Minimizing Response Time in Medical Emergency Service: A Literature Review

Muhammad Isnaini Hadiyul Umam
Doctoral Student of Industrial Engineering Department
Institute Technology of Sepuluh Nopember
Surabaya, 60111, Indonesia
ISNAINI.30@gmail.com

Budi Santosa, Nurhadi Siswanto
Industrial Engineering Department
Institute Technology of Sepuluh Nopember
Surabaya, 60111, Indonesia
budi_s@ie.its.ac.id, siswanto@ie.its.ac.id

Abstract

Medical Emergency Service (MES) or commonly known as ambulance plays a very important role in the possibility of mortality of a patient. MES has become an important issue in the world of health because of the possibility to survive a person. MES itself is preserved as an event occurrence ranging from for patient pick-up in a medical emergency to transfer of patient to hospital, but the main role of ambulance is to provide quick access to those in need or known as response time. This paper will conduct a literature review of the types of approaches that previous researchers have done to address MES-related issues. In the end can determine the direction of further research on MES.

Keywords: Ambulance, Hospital Management, Medical Emergency Service (MES), Pre-hospital, Response Time.

1. Introduction

Medical Emergency Service (MES) or commonly known as ambulance plays a very important role in the possibility of survival of a patient. Singer & Donoso (2008), Aboueljinane et al. (2013), Knyazkov et al. (2015), Su et al. (2015), Aringhieri et al. (2016) and Chen et al. (2016) agrees with the statement where MES has become an important issue in the world of health because it involves the possibility of survival. Sarier et al. (2016), states that almost all developed and developing countries have MES, which consists of pre-hospital handling and transfer to hospital facilities. MES itself is defined as a sequence of events ranging from notices to patient pickups in a medical emergency to transfer of patients to the hospital, but the main role of ambulance is to provide quick access to those in need.

The adage "time is money" feels right on the Medical Emergency Service, where each person is willing to pay any amount to increase the probability of mortality in an emergency. Jaldell et al. (2014) reveals that the time factor is one of the most decisive factors that a person will be able to survive, so there is a certain amount of cost or cost that would be willing to bear someone when in an emergency. According to Su et al. (2015) and Aringhieri et al. (2016) one second also has a tremendous influence in the probability of survival in an emergency case.

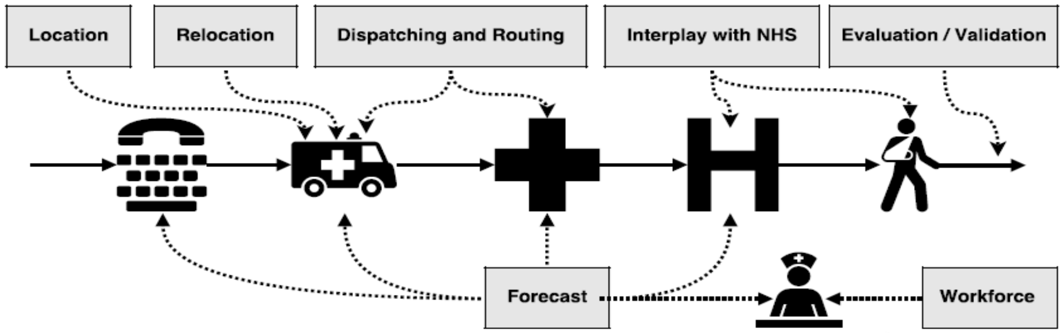

Figure 1. The handling flow and related issues of MES (Aringhieri et al.2017)

This paper is structured as follows: Section 2 to see the studies that have been done on MES. Section 3 is devoted to reviewing strategies that previous researchers have done to minimize MES response time. Section 4 presents research exposure based on the characteristics of MES. The paper concludes with some conclusions and possible directions for further research.

2. Methodology

Critical review process is done to see the direction and identify gaps that have been done by previous researchers on the problem of Medical Emergency Service. The steps that researchers do for this critical review process refers to the steps that have been done by Torchia et al. (2013) is as follows:

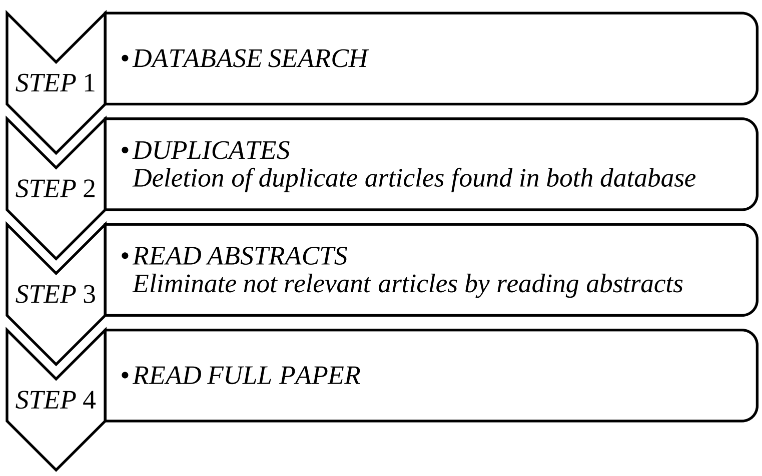

Figure 2. Methodology Process of Review Paper (Torchia et al. 2013)

Researchers conducted with the object of Medical Emergency Service and Ambulance found 153 publications of research from various sources. Then the second step is the removal of the same papers, seen from the initial number of 153 publications reduced to 127. Step 3 read the abstract from each of these studies, so that can be grouped into several groups ranging from the type of Medical Emergency Service used, the purpose of research and what strategies are applied (locationing, allocationing and dispatching). The final step reads thoroughly the filtered studies. This step is marked by a red line indicating that the type of MES solvent consists of two types of systems namely the centralized and the scattered. Then from both types it is known that MES with scattered arrangement has the ability to minimize response time with very significant when compared with centralized. So the direction of this study will make arrangements based on MES scattered.

To improve the quality of MES, Lenkes et al. (2016) in his research states that MES planning is a very important factor and has become an interesting study in the World of Operational Research (OR) starting from the mid-1960s.

Among them is the determination of the location of the ambulance placement, the amount to be allocated and the dispatch problem [Takeda et al. (2007); Knight et al. (2012); Sawaya & Elhedhli (2013); Billhardt et al. (2014); Zhen et al.(2014); McCormack & Coates (2015); Ebrahimi & Modam (2016); Sung & Lee (2016); Unluyurt & Tuncer (2016); Zarkeshzadeh et al. (2016); Dibene et al. (2016)].

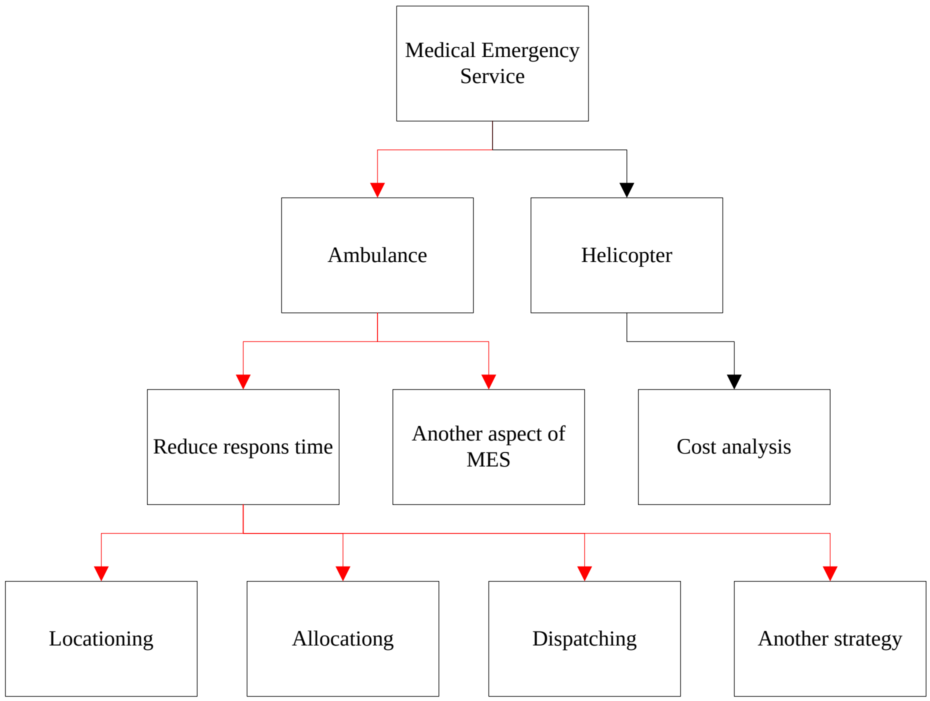

Figure 3. The focus of research in MES

Figure3. Shows the distribution of research that researchers have done about the MES problem. MES broadly divided into 2 types of ambulance and helicopter. Each of which has various aspects of the study that has been done such as reducing response time, cost analysis and more. Researchers focused on helicopter studies for MES emphasize the focus of their research on the scope of cost analysis such as Taylor et al. (2010; 2011; 2012), McArtur et al. (2014) and Stewart et al. (2015). While researchers who reviewed the ambulance focused more on minimizing response times. For the researcher developing the location determination, allocation and dispatch strategy can be seen in table 1. The other aspects studied besides the minimization of response time include Bost et al (2010) on patient handover by ambulance, Bigham et al. (2010) on the study of population density and racial differences in performance ambulance, Johansson et al.(2011), which examines patient satisfaction with ambulance, Aftyka et al. (2014) on MES personnel, Romanziera et al. (2015) the quality of the assignment, Corrado et al. (2016) on the comparison between using MES and non-MES, Te Grotenhuis et al. (2016) improving early identification (2016) on the comparative analysis of MES, Unwin et al. (2016) examines the perspectives of patients on assignment ambulance, Utku et al. (2016) MES automation between ambulance and drug inventory, Villani et al. (2016) on the utilization optimization of MES, Hertzberg et al. (2017) on the contact network and staff role of the emergency unit.

Other strategies offered by some researchers other than location, allocation and dispatch are by driving a high speed ambulance as proposed by Cung et al. (2010) and Pertzall et al. (2011). Greene (2011) suggests sharing information strategy. Another strategy offered by Sriram et al (2017) is by implementing the Public-Private Partnership scheme by integrating all existing ambulance fleets.

3. Location, Allocation and Dispatch

The problem of the importance of determining the location of a facility actually began to be discussed in about 1909 but still limited to the object warehouse. It was only around the 1960s that the problem of determining the exact location for ambulances began to be discussed. Some recent settlements concerning the determination of the location of these ambulances as did Takeda et al. (2007) which analyzed the difference of location determination system by centralize and decentralize using hypercube queuing model. The results of a decentralized system scenario can improve the performance of the ambulances and decrease the average response time, on the other hand the operational and investment costs also increase.

Schmid (2012) conducted research to find the optimal location of ambulance to reach patients in need with the shortest time and dispatching problems. The method devised to solve this problem is stochastic dynamic programming. The result is a decrease in average time of 12.89% with the note that they have to relocate their existing ambulance base. Still in the same year Shariat-Mohaymani et al. applying linear upper-bound unavailability set covering models to overcome the problem of determining the optimal location of ambulances with case studies used is the MES problem in Iran. The model calculates the extent of the demand area that the ambulance can meet maximally. With the model initiated it shows decreased response time and the need for ambulance by dividing into several locations.

Billhardt et al. (2014) suggests that there are two main problems faced by MES managers that are allocation and redeployment issues. The allocation problem is the determination of how much to raise to meet existing demand, while redeployment issues are choosing an available ambulance and which has the closest distance to demand. The scenario model is initiated in the form of coordination between ambulance by combining dynamic allocation and dynamic redeployment model. The results obtained in the form of minimized travel time and increase the level of demand fulfillment. Zhen et al. in (2014) also conducted research on relocation and redeployment strategies. Zhen et al. states that the challenge in determining the decision in estimating the amount to be allocated is the constantly changing demand at each of the different locations. The approach is to overcome these challenges by using a simulation method in order to remove barriers from stochastic demand. The results obtained are ambulance unit placement and scheduling strategy based on demand forecasting and real-time dependent. Maleki et al. (2014) conducted research by developing two new models (named MECRP) for redeployment of ambulance by determining where the best position for the health unit is as the base of the ambulance and how many ambulance fleet should be allocated to each base.

Continuing in 2016 researchers are still interested in exploring the location-determining studies of ambulances such as Sariyer et al., Nickel et al. and Van-Barneveld et al. Sariyer et al. and Nickel et al. conducting research to determine the best locations of ambulances by looking at the trends of prior demand data. So location selection is determined based on the distribution of data from those requests. While Van-Barneveld et al. do a configuration approach that allows ambulance to trade-off with each other so that the response time will be small.

In addition to the problem of location determination and allocation, another problem that is not less important is the determination of the pickup route from the patient (dispatch). Several previous studies have also discussed this issue using various approaches, ranging from the exact approach [Schmid (2012); Jaldell et al. (2014); Knyazkov et al. (2015); Cheng et al. (2016); Zarkeshzadeh et al. (2016); Hsia et al. (2016)], and through a simulated approach [Peleg et al. (2004); Zhen et al. (2015); Sung & Lee (2016)]. Overall research mapping about locationing, allocationing and dispatching on MES can be seen in Table 1.

4. Centralized vs Decentralized in MES

Broadly speaking the whole research on MES can be classified into two characteristics system, centralize and decentralize. It is said that centralize because MES only sourced from one healthcare unit facility and will return to the same healthcare unit facility, while decentralize is the opposite where MES unit spread to some health unit point then can return to the closest health unit from patient position. Figure 3 explains the proportion of the comparison between the numbers of MES studies based on centralize and decentralize.

Overall, the publications reviewing decentralize state that decentralizing will have a very significant impact on decreasing response time so as to better enhance the survival chances of the patient. Takeda et al. In 2007 states that the MES that only collects on one database cannot reach a request that is located very far away from the position with a short time, otherwise if MES spread into several bases will greatly improve the performance of the MES itself. On the other hand, Takeda et al. notes that the negative impact of implementing decentralization MES will lead to increased operation costs and investment costs.

Table 1. Problems and methods to minimizing response time in MES

Article	Problems			Methods		
	Location	**Allocation**	**Dispatch**	**Analytical**	**Heuristic**	**Simulation**
Daskin & Stern 1981 [1]		✓		✓		
Daskin 1982 [2]	✓			✓		
Bianchi et al.1988 [3]	✓			✓		
Repede 1993 [4]	✓	✓		✓		
Burwell et al. 1992 [5]			✓	✓		
Culley et al. 1994 [6]			✓	✓		
Porteous et al. 1999 [7]			✓	✓		
Brotcorne et al 2003 [8]	✓	✓		✓		
Beraldi et al. 2004 [9]	✓			✓		
Peleg et al 2004 [10]			✓			✓
Takeda et al 2007 [11]	✓			✓		
Singer & Dosono 2008 [12]		✓		✓		
Alessandrini et al. 2011 [13]			✓	✓		
Burke et al. 2012 [14]		✓		✓		
Patel et al. 2012 [15]		✓		✓		
Iannoni et al. 2011 [16]	✓				✓	
Alanis et al. 2012 [17]	✓			✓		
Schimd 2012 [18]	✓		✓	✓		
Shariat-Mohaymany et al 2012 [19]	✓			✓		
Knight et al 2012 [20]		✓		✓		
Liu et al. 2013 [21]	✓				✓	
Naom-sawaya & El Hedli 2013 [22]	✓			✓		
Torro-Diaz rt al 2013 [23]	✓		✓	✓		
Ramirez-Nafarrate et al 2014 [24]		✓		✓		✓
Jaldell et al 2014 [25]			✓	✓		
Billhardt et al 2014 [26]		✓			✓	
Degel et al. 2014 [27]		✓		✓		
Aboueljinane et al 2014 [28]	✓					✓
Maleki et al. 2014 [29]	✓	✓		✓		
Nogueira et al 2014 [30]		✓		✓		
Ramirez-Nafarrete et al. 2014 [31]		✓				✓
Zhen et al 2014 [32]	✓	✓				✓
An et al. 2015 [33]	✓			✓		
De Souza et al. 2015 [34]			✓	✓		
Jagtenberg et al. 2015 [35]		✓			✓	
Jia et al. 2015 [36]	✓			✓		
Knyazkov at al 2015 [37]			✓	✓		
Lam et al. 2015 [38]		✓				✓
McCormack & Coates 2015 [39]	✓	✓				✓
Pinto et al 2015 [40]	✓					✓
Talarico et al 2015 [41]		✓		✓		
Zhen et al 2015 [42]	✓				✓	
Van-Barneveld et al. 2016 [43]	✓				✓	
Chen & Yu 2016 [44]	✓			✓		
Chen et al 2016 [45]	✓			✓		
Cheng et al.2016 [46]			✓	✓		
Ebrahimi & Modam 2016 [47]	✓				✓	
Hsia et al 2016 [48]			✓	✓		
Ko et al. 2016 [49]	✓				✓	
Liu et al 2016 [50]		✓			✓	
Nickel et al 2016 [51]	✓	✓		✓		
Sariyeri et al 2016 [52]	✓			✓		
Sung & Lee 2016 [53]		✓	✓			✓
Swalehe & Aktas 2016 [54]	✓					✓
Unluyurt & Tuncer 2016 [55]	✓					✓
Barneveld et al 2016 [56]	✓				✓	
Zarkeshzadeh et al 2016 [57]			✓	✓		
Dibene et al 2017 [50]	✓			✓		
Jagtenberg et al.2017 [59]			✓		✓	
Kalemsky & Shwartz 2017 [60]	✓					✓
Leknes et al 2017 [61]	✓			✓		
Salimi et al.2017 [62]			✓	✓		
Total	34	21	16	40	11	12

Knyazkov et al. (2015) states that to make optimal route selection and the hospital to be addressed becomes a complex, but when the position of the MES is set based on the distribution of its demands it will be very helpful in terms of reduction of response time. Similarly, McCormak & Coates (2015) also revealed that if MES deployment is done with consideration of its demands it can be very helpful in reducing response time. Swalehe et al. (2016) takes an approach by determining the optimal number and position of the base to meet a number of requests with the same goal of reducing response time.

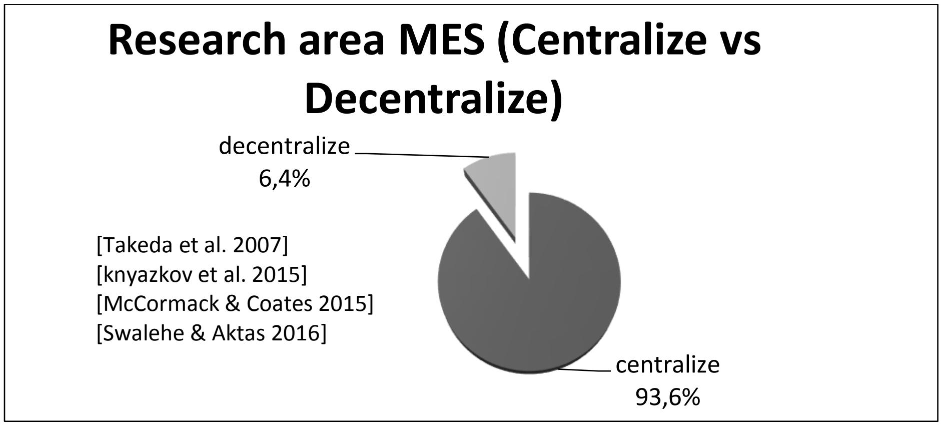

Figure 4. The Comparison Research Proportion Between Centralize and Decentralize System on MES

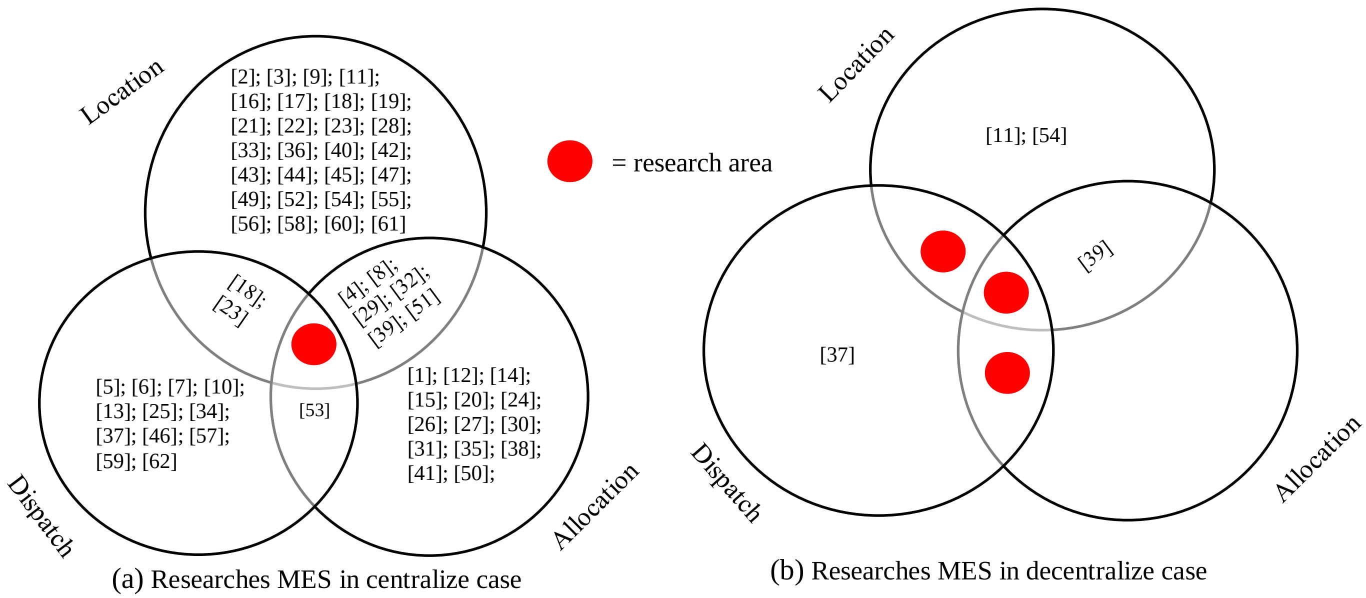

Figure 5. Research Position in MES based on Characteristic System

5. Conclusion

Figure 4 and 5 explains that there are several research areas that have not been done in the research to minimizing response time in MES especially in decentralized MES problems. Based on the overall research that has been collected, it can be concluded the next research direction is how to build a decentralize MES system with the aim to reduce the response time. By way of determining the location, the amount to be allocated to each health unit facility and the determination of pick-up route. Among them are a combination of determining the amount of allocations that optima with the dispatch, a combination of location determination and dispatch, or do a combination between the three major studies.

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Biographies

Muhammad Isnaini Hadiyul Umam is a Doctoral Student in Industrial Engineering Department at Institute Technology of Sepuluh Nopember, Surabaya, Indonesia. Earn Bachelor in Industrial Engineering from Islamic State University of Sultan Syarif Kasim, Riau, Indonesia. Master of Industrial Engineering from Institute Technology of Sepuluh Nopember, Surabaya, Indonesia. His research interests include optimization, operation research, metaheuristic, simulation, and medical emergency service.

Budi Santosa is a Professor in Industrial Engineering Department at Institute Technology of Sepuluh Nopember, Surabaya, Indonesia. He earned Bachelor in Industrial Engineering from Institut Teknologi Bandung, Bandung, Indonesia. Masters of Science and PhD from School of Industrial Engineering at Oklahoma University, USA. He has published journal and conference papers. His research interests include operation research, optimization, scheduling, metaheuristic, data mining and machine learning.

Nurhadi Siswanto is a Lecturer and Head of Industrial Engineering Department at Institute Technology of Sepuluh Nopember, Surabaya, Indonesia. He earned Bachelor in Industrial Engineering from Institute Technology of Sepuluh Nopember, Surabaya, Indonesia. Master of System Industrial Engineering from Purdue University, USA and PhD in Industrial Engineering from University of New South Wales, Australia. His research interests include operation research, large scale optimization, simulation and maritime transportation.