Ambulance services are an important part of society. In life-threatening emergency situations, the ability of ambulance service providers to arrive at the emergency scene within a few minutes to provide medical aid may make the difference between survival or death. In practice, a commonly used service-level target is that the response time for high-emergency calls should be less than $x$ minutes in $y\%$ of the cases. To realize short response times at affordable cost, efficient planning of ambulance services is crucial.

A highly promising approach to improve the efficiency of ambulance services is to implement pro-active dispatching and relocation policies, forcing ambulance vehicles to be relocated in order to maintain good coverage of the service area. Despite the fact that such dynamic ambulance management (DAM) policies are highly promising, only little is understood today about the implications of implementing DAM on the performance of ambulance services in practice.

In this article we will discuss the so-called Testing Interface for Ambulance Research (TIFAR) decision support tool that can be used to evaluate dynamic dispatch strategies. To validate the accuracy TIFAR is tested on the real-life data for the region of Amsterdam, the Netherlands. The results show that the TIFAR-based performance predictions are highly accurate.

In the next section we will briefly describe how Emergency Medical Services (EMS) work in The Netherlands. The section after that will explain how TIFAR works, and in the final section we will show some validation results for a region in The Netherlands.

EMS in The Netherlands

The Netherlands is partitioned into 25 EMS regions, each served by a single ambulance service provider, called RAV (Dutch: regionale ambulancevoorziening). The inbound Emergency Medical Call Centers (EMCCs) handle the incoming medical emergency calls by civilians, GPs, police, firefighters and health care institutions. It also coordinates all EMS vehicle movements within the RAV.

In The Netherlands, each incoming call gets an urgency levels assigned: A1, A2 and B.

A1 An urgent call with an acute threat to the patient’s life. Vital functions of the patient are not or hardly present, or cannot be determined over the telephone. The EMS vehicle uses optical and visual signals and tries to get to the patient as soon as possible. Examples: heart attacks, reanimations or serious traffic
incidents.

A2 The patient’s life is not under direct threat, but there might be serious injuries. The EMS vehicle may use optical and visual signals if the EMS personnel has discussed this with the EMCC, but this only happens on rare occasions. Examples: a broken leg or a general practitioner asks for transportation to a hospital.

B A call without urgency A1 or A2 in which the patient must be transported within a given predetermined time interval. A typical B call exists of transferring a seriously ill person from one hospital to another, because this hospital is specialized in the patient’s condition. When a seriously ill person receives a scheduled transport from an EMS vehicle to his or her home, it will be classified as a B call as well.

For each incoming call, at eight moments in time the status information is time-stamped and logged into a database, see Figure 1. The ‘response time’ is defined as the length if the time interval between the moment that the call center receives the phone call until the moment the EMS vehicle arrives at the incident location should be at most 15 minutes for A1-calls or at most 30 minutes for A2-calls. For B-calls there is no maximum response time defined, since they are usually planned in advance. A key performance indicator is the fraction of calls that meets these maximum response-time thresholds. In the case that a patient is treated at the incident location or when a transport will not occur, status 3 and status 4 are not applicable and are left empty in the database.

![Figure 1: Overview of system statuses.](image)

**TIFAR Simulation Tool**

In this section we give a brief outline of TIFAR’s inner workings. TIFAR can run in two modes: in a visual mode and a faster command line based discrete event simulator. Calls are generated by a stochastic process, vehicles are assigned to calls and patients are being brought to a hospital. Only when driving to an incident with A1 urgency the EMS vehicles ride with auditory and visual signals at accordingly adjusted travel speeds.

The timestamp of the next upcoming incident is generated by a Poisson point process. Calls are generated at a six-position postal code, for example *1011 AA*. A rule of thumb states that population is almost evenly distributed over the postal codes, which leads
to a good approximation of reality. By a Bernouilli experiment it is determined of the patient should be brought to a hospital. Both the treatment time at the incident location and the transfer time at the patients destination are taken constant for A1 and A2 calls. For ease of the model, it is assumed that each call is handled by exactly one EMS vehicle; note that this assumption can be easily relaxed. TIFAR makes use of third party route planning software and cartography made by Connexxion. It has accurate EMS travel speed estimations in it, which gives us very good results when evaluating a dispatch strategy using a set of precise relocation rules for a RAV in The Netherlands.

The call handling in TIFAR is on a first come first served non-preemptive priority basis. We always send the closest available EMS vehicle to an incident. When a patient has to be brought to an hospital, the vehicle will be sent to the nearest one. Afterwards, it returns to the closest base location. Only following these rules does not yield a good distribution of the EMS vehicles over the region. For this reason it is possible to enter a set of relocation rules into TIFAR.

The road network is modeled as a graph. Due to good memory management TIFAR can hold over 32,000 vertices and a billion edges, which is much more than other models. The graphical user interface and flexibility of the tool gives good insight in what happens and helps to make decision making easy.

Detailed information can be found in (Van Buuren, 2011) and (Van Buuren et. al., 2012). A review on EMS dispatch strategies can be found in (Brotcorne et. al., 2003). Earlier simulation models are described in (Henderson and Mason, 2005) and (Mason, 2005).

Validation Results

We have run multiple simulations for an operational RAV in The Netherlands with realistic base locations, staffing levels, travel-time models and relocation policies implemented. The results show that TIFAR’s performance for calls with a high urgency is very close to the actually realized performance by the RAV. This shows that TIFAR is able to answer what-if scenarios for different configurations, which provides RAVs with a powerful tool to enhance the efficiency of their daily operations.

References


