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# GIS-based Services Analysis and Multi-Criteria for Optimal Planning of Location of a Police Station

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## Highlights

- The selection of a location for a police station based on GIS.
- Combining service area analysis and multi-criteria analysis is proposed for the selection of a site.
- An optimal location was obtained by using a wide range of perspectives.

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## Abstract

In sustainable urban planning, finding an optimal location for land use is critical to managing the distribution of land. Therefore, finding a location requires detailed information to conduct a correct evaluation of factors influencing the choice. The purpose of this paper is to find an appropriate site for a police station based on GIS in Alaziziyah Municipality, Jeddah. A novel method is proposed by combing service area analysis and multi-criteria analysis to reduce the emergency response time. The evaluation was conducted based on travel time from the two available police stations in the study area. The ten critical zones were generated by using network analysis with each zone representing one-minute travel time coverage. The critical zones were ranking, and weightage was applied as being crime risk-prone considering the distance from facilities and the travel time. The facilities were categorised into three groups, namely education, health, and tourism services. A suitability map was created to determine the priorities of alternative locations and the highly suitable area was overlaid with aerial photograph to determine land availability. The facility location-allocation was used to select the best location for setting up a police station. This approach revealed optimal solutions for government or planners as they seek to make the right decision for site selection.

## 1. INTRODUCTION

Choosing the optimal location for something new is a key factor in sustainable urban planning. Land use planning requires the integration of data from multiple sources and complex analysis to assess site selection [1]. The problem of site suitability assessment has often been tackled using Multi-Criteria Decision Analysis (MCDA) [2-4]. The literature regarding MCDA considers different methods and processes to resolve the decision-making problem in many fields such as mathematics, management, planning, and economics [5]. Finding the optimal location for a police station is influenced by different criteria such as distance from other police stations, distance from main roads, and nearness to crime-prone areas [6]. Visualisation of the spatial distribution of hot crime points and police stations can lead to identifying a suitable site for a new police station [7]. Nevertheless, many selections of emergency locations are undertaken by simple analysis in terms of measuring the geographical distribution of police station locations and determining the gab of the service area [6-8]. The ranking is a simple method, but it lacks a mathematical foundation [9]. To overcome this problem, Saaty (1980) proposed the pairwise compression method [10]. This method was developed in the context of the Analytic Hierarchy Process (AHP). The AHP has been employed in the GIS-based emergency site suitability procedures [11, 12]. In the AHP method, every criterion under consideration is ranked in the order of individual judgment which to date has never been 100 % accurate. In GIS-based buffer analysis, it is impossible to learn where a vehicle can reach in the required travel time. Integrating multiple disciplines such as service area analysis and multicriteria

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analysis results in finding a better solution since it uses a wide range of perspectives rather than a single approach and this increases the certainty of the study.

Finding a suitable place for a new police station required to meet different objectives such as reducing response time, minimising the total cost, and maximising coverage [13]. The powerful query, analysis, and integration mechanism of GIS make it an ideal scientific tool in handling a vast amount of spatial information [14]. Fast access to critical areas is essential during an emergency. Hence the proposed location should consider travel time as the main factor in evaluation. Utilising the capabilities of GIS in mapping the service areas based on travel time from the police stations requires the building of a network dataset by combining service area analysis and Multi-Criteria Analysis (MCA) to enhance decision making in the optimal planning of the location of a new police station.

## 2. MATERIAL METHOD

The method consists of two parts. In the first part, zones were created by using network analysis around existing police stations and each zone represented one-minute travel time coverage. Then, the facilities were determined as demand points in the critical zones and categorised into three groups as education, health and tourism services. In the second part, the ranking multi-criteria decision-making analysis method was used to site the risk-prone areas and produce a suitability map. The highly suitable area was overlayed with aerial photographs to determine land availability. Facility location-allocation was used to select the best location for setting up a new police station. Finally, the model and its characteristics were illustrated.

### 2.1. Study Area

Jeddah city is the second-largest city in Saudi Arabia. Jeddah's population is increasing dramatically due to out-migration to the city by individuals in search of jobs and better living [15]. With immigration and population keeping pace, the pressure on the police services has been tremendous. Jeddah province is divided into 14 municipalities with fifteen police stations. These municipalities are divided into districts such as Alaziziyah Municipality located on the western coast of the Kingdom of Saudi Arabia in Jeddah City, between latitudes 21° 33' N and 21° 30.33' N and Longitudes 39° 13.5' E and 39° 9' E. The area was divided into five districts Alaziziyah, Alandulus, Alhamrah, Alrehab, and Mesherfah (Figure 1). It covers an area of 46 Km2, while it has the highest population among other municipalities with a density of around 13.48/km2 [15]. Therefore, Alaziziyah municipality was selected as a study area and the analysis will be restricted to the extension of the study area and its networks. There are two existing police stations in the study area Northern and AL-Sharafia Police Station (Figure 2).

### 2.2. Materials

The road network was captured from satellite images (Google Earth) after geo-referencing by four control points collected from the Survey Authority in Jeddah. GPS was used to collect the coordinates of the existing police stations. The health, education, public services layers, and attributes data of the road networks were obtained from the General Department of Urban Planning in the Jeddah Municipality. Esri online imagery was used to determine the whereabouts of the undeveloped land.

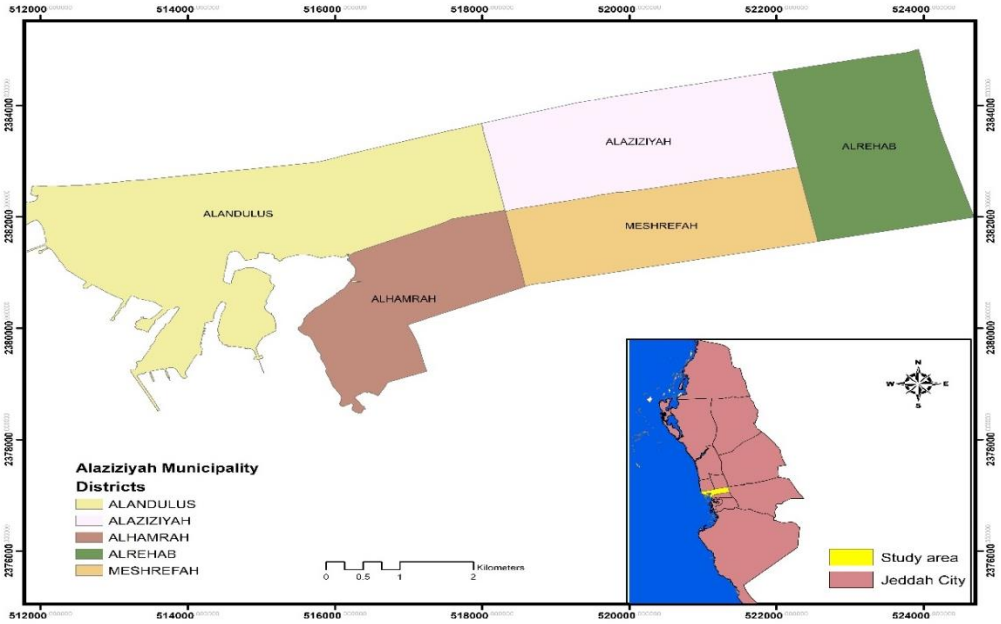


***Figure 1.*** *Al-Aziziyah Municipality*

## 2.3. Creating the Network

Network analysis can powerfully model realistic network conditions. Network analysis can be used to analyse problems such as vehicle routing, closest facility, and service area, by giving the data of roadways and cost attributes [16-19]. In emergencies, fast access to the critical area is essential to save people's lives and improve damage mitigation. The time between the police service location and the incident can be measured in seconds. During an emergency, maps play a significant role in understanding the extent of the impact, response to the event as well as search and rescue [20]. Therefore, the first evaluation will be based on travel time based on network analysis. GIS can be used to calculate the access in terms of travel time and evaluate accessibility against certain criteria [21]. The Alaziziyah street network consists of more than twenty thousand secondary streets, thirty-two main streets, and two highways (Figure 2).


***Figure 2.*** *Al-Aziziyah Street Network*

In this paper, the network data set was created, and the attributes table included essential parameters such as (distance (m), speed (km/h), road direction, road name, and type. An average speed of 40 km/h has been set for secondary roads, 50 km/h for main roads and 80 km/h for motorways. Arrival time and return time were calculated based on speed and distance in minutes. Topology was performed to ensure model validation and connectivity relationships. Finally, the network dataset was created and the ten critical zones were created around the police stations. Each zone represented one-minute travel time coverage by using the service area application (Figure 3).

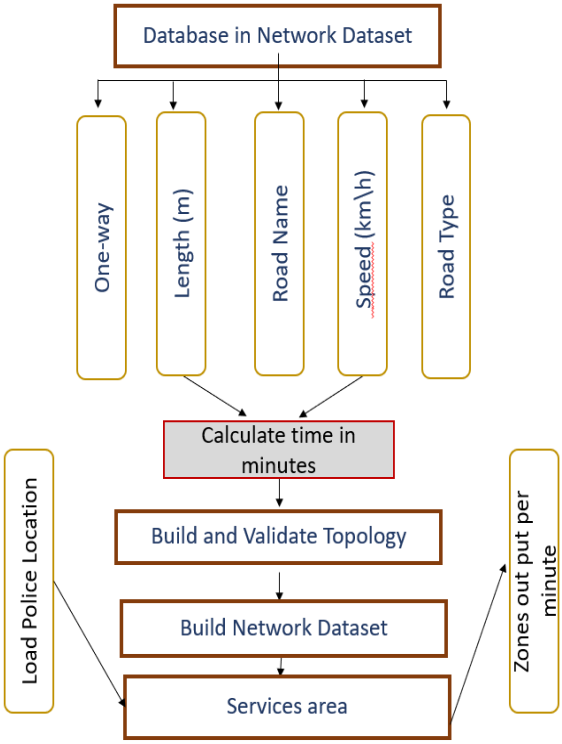


***Figure 3.*** *Network Analysis Workflow*

## 2.4. Multi-Criteria Analysis and Optimal Planning

Public facility planning includes the allocation of facilities or services at optimal locations guided by different planning criteria. In MCDA the determination of the optimum land site for an area involves the integration of data from various sources. All these datasets can be considered as criteria. Every criterion will contribute towards the site suitability at different degrees called a weight [22]. The scope of the proposed location will be limited to the critical zone. The risk-prone areas were created based on travel time coverage and the distance from facilities. The ranking and weightage overlayed all maps to produce a single suitability map. The final suitability map was derived by multiplying each factor by its relative weight followed by the summation of the results. A highly suitable area was exposed on a layer and overlayed with Esri's online imagery for determining land availability. In the available lands, ten points were selected as candidate locations and the facilities were loaded as demand points. The location-allocation method was used to determine the best location. The chosen location was selected with the minimum travel time (Figure 4).

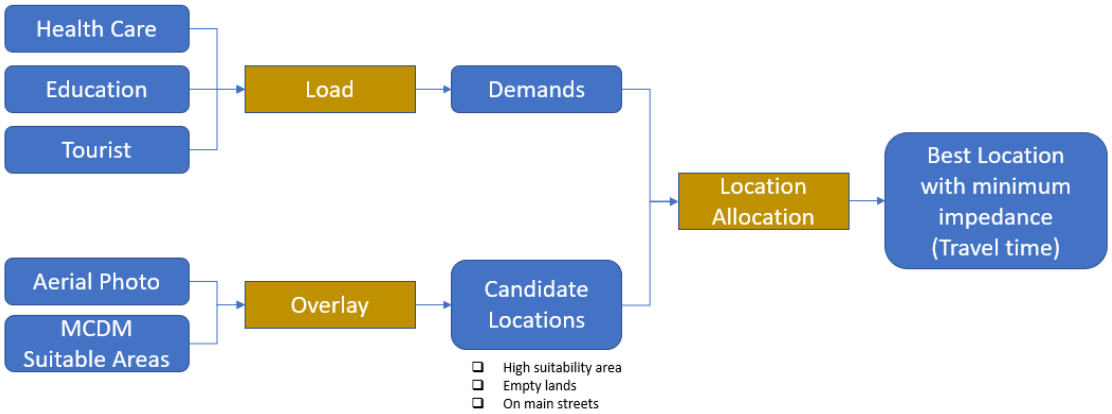


***Figure 4.*** *Location-Allocation Workflow*

## 3. RESULTS AND DISCUSSION

In many of the previous studies, the service areas were produced by creating buffer zones from a particular point [12, 23]. Accessibility always needs to be determined by travel time and road length [24]. Unlike the other studies Service Analysis was conducted based on four parameters. Firstly, time is a cost attribute chosen as impedance. Secondly, a one-way attribute is used to find solutions for vehicles that must obey one-way streets chosen as a restriction. Thirdly, a default break of 10 service areas and the extent of each one was calculated based on one minute from the police station. Finally, service areas were created by accumulating impedance in the direction away from or towards the police station (Figure 5).

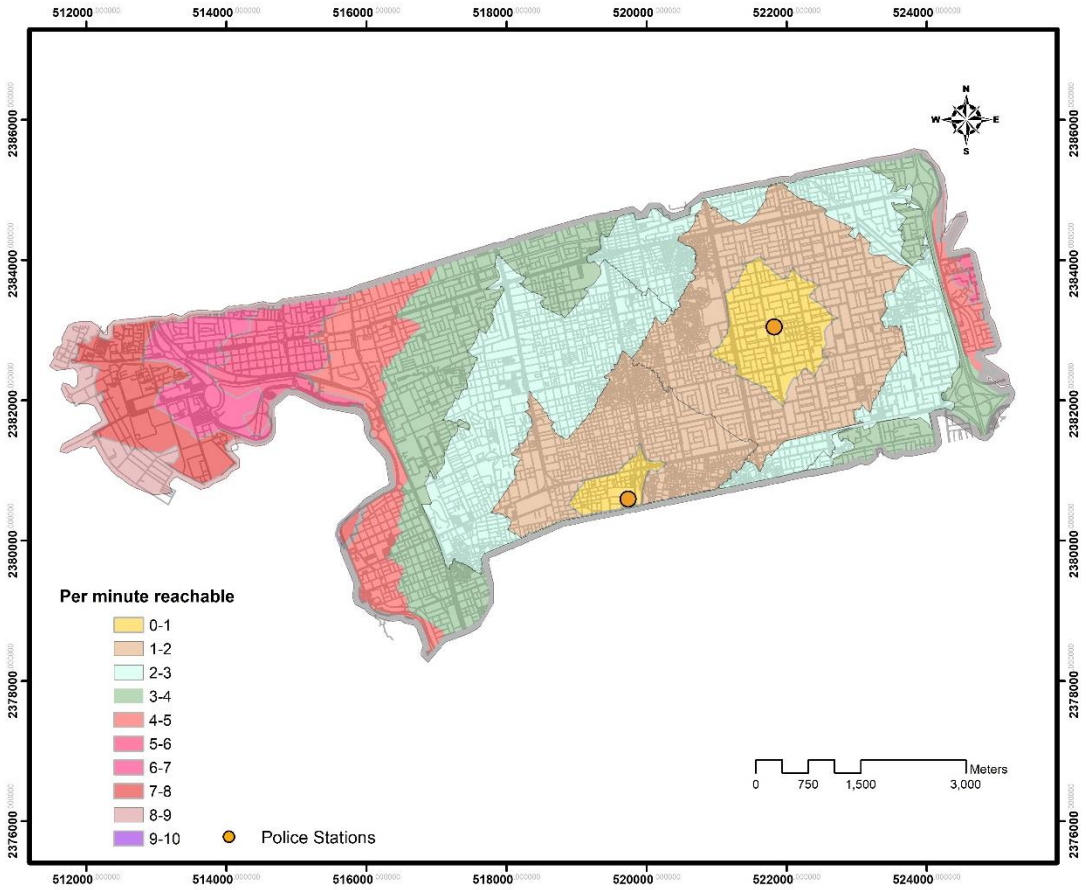


***Figure 5.*** *Service Area zones based on travel time from a police station*

The Service Area Analysis was based on time. These service areas show how accessibility varies with impedance. The emergency response time should be as low as possible and it depends on the condition of the emergency response vehicle and the possible obstructions along with the road network [25]. By arriving expeditiously, police officers can arrest any suspects and inquiring about the witnesses of the scene, along with averting the destruction or contamination of physical evidence [26]. Rapid response time (less than five minutes) is considered an effective tool used by police forces to detect crimes [27, 28]. Therefore, all zones were overlapped to evaluate the non-service area where 5 minutes of travel was considered not enough to reach a location. Such areas were considered as 'critical zones.

As stated in Table 1, up to 5 minutes of travel from the two police stations covered only about 64 % of the total area. This revealed that the critical areas cover 46 % of the study area and hence, it is required to have at least one more station for the non-served areas.

***Table 1.*** *Service Area zones and their areal coverage*

| Concentric Zones | Travel time (Minutes) | Zone Covers ($km^2$) | Cumulative Coverage ($km^2$) | % of the area covered by the fire service stations |
|---|---|---|---|---|
| 1 | 0 to 1 | 2.75 | 0 | 3 |
| 2 | 1 to 2 | 12.05 | 14.8 | 15 |
| 3 | 2 to 3 | 18.84 | 33.64 | 34 |
| 4 | 3 to 4 | 16.75 | 50.39 | 52 |
| 5 | 4 to 5 | 13.61 | 64 | 66 |
| 6 | 5 to 6 | 10.97 | 74.97 | 77.5 |
| 7 | 6 to 7 | 7.87 | 82.84 | 85 |
| 8 | 7 to 8 | 5.31 | 88.15 | 90 |
| 9 | 8 to 9 | 4.43 | 92.58 | 95 |
| 10 | 9 to 10 | 3.07 | 95.65 | 98 |

Land use planning is an effective tool for controlling and adjusting the distribution of land [29]. It involves measuring the needs of a proposed facility against the risk-prone nature of potential locations. Nowadays the hotspot trends of crime increase near a public area [30]. The facilities in critical zones were determined and classified into three classes, namely education, health, and tourism services as presented in (Figure 6).

In the ranking method, every criterion under consideration was ranked in the order of the preference of the decision maker. Inverse ranking was applied to these factors where 1 was the least important and 5 was the most important factor. The farthest areas from a particular facility received a low potential rank (1). The critical zones with 10-minute reachable time scored as the most important zones with a rank value of (5). After reclassifying and ranking all layers (Figure 7), a composite map showing the risk-prone area was created in 5 classes (Figure 8). Class 5 in a dark green colour was the highest prone-risk area and it was the most suitable site for the location of a new police station.

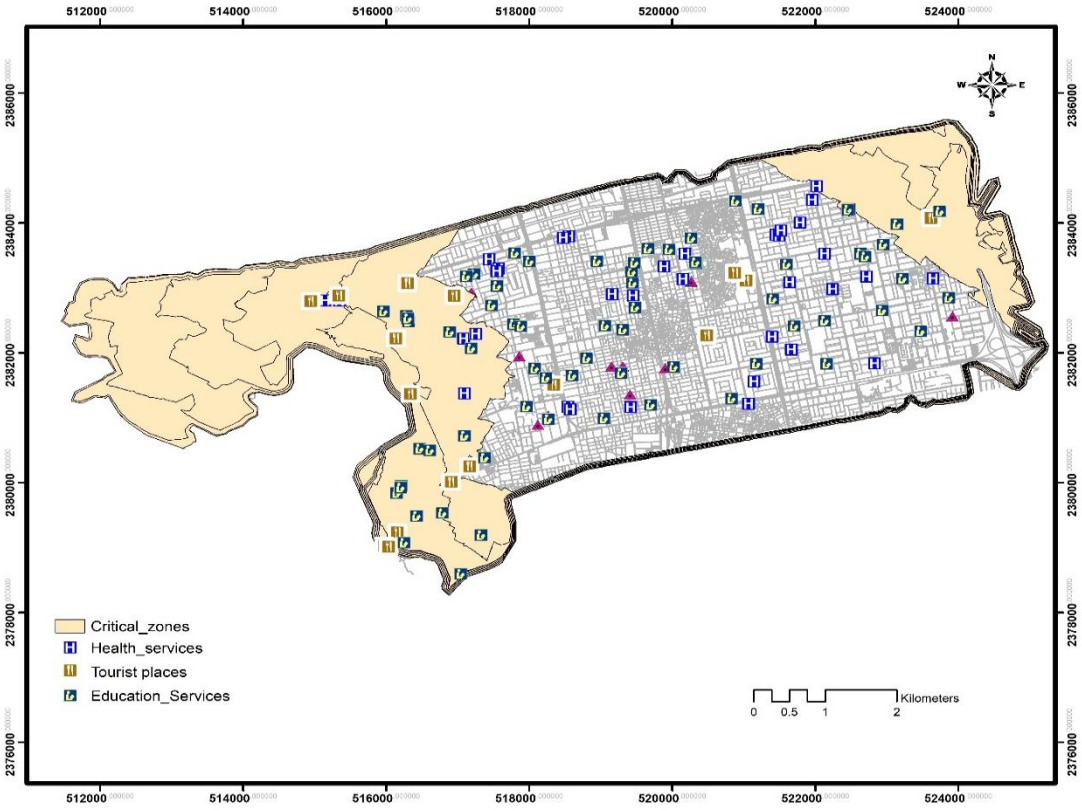


***Figure 6.*** *The facilities in the study area and critical zones*

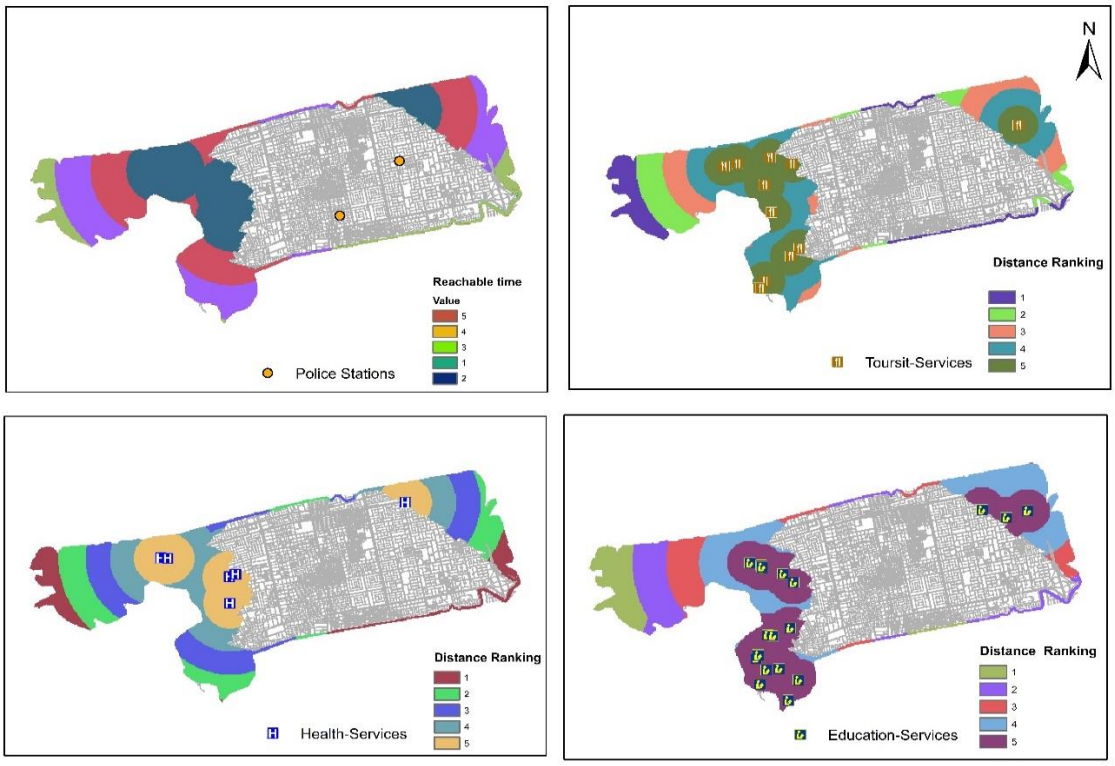


***Figure 7.*** *Multi-Criteria Analysis (Ranking layers)*

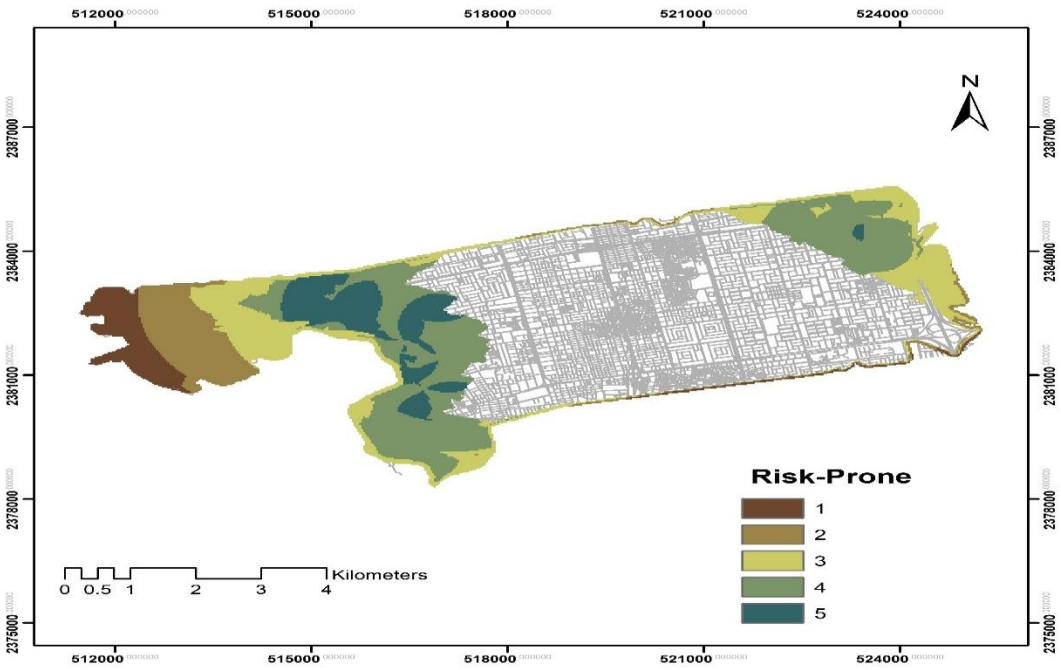


***Figure 8***. *Risk-Prone areas*

A suitability map was created to determine the priorities of alternative locations and the highly suitable area was overlayed with an aerial photograph to determine land availability. Subsequently, location-allocation analysis was used to select the best location for setting up a police station from the candidate locations. The suggested location (E: 517,216.759, N: 2,382,842.747) for a new police station was marked as a chosen location (Figure 9). It located in the intersection of Al Allaf street and Bugshan street in Alandulus District.

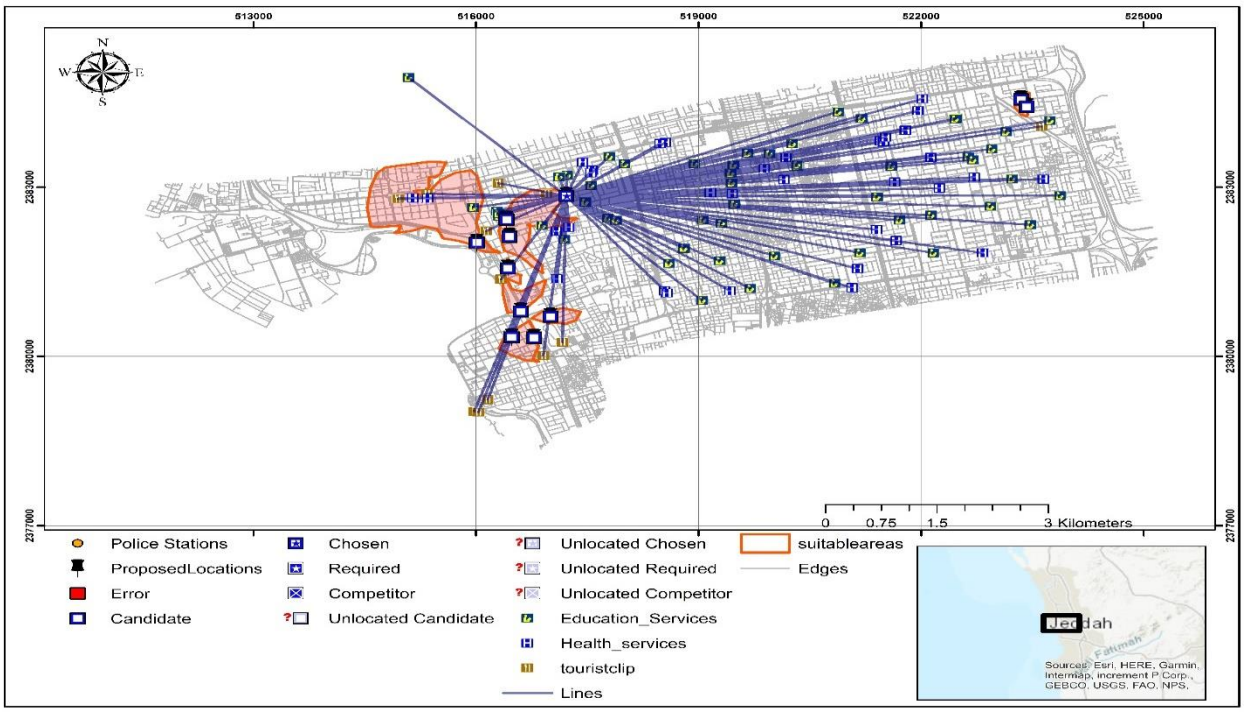


***Figure 9***. *Finding the best location by Location-Allocation Analysis*

## 4. CONCLUSION

The Risk-prone map can give planners, insurers, and emergency services a valuable tool for site selection of a new police station. The study reviewed the role of GIS in decision-making and optimal planning, improved service delivery, increased safety by considering the travel time and distance from facilities and the hotspot trends of crime. The integration of service areas in network analysis and multi-criteria analysis provided a clear picture of high-risk zones where minimising response time would be necessary. The high-risk zones were considered as highly suitable areas for the candidate locations. Location-allocation analysis chose among the candidate facilities to find the best location that would minimise cost and maximise demand allocation. This approach revealed optimal solutions for government or planners as they sought to make the right decision for site selection.

For further studies, crime information and its spatial distribution should be considered as effective factors in site selection. Network Analysis was implemented for the Alaziziyah Municipality road network. The study area coverage could be extended to the whole city.

## CONFLICTS OF INTEREST

No conflict of interest was declared by the author.

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