HEURISTIC METHOD FOR THE MODIFIED MODEL OF CAPACITATED ARC ROUTING PROBLEMS

by

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ABSTRAK

Pengurusan pengumpulan sampah di kawasan bandar adalah isu yang sangat kritikal bagi sesetengah negara-negara membangun terutamanya di Malaysia yang memerlukan perhatian segera. Analisis dan kajian yang dilakukan adalah untuk membangunkan serta mengoptimumkan mutu dan kos operasi pengumpulan sisa pepejal di negeri Perlis. Tesis ini juga, menerangkan tentang pemodelan dan pengubahsuian dalam kaedah matematik untuk Masalah Laluan Teraruh Berkapasiti terhadap Graf Campuran (MLTBGC) lanjutan daripada Masalah Laluan Teraruh Berkapasiti (MLTB). Tambahan pula, penerangan berkaitan beberapa persamaan baru yang digunapakai untuk mendapatkan keberkesanan dalam penghasilan model MLTBGC seperti berat kenderaan akan dibincangkan. Untuk mendapatkan hasil yang lebih baik, kajian ini menggunakan kaedah heuristik yang telah digunapakai untuk menyelesaikan model MLTBGC. Hasil kajian menunjukkan bahawa jumlah kos yang diperolehi adalah lebih baik dan rasional untuk diterima dengan alasan yang munasabah, walaupun kaedah heuristik yang digunapakai tidak dapat memberikan penyelesaian yang optimum tetapi keadah tersebut memberikan kecepatan masa dalam memberikan keputusan menggunakan komputer berbanding menggunakan kaedah lain untuk graf campuran berangkaian kecil dan sederhana.

Heuristics Method for the Modified Model of Capacitated Arc Routing Problems

ABSTRACT

The management of waste collection in urban areas is a critical issue for some developing countries especially in Malaysia which requires immediate attention. This study attempts to make an analysis and assessment of the development of the Perlis state waste generation distribution and the optimization of waste collection routes. This thesis describes the architecture design of the mathematical modeling for the mixed graph of Capacitated Arc Routing Problem (MCARP) extended from the Capacitated Arc Routing Problem (CARP). Furthermore, it provides a description of several equations that can be used to obtain efficient collection routes such as capacity vehicles constraint. To get the better result, this study used the existing heuristics method for solving MCARP mathematical modeling. The result shows that the total costs produced are considerably acceptable and are also reasonably improved, although the existing heuristics method do not obtain an optimal solution but in term of the computational time is good and better than other methods for small and intermediate networks especially in the mixed graph problem.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the last few decades, the advancement in transportation and logistics has greatly improved people's lives and influenced the performance of almost all economic sectors. Research studying the effective planning and optimization in the network problems and scheduling field has increased tremendously. An advance in the technology and computational power has encouraged researchers to consider various problem types and real-life constraints, and to experiment with new algorithmic techniques. A number of these techniques have been implemented in the commercial optimization software and successfully used in every day transportation and logistics applications. However, due to the large increase in demand and the growing complexity of this sector, innovations in solution techniques that can be used to optimize network problems and scheduling are still urgently needed.

In the network problem, there are two major problems that have been grabbing attention recently like the Node Routing Problems and Arc Routing Problems. In the application of Node Routing Problems, the service cost or deadheading cost will be considered in the point (or nodes) of a network graph. This problem is applicable to the salesmen, who must deliver some agreed services to each house in a town. For the application in the Arc Routing Problems, service cost and deadheading cost are applied

in every link (arcs or edges) of the network graph. For the Arc Routing Problem, for instance, it is applicable to the postman who must fulfil his or her duties serving the residents of every street. Mostly this network problem area has been done on the Node Routing Problems, but it is different from the Arc Routing Problems that have received little attention comparatively because of the latter's limited application to many problem areas, such as waste collection, meter reading under electricity operations, delivery of bread into shops and airlines problem. Therefore, the application in waste collection has purposefully been chosen as a subject of further investigation in this thesis.

In Section 1.2 we introduce the research problems that we are trying to tackle and emphasize on the motivation behind our selection of these problems. Section 1.3 highlights the statement of problem in the research. Section 1.4 and Section 1.5 give an overview of the research objectives and scope of research. Section 1.6 and Section 1.7 discuss the output expected from the research and the significance of the research. Finally, the organization for the thesis is presented in Section 1.8.

1.2 Research Background

Waste management forms an essential part of any municipality's service towards the public. Nowadays, waste management has become an issue to people who are really concerned about pollutions especially due to human growth (especially in urban areas), environmental pollutions and monetary capability in conducting waste management. These factors lead to the development of improving the waste

management system based on certain constraints that will be discussed further. Hence, the ideas have captured the researcher's interest to overcome the application problem with a better solution. The waste collection management is quite a challenging problem in Malaysia especially when this has to be overcome in the fulfilment of Vision 2020. As stated in the vision, Malaysia should be one of the cleanest environments in the world. However, a critical factor in attaining this vision is the sustenance of rapid economic growth which is achieved mainly through growth in the export-oriented secondary and tertiary sectors. Malaysian industries must be able to compete successfully in the global markets through a more effective application of science and technology as well as a more imaginative utilization of the country's inherent and acquired advantages and strengths with respect to natural, human, financial and cultural resources.

The waste collections inextricably linked with the solid waste disposal activity. The Solid Waste Disposal Act is an Act of Congress passed in 1965. The United States Environmental Protection Agency described the Act as "the first federal effort to improve waste disposal technology". Idris et al. (2004) offered some good opinions about solid waste disposal issues and allowed us to look deeper into solid waste problems. He believed that the increasing number of environmental problems especially in Asian with regards to waste management has become more serious lately. This idea is also supported by Visvanathan et al. (2004) who stated that the relationship between solid waste disposal issues and waste management problem cannot be separated. In Malaysia, there are still limited data or information awareness on the solid waste management despite the Internet expansion of technology and science development.

Toth and Vigo (2002) classified waste into three major categories: Commercial waste, Residential waste and Roll-on-Roll-off waste. These three categories bring about three different waste collection strategies.

Commercial wastes are found at small businesses, restaurants and apartments. These places supply large containers that are scattered throughout the city's geographical areas. Therefore, this applications involves the node-to-node collection as the service is only required at selected nodes. This problem can be categorized as the Node Routing Problem.

Residential wastes are wastes collected in small or intermediate containers or garbage bags from houses along the street graph. Waste collection is required at nearly all locations along the given street network. Residential wastes form the biggest percentage of wastes that need to be collected by municipalities. This is one of the Arc Routing Problems.

Roll-on-Roll-off waste collection involves the pickup, transportation, unloading and dropping off large containers which are typically found at construction sites, industrial areas and other high-volume locations. The roll-on-roll-off waste collection vehicle usually carries one container and follows one of two methods, which are either the round trip (cycle) or exchange trip. For a round trip (cycle) the vehicle picks up a full container at a site, then, transports it to the landfill for emptying and directly returns the empty container to the site. Meanwhile, for exchange trip, the vehicle picks up an empty container at the landfill, then, transports it to a site to exchange it with a full container and then returns the full container to the landfill. It is one of the Node

Routing Problems that come with a complicated solution involving many constraints that have to be considered.

The context of this research is directed to the residential waste collection which can be described as follows: Residential waste is located in containers along the streets of a defined urban area. All the containers must be collected by a fleet of vehicles which capacity cannot be exceeded. Each vehicle starts from a depot and will deliver service to certain streets (edges or arcs) before its capacity is reached. Once the vehicle's capacity is reached it travels to a depot (landfill) located somewhere to unload. The vehicle then returns to the town to start its second trip. This process is repeated until all of the streets (edges or arcs) and containers assigned to the vehicle have been serviced. The vehicle completes its final trip by proceeding to the depot (landfill) to unload for the last time. The vehicle fleet and the service cost and deadheading cost (travelling along the street without service) are considered and the problem will only address the improvement of the current waste collection routes; this is called the Capacitated Arc Routing Problem (CARP). This thesis will study the mixed graph Capacitated Arc Routing Problem (MCARP) in three different problems namely undirected, directed and mixed graph problems.

1.3 Statement of Problem

The management of solid waste has now been a worldwide phenomenon. In the context of Asian countries, China, Malaysia and South Korea require immediate attention to address this problem. According to the World Bank (2013), urban areas currently generate roughly 1.3 billion tons of solid waste per year and this figure will grow to2.2 billion tons per year by 2025-an increase of 70 percent with current urbanization trends. In Malaysia, according to Arpah Abdul Razak (2013), in 2012, there were a total of 33,000 tons per day of waste generated by Malaysians. It is important to note that ASEAN countries are among those producing higher amounts of waste. Table 1.3.1 explains the urban municipal solid waste (MSW) generation in selected ASEAN countries and its neighbourhood in 2012 and 2025 (projection).

Table 1.3.1: Municipal solid waste generation in selected Asian countries

Country	Current MSW Generation (kg/capita/day)	Projection MSW Generation in 2025 (kg/capita/day)
Brunei Darussalam	0.87	1.3
Indonesia	0.52	0.85
Lao PDR	0.7	1.1
Malaysia	1.52	1.9
Myanmar	0.44	0.85
Philippines	0.5	0.9
Singapore	1.49	1.8
Thailand	1.76	1.95
Vietnam	1.46	1.8
Hong Kong, China	1.99	2
Japan	1.71	1.7
South Korea	1.24	1.4
Bangladesh	0.43	0.75
India	0.34	0.7
Iran	0.16	0.6
Maldives	2.48	2.2
Nepal	0.12	0.7
Pakistan	0.84	1.05
Sri Lanka	5.1	4
Lower Income	0.6	0.86
Lower Middle Income	0.78	1.26
Upper Middle Income	1.16	1.59
High Income	2.13	2.06

Source: Modified from World Bank (2012).

Therefore, the management for waste collection should re-think to improve the waste collection system. Thus, we try to design a model of collection systems based on the real situations and establish rational planning and assessment at this stage. It aims to create operational features which are essential to ensure efficiency in waste collection systems. One of the collection systems that we are focusing now is based on the Arc Routing Problems, in which the pickup or delivery activities occur at links between nodes of a network graph.

The Capacitated Arc Routing Problem (CARP) is the one problem-type in Arc Routing Problems. The aim of CARP is to produce an optimum-routing cost for a fleet of vehicles without violating all constraints. However, the existing mathematical models of CARP are rudimentary and messy that could not support most asymmetric cases. From previous research, the CARP can be extended in many ways to cope with the real situations. CARP is one of the problems that deal with the undirected network graph, whereby the collection for solid waste can be on any direction along the links between nodes. In particular, this research is extended from previous work with a combination between undirected and directed network graphs, additional constraints and subsequently leading to a new problem called the mixed graph of the Capacitated Arc Routing Problem (MCARP).

1.4 Research Objectives

The main objectives of this research are to:

i. Formulate a mathematical model for the mixed graph of Capacitated Arc Routing Problem (MCARP) extended from the Arc Routing Problem.

ii. Develop an experiment using the existing heuristics for solving MCARP mathematical modelling.

iii. Conduct a comparative analysis between undirected, directed, mixed graph problems and seek optimum/lowest cost between the problems.

1.5 Scope of Research

The scopes of this study are as follows:

i. The limitation for data collection is based on small town in Perlis residential area around Arau, Kangar and Kuala Perlis.

ii. The existing heuristics are used to solve the problem within the limit of MCARP models.

iii. The limitation of the vehicle capacity in range 5000 kilogram until 10000 kilogram based on the vehicle capacity used in Perlis state.

1.6 Output Expected From Research

i. Produce a new mathematical modelling that works well in different problems (i.e. undirected, directed and mixed graph problems).

ii. Develop more experiment from the existing heuristics methods that are compatible with our mathematical formulation and produce a minimal total cost for various problems.

1.7 The Importance of the Research

Contributions to operation research body of knowledge:

i. This research tries to solve the modification MCARP model by using an existing heuristics method with new additional constraints.

ii. This research is important in order to have an insight and to foresee how the existing heuristics algorithms can produce the best routing cost for different physical rhetoric problems.

iii. This study defines the better performance of result in minimizing the total cost for MCARP by using existing heuristics method.

1.8 Organisation of Thesis

In this thesis, Chapter 1 includes the research background, the problem statement, the objectives of the research, scope of the research, output expected of the research and the significance of the study to get an overview of the research. Then, Chapter 2 will describe the literature review for the routing problems that are useful for this research. Next, Chapter 3 will discuss further on the methodology especially about the construction and addition of new constraints of the mathematical model from the previous research for the mixed graph of CARP and also the method that can be implemented to solve the chosen problem in this thesis. After that, Chapter 4 intends to

show a process of the heuristics method to make it compatible with a new mathematical modelling in order to solve the undirected, directed and mixed graph problem. Meanwhile, Chapter 5 will contain all the results obtained for different instances of three problems (i.e. undirected, directed and mixed graph problems) and the discussion of these results, and the final chapter is Chapter 6, which contains the conclusion for our research and the recommendations for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Malaysia has over the years been experiencing rapid growth in population, urbanization and industrialization. Currently, the population is about 28.5 million and more than 70% of this was reported to be living in the urban areas. This rapid development has resulted in the generation of greater amount of municipal solid wastes (Badgie et al., 2012; Fauziah & Agamuthu, 2012). In a general term, it was reported that the greater the economic prosperity of any nation, the higher the rate of urbanization and consequently the greater the amount of solid waste produced and Malaysia is one of such nations (Kathirvale et al., 2003; Uiterkamp et al., 2011). Owing to the rapid increase, the search for and the provision of an efficient management method of these wastes have become a serious concern (Al Ansari, 2012).

Currently a large number of methods, approaches and modelling tools have been developed to support decision-making in solid waste management (Finnveden et al., 2007). With the large number of methods available, however it is becoming increasingly difficult for practitioners and decision makers to understand, select and apply the method which is the most appropriate for their specific needs (Finnveden et al., 2007; Chang et al., 2011; Pires et al., 2011). Whatever the decision problem is, it

must be firstly well defined by means of clear objectives that are as specific as possible, smartly measurable and realistic.

Various studies on the mixed graph of the Capacitated Arc Routing Problem (CARP) have been documented in literature in the form of the formulation of several ideas as well as the introduction of a number of modelling approaches that can be followed. These are approaches that utilize one or more methods of assessment in combination, to develop a more holistic view of the situation or depict the consequence of a suggested alternative. They are all designed to help decision makers apply improvements in solid waste management by providing better knowledge on the situation and the consequences of a particular choice.

This chapter will be divided into three sections. Section 2.2 discusses in detail the Arc Routing Problem (ARP). Meanwhile, the overview of the knowledge related to solid waste management collection history on Malaysia and CARP will be stated in Section 2.3. Then Section 2.4 will study the mixed graph of CARP and Section 2.4 concludes this chapter.