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AN APPLICATION OF DIFFERENTIAL EVOLUTION ALGORITHM IN SPARE PART LOGISTICS

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ABSTRACT

Service Part Logistics (SPL) is management of parts that have time critical for delivery and return spare parts like ATM (Automatic Teller Machine), aviation parts, automotive, information technology infrastructure, telecommunication infrastructure, critical medical equipment,etc. Combining the transportation deliveries in SPL is difficult to do in manual without system support. Vehicle Routing Problem with Time Windows (VRP-TW) is the problem to optimize the deliveries. We propose application of Differential Evolution Algorithm to optimize VRP-TW for consolidation shipment in spare part logistics.

Key words: spare part logistics, third party logistics, differential evolution algorithm, VRP-TW.

1. INTRODUCTION

1.1. Logistics and Service Parts Logistic

Logistics management is the planning, implementation and control of the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customer requirements (CSMP, 2006) [d]. Engaging the supplier for procurement process, manufacturing and delivery goods to customer in the effective and efficient way is also where logistics play a role. In reverse logistics, pick up the goods back to distribution centre also include in the activity. Spare part logistics usually handling small weight of item with most of the items is below 10 Kg.

1.2. Third Party Logistics

Third-party logistics in logistics and supply chain management is a company's use of third party businesses to outsource elements of the company's distribution and fulfillment service [h]. This outsourcing model will make the company focus on the sales, marketing and production process when third party logistics provider will focus on operation, warehousing and transportation. Third party logistics provider focus on improving the productivity and reducing the cost to be competitive in the market. Usually a company choose third party logistics for a few years contract, so being a competitive third party logistics provider is important.

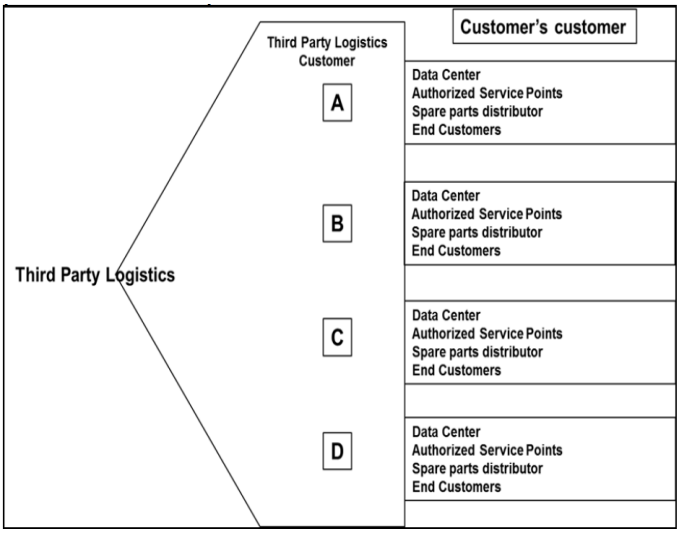

Figure 1. Relationship on third party logistics

1.3. Outsourcing the Transportation

Some third party logistics provider who handle spare part logistics outsource the transportation to the company who specialize in transportation business. Common model for outsourcing the transportation is using buy and sell method shown in Figure 2.

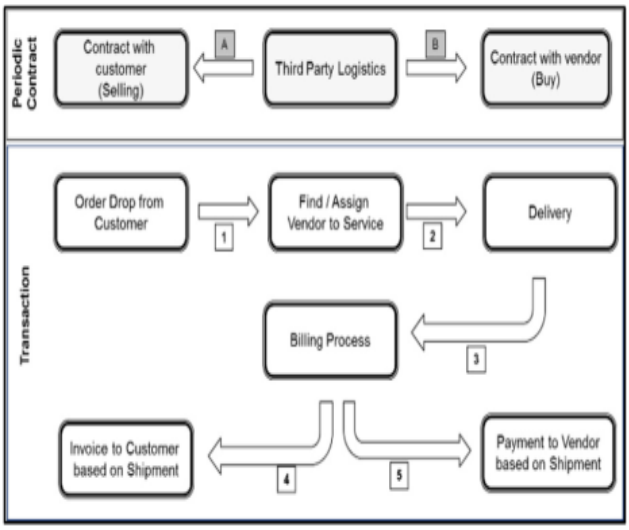

Figure 2. Buy and Sell Method

Buy and sell method is the model where third party logistics manage contract for buying rate (contract with vendor) and selling rate (contract with customer).

Process on every shipment transaction is as follows:

Step 1: customer drops shipment transaction to third party logistics.
Step 2: third party logistics define vendor that will ship the goods. Then vendor will pick up the goods from third party logistics warehouse and ship the goods to destination point.
Step 3: vendor submit the invoice to third party logistics.
Step 4: third party logistics submit invoice to customer.
Step 5: third party logistics make payment to vendor.

Outsource the transportation is common due various reason, such as: low volume, reduce complexity in operation, and no available system for consolidation the shipment. Outsource the transportation also bring some challenges: inefficient cost due all shipment cost is by minimum charges without consolidation shipment and unpredictable transportation availability. The minimum charges on outsourcing the transportation is about 10 Kg.

2. THEORETICAL BACKGROUND

2.1. Supply Chain Management

Sunil Chopra and Peter Meindl defined “A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request“ [f]. Service part logistics in third party logistics focus on function in after sales/product service and dealing with part repair. Supply chain organization on service part logistics includes: transportation, warehouse, custom, field/forward service logistics, end customer, part distributors, part repair centre, and engineers.

2.2. Transportation in A-Supply Chain

Sunil [f] stated that “Transportation refers to the movement of product from one location to another as it makes its way from the beginning of a supply chain to the customer“. Transportation must be involved in all the movements of products start from factory to distribution centre, distribution centre to field/forward service logistics, field/forward service logistics to customer and etc. Many studies of Supply Chain Management are to reduce the cost of supply chain since transportation is a significant component of the cost incurred.

2.3. Vehicle Routing Problem

The vehicle routing problem (VRP) is the problem of determining a set of minimum cost tours (in this context called routes) originating and terminating at a given central stock-point (depot) so that a corresponding number of vehicles can serve a set of given customers with the given demands [a]. This is the goal on this research to consolidate as much as delivery in shipment on third party logistics. However, consolidation the shipment in one route must consider all the constraint on the shipment.
VRP introduced by Dantzig and Ramser in 1959 for routing and truck scheduling. Clarke and Wright (1964) continuous this research and introduced depot as originating and final destination place. Research on VRP growing since transportation is one of the key element on the supply chain. Toth and Vigo [g] defined class and

interconnection for well-known various VRP as shown in Figure 3.

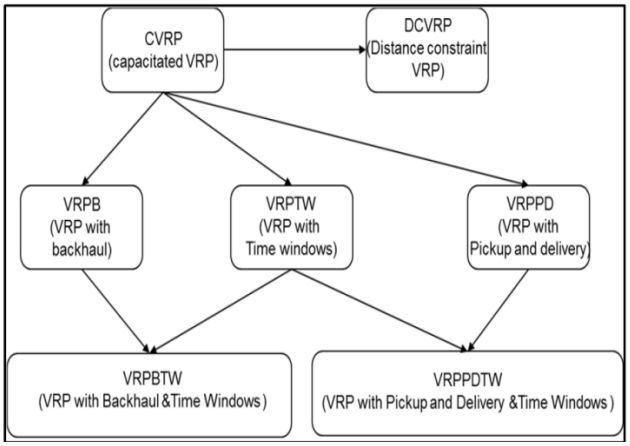

Figure 3. VRP Class and Interconnection, Toth and Vigo (2001) [g]

2.4. Differential Evolution Algorithm

Differential Evolution grew out of Ken Price's attempts to solve the Chebychev Polynomial fitting Problem that had been posed to him by Rainer Storn [b]. On first ICEO (International Contest on Evolutionary Optimization), DE become one of the best genetic algorithm that can find global optimization with more than 1 optimum value. Researcher found many Journal focus on optimization using differential evolution. DE is one of the algorithm in the Evolutionary Algorithm group like Genetic Algorithm (GA), Evolution Strategy, and Learning Classifier System. Differential Evolution algorithm inspired by biological evolution step: reproduction, mutation, combination and selection. The steps describe as follows [c]:

Step 1: Initialization. In this step, we define initiate population and control parameter. Initiate population is all individuals that can generate by random or other heuristic method. Control parameter that need to initiate on this step is Np (number of individual), F (mutation coefficient), and Cr (coefficient cross over). Np is number of individual in one population that static for all iteration.

Step 2: Mutation. Mutation is a process to formulate mutation vector which got from difference random two current vectors on current population times by mutation control parameter (F) and add with third vector on current population (also pick by random).

Step 3: Cross over. Cross over involved target population and mutant population. The objective on cross over is to increase diversity before enter next generation with combining value Cr on parameter with randomize value.

Step 4: Selection. This is the step where selection between target vector and trial vector that will enter next generation. Selection will compare evaluation on target vector and trial vector and select the best evaluation.

Step 5: Termination. This is the step where the algorithm already reaches the optimum solution or the condition for termination each like the maximum iteration.

3. RESEARCH METHOD

This research follow the methodology presented in figure 4. In high level, this research divided into five phases:

Phase 1: Collect data. In this phase, we study on current model in the third party logistics and also study on constraint for each deliveries such as fleet capacity, weight capacity, service time, window time.

Phase 2: Analyse the data. In this phase, we understand that consolidation of shipment is a key to reduce the shipment cost. Consolidation using manual is difficult to do since we need to consider a few constraint such as load weight, vehicle capacity, distance, and customer time constraint (service and window times). We understand that optimizing on this problem well known as VRP-TW.

Phase 3: Develop proposed model. In this phase, we implement differential evolution algorithm to solve the VRP-TW.

Phase 4: Comparison. In this phase, we verify the model that develop and compare with previous model.

Phase 5: Conclusion.

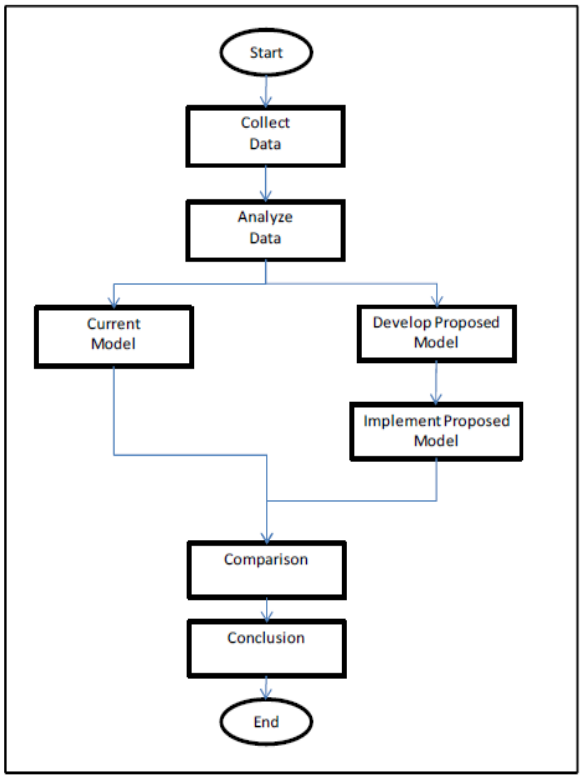

Figure 4. Research Method

4. RESULT AND DISCUSSION

4.1. Algorithm

Herewith stages of preparation the algorithm:
Stage 1: Defined the control parameter. Initiation process on development the algorithm is to define the control parameter that will use. Control parameter that need to define are number of population (NP), mutation control parameter (F), and crossover control parameter (Cr).
Stage 2: Defined initial population. Next step is to define initial population as a matrix initial individual in total number of population. This individual will represent number of route to serve all the customer and each route has each sequential delivery. Initial population generate by using random number.
Stage 3: Defined objective function. Objective function is to defined optimization objective on this algorithm. Objective function that used is minimize the distance for all vehicle.
Stage 4: Evaluation. On this stage, initiation individual will evaluate based on objective function to get which individual has shortest distance on first population.
Stage 5: Mutation. Mutation process is to produce new individual for mutant population vector.
Stage 6: Crossover. This process has objective to produce trial individual from recombination mutant individual and target individual.
Stage 7: Selection. On this stage, target individual target and individual trial vector will be selected to become next generation.

4.2. Computational Experiments

We develop an application to implement differential evolution algorithm. Application is develop using programming language C# using *differential evolution* algorithm with Visual Studio Community version as the programming tools. This application can be used for tools to solve VRP, VRPTW and VRPTW with multiple vehicle. Data source can upload from excel file with predefined template. Application displays is on Figure 5, with section for loading data from excel template, running the computation and view the result.

The differential evolution algorithm is applied to solve the 8 customer vehicle routing problem with time windows in spare part logistics delivery. Parameter on the application use describe in Table 1. There are 5 motorcycle available in the warehouse, capacity of each motorcycle is 20 kg, distances between customers and warehouse is listed in Table 2 (in km), and customer demands and time constraint (in minutes) listed on Table 3.

The simulation is running on a notebook with 2.40 GHz Intel Core i7 and 4 Gigabytes of RAM, and the runtime is 0.4535684 s. The best operational plan is using 3 motorcycle with 89 km total vehicle distance. Vehicle 1 will serve customer 3, 6, 5, 7, 4 and 2 with total load 15 kg and total distance 63 km. Vehicle 2 will serve customer 1 with total load 2 kg and distance 8 km, and customer 3 will serve customer 8 with total load 3 kg and distance 18 km. This result summarize in Table 4.

Table 1. The Parameter

Parameter	Value
F	0.8
Cr	0.4
Number of Population	20
Max Iteration	200
Max Time	20000
Vehicle Capacity (kg)	20 (motorcycle)

Table 2. The distance matrix (km)

i,j	0	1	2	3	4	5	6	7	8
0	0	4	7	8	10	24	12	19	9
1	4	0	7	4	12	6	8	13	12
2	7	7	0	8	12	12	8	8	8
3	8	4	8	0	12	6	10	10	18
4	10	12	12	12	0	12	8	8	12
5	24	12	6	6	12	0	8	10	8
6	12	8	8	10	8	8	0	8	12
7	19	13	8	10	8	10	8	0	12
8	9	12	8	18	12	8	12	12	0

Table 3. Demand on each customer

Customer	Demands (kg)	Service Time (minutes)	Window Time (minutes)
1	2	60	[60,120]
2	1	30	[300,420]
3	4	60	[60,180]
4	3	60	[240,420]
5	1	60	[180,300]
6	4	90	[120,300]
7	2	60	[240,360]
8	3	45	[60,120]

Table 4. Average Result for DE

Vehicle	Distance	Computational Time	Route
3	89	0.4535684	0-3-6-5-7-4-2-0; 0-1-0; 0-8-0

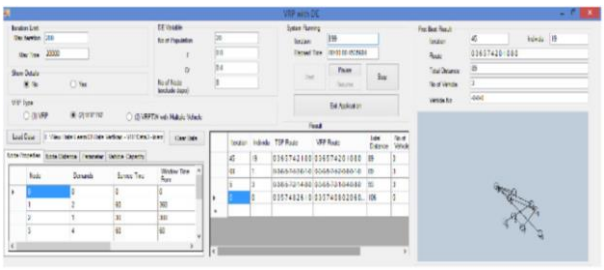

Figure 5. Application using Differential Evolution

5. CONCLUSION

This paper contributed to implementation Differential Evolution Algorithm in spare part logistics. This paper also be useful for further research on implementation of differential evolution algorithm in other topics such as VRP-TW with multiple vehicle capacity, etc. Differential Evolution algorithm can be used to solve many aspects in supply chain problem in third party logistics such as defined optimum solution for defining rack configuration, picking sequence strategy, and dock scheduling.

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