Proceedings of the 2014 Winter Simulation Conference
A. Tolk, S. Y. Diallo, I. O. Ryzhov, L. Yilmaz, S. Buckley, and J. A. Miller, eds.

LARGE SCALE MEDICAL ASSISTANCE COVERAGE SIMULATION MODEL

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ABSTRACT

Due to high costs, ambulance providers staff for the daily routine. In the case of a demand outlier, e.g. a large scale incident, EMS run out of resources and an additional source of medical aid must become operational at the incident location. The Dutch Ministry of Safety and Justice asked the Netherlands Red Cross to have a nation wide volunteer-based service operational in January 2016 that can handle the treatment of victims with minor urgencies. We designed a simulation model for the NRC to calculate both the reliability for the response time threshold of 45 minutes for the first operational team, and the number of low priority victims treated within the first 2 hours, given the number of volunteers in the region. For each potential incident location, we determine an optimal meeting point for the team of volunteers before heading to the incident location. We also provide tooling.

1 INTRODUCTION

The Netherlands are divided in 25 distinct safety regions, that are, apart from police, firefighters and EMS, also used by the Netherlands Red Cross (NRC). When an incident occurs, initially only emergency services from that region respond. Thus we divide our problem in 25 sub-problems, which we can solve separately.

We consider the country as a complete non-symmetric graph $G = (V, E)$, taking the centroids of postal code areas as vertices V and constant time-independent travel durations $t_{i,j}, i, j \in V$ as edge weights E. All mentioned locations are mapped to the corresponding vertex. These choices are common practice.

The NRC utilizes three specializations of volunteers: team leaders, drivers, and regular members. A pager system, activated by the dispatch center, informs all volunteers instantly. The driver takes an emergency vehicle from a fixed depot. Then he drives to the meeting point (MP) where a team leader and two to six members join. Team leaders and regular members directly go to the MP. When a team is complete, they drive to the incident location where they start treating patients. The location of the MP depends on the incident location. Each region has exactly one depot with one emergency vehicle stationed. Any surplus in drivers, team leaders or regular members that show up do not join the team. The initial driving by individual volunteers to the depot or the MP is without audible and visual signals (AVS). Only the emergency vehicle that the driver picks up at the depot can drive with AVS turned on.

During paging, it is not certain if a volunteer goes to the MP, and where he is located. We assume that each region's volunteers are spread proportional to the population density. We assume that each specialization s has its own probability $p_{att} = p_{att}(s)$ of going to the MP.

Alternatively, we consider the case that there are no depots, with the drivers rotating vehicle shifts.

We use simulation to solve this problem. Simulations are a proven concept in the context of emergency services, see (Aboueljinane, Sahin, and Jemai 2013) and (van Buuren, van der Mei, Aardal, and Post 2012).

2 MODEL

We split the model in two parts. For every demand point $i \in V$ we simulate how it would behave as a MP. We distribute the drivers and team leaders over the region at random, but proportionally to the population density. Each person visits the MP with probability $p_{att}(s)$. We retrieve the driving duration to the MP for every attending person from a database, and we take the minimal time $t_{d,tl}$ when both a driver and team leader are present at the meeting point. Next, we determine what fraction p of the population can reach the meeting point within time $t_{d,tl}$. For each volunteer we determine if he attends, and with probability p if he can reach the meeting point in time. This results in the number of regular members at time $t_{d,tl}$. Only if there are not enough regular members we simulate 10 000 times the arrival process of the volunteers similar to that of drivers and team leaders, and take uniformly a value from these outcomes that exceeded $t_{d,tl}$. We repeat this entire process 10 000 times for every demand point, yielding an empirical distribution $f_i(t)$ at which time the first team departs. The probability that no team formation can take place is called p_b.

In the second part we consider every demand point as a possible incident location $j \in V$. Taking $m_j = \arg\min_{i \in V}\{\mathbb{E}[f(t)] + t_{i,j}\}$ we determine an optimal MP. The arrival time distribution of incident j is given by $r_j(t) = f_{m_j}(t) + t_{m,j}$. From now on, calculation of the number of treated patients is trivial.

3 OUTCOMES

Because realistic choices for the numbers of volunteers are limited, we use these as an input for our model. Other input settings include the initial choice of depot, probability to show up, chute times, and treatment speed per specialization. Our output includes (but is not limited to) the following.

- For every possible incident location, an optimal postal code area for the meeting point.
- The distribution of the last arriving specialization at the meeting point, for example: in 60% of the cases the driver was the last specialization to arrive at the meeting point.
- The distribution when the team arrives at the incident location.
- The distribution of the number of treated low priority victims at the 2 hour time threshold.

4 CONCLUSION AND FUTURE RESEARCH

Simulation gives a great insight into effects of uncertain factors in the arrival process of NRC teams at incident locations. Our model gives a useful decision support system (DSS) for the NRC to prepare for the new situation. Using the default settings provided by the NRC (20 regular members, 9 drivers, 9 TL's and $p_{att}(s) = 1/3\ \forall s$), we get $p_b = 5.5\%$ and cover 69.0% of the postal areas within the 45 minute threshold. This corresponds to 79.2% of the inhabitants. In the alternative scenario with two drivers and $p_{att}(d) = 0.9$ we get $p_b = 3.9\%$, and 79.3% of the postal codes containing 87.4% of the inhabitants could be reached within 45 minutes. A first operational team can never treat the required 150 patients within 2 hours, because the maximum of 6 members need just over 3 hours to reach this value at a given treatment speed of 8 victims an hour. It would be useful if future models give insight in situations with multiple teams.

ACKNOWLEDGMENTS

We would like to thank Danijela Blagojevic and Murvin Chan of the Netherlands Red Cross (NRC) for their support, and Geert Jan Kommer of RIVM for providing the EMS travel duration tables. The demographical information over the year 2013 originates from Statistics Netherlands. This research is supported by the Dutch Technology Foundation STW, which is part of the Netherlands Organisation for Scientific Research (NWO), and which is partly funded by the Ministry of Economic Affairs.

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