Palestinian Medical and Pharmaceutical Journal

Volume 9 | Issue 3 Article 7

8-30-2024

Heliport Emergency Medical Services (HEMS) in Unstable Geopolitical Region; Palestine – Mobility Perspective

Anas Dirawi
1Master in Transportation and Highway Engineering, An-Najah National University, Nablus, Palestine

Khaled A. Al-Sahili
Civil and Architectural Engineering Department, An-Najah National University, Nablus, Palestine

Recommended Citation

Dirawi, Anas and Al-Sahili, Khaled A. (2024) "Heliport Emergency Medical Services (HEMS) in Unstable Geopolitical Region; Palestine – Mobility Perspective," *Palestinian Medical and Pharmaceutical Journal*: Vol. 9 : Iss. 3 , Article 7.
Available at: https://doi.org/10.59049/2790-0231.1229

Heliport Emergency Medical Services (HEMS) in Unstable Geopolitical Region; Palestine – Mobility Perspective

Abstract

Currently, emergency medical services (EMS) in Palestine are solely provided through ground transportation. This study aims to explore the potential for implementing the most effective Heliport Emergency Medical Services (HEMS) system in Palestine and evaluate its expected performance. The current average demand for ground EMS stands at 83,000 trips per year, with many rural communities experiencing response times exceeding 25 minutes, which is considered high. The study investigates the most suitable locations for HEMS based on the condition of existing hospitals and aims to achieve the highest population coverage within the shortest possible response time. To determine these locations, the Maximal Covering Location Problem technique within ArcMap GIS software was utilized. It was estimated that the demand for HEMS in the West Bank is approximately 0.23 patients per hour, totaling 2,000 patients per year. Various scenarios regarding HEMS coverage rates and response times were explored, ultimately identifying the most appropriate scenario as having two helipads with one helicopter, ensuring a maximum response time of 25 minutes to achieve a 100% coverage rate. Queuing theory analysis demonstrated that this scenario would yield satisfactory performance levels, ensuring that patients are transported to the nearest hospital within a reasonable timeframe. Additionally, the benefit-cost analysis of the proposed HEMS system indicated a worthwhile expected average cost per saved life. Furthermore, a plan framework for implementing HEMS in the WB is proposed.

Keywords

HEMS, Response Time, Medical Emergency, Optimum Location, Road Crash

Cover Page Footnote

We would like to send our gratitude and appreciation for the respectful reviewers for their valuable comments. We accept all the comments and reacted positively to all of them. With this revised version, we believe that the manuscript has improved and aligns more with the scope and guidelines of your journal.

Palestinian Medical and Pharmaceutical Journal (PMPJ). 2024; 9(3): 361-378

Heliport Emergency Medical Services (HEMS) in Unstable Geopolitical Region; Palestine – Mobility Perspective

Anas Dirawi[1] *& Khaled A. Al-Sahili*[2,*]

[1]Master in Transportation and Highway Engineering, An-Najah National University, Nablus, Palestine. [2] Civil and Architectural Engineering Department, An-Najah National University, Nablus, Palestine.

*Corresponding author: alsahili@najah.edu

Received: (18/11/2023), Accepted: (5/2/2024), Published: (1/9/2024)

ABSTRACT

Currently, emergency medical services (EMS) in Palestine are solely provided through ground transportation. This study aims to explore the potential for implementing the most effective Heliport Emergency Medical Services (HEMS) system in Palestine and evaluate its expected performance. The current average demand for ground EMS stands at 83,000 trips per year, with many rural communities experiencing response times exceeding 25 minutes, which is considered high. The study investigates the most suitable locations for HEMS based on the condition of existing hospitals and aims to achieve the highest population coverage within the shortest possible response time. To determine these locations, the Maximal Covering Location Problem technique within ArcMap GIS software was utilized. It was estimated that the demand for HEMS in the West Bank is approximately 0.23 patients per hour, totaling 2,000 patients per year. Various scenarios regarding HEMS coverage rates and response times were explored, ultimately identifying the most appropriate scenario as having two helipads with one helicopter, ensuring a maximum response time of 25 minutes to achieve a 100% coverage rate. Queuing theory analysis demonstrated that this scenario would yield satisfactory performance levels, ensuring that patients are transported to the nearest hospital within a reasonable timeframe. Additionally, the benefit-cost analysis of the proposed HEMS system indicated a worthwhile expected average cost per saved life. Furthermore, a plan framework for implementing HEMS in the WB is proposed.

Keywords: HEMS, Response Time, Medical Emergency, Optimum Location, Road Crash.

INTRODUCTION

In general, when a person is involved in a road crash, the injured person is taken by an ambulance to the nearest hospital for treatment. However, what happens if the road is blocked? What if the casualty is in a rough terrain area with no roads available? What if the hospital is so far away that a critically injured patient may die before making it to the hospital to receive life-saving treatment? Putting this in the context of the West Bank (WB), Palestine, where the mobility is subject to geopolitical constraints, answering these questions becomes the most significant and critical concern in the patient’s life.

The geopolitical constraints, as outlined in the Taba Agreement of 1995 [43], play a significant role in shaping the region's healthcare infrastructure. The division of the West Bank into areas A, B, and C, each under different levels of control, impacts the development of fast and secure transportation connections between urban and rural areas [16]. In addition, the topographical nature of the WB, which includes mountain range, poses another major challenge for Palestinians’ mobility, including ambulances transporting patients to hospitals. These challenges can result in disparities in access to emergency healthcare services.

In Palestine, emergency medical services rely solely on ground transportation. The Palestinian Red Crescent Society's (PRCS) ground EMS responds to emergency calls through the central room for reception and distribution of missions. However, in cases of high workload or a shortage of available vehicles, private ambulances and military services are often utilized. Public hospital ambulances primarily handle patient transporting between the hospitals in domestic or abroad missions [9].

For example, in 2022, road crashes in the WB resulted in 11,875 injuries, including 201 serious injuries and 144 fatalities [28]. It was estimated that 107 citizens died due to road crashes before the arrival of an ambulance [23]. Additionally, there were 1,775 work-related injuries, out of which 14 died before ambulance arrival. Cardiovascular diseases emerged as the leading cause of death among Palestinians, accounting for 30% of recorded deaths, with a significant proportion occurring due to delayed treatment.

Therefore, the Palestinian medical services should consider adopting specialized methods to assist the ambulance services and harness new technologies for the benefit of the Palestinian society. Utilizing helicopters in the evacuation and transport of the injured individuals is common and practiced in many countries worldwide. Helicopters provide significant health support in human crisis areas, rural regions, and other inaccessible terrains due to their great versatility. These services are commonly known as *Heliport Emergency Medical Services (HEMS)*.

The provision of HEMS for transfers between hospitals is potentially cost-effective offering system-wide benefits on an annual basis. It reduces the number of ground ambulances needed to transport patients over long distances and enlarges the hospital's health security footprint (Hennely et al., 2023). Other advantages include enhanced comfort for both the patient and the medical crew during transportation, along with the potential to bypass traffic congestion. Generally, HEMS are deemed more secure than land transportation due to their capability to safely land in various locations and proximity to patients. Their ability for rapid response and improved visibility owing to higher altitudes enables HEMS to reach the site in the shortest possible time [12].

Establishing HEMS in the WB requires addressing numerous region-specific challenges, foremost among them being the mobility constraints and a shortage of skilled human resources. Additionally, issues such as the construction and operational cost of the project, urban overcrowding, and the presence of tall buildings around hospitals in most Palestinian cities pose significant challenges. Moreover, the lack of adequate space for helicopter landing points (helipad) and the absence of maintenance centers for civilian helicopters in the WB are major obstacles [5].

Consequently, this paper aims to examine the implementation of HEMS (Heliport Emergency Medical Services) within the West Bank from the standpoint of mobility. The study seeks to evaluate existing infrastructure of hospitals, ambulances, and emergency services. It also aims to identify optimal locations for deploying HEMS to achieve maximum population coverage while maintaining acceptable response times. Furthermore, the utilization of queuing theory to analyze expected performance levels and determine the optimal number of HEMS stations, along with a cost-effectiveness analysis, represents a novel approach in the field of EMS.

CURRENT STATUS OF HEALTHCARE SYSTEM IN PALESTINE

Regularly published reports by the Palestinian Ministry of Health [23, 25], the Palestinian Red Crescent Society [26], the Palestinian Central Bureau of Statistics [27], and international organization such as the World Health Organization [46] and the [45] consistently provide information about the healthcare status in Palestine. These reports consistently highlight that, alongside geopolitical constraints, the Palestinian healthcare system encounters significant challenges due to limited resources, including shortages of supplies, equipment, and healthcare professionals. Financial constraints frequently impact the system's capacity to provide services, posing substantial obstacles to delivering high-quality healthcare across the Palestinian territories.

The geopolitical status (division into areas A, B, and C) significantly impacts healthcare access, resource distribution, and the overall functioning of the healthcare system in Palestine. Furthermore, it restricts access to medical facilities due to imposed geographical barriers, checkpoints, and travel restrictions by the Israeli occupation forces. These limitations particularly affect those living in remote areas or regions affected by political and military conflicts.

While Palestine hosts various medical facilities (hospitals, clinics, and healthcare centers), the quality and capacity of infrastructure vary across regions. Typically, urban areas are better-equipped with medical facilities compared to rural or marginalized communities. Consequently, access to specialized healthcare services and advanced medical treatments may be limited, particularly in rural and remote areas [25].

The shortage of skilled healthcare professionals and specialists (doctors, nurses, and technicians) also affects the quality-of-care places an increased workload on available staff [45]. Moreover, fiscal constraints and the restrictions imposed by the Israeli occupation create obstacles to accessing healthcare, adversely affecting the population, especially in Gaza. This situation persisted even before the conflict that occurred in Gaza in October 2023.

Substantial physical and administrative constraints severely restrict timely access to external medical referrals for treating severe illnesses, especially for conditions lacking effective treatments in public hospitals within the West Bank (WB) and Gaza Strip (GS). The stated [45]: "the Israeli occupation, the fragmentation of the Palestinian territories, and the broader macro-fiscal context described have significantly impacted the Palestinian healthcare system's ability to deliver these services in public hospitals. The situation is particularly critical in Gaza, which suffers from a more limited health system capacity and where patients struggle to get needed medical exit permit applications on a timely basis."

Despite these challenges, the healthcare system demonstrates resilience and innovation, and continues to provide quality services within the limitations of its available capacity. Local healthcare providers often find creative solutions to overcome limitations, utilize technology, and improve healthcare delivery. Moreover, the healthcare system in Palestine receives support from various international aid organizations and NGOs. These entities play a pivotal role in providing medical aid, training healthcare professionals, and improving infrastructure [23, 26].

There are four main providers for the healthcare in Palestine; these are the government health sector (Ministry of Health and Military Medical Services), UNRWA, NGOs, and private sector. These entities are distributed in the WB and Gaza Strip (GS). According to the Ministry of Health's statistics, there are 54 hospitals in the WB distributed in 11 governorates [23]. Additionally, there are 12 governmental hospitals in GS [24], distributed in 5 governorates, in addition to other non-governmental services.

The number of primary healthcare centers witnessed an increase from 706 centers in 2010 to a total of 765 centers in 2021 [27]. These are distributed as 64% affiliated with the MOH, followed by NGOs by 25%, UNRWA by 9%, and Military Medical Services by 2%. The number of hospitals also increased from 76 in 2010, with 51 in the WB and 25 in GS, to 89 hospitals in 2021 (54 hospitals in the WB and 35 in GS). In 2021, the total number of hospital beds was 7,296 beds; 4,270 in the WB and 3,026 in GS [27].

Additionally, according to the PCBS statistics [27, 29], the number of physicians registered in the Medical Association increased from 6,764 physicians in 2010 to 14,054 in 2021(57% in the WB and 43% in GS). The number of nurses also increased from 10,520 nurses in 2010 to 22,478 nurses in 2021 (51% in the WB and 49% in GS).

STATUS OF HEMS SERVICES IN NEIGHBORING REGIONS

Addressing the aforementioned challenges is of paramount concern in the lives of individuals in Palestine. It requires a multifaceted approach involving cooperation between the Palestinians and the Israeli occupation, investment in infrastructure and healthcare resources, and the development of contingency plans for situations where traditional road access is limited or unavailable. Additionally, considering innovative solutions such as air ambulance services and telemedicine becomes imperative to improve emergency healthcare delivery in this complex and politically sensitive region, particularly since such services are available in adjacent regions.

As an example, in Jordan, there is a general rule stipulating that hospitals with 100 beds or more should have their own helipads. This rule applies to new hospitals and those that have enough space to accommodate a helipad [41]. Currently, there are 122 public (government, military, and university) and private hospitals in Jordan [30], out of which 64 hospitals have more than 100 beds. Regarding the existing HEMS, there are 35 helipads, six of them are in Amman and the remaining are distributed across the country, with five located in border area [42].

The Jordan Air Ambulance Center (JAAC) was established in 2015 as an independent government organization, providing specialized rescue services, patient transfer, and air ambulance operations. Its primary focus lies in transporting patients from remote areas to hospitals and medical centers. In 2016, JAAC conducted approximately 250 medical evacuation trips, with expectations indicating an increase to 400 trips in the near future [42].

In Israel, the general regulation specifies that any 65-bed hospital offering emergency care, general surgery, general medicine, general orthopedics, pediatrics, maternity services, neurosurgery, plastic surgery, burns, cardiothoracic surgery, acute stroke, acute cardiology, or facial services must have a helipad. Initially, the air ambulance service was provided by Israeli Air Force helicopters. However, in 2008, Magen David Adom (MDA) introduced civil HEMS in collaboration with a private company. Non-emergency and repatriation air ambulance service is normally provided by a variety of private charter carriers [44].

There are 17 medical helipads in Israel, in addition to an airport designated for jet medical services aircraft [11]. The emergency medical services are supported by 76 helicopters operated by approximately 30 experienced MDA flight paramedics, with an average response time of 9 minutes. Moreover, the first responders from United Hatzalah have a national average response time of three minutes, and particularly in large metropolitan areas, their response time is less than 90 seconds [44].

LITERATURE REVIEW

There is a wealth of literature available globally on this subject, and this paper presents a selection of pertinent studies from various countries.

The transport of a patient means the physical movement of a patient from one facility to another or from the scene of an accident to a treating facility, irrespective of the mode of transport. There are three types of patient transfers: primary, secondary, and tertiary. Ideally, for the primary response mode, the crew should consist of two paramedics, one respiratory therapist or transport physician, and one critical care nurse [10].

Studies on EMS stations began to emerge widely in the 1970s, with researchers primarily focusing on the establishment of EMS stations, particularly the ambulance location problem [3]. For any EMS system, it is important to locate vehicles, bases, and heliports in such a way that incidents can be served as quickly as possible. Various mathematical models have been developed to allocate these resources effectively, aiming to maximize the percentage of demand served within a pre-specified target response system. One such prominent model is the Maximal Covering Location Problem (MCLP) [33], which aims to maximize the population covered within a desired service distance by allocating a fixed number of facilities. This model also enables the determination of the least number of bases required to ensure specific population coverage. The MCLP model found a wide range of applications, including the determination of the best configuration of a network of medical drones to minimize travel time to victims of out-of-hospital cardiac arrest [32].

Presented a model that could simultaneously determine optimum locations of trauma centers and helicopter stations [4]. They proposed a heuristic algorithm to solve their model and applied it to various regions across the USA. Similarly, [37] developed an approach to assign an additional helicopter station to maximize the demand coverage of regions lacking such stations. Their analysis utilized five years of critical care data from British Columbia's trauma registry, alongside population statistics and travel time data.

Effective HEMS operations will eventually rely on efficient operating procedures, tasking protocols, clinical governance, and auditing of HEMS actions. According to [6], 23 eligible studies showed that. Additionally, morbidity and mortality can be significantly reduced when pre-hospital care is rendered quickly and appropriate transfer is provided to a tertiary facility by HEMS. Likewise, the first hour (called *Golden Hour*) after injury will largely determine the chances of survival for a critically-injured person. This means that an injured patient has 60 minutes from the time of injury to receive definitive care; beyond which morbidity and mortality rates increase significantly [35]. The term "Golden Hour" is commonly used to characterize the urgent need for the trauma patient care. It implies that morbidity and mortality rates are influenced by the initiation of care within the first hour after the injury occurs.

One approach to minimize time delays in treating and transporting individuals injured in remote areas involves increasing the scope of early activation/auto launch dispatch services. Early activation/auto launch protocols are innovative programs where an air response is triggered based on information collected from computer systems in an effort to reduce the time from occurrence of severe injuries to the arrival at medical care center. In the context of HEMS, maintaining an optimal speed is paramount, keeping the noise, pressure, and vibration to the minimum level at 180 - 200 km/hr with preflight preparation time of 10 minutes. Furthermore, the top speed of HEMS is 300 km/hr [34]. In addition, preflight preparation time will decrease to half within 5 years of HEMS employment, as well as the procedural time and error rate.

Suggested two distinct methodologies to estimate the number of trips generated by the HEMS [21]; the first involved the use of trip generation rates estimated from the current ground ambulance system, and the second would consider the use of trip generation rates from other countries, which already have HEMS system.

A feasibility study on HEMS showed that a single helicopter dedicated for inter-hospital transfer HEMS would involve up to €11 million in capital investment and would incur annual operating costs of €4 million. Out of this additional annual operating cost, an estimated two-thirds to three-quarters would be directly associated with helicopter operations. The remainder is associated with medical staff salaries and asset maintenance [13].

Several modes were used to connect the ground EMS with HEMS based on coverage, case type, location, demand, built-up area, response time, and number of existing helipads and hospitals. These modes are (1) transferring patients to the hospital by ground EMS, (2) transferring patients to the helipad by ground EMS, then by HEMS to the hospital, (3) transferring patients by ground EMS to the rendezvous point, then by HEMS to the hospital, where the helipad is away from the hospital, and (4) transferring patients by ground EMS to the rendezvous point, then by HEMS to the hospital, where the helipad is near or on the hospital rooftop [8].

Some of the challenges facing the HEMS in Iran were addressed by [38] based on interviews involving 27 experienced persons. The main identified challenges were infrastructure deficiencies, safety of involved persons (staff, patients, and public), inappropriate resource management, and staff's competencies.

Estimated the cost of HEMS by differentiating between fixed, jump-fixed [36], variable, and maintenance costs for several scenarios. The study estimated an annual cost of 1.7 million € for basic scenario (12 hours of operations per day), with 765 € per primary mission. The study concluded that with a 70 € per minute of engine run-time, HEMS can be operated at a profit.

Hospital helipad design addresses elements of helicopter operations during emergencies (ambulance, staff, and equipment). Several resources cover this area, with the International Civil Aviation Organization Helipad Manual [17] being a prominent reference.

In summary, the ground EMS deals with all types of patient transfers; helicopters are often used in primary and secondary patient transfers. The MCLP allocates helipads to serve a certain percentage of demand within a pre-specified target response time and allows for the determination of the least number of helipads needed to guarantee certain population coverage. Various types of software can be used to solve the MCLP; however, the majority of these applications were used for areas that are well-established and have stable geopolitical conditions. On the other hand, using this new system in the West Bank, which has unique geopolitical and mobility constraints, needs to be progressively established to technically and operationally solve these issues.

This study explores the potential for achieving the most effective HEMS in the WB of Palestine, and evaluates its expected performance level. Furthermore, this research will employ a new tool to evaluate the performance level and; therefore, to optimize the number and location of HEMS based on the queueing theory approach and MCLP to achieve the target level of service with the minimum number of helipads and helicopters.

METHODOLOGY

Overall, this study looks at the WB as an example of how a HEMS model could be built to assist the ambulance services and harness new technologies to serve the local society. The methodology to achieving this is presented here.

Identifying the current data and demand. The demand for ground EMS was obtained from competent authorities through published reports and interviews. These include the Palestinian Red Crescent Society (PRCS), Ministry of Health (MOH), Palestinian Health Work Committees (PHWC), Palestinian Central Bureau of Statistics (PCBS), Ministry of Transport (MOT), and Ministry of Local Government (MOLG).

Heliport location-allocation. In order to select the most appropriate location for HEMS, three considerations have been determined; these are:

– The maximum percentage of population to be covered.

– The minimum number of eligible HEMS facilities to be set.

– Acceptable response time for the service.

In this case, one of the most suitable formulas to find the minimum number of facilities and locations that achieves the best possible population coverage within an acceptable response time is the MCLP [33]. The formula and the objective function are presented below:

$$Maximize\ Z = \sum_{i=1}^{I} A_i B_i \quad (1)$$

Subject to

$$B_i \leq \sum_{j \in N_i} Xj \quad i \in I \quad (2)$$

$$\sum_{j \in J}^{J} X_j = N \quad (3)$$

Where,

i, I: the index and set of population nodes.

j, J: the index and set of the facility location.

Ai: population in the node *i*.

dij: the shortest distance (or time) from the population node *i* to the facility *j*

N: number of facilities to be located.

S: coverage distance (or time) between population nodes and the facility.

Ni: $\{j | d_{ij} \leq S\}$ set of potential facilities that can cover the population *i*.

Xj: $\{0; 1\}$ a binary variable, which equals 1 if the facility is placed at node *j*; 0 otherwise.

Bi: $\{0; 1\}$ a binary variable, which equals 1 if the population node covered by one or more facilities within a distance of S; 0 otherwise.

There are several software programs that apply such formulas. Specifically, ArcMap GIS was used to build a sequence to find the optimum locations. Furthermore, the selection of these locations was based on factors such as population, population density, elevation, coverage, and presence of available hospitals, as illustrated in Figure 1.

Expected HEMS system output. Development of a special logistic system connecting HEMS and ground EMS has been done using HEMS systems currently deployed in many countries. The Babcock Scandinavian Air Ambulance and Royal Flying Doctor Services were used [7]. Furthermore, the expected HEMS system outputs in terms of mortality rate, travel time, preparation time, speed, crew, and operational cost were obtained from those systems. These were used to estimate the costs and benefits of establishing the HEMS in the WB.

DATA COLLECTION AND CURRENT DEMAND

Indeed, it is logical to expect that for a HEMS system to be viable and effective, there should be a sufficient demand for the service. The establishment and operation of a HEMS program involve significant costs, including the procurement and maintenance of helicopters, training of medical and flight personnel, infrastructure for helipads, and ongoing operational expenses. The collected data in this study, according to their sources, were:

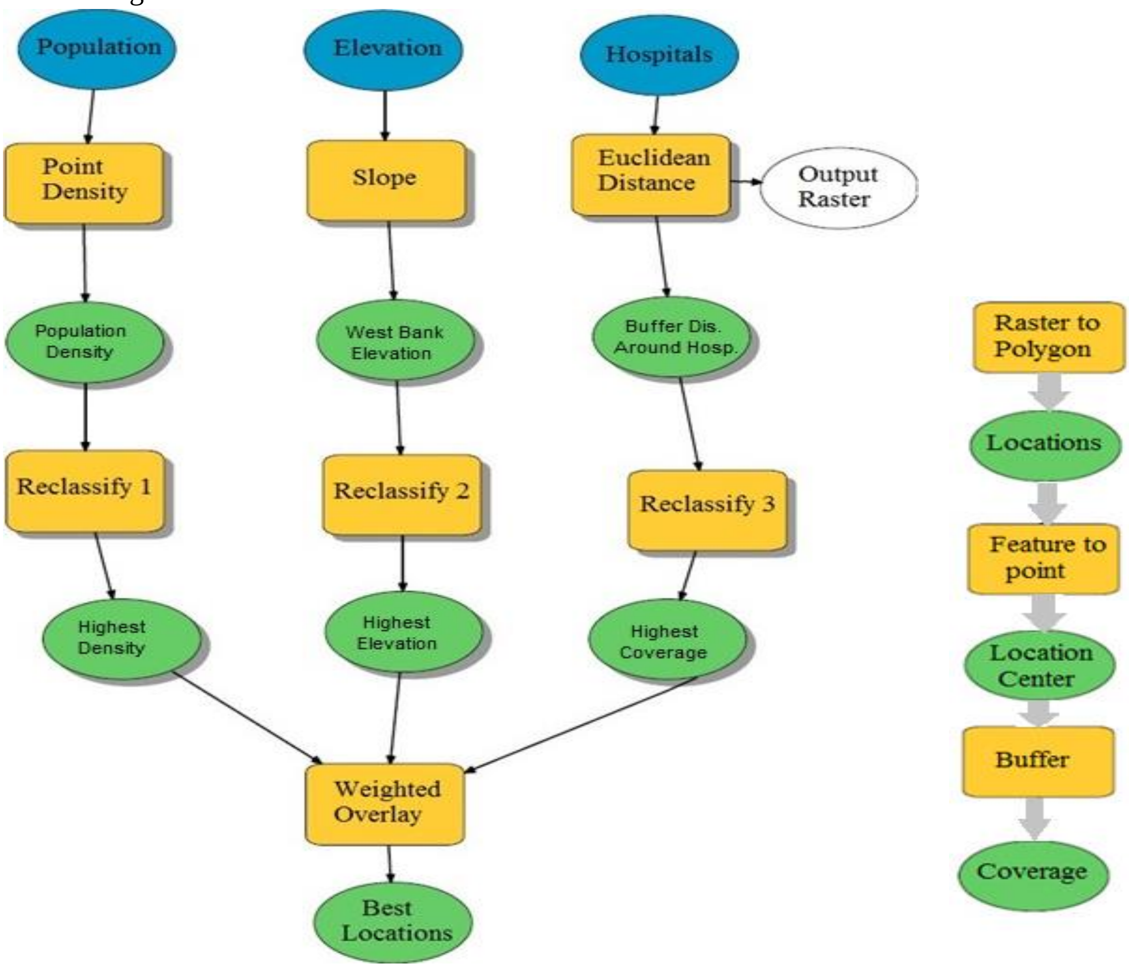

Figure (1): ArcMap GIS Best Location Model and Buffer Sequence.

Ambulance data from the PHWC, MOH, and PRCS. These include general information about the conditions of Palestinian hospitals especially the ambulance sector, number of vehicles, number of trips, average distance traveled, case type, cost, crew, geographical location, mortality rate, average trip time, and response time. The medical data were obtained from two basic log forms: Emergency Case Form (ECF) and Ambulance Log Sheet (ALS). A total of 10,718 cases were recorded by the PRCS in 2021 [26]. The results are presented in Table 1. Tables 2 and 3 present the response time and the severity of the injury of the transferred patients.

Table (1): Summary of PRCS Ambulances Log Sheets (PRCS, 2022).

Item	Avg. (per veh. per month)	Notes
Distance	1031 Km	--
Fuel Consumption	132 Liter	--
Km/l	7.81	--
Number of Cases: Transferred	27	--
Number of cases: Didn’t Transfer	8	Treatment was provided on-site
Hoax	Neglected	--
Staff	2	Driver and officer per shift
Item	**Average Cost ($) (per vehicle per month)**	**Notes**
Fuel	181	$1.37 per liter (Diesel)
Salaries	8,000	8 employees / veh / 24 hr with avg. of $1000 each
Maintenance	178	--
Medical Supplies	1,644	Medical material used in EMS trips
Total Cost	**10,003**	--

Table (2): Severity of the Injuries (PRCS, 2022).

Class	Percentage %
Mild	30
Moderate	40
Severe	15
Critical	15

– Statistical data from the PCBS and MOT. These include the population of the WB, which is approximately 3 million inhabitants with an annual growth rate of 2.5% [29], and the number of ambulances in the WB, which was 196 [20].

– Technical and geographical data from the MOLG. These were GIS shape-files of the WB area, governorates’ boundaries, population distribution, population density, roads, hospitals, political areas boundaries, and contour lines.

Table (3): EMS Summary of Response Time in the West Bank.

No. of Licensed Ambulances[2]	Avg. [I] Response Time (min)	Response time (min)					Case Location (Governorate)
		Total	>25	16-25	8-15	1-7	
		Number of Cases					
4	12.2	3782	100	626	766	2290	Hebron
2	14.9	816	46	178	278	314	Tulkarm
8	10.5	1740	41	145	334	1220	Nablus
0	12.6	480	18	85	93	284	Tubas
3	10.7	530	12	99	98	199	Qalqilya & Salfit
1	11.5	781	16	95	181	489	Jericho
1	13.5	367	10	76	98	183	Jenin
2	11.1	1127	14	167	174	772	Bethlehem
175	13.3	352	8	60	120	164	Ramallah
-	7.4	865	0	2	45	818	Jerusalem
196	**11.7**	**10718**	**265**	**1533**	**2187**	**6733**	**Total**

[I] Weighted average.
[2] Source: [20]

ANALYSIS AND DISCUSSION

Hospitals and Physicians Rates in the West Bank

The WB has a total of 54 hospitals, with 14 of them being government hospitals that collectively provide 50% of all hospital beds. This translates to an average of 2.6 hospital beds per 1000 inhabitants. Additionally, there are approximately 2.0 physicians per 1000 inhabitants in the region (Palestinian Ministry of Health, 2022). These rates are relatively low compared to countries such as Germany, where the average is 8.1 hospital beds per 1000 inhabitants and 4.2 physicians per 1000 inhabitants. Similarly, France also has higher averages with 6.2 hospital beds per 1000 inhabitants and 4.0 physicians per 1000 inhabitants [22]. However, it is worth noting that these figures are closer to the averages in Jordan in 2021, which had 2.66 physicians per 1000 inhabitants and 1.5 hospital beds per 1000 inhabitants [40]. Furthermore, the hospitals in the WB are often clustered in the more densely populated Palestinian cities, as illustrated in Figure 2.

The comparison of these healthcare metrics highlights the disparities in healthcare infrastructure and resources between different regions and countries. These statistics underscore the need for healthcare planning and resource allocation to ensure that the population's healthcare needs, including emergency medical services, are adequately met, especially in regions like the WB where there are geopolitical and resource constraints.

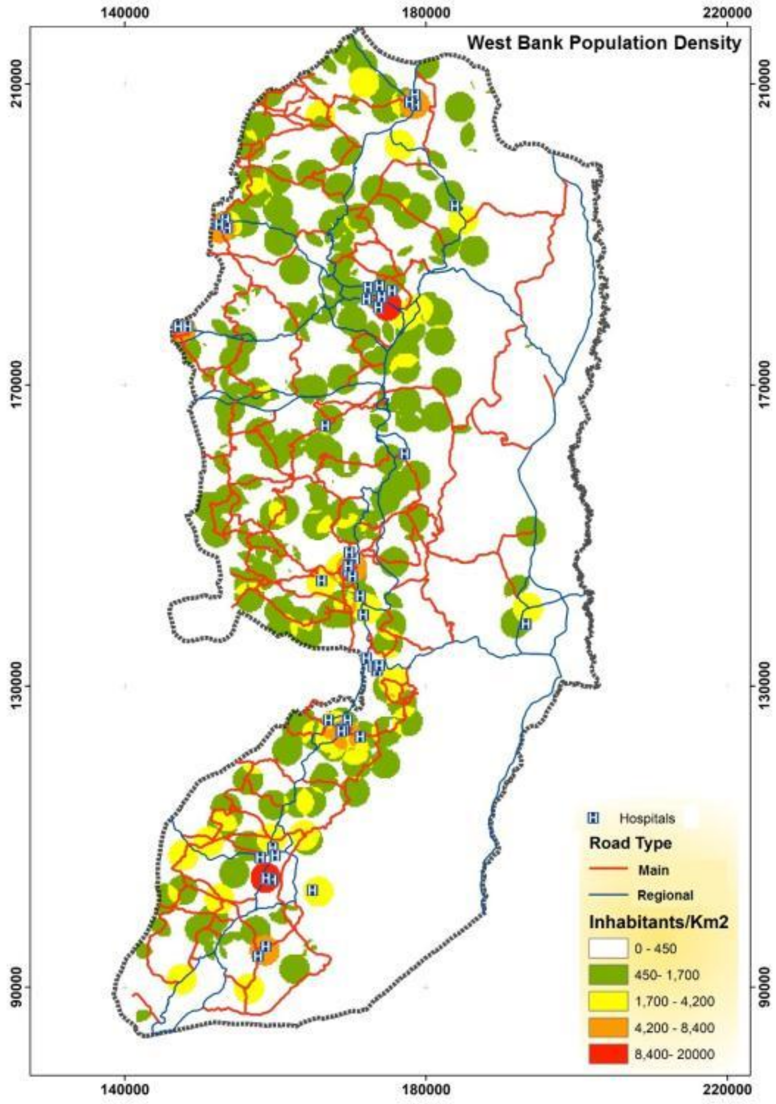

Figure (2): Palestinian Hospitals and Population Density in the West Bank.

Ground EMS and the current demand

Based on the available data from ECF and ALS, the average response time of ground EMS is less than 12 minutes. These figures can be considered good indicators, particularly considering the available resources and the challenging field conditions under which ground EMS operates. However, it's important to note significant variations in response times across different communities. Many rural areas face considerably longer response times, with some cases exceeding the norm of 25 minutes. Furthermore, 14% of cases exhibit an average response time of 20 minutes, indicating a notable segment of the population might not promptly receive medical attention during emergencies. These statistics might actually underestimate the problem as rural residents often resort to using their own vehicles to reach healthcare centers, leading to potential delays in receiving professional medical assistance during emergencies [2].

As for the demand, the average number of trips was 1.167 trips/veh/day, which means more than 83,000 (primary) trips per year. Moreover, there are certain medical cases that necessitate the transportation of patients over long distances between hospitals. In 2019, the total cost of transferring medical services to hospitals in Jordan and Israel was approximately $28.4 million, and the total number of patients transferred was 12,125 (secondary) with an average of $2,344 per patient [2].

HEMS coverage and response time

The number of helipads required is inversely proportional to the response time, and directly proportional to population coverage. Therefore, the disparity in the number of helipads will lead to different coverage rates and response times. Several scenarios were explored, as illustrated in Table 4.

Table 4 shows that one helipad in Jerusalem (in the middle of the WB) would cover the whole population in 35 minutes' response time, as so do two helipads (in Hebron (south) and Nablus (north)) in 25 minutes. Furthermore, three helipads (Jerusalem, Hebron, and Nablus) would cover 95% of the population in 20 minutes, and four helipads (Jerusalem, Hebron, Nablus, and Jenin) would cover a 100% of the population in 20 minutes. The greater the number of helipads used, the higher the cost spent; therefore, it would be illogical to increase the number of helipads, as shown at the end of Table 4.

In conclusion, based on the golden hour concept, the least number of helipads that would provide a 100% coverage rate in less than 25-minute response time are two helipads in Hebron and Nablus governorates (see Figure 3).

Table (4): Different Coverage Rates and Response Times.

Helipad No.	**Helipad Potential Location**	**Response time (minutes)** [I]				
		15	**20**	**25**	**30**	**35**
		Buffer radius (kilometers)				
		15	**30**	**45**	**60**	**75**
		Coverage rate % [2]				
1	Jerusalem	15.8	38.3	74.2	93.1	100
2	Hebron + Nablus	34.1	71.7	100		
3	+ Jerusalem	48.9	95.0	100		
4	+ Jenin	64.2	100			
5	+ Salfit	70.7	100			
6	+ South of Hebron	76.8	100			

[I] HEMS average speed is 180 km/hr, and the preparation time is 10 min.
[2] Population coverage is based on the populated area density and distribution in the WB

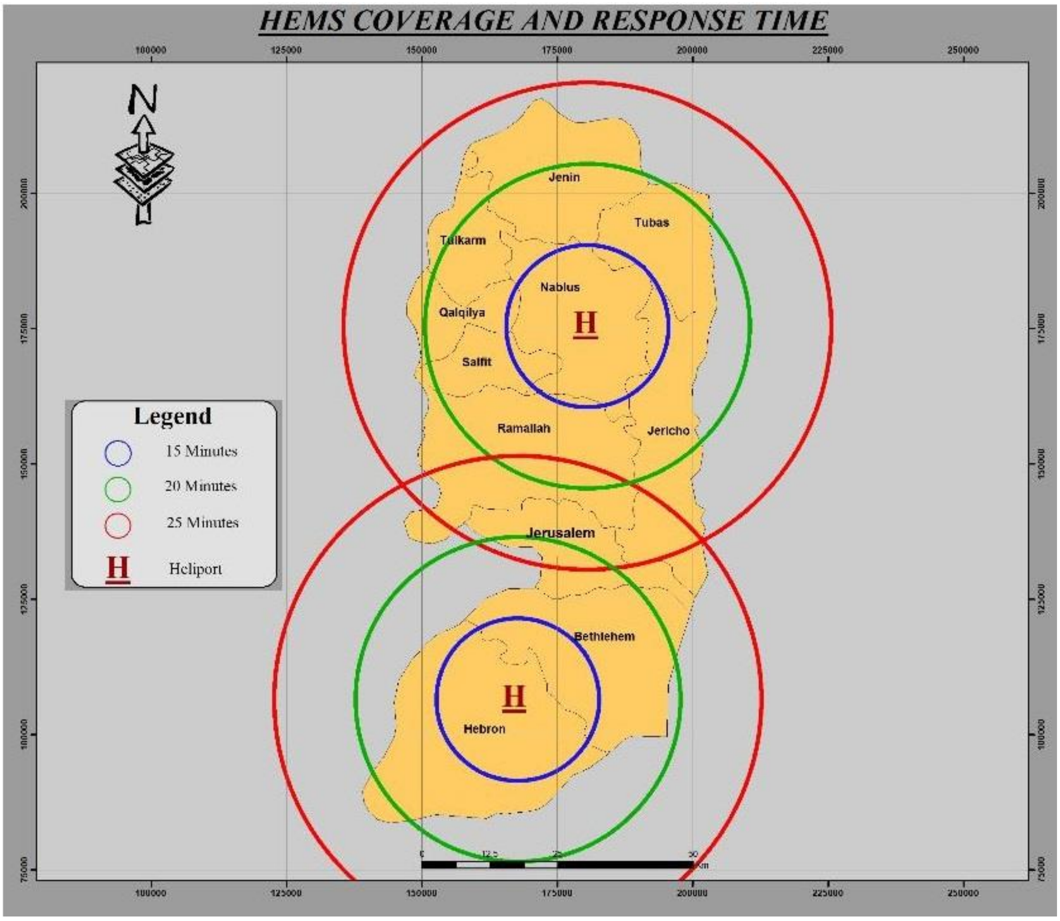

Figure (3): HEMS Coverage and Response Time, 2 Helipads.

Predicting the utilizations of the HEMS in the West Bank

There are currently no HEMS in the WB; therefore, HEMS trip generation rate is not directly available. On the other hand, an average of 1.6 missions per million capita per day (0.21 patients per hour, 1825 patients per year) was recorded in the European countries [19].

Based on collected data (Table 2), there were 1,798 cases (16.6% of the population sample) that had a response time of more than 15 minutes; equals 13,778 of 83,000 cases transferred in 2021. In addition, the percentage of the critical cases was 15% (Table 3). Therefore, the number of critical cases that have a response time exceeding 15 minutes is 2060 cases. This means 5.6 missions per day (1.8 missions per day per million capita) and 0.23 missions per hour. These cases will be assumed as HEMS expected missions per year. As for the helipad's capacities, one helicopter is equal to the service rate of the helipad.

A stochastic distribution of demand and service rates based on the queuing theory approach is assumed. In particular, a multiple-server queue approach is adopted (two helipads with one helicopter each) to analyze the number of helicopters and the service demand for the HEMS in the WB.

Using the queuing theory approach, the average HEMS arrival rate (λ) is 0.23 patients per hour (2000 patients per year). Based on the two recommended helipads in the WB, with a maximum response time of 25 minutes and 100% of population coverage, the helipad's capacity (service rate) is calculated to be 1.2 patients/hr. In addition, two helipads of single-helicopter are recommended. Furthermore, based on the population growth, the expected HEMS mission generation rate in 2030 would increase by one mission per day. This has no significant effect on the performance of the HEMS queue. Therefore, the system would still be the same; two helipads with one helicopter each.

Table 5 summarizes the resulting queuing characteristics for different number of helicopters at each helipad. It is clear that one helicopter at each of the two helipads will perform very well, with a very low number of patients waiting in the queue; an average time a patient spends in the queue is 5.2 minutes and an average time for the whole process (from the time of emergency call to reaching the hospital) is 52 minutes.

For the two helipads, one will be responsible for the northern governorates and the other for the southern governorates, while the overlapping area in the middle will be the responsibility of the closest helipad; therefore, the patient has only one reference helipad.

Table (5): HEMS Queue Characteristics.

Term	Meaning	No. of Channels		
		1 Helicopter	2 Helicopters	3 Helicopters
P(0)	Probability of zero patients in the system	0.904167	0.908549	0.908614
Lq	Average number of patients in the queue	0.010157	0.000221	0.000005
Ls	Average number of patients in the system	0.105991	0.096054	0.095838
Wq	Average time a patient spends in the queue, hr	0.088326	0.001918	0.00004
Ws	Average time a patient spends in the system[I], hr	0.921659	0.835251	0.833373

Notes: [1] From the time of calling the HEMS to the time of reaching the hospital.

- μ (mission per hour) = 1.2
- λ (patient per hour) = (0.23/N) = 0.115

N: number of servers (helipads) = 2

Helipads Locations

The following results were determined after computerizing and analyzing the data collected.

– The resultant locations were obtained after collecting the population point density, hospitals, and elevations in one overlay using the GIS; see Figure 4.

– The functioning of this system is assumed to be handed over to the PRCS, as it is an organized and experienced institution in emergency services in the WB. Therefore, 15 and 20 km buffers around the nearest PRCS hospitals were created to calculate the population coverage percentage. The most appropriate PRCS hospitals were chosen based on hospital size and site. The results were the PRCS hospitals in Hebron and Nablus.

HELIPAD PRELIMINARY LAYOUT AND DESIGN

It is not intended here to design the helipad, but rather layout the basic elements of the HEMS design, which will be used to estimate the cost. These include [17]:

– The design helicopter is the H135 helicopter, as it is the market-dominant in the HEMS sector.

– Helipad size and dimensions (total area = 1040 m^2)

– Visual aids contain; helipad marking and lighting.

– The essential helipad facilities (fixed or dragged refueling facilities, fire extinguishers with other fire-fighting equipment, and warning signs).

– The structural design considering static, dynamic, rotor loads, and pavement type, which yielded the following thicknesses:

  - ➢ Ground Level: 20 cm base course and 15-cm Portland cement concrete (PCC) layers.
  - ➢ Elevated (roof-top): 35 cm of PCC layer (roof slab)

Helipad Type and Construction Cost

In general, the hospital rooftop slab must be a 35 cm two-way solid slab as a minimum for a maximum span of 6 m, which is not available at the PRCS hospitals in Nablus or Hebron; rooftops were not prepared for such a system. In addition, the surrounding areas have some high obstacles including telecommunication poles and residential buildings, which will increase the construction cost. Therefore, for practical reasons, ground-level helipads should be used.

The estimated helipad's overall construction cost (ground level) is estimated at $65,000 each. The average unit price of fully clinical equipped H135 helicopter is $4 million [1].

As for the operational cost, it was estimated based on similar existing HEMS in Europe. The average operational cost, such as staffing, maintenance, insurance, training, medical supplies, etc. is $3,596 per trip [18], while [36] reported an estimate of less than $1000 per trip. In addition, the estimated number of lives that would be saved is 4.4 per 100 serious blunt patients transferred through the HEMS [39]. This means that for 2,000 annual patients in the WB, the total annual cost would be approximately $7.2 million, and 88 souls would be saved. Furthermore, costs up to $95,000 per saved life may be considered acceptable [31], while [14] reported a range of $50 to $100 thousand. Therefore, the expected average annual cost of the HEMS in the WB (average of $81,820 per saved life) is acceptable and worthwhile.

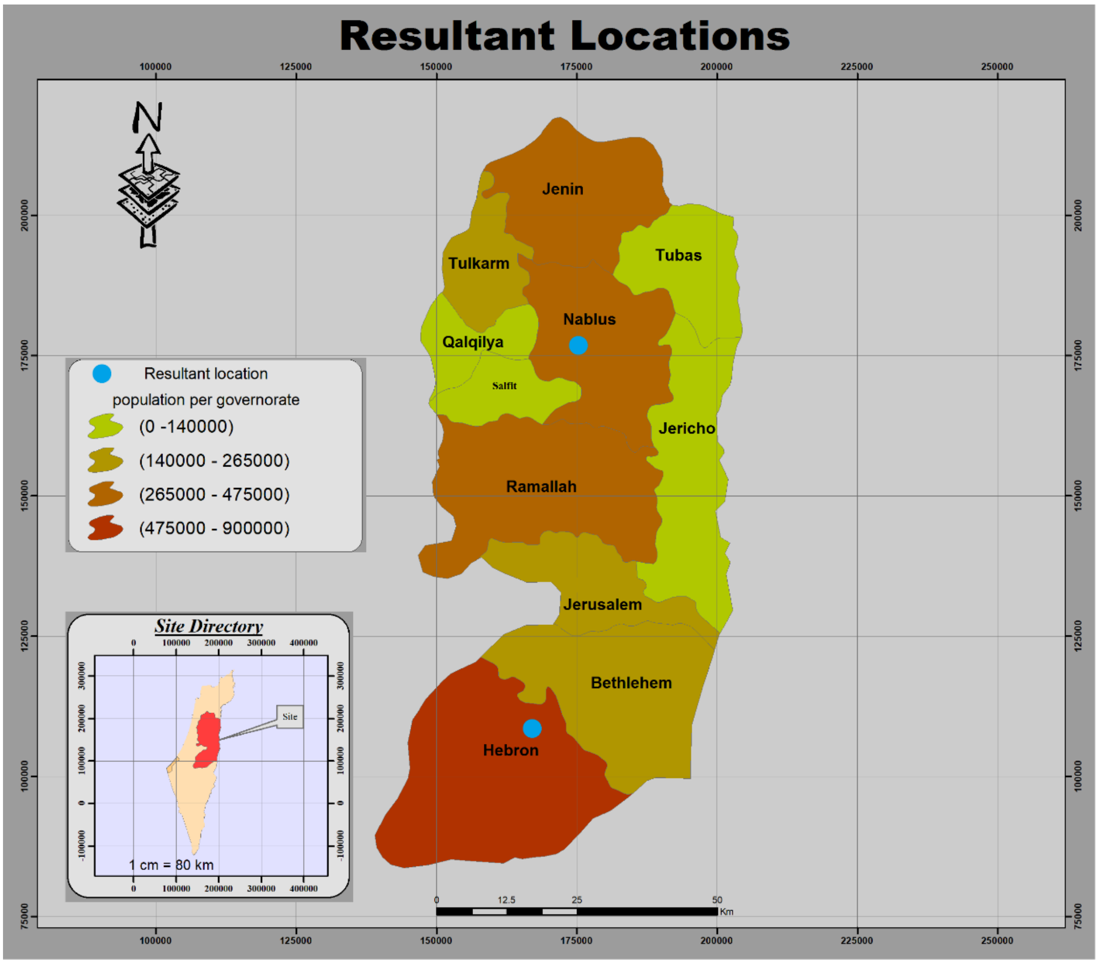

Figure (4): Resultant Locations for Helipads in the West Bank.

In summary and in the interest of optimizing emergency response in the WB, policies facilitating the establishment and operation of HEMS must be developed. These policies should prioritize healthcare requirements over financial concerns, ensuring access to swift medical assistance. Additionally, this humanitarian service should be neutralized from political conflicts in the region.

PROPOSED PLAN FOR HEMS SYSTEM AND LOGISTICS

The Ministry of Health diligently prepares and updates its strategic plans, with the latest being the National Health Strategy 2021-2023 [25]. Several of the listed priorities in this plan address aspects to improve emergency services. However, the plan does not address the potential for HEMS, likely due to current political reasons. Nevertheless, despite the challenging geopolitical landscape, it remains crucial not to disregard the planning for HEMS, even though such endeavors may appear ambitious.

A plan for HEMS should be integrated with the MOH's short- to medium-term (5- 10 years) strategy. Implementing HEMS can significantly enhance emergency medical services, especially in situations where timely access to medical care is crucial. This proposal outlines the framework for introducing and optimizing HEMS in Palestine.

The framework should follow the typical strategic planning steps. These include diagnosis of existing conditions, identifying strategic issues, establishing objectives, then strategies and framework, as well as the expected outcomes and performance indicators. The plan should be prepared by a team of specialized staff that include stakeholders, led by the MOH. Here is a summary of what the proposed framework should include.

Preparation and set up: Formulate the planning team led by the MOH and including stakeholders from relevant sectors, particularly the PCRS.

Diagnostic Phase: analysis of existing medical services and emergency conditions. This should conclude by identifying key priority issues.

Objectives: Based on the identified priority issues, objectives should be formulated; for example, improving emergency response, enhancing healthcare access, etc.

Strategic Framework: the stated objectives should be formulated in general action items. Surely, this should include establishing a HEMS benefiting from the outcome of this study; two locations are identified as optimal, Hebron and Nablus areas. It also would include action items such as infrastructure development, resource allocation (staff and equipment), training and capacity building of staff, and community engagement and awareness, among others.

Action Framework: this includes the tentative timeframe (preferably, short to medium range) and estimated cost for each action item.

Expected outcomes: the anticipated expected outcomes would include, for example, reduced response time, enhanced healthcare access, improved healthcare system resilience, among others. Key performance indicators should be established for each objective and linked to the expected outcomes.

This study established that the most appropriate locations are the PRCS hospitals in Hebron and Nablus. It also recommended that HEMS to be operated by a well-organized and experienced institution in emergency services in the WB, the PRCS, in cooperation with the MOH. These should be taken into consideration in future planning efforts to establish HEMS in Palestine.

Furthermore, due to the existing political constraints, the plan should include coordination with the Israeli occupation authority, with the support from the international community, to facilitate the service and neutralize it from any political conflict.

The PRCS has already an Emergency Operations Room (EOR) that can handle emergency calls and dispatch the service. Therefore, to guarantee that whenever calling the EOR the HEMS is effective in terms of cost and operation, a proposed logistics of operation is illustrated in Figure 5.

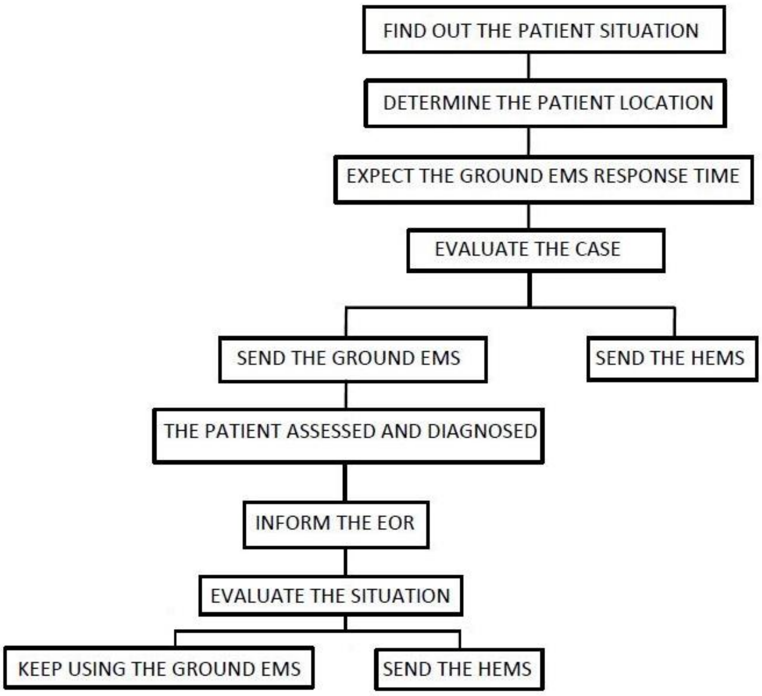

Figure (5): HEMS Logistic System.

CONCLUSIONS

In the West Bank (WB), Palestine, existing emergency medical services (EMS) rely solely on ground transportation, and the region experiences significant annual fatalities from road crashes, work-related injuries, and cardiovascular diseases, often occurring before ambulance arrival. This study, focusing on mobility, addresses this gap and proposes establishing a helicopter emergency medical service (HEMS) in the WB. The primary objectives include selecting optimal HEMS locations to maximize population coverage and acceptable response times, achieved using queuing theory and GIS tools.

Utilizing the Maximal Covering Location Problem (MCLP) method and GIS tools for current and future demand projection, the study identified that two helipads in Hebron and Nablus cities would achieve 100% coverage within the crucial one-hour response time (the golden hour). The queuing theory analysis showed that one helicopter per helipad would produce short HEMS' queue length and waiting time. Over time, with accumulated experience, the anticipated response time would reach 15 minutes for 71.7% population coverage rate and 20 minutes for 100% population coverage.

The study recommends the installation of ground-level helipads at Palestinian Red Crescent hospitals in Hebron and Nablus, acknowledging the substantial costs associated with HEMS. Hence, the study recommends prioritizing clinical needs over cost concerns, ensuring adherence to policy guidelines. For the proposed HEMS system, the benefit-cost analysis reveals an expected average cost of $81,820 per saved life, which is acceptable and worthwhile.

As a concluding note, it is crucial for both the Palestinian and Israeli occupation to neutralize this humanitarian system from political conflicts. Allowing unrestricted use of the WB's airspace for EMS is critical for swift and unimpeded assistance. Collaborative efforts in this direction can significantly enhance healthcare access and save lives in the region.

Ethics approval and consent to participate: Not applicable

Consent for publication: the authors permit the Publisher to publish the Work.

Availability of data and materials: it is available with the corresponding author.

Author's contribution: The authors confirm contribution to the paper as follows:

AD: study conception and design; data collection and processing; analysis and interpretation of results; literature review; and draft manuscript preparation. **KA:** design; supervision; critical review; and final manuscript preparation. All authors reviewed the results and approved the final version of the manuscript.

Competing Interest: The authors declare that they have no competing interests.

Funding: This research received no external funding.

REFERENCES

1] Airbus, 2022. Aircrafts. Retrieved from Airbus Company: https://www.airbus.com/en/products-services/helicopters/civil-helicopters. Accessed September 18, 2022.

2] Bitar J., Sabra N., 2019. Health annual report. Palestinian Health Information Center PHIC, Ramallah, Palestine.

3] Bozorgi-Amiri, A., Tavakoli, S., Mirzaeipour, H., Rabbani, M. 2017. Integrated Locating of Helicopter Stations and Helipads for Wounded Transfer under Demand Location Uncertainty. American Journal of Emergency Medicine, 35(3):410-417. https://doi.org/10.1016/j.ajem.2016.11.024.

4] Branas, C.C., MacKenzie, E.J., and ReVelle, C.S. 2000. A Trauma Resource Allocation Model for Ambulances and Hospitals. Health Services Research, 35(2):489-507.

5] Bullington A., Macgee E., Glassington B., 2014. Helicopter Emergency Medical Services (HEMS) Industry Risk Profile. Flight Safety Foundation, Washington DC, USA.

6] Butler D. P., Anwar I., Willett K., 2017. Is it the H or the EMS in HEMS that Has an Impact on Trauma Patient Mortality? A Systematic Review of the Evidence. Emergency Medical Journal. 27(9):692-701. doi: 10.1136/emj.2009.087486.

7] Davis, Robert, Alan, 2019. Air Medical Services. Retrieved 10 June 2021: https://aams.org/member-services/awards/history/.

8] Furuta, T., Tanaka, K.I. 2013. Minisum and Minimax Location Models for Helicopter Emergency Medical Service Systems. *Journal of the Operations Research Society of Japan*, *56*(3), 221-242. https://doi.org/10.15807/jorsj.56.221

9] Golah I., 2019. Red Crescent Status in the West Bank. RCS, Ramallah.

10] Goodloe J., Thomas S., Arthur A., 2012. Helicopter Emergency Medical Services in Oklahoma. OU Department of Emergency Medicine, Oklahoma.

11] Google. 2023. Israel Hospital Helipads. Accessed on December 10, 2023. https://www.google.com/maps/d/u/0/viewer?mid=1J86mmDTsbiJVCFnrL_btK-loP-Q&hl=en_US&ll=29.107935119487866%2C36.74866463097435&z=7

12] Griggs, J., Barrett, J., ter Avest, E., de Coverly, R., Nelson, M., Williams, J., and Lyon, R. 2021. Helicopter Emergency Medical Service Dispatch in Older Trauma: Time to Reconsider the Trigger? Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 29:62. https://doi.org/10.1186/s13049-021-00877-3

13] Hamilton B. A. 2003. Feasibility Study on a Helicopter Emergency Medical Service (HEMS) for the Island of Ireland. In. Dublin: Department of Health, Social Services and PublicSafety and Department of Health and Children.

14] Harat A, Harat M, Martinson M. 2020. A Cost-Effectiveness and Quality of Life Analysis of Different Approaches to the Management and Treatment of Localized Prostate Cancer. Frontiers in Oncology, 10:103. doi: 10.3389/fonc.2020.00103.

15] Hennelly, D., Deasy, C., Jennings, P., O'Donnell, C., Masterson, S. 2023. The Development of Helicopter Emergency Medical Services in the Republic of Ireland. Air Medical Journal 42:150−156. https://doi.org/10.1016/j.amj.2023.01.012

16] Hroob, H. 2013. Annual Report. Ramallah, Palestine: Ministry of Local Government, 20-110

17] ICAO, 1995. Heliport Manual –ICAO, Third Edition, vol. 3, USA: Flight Light Inc.

18] Lyon M., Vernon J., Nelson M., Tunnicliff M., 2015. The Need for a UK Helicopter Emergency Medical Service by Night: a Prospective, Simulation Study. Air Medical Journal 34(4):195-8. DOI: 10.1016/j.amj.2015.03.005

19] Misuraca D., 2018. HEMS in EUROPA Modelli Nazionali a Confronto. Italy. Accessed on September 18, 2022. https://www.hems-association.com/assets/courses/padova2018/HEMS_in_europa.pdf.

20] MOT, 2023. Annual Statistical Report. Ministry of Transport, Ramallah, Palestine.

21] Nguyen, Ngoc-Hien, Thi N., 2015. Quantitative Analysis of Ambulance Location-Allocation and Ambulance State Prediction. Linköping University, The Institute of Technology, Sweden. Accessed On September 18, 2022. http://liu.diva-portal.org/smash/get/diva2:781472/FULLTEXT01.pdf&p=1&pos=1

22] OECD, 2017. Government at a Glance: Serving Citizens. Online Available: https://stats.oecd.org/.

23] Palestinian Ministry of Health. 2022a. Annual Report 2022. Emergrncy Operations Center. Ramallah, Palestine.

24] Palestinian Ministry of Health. 2022b. Annual Statistical Report for Hosiptals Performance Year 2021 - Gaza. Ramallah, Palestine.

25] Palestinian Ministry of Health. 2021. National Health Strategy 2021-2023. Ramallah, Palestine.

26] Palestinian Red Crescent Society. 2022. Annual Report 2021. Ramallah, Palestine.

27] PCBS. 2023a. On the Occasion of the World Health Day, 07/04/2023. Accessed on December 10, 2023. https://pcbs.gov.ps/post.aspx?lang=en&ItemID=4487

28] PCBS. 2023b. Transportation and Communications Statistics – Annual Report 2022. Palestinian Central Bureau of Statistics, Ramalah, Palestine.

29] PCBS, 2022. Population in Palestine. Palestinian Central Bureau of Statistics, Ramalah, Palestine.

30] Private Hospitals Association Jordan. 2022. An Overview Of The Jordanian Health Sector. Accessed on December 10, 2023. https://phajordan.org/EN-article-3809-

31] Polinder S., 2009. Cost-Effectiveness and Quality-of-Life Analysis of Physician-Staffed Helicopter Emergency Medical Services. British Journal of Surgery 96(11):1365-70. DOI: 10.1002/bjs.6720

32] Pulver, A., Wei, R., Mann, C. 2016. Locating AED Enabled Medical Drones to Enhance Cardiac Arrest Response Times. Prehospital Emergency Care, 20(3):378-89. DOI: 10.3109/10903127.2015.1115932

33] ReVelle, C., Church, R. 1974. The Maximal Covering Location Problem. Regional Science Association International, 32(1):101-118. https://doi.org/10.1111/j.1435-5597.1974.tb00902.x

34] Røislien, J., van den Berg, PL., Lindner, T., Zakariassen, E., Aardal, K., van Essen, JT. 2017. Exploring Optimal Air Ambulance Base Locations in Norway Using Advanced Mathematical Modelling. Injury Prevention, 23(1):10–15. DOI: 10.1136/injuryprev-2016-041973.

35] Rogers, F. Rittenhouse, K., Gross, BW. 2015. The Golden Hour in Trauma: Dogma or Medical Folklore? Injury, 46(4):525-7. doi: 10.1016/j.injury.2014.08.043.

36] Röper, J., Krohn, M., Fleßa, S. Thies, KC. 2020. Costing of Helicopter Emergency Services- a Strategic Simulation Based on the Example of a

German Rural Region. *Health Economics Review*. **10**, 34. https://doi.org/10.1186/s13561-020-00287-8

37] Schuurman N, Bell NJ, L'Heureux R, Hameed SM. 2009. Modelling Optimal Location for Pre-Hospital Helicopter Emergency Medical Services. BMC Emergency Medicine, 9;9:6. doi: 10.1186/1471-227X-9-6.

38] Sorani, M., Tourani, S., Reza, H. K, Panahi, S. 2018. Challenges of Helicopter Emergency Medical Service: A Qualitative Content Analysis in Iranian Context. Health Policy and Technology, 7(4): 374-378. https://doi.org/10.1016/j.hlpt.2018.09.001.

39] Stevens, K., O'keeffe, C., Cross, L., Goodacre, S. 2003. A Review of the Costs and Benefits of Helicopter Emergency Ambulance Services in England and Wales. University of Sheffield, Wales.

40] The Jordan Times. 2023. UNWTO declares Jordan a regional hub for medical tourism. The Jordan Times, June 28, 2023. https://jordantimes.com/news/local/unwto-declares-jordan-regional-hub-medical-tourism.

41] The Jordan Times. 2016a. Helipads required at private hospitals with 100 beds or more. The Jordan Times, March 21, 2016. https://jordantimes.com/news/local/helipads-required-private-hospitals-100-beds-or-more.

42] The Jordan Times. 2016b. Air ambulance service a regional healthcare 'milestone' — CEO. The Jordan Times, February 20, 2016. https://jordantimes.com/news/local/air-ambulance-service-regional-healthcare-milestone-%E2%80%94-ceo.

43] UN Peacemaker, 1995. UN Peacemaker. Online Available: https://peacemaker.un.org/israelopt-osloII95.

44] Wikipedia. 2023. Emergency medical services in Israel. Accessed on December 10, 2023. https://en.wikipedia.org/wiki/Emergency_medical_services_in_Israel

45] World Bank. 2023. Palestinian Healthcare Critically Impacted by Weak Economy and Barriers. Accessed on December 10, 2023. https://www.worldbank.org/en/news/press-release/2023/09/18/palestinian-healthcare-critically-impacted-by-weak-economy-and-barriers

46] World Health Organization. 2023. Health conditions in the occupied Palestinian territory, including east Jerusalem, and in the occupied Syrian Golan - Report by the Director-General. Seventy-sixth World Health Assembly, A76/15, Provisional agenda item 18, 17 May 2023.