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A GIS- Based Fire-Response Efficiency Analysis – Benghazi

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ABSTRACT

Cities in Libya face fundamental challenges in firefighting due to the absence of fire hydrant networks, which are widely recognized as the global standard for providing rapid and direct water access during emergencies. Instead, urban areas rely entirely on fire trucks as the sole source of water supply, creating serious limitations in both response speed and firefighting efficiency. This study develops an analytical model designed to evaluate the effectiveness of fire response in environments lacking hydrant systems and dependent exclusively on mobile water carriers, as is the case in Libya. The proposed model integrates GIS with routing algorithms to simulate the dispatch of fire trucks. It further compares the actual water delivered with the required demand in accordance with international standard such as NFPA 1141. The model also estimates the number of vehicles required, water efficiency index, and visualizes results through interactive dashboards and isochrone-based coverage maps. The model was applied to Benghazi using logistical data, including the current single fire station, 32 residential neighborhoods, estimated water demand, and travel times. Data were processed using Python-based GIS tools. The evaluation included the calculation of response times, assessment of water supply adequacy, and multi-scenario simulations to identify areas meeting or failing to meet standard response requirements. Results showed that only 53% of neighborhoods met the required response thresholds at night, while the percentage dropped to 31.25% during midday, leaving the majority underserved and revealing major gaps in resource allocation and preparedness. The study provides a practical framework that can support decision-makers in proactive planning, with the aim of reducing fire risk and enhancing the sustainability of urban emergency management in contexts without traditional hydrant infrastructure. Furthermore, the model was able to identify the required number and optimize the spatial distribution of fire stations to ensure compliance with standard response times.

Keywords; Firefighting systems, Response time, GIS-based assessment, Water demand.

تحليل كفاءة الاستجابة للحرائق باستخدام نظم المعلومات الجغرافية– بنغازي

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ملخـــــــص البحـــــــث

تواجه المدن في ليبيا تحديات جوهرية في مجال مكافحة الحرائق بسبب غياب شبكات صمامات المياه، والتي تُعتبر المعيار العالمي المعترف به لتوفير وصول سريع ومباشر للمياه أثناء حالات الطوارئ. وبدلاً من ذلك، تعتمد المناطق الحضرية بالكامل على سيارات الإطفاء كمصدر وحيد لتوفير المياه، مما يخلق قيوداً كبيرة على سرعة الاستجابة وكفاءة مكافحة الحرائق. تستعرض هذه الدراسة نموذجاً تحليلياً مصمماً لتقييم فعالية الاستجابة للحرائق في بيئات تفتقر إلى أنظمة الصمامات وتعتمد حصرياً على ناقلات المياه المتنقلة، كما هو الحال في ليبيا. يدمج النموذج المقترح نظم المعلومات الجغرافية (GIS) مع خوارزميات التوجيه لمحاكاة إرسال سيارات الإطفاء،

ويقارن كمية المياه الفعلية المقدمة بالطلب المطلوب وفقاً للمعايير الدولية مثل NFPA 1141. كما يقدّر النموذج عدد المركبات المطلوبة، ومؤشر كفاءة المياه، ويعرض النتائج من خلال لوحات بيانات تفاعلية وخرائط تغطية تعتمد على خطوط الزمن(isochrone) . تم تطبيق النموذج على مدينة بنغازي باستخدام بيانات لوجستية، بما في ذلك محطة الإطفاء الوحيدة الحالية، و32 حيّاً سكنياً، والطلب المقدر على المياه، وأوقات السفر. تم معالجة البيانات باستخدام أدوات GIS مبنية على لغة Python. شملت عملية التقييم حساب أوقات الاستجابة، وتقييم كفاية إمدادات المياه، وإجراء محاكاة متعددة السيناريوهات لتحديد الأحياء التي تلبي أو تفشل في تلبية متطلبات الاستجابة القياسية. أظهرت النتائج أن 53٪ فقط من الأحياء استوفت حدود الاستجابة المطلوبة ليلاً، بينما انخفضت النسبة إلى 31.25٪ خلال منتصف النهار، ما ترك غالبية الأحياء دون خدمة وكشف عن فجوات كبيرة في تخصيص الموارد والجاهزية .توفر الدراسة إطاراً عملياً يمكن أن يدعم صانعي القرار في التخطيط الاستباقي، بهدف تقليل مخاطر الحرائق وتعزيز استدامة إدارة الطوارئ الحضرية في سياقات تفتقر للبنية التحتية التقليدية للصمامات. علاوة على ذلك، تمكن النموذج من تحديد العدد المطلوب من محطات الإطفاء وتحسين توزيعها المكاني لضمان الالتزام بأوقات الاستجابة القياسية.

الكلمات الدالة :أنظمة مكافحة الحرائق، زمن الاستجابة، نظم المعلومات الجغرافية، الطلب على المياه.

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1. INTRODUCTION

Globally, firefighting systems are based on one of two main models: the water network system with fire hydrants and the system based on fire trucks. In the network-based system, cities are equipped with a network of distributed pipes and hydrants, ensuring an immediate flow of water at sufficient pressure according to standards such as NFPA 291[1]. This system is evaluated through hydraulic modeling and field flow tests. This system is responsive and reliable, but requires significant investment and ongoing maintenance, and is limited in off-network areas [2]. The fire truck system relies on mobile tanks as the sole source or support of the water supply. The system is evaluated against standards such as NFPA 1141 by calculating the response time, capacity of the vehicles' tanks, and the number of trips needed to cover the water demand. This system is flexible and accessible to remote areas, but it is slower in response, has limited capacity, and depends on operational efficiency [3]. A hybrid system that combines the network and fire hydrants within cities, supported by fire trucks, is the perfect choice to achieve a balance between reliability and operational flexibility [4]. A comparison of these systems shows that the efficiency of a firefighting system is measured not only by the amount of water available, but also by the system's ability to respond timely, continuously, and operationally. The results underscore the need to develop comprehensive assessment models that integrate hydraulic analysis, spatial coverage, and operational simulation to support decision-makers in planning ahead and improving the readiness of emergency systems [5].

Libyan cities face a fundamental firefighting challenge: the absence of a network system with fire hydrants, which is a global standard for providing water immediately and directly when fires break out. Instead, Libya relies entirely on fire trucks as its sole source of water supply, which imposes significant operational constraints on the speed of response and efficient fire control.

This research aims to evaluate the response time, which includes the time of communication, movement, and access to the fire site in the city of Benghazi, which relies on the fire truck system as the only alternative to fire networks, by analyzing its main elements:

1. The number of fire trucks available and their adequacy to cover needs.

2. The capacity of the water tanks in the trucks, which determines the amount of water that can be pumped per trip.
3. The pumping and flow rate provided by field pumps.
4. The number of trips required to secure water needs according to the size of the fire and the area affected.
5. The efficiency of the spatial distribution of fire stations compared to residential neighborhoods and industrial areas.

The methodology is based on the use of GIS Python-based mathematical modeling techniques to calculate response time and estimate the amount of water available against standard demand according to standards such as NFPA 1141, and efficiency indicators are built that include the proportion of on-time water demand met and the extent of geographical coverage.

The importance of this assessment is that it provides a practical tool for decision-makers in Libya to identify the shortcomings of the current response system, and to propose strategic solutions such as strengthening the fleet of fire engines, improving the distribution of stations, or gradually transitioning to hybrid systems that combine fixed networks and mobile vehicles, by applying it to the city of Benghazi as a model.

Based on the above, this research presents an analytical model based on actual data from Benghazi city neighborhoods and stations, and combines fire fleet operational capacity calculations with route selection algorithms to estimate latency and water demand coverage efficiency. The results are presented using interactive maps and an Excel dashboard that includes quantitative indicators and graphs, providing engineers and decision-makers with a practical tool to assess system readiness and enhance emergency response plans.

1.1 Response Speed:

Many previous studies have addressed response speed in emergency water distribution systems and the importance of improving latency for tanks and pumps. For example, the study by [2] provided a simulated model of emergency water distribution using path-finding algorithms to reduce latency. The study by [1] also focused on developing an interactive dashboard to assess the efficiency of urban distribution during emergencies, taking into account real travel times and road conditions [6] study showed that improving advance planning of fire truck routes can reduce the overall time to arrive by up to 25%, and increase water demand coverage. The study of [3] also showed the importance of developing short-term operational schedules for the management of water distribution in tankers under conditions of uncertainty, while the study of [6] presented the importance of developing short-term operational schedules for the management of water distribution in tanks. [2] A framework for planning short-term operations in urban areas. Finally, a review by [7] highlighted the role of incident prediction, resource allocation, and transmission models in improving the speed of emergency response. GIS was also used in the [4] study to assess rural water network performance and identify critical points, and the model [5] showed the effectiveness of integrating simulation and remote sensing. To analyze the speed of the system's response in an emergency. These studies emphasize the importance of integrating GIS, EPANET and GIS simulations, and dashboards to efficiently analyze response speed and resource planning, which has been applied and expanded in the model proposed in this paper. Response time is a key element of a fire engine-based system, as it is related to the road network and traffic, while exceeding it for a few minutes (5 to 10 minutes) negatively affects the effectiveness of firefighting. Therefore, it is necessary to estimate the number of vehicles needed for each location through an equation that relates the total water demand, the capacity of the vehicle's tank, and the number of possible trips during the duration of the fire. Provides geographic analysis via geographic information systems (GIS) Accurately visualize time coverage areas, and helps identify deficit areas that are not accessible in a timely manner.[5]. Therefore, the speed of response to firefighting is a key element in the efficiency of emergency water supply systems, as the extinguishing time is directly related to the speed of fire spread, the area of the fire, the water requirement, as well as the rate of flow required. Engineering modeling uses discretionary equations to represent this relationship, such as:

$$A(t) = A_0 \cdot e^{kt} \qquad (1)$$

where *A(t)* is the area burned after the time *t*, *A0* is the initial area, and k is the diffusion coefficient which is affected by the type of material, ventilation, weather conditions, fire extinguishing systems and the function of the area (residential-commercial-industrial). Through this, the time required for the fire to reach a certain area can be calculated. Equation

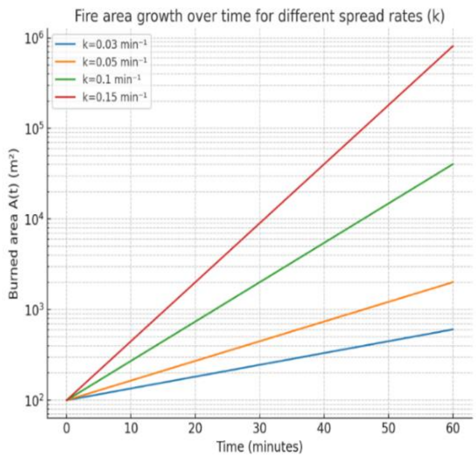


Fig1. Fire Area with Response Time for Different Diffusion Coefficient.

(1) expresses the evolution of the area of the fire *A(t)* as a function of time, indicating that the area increases exponentially over time, in the absence of immediate intervention to extinguish the fire (e.g., the delay in the arrival of fire brigades).This exponential growth is represented by a set of graphical curves that illustrate the relationship between the area of the fire and time, with the values of the diffusion coefficient k. [8], For example, assuming that the fire started with an initial area of A_0 = 100 m², and by testing different response times from 5 minutes to 60 minutes, we can observe a rapid increase in the area of the fire (see Table 1). These results, shown in Table 1 and Figure 1, highlight the significant effect of the delayed response on the speed of the spread of the fire, as a relatively small area (only 100 m² at the beginning) can inflate dramatically within one hour, depending on the value of the diffusion coefficient k. This underscores the paramount importance of rapid response and efficient water supply systems in containing and controlling a fire in its early stages before it expands in a way that is difficult to control.

Table 1. The effect of the value of the diffusion coefficient k on the burned area after 60 minutes, at an initial area A0=100 m2

Primary Area A_0 (m^2)	Diffusion coefficient k (min^{-1})	Area burned after 60 minutes (A_t) (m^2)
100	0.03	605
100	0.05	2,009
100	0.10	40,342
100	0.15	814,930

The required flow rate increases depending on the building area, the Insurance Services Office (ISO) equation is used to estimate the required flow rate at the building level, known as Needed Fire Flow (NFF), and this equation is a tool for estimating the amount of water demand required to fight a fire in a specific building or neighborhood, and the flow is given according to the relationship:

$Q = 3.73 \cdot (C \cdot A)^{0.5}$ *(3)*

where Q is measured *(L/s)* and C is the building coefficient (1.5 for concrete buildings and 2.0 for industrial buildings or warehouses), while A refers to the combustible area in square meters (m^2). For example, with a diffusion coefficient k= $0.15 min^{-1}$ of the volume of water required to control the fire increases from about 20 m^3 within the first five minutes to approximately 15,000 m^3 when the response is delayed by 60 minutes, fig 2. The mathematical curves of these results clearly show that response speed is a critical factor in reducing fire growth and reducing the amount of water needed for extinguishing, underscoring the need to develop an effective early response system. Therefore, the speed of response in firefighting is a key factor in reducing the spread of fires and reducing their effects. Each delay in intervention leads to an accelerated increase in the area of the fire, which increases the water required for extinguishing and increases the rate of flow required from the network or pumps. Therefore, reducing the response time is key to keeping the fire under control in its early stages and ensuring the efficiency of emergency water supply systems. As for calculating and assessing the fire needs in the absence of a network and relying entirely on the fire engine system only (which is the subject of the research), it is based on the capacity of the vehicle's tank and the time it takes to travel to and from the fire site, including the filling time (average supply rate per vehicle) – which will be explained in detail in the research methodology and methodology.

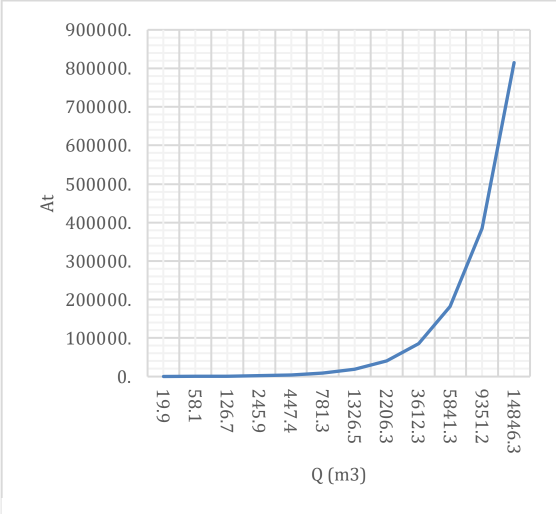


Fig 2. The relationship between water requirement and fire area.

2. Research Methods and Tools:

This study relied on geographical and logistical data related to "fire station" and residential neighborhoods in the city of Benghazi, including latitude and longitude coordinates, estimates of the water demands of each neighborhood, and the expected time to carry out the trips. This data has been collected and organized into tables using the Pandas language library. Python is a software model developed to simulate the response time of "fire station" and analyze its spatial efficiency, with a focus on identifying neighborhoods that meet the approved time standards and comparing them to those that do not. The evaluation process included calculating truck arrival time, measuring the water efficiency index, and conducting multi-scenario time simulations. The model also provided visual analysis tools in the form of graphs and time coverage maps (Isochrones), which allowed for an integrated spatial and temporal representation. Thus, the study is based on a methodological framework that combines quantitative analysis with spatial and temporal modeling, with the aim of evaluating the efficiency of the response of fire stations in the city of Benghazi and measuring their compliance with the relevant international standards. The steps of the methodology were organized as follows:

Data Collection:

1. Data from the only fire station in Benghazi city, including latitude and longitude coordinates, number of trucks available, and storage capacity.
2. Neighborhood data, including geographic coordinates, water demands for each

neighborhood, and area classification (urban/suburban).

3. Time parameters, including call time (Tcall), crew movement time (Tturnout), and initial on-site time (Taccess).
4. Road data, including variable speeds according to the time period (morning/noon/night), with the input of the road factor to correct the theoretical distance.

The distance between the neighborhood and the station was calculated by the method of "Haversine" [4], which is a straight line (as if it were an airline). Fire trucks do not move in a straight line, but through a network of winding roads, traffic lights and deviations. Therefore, a corrective indicator called the road factor is used that makes the hypothetical distance closer to reality, for example if the air distance is 5 km, and the correction index = 1.3 (the average deviation of the roads, which is a common value in urban transport studies), then the assumed distance on the roads becomes 6.5 km. (Travel Time) According to the specified speed [6].

2-2 Time Modeling:

A time model has been developed to calculate the Total Response Time (T_{total}), which is expressed in the following relations:

$$T_{total} = T_{call} + T_{turnout} + T_{access} + T_{travel} \quad (4)$$

Calculating the Travel time (T_{travel})according to the equation:

$$T_{travel} = \frac{d}{v} \times 60 \quad (5)$$

where *d* is the length of the path modified by the Road Factor, and *v is* the velocity of the vehicle.

The results were compared to the international standards (NFPA/ISO):

1. T_{target}; 4–6 minutes for urbans, T_{target}; 8–14 minutes for suburbs
2. In this model T_{target} assumed 10 min in all cases.
3. A neighborhood is considered to be a Target achiever if the condition is met $T_{total} \leq T_{target}$, otherwise it is outside the Target.
4. The best station for each neighborhood is determined on the basis of the shortest response time.

2.3 Water Demand Estimation:

Water demands were calculated according to NFPA and ISO standards based on the following equations:

Number of trucks required:

$$N_{trucks} = \frac{Q_{req} \cdot t}{V_{truck} \cdot n_{trips}} \quad (6)$$

Number of possible trips per truck:

$$n_{trips} = \frac{t}{t_{round}} \quad (7)$$

$$t_{round} = t_{go} + t_{fill} + t_{return} \quad (8)$$

Where: Q_{req} Water demand, V_{truck} vehicle capacity, n_{trips} number of trips and t time of water supply required (duration of continuous pumping of water, e.g.: 2 hours).

Efficiency Index:

$$Efficiency = \frac{Water\ Supplied}{Water\ Required} \quad (9)$$

A neighborhood is considered safe if Efficiency≥1.

2.4 Evaluation & Analysis:

A time analysis was conducted across three periods (morning, noon, and night) to capture the effect of traffic variations on response performance and to determine the response time for each neighborhood. The analysis involved calculating the round-trip time (t_{round}) and assessing compliance with the target time (T_{target}) as well as estimating the number of trucks required (N_{trucks}) and the efficiency of water coverage. The system was then evaluated using quantitative indicators including:

- The percentage of neighborhoods covered within the target time (True) compared to uncovered areas (False).
- Average travel time and efficiency index for each neighborhood.
- The spatial distribution of trucks required to meet water demand across the city.

2.5 Visualization:

Spatial analysis tools have been employed to prepare visual outputs that support the evaluation process, including: interactive GIS maps displaying station coverage and travel lines, bar charts illustrating truck requirements per neighborhood, and Excel tables summarizing response times, required resources, and efficiency indices.

2.6 Assumptions:

1. ***Water Availability***
   a. Each area's water demand (L) is assumed to be fully available.
   b. No shortages in water supply from stations.
2. ***Truck Availability***
   a. Sufficient number of trucks are assumed for each area based on calculated demand, in addition each truck capacity assumed = 8,000 L.
   b. No limitation in fleet size or dispatch capacity
3. ***Response Time Target***
   a. Target Time (min) = 10 minutes (one-way)
   b. Evaluated by Travel Time (min) = (Distance × Road Factor) ÷ Speed, per period (Morning / Noon / Night.
   c. Travel time includes road detour adjustment only
4. ***Focus of Study***
   a. In this study, the analysis focuses exclusively on travel time as the primary determinant of response performance.
   b. Other temporal components such as call processing, crew turnout, and on-site access are excluded, as they are assumed to be relatively constant across scenarios.
   c. This isolation allows the model to specifically evaluate the spatial and traffic-related factors influencing fire response efficiency.
5. ***Spatial Coverage***
   a. Original station(s) considered first.
   b. Proposed stations added iteratively to cover all areas exceeding the target response time.
   c. Circle radii indicate maximum theoretical reach per period (dotted lines in maps.

1- Results and Discussion:

3.1 Response Times:

Response times were calculated for three periods of the day—Morning, Noon, and Night—using a road detour factor of 1.3 to approximate realistic travel times. The resulting isochrone map (Map 1) shows neighborhoods within the target response time (green dots) versus those outside it (red dots), with dotted circles indicating reachability for each period and highlighting clear spatial disparities. Analysis of the map reveals that:

1- Neighborhoods closer to the fire station consistently meet the standard response thresholds, while distant areas fall outside the acceptable range. The number of neighborhoods within the target varied by time of day, where14 in the morning, 10 at noon, and 17 at night, representing less than half of the city's 32 neighborhoods.

2- Moreover, the remote areas necessitate either an augmentation of the available truck fleet or enhancements to the transportation routes, indicated in red on Map 1. Specifically, these encompass 18 neighborhoods during the morning period, 22 in the afternoon and 15 neighborhoods during the night period.

Fig 3 summarizes in bar chart the number of neighborhoods areas achieve response time (True) and the areas do not achieve (False). While table 2 below summarizes the neighborhood that is the shortest and farthest from the fire station, the journey time, the water fire demand, the number of trucks required, the number of neighborhoods that achieve the Target in each period of the day, and the neighborhoods outside the target.

3.2 Travel Times and Distances:

Travel times and distances between the fire station and each neighborhood were computed using realistic routing algorithms, which also facilitated the estimation of the required number of trucks for each area. The results mentioned above revealed that, although certain neighborhoods met the established target response times, others exceeded them. The distributions of average travel time and distance from the fire station to the neighborhoods are comprehensively illustrated in the following histograms presented in Figures 4 **and 5.**

3.3 Efficiency and Number of trucks

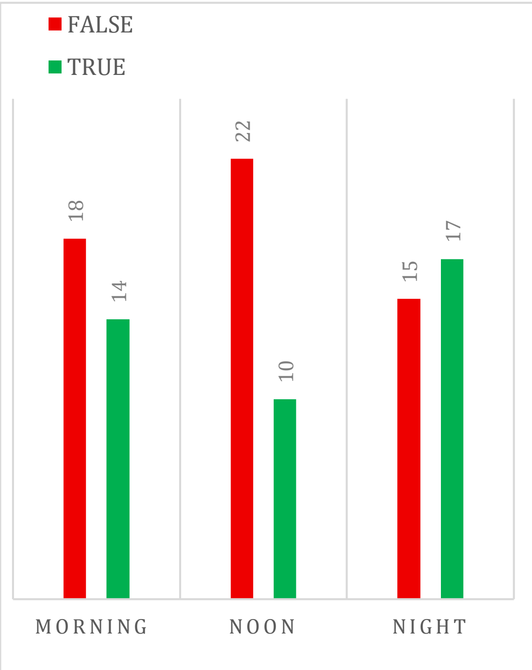
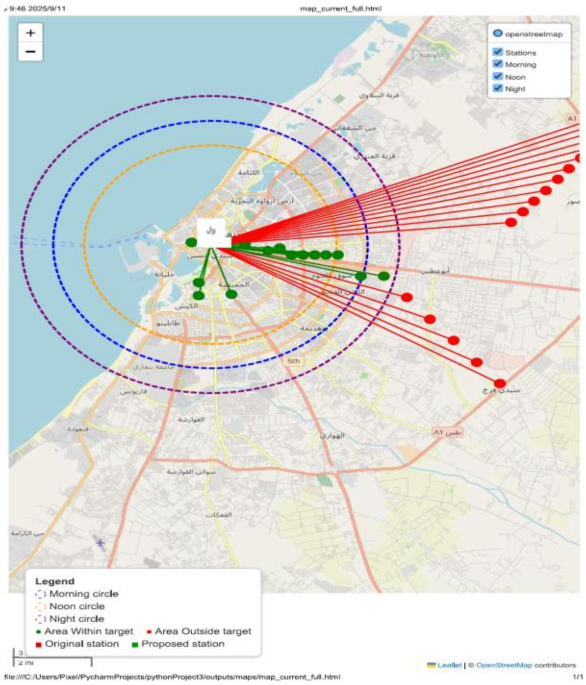


Fig3. bar chart representing number of neighborhoods areas achieve response time (True) and the areas do not achieve (False).

a. Distribution efficiency ranged from 1 to 1.41, no constraints on water availability or supply capacity from the plant are assumed in the code.

b. The number of trucks needed per area ranged from 1 to 5, depending on the demand.



**Map Legend: Colored circles: Green: Area Within target, Red: Area Outside, target, Dotted circles: Max theoretical reach for Morning (blue), Noon (orange), Night (purple)*

Map 1. Model's output Isochrone illustration (Current Fire Station Scenario) shows **neighborhoods** in Target (green) and off Target.

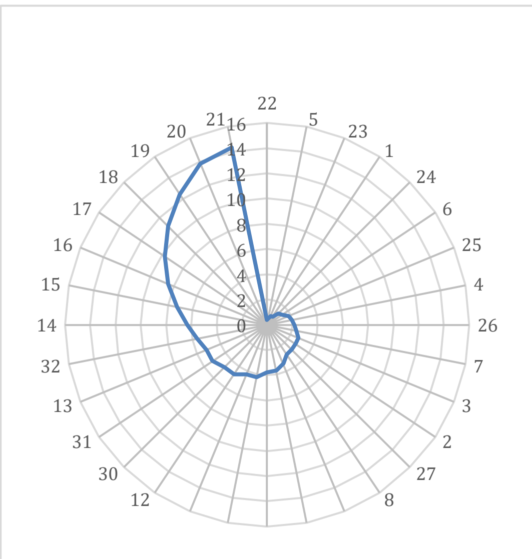


Fig 4. summarizes the distance in Km from fire station to the neighborhood areas of Benghazi.

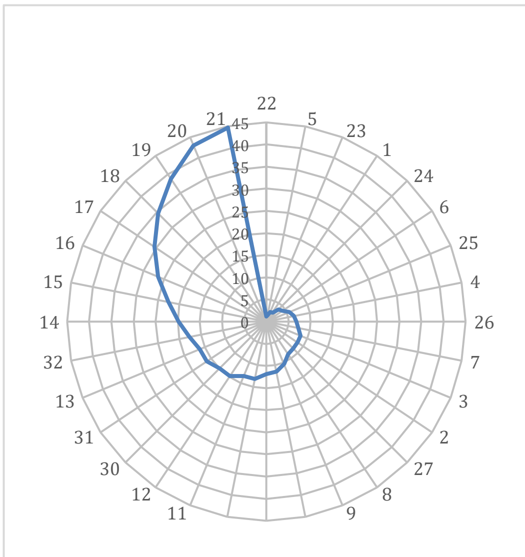


Fig 5. summarizes the travel time in min. from fire station to the neighborhood areas of Benghazi.

Table2. summarizes the model's output of shown in isochrone map and dashboard.

Statues		No of Areas	Name of Area	Period	Distance (Km)	Travel Time (Min)	Demand (L)	Number of Trucks
Min	Distance and Travel Distance	1	Al-Berka	NIGHT	0.469	0.61		
Max		1	Area32	NOON	18.867	36.79		
Min	Demand	1	Kufiyah	Morning+ Noon			15000	2
Max		1	Al-Lythi.	Noon + Night			40000	5
TRUE		14		Morning				
		12		Noon				
		15		Night				
False		18		Morning				
		20		Noon				
		17		Night				

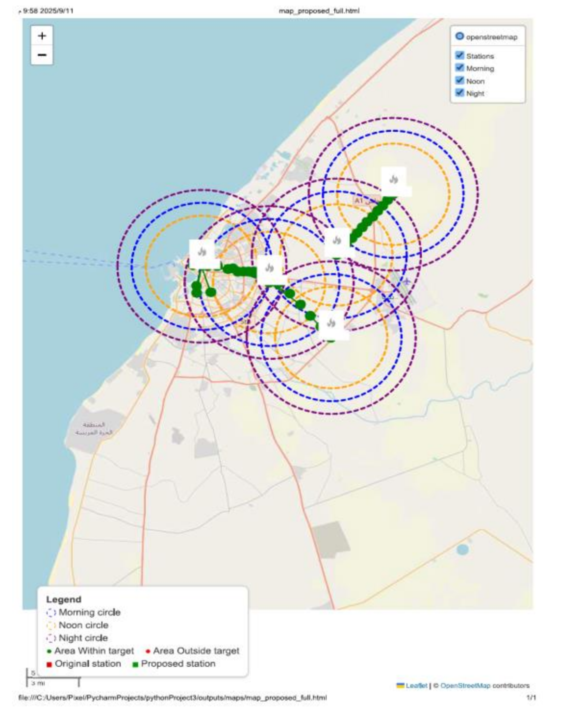
4. Proposed Fire Stations Scenario:

Upon identifying neighborhoods that exceeded the target response time, the code was enhanced with an additional functionality capable of recommending the optimal number and strategic locations of new fire stations. This enhancement ensures comprehensive coverage of all neighborhoods while maintaining response times within the established target. Application of a greedy coverage algorithm resulted in the identification of four additional stations at strategically selected locations, aimed at ensuring that all areas are served within the target response time. The proposed positions of these new stations are depicted in Map 2. With the establishment of the four additional stations, the city of Benghazi is expected to achieve the following improvements**:**

- All areas now fall within the 10-minute target for all periods.
- Maximum travel time reduced from 6.5 minutes to 3.8 minutes, improving overall efficiency.
- Number of trucks needed per area remained similar; however, delivery

efficiency increased slightly in previously under-served areas.

- Efficiency values are closer to 1 across all areas.
- Areas previously marked in red (outside target) are now green, indicating full coverage.



Map 2. shows the proposed 4 stations and their locations in the city so that all residential neighborhoods are in Target.

5. Conclusion:

When the fire growth equation was applied to a hypothetical case with an initial area of 100 m^2 and a diffusion coefficient of $k=0.15\ min^{-1,}$ the area of the fire increased rapidly from 100 m^2 just five minutes after the onset of the ignition, to about 814,929 m^2 after 60 minutes. This exponential growth in area reflects the significant impact of delayed response, as the delay of fire brigades leads to a significant doubling of water needs. The mathematical curves of these results clearly show that the speed of response is a crucial factor in reducing the area of the fire and the amount of water required, which emphasizes the importance of developing an effective early response system. Accordingly; an integrated analysis of emergency fire-response efficiency in Benghazi, using GIS Python-based mathematical modeling techniques, is presented in this paper. Benghazi City Fire Response Model is based on the integration of spatial and operational data to assess the efficiency of emergency coverage from a single fire station. Inputs include fire station locations, neighborhood coordinates, and water demand for each neighborhood. General assumptions, such as target response time, truck capacities, and truck speeds for different periods (Morning, Noon, Night), are also incorporated. The model computed for each neighborhood: total travel time from station to neighborhood and back, the number of trucks needed to meet the water demand, efficiency in meeting water demand and whether the neighborhood is served within the target response time or not. Outputs include Excel tables summarizing the results for each neighborhood, graphs showing the number of trucks required, as well as interactive maps showing the coverage area. Maps feature time radial circles, colored neighborhoods by response state (True/False of target time), and lines connecting the station to neighborhoods, with comparative information for each period displayed via the Tooltip windows. The combination of tabular, graphic, and spatial outputs provides a comprehensive decision support tool for assessing the efficiency of fire service coverage. To address neighborhoods exceeding the target response time, the model was enhanced with a greedy coverage algorithm that recommends the optimal number and locations of new fire stations. The analysis identified four additional stations that would ensure comprehensive coverage of all neighborhoods within the established response threshold. The major outcomes of the study:

- The Single fire station coverage is not adequate leaving numbers of areas above target during all periods of day time.
- Introducing four additional stations ensures full city coverage, reduces travel times, and improves response reliability.
- Decision-makers can prioritize strategic locations for new stations based on the uncovered areas identified in this model.
- The model allows dynamic updates of time periods, trucks speeds, water demand, and the coordinates of any additional

neighborhoods, enabling flexible planning for future fire-response scenarios.

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