Determining the optimal locations for bike-sharing stations: methodological approach and application in the city of Thessaloniki, Greece

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Abstract

The present paper aims to develop a methodological approach for determining the optimal locations for installing bike-sharing stations, taking into account the operators’ perspective. Through the developed methodological approach, it is sought to select locations which maximize the demand and the area (built environment) coverage and at the same time minimize the needs for bike redistribution within the day. Thus, the optimal selection of locations for bike-sharing stations is being set as a multi-objective optimization problem. The proposed methodological approach is being applied in the city of Thessaloniki, Greece.

Keywords: micromobility; bike-sharing; dock-based systems; station location problem; multi-objective optimization

1. Introduction

For the optimization of the locations of bike-sharing stations, various methodologies have been developed and proposed. Martinez et al (2012) propose a methodology based on mixed integer linear programming and apply it in the city of Lisbon, Portugal. Saharidis, Fragkogios and Zygouri (2014) formulate a methodology based on pure integer linear programming that seeks to minimize the number of users who have to walk long distances to reach a station and at the same time to minimize unmet demand. In the methodology of Angelopoulos et al (2016), mixed integer linear programming is being used and the maximization of the covered demand is defined as optimization criterion, setting budget as the main constraint. A mixed integer linear programming model is being also developed by Yuan et al (2019). Of particular interest is the methodology of Lin and Yang (2011), as in addition to the locations of bike-sharing stations it attempts to determine the network structure of bicycle paths. The methodological approach presented in this paper is being set as a multi-objective model. The scope of the methodology is to constitute a useful and easy to use tool for the bike-sharing systems’ operators and for this reason the objective functions and the constraints have been set from the operators’ point of view.

2. Methodology

Following a review of the literature and discussion with companies implementing and operating bike-sharing systems, the following criteria were considered significant for the selection of the optimal locations for installing bike-sharing stations: a) demand coverage, b) area (built environment) coverage, c) bike re-distribution needs. Also, the following constraints were applied: a) maximum monthly budget for renting public or private space, b) maximum number of new stations, c) minimum distance between stations (taking into account the existing stations),

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d) type of available space (if there is only public available space for installing a station or if there is both public and private available space). Based on the above, the selection of the optimal locations is being set as a multi-objective optimization problem. The mathematical model consists of two phases. In the first phase, a single-objective solution for each of the three criteria is sought, in order to determine their optimal values (goals). In the second phase of the mathematical model, a balanced solution for the multi-objective problem is being sought.

3. Case study and data description

The proposed methodology was applied and evaluated in the city of Thessaloniki, Greece. Probably the most critical step when applying the methodology, for getting reliable results, is the determination of the demand and the locations of the demand points. In the case of Thessaloniki, there is a dockless bike-sharing system that operated as a pilot for approximately 4 months and recently started operating officially. During this 4-month period 1134 rentals were carried out. After cleaning the rental data, 654 rentals were further used and they were grouped per traffic zone. Thus, the centroids of those traffic zones were considered as demand points and the total number of pick-ups and drop-offs within the zone was used for expressing the demand. The demand was allocated to the different candidate stations based on the calculated Euclidian distance. Also, by computing the net pick-up and net drop-off for all demand points and based on which demand points serve each candidate station, the candidate stations were characterized as balanced or unbalanced.

4. Results

After discussing with the bike-sharing system operator, specific values were used for the constraints, during resolving the optimization problem. Moreover, three different scenarios were formed for the criteria weights (Scenario 1, in favour of area coverage; Scenario 2, a balanced scenario; Scenario 3, in favour of demand coverage). From the application of the methodology, in the case of Thessaloniki, it was found that there are 3 candidate stations, which are selected in all the investigated scenarios. Also, it was indicated that the results slightly vary based on the weights given to each of the three objectives. More specifically, it was identified that greater weight to the “demand coverage” criterion results in selecting more stations close to the city’s waterfront, where a very popular and attractive pedestrians-cyclists shared-use infrastructure is located. On the contrary, assigning lower importance to the demand coverage, results in the selection of more stations in the inner city, which is also very densely populated.

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