

A Pilot Study on Smart Search for Optimal Parking Space Allocation

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Abstract— Smart cities are concerned with the implementation of the new technologies and systems, which demonstrate the relationships between virtual and physical environment through proper applications. Transportation systems are among the fields which have been taken into consideration in this research. A pilot study for the parking system at An-Najah National University-New Campus has been made as part of the attempt to look forward towards transferring the university into a smart one by 2020. Smart parking helps in managing the parking supply and in understanding the interaction between parking supply and demand. In addition, it helps in finding the optimal allocation of parking spaces, through determining the best route, therefore reduces the delay to achieve a better time management. The goal of the smart parking is having an efficient parking system which delivers real improvements in user service quality and provides real-time flexibility. Proper management and control of parking lots also help through utilization of available parking spaces (supply) most efficiently. Moreover, parking availability information contributes to better allocation of spaces to users and in allowing good distribution over parking facilities. One aspect of smart parking is being considered using advanced technology. An implementation of Geographic Information System to Transportation (GIS-T) has been used with the association of GIS applications and taking into consideration the impedance of travel time or the distance travelled to find the optimal system assignment. The results show the outcome of the system optimal allocation of parking stalls for a sample of instructors' offices in Faculty of Engineering at An-Najah National University.

Index Terms— GIS, GIS-Transportation, Smart Cities, Parking Systems, Palestine

I INTRODUCTION

An-Najah National University, located in Nablus city, is the largest university in the West Bank. It has about 20,000 student distributed on 13 different faculties [1]. Due to the needs for expansion of the university to meet the increasing student enrollment, continuous development and construction of a new campus, extending over 130 dunums of land in Beit Wazan/Al-Jneid Area, is still in progress for the past 15 years. There is considerable movement to, from and within the new campus. The focus of this research is on parking related problems at the new campus and how a friendly intelligent solution for the problem is developed, which could be a model on how to solve aspects of the parking problems.

Parking is an essential component of the transportation system. Its convenience affects the time needed and eases of reaching destinations and therefore affects overall accessibility. Currently, An-Najah National University has its own on-street parking lanes as well as off-street parking lots. However, these parking lots have problems which arise from the gap between demand and supply of parking spaces, and the improper allocation of parking stalls and lots to faculty and

administrative staff.

Limited research has been published on the optimal allocation of parking space as part of the smart parking management literature. A new trend is observed in the general area of smart parking management, as part of smart cities, which has concentrated on application of secured wireless network and sensor communication for parking reservation (examples are presented in [2] and [3]). Various approaches have been considered in the modeling of smart parking systems such as Multi-Agent based models [4].

II OBJECTIVES

The research aims to utilize the available parking spaces (supply) more efficiently, through proper management and control of the parking supply, in general, and to consider advanced technologies to better allocate the parking supply stalls through identifying minimal total travelled distances for the faculty and staff, which contribute to optimal allocation of spaces to users and in allowing good distribution

over parking facilities.

III METHODOLOGY

In this research, a number of steps had been considered in the study, analysis, and modeling of parking conditions at the new campus of An-Najah National University. This had led to the design of the process of the identification of the optimal allocation of the parking spaces for giving levels of parking demand.

The first step was getting insight information on the study area and collecting basic parking supply and demand data, as well as any relevant data which would help in understanding the current parking status at the new campus.

This step involved conducting parking field studies that are related to parking supply and parking demand through identifying the available parking supply as well as conducting parking use studies on two days to find out all the relevant parking use parameters [5]. Then, a survey study was conducted on a sample of the customers to make an overview of the nature of the customers' behavior and to emphasize the determined parking parameters. Academic and administrative staff offices were identified and specified on the relevant maps.

Analysis was then conducted to assess supply sufficiency to satisfy the current level of demand.

Next, and in order to create the model to optimally allocate parking spaces for the demand, AutoCAD program was used to build the computerized model. This model was transferred to Geographic Information Systems (GIS), where a network was created to represent all available parking spaces and offices and the routes connecting them. Finally, a program developed using Java is used for the optimal allocation of the parking spaces to the customers.

The developed method differs from other methods that consider mathematical programming to achieve the optimal allocation of parking spaces, such as that adopted by Geng and Cassandras [6], in that it uses GIS in the optimal allocation of spaces. Other research had considered combining GIS with GPS and 3G for searching of parking space and parking guidance and information system, but again without the optimal allocation of parking spaces [7].

It is to be stated that the research focuses on the Faculty of Engineering Block within the university new campus as the case study for the implementation of the smart solution of the allocation of parking spaces to customers. The implementation of the developed approach will eventually result in the proper management of the parking supply, and thus will assist in the transformation of the parking system into a smart parking system. The methodology highlights the use of GIS application as the aspect of the application of ad-

vanced technologies to arrive at better solutions to ensure optimal parking allocation.

IV MODELING, ANALYSIS, AND DESIGN

In order to use advanced technologies for the allocation of the parking stalls to users, modeling was done to give reasonable results in allowing good distribution over parking facilities. Besides, one of the proper techniques for arranging the results is using programming software.

Modeling using software was not a direct task. First, the Faculty of Engineering was modeled using two-dimensional and three-dimensional models to give proper representation of the offices and paths, in order to arrive at the best route for each office in the Faculty of Engineering, considering impedance, which is the distance, in order to reach the best parking stall for each of the customers, located in offices in the Faculty of Engineering building.

The optimized allocation of the parking stalls is corresponding to the optimal equilibrium condition, considering the concept of system equilibrium. The concept of system equilibrium implies that the overall system has achieved the minimal cost, in this case the minimum distance, which does not necessarily imply achieving the minimum cost for each of the customers. Smart parking is achieved to manage the current status of the parking supply in the Faculty of Engineering block, without consideration of any expansion.

The three-dimensional network of the Faculty of Engineering doesn't need to be limited to only one building. It can be expanded to include the surrounding parking supply, which include all the parking garages, the surface lots, as well as the on-street parking spaces.

The network dataset that have been created has source features that have a geometry that includes z-coordinate values. The network has been created through ArcScene, which is a 3D viewing application for GIS data using ArcGIS, applying the three-dimensional network analyst extension. Spatial analyses were performed based on the results of such application considering relevant features of ArcGIS [8]. Figure 1 shows the Faculty of Engineering building and the parking supply network.

The geoprocessing model builder that is shown in Figure 2 finds least-cost (or least distance) routes which are the best routes between any two locations.

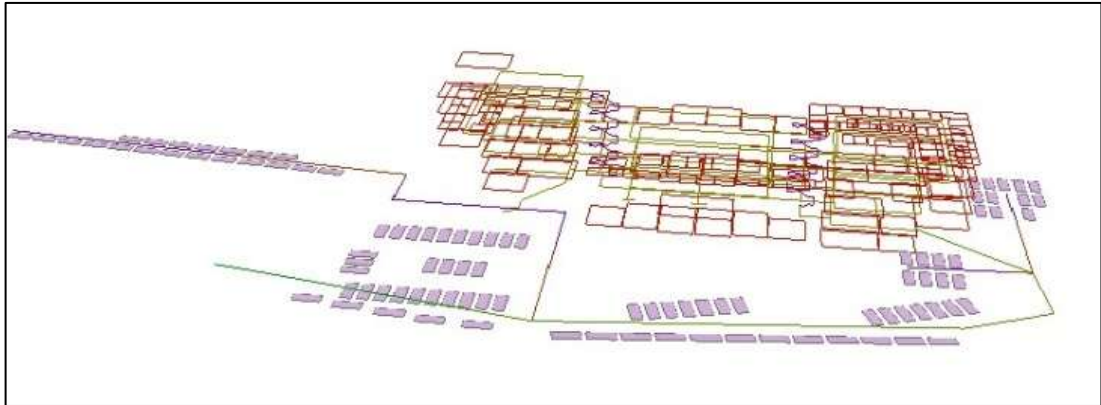


Figure 1 Representation of Faculty of Engineering building and the parking supply network

As a result of this process, a route between location 1 of the office inside the building and location 2 of the parking spaces, as an example, is shown in Figure 3.

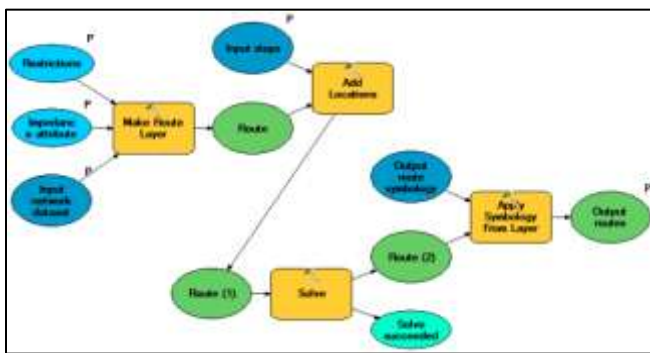


Figure 2 Model Builder for finding the best route between two locations

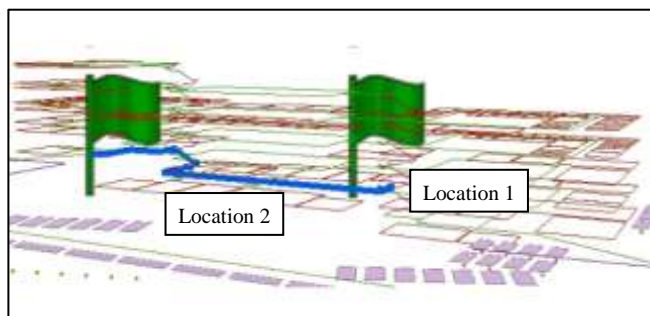


Figure 3 Best route between two locations in 3D model network

The search for the solution for the optimal allocation of parking stalls, the 3D modeling is facilitated by considering a 2D transformation of the Faculty of Engineering block and the associated parking facilities.

The resulting two-dimensional network is then used to find the optimal cost for each Origin-Destination (OD) pair of office-parking stall combination. Figure 4 shows the resulting two-dimensional network for part of the Faculty of Engineering block. It is to be noted that such 2D transformation considers the equivalent horizontal spatial dimensions with respect to the vertical distances.

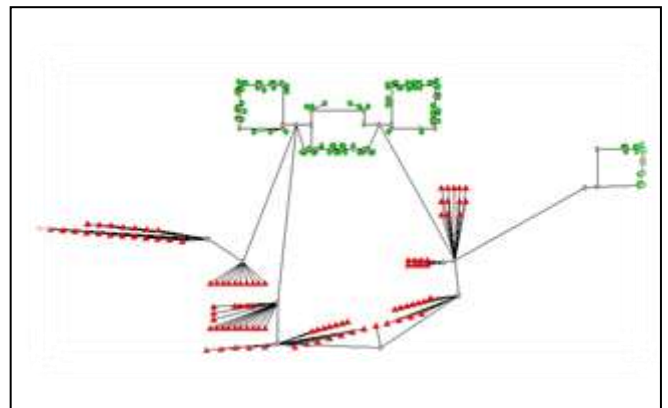


Figure 4 Partial presentation of 2D network for the Faculty of Engineering block

Using network analyst extension of ArcGIS, which is usually utilized to dynamically model realistic network conditions and solve vehicle routing problems, is used here to find the best walking route (or path) between any two locations in the network, by selecting the locations within the network and solving the best route.

The OD cost matrix (Origin-Destination Cost Matrix) finds the least cost paths (or distances) within the network from multiple origins to multiple destinations [9]. The locations of the offices are loaded and defined as points of origins, while the parking stalls are defined as points of destinations.

V RESULTS AND DISCUSSION

After many trials, the outcome shows that the two-dimensional model gives accurate results for more offices rather than the three-dimensional model. The results imply the implementation of the concept of both the 2D and the 3D network analyst to arrive at the optimal OD Cost Matrix.

Java program was developed to assist in achieving system equilibrium, where optimal allocation of parking spaces to customers ensures that the overall cost (or distance) is minimal.

The results give the optimum allocation for the offices and parking spaces, through defining the optimal OD routes or paths. Table 1 shows an example of the optimum allocation for some offices. It has to be stated that the computational time needs to find the optimal route for the study case is not high, which is about 150 second for the study case of 41 offices and 98 parking spaces.

TABLE 1
Partial optimal parking allocation

Office No.	32	33	34	46	87	90
Parking Space No.	27	25	28	21	79	91
Distance (m)	95.8	105.9	106.2	77.2	104.8	107.3

Figure 5 shows the optimal parking space for office 33 as an example. Similarly, the optimal parking space for each of the offices is specified.

VI CONCLUSIONS AND RECOMMENDATIONS

The Faculty of Engineering parking is converted into smart parking through the proper distribution and management for the parking facilities using GIS applications. The network was created utilizing ArcScene, which is a 3D viewing application using ArcGIS, and applying the three-dimensional network analyst extension.

Origin-Destination cost matrix results from the network analyst and Java program manages these results in a smart way by giving assigning to each office the optimum space in the available Faculty of Engineering parking supply. This had assisted to achieve the system equilibrium route (path) assignment, which gave the overall minimum sum of distances that would be walked by the academic and administrative staff between their offices and allocated parking spaces.

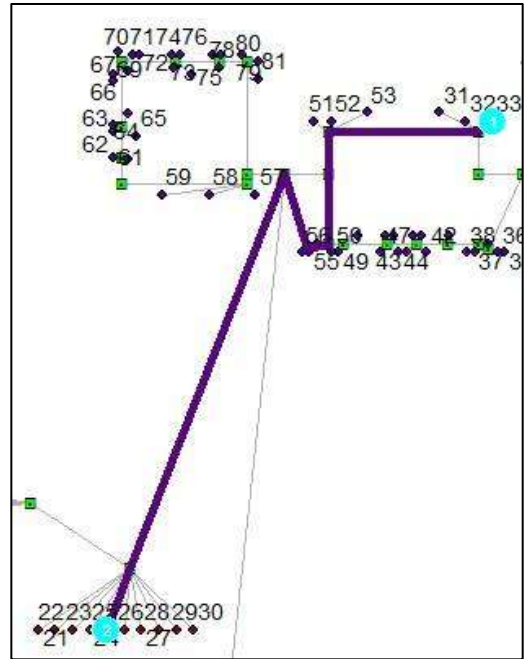


Figure 5 The optimal parking space for office 33.

It is recommended to further develop the used model to consider the parking durations for each customer (office occupant) in order to minimize the needed parking spaces considering parking duration. As a result, equilibrium between the demand and the supply will be achieved over time, and therefore, the problem could be solved over the whole length of the work day. Moreover, extension of the model towards adopting user equilibrium is recommended in order to achieve the minimum costs (distances) for each of the users, not for the system as a whole.

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