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# EMERGENCY MEDICAL SERVICE LOCATION PROBLEM: A CASE STUDY IN MISURATA, LIBYA

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***Abstract:***
*The researchers applies The Location Set Covering Model to Misurata city to find the optimal medical service locations. The model determines the minimal number of location sites needed to cover all demand points using different maximal response times of 10, and 15 minutes. As a result, the optimal output of the model is 24 and 7 location sites. The optimum solution to the model reduces the number of location sites by a percentage of 12.5%, and increases the most expected coverage by 71%.*

***Key words:***
*Emergency Medical Services, Location, Libya*

## INTRODUCTION

Location theory is very important and popular in different areas. German agricultural economists Thun and Weber are considered the pioneers for the development of location theory. While in terms of mathematical formulations, it is believed that Ferma was the first to consider location problems [1]. In this research, we will provide locations of Emergency Medical Service EMS in Misurata city, using Location Set Covering Model.

The Emergency Medical Service EMS provides emergency care, and transports patients to the hospital immediately, when they need the health care to reduce patients' mortality, disability or suffering. The emergency treatment might reduce the risk of death for patients. However, the lack of this treatment might increase, due to long ambulance response time. Response time is defined as the time consumed between the minutes an operator finishes receiving the information from a caller, to the time an ambulance arrives at the emergency site [2].

The response time is affected by the EMS locations. Nevertheless, selecting appropriate locations can improve the response time. Location Set Covering Model (LSCM) determines the suitable ambulance locations to cover all demands on pre-specified time and distance, while limiting the number of ambulances.

Karatasa et al. used two classic location models, which are the p-median and maximal coverage location, and compared the results obtained from these models with respect to five decision criteria under Q-coverage requirement [3].

Emergency service planners must solve the strategic problem of where to locate emergency services centres, and the tactical problem of allocating demand on those centres. The performance of an emergency centre may be judged by the number of people in queue, or by the length of time that a person must wait after he or she arrives at the centre. These indicators are strongly correlated with the number of centres available, along with their locations [4].

Additionally, Emergency Medical Service is one of the most important health care services, since it plays a vital role in saving people's lives, and reducing the rate of mortality and morbidity [5]. In fact, the primary objective of an emergency medical service (EMS) system is to save lives, and to minimize the effect of an emergency health incident [6].

## 1 LSCM Model

An important strategic and tactical problem is the location of ambulance stations, and the allocation of ambulances to these stations [7].

Generally, ambulance location models are defined on graphs. V denotes the set of demand points, and W Likewise denotes the set of potential ambulance location sites. Furthermore, the shortest travel time $t_{ij}$ from vertex i to vertex j of the graph is known. A demand pointed $i \in V$ is said to be covered by site $j \in W$ if and only $t_{ij} \leq r$, in which r, is a pre-set coverage standard. Let $Wi = \{j \in W: t_{ij} \leq r\}$ be the set of location sites covering the demand point i [8].

Moreover, The Location Set Covering (LSC) Model presented in Toregas et al. (1971) [9] is one of the earliest model of ambulance locating. The Location Set Covering Model (LSCM) aims to minimize the number of ambulance needed to cover all demand nodes [10]. The Emergency Medical Service is important to all participations of the city and has direct effects on their lives. Therefore, the location of EMS is one of the most important things, and there is a large number of studies with EMS location [5, 7, 11, 12, and 13].

The formulation of LSCM is:

Minimize

$$\sum_{j \in w} Xj \tag{1}$$

Subject to:

$$\sum_{j \in wi} \boldsymbol{Xj} \geq \mathbf{1} \quad \forall \boldsymbol{i} \in \boldsymbol{V} \tag{2}$$

$$Xj= (0, 1)\ \forall j \in w \tag{3}$$

For LSCM model, the objective function (1) minimizes the number of facilities to be located. Constraint (2) ensures that each demand node is covered by at least one facility, while constraint (3) enforces the yes or no of siting the decision.

## 2. The Case Study

Misurata city lies 211 kms east of Tripoli on the Mediterranean Sea coast. With a population of about 300,000, where Misurata is the third largest city in Libya.
Additionally, Misurata city is divided into 8 regions. The residents' density varies from 12 residents per $km^2$, to 1278 residents per $km^2$. The researchers divided the city into 315 zones. Each zone area is 10 $km^2$. Figure 1 shows Misurata city with the current EMS stations in which there are eight stations.

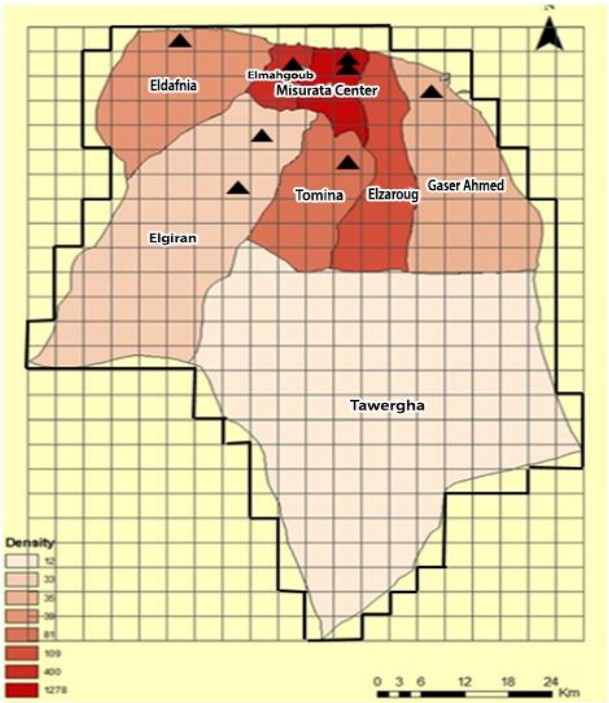


***Fig. 1*** *Currsent state of the EMS in Misurata*

The results of different coverage standard for the current situation of EMS are as follows: At travel time r=10 minutes, the current EMS covers 55 zones with a coverage percentage of 17%, and at travel time r= 15 minutes , it covers 91 zones with a coverage percentage of 29%.

Undoubtedly , the LSCM model used to compute the minimal number of location sites needed to cover all demand points. This was done for the two different maximal travel time :10 and 15 minutes.

Figure 2 shows 46 possible locations for the EMS . These locations are suggested after discussions with the emergency service authorities. In addition ,the suggested possible locations coverage is for the whole area of the city.

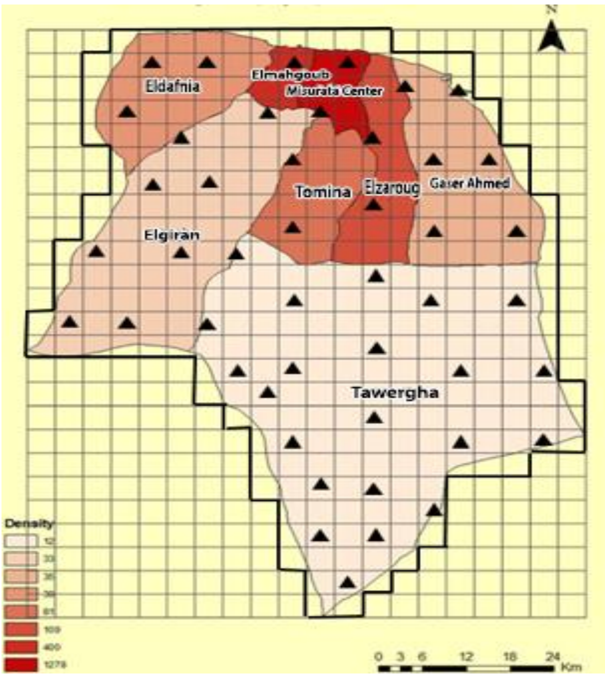


***Fig. 2** Suggested possible locations of EMS*

## 2.1 First scenario

In the first scenario, we consider the following data:

Response time r = 10 minutes.

Vehicle velocity v = 60 km/ hr.

Figure 3 (a) shows that 24 stations are opened, covering 100% of the zones , whereas Figure 3 (b) shows that the zones covered by one station (red) up to four stations (dark green). Moreover, there are 160 zones covered by one station (51% of the total number of zones), and 127 zones covered by two stations (40% of the total number of zones).

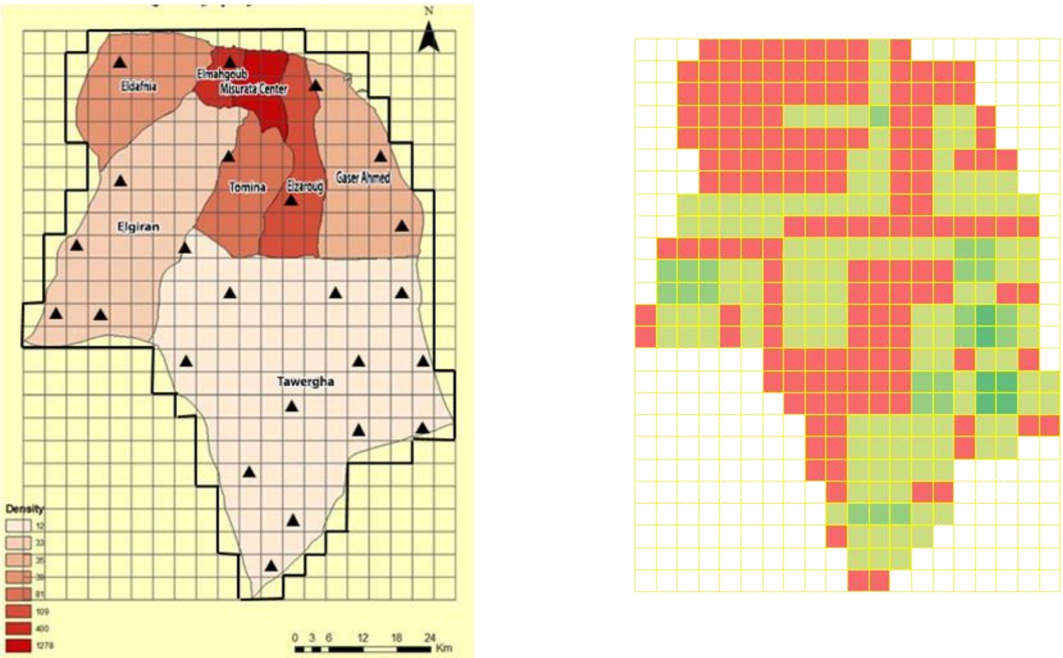


***Fig. 3** (a) Opened stations* *(b) Number of stations covering each zone*

### 2.2 Second scenario

In the second scenario, we consider the following data:
Response time r = 15 minutes.
Vehicle velocity v = 60 km/ hr.

Figure 4 (a) shows that 7 stations are opened, covering 100% of the zones , whereas Figure 3 (b) shows that the zones covered by one station (red) up to four stations (dark green). In addition, there are 212 zones covered by one station (67% of the total number of zones), and 100 zones covered by two stations (32% of the total number of zones).

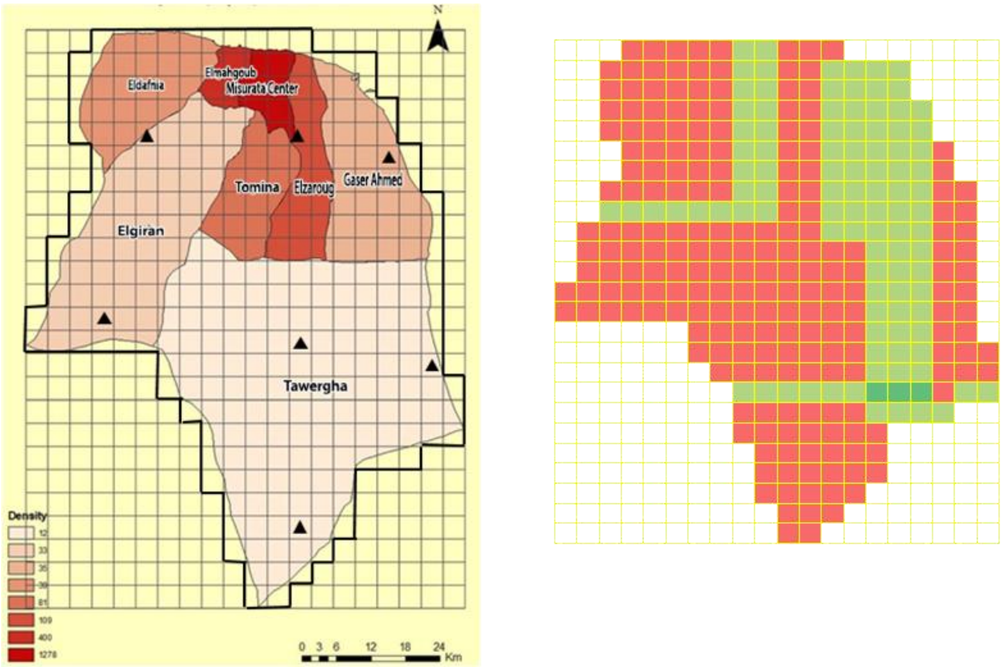


***Fig. 4** (a) Opened stations* *(b) Nnumber of stations covering each zone*

Table 1 summarizes and compares the results of the current situation of the EMS, as well as, the results of the two scenarios. It is clear that the current EMS stations could not cover the whole city, even with the response time 15 minutes. With the response time 15 minutes, the number of stations required to cover the whole city is 7, which is less than the current number of stations. At the same time, the percentage of the covered zone will increase by 71%.

***Tab. 1** Summary of the model*

| Response time | Current situation | | | Suggested stations | | | % improvements |
|---|---|---|---|---|---|---|---|
| | No. of stations | Covered zones | % covered | No. of stations | Covered zones | % covered | |
| **10 minutes** | 8 | 55 | 17% | 24 | 315 | 100% | 83% |
| **15 minutes** | | 91 | 29% | 7 | 315 | 100% | 71% |

## 3 CONCLUSIONS

This paper presents a solving EMS location using Location Set Covering. In fact, the Emergency Medical Service EMS has a significant impact on health service provision. Its importance lies behind that failure of ambulances to respond to emergency calls within set times, which may result in the loss of lives. In addition, the paper represents two scenarios of locations using LSCM: the first scenario is at 10 minutes response time, and the second scenario is at 15 minutes response time. The first scenario improves the covered zones by 83%, and the second scenario improves it by 71%. Furthermore, the second scenario will reduce the number of stations by 12.5%. To conclude, it is obvious that the current distribution of the stations needs improvement, and it could be improved using one of these scenarios.

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