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A Multi-Objective Airport Service Cars Location/Allocation Problem with Spatiotemporal constraints

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Abstract. The continuous growth of air traffic implies an increase of the number of vehicles that provide service to aircrafts. Increasing traffic in airport causes decreasing efficiency of airport operations and need to improve service operations. Location-allocation models are improved in two ways: 1) the allocation rule is developed to more accurately reflect customer choice processes; and 2) the objective function is developed to incorporate future changes. In this paper we propose a covering problem in a discrete space where the covering radius will be determined according to the flight time. In this problem the best locations of airport service cars located, so that servicing efficiency improved. Allocating of each aircraft to the service car regarding the covering time is done by finding optimum service car(s) location at minimum travel distance. This problem solved for airport providing service in different situations. There are some spatiotemporal constraints in airport field that must be considered. Some parameters including network restrictions, departure constraint and runway limitation which must be considered in developed model. Proposed method implemented for Imam Khomeini international airport and the numerical result shows that using A,B,C stations reduced traveling distance about 400 meters. In addition, service cars allocation has been implemented in a mobile information system.

Keywords: Location Allocation, Spatiotemporal analysis, Airport, Service cars
1. Introduction

Location-allocation (LA) models seek to locate facilities and allocate demand points to them optimally (Bischoff and Klamroth 2007). The aim of location-allocation problems is optimizing objective function which is defined based on effective parameters in decision process. There are three general set of location allocation problems including median, covering and center problems. The most widely used LA model is the p-median problem, that assumes demand points are best served when facilities are as close to them as possible. A way to estimate the suitability of the location of a service center is measuring average mileage travelled by demand points to reach the service center (Church and ReVelle 1976). P-median problem, first by Hakimi (Hakimi 1964), was introduced using the distance performance index. According to this index, any increase in distance traveled mean, decrease access to services and reduce efficiency of the designated location for service center.

Various models for different conditions are proposed for location allocation problem such as p-median problem (Yang, Yu et al. 2016), p-center problem(Gupta, Muttoo et al. 2017), multisource Weber problem hierarchical location allocation problem (Kariv and Hakimi 1979)and so on.

Service in airports are done according to the time schedule and several constraints impressive the services. In the airport field, the departure time of flight could be assume as the covering radius. Additionally, the service cars as the service points operate dynamicly. Also, the aircraft stations as the demand points are changed during time.

The main innovation of this paper is considering the airport appropriate spatial and temporal parameters which are limited the problem. The proposed model of this paper has three objective functions which are median and covering problems. Objective functions are average of traveled distance as median problem and services serving in the certain time before departure time as covering problem. The last objective function is minimizing the number of service cars.

As a case study the pus and tow service is considered. The goal is location allocation of pushback tractores in limited time aside minimizing the number of this service cars.

2. Proposed model

Push and tow service is one of the several services that is serving to airplanes. In this service the push back tractor does carry the airplane from apron to taxiway. There are other services in airport. For example, there are passenger
and cargo transport service, air condition service, lavatory service, water service and fuel service. Pushback tractor spends time for travel from its station to aircraft station. Pushback tractor through push and tow operation transmit aircraft to taxiway. Push and tow procedure is dependent on distance from the plane to taxi and the traffic around. After transferring aircraft to taxi way, aircraft goes to runway and push back tractor returns to its EPA.

\[
\begin{align*}
&\min \sum_{a=1}^{a} \sum_{p=1}^{b} \sum_{n=1}^{c} \sum_{o=1}^{d} (((T_{sl} + \frac{d_{an}}{v_{no}}) + T_{pl} + T_{tr}) - \\
&\forall l.p.n.o) \quad (1) \\
&\min \sum_{i=1}^{c} \sum_{n=1}^{c} \sum_{o=1}^{d} d_{na}x_{lpz_{po}yl_{n}} \forall l.p.n.o \quad (2) \\
&\min \sum_{b=1}^{b} p_{b} \forall p \quad (3)
\end{align*}
\]

There are four sigma notations in the formulae 1, 2 that related to the aircrafts, the pushback tractors, the aircraft stations and the pushback tractor stations. All four parameters are present in each service operations and are effective in optimizing service time, so considered in objective function. In formula 3, number of service cars are minimized.

3. Implementation

In order to implement proposed method, the Imam Khomeini international airport of Iran is considered. This airport has located in the twenty kilometers away in south of Tehran city.

In order to implementing of the proposed model, the mobile information system is used. According to the proposed model one of the important parameter is distance between aircrafts and service cars. This parameter is calculated, using network analysis and by combining with other parameters the location allocation is solved. Figures 1 showed the process of calculating distances between the service cars and the aircrafts.
Figure 1. Calculating distance between station “B” and station “4”.

After calculating distances between service cars and aircrafts, using the proposed model the service car at station “B” allocated to the aircraft at station “7”. The allocation is announced to the service car using mobile information system (Fig. 2).

Figure 2. Allocation of service car at station “B” to aircraft at station “7”.

Numerical results of location allocation from A, B, C stations when the pushback tractors return to the EPA are showed in table (1).
Service providing from A, B and C stations

<table>
<thead>
<tr>
<th>Departure time</th>
<th>Aircraft stations</th>
<th>Distance to A,B,C</th>
<th>Push&amp;Tow consumed time</th>
<th>Distance time(sec)</th>
<th>Ready to receive service</th>
<th>Ready to take off</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>18</td>
<td>450</td>
<td>7</td>
<td>54</td>
<td>14:15</td>
<td>14:26</td>
</tr>
<tr>
<td>14:30</td>
<td>13</td>
<td>250</td>
<td>5</td>
<td>30</td>
<td>14:20</td>
<td>14:28:30</td>
</tr>
<tr>
<td>14:35</td>
<td>4</td>
<td>250</td>
<td>10</td>
<td>30</td>
<td>14:20</td>
<td>14:33:30</td>
</tr>
<tr>
<td>14:35</td>
<td>19</td>
<td>450</td>
<td>4</td>
<td>54</td>
<td>14:25</td>
<td>14:33</td>
</tr>
<tr>
<td>14:45</td>
<td>1</td>
<td>50</td>
<td>6</td>
<td>6</td>
<td>14:30</td>
<td>14:40:30</td>
</tr>
<tr>
<td>14:55</td>
<td>7</td>
<td>750</td>
<td>8</td>
<td>90</td>
<td>14:40</td>
<td>14:52:30</td>
</tr>
<tr>
<td>14:55</td>
<td>14</td>
<td>1000</td>
<td>5</td>
<td>120</td>
<td>14:45</td>
<td>14:55</td>
</tr>
<tr>
<td>15:00</td>
<td>21</td>
<td>250</td>
<td>9</td>
<td>30</td>
<td>14:45</td>
<td>14:57:30</td>
</tr>
<tr>
<td>15:00</td>
<td>17</td>
<td>750</td>
<td>4</td>
<td>90</td>
<td>14:50</td>
<td>14:59</td>
</tr>
</tbody>
</table>

**Table 1.** Location allocation from A,B,C stations if pushback tractor return to EPA.

Location allocation using proposed model from A, B, C and D stations have no delays. Total traveled distance from these four stations showed in table (2).

<table>
<thead>
<tr>
<th>stations</th>
<th>total traveled distances</th>
</tr>
</thead>
<tbody>
<tr>
<td>A,B,C</td>
<td>8400</td>
</tr>
<tr>
<td>A,B,D</td>
<td>9200</td>
</tr>
<tr>
<td>B,C,D</td>
<td>10500</td>
</tr>
<tr>
<td>A,C,D</td>
<td>9600</td>
</tr>
</tbody>
</table>

**Table 2.** The total traveled distance from different stations when the service cars return to the EPA

4. Conclusion

The main innovation of this paper was proposing a multi objective location allocation problem in airport field considering spatiotemporal constraints. The problem was solved in a discrete space where the covering radius was determined according to the departure time. The problem had three objective functions included minimizing the number of service cars regarding to the covering time and finding the best location of service cars stations which minimize the total traveled distances. The problem was solved for Imam
Khomeini International airport. The numerical result of proposed model indicated that, the total traveled distance was decreased about 400 meters. Also, if the service cars, went to the ESA, the total traveled distance for 9 flights reduced about 1400 meters. The results showed that, using proposed method you can reduce the traffic volume in the airport field.

References


