with chromosome as its complexity of constraints and problem size is bigger than general VRP. This study is intended, therefore, to solve dispatching problem of the container truck reflected with complicated constraints and various transportation types that are considered in the actual operating sites with the genetic algorithm.

<table>
<thead>
<tr>
<th>Division</th>
<th>Researcher</th>
</tr>
</thead>
</table>
| VRPPD & HVRP | Ko et al.(2004)  
Shin et al.(2000) |
| VRPPD & VRPTW | Yoon et al.(2005)  
Lua(2001)  
Namry et al.(2000)  
Kim et al.(1997) |
| VRPPD & VRPTW & VRPMT | Yun et al.(1999) |
| VRPPD & HVRP & VRPTW | Lee et al.(2007)  
Goel et al.(2005) |
| VRPPD & HVRP & VRPMT & VRPTW | This research |

Figure 1. Research type of dispatching problem
3. Dispatching Problems of Container Truck

3.1 Problem Definition

The dispatching problem of container truck is to determine the vehicle allocation for minimum transportation cost. In this situation, multiple container trucks should return to each initial depot after picking container up and delivering it to the designated depot. Each container truck is divided into header (tractor) and chassis (trailer). Header is the means to move the chassis (trailer), which does not have its own capacity, but it must return to the depot after completion of transportation within available time as each header has different available time with each other. Also, each header is classified into container transportation company-owned vehicle, mandated vehicle, and rented vehicle according to its proprietor. For the viewpoint of minimizing total transportation cost, the company-owned vehicle should be allocated with priority, in this allocation process, then in the order of mandated vehicle and rented vehicle. Chassis is for the loading of container on it to carry to the destination, so the chassis matching the container capacity must be mounted on the header. Among the 5 kinds of chassis used in the operating site, this study is considering 20ft-only chassis for loading only one 20ft container, 40ft-only chassis for loading only one 40ft container, and combined chassis for loading two 20ft containers or one 40ft container.

The first thing for the transportation of container cargo is that header should move the chassis depot to attach the chassis conforming to the cargo capacity for transportation. In this situation, the distance between header and chassis is corresponding to the empty carriage distance (distance for moving without loading of cargo). The distance moving to pickup depot after combination of header and chassis also is included in the empty carriage distance. Figure 2 shows the empty carriage distance generated in the processes for the header mounting the chassis and picking the container up.

![Figure 2. Empty carriage distance in dispatching of container truck](image)

Empty carriage distance generated is causing the increase in total transportation cost. This study establishes the constraints to have the minimum value of \( ① + ② \) in Figure 2, when allocating the combination of vehicles to the cargo, in order to set up the dispatching for minimum empty carriage distance.

In the actual operating site, however, there exist various types in the transportation of container. Specific definitions for separated transportation are needed to reflect such transportation types on the dispatching algorithm. Therefore, this study defines the types of container transportation by dividing into shuttle transportation, bob-tail transportation, and general container freight transportation excluding the shuttle transportation and bob-tail transportation.

Shuttle transportation means the transportation type that the combination of vehicle (header and chassis) picks up the container, unloads it at the destination, picks up the cargo in the destination again, and returns to the initial depot. The destination of final cargo is the header's depot, in this time, so the cargo is unloaded upon the header's return to the depot. Following Figure 3 shows the diagram of shuttle transportation type.
Bob-tail transportation means the transportation type that the combination of vehicle (header and chassis) picks up the container, moves to the destination, leaves the container with chassis in the destination, and moves in the status of header only. This is a transportation type that shippers are requesting to the container transportation company when it takes long time for stuffing and devanning works. When the bob-tail process has been completed, the header is able to return to the depot or move to another loading place for multiple transportations by checking the available time status. Such a bob-tail transportation type had not been reflected in the previous researches, but this study considers it as one of the transportation types to set up the dispatching as shown in Figure 4.

Finally, the general container transportation means all the transportation types besides the two types described as above, and it is divided into the full container transportation and the empty container transportation as shown in Figure 5. The transportation process of vehicle combined with header and chassis is divided into two types when it has loaded with full container. First type is unloading container itself from the full container loaded vehicle. The combination of header and chassis after unloading work, returns to the initial depot or moves to carry other container after identifying the header's available time. Another type is devanning of the cargo in the container using the forklift or so. Then, the combination of header and chassis becomes empty container loaded status after the devanning work is finished (2.1 of Figure 5). So, the combined vehicle of header and chassis loaded with empty container does not return to the initial depot, but carries out another work to transport the empty container. It will be described separately in the empty container transportation type as below.
In the meanwhile, the work process is divided into two types when the combination vehicle of header and chassis is loaded with empty container. First type is unloading container itself from the empty container loaded vehicle, which has the same process as the full container transportation type mentioned as above. However, the combination vehicle becomes full container loaded status if stuffing work starts immediately instead of unloading empty container (1.1 of Figure 5). The work process is repeated as described in the above, after then, and the header returns to the initial depot before the available time is terminated.

It is necessary to express the constraints and assumptions reflected on each transportation type systematically to solve the problems defined in the above with the genetic algorithm. The constraints and assumptions considered in this study, therefore, are defined specifically in the Section 3.2.

### 3.2 Assumptions & Constraints

An interview with a container transportation company in Busan had been carried out to systemize the assumptions and constraints considered in the actual operating site based on the problem defined in the prior section. And the deduced assumptions and constraints have been specified as follow based on the result of interview.

- **Assumptions**
  - Container information and truck(header and chassis) information have been firmly established at the planning time.
  - Chassis has been divided into 20ft-only, 40ft-only, and combined chassis, and the combined chassis can load two 20’ containers or one 40’ container.
  - Header is divided into container transportation company-owned vehicle, mandated vehicle, and rented vehicle.
  - Maximum available time is given to each header differently, and the header returns to the initial depot within its available time. But in case of rented vehicles, they do not have to return initial depot.
  - Every header is belonging to one of multiple depots, each header is allowed with multiple trip within its maximum available time.
  - Container capacity is divided into 20ft and 40ft, which are dispersed in each depot.
  - All the cargos requested for transportation must be transported within the time determined, and rented vehicle can be used only when the vehicle is insufficient.
Table 2. Realistic constraints of container transportation field

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity of chassis</td>
<td>Each chassis should be allocated according to capacity of each container as shown in below</td>
</tr>
<tr>
<td>Available time of header</td>
<td>Available time of header $\geq$ total time of transportation</td>
</tr>
<tr>
<td>Affiliation of header</td>
<td>Each header should be allocated in order of, company-owned $&gt;$ mandated $&gt;$ rented</td>
</tr>
<tr>
<td>Combination rule of header, chassis and container</td>
<td>Vehicle combination should be composed to minimize distance between header, chassis and container</td>
</tr>
<tr>
<td>Multiple trip of header</td>
<td>Multiple trip could be considered within the available time of each header</td>
</tr>
</tbody>
</table>

4. Genetic Algorithm for Dispatching

Genetic algorithm is the most widely used methodology among the various meta heuristic techniques, which had been applied to the various vehicle routing problems [5]. Genetic algorithm uses the chromosome coded with symbols instead of decision variables dealt with in the deterministic methodology. Therefore, the most important thing in the application of genetic algorithm to the optimization problem is to express the problem to be solved by the chromosome using symbols [32][33].

4.1 Data Collection and Variable Definition

General genetic algorithm is using the initial solution by random generation. However, a population has been generated as a good initial solution for the evaluation in order to obtain better final solution in short time, as there are a lot of vehicles and cargos to be considered and the restrictions are complicated in the dispatching problem[34]. This study has generated various initial solutions, in the meantime, to lessen the premature convergence because the variety of solutions should be considered most importantly in the generation of population. Following is the procedure for the generation of initial solution.

Step 1) $k=1$

Step 2) Select a random depot $j$ from the depot set $P = \{1, 2, 3, ..., j\}$. If the set $P = \emptyset$, proceed to the Step 7.

Step 3) Generate the set of combination of vehicles that is capable to load container, $Q = \{s \mid \text{Travel time - Available time} \geq 0, \text{for all } s\}$. If $Q = \emptyset$, proceed to the Step 6.

Step 4) Select the combination of vehicles out of the set $Q$ with priority that has the shortest travel distance to the container location. If there are several combinations of vehicles of the same travel distance, select one vehicle combination arbitrarily.

Step 5) Allocate the container $j$ to the selected combination of vehicles.

Step 6) Process $k=k+1$ if $k<K$, delete the container $j$ from the set $P$, and proceed to the Step 2.
Step 7) Stop

4.2. Chromosome Representation

The solution of problem must be expressed by chromosome firstly in order to solve the automatic dispatching problem with genetic algorithm. The expression of genetic chromosome proposed is constituted in the form of repeating the order numbers. One gene means the allocation of vehicle owned by the container transportation company and rented vehicle from outside to the order number expressed in the form of gene. For instance, Figure 6 shows the case of 5 containers and 4 vehicles. Also, the chromosome expression in Figure 6 shows the allocation of container 1 to the combination of header No. 1 and chassis No. 1. In the meanwhile, Cargo 5 means that rented vehicle has been used as all the headers possessed by the container transportation company had been allocated and then expressed by 0.

<table>
<thead>
<tr>
<th>Header no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis no.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Figure 6. Chromosome representation (example)**

4.3. Genetic Operator

A genetic operator is needed in order to improve the solution gradually in the evolutionary process while maintaining a good orderly relationship with chromosomes. In this respect, crossover can play the most important role in the genetic algorithms. In this study, one point crossover is used as crossover genetic operator as shown in Figure 7.

**Figure 7. Crossover genetic operator**

4.4. Repair Process of Solutions

An infeasible solution is generated that is over the loading capacity of vehicle, after processing the genetic operator. So the procedure is necessary to change it to a feasible solution. Following is the procedure changing the infeasible solution to the feasible solution. And the infeasible solution has been prevented by modifying the existing crossover genetic operator.

Step 1) Generate 2 parents for the crossover genetic operator.

Step 2) Generate the random numbers for the crossover operation.

Step 3) Select 1 solution by random numbers out of the 2 parents.
Step 4) Delete the same item in the mother, when selecting from the father, and vice versa.

Step 5) Repeat above steps until the allocation is completed. Multiple regression analysis was used to identify the factors affecting the quality of the IS project.

5. Performance Evaluation

The experiment reflected with the actual problem size is carried out to determine the crossover rate and mutation rate used in the genetic algorithm proposed. The problem size in the experiment has been set up with 1,000 containers, 400 headers, and 18 depots. Experiments are processed for the crossover rate of 0.7, 0.75, 0.8, and 0.85 and the mutation rate of 0.05, 0.1, and 0.15 respectively. Also, the population size is set up at 100, generation size at 100, elitism size at 50, and the seed selection size at 50. In this environment, test will be repeated 50 times each, and the test results for a minimum solution and an average solution will be calculated in the future study.

6. Conclusion

This study has proposed the genetic algorithm for the establishment of efficient dispatching of container truck. The proposed genetic algorithm provides the user with optimized alternative plan in the viewpoint of expenses by the automation of conventional planning process of manual method. Also, this study has tried to present the algorithm with maximum reflection of various and complicated and constraints in the practical viewpoint, which is expected to enhance its utilization in the actual operating site afterward. The comparison with mathematical optimization model will be carried out in the future studies based on the performance evaluation result. The proximity to the optimal solution and the superiority of proposed genetic algorithm can be verified through the comparison. Also, its practicality to the actual problems will be validated by processing the experiments based on the actual data in the operating site.

7. Footnotes

"This work was supported by the Grant of the Korean Ministry of Education, Science and Technology" (The Regional Core Research Program/Institute of Logistics Information Technology)

8. References
