Simulation of emergency care for patients with ACS in Saint Petersburg for ambulance decision making

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Abstract
One of the stages of emergency medical care in case of Acute Coronary Syndrome (ACS) (if there are medical conditions for surgical intervention) is directly linked to the time between the first contact with the patient and the and inflating the balloon in the coronary artery (in a medical institution). Time of the operation start a medical facility depends on the time of patient delivery to hospital, as well as on the waiting time in the queue in the institution. This paper describes a development of ambulance model for obtaining aggregate estimation of these two periods of time. The estimation time is obtained by means of described in the article the decision support system (DSS) in the ambulance service. Unlike modern navigation systems DSS takes into account ambulance vehicle behavior (the ability to exit into oncoming traffic) and availability of free operation rooms. With the help of the described simulation model of the ambulance service we carried out the time distribution analysis (between the first contact with the patient and surgical intervention in case of ACS) in St. Petersburg, Russia. Simulation scenario uses real data on the work of ambulance service in the city.

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1 Introduction

Modern ambulance service is a dynamic multi-functional system, which has a complicated maintenance mechanism. Relevance of the research decision support systems in the ambulance service is caused by the necessity to optimize decision-making, in order to improve the quality of patient care. Among the key features of the work of the ambulance service, we can highlight the increased need for "reliability" of every decision, due to its importance for human life and health. Thus, the use of DSS is
an effective approach that automates processing large amounts of information. Another key ambulance service feature is the high dynamics of the service work. High dynamics results from little time to make a decision that healthcare providers usually have. Consequently, the DSS can be used to reduce the time of decision-making in complicated cases by automating the analysis of the situation.

This paper describes the methodology of development of DSS in the ambulance service. One of the DSS modules solves the problem of time estimation between the first contact with the patient and the beginning of the surgical intervention for patients with ACS. This estimate was obtained using a complex model, which includes a transport model, (that assessed the time of the patient delivery to the hospital), flow of calls model, as well as the queuing model that evaluates the waiting time.

According to the paper, by (Tereshchenko & Zhirov 2010), in the provision of care for patients with ACS (patients with medical conditions for Percutaneous Coronary Intervention, PCI) the algorithm of actions of a medical brigade depends on the predicted time of start PCI. Tereshchenko and Jirov state that if the time between the first contact with medical personnel and inflating the balloon in the SC (coronary artery) exceeds 90 minutes, it is preferable to use thrombolytic therapy. If the predicted time is less than 90 minutes, then the use of invasive strategy is preferable. Thus, the task of predicting the time between the first contact of medical staff with patients and the beginning of the operation is an urgent one. The quality of the forecast impacts the patient's treatment strategy.

2 Related Works

2.1 Time estimation of the patient transportation to a hospital

The period time between the first contact with the patient and the start of the operation can be divided into two parts. The first step is to calculate the patient delivery time. Delivery time is calculated on the basis of the selected route from the patient initial location to the hospital. Thus, when calculating the patient delivery time, it is necessary to find the fastest route.

The problem of finding the fastest routes for ambulances may be considered from the perspective of the search of the optimal path in a weighted graph. To find the way we must take into account dynamic changes in the traffic situation and also the specific behavior of the ambulance vehicles.

One of solutions to the problem of the ambulance fastest path search is proposed in (Gayathri & Chandrakala 2014). The authors apply Dijkstra algorithm of the shortest path search in a weighted graph, which takes into account the current state of traffic. The paper (Nordin et al. 2011) proposes a more efficient (in terms of performance) algorithm A * of finding the shortest path in the graph. In (Maxwell et al. 2010) the shortest route is searched using ADP dynamic programming techniques. In (Gendreau et al. 2001) ambulance route search problem is solved by a heuristic tabu search algorithm. In (Kergosien et al. 2015) it is proposed to seek the shortest path between two points and estimate the time of its passage, on the basis statistical data of prior ambulance trips, and comparing estimated routes to the current ones. Data of base previous ambulance trips helping in choosing the optimal route is also described in (López et al. 2005). In (Créput et al. 2011) proposed to use the method of neural networks (Kohonen self-organizing maps) to find the shortest path for an ambulance.

One of the disadvantages of these approaches is the lack of consideration of the special behavior of ambulances on the roads. For example, the possibility of entering the opposite lane can change route selection. Unlike the above mentioned approaches, in the ambulances movement model, described in this paper, simulates travel into the oncoming lane.

2.2 Queuing models in ambulance service

The second step of estimating time from the first contact with patient to the moment of surgery beginning is to calculate waiting time which patient has to spent in hospital after arrival.
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