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Off-Street Parking Facility Location on Urban Transportation Network Considering Multiple Objectives: A Case Study of Isfahan (Iran)

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Abstract:

The increasing population in large cities and the unbalanced urban growth associated with massive use of private cars in metropolitan areas often lead to traffic jams and road congestion that warrant the construction of such capital-intensive buildings as off-street public parking facilities. However, the initial problem in such projects is locating a suitable spot where all citizens can be conveniently served and the traffic load in busy city centres can be reduced by removing the need for on-street parking facilities.
In this paper, an urban transportation network including, a number of parking demand points, a set of possible sitting locations, and several entry points of traffic flow are considered. Four objectives are generally considered for the public off-street parking location problem that include reducing traffic congestion, maximizing coverage demand, minimizing walking distance between demand points and new parking facilities, and decreasing related costs.
The flow capturing model has been exploited to develop two approaches for minimizing traffic congestion. Based on these approaches and other objectives, two models have been proposed. The covering distance of parking facilities will be uncertain in these models. Traffic flow entry points, driver's path, and different types of parking lots have also been considered. Finally, relevant information and data required for implementing the proposed models were collected on two traffic zones in central business districts (CBD) of Isfahan. Then, the ε-constraint method was used to solve the proposed multi-objectives models and the best candidate points for establishing new off-street parking facilities were determined.
Keywords: Facility location, Public parking lots, Off-street parking facility, Mathematical modeling, Isfahan.

Introduction:

Traffic congestion is a major problem in metropolitan cities. It is being aggravated by such factors as growing urbanization, concentration of activities in central business districts, population influx, and poor public transport systems. The main objective of the present study is to determine the best location and the most appropriate type of new off-street parking facilities to achieve maximally reduced traffic congestion, to provide maximum coverage at demand points, and to minimize the walking distances among the facilities at the lowest total costs.

Modeling:

In this research, it is assumed that part of the urban transportation network includes a number of parking demand points (places where attract trips) and a number of candidate points for locating parking lots where cars arrive from different points and routes. It is further assumed that cars enter the area from different points (called flow entry points) at a certain or prespecified rate. In addition, there is a possibility to locate any type of parking lot at any candidate point but only at varying costs and with different capacities depending on the parking type selected.

MOPLP1 model
This model is based on the first approach as follows:

$$Minimize \quad Z_1 = \sum_{k\in K}\sum_{i\in I}\sum_{j\in J}\sum_{p\in P}[d'_{kj}\theta_{ij}x_{kijp} + M(1-\theta_{ij})x_{kijp}] + \sum_{k\in K}\sum_{i\in I} Mf \times z_{ki}$$

$$Maximize \quad Z_2 = \sum_{k\in K}\sum_{i\in I}\sum_{j\in J}\sum_{p\in P} u_{ij}x_{kijp}$$

$$Minimize \quad Z_3 = \sum_{j\in J}\sum_{p\in P}(Cc_{jp} + OMc_p \times b_{jp}) \times y_{jp} + \sum_{k\in K}\sum_{i\in I} Pc \times z_{ki}$$

Subject to :

$$\sum_{j\in J}\sum_{p\in P} x_{kijp} + z_{ki} = Pd_{ki} \qquad \forall k \in K, \forall i \in I$$

$$\sum_{k\in K}\sum_{i\in I} x_{kijp} + v_{jp} = b_{jp}y_{jp} \qquad \forall j \in J, \forall p \in P$$

$$\sum_{p\in P} y_{jp} \le 1 \qquad \forall j \in J$$

$$\sum_{j\in J}\sum_{p\in P} y_{jp} = n$$

$$y_{jp} \in \{0,1\} \qquad \forall j \in J, \forall p \in P$$

$$x_{kijp} \ge 0 \qquad \forall k \in K, \forall i \in I, \forall j \in J, \forall p \in P$$

$$z_{ki} \ge 0 \qquad \forall k \in K, \forall i \in I$$

Results:

In this study, the location theory was employed to investigate the public parking lot location problem. Also the multi-objective mathematical programming was used to satisfy the stakeholders by the different objectives. The objectives considered here included minimizing traffic congestion, maximizing the coverage demand, and minimizing the walking distances and different costs.
For reducing traffic congestion, two different approaches were proposed and the flow entry points and vehicle paths were taken into account. The first approach was based on the distance between entry points and new parking facilities while the second was based on the distance between demand points and new parking facilities. Based on these two approaches, two different models were developed. The objective functions of maximizing covered demand and minimizing walking distances were combined and the coverage distance of the parking facilities was assumed to be uncertain. Due to differences in capacity and costs associated with each parking lot type, different types of parking facilities were considered.

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