Reducing Ambulance Response Times Using Discrete Event Simulation

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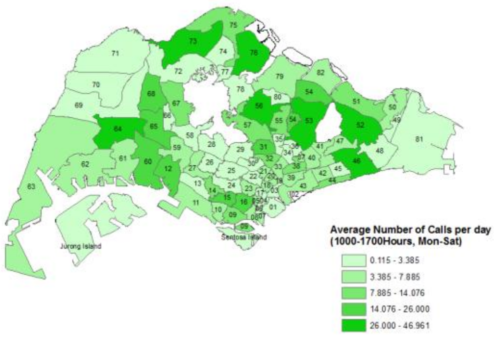
A. Background

Emergency Medical Services (EMS) play an important role in health service provision.

- **EMS:** A system which provides for the arrangement of personnel, facilities, and equipment for the effective and coordinated delivery of health care services under emergency conditions.
- **One of the Primary Goals of EMS:** To reduce the morbidity and mortality of patients involved in out-of-hospital medical and trauma events.
- **Response Time:** The time it takes for a dispatched ambulance to arrive on scene.

Spatial distribution of ambulance calls (average calls from Monday-Saturday, 1000-1700 hours)



The call arrival rates vary across different times of the day, and day of the week. The average call volume for Monday was highest as compared to other days.

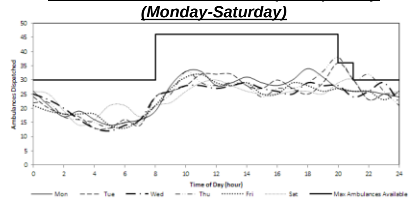
The call arrival rates also varied geospatially across postal districts. Within each district, the frequency and location of emergency calls were also found to vary across different building types.

The spatial and temporal variations of call arrivals are displayed in the figures above and on the right, respectively.

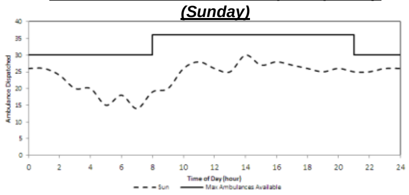
Reduction of ambulance response times can possibly improve clinical outcomes as the ambulance crews are usually the EMS system's first point of physical contact with the patient.

The response time of ambulances is an important modifier and predictor of clinical outcomes for critical conditions like Out-of-Hospital Cardiac Arrest (OHCA).

Number of ambulances on dispatch per day (Monday-Saturday)



Number of ambulances on dispatch per day (Sunday)

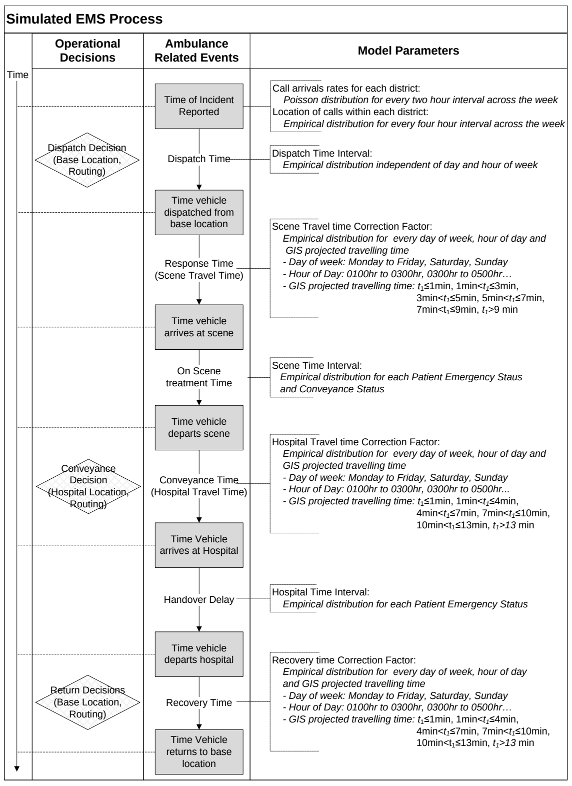


B. Aim

- To develop a discrete-event simulation (DES) model for the Singapore Emergency Medical Services (EMS) for the cost-effective improvement of ambulance response times.

C. Methods

Study Design:
A computer-based DES model was developed based on retrospective emergency calls data over a continuous 6 months period from May 2009 to October 2009 for the entire Singapore.



Outcome Measure:
The main outcome measure is the distribution of response times.

The secondary outcome measure is ambulance utilization levels based on unit hour utilization (UHU) ratios.

Study Protocol:
The flowchart on the left shows a detailed representation of the operational processes of Singapore EMS system.

Travel time estimation forms an important consideration in the model. The ideal travel times are projected using ArcGIS 10 software, and a correction factor was computed based on the ratio of historical ambulance travel time to the ideal travel time.

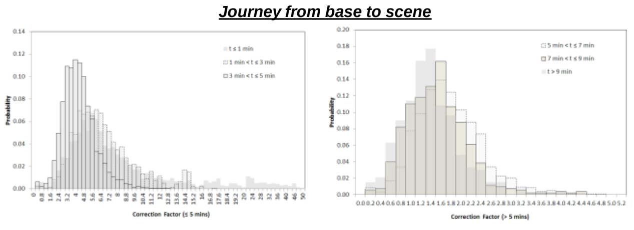
Policy Evaluation
The DES model was used to evaluate different policies to improve the response times, whilst maintaining reasonable fleet utilization levels. These policies are described along the following strategy dimensions:

- *Strategy 1*: Ambulance Reallocation
- *Strategy 2*: Addition of Ambulances
- *Strategy 3*: Ambulance Dispatch Policy

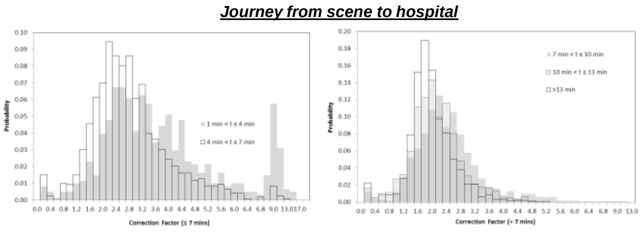
D. Results

Travel Times Correction Factors. The correction factor varies across four dimensions: (1) day of week; (2) time of day; (3) ideal travel time, and; (4) nature of trip.

Journey from base to scene



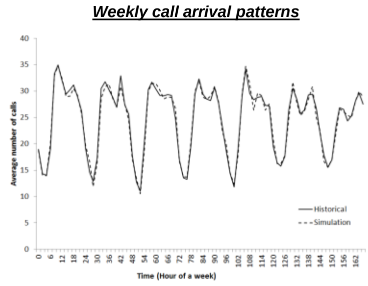
Journey from scene to hospital



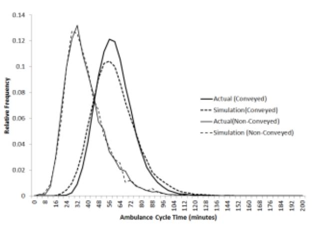
Model Validation. The figures on the right and below illustrate the validation results by comparing the simulated outputs with historical data on the arrival call patterns, the ambulance cycle times and ambulance response times.

The model projections for these criteria matched closely to the historical performance of the EMS system.

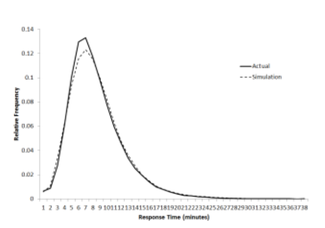
Weekly call arrival patterns



Ambulance cycle times distribution



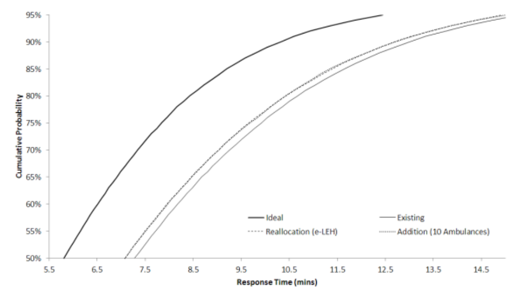
Ambulance response times distribution



Policy Evaluation. Policy alternatives looking at the reallocation of ambulances, the addition of new ambulances and alternative dispatch policies were evaluated.

Modification of current dispatch policy combined with the reallocation of existing ambulances was able to achieve response time performance equivalent to that of adding 10 ambulances. The median (90th percentile) response time was 7.08 (12.69) minutes, an improvement of approximately 13 seconds. The median UHU under this combined strategy was 0.324 with an interquartile range (IQR) of 0.047 versus a median utilization of 0.285 (IQR of 0.051) resulting from the introduction of 10 additional ambulances.

Cumulative probability distributions of response time



E. Conclusion

DES serves as a versatile platform to model dynamic system complexities of Singapore's EMS systems for the evaluation of operational strategies to improve ambulance response time performance. It was shown through DES that response times can be improved via a more effective reallocation of ambulances and dispatch policy.

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