Local search algorithm for solving periodic location routing problem

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Abstract. This study examines the problem of facility location and vehicle routes determination in supply chain system periodically. The problem is determining the location and route to meet the supply of commodity to the power plant that taken from the case of an electricity company in Indonesia. In this study, the problem is called Periodic Location Routing Problem (PLRP). Periodic Location Routing Problem is a non-polynomial hard problem (NP-hard), if locations considered is increase, the computation time used is increasing exponentially. Therefore, to solve a large-scale of this problem, a local search algorithm is proposed. Local search is a very simple metaheuristic algorithm. To explore the solution space for the problem, this algorithm will use the relocation operator. The results of computational experiments from 10 instances indicate that the results of the solution have a small standard deviation with short computing time in less than 2 hours.

Keyword: PLRP, NP-hard, Metaheuristic, Local search, Relocation

1. Introduction
Distribution system is a sub-system in supply chain management. The distribution system has the role of ensuring the delivery of commodities from suppliers to users in a supply chain. To ensure the arrival of this commodity, the costs incurred will be very large if the existing supply chain network is ineffective. To create an effective supply chain network, resource points and routes must be determined in advance in the commodity delivery process.

Determining the resource points of a supply chain is usually called the facility location problem [1]. The route that must be traversed in a supply chain network is called vehicle routing problem [2]. If these two problems are integrated, it is called the Location Routing Problem (LRP) [3], [4] and [5] divide LRP models into several structures and hierarchies based on the characteristics of the problem, the solution search method and the number of objective functions. There are three decisions made in LRP, namely the location of the facility, the route of the vehicle, and the allocation of requests for each facility [4].

In this study, the problem was more like LRP with two echelon (2ELRP). This type of LRP was first discussed by [6] in the newspaper delivery system. The problems studied are commodity delivery systems in a company in Indonesia. Commodity are taken from several permanent resources. These commodities are collected in the warehouse before being delivered to user points. In its implementation, the delivery of commodity must be based on a particular delivery schedule. The problems in this study
are called Two Echelon Periodic Location Routing Problems (2EPLRP). The objective function of this problem is to minimize shipping costs and operations within the planning horizon.

2EPLRP is an NP-Hard problem [3]. This problem requires very long computational time to find the optimal solution if using analytical methods. Therefore, to obtain near-optimal solutions, one algorithm is needed to explore the solution space of the problem, for example the heuristic algorithm. The Tabu Search (TS) algorithm is used by [7] for 2ELRP problems. This algorithm is able to provide a good solution to the problems studied with efficient computing. The Local Search algorithm (LS) is used by [8]. This algorithm is then compared to TS. This algorithm looks for solutions faster than TS with similar quality solutions.

This paper proposes the LS algorithm at 2EPLRP. This algorithm is used because the implementation is quite easy, it also provides a promising quality solution. The difference between this paper and previous studies is the characteristic problem that considers delivery schedules. The objective of this study is minimizing the total cost, including fixed cost and operational cost both in echelon-1 and echelon-2.

Theater distribution was studied by [9]. That is the problem which is the model of 2ELRP in multicultural shuttle routes, time windows, limited heterogeneous vehicles, and capacity constraints. Field of logistics for the city was developed by [10]. [11] presents the Mixed Programming Integer (MIP) based on arc-variable formulation for one echelon-1 facility and echelon-2 facility of 2ELRP. These facilities were capitalized except a fixed cost of the opening facility. This study [11] was the first to introduce the term multi-echelon LRP. [12] developed another of 2ELRP variant with no-capacity echelon-1 facilities and capacitated echelon-2 facilities that consider window time constraints. Research [13] examined a special case of 2E-LRP where the customer set was divided into a number of clusters and customer requests consisted of two parts that had to be fulfilled from inside and outside the cluster. [14] study 2E-LRP with the time window as soft-constraint. [15], [7] and [16] present the MIP formulation for problems with several echelon-1 facilities which are then resolved using the TS algorithm. [7] and [16] are technical reports that explain the results obtained in [15], [17] developed a mathematical model of three indices and Genetic Algorithm for 2E-LRP problems with several no-capacity facilities of echelon-1, capacitated facilities of echelon-2, and route decisions with heterogeneous fleets. [18] uses a multi-start heuristic algorithm consisting of two components, namely Greedy randomized adaptive search procedure (GRASP) and Embedded Evolutionary Local Search (ELS) / Iterated LS (ILS) to obtain solutions to 2E-LRP problems. [11] added limitation of quality and developed two metaheuristic methods for the model [11]. [19] developed an algorithm [18] using multi-start ILS combined with taboo lists and Relinking Path (PR). [20] solved the variants studied in two previous studies (18) and (19]) and developed GRASP which was reinforced by learning process and PR. [21] present branch-and-cut and Adaptive Large Neighborhood Search (ALNS) algorithms. The most recent development that can be found include research [22] which develops research [14] to be multi-objective in the context of perishable food supply chains. For this bi-objective case, [22] developed the MHPV algorithm which is a combination of Multi Objective Particle Swarm Optimization (MOPSO) and Adapted Multi Objective Variable Neighborhood Search (AMOVNS). In the same year, [23] developed bi-objective 2E-LRP which was solved using the Scatter TS procedure for non-linear Multi-Objective Optimization (SSPMO) and Non-dominated Sorting GA II (NSGA-II) methods.

PLRP combines standard LRP with Periodic VRP, where the route of visit is planned along the horizon that have a multi period. A visit patterns set that have been predetermined chose the visit period for each customer. PLRP aims to determine (i) configuration of facilities to be used in all planning periods, (ii) allocation of visit patterns to customers, (iii) allocation of customers to facilities for each period during the planning horizon where one customer does not have to be served by the same facility in each period, and (iv) vehicle routes from each facility for all periods. The objective function of PLRP is generally to minimize the total cost of opening and operating the facility, the fixed cost of the vehicle, and the cost of administering the route. Therefore, the fixed cost of the vehicle for each facility is based on the maximum number of vehicle routes carried out from each facility in each period along the planning horizon.
2. Methods

2.1. Local Search Approach

The local search algorithm is a heuristic method that uses several optimization techniques in finding solutions [2]. In generating solutions, the operators used are usually insertions or exchanges a point in a solution. In this study, the objective function of the problem is divided into two: product delivery costs which consist of two echelon and operating costs of selected resource points. The constraints on the problem is:

1. Vehicle capacity in echelon 1
2. Vehicle capacity in echelon 2
3. Allocation of delivery period
4. Capacity of resource in echelon 1
5. Capacity of resource in echelon 2 (warehouse)
6. Customer allocation
7. Constraint related vehicle routing problem

![Figure 1. Solution example of 2E-LRP](image)

Step of proposed LS in this paper are given as follows:

0. Initialize the number of generation parameters \( I \) and number of relocation \( G \).
1. Generate initial solution \( \sigma_0 \) using insertion heuristic.
2. Set the current solution \( \sigma_c = \sigma_0 \).
3. Repair current solution \( \sigma_o \) and generate new solution using relocation operator based on echelon.
4. Take one best solution \( \sigma_b \) based on objective function.
5. Calculate \( \Delta = f(\sigma_b) - f(\sigma_c) \).
6. If \( \Delta < 0 \), set \( \sigma_c = \sigma_b \). Otherwise, reject all new solutions.
7. Investigate \( I \). If it is the same as the number of generations, set \( \sigma_a = \sigma_c \) Stop, otherwise, back to step 3.

3. Result
The data used in the experiment is hypothetical data. The hypothetical data used consists of 2 resource points (S), 4 potential hub nodes (H) and 4 customer nodes (C). Customer demand and source capacity are randomly varied for each data set while taking into account the limitations of the algorithm. In this performance analysis 10 hypothetical data sets are used. Naming the test data set, for example 8N_01, means that 8N is a data set with eight nodes and 01 means the first set of data. The processing for each data set is done ten times replication and then the best value is taken, the data set with the best objective function. The LS algorithm used is implemented in the programming language MATLAB™.

Experimental results can be seen in table 1. Based on these results, the resulting objective has a small deviation. This can be seen from the average. The computing time needed to get the results is also short based on the table. This applies to all data tested. Based on the examination of all constraints, the solution obtained shows that there are no constraints that is violated. This can be seen in table 2. The resulting solution is the optimal local solution. This is because the operators used are still very random.

Overall, the LS can solve all kinds of instances with short computation. After being examined, there are no violating constraints which can conclude that the LS can solve the problem with large scale of data.

| Data  | Best Objective | Average   | Time (seconds) |
|-------|----------------|-----------|----------------|
| 8N_01 | 37364          | 37455,6   | 101,2          |
| 8N_02 | 25366          | 25466,7   | 150,3          |
| 8N_03 | 19733          | 19677,5   | 133,4          |
| 8N_04 | 30167          | 30166,8   | 148,2          |
| 8N_05 | 23345          | 23446,6   | 114,1          |
| 8N_06 | 18721          | 18733,7   | 129,3          |
| 8N_07 | 28932          | 28995,3   | 133,5          |
| 8N_08 | 24566          | 24666,7   | 178,2          |
| 8N_09 | 26615          | 26744,2   | 144,3          |
| 8N_10 | 27954          | 28123,9   | 126,5          |

| Constraints                     | State       |
|---------------------------------|-------------|
| Echelon 1 vehicle capacity      | Unviolated  |
| Echelon 2 vehicle capacity      | Unviolated  |
| Delivery period allocation      | Unviolated  |
| Echelon 1 resource capacity     | Unviolated  |
| Echelon 2 resource capacity     | Unviolated  |
| Customer allocation             | Unviolated  |
| Vehicle routing problem constraint | Unviolated |

4. Conclusion
This study proposed the 2E-LRP to address the problems on a company in Indonesia. The objective of this problem is to minimize product delivery costs which consist of two echelon and operating costs of selected resource points. The contribution of this paper is considered delivery schedules at the customer. The problem is solved using the local search algorithm. The results shown by the algorithm are a good solution, but are still local optimal. This is caused by the selection of operators that are still random.
Future work can improve this algorithm, or can use other algorithms to improve the quality of the solution. In addition, future work can develop mathematical models as a comparison of the quality of the solutions produced by the algorithm.

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