Model development of Multi depot SDVRPTW

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Abstract

Vehicle Routing Problem (VRP) is a route optimization problem. The current situation grows more complex so the VRP needs to adapt for being close to the practical problems. Perishable products are one example that need route optimization because perishable products require fast delivery time to maintain freshness. Often several companies has several distributors & some retailers (multi-depot), and often found that demand of customer that exceeds of the vehicle capacity so it needs to be visited more than once for each customer to meet customer demands (split-delivery) and with consideration of customer allowed service time (time-windows). In the traditional VRP, there are no consideration factors such as multi-depot (MD), split-delivery (SD) and time-window (TW). Therefore, we developed a model multi-depot split-delivery VRP with time-windows (MDSDVRPTW), which is the relaxation of traditional VRP limitation, with an objective function to minimize the total travel time.

Keywords
Multi depot, Split delivery, Time windows, Vehicle routing problem

1. Introduction

VRP is one of the solutions to logistic's problem with its main purpose to find the best route to go through. In general, the benefit of using VRP is minimizing the total cost or the distance by using a bunch of vehicles to give the shipping services to the consumers.

The term of vehicle routing problem was found by Dantzig & Ramser in 1959 when they were working on a project called Truck Dispatcing Problem; a shipping truck problem to manage/organize the shipping routes of fuel (Sharda & Voβ, 2007). Nowadays or about more than fifty five years after VRP was found, it experienced a drastic change and it became a research's favorite topic in the whole world. Today, there are 498.000 results for vehicle routing problem search key in online search such as Google and about 78.804 results in sciencedirect.

Beside the low cost of delivery, the shipping speed is one of the consumer's requirements (Santoso et al., 2012). VRP that is equipped with only one depot to serve group of consumers will not give satisfying results and will take a longer time to fulfill its duties. Therefore, rich VRP is needed; a VRP that resembles the previous VRP but with relaxation from the previous' restrictions. According to Baldacci et al., (2008), "rich VRP" can be identified by the existence of some depots, some road' routes, some vehicle types or other restrictions.

In vehicle routing problem (VRP), the vehicle's armada (the fleet of vehicles) can serve or fulfill the request of more than one consumer, each consumer can only be visited by one vehicle and the purpose to minimize total distances taken by the vehicle. In split-delivery vehicle routing problem (SD-VRP), the limits in accordance to the visitation of vehicle's armada (the fleet of vehicles) to the consumer which only can be done once is removed, thus the consumer can be visited by the vehicle's armada more than once (Sharda and Voβ, 2007). Split-delivery vehicle routing problem (SD-VRP) is a VRP model that allows visiting consumer more than once due to the request that exceed the vehicle's capacity (Dror and Tredeau, 1989; Jin *et al.*,2008 in Santoso *et al.*, 2012). The purpose of SD-VRP itself is to find a set of route that is passed by vehicle to serve consumer's request with capacity lower than the capacity that can be carried by the vehicle and the total distance taken by the vehicle (Sharda and Voβ, 2007).

In this study, the model development using multi-depot limitation that is considered as a near real-life problem is represented. This multi-depot owns some customers that can be served by some depots (distributors). It is expected that using this multi-depot variants, the route distance and the time taken to serve group of consumers can be minimized. Mancini (2015) developed a multi-depot model that enables the vehicle's armada to leave and stop at a different depot. That model increases the complexities of classical MDVRP where originally it only allows the fleet of vehicles to depart and stop at the same depot. Alinaghian and Shokouhi (2017) developed a multi-depot multi-compartment VRP. What it means by multi-compartment is a different place for a different product for each vehicle. The purpose of the research is to minimize the number of vehicle used and then to minimize the routes taken by the vehicle.

Vehicle Routing Problem with time-window (VRPTW) is one of the VRP variant that allows a customer to be served in a certain time span, so the vehicle's schedule must be determined beforehand (Sharda and Voβ, 2007). Similar research has been done by Santoso *et al.*, (2012) with the title Split-Delivery Vehicle Routing Problem with Balanced Total Service Time (SDVRPBTST). Another similar research was also conducted by Yan *et al*., (2015) but it used only one depot and as the result the time service tend to take longer time. Research related to multi-depot has been conducted by Ray *et al.*, (2014) with the title Multi-Depot Split-Delivery Vehicle Routing Problem (MDSDVRP) that focused on the determination of the depot location placement and the depot route with the purpose to serve the consumer. Unfortunately, this research has not considered the time-windows.

Distribution network can be solved as multiple individual single depot VRP's, if consumers are seen to clustered around each depot, if not, a multi depot approach need to be used where customers are can be served from any of the depots available and using the available fleet of vehicles (Montaya-Torres *et al* 2014). Those gaps can be filled with the development a new model called 'multi-depot split-delivery VRP with time-window (MDSDVRPTW).

2. Literature review

In this literature review, types of available variants of VRP is presented, furthermore, the combination development of multi-depot split-delivery vehicle routing problem with time-window (MDSDVRPTW) will also be explained.

2.1. Capacitated VRP

CVRP is one of the VRP varians that only has one limitation. CVRP decides the vehicle route from one depot (single-depot) to some consumers with the purpose to minimize the total distances (Wilck IV & Cavalier, 2012)

2.2. Split-delivery VRP (SDVRP)

In the above Capacitated VRP (CVRP), consumers may only be visited once in a single delivery period. While the split-delivery VRP (SDVRP) itself is a relaxation of CVRP, because the SDVRP consumer demand can be met by more than one visit (Yan et al., 2015). Wilck IV & Cavalier (2012) developed a new construction heuristic for the VRP split-delivery model (SDVRP) and compared the speed of the computerized process with column generation and two-phase methods, and found that the new heuristic was faster and could be useful for early solution development (initial soluttion).

2.3. VRP with time-windows (VRPTW)

Some cases of vehicle routing problems (VRPs) must be resolved with time constraints and these constraints can be called VRP with time-windows (VRPTW) (Yan et al., 2015). Vehicle Routing Problem with time-window (VRPTW) itself is a limitation relaxation that allows customers to be served within a certain time span, so the schedule of vehicles must be determined first (Sharda and Voß, 2007).

There are two types in time-windows (TW), hard time-windows are applied when delivery is within the required time range and soft time-windows are used when there is flexibility for delivery time (Yan et al., 2015).

2.4. Multi depot VRP (MDVRP)

Multi-depot VRP (MDVRP) is one of the VRP variants that allow consumers to be served by more than one depot (de Oliveira et al., 2016). Related Multi-depot research is also conducted by Ray et al., (2014), which has a multi-depot split-delivery vehicle routing problem (MDSDVRP) title that focusing on locating depots and depot routes and aimed at serving consumers, Ray et al ., (2014) uses a heuristic algorithm to achieve near-optimal results in search of results from multi-depot split-delivery VRP (MDSDVRP).

2.5. Multi depot split-delivery VRP with time-window (MDSDVRPTW)

In the previous variants described in relation to traditional VRP variants which include Capacitated VRP (CVRP) which can not be split-delivery and only one depot, split-delivery VRP (SDVRP) with only one depot, and multi-depot VRP (MDVRP) which also can not be split-delivery.

To reach the near-life problem requires the complexity of the VRP itself. the need for a complex VRP model emerged, commonly called "rich VRP", similar to the previous VRP but with some additional restrictions. According to Baldacci et al., (2008), "rich VRP" can be identified by several depots, some road routes to be undertaken, some types of vehicles or other restrictions.

Therefore, in this study will combine the traditional VRP-related variants such as SDVRP, MDVRP and VRPTW into MDSDVRPTW to cover each other's deficiencies by each of the traditional VRP variants.

3. Preliminaries

On this preliminaries, information about model development multi depot SDVRPTW source that come from Kulkarni and Bhave (1985) in Montaya-Torres *et al* (2014) and Santoso *et al* (2012). Integration mathematical model for multi-depot SDVRPTW that come from Kulkarni and Bhave (1985) in Montaya-Torres *et al* (2014) and Santoso *et al* (2012) is presented.

3.1. Model development

Model development of MDSDVRPTW on this paper was created from the integration of two models that have been done previously by Kulkarni and Bhave (1985) in Montaya-Torres *et al* (2014) paper with title 'A literature review on the vehicle routing problem with multiple depots' and with paper belong to Santoso *et al* (2012) with title 'split delivery vehicle routing problem yang menyeimbangkan total waktu layanan'. For the multi depot model, I took it from Kulkarni and Bhave (1985) in Montaya-Torres *et al* (2014), while for the split delivery and time windows model I got it from Santoso *et al* (2012) paper.

3.2. Mathematical model

Minimize

$$\sum_{i=1}^{N+M} \sum_{j=1}^{N+M} \sum_{K=1}^{K} (C_{ij} X_{ijk})$$

Subject to :

$$\sum_{j=1}^{N+M} \sum_{k=1}^{K} X_{ijk} = 1 \quad i = 1, \dots, N \tag{2}$$

$$\sum_{j=1}^{N+M} \sum_{k=1}^{K} X_{ijk} = 1 \quad i = 1, \dots, N \tag{3}$$

$$\sum_{i=1}^{N+M} X_{ihk} - \sum_{j=1}^{N+M} X_{hjk} = 0 \quad \begin{cases} k = 1, \dots K \\ h = 1, \dots, N+M \end{cases} \tag{4}$$

$$\sum_{i=1}^{N+M} Q_i \sum_{j=1}^{N+M} X_{ijk} \le P_k \quad k = 1, \dots, K \tag{5}$$

$$\sum_{i=1}^{N+M} \sum_{j=1}^{N+M} C_{ij} X_{ijk} \le T_k \quad k = 1, \dots, K \tag{6}$$

$$\sum_{i=N+1}^{N+M} \sum_{j=1}^{N} X_{ijk} \le 1 \quad k = 1, \dots, K \tag{7}$$

$$\sum_{j=N+1}^{N+M} \sum_{j=1}^{N} X_{ijk} \le 1 \quad k = 1, \dots, K \tag{8}$$

$$y_i - y_j + (M+N) X_{ijk} \le N + M - 1 \quad 1 \le i \ne j \le N \text{ and } 1 \le k \le K \tag{9}$$

$$x_{ijk} \in \{0,1\} \quad \forall i, j, k \tag{10}$$

$\sum_{k\in V} f_{ik} = 1 \quad \forall i \in C$ (11)
$\sum_{j\in N} X_{jik} \geq f_{ik} \quad \forall i \in C, \forall k \in V$ (12)
$f_{ik} \geq 0 \quad \forall i \in C, \forall k \in V$ (13)
$q_{ik} \geq d_i f_{ik} \quad \forall i \in C, \forall k \in V$ (14)

$s_{ik} + S_i + t_{ij} - K_{ij}(1 - X_{ijk}) \leq s_{jk} \quad \forall j \in C, \forall i \in N, \forall k \in V$ (15)
$s_{ik} + S_i + t_{i0} - K_{i0}(1 - X_{i0k}) \leq b_0 \quad \forall j \in C, \forall i \in N, \forall k \in V$ (16)
$a_i \leq s_{ik} + S_i \leq b_i \quad \forall i \in N, \forall k \in V$ (17)
$s_{ik} \leq (\sum_{j\in N} x_{ijk}) \times b_i \quad \forall i \in N, \forall k \in V$ (18)

In this formula, constraints (2) and (3) is to ensure every customer is served only by one vehicle. Constrain (4) is for route contiunity. Capacity of vehicle and total route cost is declared in (5) and (6). Constrain (7) and (8) is used for vehicles availability and constrain (9) is for subtour elimination. Constrain (11) to (14) is for splid delivery, and constrain (15) to (18) is served for time windows.

4. Research methods

The research type according to Parung (2012) can be classified into five categories, consisting of research classification based on outcome (research nature), research classification based on philosophy (research philosophy), research based based on objectives, research approach based on modes), research strategies.

4.1. Classification of research based on outcome (research nature)

Research nature is divided into two types, consisting of applied research and basic research. In this multi-depot split-delivery study VRP time-window (MDSDVRPTW) can be categorized into basic research because the main objective is to contribute in the science of model / theory development. The basic research itself is categorized into three consisting of discovery, Invention, and reflection. In this research is included in the reflection because in this research the development of pre-existing models by adding new variations of the boundaries.

4.2. research classification based on philosophy (research philosophy)

Reseach philosophy in this study can be categorized into two aspects, consisting of ontological and epitemological. Esterby et al. (2002) in Parung (2012) proposes two contrasting philosophical traditions, consisting of posisitivis and social construction (phenomenology). This research is included in research posisitivis because this research is quantitative. While on the epitemological aspect, this research also included into the posisitivis research because there is no relationship between the researcher with the object under study

4.3. research approach based on goals

the research approach based on these goals can be categorized into 3, consisting of descriptive, explanatory, and exploratory (Tellis, 1997; Yin, 1994; in Parung, 2012). In this study can be categorized into exploratory research because in this study aims to develop a pre-existing model.

4.4. research approach based on modes

Research based on this modes is known 2 modes of research consisting of induction and deduction (Buckley et al., 1976; in Parung, 2012). In this study can be categorized into Induction research because in this study plans to generate a new model.

4.5. research strategies

There are 5 possibilities in research strategies, consisting of opinions, empirical, archives, analytics, and survey (Parung, 2012). In this research can be said to go into analytics because in this research is done model development.

5. Conclusion & Future search

In this paper, we presented VRP model with cosider multiple relaxation of capability from traditional VRP. Relaxation of multi-depot is used because often several companies has several distributors & some retailers (multi depot), and relaxation of number of visit to customer is used because often found that demand of customer that exceeds of the vehicle capacity so it needs to be visited more than once for each customer to meet customer demands (split-delivery) and relaxation of customer allowed service (time-windows). On this paper, we develop the model only, so computational approach can become future research for this model.

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