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ScienceDirect

Procedia Environmental Sciences 36 (2016) 199 – 206

Procedia Environmental Sciences

International Conference on Geographies of Health and Living in Cities: Making Cities Healthy for All, Healthy Cities 2016

Dynamic Ambulance Deployment to Reduce Ambulance Response Times using Geographic Information Systems: A Case Study of Odunpazari District of Eskisehir Province, Turkey

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Abstract

Background and Objective: Ambulances should always reach patients in the shortest time possible whenever they are called upon so as to increase patient survival chances especially in cardiac related medical cases. The placement of ambulances directly affects the time ambulances reach patients. The objective of the study was to find optimal stations to deploy ambulances so as to reduce ambulance response times and increase patient survival chances as a result.

Data and Methods: To reduce ambulance response times for Odunpazari district, the study employed system status management technique and maximal coverage location problem optimization model, to deploy ambulances according to ambulance demand and ensure maximum ambulance demand coverage is realized with a small ambulance fleet size, respectively. ArcGIS network analyst location allocation tool was used to find optimal ambulance stations from where ambulance demand areas can be reached within 5 minutes of drive time. Four different ambulance deployment plans were modeled for periods ranging from 00:00 to 06:00 hrs, 06:00 to 12:00 hrs, 12:00 to 18:00 hrs and 18:00 to 24:00 hrs. The study used a total of 20,260 ambulance demand calls' data for Odunpazari district collected from January 1st to December 31st 2014.

Results: The Odunpazari district fleet of 17 ambulances was deployed differently for every six hours; between 00:00 to 06:00 hrs, 06:00 to 12:00 hrs, 12:00 to 18:00 hrs and 18:00 to 24:00 hrs to match ambulance demand and as a result, 77.6% of ambulance demand areas were located within 5 minutes of drive time from the nearest ambulance station.

Conclusion: The study found out that moving ambulances closer to ambulance demand areas reduces ambulance response times and dynamic ambulance deployment is by far a more effective ambulance deployment strategy than static ambulance deployment.

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Peer-review under responsibility of the organizing committee of Healthy Cities 2016
doi:10.1016/j.proenv.2016.09.033

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Keywords: Ambulance response times; dynamic ambulance deployment; maximal coverage location problem

1. Introduction

The utilisation of ambulance services in response to emergency medical cases has been an integral part of healthcare service delivery for a long time in most parts of the world. Ambulance response time is a key criterion for evaluating the effectiveness of an emergency medical services (EMS) system. One of the important components of healthcare service provision is pre-hospital care provided by EMS. The mission of EMS is to coordinate the delivery of timely and appropriate first aid services to patients under emergency conditions to prevent disability, and increase patient survival chances1. The main aim of the study was to model ambulance deployment plans for Odunpazari district using geographic information systems (GIS) technology that would ensure the reduction of ambulance response times without expanding the Odunpazari district ambulance fleet.

1.1. Ambulance response time

Ambulance response time is the period between when an emergency call is recorded and the time the first ambulance arrives at the scene in a life-threatening event to provide out of hospital medical care[10]. Ambulance response time is an integral part of out-of-hospital healthcare provision. Apart from the relation to clinical outcomes, EMS response time is also an important public expectation and quality of service benchmark. Because resources are often constrained and EMS providers cannot continuously expand their ambulance fleet, a more optimal deployment of ambulances to meet the demands for ambulance services is an attractive option to achieve faster response. Dynamically reassigning ambulance deployment locations to balance ambulance availability and demands can be a more effective strategy to reduce ambulance response time and increase patient survival chances as a result[9].

The survival of individuals with serious medical cases of stroke, myocardial infarction, pulmonary embolism, and cardiac arrest is largely dependent on ambulance response time. The shorter the ambulance response time, the greater the possibilities of survival. The immediate delivery of medical services to a patient in a cardiac arrest can have a survival rate of approximately 67%, while the decline in survival rate without treatment is 5.5% per minute and after 12 minutes, there is no possibility of a patient to survive[14]. The 'chain-of-survival' concept, states that survival in case of a cardiac related medical condition, can be improved with early access, early cardiopulmonary resuscitation, early defibrillation, and early advanced care[6, 12, 17]. A study carried out in Texas which was tasked to come up with an efficient ambulance deployment strategy that ensured reduction in average ambulance response time, improved prehospital medical care, equity improvements, and capital and operation costs savings was a success with the introduction of dynamic ambulance deployment strategy[5]. The placement or deployment of ambulances, which has been a subject of thorough investigations, has been found to have an effect on the time ambulance services reach patients[1, 2, 8]. Various studies undertaken to investigate dynamic ambulance deployment have all registered steady reduction in ambulance response time making use of dynamic ambulance deployment basing on system status management (SSM) implemented by GIS technology[11,12]. Emergency medical systems could become more effective if a dynamic, load-responsive ambulance deployment plan is adapted[13].

1.2. Study area

Odunpazari district of Eskisehir province is located between latitude 39°45'32' N, and longitude 30°31'33'E. The district is found in Eskisehir province in the Northwestern part of the Central Anatolian region of Turkey as shown in Fig. 1a. Odunpazari district is located on an altitude of 788 m (2.585 ft.) and has a population of 376,650 people according to Turkish Bureau of Statistics 2014. Odunpazari district is made up of 85 parishes.