# An Optimization-based Approach Model for the Improvement of the Performance of Emergency Medical Service Ambulances

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## Abstract

The Emergency Medical Services Systems (EMS) plays an important role in healthcare management. The alarming number of emergency cases resulting from natural and man-made disasters is experienced by any country. In the Philippines, some organizations practice the EMS System, however, their average response time of 15 to 30 minutes falls below the international standard of 8 minutes. This paper assesses the current performance of emergency ambulance service (EAS) providers in Quezon City. Significant factors affecting their performance were identified using statistical tools. Moreover, proposed alternative solutions were evaluated in order for EAS providers attain the international standard of response time using the ArcGIS (Geographic Information System) software. The results showed that the current performance of the public and private EAS providers exceeded their standard of response and service times and they cannot reach 100% demand coverage using the 8-minute international standard of response. To address these inefficiencies, an optimal routing system was proposed by adding new stations so that performance measures are achieved. Moreover, policies and procedures were developed to attain a standardized communication system, work schedule, and dispatch method for emergency response action. The proposed solutions improved the current performance of both public and private EAS providers in Quezon City.

## **Keywords**

Response Time, Service Time, Emergency Medical Service System, Location-Allocation Tool, ArcGIS Software

## 1. Introduction

Emergencies are considered as time-sensitive cases because they need immediate attention since lives are at stake. With reference to a study by Chan in 2015, the AERO (Ambulance Emergency Response Optimization) project in Dhaka, it was stated therein that "time-sensitive medical emergencies are a major health concern, comprising over a third of all deaths in low- and middle-income." Some cases considered as time-sensitive medical emergencies include 1) cardiac arrest, 2) motor countries vehicle accidents, and 3) child and maternal health issues. The immediate response to emergencies is to bring the victims to the nearest medical facility or hospital, to administer treatment to a patient on the scene of an emergency, or simultaneous treatment and transport of patient to a medical facility. There are various vehicles which are exclusively used to immediately respond to on-call emergencies such as ambulances and other vehicles like fire trucks, police patrol cars, and rescue units, being categorized as Emergency Response Vehicles (ERV). Nowadays, ambulances have been developed with the capacity to administer immediate treatment right on site. This is what people call as the EMS (also known as Emergency Medical Services). An emergency medical service, as defined by the Department of Health, is a service that provides out-of-hospital acute care and transport to definitive care, to patients with illnesses and injuries which the patient believes constitute a medical emergency. EMS ambulances or Emergency Ambulance Service Providers, and other emergency response vehicles are thus very essential to effectively administer immediate responses (Gaston, C., 2007). Emergency Ambulance Service Providers are vital during emergencies: a) from receipt of emergency calls to arrival at the emergency scene (response time), and b) treatment and transport of patients to hospitals or other medical health facilities (service time) if needed. As reference to the study entitled, "Response Time Effectiveness: Comparison of Response Time and Survival in an Urban Emergency Medical Services System", response time is the interval between the call receipt and arrival on scene. (Blackwell and Kaufman, 2002). Using this concept, a process flowchart, as shown in Figure 1, is presented containing the EMS operations.



Figure 1. Emergency Medical Services Process Flowchart

In other countries, Boston EMS (Page et al ,2013) which is located in United States, established its own response time goals but still within the required 8-minute response time. It can be understood therefore that this DOH policy is within the international standards. The country's alarming number of emergency cases resulting from natural and man-made disasters, sicknesses, diseases, and other activities led to the approval of the Emergency Medical Services Systems Act of 2009 which is also known as the EMS Bill (Senate Bill No. 3458). However, this bill is still in the process of deliberation in the Philippine Congress and Senate to be passed as the EMS Law. The lack of standardization of the law somehow limits the prioritization of Emergency Medical Service System in the country. Fortunately, there are organizations in the Philippines which practice the EMS System just like in the other countries. In this study, it was found out that the International Standard for response time is 8 minutes. In the Philippines, the response time falls between 15 and 30 minutes.

Since ambulance action time is the most important variable in an emergency situation, previous researchers aimed to reduce it by using different techniques and strategies. In a study conducted by Henderson & Mason (2005), it was determined that the ambulance-planning problem includes operational decisions such as choice of dispatching policy and strategic decisions such as the location of ambulance stations and ambulance time operations. The study used simulation and analysis software tool 'BartSim' that was developed as a decision support tool for use within the St. John Ambulance Service in New Zealand. In this study, the results proved that a customized system such as 'BartSim' can successfully combine GIS and simulation approach to design a model for the minimization of ambulance response time performance in a cost-efficient way, it would be better to cover areas where the probability of an ambulance deployment is the highest. Hence, moving stations or relocation strategy was the best solutions in order to provide multiple coverage for high demand areas.

Moreover, in a recent study by Swalehe & Aktas (2016), system status management technique and maximal coverage location problem optimization mode was used to deploy ambulances according to ambulance demand and ensure maximum ambulance demand coverage. As a result, it was concluded that moving ambulances closer to ambulance demand areas reduces response times and dynamic ambulance deployment is by far a more effective ambulance deployment strategy than static ambulance deployment. On the other hand, Liu et al, (2016) studied the model of vehicle scheduling optimization based on chaos ant colony algorithm in emergency rescue. The study established a multi-objective optimization model, which takes minimizing variable bidirectional distance, path risk, and cost as the optimization target. As a result, researchers proposed a chaos-based improved ant colony system algorithm (Blum, C., 2005), (Wei Yi, A. K. 2006), (Goodwill, M. 2013), which can overall update the chaos disturbance to pheromone. Simulation results show that the algorithm is feasible, which can well meet the demand of vehicle scheduling optimization in emergency rescue. There are several researches regarding response optimization of ambulances in different cities in the world (Peleg, K., & Pliskin, J. S. 2004), (Pell, et al, 2001), (Chin, S., Cheah, P. et al, 2017), (Pons, P. T., Markovchick, V. J. 2002). These researchers may have used different models but they still met at a common objective which is to minimize ambulance travel time (England, N., 2016), (Lam, S., Nguyen, F., Ng, Y., et al, n.d.), (Weiss, S., Fullerton, L., Oglesbee, S., et al, 2013), (Wilde, E. T. 2013), (Zaffar, M., Rajagopalan, H. K., Saydam, C., et al, 2016), (Zarkeshzadeh, M., Zare, H., Zainabolhoda, H., et al, 2016). In fact, several studies were

already used for the improvement of Emergency Medical Service (EMS) system (Bandara, D. 2012), (Razzak, J. A., Kellemann, A. L. 2002) but most of these studies were not conducted in the Philippines.

However, a study regarding the EMS System was conducted in Davao City (Ocampo, 2016) which is known to be the only centralized Emergency Medical Service (EMS) system in the Philippines. This study used Maximum Coverage Location Problem (MCLP) model (Paulican, A., Ortega, J. 2013) to propose a new ambulance stations to reach maximum coverage of demand in Davao City. Yet, this study does not provide the process of identifying the significant factors that might affect the current EMS performance and it is limited to ambulance response time only. With this study, some of the possible minor to major medical complications can be avoided with faster ambulance service response. Here in the Philippines, various challenges and obstacles are faced by the emergency responders (Live, E., 2014), (De Borja, B., 2014). This is because the country has also admitted the infancy of the Prehospital medical service. As from the previous statements, these are some challenges or the factors that have been affecting the response actions of EAS Providers. The researchers focused on the action time (response time and service time). With the statements presented previously, the researchers intended to determine the substantial parts of EMSS affecting its emergency response actions.

## 2. Methods

#### 2.1 Data Collection

The study analyzed a total of 611 incident reports recorded from October to December 2016 of both Public (446) and Private (165) EAS Providers situated in Quezon City. The researchers analyzed the response time using different factors that affected it, and the service time with three schemes: 1) treatment of patient right on the emergency scene, 2) transport of patient to a medical facility (King, J. 2010), and 3) treatment of patients while transporting to a medical facility. Included in the data collected were the information that were used as the factors to determine the significant factors for both response time and service time. These factors were divided into two groups namely, categorical variables, and numerical variables. Categorical variables were Day of Week, Ambulance Type, Equipment Readiness, Number or Lanes, Weather Condition, Road Construction, Location Accessibility, Time of Day, and Dispatch Time. Numerical variables were Ambulance Speed, Ambulance Capacity, Ambulance Age, Number of Personnel, Years of Experience, Distance of Location, and Traffic Condition.

Different personnel, including the drivers, paramedics, medical technicians, and most specially the head of these organizations were interviewed. In order to use the ArcGIS software, different geographical data were needed (Peters, J. 2000). The researchers requested the road network, and health facilities located in Quezon City from National Mapping and Resource Information Authority (NAMRIA). The researchers conducted this study in the Quezon City area, which is one of the most densely populated areas in Metro Manila. As stated previously, the demand for ambulance services increases as the number of people in that particular area also increases. For this study, the researchers interviewed the desired respondents, who were the personnel of the EMS ambulances. In addition, request letters were given before using these instruments.

Table 1 shows the current demand calls coverage for every drive time (min) of both Public and Private EAS Providers in Quezon City. For a 10-minute drive time, the Public can reach about 188 demand calls while the Private can reach 87 demand calls. As a total, both can reach 275 demand calls, about 45% of 611 total demand calls. The interpretation for the 10 minute-drive time is the same for the 15 to 40 minute-drive times listed in the table.

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Table 1. Sample Data for the Analyses of Response Times of Public (above) and Private EAS Provider (below)

Figure 2 shows the generated simulation of the current demand calls coverage of both Public and Private EAS Providers using the 40 minute-drive time. This means that in order to meet all the demand calls, both Public and Private EAS Provider travels at least 40 minutes to reach the farther incident locations of the demand calls. This simulation helped the researchers identify what is the current response time of EAS Providers using 20 kph speed, as stated by the interviewees. The simulations were done with the help of ArcGIS software and using the data collected from NAMRIA



Figure 2. Simulation of EAS Providers' Demand Calls Coverage using 40 minute-drive time.

#### 2.2 Statistical Analyses

For the statistical analyses, the Normality Test, Correlation Coefficient, Analysis of Variance, and Multiple Linear Regression Model were used to determine the significant factors for EAS Providers' response time and service time.

## 3. Results

Table 2 shows the summarized results of the statistical tools used in this study. Distance of Location, Traffic Condition, Time of Day, Ambulance Speed, and Dispatch Time were the factors that resulted to be significant factors for response time. However, Day of Week, Equipment Readiness, and Weather Condition also appeared only in Analysis of Variance. These factors were also considered as factors that also affect the response time, and were used to generate alternatives to help solve the problem.

Factors	Public EAS Provider			Private EAS Provider		
ractors	Correlation	ANOVA	Linear Regression	Correlation	ANOVA	Linear Regression
Dispatch Time	NS	S	S	NS	S	S
Ambulance Speed	NS	S	S	NS	S	S
Ambulance Age	NS	NS	NS	NS	NS	NS
Ambulance Type	NS	NS	NS	NS	NS	NS
Ambulance Capacity	NS	NS	NS	NS	NS	NS
Weather Condition	NS	NS	S	NS	NS	NS
<b>Road Construction</b>	NS	NS	NS	NS	NS	NS
Traffic Condition	S	S	S	S	S	S
Number of Lanes	NS	NS	NS	NS	NS	NS
Location Accessibility	NS	NS	NS	NS	NS	NS
Distance of Location	S	S	S	S	S	S
Equipment Readiness	NS	S	NS	NS	NS	NS
Number of Personnel	NS	NS	NS	NS	NS	NS
Years of Experience	NS	NS	NS	NS	NS	NS
Time of Day	NS	S	S	NS	S	S
Day of Week	NS	S	NS	NS	S	NS
LEGEND: NS – Not Significa	ant; S – Significant	·		·	•	

Table 2. Summarized Results using the three (3) Statistical Tools for Response Time

Table 3 shows that Ambulance Speed, Distance of Location, Traffic Condition, and Time of Day are the factors that were significant to service time. These factors were considered when the researchers proposed solutions for the improvement of the performance of Emergency Medical Service Ambulances in Quezon City.

E	Public EAS Provider			Private EAS Provider			
Factors	Correlation	ANOVA	Linear Regression	Correlation	ANOVA	Linear Regression	
Ambulance Speed	S	S	S	S	S	S	
Ambulance Age	NS	NS	NS	NS	NS	NS	
Ambulance Type	NS	NS	NS	NS	NS	NS	
Ambulance Capacity	NS	NS	NS	NS	NS	NS	
Weather Condition	NS	NS	NS	NS	NS	NS	
Road Construction	NS	NS	NS	NS	NS	NS	
Traffic Condition	S	S	S	S	S	S	
Number of Lanes	NS	NS	NS	NS	NS	NS	
Location Accessibility	NS	NS	NS	NS	NS	NS	
Distance of Location	S	S	S	S	S	S	
Number of Personnel	NS	NS	NS	NS	NS	NS	
Years of Experience	NS	NS	NS	NS	NS	NS	
Time of Day	NS	S	S	NS	NS	S	
Day of Week	NS	NS	NS	NS	NS	NS	
LEGEND: NS – Not Significant; S – Significant							

Table 3. Summarized Results using the three (3) Statistical Tools for Service Time

The researchers generated two alternatives for the improvement of the performance of Emergency Medical Service Ambulances in Quezon City. The simulations of these alternatives were done in ArcGIS software using the data collected from NAMRIA. Considering the significant factors for the improvement, ambulance speed, and distance of location were the factors used in the first alternative which is increasing the current 20 kph speed. Table 4 shows the significant increase in demand calls coverage of both EAS Providers as the speed increases. For the second alternative, the researchers proposed additional ambulance stations that would be near the demand call locations.

2 existing stations	Ambulance Speed	Percent	
+	37–40 kph	Coverage	
3 stations	583	95.4%	
4 stations	606	99.2%	
5 stations	609	99.7%	
6 stations or more	611	100.0%	

Table 4. Alternative 1: Increasing the Ambulance Speed

Table 5 shows the number of stations to be added in Quezon City using a 37-40 kph speed, since this speed is the minimum required speed to reach a total of 100% demand call coverage.

Speed	EAS Provider		Total	Demont Community
(kph)	Public	Private	Total	rercent Coverage
20	146	68	214	35%
30	229	101	330	54%
37-40	293	110	403	66%
60	414	122	536	88%

Table 5. Alternative 2: Proposing Additional Ambulance Stations

Table 5 shows the number of stations to be added in Quezon City using a 37-40 kph speed, since this speed is the minimum required speed to reach a total of 100% demand call coverage.

## 4. Discussions

Based on the number of significant factors, and the statistical analyses done for comparing the two EAS Providers, the researchers chose the Public EAS Provider as the standard for this study. The Public EAS Provider will be useful for this study since according to them, they will be dispatching a total of 150 ambulances in within Quezon City. The Public EAS Provider is also the most-called EAS Provider in Quezon City since it does not require payments from the victims. It is a free-service help provider for any emergency call they will receive. With all of these details altogether, it justifies the selection of the Public EAS Provider as the object of this study.

Table 6. Proposed Locations for the Additional Ambulance Stations

Incident Location		Drive Time (I	min)	Hospital			
4			Philippine Children's Medical Center (4.t)				
		4	Veterans Memorial Medical Center (4.u)				
		4	Providence Hospital (4.v)				
Agham R	oad		Metro North Medical Center and Hospital (4.w)				
	1	6	Quezon City General Hospital (4.x)				
STATION		LOC <sup>8</sup> ATION NAME		No <b>PloSTRUG</b> TEar	the Inoland FREE For	DEMAND	
NUMBER		10		Sta CTA BET Ge	neral Hospitan (4.y)	COVERAGE	
1		Private EAS Provider		4	Free	43	
2		Public EAS Provider		4	Free	119	
3		Capitol Medical Center	•	4	Free	103	
4		Commonwealth Hospital and Med	lical Center	5	Free	42	
5	Fairview General Hospital			2	Prone	57	
6	General Miguel Malvar Hospital			3	Free	75	
7	Metro North Medical Center and Hospital			1	Free	49	
8	Pacific Global Medical Center			6	Free	36	
9	Quezon City General Hospital			1	Prone	47	
10	Quirino Memorial Hospital			3	Free	40	

Table 7. Routing analysis (additional part for chosen alternative)

From the two alternatives presented in the results and the evaluation using the force field analysis, the researchers chose the second alternative. It would be costly but the additional stations that would be closer to demand locations are ideal for effective response of EAS Providers in Quezon City. All of the significant factors were also considered in proposing locations for additional ambulance stations. Table 6 shows the number of stations to be added in Quezon City. The ambulance stations would be situated near the hospital indicated in the table. This is because most of the patients responded by the EAS Providers were brought to hospitals, therefore with stations being near hospitals mean faster emergency response for patients. Every district in Quezon City has its own at least one ambulance station. The area of the location is also considered if it is free from any calamities. As much as possible, the flood prone areas were only minimized since these are uncontrollable. Table 7 shows the proposed routes for the improvement of the service time of the EAS Providers. It begins from the incident location to the nearest hospital from the area. Drive time (min) are also indicated. For example, Agham road is 4 minutes away from Philippine Children's Medical center, and so on. The proposed solutions for other factors such as the communication system, dispatching method, and working schedules, the researchers generated respective policies and procedures for each.

Figure 4 shows the station coverage map of the selected stations within Quezon City. The colors of the circles on the map indicate different kilometer radii. Dark green is for 2-km radius, yellow green is for 3-km radius, yellow is for 4-km radius, and red is 5-km radius. It can be seen that the 3-km radius, 4-km radius cover the whole part of Quezon City.



Figure 4. Coverage map in 4 different kilometer radii

## 4 Conclusion

In this study, the current performance of the Public and Private Emergency Ambulance Services (EAS) Providers in Quezon City were assessed. By using statistical analysis, factors for response time such as Distance of Location, Traffic Condition, Time of Day, Ambulance Speed, Dispatch Time, Day of Week, Equipment Readiness and Weather Condition, and factors for service time such as Ambulance Speed, Distance of Location, Traffic Condition, and Time of day were found to be significant factors. Using these factors as bases, the researchers proposed two alternatives to improve the current performance of the EAS providers. Alternative 1 aims to increase ambulance speed to at least 40 kph. In this way, the actual 35% demand coverage within an 8-minute response criterion will increase to 66% (or higher) demand coverage. A routing analysis was used to help improve the ambulance speed to at least 40 kph. While Alternative 2 was proposed to fully cover all the demand areas in Quezon City. In Alternative 2, a minimum of 6 additional ambulance stations is needed to achieve 100% demand coverage. However, some of the stations are placed in the flooded areas, this lead to an optimal solution which is an additional 8 ambulance stations. Also, a routing analysis was used to locate the nearest hospitals in a certain demand areas and proposed ambulance station. Also, the

researchers proposed a Standard Policies and Procedures to gain an organized dispatch process, communication system, and work schedule. Comparing the two alternatives, Alternative 1 was cost-effective compared to Alternative 2. Although, Alternative 2 has a higher chance of reaching 100% demand coverage in Quezon City with an 8-minute response criterion. Alternative 2 will greatly improve the performance of EAS providers

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