OPTIMIZATION OF A MULTI-OBJECTIVE-MULTI-PERIOD TRAVELING SALESMAN PROBLEM WITH PICKUP AND DELIVERY USING GENETIC ALGORITHM

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Thanks God to enable me performing this research despite all difficulties. I would like to dedicate this thesis with respect and love to my family who helped me to overcome all obstacles during my study. It belongs to my beloved father, Seyed Mohammad Pourhejazy, who taught me how to be strong. It is also dedicated to my beloved mother, Zahra Pakdaman Haghighi, who taught me how to love people kindly.

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ABSTRACT

Nowadays, managerial decisions regarding how to select the company's strategy between a responsive or cost effective manner to serve the customers, contributes a lot to a firm's competitiveness. It takes many factors into consideration one of which is the sequence of customers to be visited in a logistics system. The Travelling Salesman Problem (TSP) is one of the most famous combinatorial optimization problems in this area. Optimization of such problem would directly affect the total cost and also customer satisfaction level in that system. This study aims at proposing a new extension of TSP which is 'multi-objective-multi-period Travelling Salesman Problem with pickup and delivery' to represent the problem. The cost studied in this research is transportation cost associated with travel time. Delivery time (the secondary objective in the objective function) is considered as the only influential factor on the customer satisfaction. Optimization of the proposed model is done using Genetic Algorithm. The proposed model has been tested on data collected from a Company from service sector. The applied algorithm has been encoded by Matlab software. Final results are given illustrating the validity and practicality of the proposed model for different strategies in a company according to its customer's expectation.

ABSTRAK

Dalam dunia hari ini, keputusan pihak pengurusan syarikat berkaitan dengan strategi syarikat samada untuk mengambil sikap responsif terhadap pengguna atau pun menggunakan pendekatan penjimatan kos terhadap pelanggan mereka. Tindakan ini banyak mempengaruhi nilai kompetitif syarikat. Terdapat banyak faktor yang perlu diberi pertimbangan antaranya giliran lawatan ke tempat pelanggan terutamanya di bahagian sistem logistik. Masalah pergerakan penjual merupakan salah satu masalah utama yang perlu diberikan perhatian kerana ia akan memberikan kesan secara langsung terhadap jumlah kos keseluruhan dan juga akan mempengaruhi kepuasan pengguna. Kajian ini bertujuan untuk mencadangkan pendekatan baru dalam menyelesaikan masalah tersebut. Faktor kos yang dimasukkan dalam kajian ini adalah berkenaan dengan kos pengangkutan yang berkadar dengan masa. Masa yang diambil untuk penghantaran juga telah diambilkira dan dianggap sebagai satu-satunya faktor yang mempengaruhi kepuasan pelanggan. Model yang dicadangkan telah dioptimaskan dengan menggunakan algoritma genetik. Selain itu, model ini juga telah diuji dengan menggunakan data yang dikumpulkan daripada sebuah syarikat yang terlibat dalam bidang perkhidmatan. Algoritma yang digunakan dalam kajian ini telah dibina dengan menggunakan aplikasi Matlab. Hasil kajian ini telah menunjukkan praktikaliti model tersebut terhadap strategi syarikat berdasarkan kepada apa yang dimahukan oleh pelanggan.

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CHAPTER 1

INTRODUCTION

1.1. Introduction

In today's dynamic business environment, organizations are obliged to think tactically and strategically to stay competitive. Supply Chain managers are trying to find efficient designs and competent operating systems of the supply chain to satisfy various customer needs and enhance firm's profitability.

There are many definitions holding different attitudes toward Supply Chain. It is actually the integration of business processes from end user to the suppliers which present products, services and information include value added for the customers (Lambert *et al.*, 1998). Christopher (1992) takes other factors into consideration. He defined the supply chain as the organization's network that encompasses upstream and downstream relations with suppliers and customers during various activities producing value in the form of services or products to the final marketplace at least cost. These two definitions both are defining the Supply Chain as the stream of materials and information via linking parties to provide services to the end-customer. The word 'Network' in the second definition refers to a

more complicated formation in which organizations are cross-linked with a two-way trade, while ‘chain’ refers to an easier chronological set of linkages.

According to Mentzer et al. (2007) all the business activities encompass several entities such as marketing and sales, research and development, production, purchasing, logistics, information system, finance and customer service. Logistics is one of the supply chain parts that is responsible for the “process of planning, implementing and controlling the effective and efficient flow and storage of goods, services and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements” (Council of Logistics Management, 1998). Logistics plays an inseparable role in todays business environment. No marketing, manufacturing or project execution can even continue without logistics support. A notable portion of gross sales in companies is logistics cost; this amount depends on the business, geography and weight/value ratio. Service sector companies have been affected by logistics more than other businesses because of their diverse nature.

The alteration from an industrial based economy to a service based economy has been proceeding in most of the developed countries over past years. As a good instance, service industry has been continuously growing and swiftly becoming a vital segment in the economy of the Dow Jones stock indices which is 26.7% (CNN Money, 2012). Among the U.S. large commercial entities, General Electric and IBM can be mentioned as the world’s most competitive operations in the service sector. New information technology makes the most contribution to this transformation from manufacturing to services (Julie, 2012).

The significance of supply chain and logistics in the service sectors cannot be overstated; indeed, they are the major drivers of technical progress in services. This area has drawn great researcher’s attention from various fields one of which is applied mathematics. Applied mathematics as a subdivision of mathematics is

associated with the application of mathematical knowledge to other fields. Frequent practical application of mathematical models like the travelling salesman problems have been found in Supply Chain and logistics. These models aim at making the business work smarter. Distribution of products from manufacturers to customers, distribution of fuel to petrol stations, visits of repairman at customers´ homes and many of other cases can be formulated in such mathematical models.

The Traveling Salesman Problem (TSP) is one of the most famous mathematical models which placed in NP-hard combinatorial optimization problems (Lawler *et al.*, 1985). The TSP purpose is to find the closed route of the shortest length or of the least cost visiting a certain group of cities once and only once. Real-world applications of the TSP contains a variety of problems in science and engineering, such as vehicle routing problems, wiring, scheduling, flexible manufacturing and so on (Majumdar & Bhunia, 2011). This thesis aims at studying on TSP as well proposing a new extension which would be useful for the service sector companies.

1.2.Background of the study

Logistics is the science of planning, organizing and managing the activities related to presentation of products in the form of goods or services (LogisticsWorld, 1997). According to this definition studies relateding find the sequence of customer visit and especially routing problems in transportation cases would play a significant role in the logistics. Although the primary purpose of supply chain networks is to decrease the costs, there are other significant qualitative factors such as customer satisfaction that are vital for the firms to stay competitive in the marketplace.

During past years, researchers have put more emphasis on modeling and simulation approaches with focus on optimization of the processes involved in managing the supply chain network, logistics and transportation. These models and approaches are based on the real-world variables tending to be affected by the external factors of the marketplace. These complexities cause many research challenges that require to be addressed to provide solutions those can reduce costs, enhance the quality and as a result improve firm profitability.

The Travelling Salesman Problem is one of the most famous combinatorial optimization problems in this area. The origin of the problem refers to a game called the "Icosian Game" introduced by Hamilton in 1856. Hamilton formed the game to find a Hamiltonian Circuit along the edges of a dodecahedron. The purpose of this game was to find a path in a way that all nodes must be visited once and only once, and the ending node is the starting point (Weisstein, 2003). Today the target of this game is known as a Hamiltonian Circuit that is the basis of the famous TSP.

A significant number of extensions have been proposed to the basic Traveling salesman problem in order to make more realistic results from the mathematical models. It has been studied increasingly in the last decades and a review on previous works demonstrates that most of these models tend to be probabilistic. Generally, the TSP can be categorized into four main versions; symmetric travelling salesman problem (sTSP), asymmetric travelling salesman problem (aTSP), multi travelling salesman problem (mTSP), and probabilistic travelling salesman problem (PTSP). From another point of view some other factors such as time window, prize and penalty, pickup and delivery, and draft limit have been added to the classic TSP model.

Numerous applications of TSP has led to a wide range of studies to generalize it's features. Travelling Repairman Problem, Travelling Politician Problem, and

Chinese Postman Problem are among the generalized problems have been proposed during last years. The TRPP has some similarities to the traveling salesman problem (Applegate *et al.,* 2006). However, unlike the TSP, in the TRPP there is no need to visit all the nodes. Moreover, an optimal solution in Travelling Repairman is a path that has been affected by the depot location and may include intersections. The Chinese Postman Problem proposed by the Chinese mathematician Mei-Ko Kwan (M. Guan, 1962) is a model aimed at minimizing the lengths of routes walked by a postman. Actually, the CPP objective is to determine a shortest closed route which goes across every edge at least once and delivers mail on every designated street block (Kramberger & Zerovnik, 2007). The most important difference between TSP and CPP is about the visiting criteria that is based on the edges, while TSP focus is on vertices.

Despite a lot of studies regarding TSP, there are many opportunities to enhance it's applications in real world. Having time frame, the prize and penalty, number of depots, number of commodity flow, number of salesmen, objective type and necessity of visiting all nodes are among efforts to proposing realistic TSP rxtensions. Although most of the TSP's features has been studied in previous works, in many cases they are not comprehensive enough to satisfy many of the real world conditions. Therefore, the main aim of this study is to propose a new TSP model to apply in service sector those include logistics in their activities.

1.3. Problem Statement

Modeling and optimization of routing problems such as TSP in a way that is near to real-world condition has always been a big matter for the researchers. This complexity has been originated from consideration of a wide range of constraints and variables. Most of the TSP models have been proposed under deterministic

condition. On the other hand, in majority of the probabilistic cases customer presense is considered as the source of uncertainty other factors are assumed deterministic. Although the primary purpose of the TSP is to find the minimum travelled distance, some other factors such as the salesman salary can also be added to the objective function. In service cases, the factors those affecting on qualitative goals such as customer satisfaction can also be considered as the secondary objective. Consideration of such factors contributes a lot to the competitiveness of a company.

Estimation of exact travel time and service time naturally is an infeasible task. Since many external factors such as traffic conditions, traffic jams and weather condition influencing the traveling time, a deterministic model cannot be appropriate. To overcome this weakness, consideration of intervals for time factors should be taken on account. Furthermore, consideration of pickup and deliveries within a time period can provide us by a more realistic model in the after sale service cases. In the classic pickup and delivery, a single incapacitated vehicle has to supply a number of transportation demands by a certain origin and destination in same tour. While in this case, picked up items from previous days (during the M-day period) have to be delivered and some of the new requests need to be picked up for applying repair services in the depot (Company). The pickup decision versus repair at customer place should be made according to the company's strategy.

Lack of developing a TSP with pickup and delivery in a specific period considering a secondary objective working under time intervals is the discovered gap this thesis is going to address it.

1.4. Objective of the study

The main aim of this study is to solve a new practical version of TSP. In order to achieve this aim, the following objectives are defined:

I. To propose a mathematical model for the multi-objective-multi-period Traveling Salesman Problem (TSP) with pickup and delivery.
II. To find the optimal solution for the proposed model using Genetic algorithm.

1.5. Scope of the study

I. In this study, the optimal design and operation of a multi-objective-multi-period TSP with pickup and delivery will be proposed.
II. Travel time and service time are incorporated into the model within specific intervals.
III. The Genetic algorithm will be used to solve the model.
IV. Linear Programming approach will be used for multi-objective modeling.
V. An after sale service company (CY) is considered as the case study.
VI. The model will be encoded using the Matlab software.

1.6. Significance of the study

The impact of service firms to the economy is well-known; therefore, it is necessary to improve services and make them efficient and responsive. Particularly

since this segment depends seriously on the customers, new paradigms, frameworks and performance measures purposely considered for the services are essential to make sure of this upward trend. The field of Stochastic Combinatorial Optimization is one of the fields that is playing an increasingly important role in this area. Since the real world and specially modern world is extremely uncertain and dynamic, time interval can be used to create more realistic models of real world problems. While those models can represent a lot of problems more appropriately, finding sufficiently good solutions can notably reduce costs as well as enhancing customer satisfaction.

To the best of my knowledge, there is no reference in the literature deals with the multi-objective-multi-period TSP with pick up and delivery considering time intervals as the input parameters. As the model has been defined in this study, the literature on similar problems is also very scarce. The most similar problem to this extension is the period TSP that has been proposed by Giuseppe Paletta (2002).

The main contribution of this study is to propose a mathematical model to fill the mentioned gap, and solve it using a meta-heuristic algorithm. The proposed model would be useful for after sale service cases those have pickup and delivery and visits in customer's place. Outcomes of this study would be helpful for practitioners in Industrial engineering and logistics.

1.7. Thesis outline

The remainder of this thesis is arranged as follows. Chapter one illustrates the background and rational and also objectives of the study as well as the scope of this thesis. Chapter two is a review on the previous works related to the study. The

literature review part starts by the Traveling Salesman Problem and its various forms. It continues by investigation on assorted optimization approaches. In Chapter three, the sequence of research methodology is structured sequentially and a primary description about the solving method has been introduced. Chapter four has been assigned to the mathematical model and its requirements. Algorithm implementation, software coding and case study are addressed in chapter five. The coded algorithm and mathematical model have been validated in chapter six. Moreover, numerical results are discussed and analyzed in this chapter. Finally, some recommendations for possible future works and conclusion of the study have been commited in last chapter.

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