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

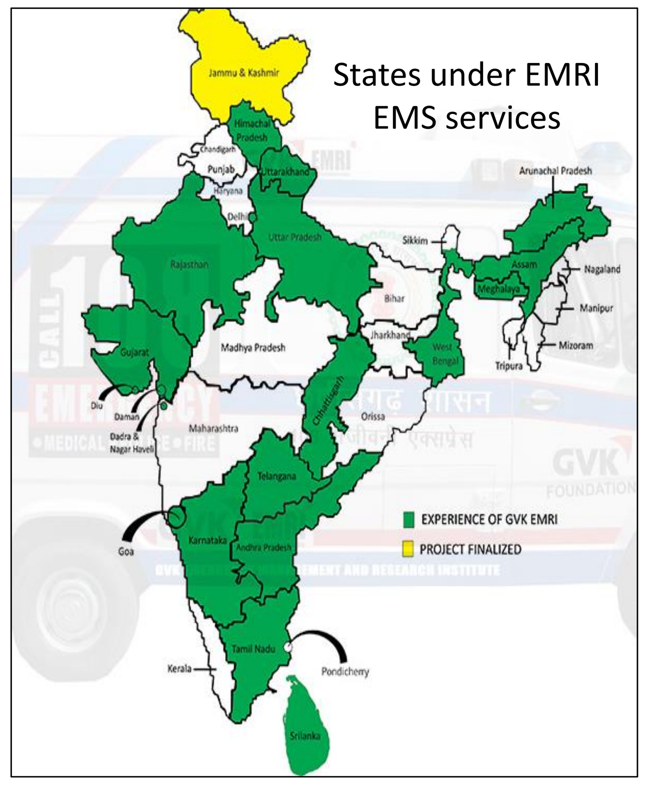
Shayesta Wajid
PhD Student, IIT Delhi
Email: shayestawajid@gmail.com

N. Nezamuddin
Assistant Professor, IIT Delhi
Email: nezam@civil.iitd.ac.in

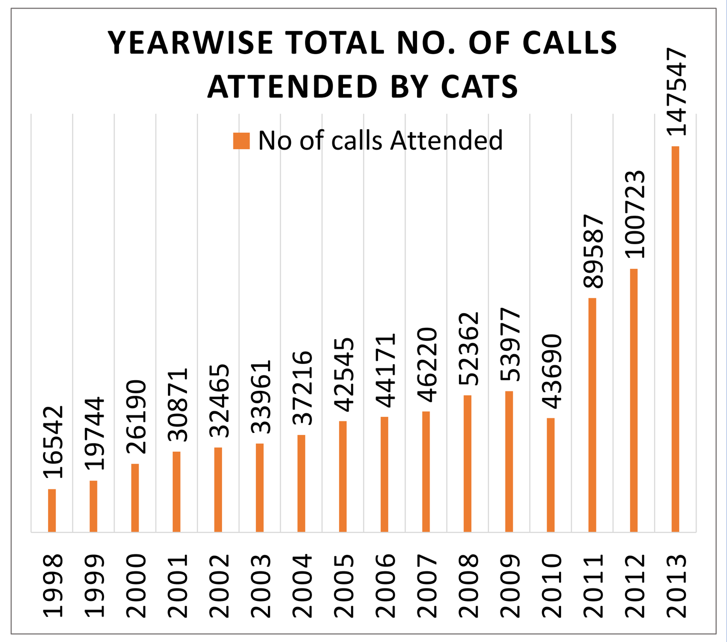
Avinash Unnikrishnan
Associate Professor, Portland State University
Email: uavinash@pdx.edu

Introduction

❖ **Status of Emergency Services in India**



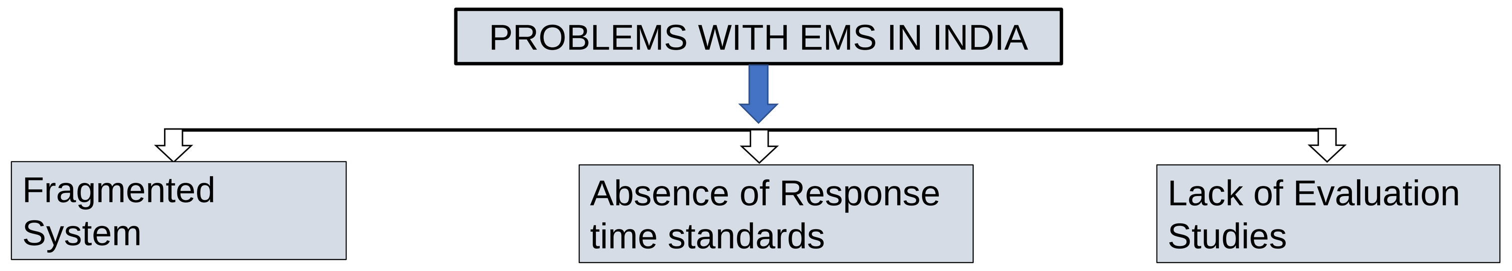
- *Emergency Management and Research Institute* (EMRI) in 15 states and 2 union territories.
- *Maharashtra Emergency Medical Services*(MEMS) in Maharashtra.
- *Gujarat Emergency Medical Services Authority* (GEMSA) in Gujarat.
- *Centralized Accident and Trauma Services* (CATS) in Delhi.
- *State Health 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



- The goals of an EMS provider are to make their ambulances reachable and available within minimum response time possible. Variation of traffic conditions across the day hinders the response time and thus the coverage of ambulance services. Thus pressing the need for incorporation of travel time variability into ambulance location.

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.

2. Data Preparation:

- Geocoding of call and ambulance locations.
- Clustering of geocoded call sites forming 1777 demand clusters (Fig.1)
- Identification of 1120 potential ambulance location sites (Fig.1)
- Formation of eight demand scenarios for weekday and weekends

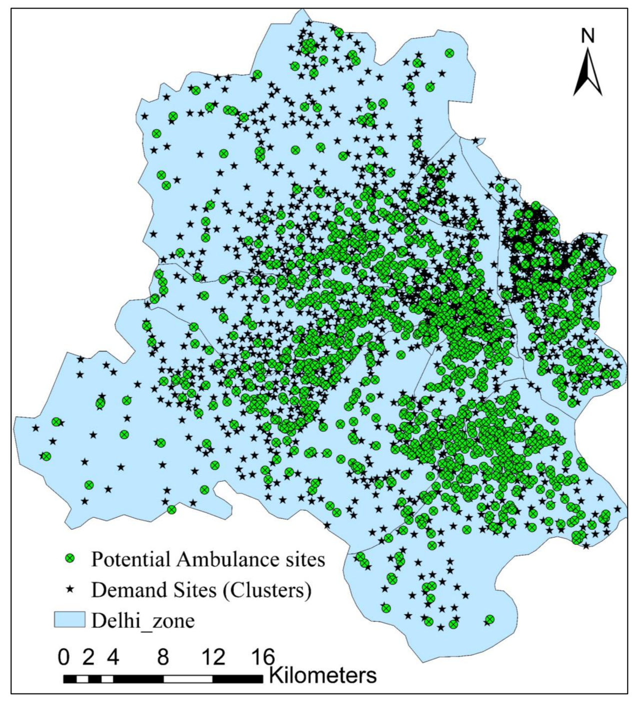


Fig.1 Spatial distribution of ambulance demand sites and potential sites

3. O-D level 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
- Variability Analysis using Gaussian Mixture Model (Fig. 2) with 3 components given in Table 1 and represented as:

$$X \sim \sum_{k=1}^{3} \lambda_k N(X|\mu_k, \sigma_k^2)$$

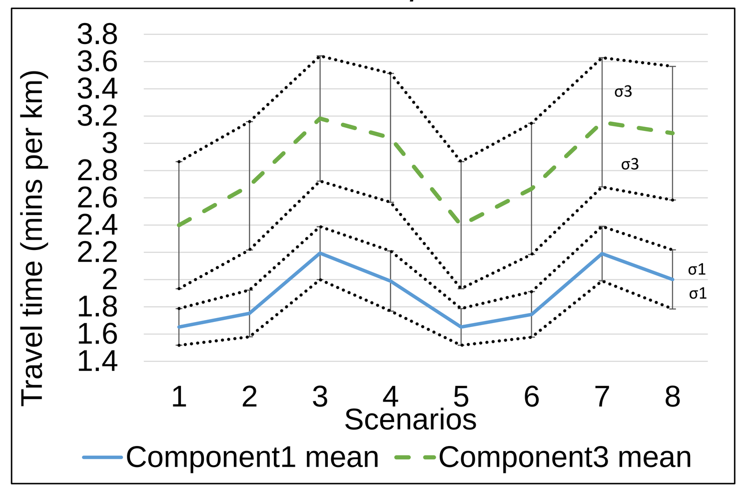


Fig.2 Variation of mean travel times of congested and non-congested traffic states across the day

Table 1 GMM parameters over scenarios of the day

Scenarios	Demand (%)	Mixture Coefficient (%)			Mean Travel time (mins/km)			Standard deviation (mins/km)			Planning Time (mins/km)		
		λ1	λ2	λ3	μ1	μ2	μ3	σ1	σ2	σ3	p1	p2	p3
Weekday													
S1 (00-06)	12.4	59	32	9	1.65	1.97	2.4	0.13	0.19	0.47	1.87	2.28	3.17
S2 (06-12)	26.4	49	38	13	1.75	2.17	2.69	0.17	0.22	0.47	2.03	2.54	3.46
S3 (12-18)	32.8	52	33	15	2.19	2.63	3.18	0.19	0.24	0.46	2.51	3.02	3.94
S4 (18-24)	28.4	45	40	15	1.99	2.48	3.04	0.22	0.25	0.47	2.35	2.88	3.82
Weekend													
S5 (00-06)	14.3	59	32	9	1.65	1.97	2.4	0.13	0.19	0.47	1.87	2.28	3.17
S6 (06-12)	24.2	51	36	13	1.74	2.14	2.67	0.17	0.22	0.48	2.01	2.50	3.46
S7 (12-18)	30.0	51	34	15	2.19	2.62	3.15	0.2	0.25	0.47	2.52	3.03	3.93
S8 (18-24)	31.5	49	37	14	2	2.47	3.07	0.22	0.25	0.49	2.36	2.88	3.88

4. Ambulance Location Model:

A Robust Double Standard model (r-DSM) is modified (modified r-DSM) and adopted for computation of Double Coverage using different travel time for each scenario. The model

- ➢ maximizes weighted sum of demand doubly covered within primary coverage standard (r_1) for all scenarios s∈S
- ➢ Covers at least a fraction α∈[0,1] of demand in each scenario s∈S within r_1 time units
- ➢ Ensures coverage of all demand points at least once under secondary coverage standard (r_2) under all scenarios ($r_2 > r_1$)
- ➢ Places total p=259 ambulances over Delhi with at most p_j ambulances at each ambulance location site j

Results

- ❑ Uncongested traffic scenario (T1) – The existing system achieves 91% coverage in 10 mins as compared to 100% with the optimized system in 9 mins.
- ❑ 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.

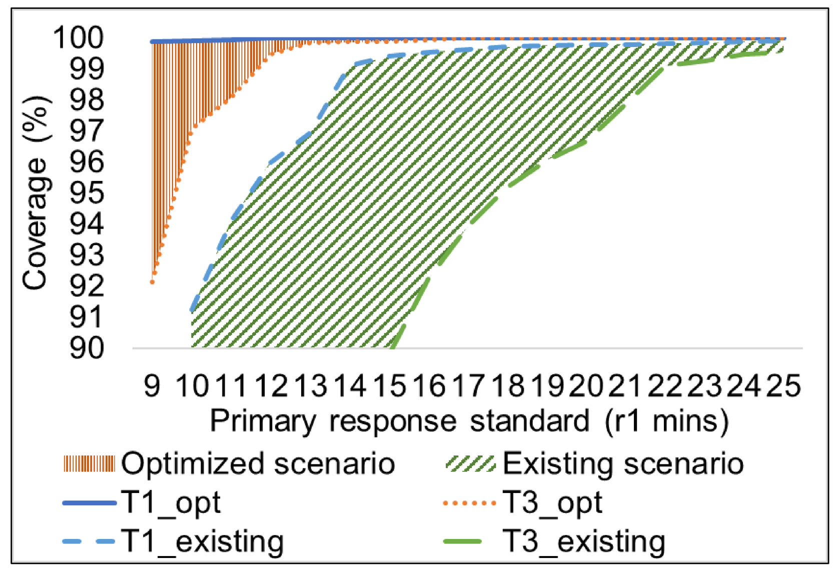


Fig.3 Estimation of coverage for varying primary coverage standard

- ❑ 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.

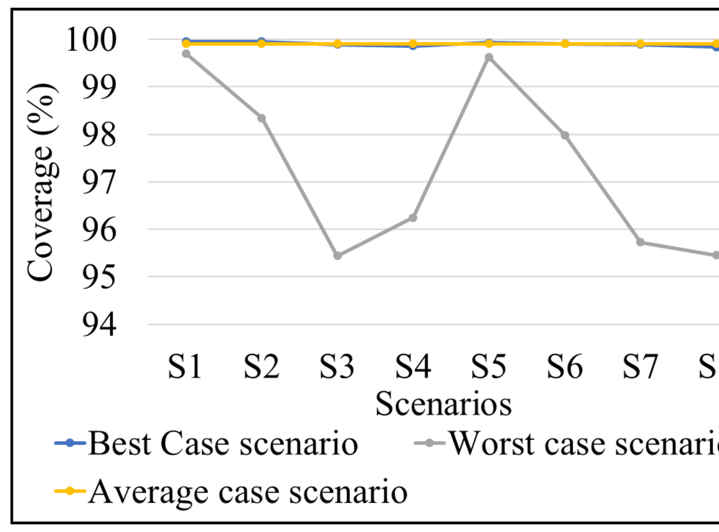


Fig.4 Variation of Coverage for the best case (T1), worst case (T3) and average case scenarios

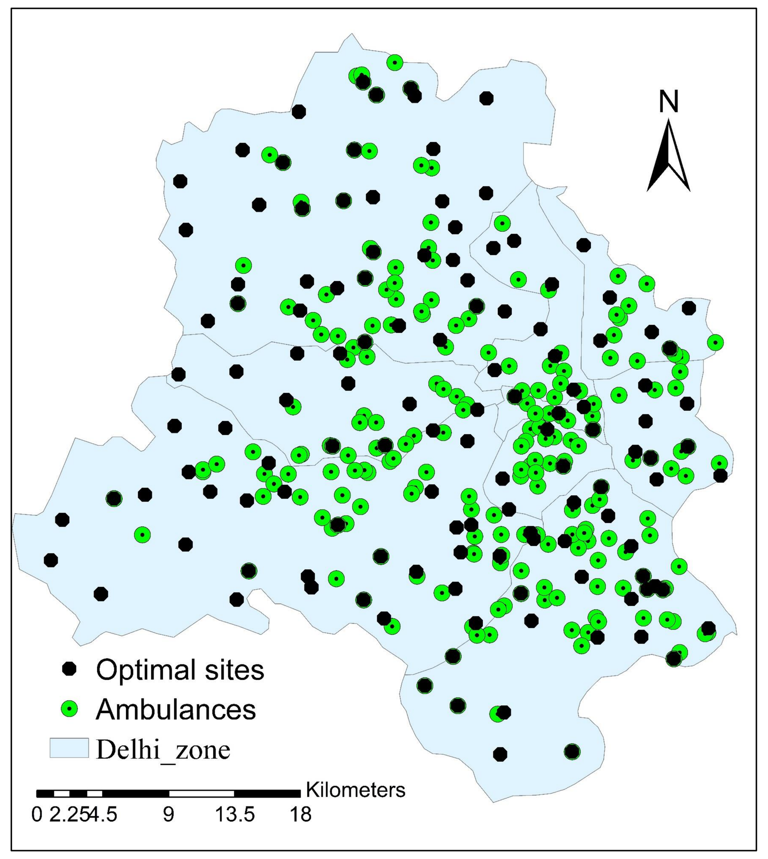


Fig.5 Location of ambulances in the current and optimized system

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 9% 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

- Dibene, J. C., Y. Maldonado, C. Vera, M. de Oliveira, L. Trujillo, and O. Schütze. Optimizing the Location of Ambulances in Tijuana, Mexico. *Computers in Biology and Medicine*, Vol. 80, No. November 2016, 2017, pp. 107–113.
- Gopinathan, A., J. Baswala, B. Bahl Asstt, K. Satija, K. Ashok, D. Narain, J. Arora, C. Naresh, Rajkumar, K. Sanir, and K. Mukesh. *Report of Evaluation Study on Centralised Accident & Trauma Services (CATS)*. 2001.