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Analyze emergency-vehicle dispatches in Dallas, Texas, USA

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Introduction

Response time is an important quality indicator to assess the performance of emergency management (Cordner & Muhlhausen, 2020). While the definition of response time varies across regions, a common measure is a duration between the time the Call Center receives a call to the time an emergency vehicle arrives at the incident location. The response time reflects the effectiveness of emergency performance, so government agencies work to improve strategies that reduce the response time of emergency vehicles (EVs). Route optimization (designing an optimized dispatched route) is one critical strategy to minimize travel time for the first responder to arrive at incident locations in time. Despite algorithmic improvements to route optimization, many EV dispatches have missed their targeted response time. In the context of route optimization, we examined distributions of unsuccessful EV dispatches in the city of Dallas, where the target response time is 8 minutes. The unsuccessful EV dispatches are delayed for some reason at certain locations. So this research aims to identify the delay causes and further improve emergency service.

Route optimization can be based on distance or time (Eksioglu et al., 2009). Distance-based optimization commonly applies Dijkstra's shortest path algorithm with considerations of road features like hourly traffic patterns (Kula et al., 2012), lane counts, intersections (Brady & Park, 2016), etc. Similarly, Nicoara & Haidu. (2014) and Hailong et al. (2014) used Dijkstra's algorithm and integrated real-time traffic data to recommend a new route if needed during a dispatch. Distance, nevertheless, plays a secondary role; the actual time taken to reach the incident location is critical for life-threatening incidents. Time-based approaches identified the optimal route with the shortest travel time via various algorithms (Elalouf, 2012), communication systems, wireless sensors on the roads (Wang & Liu, 2011), or GPS installed on the EVs (Derekenaris et al., 2001).

Travel time has been examined at the macro and micro levels. Lupa et al. (2021) studied dispatches of emergency ambulances and found that there is a statically significant relationship between travel speed (calculated by travel time and travel distance) and the density of the road network and built-up areas of a given city. Micro-level studies are focused on streets. Zhang et al. (2016) developed a utility model with travel time and delay scenarios to generate an index assessing the reliability of a given street segment, the reliability index suggests if a street segment can be a route with a shorter time for the emergency vehicle dispatch. Even though the cause for and factors of unreliable road links remain unclear: specifically, to what degree such local features or areal features may lead to unsuccessful dispatches.

To this end, this study developed a framework to identify unsuccessful dispatches based on travel time and assess the association of surrounding features correlating with unsuccessful dispatches. We used EVs data in the City of Dallas from October 2015 to December 2017. A total of 26,185,419 GPS points present 554,891 emergency runs from different fire departments to various incident locations with a target response time of 8 minutes. A call center commonly dispatched multiple EVs to an incident. As long as one EV arrived at the incident site in 8 minutes, the dispatch was considered successful for this incident. The preliminary work aims to discern the proportion of unsuccessful dispatch on street segments and in census tracts. The trajectory of an EV dispatch at the street level is associated with local features along a run. Brady & Park (2016) considered that the number of lanes and type of median construction were street factors for routing: EVs (especially fire engines) would be difficult to maneuver in streets with fewer lanes and permanent median strips. Other street and areal features, such as sharp turns, over-grown canopy, POI clusters, or building layouts, may be contributing factors. Nevertheless, the first step is to identify spatial associations of locations and unsuccessful dispatches.

The research uses a data-driven evidence-based approach to explore the distribution of unsuccessful dispatch. Although many studies have been employed for reducing the response time, there has not been sufficient study to confirm the features that put constraints on emergency vehicles' move and further delay them. Our follow-up study will consider spatial features, temporal features, and socio-economic status on their influences on unsuccessful dispatches.

Method

Each EV that responds to an emergency scene is defined as an ‘emergency run (i)’ in the dispatch. In our study, we focus on the unsuccessful emergency runs (ui) that exist in unsuccessful dispatch (ud) and successful emergency runs (si) in successful dispatch (sd). We exclude unsuccessful emergency runs of successful dispatch because their delay is probably due to return or re-assign after one EV already successfully arrived. For each street segment (y), we estimate the proportion of unsuccessful runs (f_y):

$$f_y = \frac{\sum_i^n I(i = ui)}{\sum_i^n I(i = ui) + \sum_i^n I(i = si)}$$

We review all runs from i to n that included street segment y en route. Here $I(i = ui)$ is an *indicator variable* that equals 1 if i satisfies the definition of ui ($i = ui$) and zero if i violates the definition of ui ($i \neq ui$). The same process to calculate the $I(i = si)$.

Results

Fig. 1 shows the distribution of unsuccessful dispatch on street segments (micro-level) and in the census tracts (macro-level) for 8,523 unsuccessful emergency runs and 5,684 unsuccessful dispatches (one dispatch is responding to an incident and involving multiple runs) which did not receive emergency service within 8 minutes in 2015. Based on data from 2015, we can conclude that the northwest area, or road segment and census tracts in the city peripheral experience more unsuccessful dispatches than other areas. On the micro-level, our research discovers that highway comes with a high proportion of unsuccessful run, nevertheless, highways are commonly chosen as dispatch path due to the highest speed limits, and no traffic light or intersection. Some local roads in the northeast area experience with higher proportion, this suggests the influence of road network density or the complex street design. At the macro-level, we need to examine whether an association exists between socio-economic level and emergency service distributions as previous studies suggested. In the follow-up study, we will consider these factors and quantify their influence.

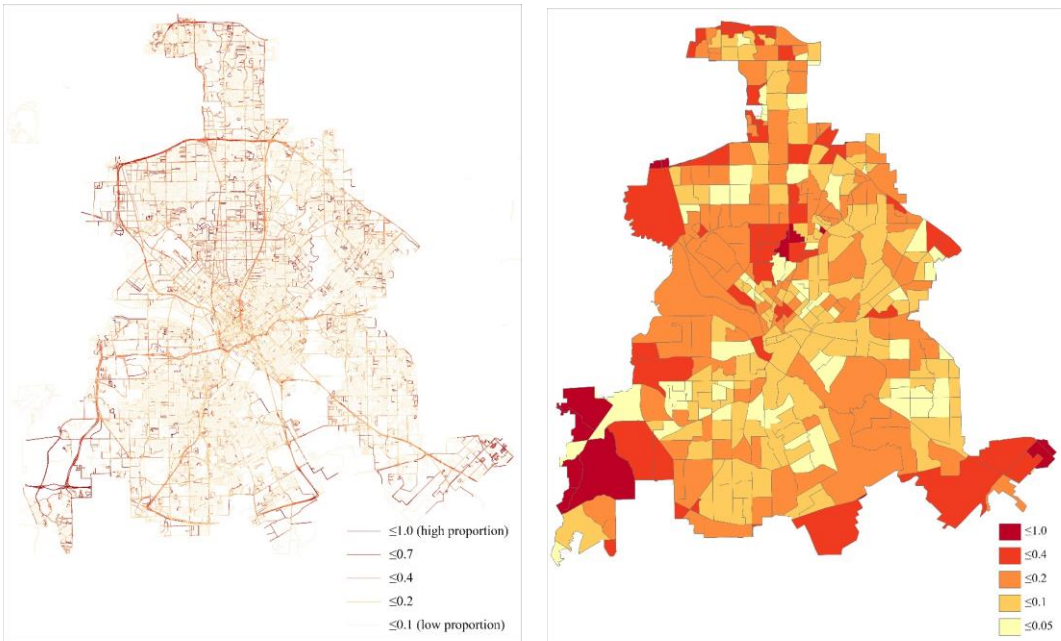

Figure 1: Proportion of unsuccessful dispatches at micro-level (left) and macro-level (right).

Discussion and Conclusion

This study demonstrated a preliminary result of a framework to truly reflect the quality of response time at the micro-level and macro-level. The preliminary suggests the uneven distribution of unsuccessful dispatch across the city of Dallas in two different spatial units. In the next step, we will examine possible causes for the delay scenario from local factors and area factors. Lupa et al. (2021) presented how the emergency vehicle move is dependent on the local environment. So, the delay occurrence can be examined with a variety of local factors. At the area level, Heidet et al. (2020) found that increased response time in the deprivation level compared to the less deprived level due to access constraints (e.g., fences, broken elevators), poor road conditions, and suboptimal environment (e.g., higher density of multistorey building). Those factors are associated with the level of socioeconomic and put constraints on emergency services accessibility. Identified local and area factors that may delay emergency dispatching can improve algorithms for route optimization and inform first responders on training and routing selection. Moreover, policymakers, urban planners, and public authorities should pay more attention to maintaining or upgrading the neighborhoods if their deprivation levels make an impact on response time.

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References

Brady, D., & Park, B. B. (2016). *Improving Emergency Vehicle Routing with Additional Road Features*.

Cordner, G., & Muhlhausen, D. B. (2020). *EVIDENCE-BASED POLICING IN 45 SMALL BYTES*.

Derekenaris, G., Garofalakis, J., Makris, C., Prentzas, J., Sioutas, S., & Tsakalidis, A. (2001). *Integrating GIS, GPS and GSM technologies for the effective management of ambulances*. www.elsevier.com/locate/compenvurbsys

Eksioglu, B., Vural, A. V., & Reisman, A. (2009). The vehicle routing problem: A taxonomic review. *Computers and Industrial Engineering*, *57*(4), 1472–1483. https://doi.org/10.1016/j.cie.2009.05.009

Elalouf, A. (2012). Efficient Routing of Emergency Vehicles under Uncertain Urban Traffic Conditions. *Journal of Service Science and Management*, *5*, 241–248. https://doi.org/10.4236/jssm.2012.53029

Hailong, S., Liyan, Y., & Shengyong, Y. (2014). *Study on Path Selection of Emergency Rescue Based on GIS*. https://doi.org/10.4028/www.scientific.net/AMR.864-867.2804

Heidet, M., Cunha, T. Da, Brami, E., Mermet, E., Dru, M., Simonnard, B., Lecarpentier, E., Chollet-Xémard, C., Bergeron, C., Khalid, M., Grunau, B., Marty, J., & Audureau, E. (2020). Ems access constraints and response time delays for deprived critically ill patients near paris, france. *Health Affairs*, *39*(7), 1175–1184. https://doi.org/10.1377/HLTHAFF.2019.00842/ASSET/IMAGES/LARGE/FIGUREEX3.JPEG

Kula, U., Tozanli, O., & Tarakcio, S. (2012). Emergency Vehicle Routing in Disaster Response Operations. *23rd Annual Conference on Production and Operation Management Society,2012*. http://www.pomsmeetings.org/ConfProceedings/025/FullPapers/FullPaper_files/025-1259.pdf

Lupa, M., Chuchro, M., Sarlej, W., & Adamek, K. (2021). Emergency ambulance speed characteristics: a case study of Lesser Poland voivodeship, southern Poland. *GeoInformatica*, *25*(4), 775–798. https://doi.org/10.1007/s10707-021-00447-w

Nicoara, P. S., & Haidu, I. (2014). a Gis Based Network Analysis for the Identification of. *Geographia Technica*, *09*(2), 60–67.

Pasnak, I., & Renkas, A. (n.d.). *OPTIMIZATION OF THE DURATION OF EMERGENCY VEHICLE MOVEMENT TO THE PLACE OF FIRE*. https://doi.org/10.21307/tp-2020-053

Wang, X., & Liu, J. (2011). Design and implementation for ambulance route search based on the internet of things. *Proceedings - 2011 3rd International Conference on Communications and Mobile Computing, CMC 2011*, 523–526. https://doi.org/10.1109/CMC.2011.110

Zhang, Z., He, Q., Gou, J., & Li, X. (2016). *Performance measure for reliable travel time of emergency vehicles*. https://doi.org/10.1016/j.trc.2016.01.015