AMBULANCE LOCATION OPTIMIZATION INCORPORATING O-D TRAVEL TIME VARIABILITY: A CASE STUDY OF DELHI

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Introduction

- Status of Emergency Services in India
  - Emergency Management and Research Institute (EMRI) in 15 states and 2 union territories.
  - Maharashtra Emergency Medical Services (MEMS) in Maharashtra.
  - Gujarat Emergency Medical Services Authority (GEMSA) in Gujarat.
  - Centralized Accident and Trauma Services (CATS) in Delhi.
  - State Health Society of Bihar (SHSB) under NRHM in Bihar.

- Status of Emergency Services in Delhi
  - CATS has 259 ambulances - 124 Patient Transport Ambulances, 106 BLS ambulances and 29 ALS ambulances.
  - Time taken by ambulances to reach the site of emergency or from site of emergency to hospital was 10 to 20 minutes (Gopinathan et al., 2001).

Motivation for the Study

- Problems with EMS in India
  - Absence of response time standards
  - Lack of evaluation of systems
  - Fragmented system

- The goals of an EMS provider are to make their ambulances reachable and available to provide double coverage under a 10 mins primary coverage standard.

Objectives

- To evaluate the coverage performance of the current system of emergency services (CATS) operating in Delhi.
- To optimize the CATS system to achieve higher coverage with available ambulances.
- To enhance robustness of the model by incorporating travel time variability at O-D level across the day for Delhi.

Methodology

1. Data Acquisition:
   - Ambulance locations and CATS call records (Jan-July 2018) obtained from CATS control room, Delhi.
   - Congested Traffic Scenario (T3)
   - Extraction of travel time for each scenario.

2. Data Preparation:
   - Geocoding of call and ambulance locations.
   - Clustering of geocoded call sites forming 1777 demand clusters (Fig 1).
   - Identification of 120 potential ambulance location sites (Fig 1).
   - Formation of eight demand scenarios for weekday and weekends.

3. O-D travel time variability analysis:
   - Random Sampling of Demand sites and Potential ambulance sites for travel time variability analysis.
   - Extraction of travel time for sampled data every hour for 24 hours for one week using Maps API.
   - Travel time variability using Gaussian Mixture Model (Fig 2) with 3 components given in Table 1 and represented as:

\[ X_k = \sum \lambda_j N(\mu_j, \sigma_j^2) \]

Table 1 GMM parameters over scenarios of the day

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Demand %</th>
<th>Mixture Coefficient (%)</th>
<th>Mean Travel time (m/km)</th>
<th>Standard deviation (m/km)</th>
<th>Planning Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workday</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1 (04-12)</td>
<td>54.1</td>
<td>1.57</td>
<td>2.9</td>
<td>0.19</td>
<td>2.37</td>
</tr>
<tr>
<td>S2 (12-18)</td>
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<td>2.17</td>
<td>2.6</td>
<td>0.22</td>
<td>2.34</td>
</tr>
<tr>
<td>S3 (18-24)</td>
<td>33.1</td>
<td>1.65</td>
<td>2.4</td>
<td>0.19</td>
<td>2.17</td>
</tr>
</tbody>
</table>

Fig. 1 Spatial distribution of ambulance demand sites and potential sites.

Fig. 2 Variation of mean travel times of congested and non-congested traffic states across the day.

Fig. 3 Estimation of coverage for varying primary coverage standard.

Fig. 4 Variation of Coverage for the best case (T1), worst case (T3) and average case scenarios.

Fig. 5 Location of ambulances in the current and optimized system.

Results

- Congested Traffic Scenario (T3) - The existing system covers only 90% of the sites in 15 mins and below this standard, the model turns infeasible. Optimized system covers 92% of the sites in 9 mins.
- The coverage values reduce from around 100% in early morning hours (12 am to 6 am, S1 and S5) to around 95% in evening hours of 12 pm to 6 pm (S3 and S7) (Fig 4).
- The optimal sites are homogeneously located across the city.

Conclusion

- Before optimization, secondary response time standard for the current system is 34 mins during uncongested condition and 53 mins during congested condition. After optimization, the standard reduced to 18 mins and 28 mins, respectively.
- Under uncongested condition, the optimized system is able to achieve 91% higher coverage in 10 mins primary coverage standard.
- Under congested condition, the current system fails to provide double coverage under a primary response time standard of 15 mins or lower, while the optimized system can achieve 92% double coverage in 9 min.
- The existing ambulance sites are concentrated at the centre of city while the optimal sites are located in sparse regions.

References