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The Shortest Road Algorithm Approach In Determining The Route Of Solid Waste Collection Vehicles: The Case Of Manisa 75. Yıl Neighborhood

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Abstract: Many studies have been conducted in recent years to solve the Shortest Route Problem, and the solutions produced as a result of these studies are used in all aspects of everyday life. Package distribution of cargo companies, school services leaving students home, bank branches collecting money and forwarding it to the central bank, municipalities collecting wastes, and bread companies distributing bread to bakery markets, and similar transportation services in which vehicle routing is needed make use of these solutions. Some algorithms related to the Shortest Route Problem were examined in this article, and among these, the Dijkstra Algorithm was applied to a real example problem. In this example, 75. Yıl Neighborhood of Yunus Emre District of Manisa Province was modeled with the Graph Data Model, and the best road destination for solid waste collection vehicles was determined. Based on the results obtained, it was determined that the Dijkstra Algorithm identified the shortest route successfully.

Key words: Shortest road, vehicle routing, shortest path algorithm, graph model.

Katı Atık Toplama Araçlarının Güzergâh Tespitinde En Kısa Yol Algoritması Yaklaşımı: Manisa 75.Yıl Mahallesi Örneği

Öz: Son yıllarda en kısa yol probleminin çözümüne yönelik birçok çalışma yapılmakta ve bu çalışmalar neticesinde üretilen çözümler hayatın her alanında kullanılmaktadır. Kargo şirketlerinin paket dağıtımı, okul servislerinin öğrencileri evine bırakması, banka şubelerden paraların toplanıp merkez bankaya iletilmesi, belediyelerin atıkları toplaması ve ekmek fırının marketlere ekmek dağıtımı gibi araç rotalamanın gerekli olduğu her türlü taşımacılık hizmeti bu çözümlerden faydalanmaktadır. Bu makalede en kısa yol problemine ilişkin bazı algoritmalar incelenmiş ve incelenen algoritmalardan Dijkstra algoritması gerçek bir örnek problem üzerinde gerçekleştirilmiştir. Ele alınan örnekte Manisa ili Yunus Emre İlçesi 75. Yıl Mahallesinin belirlenen bir kesiti graf veri modeli ile modellenmiş ve katı atık toplama araçları için en uygun yol güzergâhı tespit edilmiştir. Elde edilen sonuçlardan Dijkstra algoritmasının en kısa yolu oldukça başarılı bir şekilde tespit ettiği görülmüştür.

Anahtar kelimeler: En kısa yol, araç rotalama, en kısa yol algoritması, graf modeli.

1. Giriş

Parallel to the developing technology, the solutions that are produced as a result of the Shortest Route Problem are widely used in all areas of everyday life. Package distribution of cargo companies, school services leaving students home, bank branches collecting money and forwarding it to the central bank, municipalities collecting wastes, bread companies distributing bread to bakery markets, and similar transportation services in which Navigation and GPS are needed make use of these solutions. There might be many ways to travel from a source point to a specific destination. Shortcut discovery algorithms target to find the shortest road to navigate between these two points [1].

The logic of shortcut discovery algorithms is based on reaching the target from different nodes with the shortest route, and this algorithm constitutes the basis of vehicle routing problems. Because, in Shortest Route Problems, the purpose is to calculate the shortest route from a specific node or to all other nodes [2].

Vehicle Routing Problem (VRP) has been applied in many fields. Vehicles need to be routed especially in the transportation business. Some of the transportation works in which VRP can be used are listed as follows [3]:

1- Routing student or worker employee vehicles,

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2- Collection solid wastes,
3- Package collection and distribution of cargo companies,
4- Distribution of the food and beverage products of companies to grocery stores or dealers,
5- Collection of the money from bank branches at the end of the day,
6- Food distribution of food companies to institutions like workplaces and schools,
7- Distribution of the milk produced in dairies.

Solid waste is defined as the production of unwanted items littered after use. In addition, it can also be defined as unwanted solid items after any activity discarded by the community [4]. In general, solid wastes can be collected in three groups. The first group consists of materials that are now unwanted like scrap metal, glass, cans, paper, plastic, wood and similar materials, which can be useful objects that may be recycled or accumulated [5]. The second group consists of wastes that can be separated for destruction or burned for energy recovery [6]. The third group consists of abandoned and naturally-discarded waste-like materials that are unwanted [4].

The fast increase in solid wastes is a critical problem not only in our country but also in most countries all around the world because this poses serious risks for human health. For this reason, effective solid waste management must be planned; and for this, it is necessary to design and develop appropriate collection route plans [7]. For municipalities, the collection and transportation of solid wastes have a high share among many other costs [8].

In cities, solid wastes are usually produced in residential areas and commercial and industrial facilities. For this reason, the collection of solid wastes is requested because of the density of the population and human activities. As the distribution and quantity of waste production increases, collection logistics becomes more complex. Although these problems always exist, 50-70% of the total amount of the money spent to collect, transport and dispose of solid wastes is used in the collection step [9]. For this reason, the collection process must be improved as it may affect the total costs and durations of solid waste management. One of the ways of improving waste collection is to guide garbage collectors for choosing the shortest routes during collection [7]. For this purpose, the routes of solid waste collection vehicles must be examined, and collection and transport routes must be created with the lowest cost and minimum time and distance. In our present day, many municipalities and waste collection companies perform waste collection operations with intuitive behaviors of their employees completely at their initiatives considering relevant studies [8].

The shortest route problem within the vehicle routing problem was dealt with in the present study, and the Dijkstra Algorithm, which is among the algorithms used to solve this problem, was explained with a real example. The shortest road was found among the solid waste containers located in a pre-defined section of 75. Yıl Neighborhood of Yunus Emre Municipality of Manisa Province.

The continuation of the present study is organized as follows. Similar studies in the literature were mentioned in the second part of the study. The area where the study was carried out, the data used, the analysis of the data used in the graph model, and the process of determining the solid waste collection routes are explained in the third part. Finally, the results of the study were evaluated, and what can be done in future studies are mentioned in the fourth part.

2. Relevant Studıes

Many studies were conducted in the past to model and solve the Shortest Route Problem. Some algorithms were developed by Dijkstra [10], Bellman-Ford [11], Floyd-Warshall [12], Johnson [13], Martin [14], Bhandari [15], and Dreyfus [16]. On the other hand, Ramakrishna and Wook proposed a genetic algorithm to solve this problem [17]. Singh, Rathi and Haris used the Dijkstra algorithm to carry out solid waste management. The method proposed in this study was applied to Kanpur Province of India, and the shortest path algorithm was performed by using the C programming language for the collection of solid wastes [18]. In the study conducted by Bayzan, he performed the simulation of the vehicle routing problem in a geographic area adapted to the graph data model with C# programming language. With the help of this application, the effect of the waiting times of the vehicles on the cost of solid waste management was examined [3]. In their study, Büke and Erturaç conducted the shortest route analysis, service analysis and optimal location analysis for Sakarya University Esentepe Campus by using Dijkstra Algorithm, and mapped it. They also prepared a web-based page to enable users to easily access the prepared database [19]. Selim determined a trekking route by conducting the most appropriate route analysis based on Dijkstra Algorithm by working with the logic of graph theory. The trekking route of Güllük Mountain National Park, which hosts the Termessos Ancient City, was determined to find the shortest route and the lowest slope [20].

Gene and Lin made use of a genetic algorithm with random key-based encryption to find a solution to the shortest route problem. In addition, they also developed a new algorithm by using arithmetic crossover, mutation and transition operator [21]. In the study conducted by Tomis, Martinovic, Slaninova, Rapant and Vondrak, they planned a time-based route for the highways of Czech Republic. They calculated the dynamic travel route and duration with the algorithm they used. Alternative routes were developed against possible traffic problems [22]. In the study that was conducted by Norhafezah, Nurfadzliana and Megawati, they simulated solid waste collection paths with a mathematical model of Dijkstra Algorithm. With the algorithm that was applied to Shah Alam, which is the capital of Selangor Province of Malaysia, they provided route optimization by shortening the distance traveled by solid waste collection vehicles [7]. In their study, Cooke and Halsey brought a solution to the shortest route problem by creating a modified form of Bellman's Iteration Scheme [23]. Cowen, Jensen, Hendrix, Hodgson and Schill worked on an econometric route detection model, which explored potential railway routes. They showed that the results with approximate values from Geographic Information Systems could be balanced with the data that had high resolution and accuracy by using the high-accuracy numerical height model [24].

3. MATERIAL AND METHOD

With the fast increase in the population of the world, urbanization also increased, and new settlements came into being. With this development, transportation networks among settlements and transportation alternatives that can be used in the transportation network also increased. The target was not only to reach another point from one point but also to reach it as soon as possible and with the lowest cost. Several methods were made use of and modeling was made to find the distance among settlements and to determine the shortest route between them. One of these models is Graph Theory [3].

Many sciences and social sciences problems can be solved with Graph Theory. Problems like mapping, traveler vendor, widest independent cluster, distribution, central placement, shortest route, and network flow problem are some of the problems, which might be solved with the Graph Theory [25]. Especially some problems can be modeled by adapting them to graphs. Transportation networks among settlements can be solved easily when modeled with Local Area Networks (LAN), Wide Area Networks (WAN) and similar networks [3].

Modeling a problem with edge and nodes and showing this model in the form of a diagram refers to the basic use of the Graph Theory. In real life, settlements, intersections, warehouses, shops, and schools show the node points on the graph; and the roads connecting these to each other show the edges of the graph. One of the first problems to which the Graph Theory was applied was the Königsberg Bridge problem that was solved by Leonhard Euler in 1736. The Königsberg Bridge and the Graf Model are given in Figure 1.

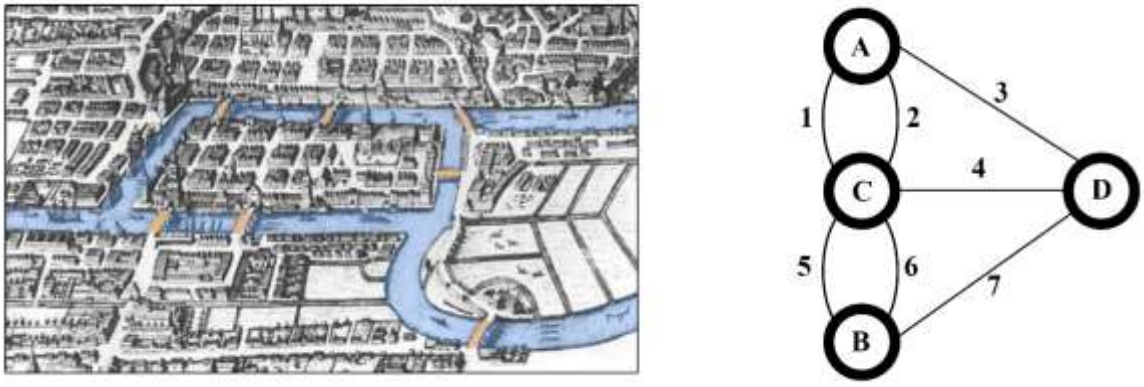

Figure 1. Königsberg Bridge and Graph Model

Yunus Emre District was established as a result of the separation of the provincial center to two districts when Manisa Province has the metropolitan status [26]. The Dijkstra Algorithm, which is used to solve the vehicle routing problem, or in other words, to detect solid waste collection route, was applied to 75. Yıl Neighborhood among the 87 neighborhoods of this district. The necessary data on the solid waste collection system of the neighborhood was obtained from the Sanitation Works Directorate of Yunus Emre Municipality. This neighborhood has 3 sub-districts. The solid waste collection sub-districts of the 75. Yıl Neighborhood are shown in Figure 2. The first district was the Sanayi Sub-District. Here, solid wastes are collected here every weekday

except Sunday. The second sub-district is the area where the main artery is located. The third sub-district is the residential area where household solid wastes are found, and solid wastes are collected every weekday. Although the route designated for the collection of solid wastes in this area was developed and improved every period, it is generally determined according to the initiative of the driver of the waste collection vehicle and other staff.

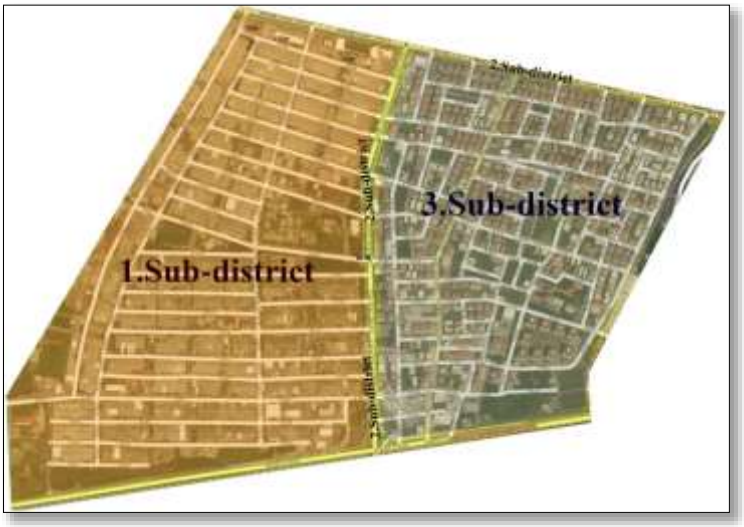

Figure 2. 75. Yıl Neighborhood Sub-Districts (Manisa/Yunus Emre)

The locations of the containers and the digital data of the street are given in Figure 3. Here, the containers form the nodes of the graph structure; and are named in letters like A, B, C, and D. The roads between are the edges of the graph. In the present study, the data on the distances of the streets were obtained from Google Maps. The raw data that contained the distance was converted into a graph data type. The graph data were applied as a weighted neighboring matrix with a traffic direction among the nodes.

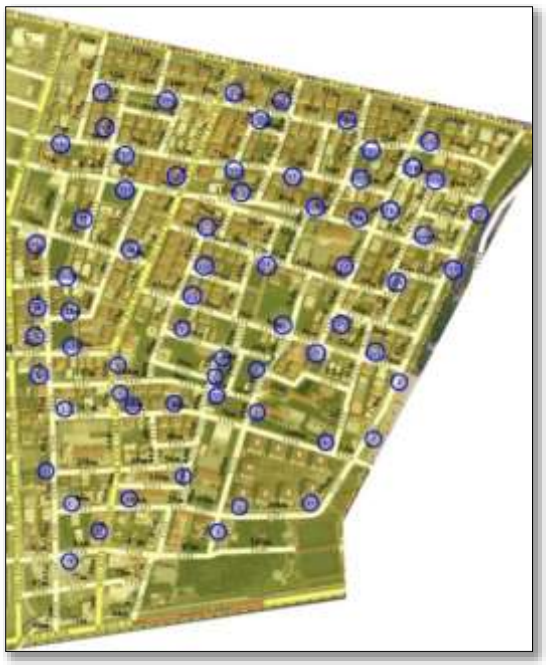

Figure 3. Solid Waste Container Locations and Digital Data

When the nodes given in Figure 3 are evaluated, it is seen that there might be many alternatives to reach the CA node from BM. It is possible to denote some of these as follows:

Preference: BM > BE > CA,
Preference: BM > AU > AN > CA,
Preference: BM > AN > CA,
Preference: BM > AU > AT > AM > CA,
Preference: BM > BL > BO > BE > CA

A person who chooses No. 1 will reach his/her target in the shortest way with the lowest cost; however, a person who chooses routes 4 or 5 will reach his/her target in the longest way. Another example may be given in the section in Figure 4. As shown in Figure 4, a vehicle can follow different routes to reach AO from AL. However, with the help of the algorithm used, the vehicle will use the shortest way by selecting the fifth option.

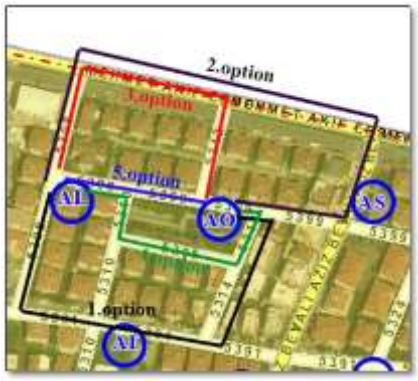

Figure 4. Route Choices between AL - AO Nodes

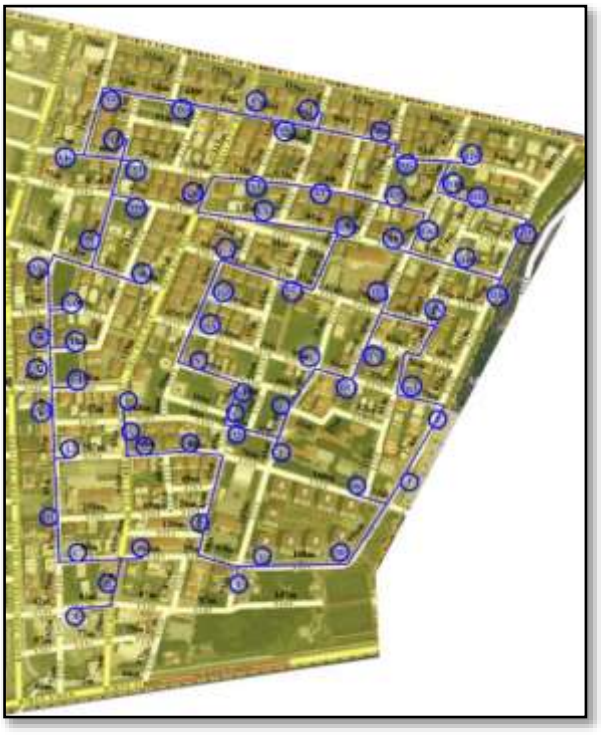

Figure 5. The Shortest Route Determined

The destination obtained by using the Dijkstra Algorithm to collect domestic solid wastes is given in Figure 5. According to this result, if a vehicle starting from A Point follows a route by visiting all knots as follows A > B

> E > C > D > U > AA >> CB > CC > AC > AB > AD > AG > AF > AE > AH > AI > AJ > AK > AL > AO > AS > AY > AV > AZ > BG > BD > BF > BH > BI > BR > BP > BL > BK > BJ > AU > AT > AM > AN > BM > BE > CA > BZ > BY > Y > O > N > M > L > V > BV >BU > BS > BO > BN > BT > Z > J > K > H> I > F > G > P > S > T, it will have followed the shortest route.

4. Results

The Dijkstra Algorithm, which is among the algorithms used to solve the shortest route problem, was applied to a real example in this article. In the study, the purpose was to find the shortest route among the solid waste containers located in a predefined section of 75. Yıl Neighborhood of Yunus Emre Municipality. The study was conducted with the help of real data from the residential area defined in the study. Firstly, the identified settlement was adapted to the graph model. Then the Dijkstra Algorithm was applied to solve the shortest route problem on a 66-node graph. In addition, the data like slope, traffic density, instant road status, and vehicle capacity were neglected in this study.

In case the solid waste collection and transportation operations were carried out by using the routs that were at the initiatives of vehicle drivers without depending on a specific route, the total road traveled was 3348 km; however, this value was reduced to 2016 km as a result of the optimization study. In this case, approximately 40% of fuel and time were saved. As a result, it is seen that if municipalities use route determination algorithms in solid waste collection and transport operations, the time spent on collecting solid wastes, workforce, and expenses will decrease. In addition, it is also considered that the savings will increase with route optimization, less vehicle use, reduced usage-related costs like maintenance, repair, spare parts and labor costs. This study was conducted for a limited area with a single algorithm and with some omissions. In future studies, routing for an entire district or city will be done by using different shortest route algorithms and considering the omissions. In addition, interactive route applications may be developed by using Geographic Information Systems and instant road data.

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