OCTOBER 2023

M.Sc. in Industrial Engineering

M. RADWAN MOUKET

REPUBLIC OF TÜRKİYE

GAZİANTEP UNIVERSITY

GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

A SPATIAL ANALYZE APPROACH FOR DETERMINING THE BEST POSSIBLE LOCATIONS OF POLICE STATIONS IN AZAZ

M.Sc. THESIS

IN

INDUSTRIAL ENGINEERING

BY

M. RADWAN MOUKET

OCTOBER 2023

A SPATIAL ANALYZE APPROACH FOR DETERMINING THE BEST POSSIBLE LOCATIONS OF POLICE STATIONS IN AZAZ

M.Sc. Thesis

in

Industrial Engineering

Gaziantep University

Supervisor

Assoc. Prof. Dr. Alptekin DURMUŞOĞLU

by

M. Radwan MOUKET

October 2023

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

M. Radwan MOUKET

ABSTRACT

A SPATIAL ANALYZE APPROACH FOR DETERMINING THE BEST POSSIBLE LOCATIONS OF POLICE STATIONS IN AZAZ

MOUKET, M. Radwan
M.Sc. in Industrial Engineering
Supervisor: Assoc. Prof. Dr. Alptekin DURMUŞOĞLU

October 2023

79 pages

Safety and security are fundamental concerns for humanity from various perspectives and serve as the cornerstone for all nations. Since 2011, Syria has been grappling with a protracted conflict, leading to numerous challenges. This thesis aims to develop a systematic approach to safety and security planning in Azaz City, Syria. To achieve this, we first input geographical information regarding the current police station location and calculate the population of the inhabited areas in a Geographic Information System (GIS). Subsequently, we propose a novel approach that integrates service area analysis and multi-criteria analysis to optimize emergency response times. The evaluation is conducted by factoring in travel times from the available police stations within the study area. Through network analysis, we identify three critical zones, each representing an area reachable within a one-minute travel time. Facilities are categorized into education, health, and tourism. We create a suitability map and use aerial photographs to assess land availability. Set covering analysis ensures the existing police station covers areas reachable within a five-minute car ride, ranging from 37% to 90%. We suggest potential new police station locations using facility location-allocation methods. Computational experiments show this approach improves security planning, benefiting governments, local councils, urban planners, and citizens.

Key Words: Geographic Information System GIS, Spatial Analysis, Police Station, Safety and Security, Land Use, Crime Statistics, Azaz, Syria.

ÖZET

AZAZ ŞEHRİNDE POLİS MERKEZLERİNİN OLASI EN İYİ YERLERİNİN BELİRLENMESİ İÇİN MEKANSAL ANALİZ YAKLAŞIMI

MOUKET, M.Radwan
Yüksek Lisans, Endüstri Mühendisliği Bölümü

Danışman: Doç.Dr. Alptekin DURMUŞOĞLU

Ekim 2023

79 sayfa

Emniyet ve güvenlik, bireyler için pek çok açıdan önemli endişe unsurları olmalarının yanı sıra uluslar için de hayati öneme sahiptirler. Suriye, 2011 yılından bu yana pek çok zorluğa yol açan bir çatışma ile karşı karşıya bulunmaktadır. Bu tez, Suriye'nin Azaz şehrinde emniyet ve güvenlik planlamasına sistematik bir yaklaşım geliştirmeyi amaçlamaktadır. Bu kapsamda, ilk olarak mevcut polis karakolunun konumu ile ilgili coğrafi bilgiler toplanmış ve yerleşim yerlerinin nüfusunu hesaplamak için Coğrafi Bilgi Sistemi(CBS) kullanılmıştır. Sonrasında acil müdahale sürelerini optimize etmek için hizmet alanı analizi ve çok kriterli analizi birleştiren yeni bir yaklaşım önerilmiştir. Değerlendirme, çalışma alanı içindeki mevcut polis karakollarına seyahat süreleri dikkate alınarak yapılmıştır. Ağ analizi sayesinde, bir dakikalık araba yolculuğu içinde ulaşılabilen üç kritik bölge belirlenmiştir. Tesisler eğitim, sağlık ve turizm gibi kategorilere ayrılmıştır. Ayrıca, arazi kullanılabilirliğini değerlendirebilmek için havadan çekilen fotoğraflar kullanılarak bir uygunluk haritası oluşturulmuştur. Küme kapsama analizi ile mevcut polis karakolunun %37 ile %90 arasında değişen alanları kapsadığı ve bu alanlara beş dakikalık araba yolculuğu ile ulaşılması sağlanmıştır. Ayrıca, potansiyel yeni polis karakolu konumlarını belirlemek için tesis konum tahsisi yöntemleri kullanılarak önerilerde bulunulmuştur. Hesaplamalı deneyler, bu yaklaşımın güvenlik planlamasını iyileştirdiğini ve hükümetlere, şehir plancılarına ve vatandaşlara fayda sağladığını göstermiştir.

Anahtar Kelimeler: Coğrafi Bilgi Sistemi (CBS), Mekansal Analiz, Polis Karakolu, Emniyet ve Güvenlik, Arazi Kullanımı, Suç İstatistikleri, Azaz, Suriye.

"Dedicated to my family"

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Assoc. Prof. Dr. Alptekin DURMUŞOĞLU for his guidance and support throughout the thesis. I am thankful for his encouragement and motivation.

I would like to express my love and gratitude to my family for their support and wish them the best wishes.

This work is supported by Urban Research Center (URC) through project activities.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
CP	Community Policing
EVTOL	Electric Vertical Take-Off And Landing Vehicles
FANP	Fuzzy Analytic Network Process
GPS	Global Positioning System
GNSS	Global Navigation Satellite Systems
GIS	Geographical Information Systems
GIS-RAV	Geographic Information System and Road Accident View System
IMS	Information Management System
IDP	Internally Displaced People
IMT	Mexican Transportation Institute
LBS	Location Based Services
LBSN	Location-Based Social Networks
MCA	Multi-criteria Analysis
MCDA	Multi-criteria Decision Analysis
MCLP	Maximal Covering Location Problem
MRT	Mass Rapid Transit Stations
MSAP	Maximal Service Area Problem
TOD	Transit-Oriented Development
UAM	Urban Air Mobility
UML	Unified Modeling Language
VS	Vulnerability Surface
VGI	Volunteered Geographic Information
WLC	Weighted Linear Combination Method

CHAPTER 1
INTRODUCTION

1.1 The importance of safety and security

Safety and security constitute foundational elements for development across various sectors, significantly impacting a country's potential for sustainable progress. These measures not only safeguard a nation's populace but also create a conducive environment for economic growth and investment, vital for governmental success. Furthermore, they exert a direct influence on the overall quality of life, individual productivity, and creativity, as well as the intricacies of urban planning. Thus, comprehensive planning and advanced technological integration for efficient analysis and decision-making are imperative to bolster safety and security measures. In recent years, urban safety has evolved beyond conventional crime prevention to encompass citizen well-being and urban area quality. However, the concept of security management, characterized by continuous regulation rather than eradication, is often underrepresented outside major urban hubs. This approach necessitates a holistic and systemic strategy, involving diverse institutions and stakeholders, to effectively address security challenges at both local and broader scales [1].

1.2 Safety and security in war weary areas

Safety and security in conflict-ridden regions are pressing concerns that demand immediate attention. These areas, often plagued by violence, displacement, and the breakdown of law and order, exhibit a severe lack of essential services and widespread suffering among civilians.

The complexity of conflicts in such regions is exacerbated by the involvement of various armed groups and international interventions. The international community, employing both military and humanitarian strategies, endeavors to support vulnerable populations in insecure areas by providing safety, sustenance, and clean water. These endeavors aim to expand to include basic services, education, and economic stability in the long term. However, it is important to note that such interventions may not necessarily result in enduring solutions or foster a comprehensive sense of peace [2].

When law and order break down in war-affected areas, a lack of safety and security occurs that can have serious impacts on populations and communities [3]. The following is an overview of some of the effects that can occur:

1. Increase in violence and crime: As law enforcement falters, incidents of violence and criminal activities often surge, posing a grave threat to residents.

2. The outbreak of gang wars and internal conflicts: With governance in disarray, power struggles among various armed groups or factions can intensify, leading to dangerous internal conflicts and gang warfare.

3. Spreading chaos and instability: The erosion of law and order can create an environment of utter chaos and instability, rendering daily life perilous for ordinary civilians.

4. Violation of human rights: The absence of legal protections and oversight can pave the way for widespread human rights abuses, adding to the suffering of the affected population.

5. Population displacement: Escalating insecurity frequently compels people to flee their homes, resulting in large-scale displacement and the emergence of refugee crises.

6. Spread of hunger and disease: The disruption of essential services, such as healthcare and food distribution, often leads to rising rates of malnutrition and the outbreak of infectious diseases among vulnerable communities.

In such environments, ensuring safety and security in conflict-affected areas is a critical challenge that requires collaboration between humanitarian organizations, governments, and international agencies. This involves protecting vulnerable populations, reestablishing the rule of law, and promoting sustainable peacebuilding. Prioritizing safety and security is essential for saving lives, reducing suffering, and building resilient post-war communities.

1.3 Safety and security in Syria

The war in Syria has been an ongoing conflict characterized by immense devastation and human suffering. It began in 2011 as a result of a series of protests against the government, but quickly escalated into a full-scale civil war involving various factions and international actors. The war has resulted in widespread destruction of infrastructure, displacement of millions of people, and a humanitarian crisis of unprecedented proportions. Civilians have borne the brunt of the conflict, enduring indiscriminate bombings, sieges, and human rights abuses. The war has had far-reaching consequences, including a severe impact on the country's economy, education system, healthcare infrastructure, and cultural heritage. Efforts to find a resolution and bring about peace have been complex and challenging, with numerous failed negotiations and ongoing violence. The war in Syria stands as a tragic example of the devastating consequences of armed conflict and the urgent need for international attention and collective action to alleviate the suffering of the Syrian people and work towards a sustainable solution.

1.4 Network Analysis

Network analysis is a powerful tool that can effectively model real-world network conditions. It can be utilized to analyze various problems such as vehicle routing, closest facility, and service area, by incorporating data on roadways and cost attributes. In emergency situations, rapid access to critical areas is crucial for saving lives and minimizing damage.

Transportation planning is a crucial field of study and practice that focuses on the efficient and effective design, management, and development of transportation systems to meet the mobility and accessibility needs of people and goods within a region or community. This field plays a vital role in urban and regional planning, as well as in addressing various transportation-related challenges, including congestion, environmental sustainability, and accessibility. Here are key aspects and concepts related to transportation planning:

1. Modal Analysis: Transportation planning involves the analysis of different transportation modes, such as roadways, railways, public transit, cycling,

and walking. Planners assess the strengths and weaknesses of each mode and aim to create a balanced, multimodal transportation system.

2. Traffic Engineering: This subfield focuses on the design and management of roadways, intersections, traffic signals, and signage to ensure safe and efficient traffic flow. Traffic engineers use various tools and techniques to optimize road infrastructure.
3. Public Transit: Public transit planning involves the design and operation of bus, subway, light rail, and commuter rail systems. Planners consider factors like route planning, scheduling, fare structures, and accessibility for riders.
4. Sustainable Transportation: Sustainable transportation planning emphasizes reducing the environmental impact of transportation systems. It includes promoting alternatives to single-occupancy vehicles, such as public transit, cycling, walking, and electric vehicles.
5. Land Use and Transportation Integration: Transportation planners work closely with urban and regional planners to ensure that land use and transportation decisions align. This integration aims to reduce sprawl, minimize commute times, and promote transit-oriented development.
6. Traffic Demand Management: Strategies like congestion pricing, carpooling, and telecommuting are part of traffic demand management. These approaches aim to reduce traffic congestion and improve overall transportation system efficiency.
7. Safety: Transportation planners prioritize road safety through initiatives like road design improvements, traffic enforcement, and public awareness campaigns. Reducing traffic accidents and fatalities is a primary goal.
8. Infrastructure Planning: Infrastructure planning involves identifying where new roads, bridges, tunnels, and transit lines are needed and determining their design, construction, and maintenance requirements.
9. Data Analysis: Transportation planners use data from various sources, including traffic sensors, surveys, and geographic information systems (GIS), to inform decisions about transportation system improvements and policies.

10. Long-Term Planning: Transportation planning often involves long-term visioning and strategic planning. Regional transportation plans can span several decades and help guide infrastructure investments over time.
11. Public Engagement: Engaging with the community and stakeholders is a critical aspect of transportation planning. Public input is sought to ensure that transportation decisions align with the needs and preferences of the people affected by them.
12. Funding and Finance: Transportation projects require substantial funding. Planners work on securing funding from various sources, including government grants, user fees, and public-private partnerships.
13. Environmental Impact Assessment: Assessing the environmental impacts of transportation projects is essential to ensure compliance with environmental regulations. This includes considerations for air quality, noise, and habitat preservation.
14. Transportation planning is a multidisciplinary field that requires collaboration among urban planners, engineers, environmental scientists, economists, and policymakers. The goal is to create a transportation system that is safe, efficient, sustainable, and responsive to the needs of the community it serves.

1.5 Emergence of GIS in Crime Analysis and Spatial Mapping

The field of GIS is experiencing rapid expansion, particularly in its application to crime analysis. In recent times, significant progress has been achieved in crime mapping, fueled by increased data accessibility and advancements in analytical methodologies.

Crime possesses an inherent spatial nature, and crime mapping typically revolves around pinpointing specific locations. While certain crimes pose challenges for mapping (like internet fraud, tax evasion, and certain motor-related offenses such as unlicensed driving), a significant portion of criminal behavior and routine incidents that law enforcement must address can be examined in a spatial context. The incidents that necessitate mapping are generally familiar: thefts commonly target businesses at particular sites, residential burglaries take place at houses, and street-related crimes (such as assaults and vehicle thefts) frequently unfold near premises with known addresses [4].

1.6 Purpose

In recent years, conflict and turmoil have unfortunately become an all-too-familiar reality for many regions around the world. Syria, in particular, has been severely impacted by ongoing armed conflict, leading to significant challenges in maintaining law and order within its cities. One such city grappling with these challenges is Azaz. As the city strives to rebuild and establish a sense of security for its residents, the need for effective law enforcement becomes paramount.

This thesis aims to address this pressing issue by employing a GIS approach to determine the optimal locations for police stations in Azaz city, Syria. By utilizing GIS technology, we can leverage spatial analysis techniques and pertinent data to identify strategic locations that will enhance the effectiveness and efficiency of law enforcement efforts. The findings and recommendations derived from this research will not only contribute to improving the safety and security of Azaz city but may also serve as a valuable resource for other conflict-affected regions facing similar challenges.

The thesis is organized into multiple chapters, each dedicated to the examination and analysis of different facets of the subject matter, with each chapter concentrating on distinct elements that collectively contribute to the comprehensive comprehension and research outcomes. An outline of the primary components addressed in each chapter is presented as follows:

Chapter 1 introduces the importance of safety and security, particularly in war-affected areas like Syria, and discusses the role of GIS in crime analysis and mapping. It outlines the research's purpose.

Chapter 2 reviews existing literature on safety and security, focusing on war-torn regions and Syria, highlighting previous research findings.

Chapter 3 explains the research methodology, detailing how the study was conducted, including data collection methods and analytical tools.

Chapter 4 presents research findings and engages in discussions, it offers an in-depth analysis of the data collected.

Chapter 5 summarizes key findings, their implications, and suggests potential avenues for future research in the context of safety and security in conflict zones like Syria.

CHAPTER 2
LITERATURE REVIEW

GIS is a computer program that combines two different databases: one holding numerical data and the other holding geographic data such as the location of schools, boundaries of regions, roads, rivers, mountains, and other relevant geographical characteristics. GIS links these two sets of data to enable users to analyze spatial patterns and present statistical data not only as tables and graphs, but also as maps [5].

GIS extend beyond mere software; they encompass a fusion of people, methodologies, and geospatial tools for spatial analysis, data management, and information visualization through maps and graphics. This multifaceted nature positions GIS as a potent decision-making instrument across various domains, including education. Administrators, leveraging GIS, gain a panoramic grasp of areas like safety, infrastructure, campus buildings, school bus routes, and supply chain logistics [6].

Illustrating this potential, J. Huang et al. [7] detailed the creation and execution of a GIS-based campus navigation system for Wuhan University of Technology. This system harnessed GIS and spatial information technologies to intelligently administer the campus, delivering functions such as educational management, service guidance, virtual navigation, and informed decision-making. The overarching aspiration was to craft an intelligent campus expert system by harmonizing data resources, streamlining application systems, and eradicating data silos and digital divides.

In a similar vein, Wendy L. Wallace [8] spearheaded the Montessori Green School Mapping Project to enhance environmental awareness among students and facilitate the strategic deployment of the Green School Initiative. The project hinged on mapping the school's campus and data to generate a web-based GIS platform. This platform facilitated tree inventory management, coordination of carpooling, utilization statistics analysis, and interactive educational tools fostering environmental education. Claiborne Lewis Phillips [9] conducted a quantitative study assessing school bus stop risks in Redlands, California. The study aimed to identify high-risk bus stops, considering factors such as violent and drug-related crimes, as well as proximity to convicted offenders' residences. Employing ESRI's ArcGIS software, the study employed Kernel density and Getis-Ord Hotspot analyses individually and in tandem, resulting in risk surface visualization and the identification of crime hotspots and coldspots. The insights informed the creation of maps and an Information Management System (IMS) to aid law enforcement, school officials, and parents in understanding bus stop-related risks. A. M. Azlan and N. Naharudin [10] proposed a framework that uses AHP-GIS to assess pedestrian safety when accessing rail transit stations in Malaysia, addressing the concerning problem of pedestrian accidents accounting for 7 percent of road fatalities. This framework combines AHP for prioritizing important factors and GIS for identifying safe pedestrian routes, providing insights for both transit users and authorities to enhance safety.

The roots of hot spot mapping research trace back to Sherman et al. [11], who pioneered this field. Their seminal work employed spatial data to scrutinize routine activity theory, analyzing a year's worth of service call data encompassing all addresses and intersections in 2 Minneapolis. The analysis unveiled a striking concentration of calls (50%) at a small number of addresses (3%). This pivotal discovery led the authors to conclude that crime manifests both scarcity and focal points, giving rise to distinctive "hot spots" of criminal activity. This novel pattern, distinct from earlier models presupposing random crime distribution, triggered an entire body of literature dedicated to unraveling this non-random crime dissemination.

Since the publication of this research, numerous subsequent studies have delved into this phenomenon, solidifying a consensus that crime indeed clusters spatially. Furthermore, this research has illuminated temporal and demographic concentrations of crime. A significant proportion of criminal incidents occurs at specific locations during distinct time intervals, mirroring similar concentrations within a limited subset of individuals, encompassing both perpetrators and victims [12].

In a similar vein, R. A. Elsheikh and W. A S. Hassan [13] demonstrated the application of GIS and Multi-criteria Analysis (MCA) in determining suitable routes for Khartoum city. The study incorporated various data sets from different sources, categorizing destination points of service and weighting them to establish an order of priority. This research successfully showcased the applicability of GIS and MCA in complex planning processes, not only for route planning but also for projects such as airports and industrial areas.

Furthermore, G. F. Nama [14] focused on developing a web-based GIS for public services in Bandar Lampung City. The application aimed to provide citizens with easy access to information about various public service locations, including housing, health facilities, and government offices. The system utilized Unified Modeling Language (UML) for design and incorporated non-commercial applications like Apache, PHP, and MySQL. It could be integrated with the city government web portal using XML data transport technology, enhancing public service delivery for the citizens of Bandar Lampung City.

M. Mohsin and H. Maraş [15] discussed the importance of information technology and GIS in academic environments, particularly for creating a map-based campus information system (CIS). The designed CIS integrated various data types, including spatial and non-spatial data, to provide an effective platform for academic and administrative personnel, students, and visitors to access information about the university. The application of GIS in the management of university facilities is demonstrated as a valuable tool, particularly for countries where manual management systems are prevalent.

D. N. Fadhil et al. [16] conducted a study to investigate the potential of using electric vertical take-off and landing (eVTOL) vehicles for urban air mobility (UAM) as a solution to alleviate the growing traffic congestion in metropolitan areas. The study employed a GIS-based analysis to identify suitable locations for UAM ground infrastructure. Through the utilization of the weighted linear combination (WLC) method and an analytic hierarchy process (AHP) Delphi approach, the study identified key factors and generated various scenarios. Case studies conducted in Los Angeles and Munich demonstrated that city centers, airports, and intercity train stations are viable options for the initial implementation of UAM operations, with points of interest presenting additional opportunities for tourism.

M. Vogiatzaki et al. [17] presented a conceptual framework that connects safety in urban public spaces (UPS), lighting, and Information and Communication Technology (ICT)-based surveillance to enhance social, cultural, and environmental sustainability in cities. Their study investigated the decline in research on lighting and crime due to the emergence of LED technology and suggested a framework that utilizes dimmable LED lights, sensors, cameras, AI, and data analysis to enhance urban safety, deter criminal activity, and improve public perception of safety. This framework also has the potential to map and categorize crime-prone areas.

In their study, M. Garramone et al. [18] examined the knowledge gaps in GeoBIM for infrastructure asset management and categorized them into three groups: data management, interoperability and integration, and process and service management. The challenges include producing reliable as-built models and ensuring data quality. There are also concerns regarding interoperability between BIM and GIS formats and integrating existing information management systems with GeoBIM. The study emphasizes the advantages of combining BIM and GIS in various asset management functions, such as risk management and facility management. Railways are proposed as a suitable asset class for exploring the integration potential of BIM and GIS. Collaborative efforts to address these issues would benefit the broader GeoBIM community.

Moreover, the application of GIS in police station mapping is a term used in safety and security planning and management, covering a wide range of safety concerns such as resource allocation, efficient delivery of services, and improvement in efficient security. Mapping is a tool that can be used to reveal the relationships between the distribution of police stations and the distribution of facilities in a given area. GIS provides a comprehensive framework and organization of both spatial and non-spatial data, which can assist in decision making. Mapping of police stations, along with information on administrative boundaries and other layers ,such as road networks, provides a realistic picture of geographic coverage.

Safety and security are paramount concerns for modern societies, and the efficient allocation of resources, such as police stations, plays a vital role in maintaining public order. GIS technology has emerged as a powerful tool for analyzing spatial data, aiding decision-making processes, and optimizing resource allocation. This literature review explores the applications of GIS in safety and security, with a specific focus on finding the best location for a police station. The review covers theoretical frameworks, spatial analysis techniques, case studies, and emerging trends in the field.

Dean R. Anderson [19] addressed the challenges of urban crime and the need for effective crime analysis tools within police departments. It highlights the potential of GIS to enhance traditional crime record keeping systems by providing spatial analysis capabilities. The study emphasizes the importance of integrating GIS tools into existing operations, ensuring user-friendly interfaces, and following good design methodology. The applications of GIS in crime analysis extend beyond crime-related issues to other urban problems such as emergency response, permit applications, fire incident analysis, and zoning.

B. Sadoun and O. Al-Bayari [20] discussed Location Based Services (LBS) and the technologies used for positioning, such as GPS and network-based methods. LBS offers personalized services based on user location, utilizing Global Navigation Satellite Systems (GNSS), GIS, and wireless communication. The paper presented two applications: automatic vehicle location for fleet management and a police traffic information system. LBS is in high demand, particularly for information and navigation services, emergency assistance, and network-related services, making it a valuable tool for efficient management and emergency response.

A. T. Pour and W. L. Yue [21] focused in their study on the inadequate positioning of emergency services along roads in Iran, leading to high rates of pre-hospital deaths in road accidents. By utilizing GIS, the study identifies crash black spots and recommends suitable locations for emergency services in Khuzestan province. The findings emphasize the importance of timely access to medical assistance and propose strategies for optimizing emergency response and minimizing social costs.

E. Baloyi [22] used in her study a GIS-based accessibility analysis technique to evaluate and improve the sites of fire stations in the Ekurhuleni Metropolitan Municipality. The analysis examines the spatial distribution of existing fire stations and assesses their ability to meet response time standards. The study identifies areas with inadequate coverage and proposes optimal sites for additional fire stations to address the backlog, providing decision-makers with valuable information for prioritizing and investing in fire services.

V. Indriasari et al. [23] explored the use of GIS in the maximal service area problem (MSAP) for emergency facility location. Their study demonstrated the application of three heuristics (genetic algorithm, tabu search, and simulated annealing) to maximize the service area coverage of fire stations in South Jakarta, Indonesia. The results show that the heuristics outperform the existing coverage, with the tabu search algorithm achieving the highest coverage (83.20%) in the shortest time (3.73 minutes).

A. T. Murray [24] studied the maximal covering location problem (MCLP), which introduced in 1973 and has become a seminal contribution to location analysis and modeling. It has been widely applied, extended, and integrated into GIS software packages. The MCLP remains relevant and significant today, with ongoing research and developments expanding its application areas and improving solution techniques, driven by the goal of providing maximum coverage with limited resources. The MCLP is expected to continue evolving and contributing to location analytics in the future.

The study of A. Kermanshah and S. Derrible [25] aimed to assess the vulnerability of road networks to extreme earthquakes in Los Angeles and San Francisco using a geographical and multi-criteria approach. By simulating the impact of extreme earthquakes and measuring various metrics such as network properties, topological indicators, accessibility, and travel demand, a vulnerability surface (VS) is created to capture the overall vulnerability. The method provides valuable insights for planners and stakeholders in assessing the robustness of transportation systems, prioritizing infrastructure projects, and improving emergency response preparations for seismic events, ultimately contributing to the design of sustainable and resilient cities.

Mark W. Horner and Joni A. Downs [26] addressed the challenges of efficient relief goods distribution in hurricane disaster planning. The study developed a flexible network flow model integrated with a geographic information system to identify accessible locations for intraurban relief distribution sites. The model allowed for cost trade-offs and visualizes relief planning scenarios, demonstrating the impact of cost structure on population accessibility to relief facilities. The research provided insights for future work on comprehensive hurricane relief models, including incorporating stochastic demand, accounting for transportation disruptions, and comparing suggested facility locations with existing relief plans.

F. Zhang et al. [27] proposed an integrated methodology that combines GIS technology, simulation modeling, and optimization techniques to minimize the overall cost of locating and designing biofuel facilities. The GIS-based method is used to select suitable locations for biofuel production, while the simulation and optimization models determine the optimal cost, energy consumption, and emissions for candidate locations. The study demonstrates the effectiveness of this approach in characterizing the biofuel supply chain and provides valuable insights for decision-makers in the biofuel industry. In their study, W. Wey et al. [28] used transit-oriented development (TOD) as an urban sprawl remedy to achieve sustainable mobility. The fuzzy Delphi technique and fuzzy analytic network process (FANP) were used in the study to calculate the weights of the evaluation criteria for TOD based on the goals of sustainable transportation. The outcomes showed that the chosen TOD evaluation criteria are crucial, and the environmental carrying capacity is the most crucial parameter. GIS is also used in the study to assess the performance of mass rapid transit stations (MRT), and it made suggestions for built environment development based on TOD criteria.

M. Jelokhani-niaraki et al. [29] developed a Volunteered Geographic Information (VGI) system for crime management in District #22 of Tehran. The system allowed citizens to report and analyze crime data, providing accurate location, type, photos, and timestamps. The evaluation showed that citizens found the system easy to use and suitable for reporting crimes, while police departments found it helpful in the entire crime management process. Future research can explore integrating the VGI-based crime management tool with other technologies like Multicriteria Spatial Decision Support System (MC-SDSS) and Location-Based Social Networks (LBSN) to enhance crime-related decision-making and citizen engagement in reporting and sharing crime information.

A. L. Achu and R. S. Suja Rose [30] studied the spatial variation and hotspot analysis of crime in Thiruvananthapuram city from 2010 to 2014. Using GIS technology and Geographic data, the research identifies crime hotspots, such as murder, robbery, snatching, and theft incidents. The central area of the city emerges as a crime-prone region, while the northern and southern parts have lower crime rates. The findings highlight the importance of police vigilance and efficiency in controlling crime, particularly in slum areas. The study emphasizes the impact of crime on law and order and the city's growth, emphasizing the need for effective crime control measures.

The study by A. F. Mohammed and W. R. Baiee [31] examines the increasing crime rate in developing countries, focusing on the unequal distribution of psychological and economic conditions. The research uses GIS analysis and data mining algorithms to identify crime hotspots and spatial patterns in Baltimore city from 2012 to 2018. The findings highlight concentrated hotspots in the central area of the city, particularly in homicides, assault by threat, and shooting incidents. The study emphasizes the importance of efficient policing and vigilance in controlling crime in these areas. It also notes that the northern and southern parts of the city generally have lower crime rates. The research underscores the need for effective crime control measures to ensure law and order and promote the city's growth. K. J. Samuel et al. [32] utilized GIS to examine spatio-temporal patterns of household crimes in Durban, South Africa. Their analysis revealed a shift in crime patterns from the city center to less densely populated suburbs, particularly for home burglary, despite multi-level crime prevention efforts. These findings emphasize the necessity for thorough investigations into the socio-spatial factors influencing crime, highlighting that addressing these root causes may be equally, if not more, crucial than allocating additional policing resources to effectively address the rising rates of household crimes.

M. Eh Ong et al. [33] examined the geographic and temporal patterns of ambulance calls in a large urban city and conducted a demand analysis to optimize ambulance deployment. They used GIS technology to map the locations of ambulance calls and analyze response times. The study found distinct patterns in call volumes, with higher volumes during the day and in suburban town centers. The findings can inform the development of a Systems Status Plan for more cost-effective ambulance deployment.

L. Y. Liang et al. [34] presented the development of a GIS and Road Accident View System for managing accident data. The system allowed users to enter, search, and retrieve information from a database, and provided functions such as node analysis and distribution plot for visualizing and analyzing accident locations. The GIS-RAV System offered advantages in terms of quick access to information, accurate location mapping, and identifying accident-prone areas, making it a useful tool for traffic accident applications.

J. M. Restrepo [35] recommends defining technical requirements for application development in GIS and emphasizes the decreasing costs of implementing GIS in business processes. The study suggests using standards for sharing geographic information with stakeholders and leveraging graphical layer styles to improve information readability on maps. It recommends presenting critical moments that require action to the operator rather than managing only external base maps. Additionally, it suggests utilizing map server technology within the company's infrastructure to ensure high service availability.

The study by S. Islam [36] explores the concept of Community Policing (CP) as an organizational strategy and philosophical approach that fosters collaboration between the police and the community to prevent and solve crime while promoting human security. The research emphasizes the need for a shift in police methods and practices towards a proactive approach, as well as the importance of building strong relationships between the police and the public. In Bangladesh, the police traditionally focus on reactive measures, lacking awareness, training, and leadership in crime prevention and community safety. The study delves into the implementation of community policing, its contributions to crime prevention, and strategies to enhance its effectiveness, aiming to create a safer and more secure Bangladesh. Recommendations include clarifying the working philosophy of community policing, developing clear policies and functions, providing proper training to police officers, expanding community police centers across districts, and evaluating community policing efforts based on qualitative indicators. The study emphasizes that community policing is essential for decreasing crime, ensuring human security, and fostering a peaceful society in the face of increasing population and crime rates in Bangladesh.

M. Saraiva et al. [37] concentrated on improving urban safety and security through the analysis of crime patterns using geospatial technologies, machine learning, and sentiment analysis. The study effectively identified crime hotspots and related factors, highlighting the significance of adopting a comprehensive approach that integrates various data sources and underscores the necessity for more in-depth modeling and spatial comprehension in urban crime analysis and policy formulation.

The Mexican Transportation Institute (IMT) developed a GIS-based data management system to handle accident data on federal roads in Mexico [38]. This system aims to improve efficiency and reliability by automating data processing. The study focuses on the implementation of the system in Oaxaca and highlights its use in generating meaningful results. The cost-effective and capable ArcView GIS was chosen for this project. The integrated data includes cartographic representation, road classification, traffic volume, and accident information. The findings reveal inadequate distribution of emergency medical aid centers in Oaxaca and other states. The study suggests applying similar systems for other relevant data to support planning purposes, such as infrastructure and pavement management.

The study by J. Choudhary et al. [39] focuses on highway safety engineering, aiming to reduce traffic accidents by identifying and evaluating measures to improve highway safety. The research utilizes GIS and spatial analysis techniques to visually and statistically identify accident hot spots in Varanasi city. The findings demonstrate the concentration of hot spots in various road stretches and intersections, offering valuable insights for planning and management strategies to enhance traffic conditions. The study compares statistical methods and severity weighing systems, highlighting the effectiveness of the Getis-Ord Gi statistic in accurately identifying hot spots in mixed traffic conditions. The research provides practical implications for accident reduction and improved traffic operating conditions, emphasizing the need for detailed accident records and future research on optimal severity weighing systems.

The aim of this thesis is to create a spatial analysis approach to identify the most suitable locations for police stations within Azaz. This approach will involve the integration of diverse data sources, such as crime statistics, population density, road networks, and emergency response times. By utilizing these data sets, the study seeks to identify areas that are currently underserved by existing police stations and require additional coverage. The ultimate objective is to develop a comprehensive and systematic method that decision-makers can utilize to pinpoint optimal sites for police stations, maximizing their effectiveness in both preventing and responding to crime.

CHAPTER 3
METHODOLOGY

3.1 Introduction

In today's complex and rapidly changing world, ensuring the safety and security of communities is of utmost importance. Effective law enforcement plays a crucial role in maintaining peace and order within a society. However, determining the optimal locations for police stations presents a challenging task, especially in areas affected by conflict and instability. This is particularly true for the city of Azaz, which has experienced significant turmoil and upheaval in recent times.

In response to the pressing need for enhanced law enforcement capabilities in Azaz, this thesis employs a spatial analysis approach to determine the best possible locations for police stations. By utilizing GIS technology and geospatial data, this methodology aims to provide valuable insights and recommendations to support the establishment of an efficient and strategically positioned network of police stations in Azaz (figure 3.1).

The spatial analysis approach offers a systematic framework for evaluating various factors that influence the optimal placement of police stations. This includes considering factors such as population density, crime hotspots, transportation accessibility, and existing infrastructure. By integrating these diverse data sources and conducting spatial analyses, this methodology seeks to identify areas within Azaz that would benefit the most from the presence of police stations, ensuring wider coverage and rapid response to potential incidents.

This study endeavors to make a meaningful contribution to the law enforcement and community safety field in Azaz. By utilizing spatial analysis and GIS technology, it aims to assist decision-makers and stakeholders in establishing an optimized network of police stations, thereby enhancing the security and well-being of the community.

3.2 Comprehensive City Profile of Azaz

3.2.1 Executive Summary

Due to its proximity to the Turkish border, Azaz developed a twofold role in recent years (figure 3.1). On the one hand, it grew as a trade center where Turkish products feed into the regional markets. On the other hand, Azaz and its surroundings adopted the role of a refugee hub. The resulting influx of Internally Displaced People (IDPs) has led to an increased pressure on the already-deteriorating infrastructure. However, since early 2016, many left the city because of conflict escalation.

Azaz's 56,000 residents cluster around its central neighborhoods. More than half of the population are male. Ethnically, the majority are Arabs with a Kurdish minority. IDPs represent one in every four among the city's residents. They mostly come from other parts of Aleppo Governorate, and this has helped ease their social integration in Azaz. One third of the population are under 15 years old, and as high as 10% of school students are estimated to have dropped out school. Azaz residents tend to live close to their relatives, indicating a high density of family bonds within the city.

City boundaries cover 4.25 km2 of land, slightly more than half of which is built. The majority of the city's 6,600 buildings are modern connected buildings. Housing occupancy rate is high, and it follows that rental rates are relatively high as well. This denies many IDPs access to housing in the city: an additional 85,000 IDPs live in camps around the city.

In recent years, about 400 residential buildings were damaged or destroyed as a result of the conflict. In addition, several schools, markets and health centers were partially damaged. Most health centers are no longer in service; in most cases, residents have to leave the city for medical services. Electricity, water and sewage disposal networks have become dysfunctional. This is because of supply shortages in some instances, and network sources being located in other groups' control areas in others. Service shortages fertilized the ground for private local service provision as a coping mechanism.

Azaz has a service-centric economy with retail at its core. It has benefited from its location as a connecting market for the distribution of Turkish goods, typically sold at markets in the city center. To keep up with housing market growth, construction has boomed in recent years. Agriculture and manufacturing provide a limited number of jobs to residents. Men have a more evident presence in the workforce than women, and their employment rate is high. While the conflict led some businesses to close, a number of new activities emerged, such as private provision of electricity and water, and trade of used clothing and furniture.

Surrounded by conflict boundaries, Azaz communicates with its periphery through a limited flow of people and exchange of goods. As for goods, Azaz has can import from Turkey, but has a limited access to its hinterland and the rest of Syria. This translates into food and fuel shortages. While residents can easily move to other areas in the Azaz Nahiya, their mobility further afield is quite restricted. Passing through checkpoints of other control groups means that they have to undergo security measures and bear additional costs. Due to geopolitical changes, Azaz has been adapting to survive through minimal exchanges with the outside world.

Figure 3.1. Azaz City

3.2.2 Land Use

In Azaz city in Syria, the land use is characterized by distinct features: the central fort serves as the primary focal point, while residential buildings dominate the built-up area, particularly in the city center and certain northern sections. The city is home to three significant markets, ensuring accessible shopping options for its residents. Educational facilities, including primary and intermediate schools, are strategically dispersed, with most students residing within a 1-kilometer radius of their school. Healthcare services are primarily concentrated in the central and western parts of the city (figure 3.2). Agricultural activities are evident in the western, southwest, and northeastern areas, and light industrial workshops are situated in the northeast. The northern part of Azaz remains largely undeveloped. Regrettably, the establishment of refugee camps in the vicinity led to the felling of approximately 5,000 trees, impacting the city's natural surroundings (Figure 3.3).

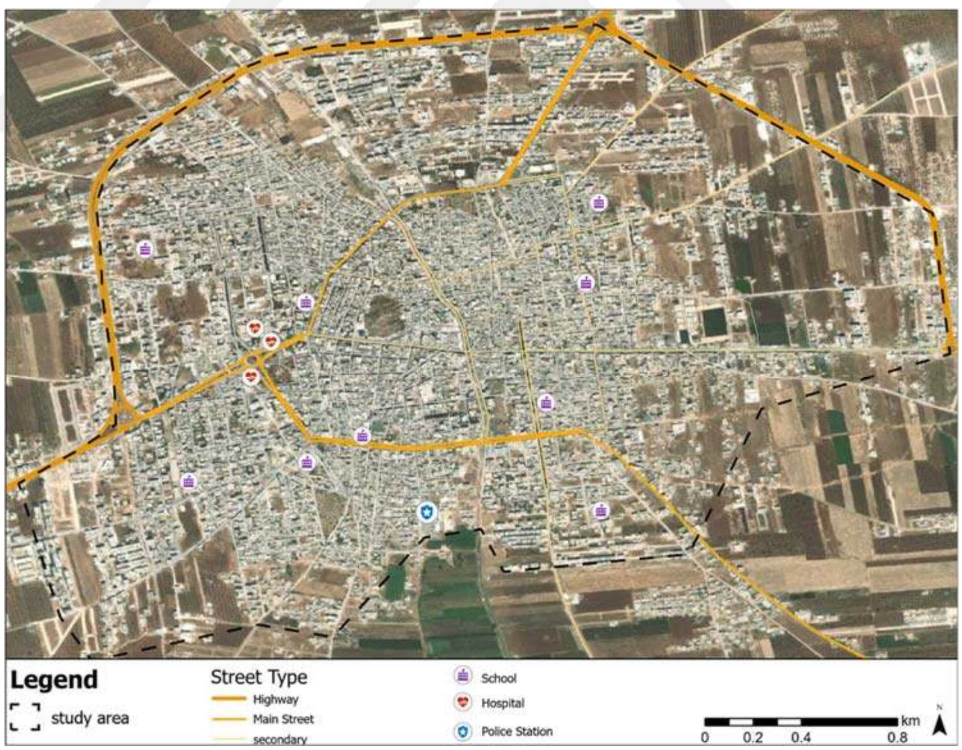

Figure 3.2. Street Network of Azaz City

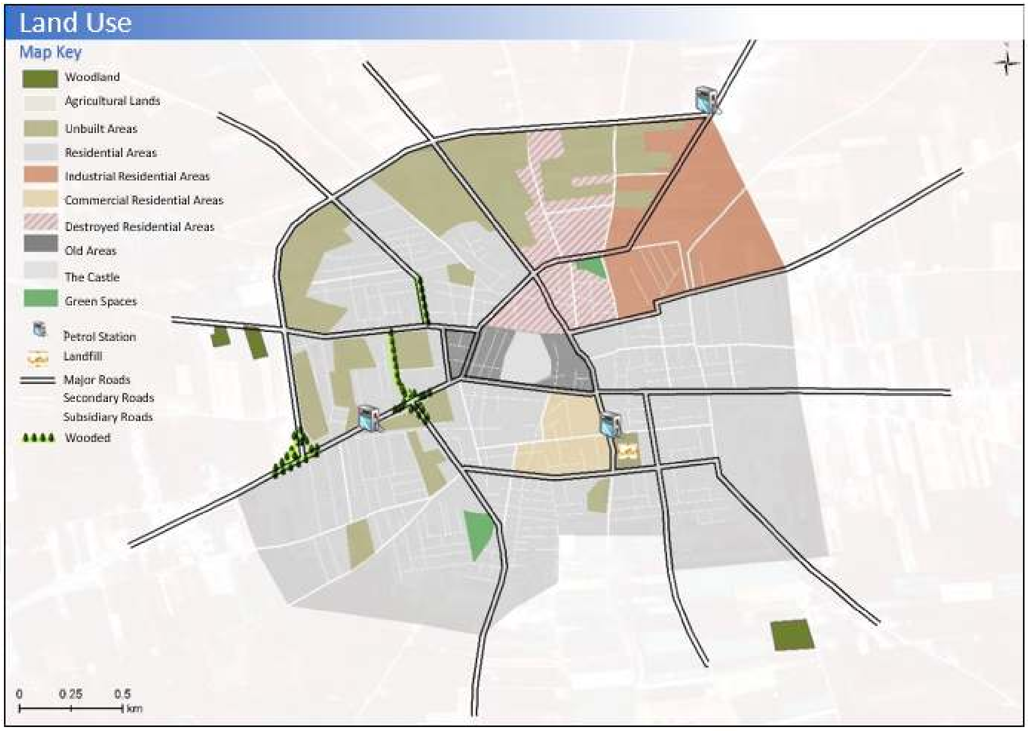

Figure 3.3. Land use of Azaz City

3.2.3 Regional Context

Azaz lies in the northwest corner of Syria near the border with Turkey. Administratively, it is the seat of Azaz Nahiya (Subdistrict) which is part of the Azaz District of Aleppo Governorate. It is around a 50 km drive north from Aleppo. It lies on the route between Aleppo and the Turkish border crossing of Bab Al-Salameh. To its north, the Turkish city of Killis is only 15 km away (figure 3.4).

The city is the economic pole of the Nahiya. Residents of surrounding villages flow to Azaz for work, shopping and administrative purposes. In addition, the city has received over 10,000 IDPs mostly arriving from Aleppo Governorate. A larger number settled around the city in camps. However, because of worsening security, some IDPs have been leaving the city lately. Azaz has a logistical significance due to its proximity to the Turkish-Syrian border. On the one hand, this stems from trade advantages, which allowed the city to become a connecting point for Turkish products retailed in local markets and distributed to regional ones. On the other hand, this logistical importance relates to military control (figure 3.5).

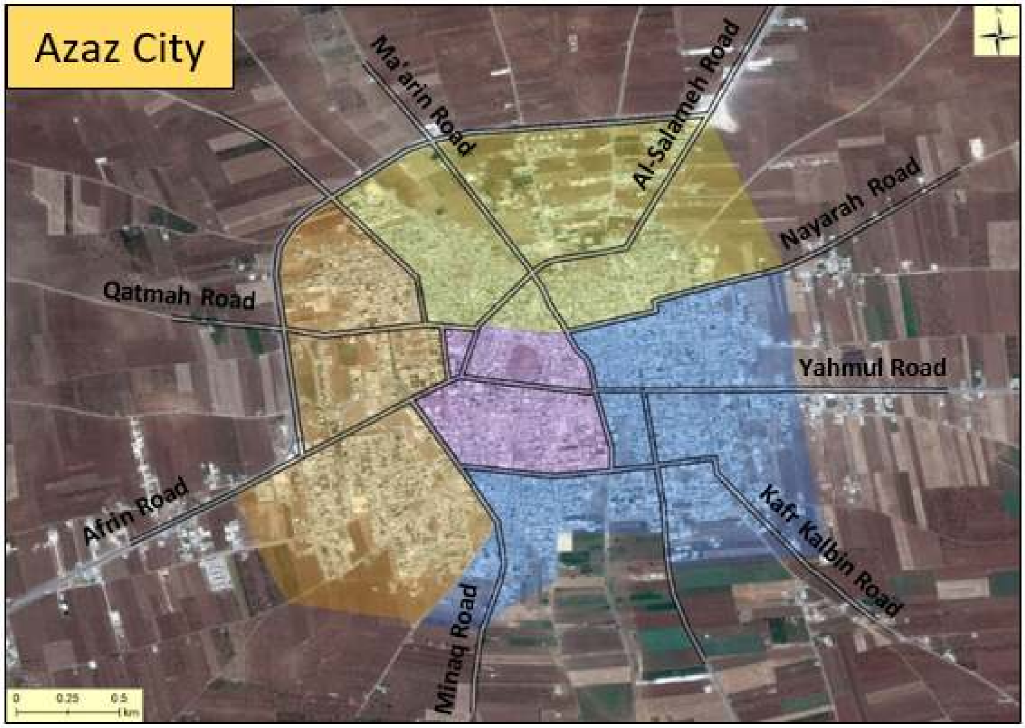

Figure 3.4. Aerial View of Azaz City.

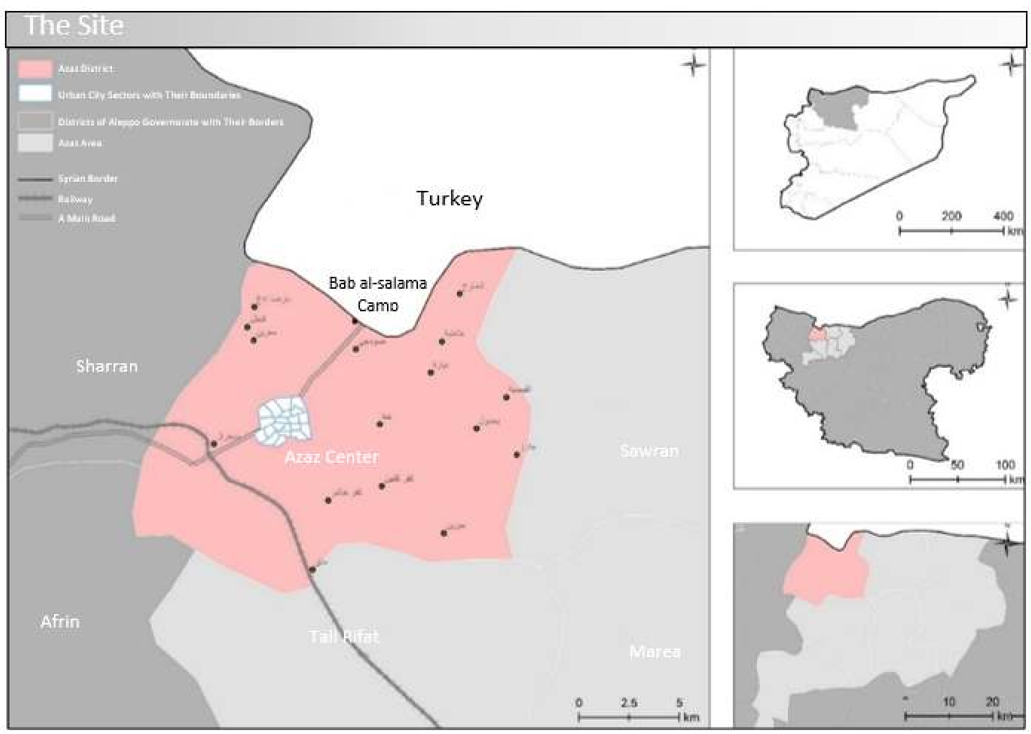

Figure 3.5. The location of the city of Azaz and its borders.

3.2.4 Urban Structure and Development in Azaz City

The urban structure of Azaz city is characterized by various features and patterns that define its layout and development.

Regarding the urban structure, the city encompasses an area of approximately 4.25 square kilometers, with roughly 56% of this area developed. Within this space, you can find 6,600 residential buildings spread along 340 streets. Population density tends to be higher in the central and northern neighborhoods, while it is lower in the western, southeastern, and some northern parts (figure 3.6). When it comes to the building types, over half of the city's structures are modern connected buildings, while approximately one-fifth are comprised of old houses nestled in narrow alleyways, and another one-fifth consist of informal housing units (figure 3.7 and figure 3.8). The prevalence of modern connected buildings is noticeable in central and southeastern neighborhoods, whereas old houses are more common in the northern and western areas. Informal housing, on the other hand, is particularly visible in the northern and southeastern neighborhoods, accounting for a significant portion of the housing stock. Urban expansion is concentrated in areas with relatively lower density, especially in the southeast, while large vacant land lots can be found along the northeastern and southwestern perimeters of the city. Additionally, the city is encircled by agricultural lands on all sides.

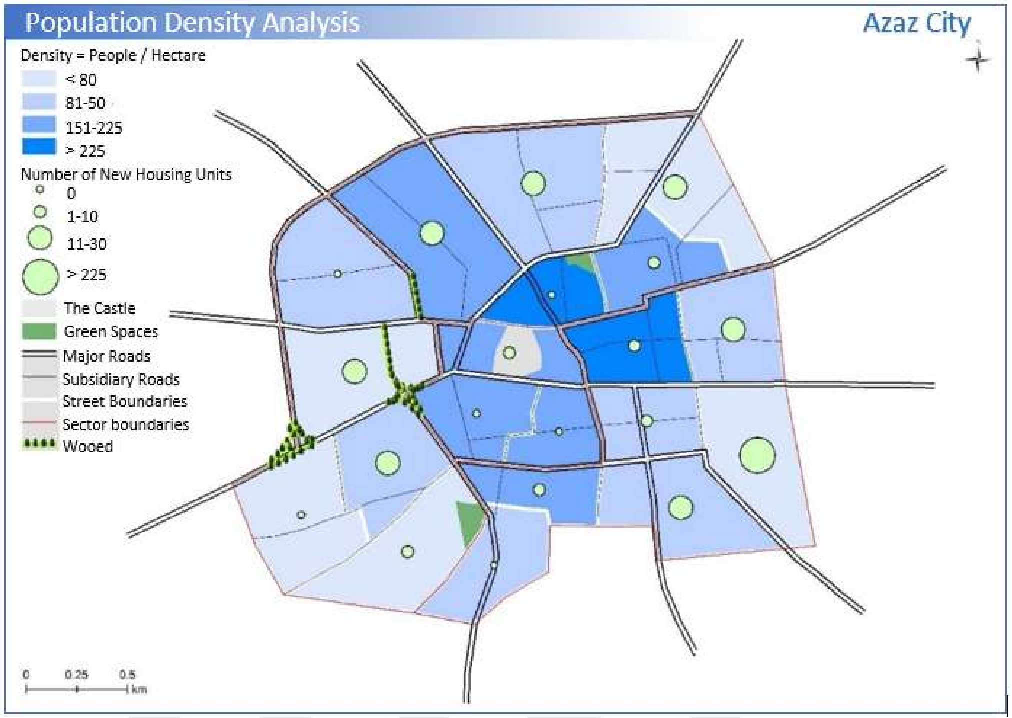

Figure 3.6. Population Density Analysis and New Building Distribution in Azaz.

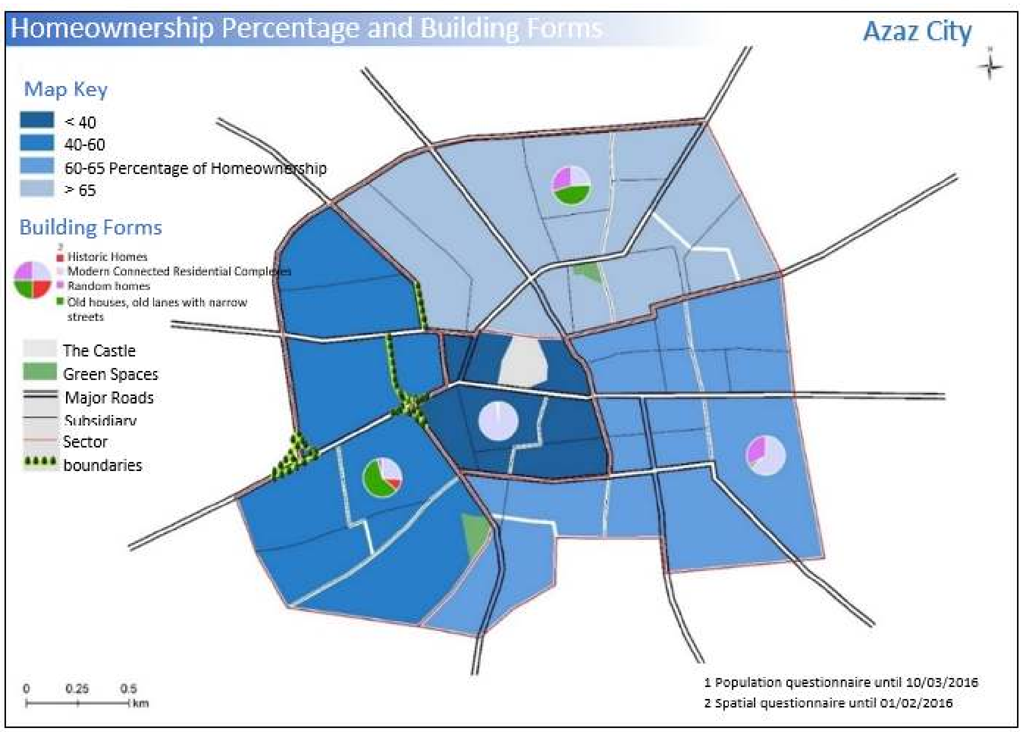

Figure 3.7. Urban Structure of Azaz City and Homeownership Percentage.

Figure 3.8. Street View Snapshot: Azaz City.

3.2.5 Population and Displacement

Around 56,000 are estimated to inhabit the city of Azaz. Approximately 56% of the population are male. One third of the population are between 6 months and 15 years old. Median age is 30. On average, families consist of 5.2 members each. Ethnically, the majority of the population is Arab with a Kurdish minority (figure 3.9).

IDPs represent one in every four among the city's residents. They mostly escaped conflict zones in Northern Syria. The majority came from other parts of Aleppo Governorate, and this has helped ease their social integration in Azaz. Most of the IDPs sought refuge more than once since 2011 (figure 3.10).

Within the city, IDPs live in refugee centers, schools and mosques. Some families rent houses, mostly sharing them with other families. An additional 85,000 IDPs live in camps around the city.

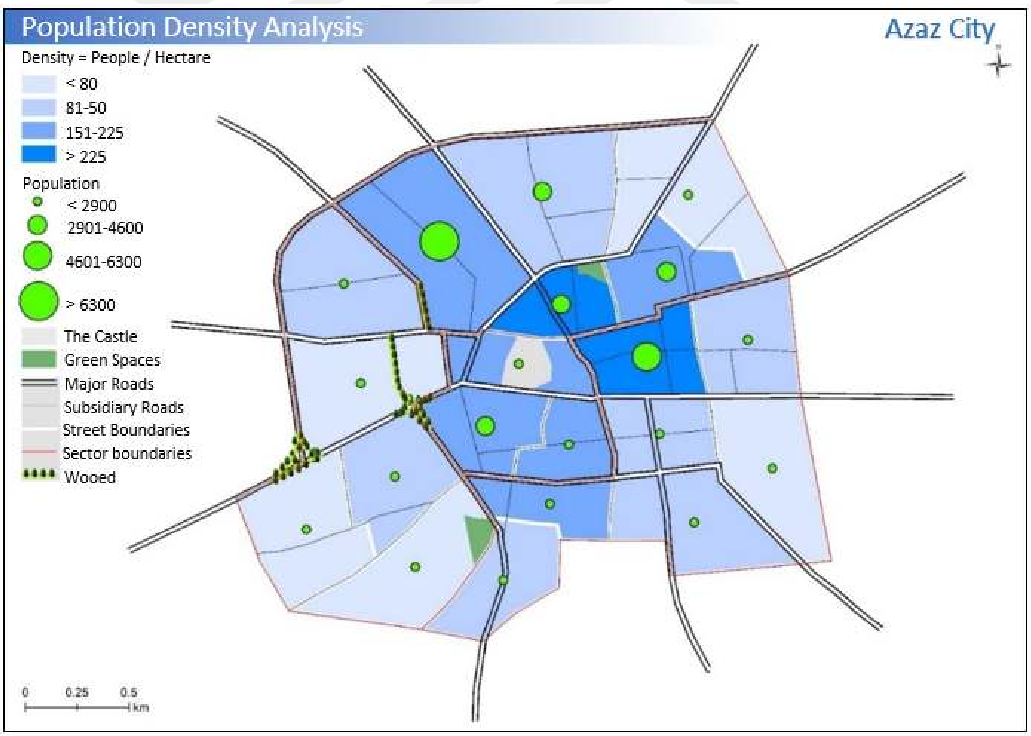

Figure 3.9. Population density in Azaz.

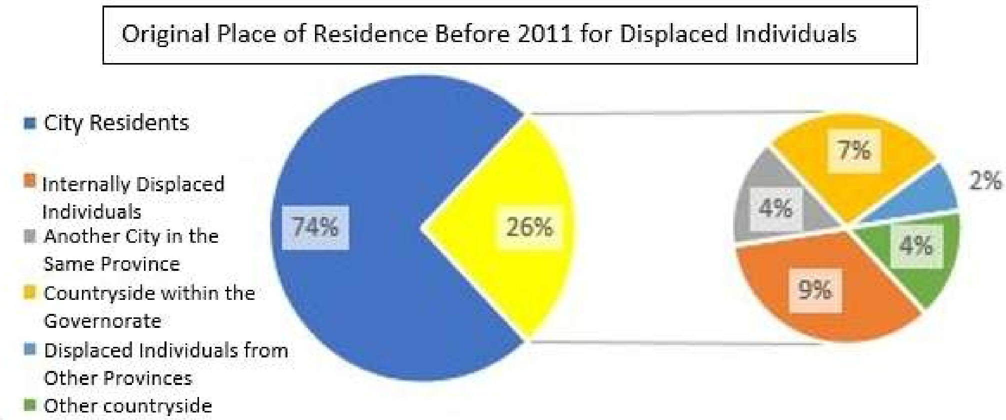

Figure 3.10. The original place of residence of the displaced before 2011.

3.2.6 Damage Assessment

The assessment of damage in Azaz city reveals several significant impacts on its infrastructure and facilities. Approximately 400 residential buildings, constituting approximately 6% of the city's housing stock, suffered damage or were completely destroyed (figure 3.11). Roads throughout the city have experienced a general deterioration, with the northwestern areas being particularly affected, largely due to factors such as shell damage and heavy vehicular traffic. The city's healthcare infrastructure was also significantly impacted, with four hospitals and health centers rendered inoperative due to fighter attacks. Additionally, three out of thirteen schools sustained partial damage, and the Al-Akrad market was partially destroyed. Some manufacturing workshops in the industrial area ceased operations due to damage dating back to early 2016. Although minimal damage is estimated to have affected the electricity and water infrastructures within the city, more than half of the sewage network is in poor condition due to a lack of maintenance.

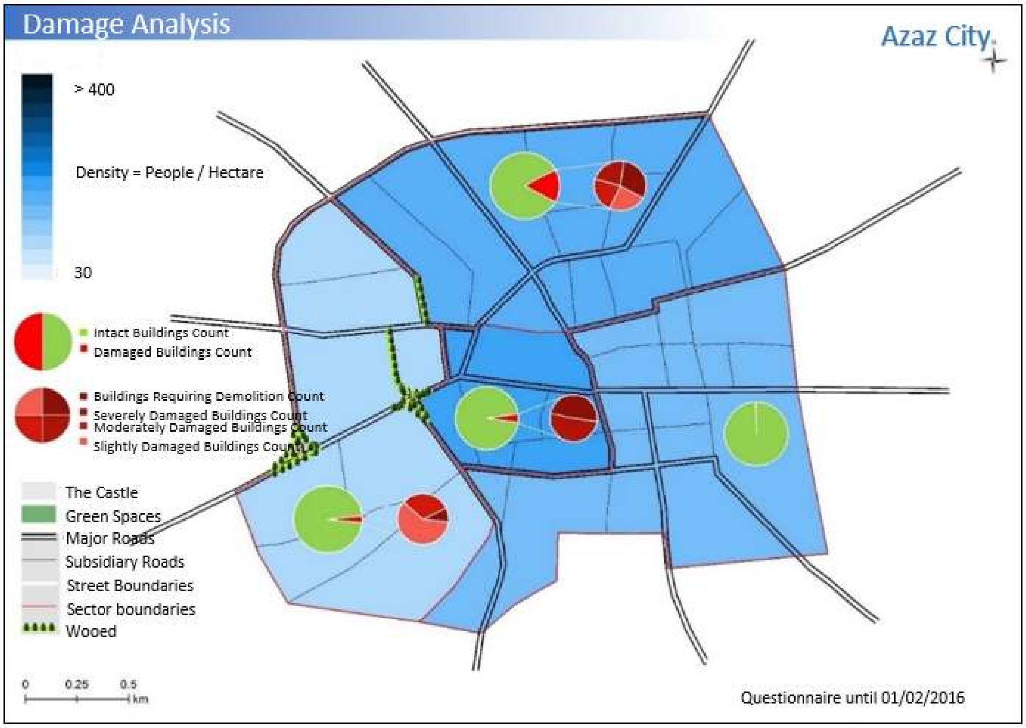

Figure 3.11. Analysis of damages in residential buildings in the city of Azaz.

3.2.7 Sector Analysis

3.2.7.1 Infrastructure in Azaz City

In Azaz, the housing landscape comprises approximately 6,600 residential buildings, with modern connected buildings accounting for more than half of this inventory. Notably, a quarter of the city's residents rent their homes, reflecting a significant rental market. High occupancy rates contribute to elevated rental costs, rendering city housing inaccessible to many IDPs, who instead reside in surrounding camps. On average, 1.4 individuals inhabit each room in these houses. The housing market sees homes selling for an average of $130-140 per square meter, while a typical 110-square-meter dwelling rents for $40-80 per month.

The electricity infrastructure in Azaz has experienced minimal damage, although electricity supply has been disrupted since the Hritan electrical power station ceased operation. The city relies on individual providers, operating around 60 generators, to supply electricity for an average of 8 hours daily, charging subscribers $2 per ampere per week. Maintenance of these generators occurs locally, with most generators and spare parts being imported from Turkey. While shared-generator providers are the primary source of electricity for most households, one in three households utilizes their own generators, contingent on the availability of fuel in the local market. Regrettably, the use of clean energy sources remains extremely limited (figure 3.12).

The water supply in Azaz faces challenges, as water pumping from the Midanki source station has been disrupted. Water extraction now relies on three communal artesian wells, primarily serving the northern parts of the city. Individual water table wells are common but are often polluted (figure 3.13). The City Council maintains these communal wells, but the extraction and pumping of water are dependent on fuel availability. Many neighborhoods resort to obtaining water through water tank trucks, incurring costs of $40 per cubic meter. Sewage disposal follows a river path that carries sewage outside the city to a designated land plot, but more than half of the sewage network is in disrepair due to a lack of maintenance, leading some residents to resort to informal sewage installations (figure 3.14).

Solid waste management involves twice-weekly collections at various points across the city, amounting to an average daily collection of 9 tons of waste. However, an additional 10 tons or more remain uncollected due to limitations in machinery and financing. These collected wastes are transferred to two landfills, one located within city limits and the other 2.5 km away. Unfortunately, no recycling efforts are in place at these sites, and the landfill within the city poses environmental hazards (figure 3.15).

The city's communication infrastructure remains functional, with a functioning phone land network. Syrian and Turkish mobile networks are accessible within Azaz, and residents often subscribe to internet plans offered by the Turkish network for their connectivity needs.

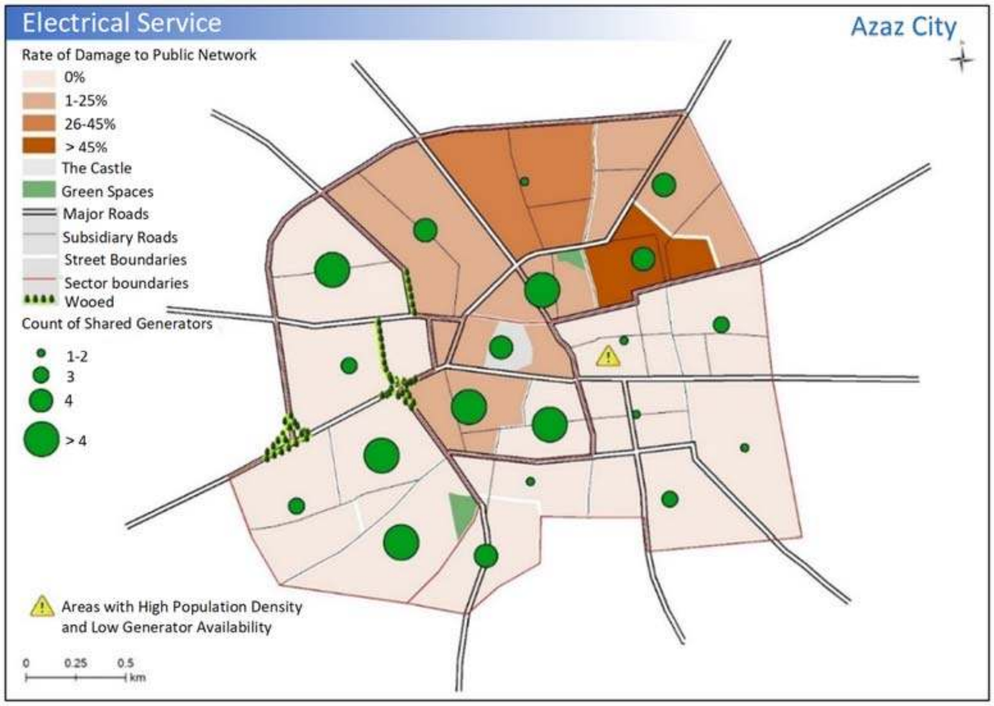

Figure 3.12. Damage to electrical service and distribution of shared generators in the city of Azaz.

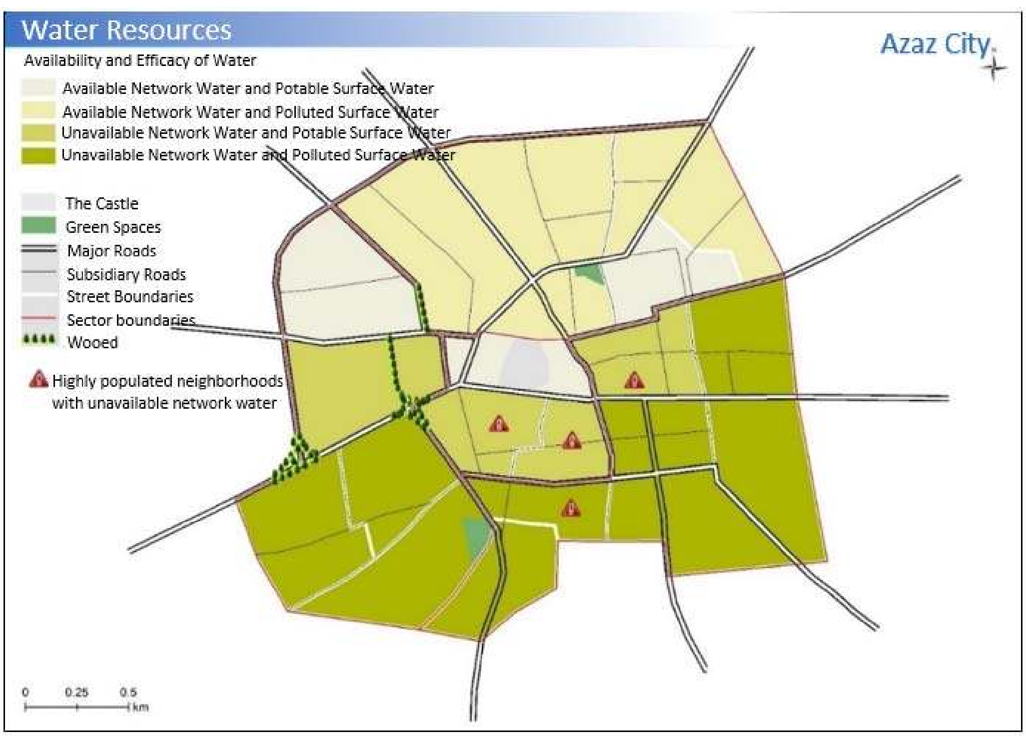

Figure 3.13. Water sources in the city of Azaz.

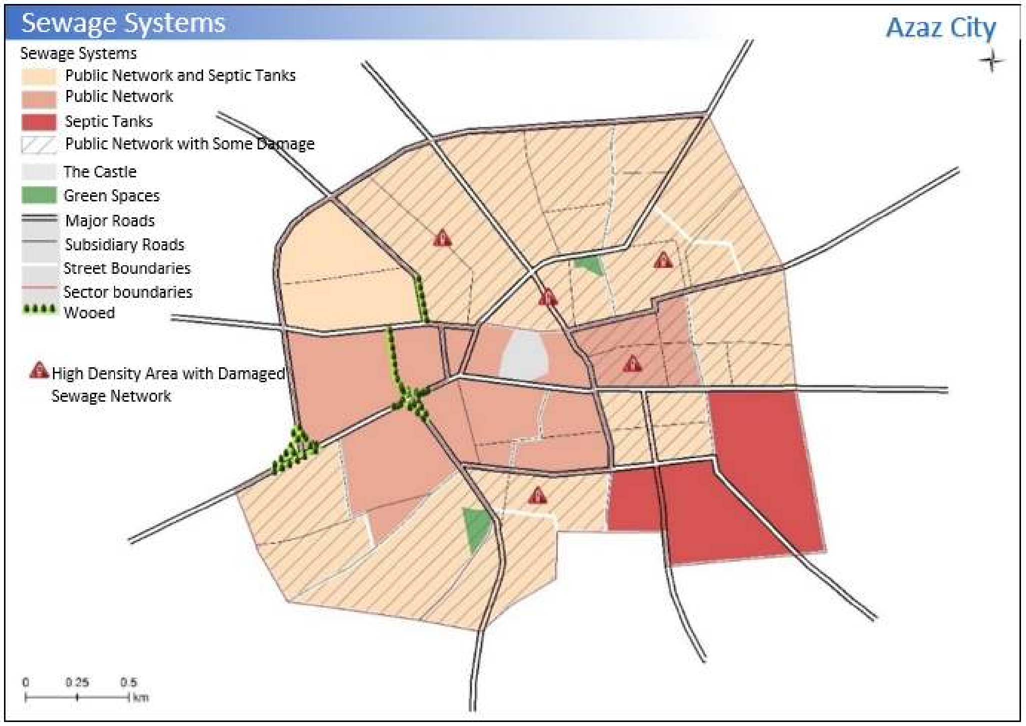

Figure 3.14. Sewage systems in the city of Azaz.

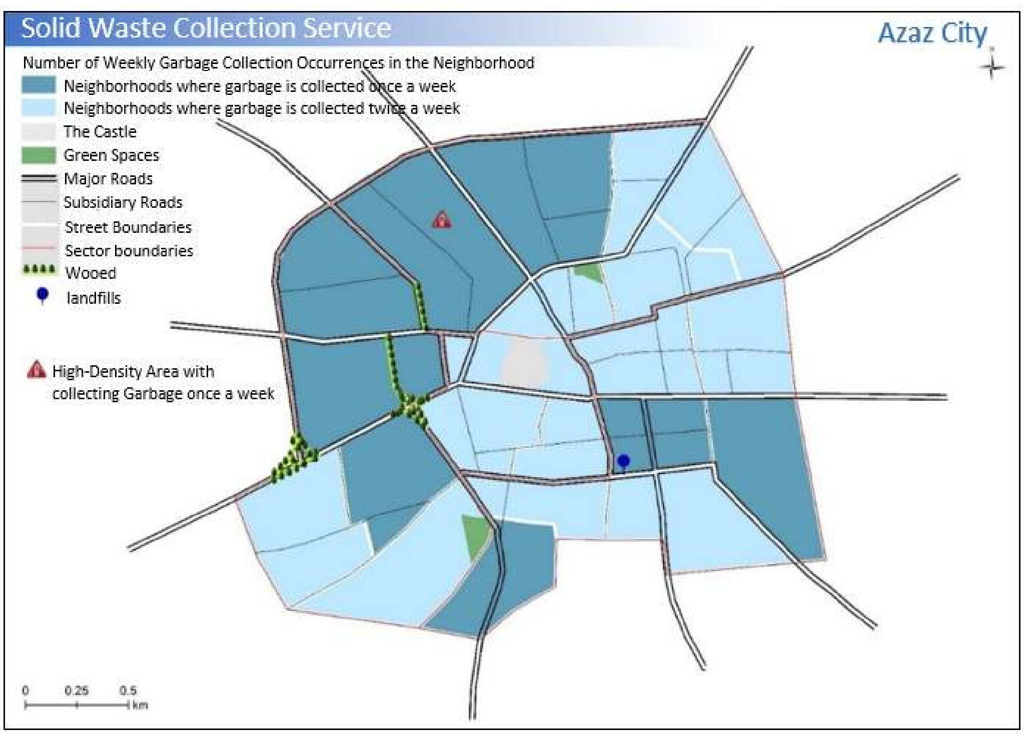

Figure 3.15. Solid waste collection service in the city of Azaz.

3.2.7.2 Healthcare and Education in Azaz City

In Azaz city, the healthcare system includes three hospitals, with one specializing in pediatrics, as well as a dispensary. Unfortunately, three additional hospitals have become non-functional due to damage incurred during the conflict. Healthcare facilities, even those that are operational, often face shortages of medical staff, essential equipment, and operation facilities. Additionally, two dispensaries located between Azaz and the Bab Al-Salameh border crossing struggle with a scarcity of medical personnel, especially gynecologists. Ambulance services are managed by the Aleppo Health Administration and are primarily used to transfer individuals injured during conflict situations to the nearest health center. While both local and imported medicines are available, the price of local medications has significantly increased (figure 3.16).

In the realm of education, Azaz houses 13 schools, with four of these schools currently repurposed to accommodate IDPs. These educational institutions consist of seven primary and intermediate schools and two secondary schools, catering to approximately 4,600 students, with females comprising 60% of the student body. The teacher-to-student ratio averages 1:24. Nevertheless, security challenges and financial constraints contribute to a dropout rate of one in every ten students, highlighting the educational hurdles faced by the community.

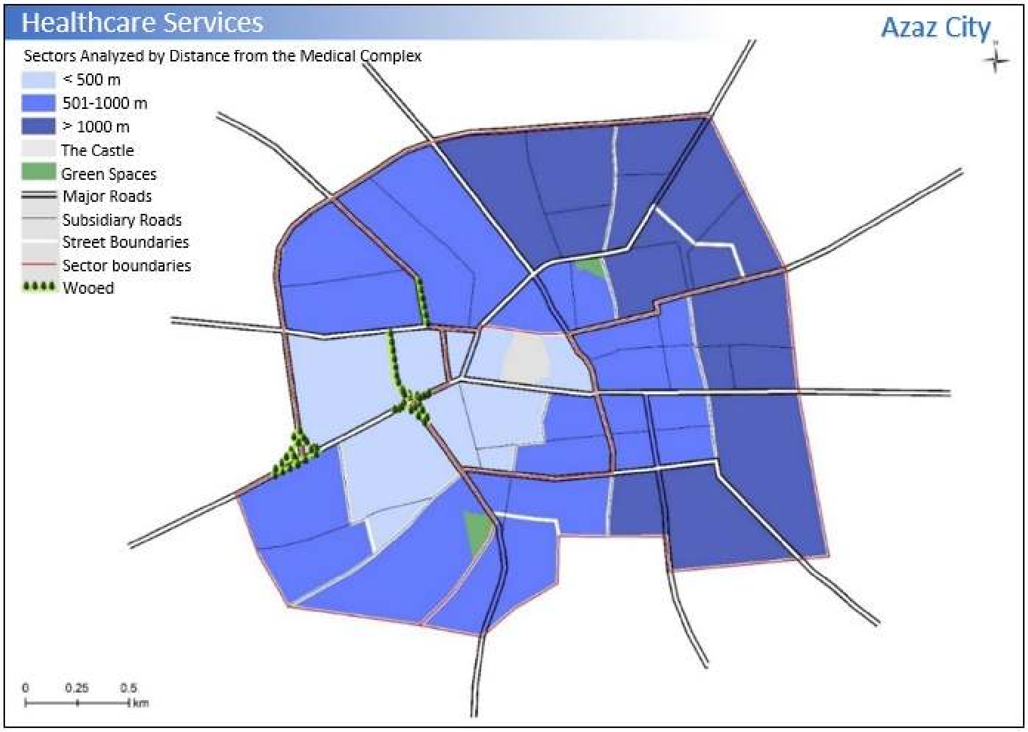

Figure 3.16. The sectors are referred according to their distance from the medical complex in the city of Azaz.

3.2.7.3 Security and Food Situation in Azaz City

In Azaz, human security is a prominent concern for its residents, with over 30% considering it their top priority, despite the absence of military bases within the city. Sadly, violent conflict remains a significant contributor to approximately 50% of deaths. The local police center, comprising about 100 employees, is underutilized by most residents when dealing with security issues, as they typically seek support from local leaders or the court.

Turning to food security, agriculture in the city primarily relies on rainfed methods, with key agricultural products including olive, wheat, barley, onion, potato, and cherry, predominantly sourced from Azaz and its hinterland. The livestock industry faces limitations due to resource shortages, with only 60% of the demand for fodder being met. Daily milk production hovers around 3 tons, and the city's automated bakery, alongside five other bakeries, produces approximately 22.5 tons of bread each day. Many residents also rely on gas for cooking, but the instability in fuel supply and pricing poses a significant risk to their food security.

3.2.7.4 Transportation and Accessibility in Azaz City

In terms of transportation in Azaz, approximately one in every five households owns a car, while more than half of the population relies on shared means of transportation. Most workers have commutes of less than 15 minutes to their workplaces, whereas many students spend up to 30 minutes traveling to school. Family visits typically take less than 15 minutes. Despite roads being in moderate condition on average, their condition has deteriorated since the conflict began, particularly in the northwestern areas due to factors like shells, tanks, and unmonitored heavy-truck usage. Road maintenance efforts have been limited, with the last large-scale maintenance occurring in 2008 and some limited maintenance in late 2015 (figure 3.17).

Accessibility to and from Azaz faces challenges, as movement of people and goods often necessitates passing through checkpoints controlled by various groups, restricting accessibility to the city. Azaz is in close proximity to the Bab Al-Salameh border crossing with Turkey, allowing for the importation of certain goods. However, neither good nor residents are currently permitted to move in the opposite direction, further impacting accessibility.

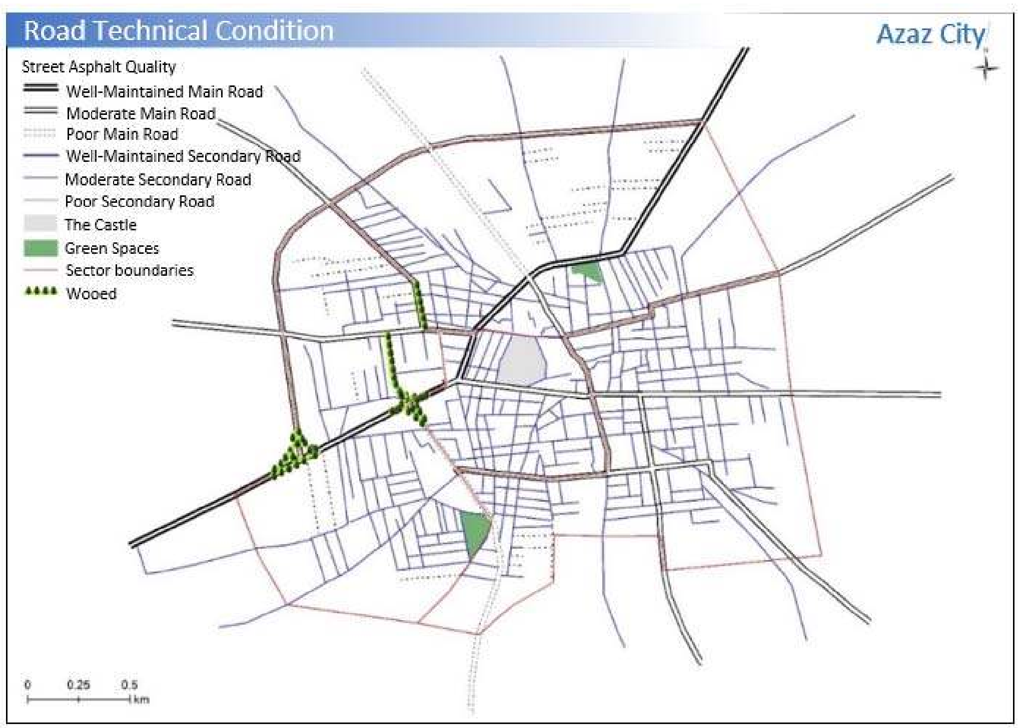

Figure 3.17. The Technical Condition of the Roads in the City of Azaz.

3.2.7.5 Economic Activities in Azaz City

Azaz's economy predominantly relies on services, with retail trade being a prominent economic activity. Its strategic location near the Turkish border has positioned it as a crucial connecting market for the distribution of Turkish goods, which are typically sold at markets in the city center, including Al-Akrad, Al-Kabir, and Al-Bazar. While manufacturing plays a role, it offers a limited number of jobs, primarily focusing on providing maintenance services for vehicles and agricultural machinery. However, some of these workshops were forced to close due to attacks in early 2016.

The city has experienced a construction boom in recent years to accommodate the growing housing market. Employment is diverse, with approximately 8% of the workforce engaged in agriculture and another 15% in the education sector. Despite the absence of banks or financial institutions, money exchange and transfer brokers have become more numerous. Notably, men have a more prominent presence in the workforce compared to women, with only 13% of women being employed. However, over 80% of household heads are engaged in employment (figure 3.18).

Additionally, the conflict has given rise to new economic activities, including smuggling, private provision of electricity and water, as well as the trade of used clothes, furniture, and cars.

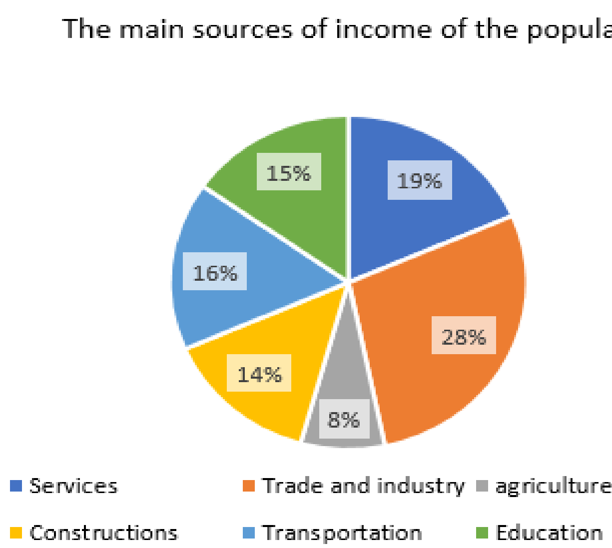

Figure 3.18. The main sources of income for the population in the city of Azaz.

3.3 Current case study area: Urban Dynamics and Security Landscape

3.3.1 Land Use Dynamics and Security Considerations in Azaz

In terms of land use, Azaz exhibits a specific pattern that influences the city's security dynamics. The focal point of the city center is the fort, which holds historical and cultural significance. The majority of the built area consists of residential buildings, particularly concentrated in the center and certain parts of the north. These densely populated areas can have implications for safety and security.

Within the city center, three major markets serve as bustling economic hubs, attracting a significant number of residents and visitors. This concentration of commercial activity may present security challenges, such as the risk of theft or other criminal activities. Dispersed throughout the city are schools, ensuring that most primary and intermediate school students have convenient access to educational facilities within a 1 km radius from their homes. This proximity contributes to the safety and security of children who can easily commute to school.

Healthcare facilities are primarily located in the central and western areas of the city, ensuring that residents have access to medical services. However, the geographical distribution of these facilities may pose security challenges in terms of transportation and emergency response times. In the western, southwest, and northeastern parts of Azaz, agricultural land is utilized, which not only contributes to the city's economy but also provides a source of food security for the population.

In terms of industrial activities, light industrial workshops are predominantly situated in the northeastern region of Azaz.

Significantly, a large portion of the northern part of Azaz remains unbuilt, potentially leaving open spaces that could be utilized for various purposes. The security implications of such unbuilt areas depend on factors like surveillance, access control, and the potential for illegal activities.

The diverse land use in Azaz, ranging from residential and commercial areas to agricultural and industrial zones, poses security challenges that require comprehensive planning and management strategies. Balancing the needs of the population with maintaining a safe and secure environment is crucial for the overall well-being and stability of the city.

3.3.2 Urban Structure of Azaz

The city proper of Azaz spans across 4.25 km2 of land, with approximately 56% of this area being built-up. A total of 6,600 residential buildings are distributed along 340 streets, reflecting the urban fabric of the city.

Population density varies across different neighborhoods within Azaz. The central and northern areas exhibit relatively high population density, while the western, southeastern, and certain parts of the northern neighborhoods experience lower population density.

The majority of the building area in Azaz consists of modern connected buildings, comprising over half of the housing stock. These buildings are prevalent in the central and southeastern neighborhoods. Another notable portion, approximately one-fifth of the housing stock, consists of old houses characterized by narrow alleys. These older structures are commonly found in the northern and western areas of the city. Additionally, informal housing units make up approximately one-fifth of the housing stock, with higher visibility in the northern and southeastern neighborhoods. These informal units contribute to the diverse housing landscape in Azaz, representing about one-third of the overall housing stock in those areas.

Understanding the distribution and characteristics of residential buildings in Azaz is crucial for assessing the city's security and housing conditions. The combination of modern connected buildings, old houses, and informal units presents unique challenges in terms of infrastructure, access to services, and overall safety. Managing and addressing these diverse housing types is important for ensuring the security of the city's residents.

3.3.3 Human Security in Azaz

Human Security in Azaz: Safety Concerns and Challenges

While the city is free from military bases of any partition, it still faces significant safety challenges. Security is the top concern for over 30% of residents, highlighting the prevailing sense of insecurity.

Violent conflict plays a significant role, contributing to approximately 50% of deaths in the area.

Azaz has a local police center with around 100 employees, but most residents do not rely on the police when dealing with security issues. Instead, they typically seek support from local leaders or turn to the court for assistance.

3.4 Methodology of the study

The methodology utilized in this research comprises four main parts (figure 3.19):

In the first part (1), critical zones were delineated around the existing police stations using network analysis. These zones represented areas that could be reached within one minute of travel time and were considered crucial for police coverage. Within these critical zones, demand points were identified, including facilities related to education, health, and tourism services.

In the second part of the methodology (2), a ranking multi-criteria decision-making analysis method was employed to identify areas within the critical zones that were at higher risk for crime or required increased police presence. This analysis facilitated the generation of a suitability map highlighting areas with higher crime susceptibility, allowing for a targeted approach in selecting optimal locations for new police stations. The highly suitable areas were then overlaid with aerial photographs to assess the availability of land for potential police station locations, ensuring that the physical feasibility of establishing new police stations was taken into consideration.

In the third part (3), facility location-allocation techniques were used to further refine the selection process to identify the best location for a new police station. Factors such as accessibility, risk-prone areas, and land availability were carefully considered in order to determine the optimal location. This comprehensive analysis enabled the research to provide evidence-based recommendations for placing new police stations, maximizing their effectiveness in addressing crime prevention and response.

Finally (4), the model and its characteristics were illustrated to provide a comprehensive understanding of the methodology employed in this research. The specific tools and techniques used may vary depending on the software or technology employed, such as ArcGIS or other GIS software. Adapting the methodology to the available resources and technology is essential, ensuring its applicability and reproducibility in similar studies.

Through the utilization of this approach, the objective of this study is to provide assistance to individuals involved in decision-making and those with vested interests. This assistance is directed towards the improvement of law enforcement capacities, with a focus on safeguarding the well-being and tranquility of the Azaz community. The insights and suggestions generated from this investigation possess the potential to play a role in the establishment of police stations that are not only operationally proficient but also tactically advantageous. This, in turn, works towards cultivating an atmosphere that prioritizes the safety and security of Azaz's inhabitants, ultimately contributing to their overall welfare.

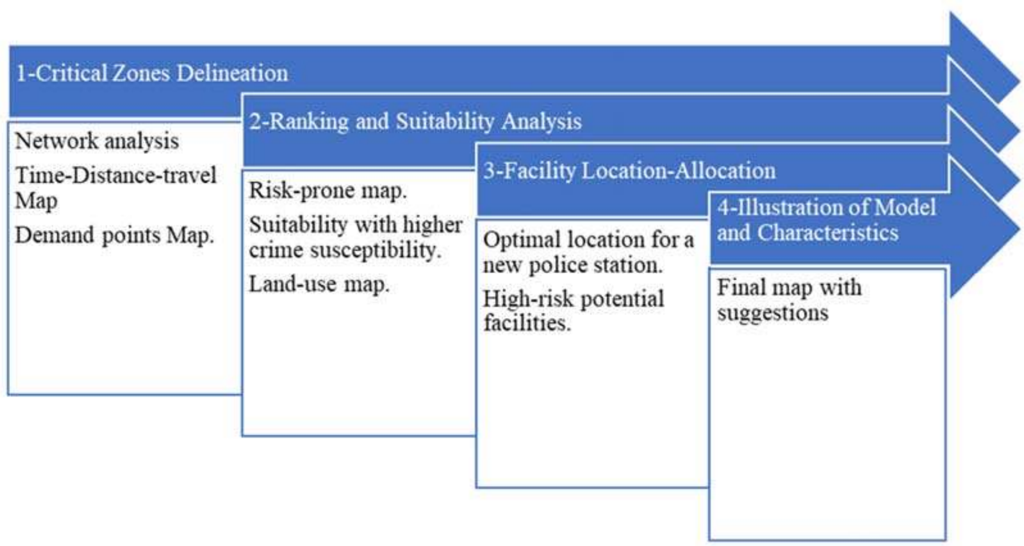

Figure 3.19. Methodology Workflow.

3.5 GIS Data

The road network data used in this study was obtained from satellite images (Google Earth) after geo-referencing using four control points collected by the Urban Research Center (URC) team in Azaz. GPS coordinates of the existing police stations were also collected. Data related to health, education, and public services layers, as well as attribute data of the road networks, were obtained from URC's Azaz City Profile (URC 2016) [40].

3.6 Network analysis

In order to facilitate the analysis and evaluation process, a comprehensive network dataset was created for this study. This dataset incorporated various essential parameters, including distance in meters, speed in kilometers per hour, road direction, road name, and road type. By considering these factors, arrival and return times could be accurately calculated in minutes, taking into account the speed and distance involved.

To ensure the reliability and validity of the network dataset, a thorough topology analysis was conducted. This analysis validated the model and established the necessary connectivity relationships between different road segments.

Utilizing the network dataset, the study employed the service area application to identify and delineate three critical zones surrounding the existing police stations. Each of these zones represents an area that can be reached within one minute of travel time (as illustrated in Figure 3.20). By defining these critical zones, we aimed to highlight the areas where immediate police coverage is of utmost importance, ensuring prompt response times and effective law enforcement.

Incorporating these critical zones within the analysis framework enables a focused evaluation of the existing police station coverage. It provides valuable insights into the potential gaps in the current law enforcement network. This approach aids in identifying areas within Azaz that may require additional police presence and further supports the objective of establishing an efficient and strategically positioned network of police stations.

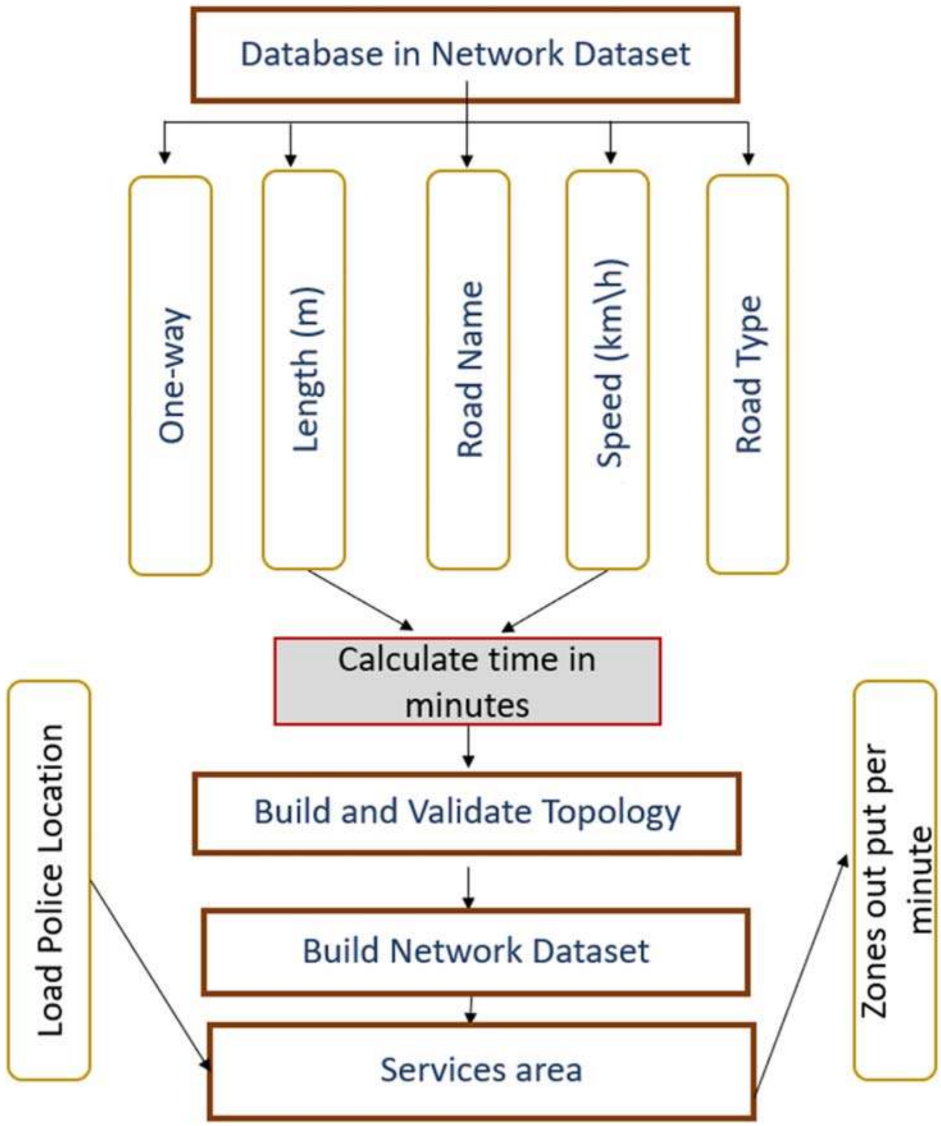

Figure 3.20. Network Analysis Workflow.

3.7 Building the Model

The next table is determining the distances between the demand points and the police stations.

Table 3.1. the distances between the demand points and the police stations.

Demand ID	X Coordination	Y Coordination	Total Length from P1	Total Length from P2
S1	37.052717	36.590362	1766	1000
S2	37.043895	36.581652	447	1864
S3	37.037416	36.579946	888	2258
S4	37.041826	36.580661	505	2016
S5	37.035788	36.588623	1827	1795
S6	37.04179	36.586647	1211	1284
S7	37.050751	36.582888	831	1518
S8	37.052805	36.578864	1143	2068
S9	37.052245	36.587372	1444	1036
H1	37.039743	36.583853	897	1673
H2	37.040487	36.585165	1028	1527
H3	37.039805	36.586523	1282	1536

3.7.1 Set Covering

$$y_k = \begin{cases} 1 & \text{if potential police station k is available } (\forall k \in K) \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Minimize } Z = \sum_{k \in K} yk \qquad (3.1)$$

$$\text{Minimize } Z = \sum_{k \in K} a_{ik} y_k \geq 1 \qquad \forall i \in I \qquad (3.2)$$

$$y_k \in \{0,1\} \qquad \forall k \in K \qquad (3.3)$$

The objective function (3.1) is to minimize the number of police station to be opened. Constraint (3.2) is to provide service from at least one police station to all demand points (schools and hospitals) within the predetermined distance. Constraint (3.3) is the integrity constraint of the decision variable. Here, *aik* is 1, if can be reached from k to i in a predetermined distance; 0 otherwise.

The Model Result:

Table 3.2. The result of solving the problem by set covering model.

Case	Maximum distance (m)	Open Police Station	The maximum distance between two points
1	1827	Only P1	P1-S5
2	2258	Only P2	P2-S3
3	1795	Both P1 & P2	P2-S5

ARC-GIS Analyze Result:

Case 1 : Police station No.1 for 3 distances : 1000m – 1500m – 2000m

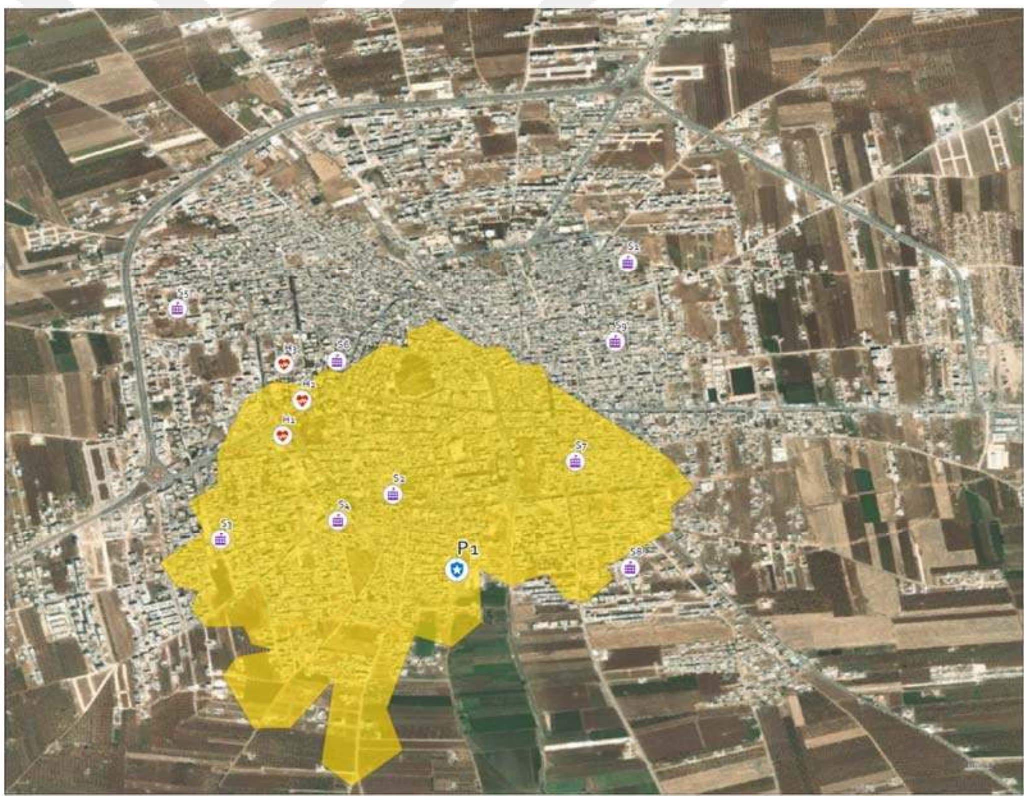

Figure 3.21. Police Station No.1 – Set Covering 1000m.

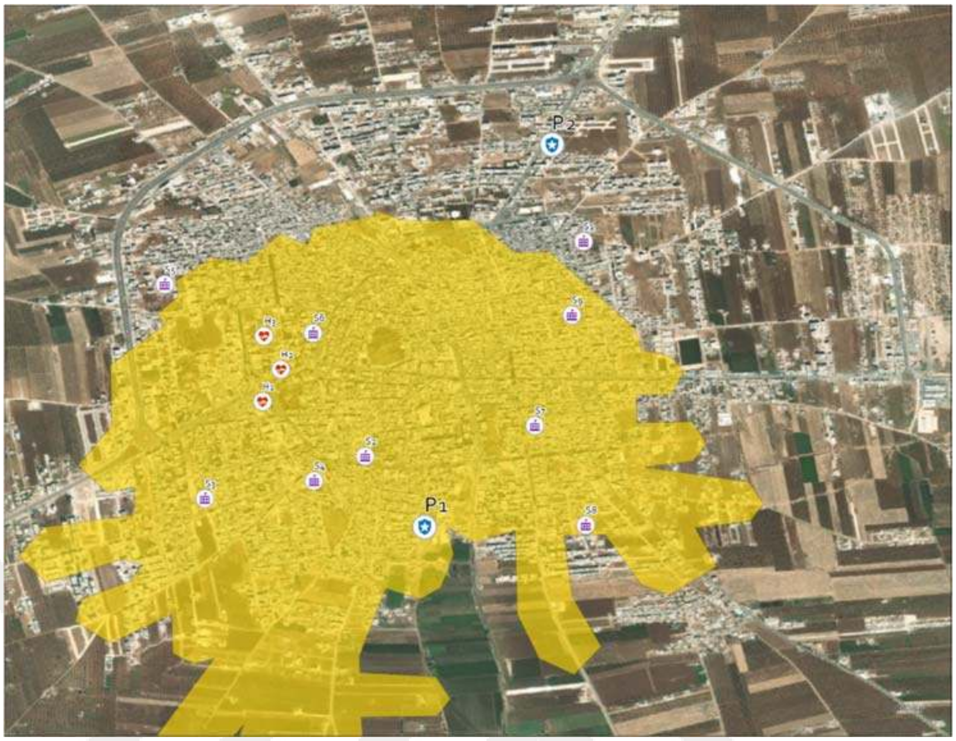

Figure 3.22. Police Station No.1 – Set Covering 1500m.

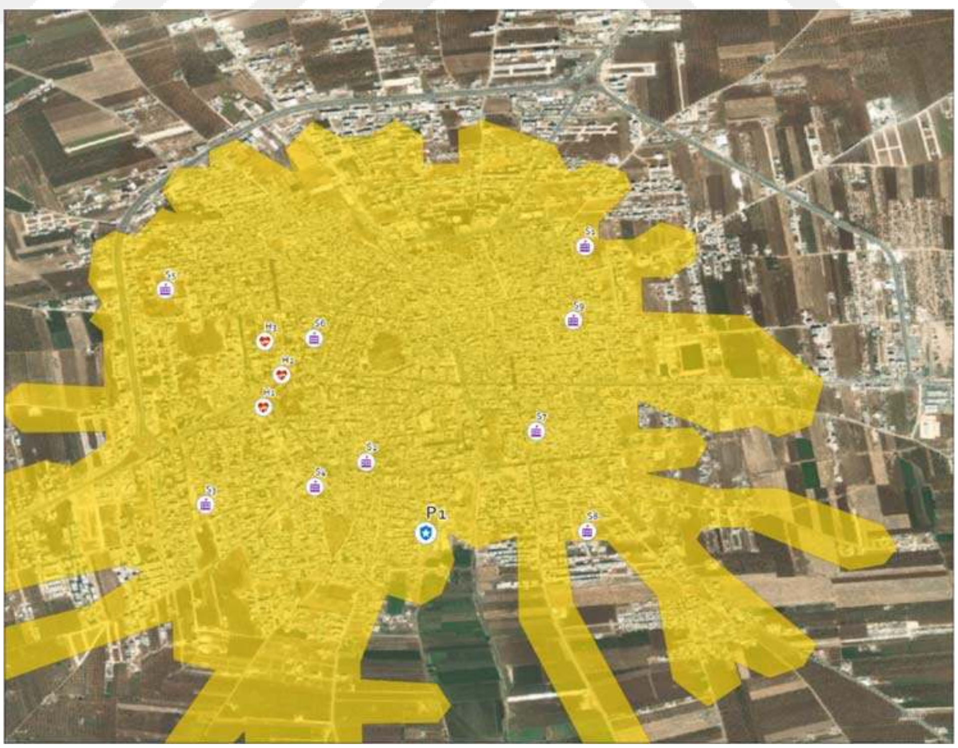

Figure 3.23. Police Station No.1 – Set Covering 2000m.

Case 2 : Police station No.2 for 3 distances : 1000m – 1500m – 2000m

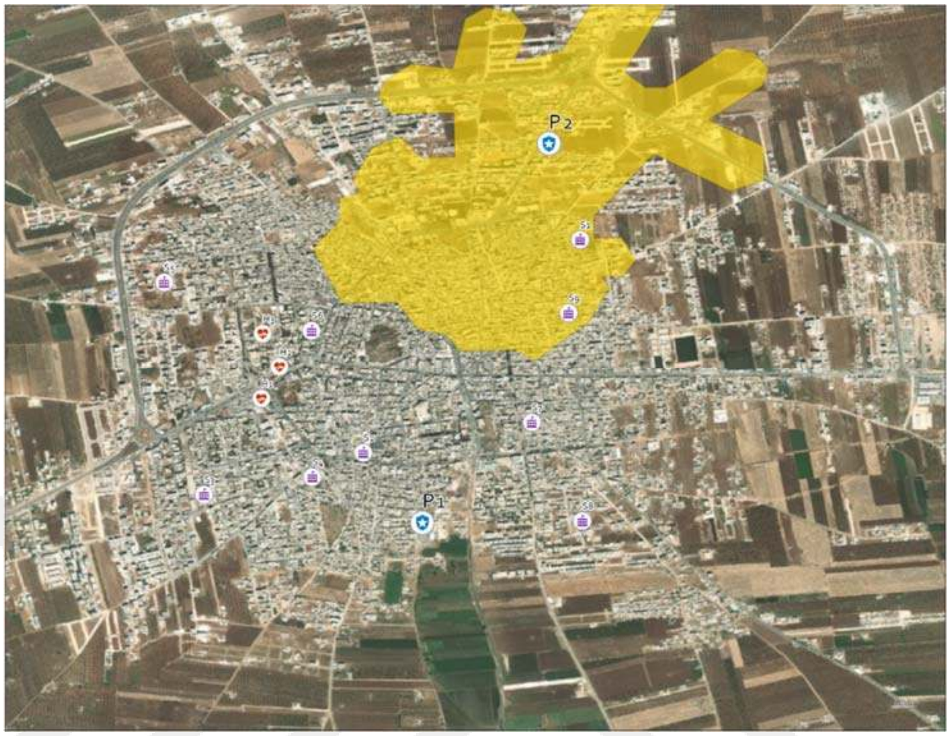

Figure 3.24. Police Station No.2 – Set Covering 1000m.

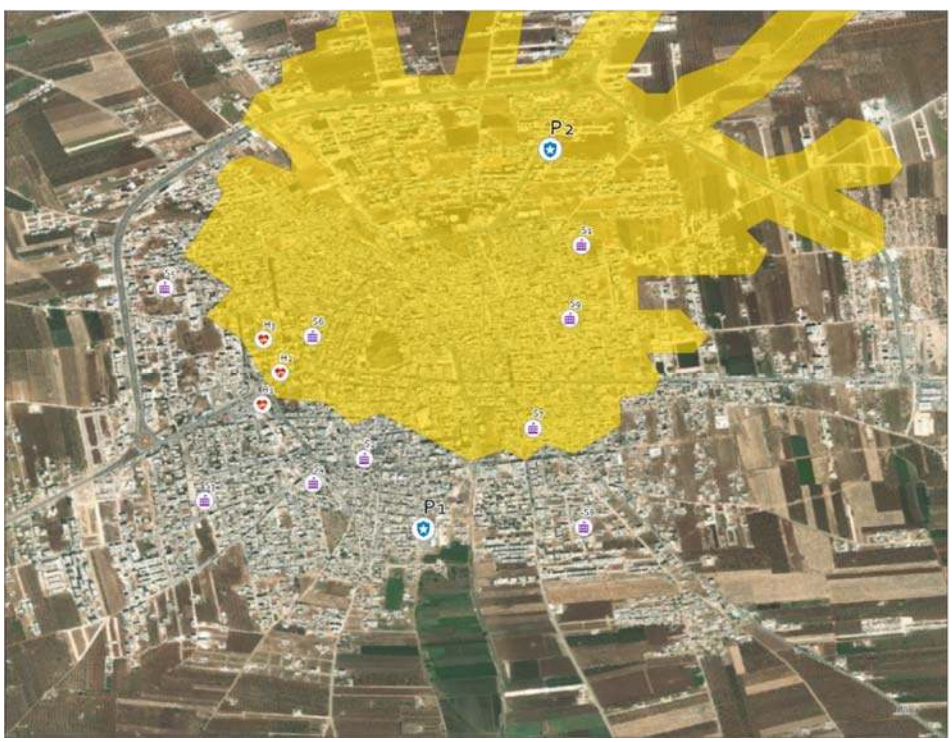

Figure 3.25. Police Station No.2 – Set Covering 1500m.

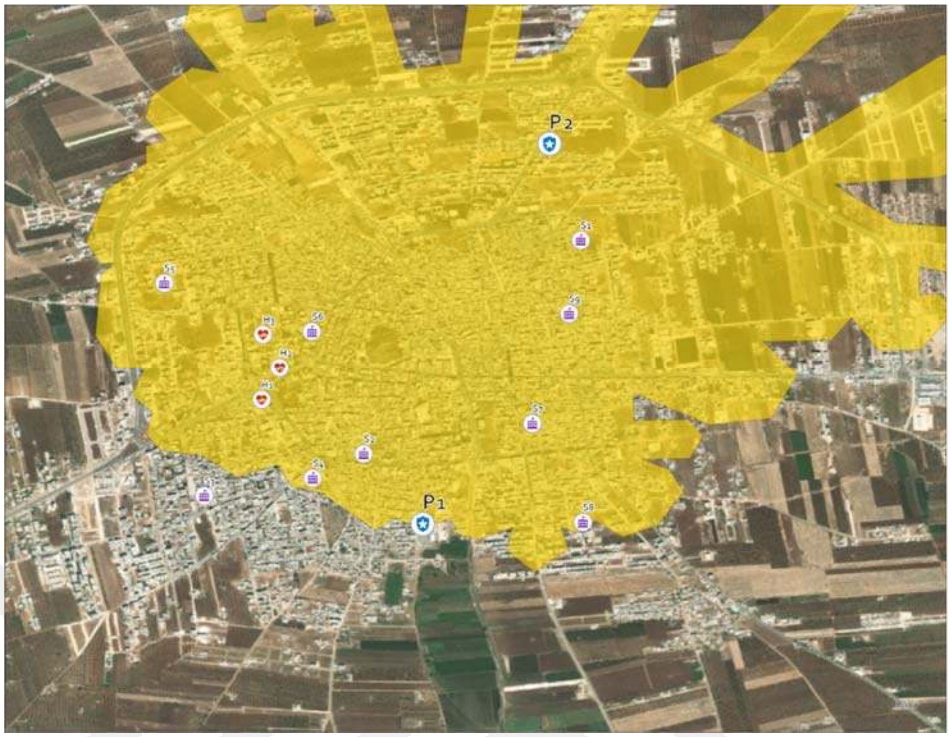

Figure 3.26. Police Station No.2 – Set Covering 2000m.

Case 3 : Police station No.1 & 2 for 3 distances : 1000m – 1500m – 2000m

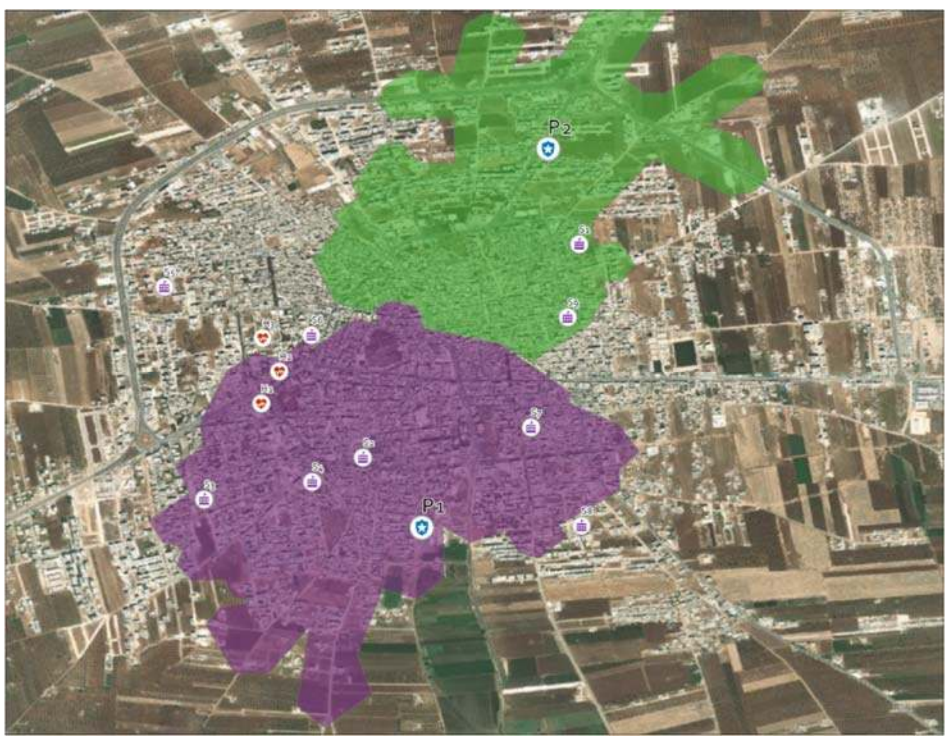

Figure 3.27. Police Station No.1&2 – Set Covering 1000m.

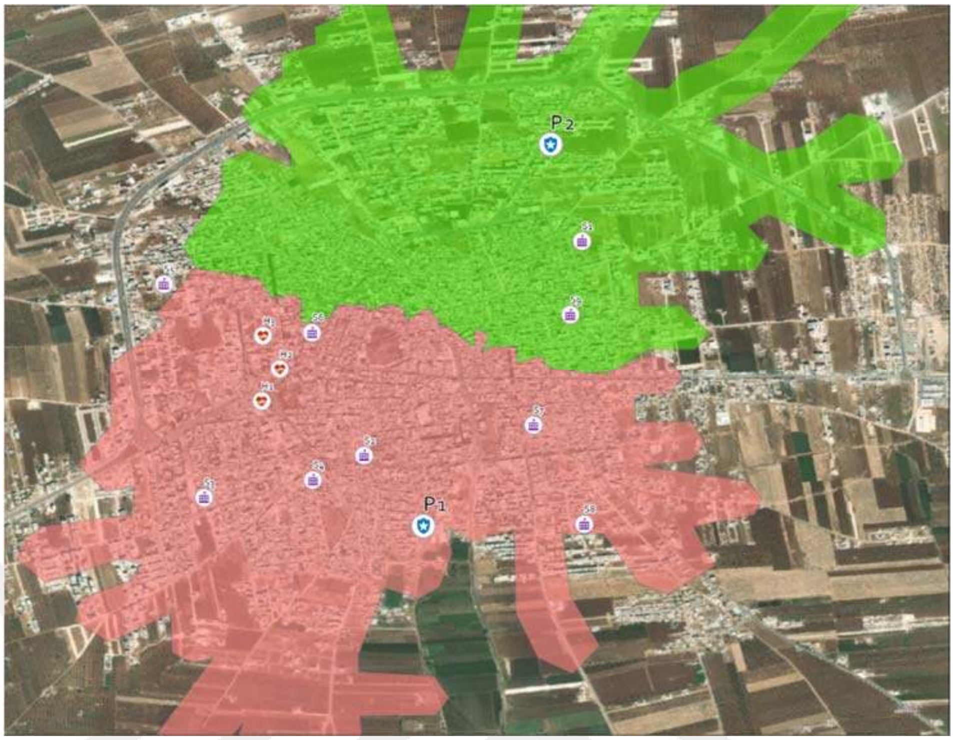

Figure 3.28. Police Station No.1&2 – Set Covering 1500m.

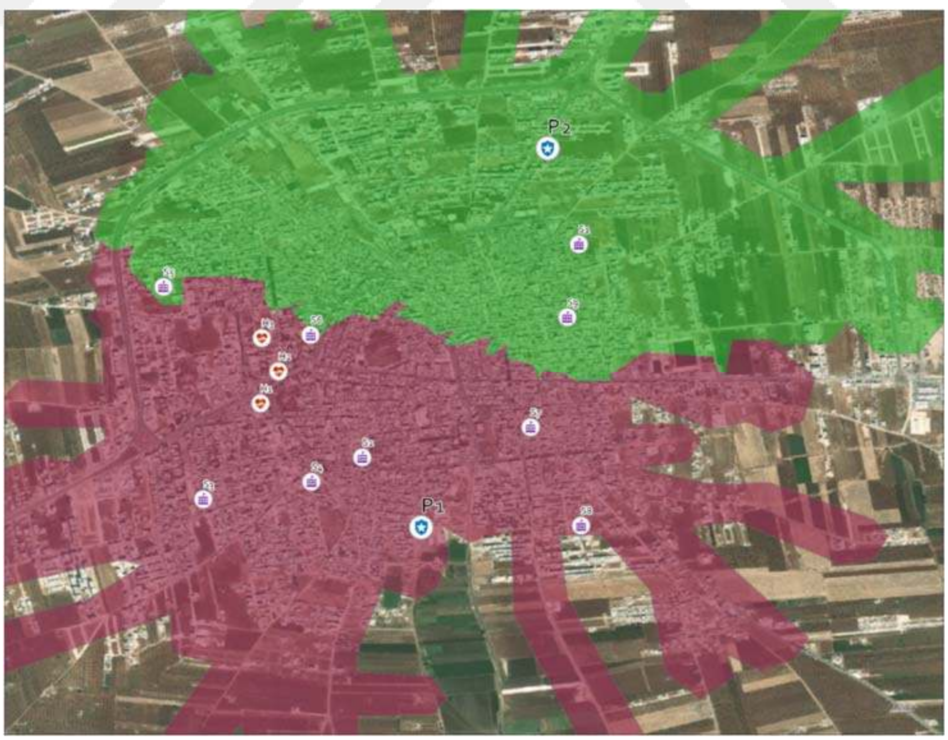

Figure 3.29. Police Station No.1&2 – Set Covering 2000m.

Table 3.3. The result of solving the problem by ARC-GIS set covering model.

Coverage area (m)	Opened Police Station	No. of demand points in the coverage area	No. of demand points out of the coverage area	Covered	Non-Covered
1000	Only P1	6	6	S2-S3-S4-S7-H1-H2	S1-S5-S6-S8-S9-H3
1000	Only P2	2	10	S1-S9	S2-S3-S4-S5-S6-S7-S8-H1-H2-H3
1000	Both P1 & P2	8	4	S1-S2-S3-S4	
1500	Only P1	10	2	S2-S3-S4-S6-S7-S8-S9-H1-H2-H3	S1-S5
1500	Only P2	6	6	S1-S6-S7-S9-H2-H3	S2-S3-S4-S5-S8-H1
1500	Both P1 & P2	11	1	S1-S2-S3-S4-S6 S7-S8-S9-H1-H2-H3	S5
2000	Only P1	12	0	S1-S2-S3-S4-S5-S6 S7-S8-S9-H1-H2-H3	-
2000	Only P2	10	2	S1-S2-S4-S5-S6	Only P2
2000	Both P1 & P2	12	0	S1-S2-S3-S4-S5-S6	Both P1 & P2

3.7.2 P-Median Model

Model parameters:

I : Set of demand nodes; $i \epsilon I$

J : Set of candidate police station; $j \epsilon J$

d_{ij} : Distance between demand node i and location of police station j (acquired from building road network dataset by GIS)

Model decision variables:

$$X_j \quad : \begin{cases} 1 & \text{if we select a station at location j} \\ 0 & \text{otherwise} \end{cases}$$

$$y_{ij} \quad : \begin{cases} 1 & \text{if job demand node i is allocated to a station j} \\ 0 & \text{otherwise} \end{cases}$$

Objective functions:

$$\text{Minimize } \sum_{ij} d_{ij}\, y_{ij} \tag{3.4}$$

Subject to

$$\sum_{j \in J} y_{ij} = 1 \qquad \forall\, i \in I \tag{3.5}$$

$$y_{ij} \leq X_j \qquad \forall\, i \in I, \forall\, j \in J \tag{3.6}$$

$$X_j, y_{ij} \in [0,1] \tag{3.7}$$

The objective function (3.4) minimizes the total distance between each demand node and the assigned station. Constraint (3.5) requires each demand node i to be assigned to exactly one facility j. Constraints (3.6) link the location variables (X) and the allocation variables (Y). They state that demands at node i can only be assigned to a facility at location j if a facility is located at node j. Constraints (3.7) is the standard integrity conditions.

Results of solving the model:

Table 3.4. The result of solving the problem by P-Median Model.

Demand ID	P1	P2	Total Length from P1	Total Length from P2
S1		1		1000
S2	1		447	
S3	1		888	
S4	1		505	
S5		1		1795
S6	1		1211	
S7	1		831	
S8	1		1143	
S9		1		1036
H1	1		897	
H2	1		1028	
H3	1		1282	
			8234	3831
			12064	

ARC-GIS Analyze Result:

Figure 3.30. Police Station No.1 – P-Median Model.

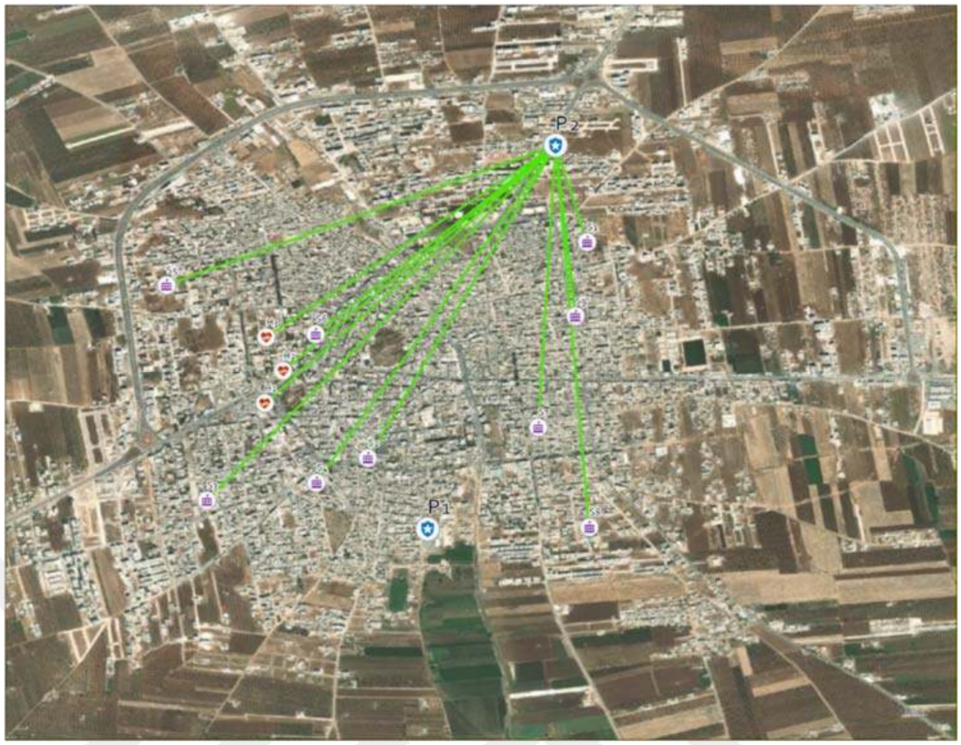

Figure 3.31. Police Station No.2 – P-Median Model.

Figure 3.32. Police Station No.1&2 – P-Median Model.

3.7.3 MCDA

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. The scope of the proposed location will be limited to the critical zone. The risk 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, two 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 distance (Figure 3.33) [41].

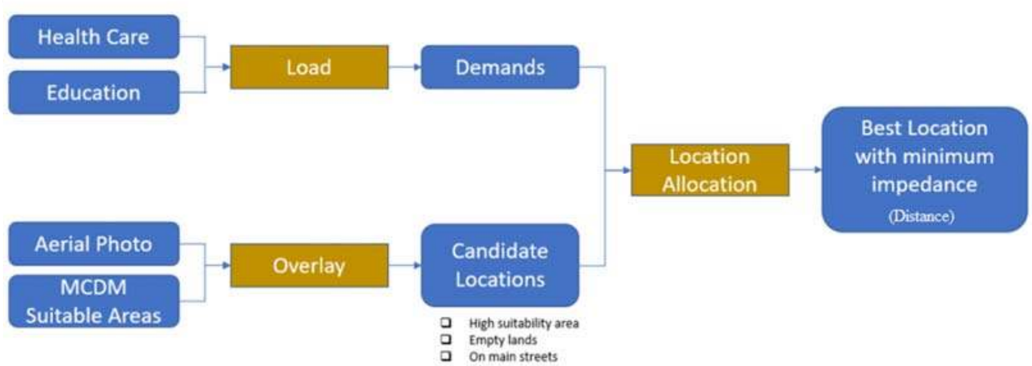

Figure 3.33. Location-Allocation Workflow.

Table 3.5. Service Area zones and their areal coverage.

Concentric Zones	Distance	Area Cover m2	Cumulative Coverage	% of the area covered by the police center
1	0-500	474406.57		10.78
2	500-1000	1147319.51	1621726.08	36.86
3	1000-1500	1419714.9	3041440.98	69.12
4	1500-2000	1202074	4243514.98	96.44

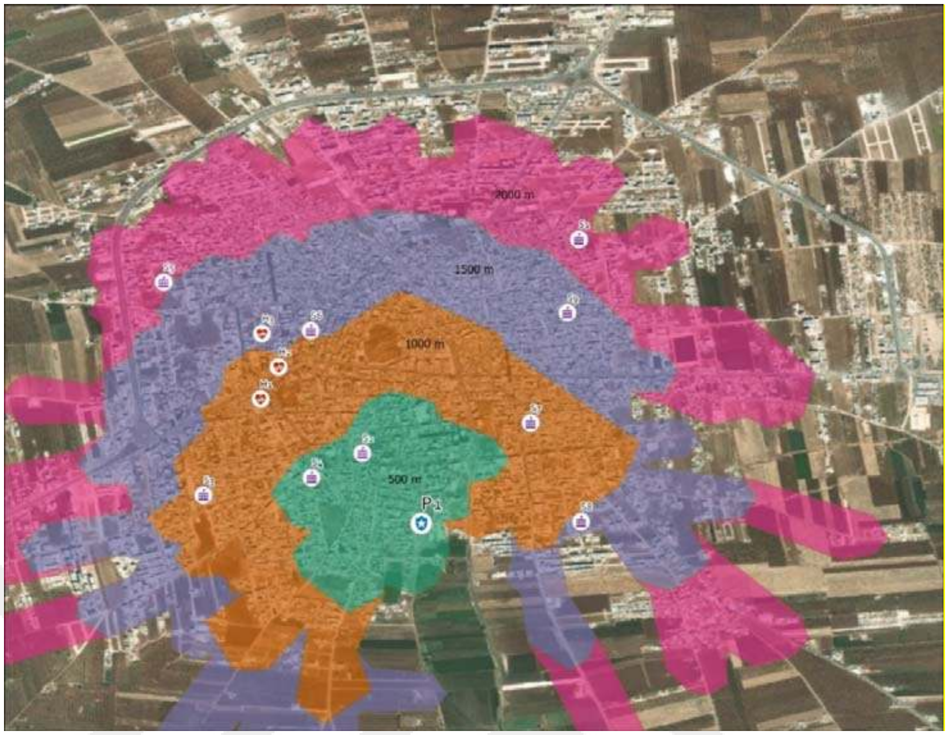

Figure 3.34. Police Station No.1-Set Covering 500-1000-1500-2000 m.

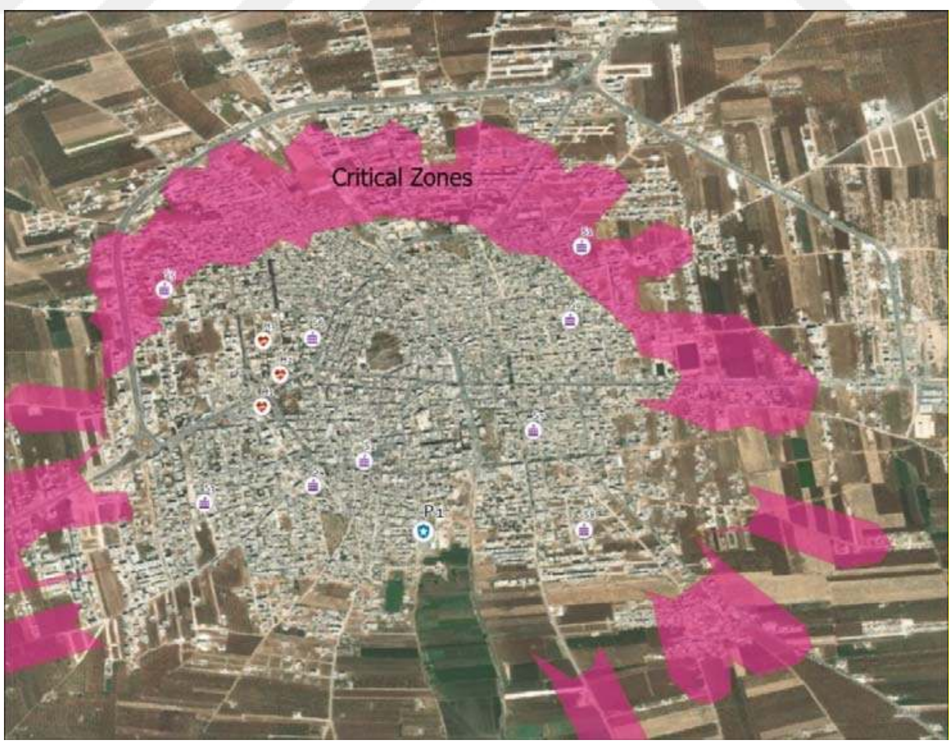

Figure 3.35. Police Station No.1-Determine Critical Zone (1500-2000) m.

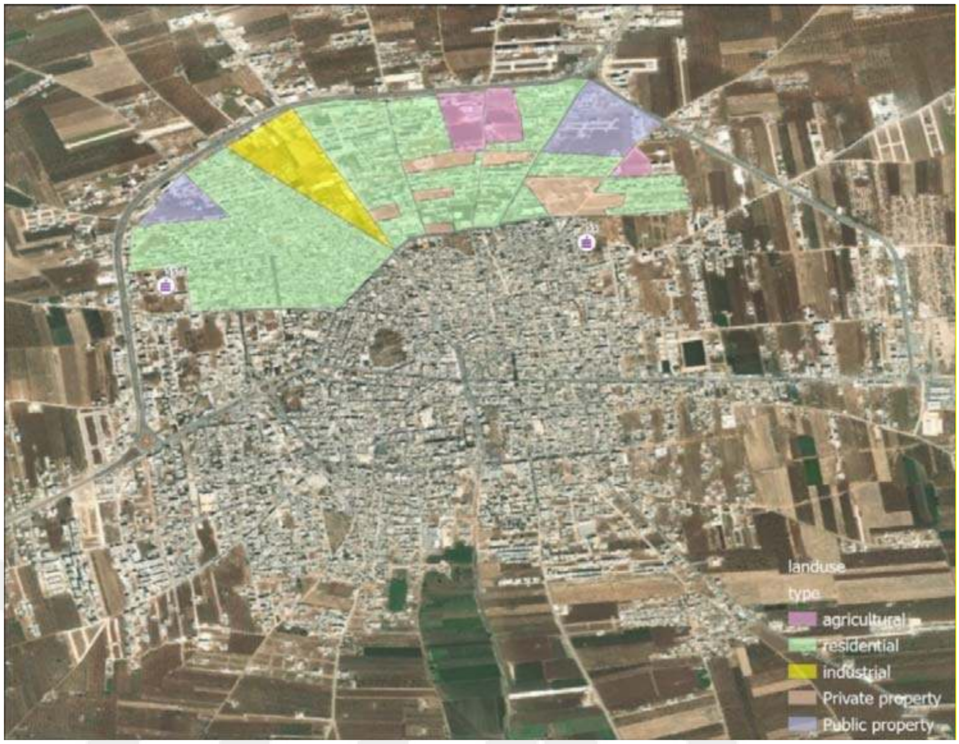

Figure 3.36. Land Use analyze according to data from the City Profile.

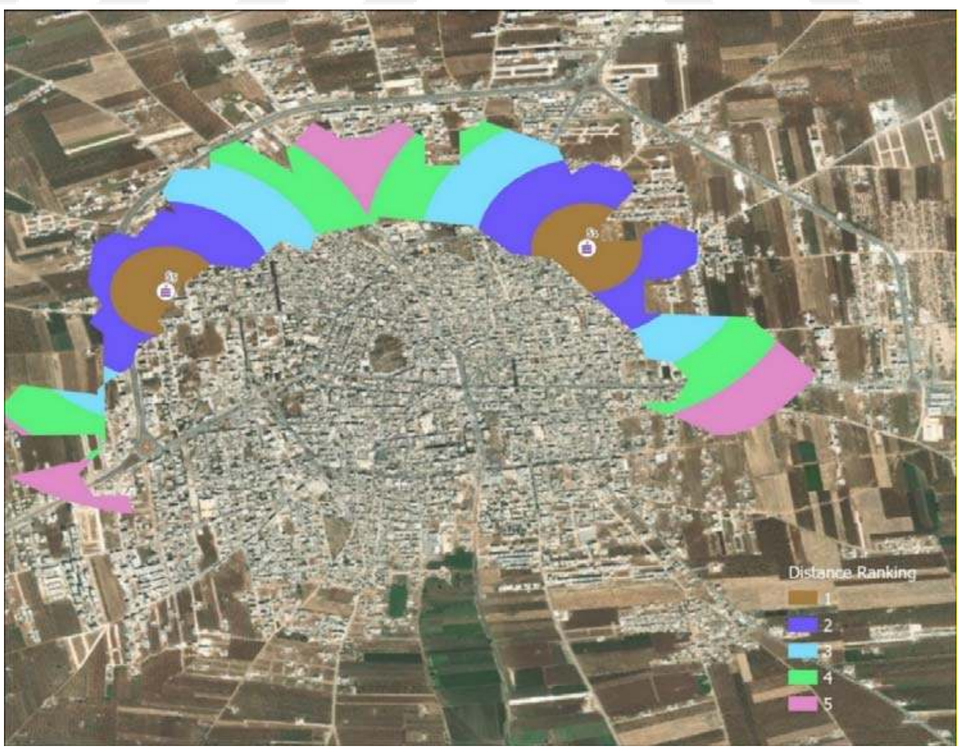

Figure 3.37. Multi-Criteria Analyze for the Demand Points in the Critical Zones

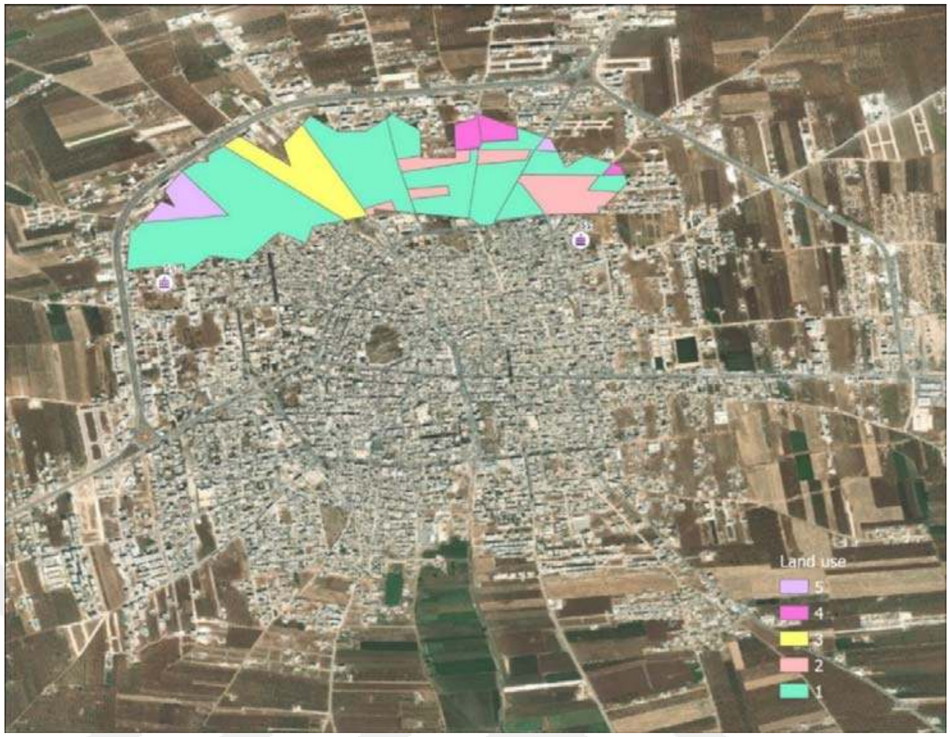

Figure 3.38. Multi-Criteria Analyze for the Demand Points with Land Use

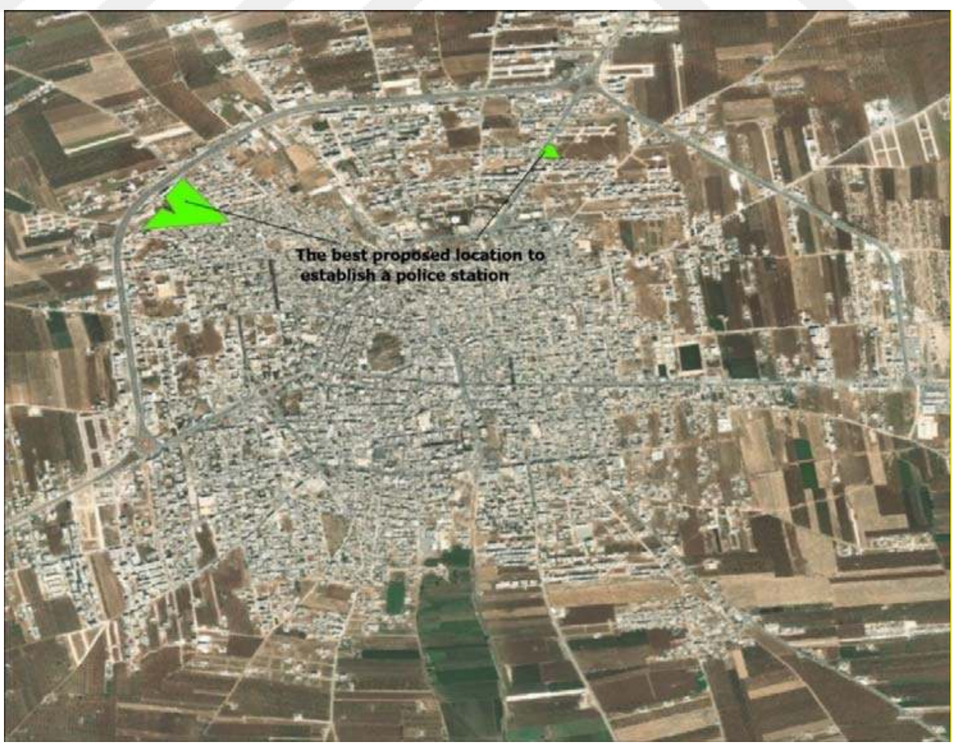

Figure 3.39. First Analyze - best proposed locations to establish police stations

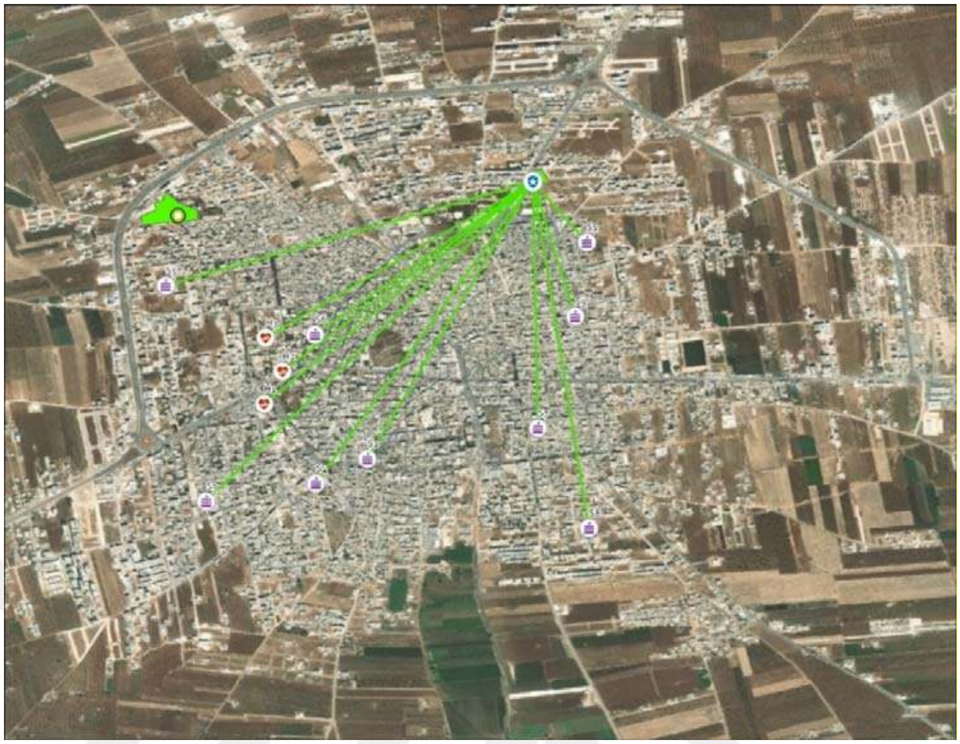

Figure 3.40. Final Analyze – The Best location to establish police station.

As we can see from the previous analyzing maps, the last result is matched with the P-Median and Set Covering Models, due to the limited available area that are suggested by the local council and the authority community in the city.

Even there was new suggested location by the MCDA, but it's location was not suitable for the covering the service areas with the needed time or the suggested distance.

CHAPTER 4
RESULTS AND DISCUSSION

In this study, service analysis was conducted using four parameters. Firstly, time was chosen as a cost attribute to determine accessibility. Secondly, a one-way attribute was incorporated to account for vehicles that must follow one-way streets, treated as restrictions. Thirdly, default service areas were set with a break of three, and the extent of each service area was calculated based on a one-minute travel time from the police station. Finally, service areas were generated by accumulating impedance in either the direction away from or towards the police station. This approach takes into account travel time, road network restrictions, and impedance accumulation to create more accurate and realistic service areas for analysis.

Service Area Analysis in this study was conducted based on distance and time, which illustrates how accessibility varies with impedance. Emergency response time is crucial and depends on factors such as the condition of the emergency response vehicle and potential obstructions along the road network [42]. Quick arrival of police officers at the scene allows for timely arrest of suspects, gathering witness testimonies, and preventing destruction or contamination of physical evidence [43]. Rapid response time is considered an effective tool for crime detection by police forces. In this study, all service areas were overlapped to identify non-service areas where travel time of 5 minutes was deemed insufficient to reach a location. These areas were designated as 'critical zones' for further evaluation.

Based on the map data, it is observed that only 64% of the total area is covered by police stations within a 5-minute travel distance (equivalent to more than 2000 meters). This indicates that 46% of the study area is not adequately served by police stations, particularly in the Blue Area. As a result, it is necessary to establish at least one additional police station to cover the unserved areas. Land use planning involves assessing the requirements of a proposed facility against the likelihood of crime-prone areas. The facilities located in critical zones were identified and categorized into three clusters: education, health, and tourism services.

The ranking method was used to assess each criterion by assigning a preference order as determined by the decision maker. The factors were ranked using inverse ranking, where 1 represented the least important and 3 represented the most important factor. Areas that were farthest from a particular facility received a low potential rank of 1. The critical zones that were reachable within a 10-minute (more than 2000m) timeframe were ranked as the most important with a rank value of 3. After reclassifying and ranking all layers, a composite map was generated to identify risk-prone areas, which were categorized into three clusters (as shown in Figure 4.1). Class 3, represented by the color blue, was identified as the highest-risk area and the most suitable site for locating a new police station.

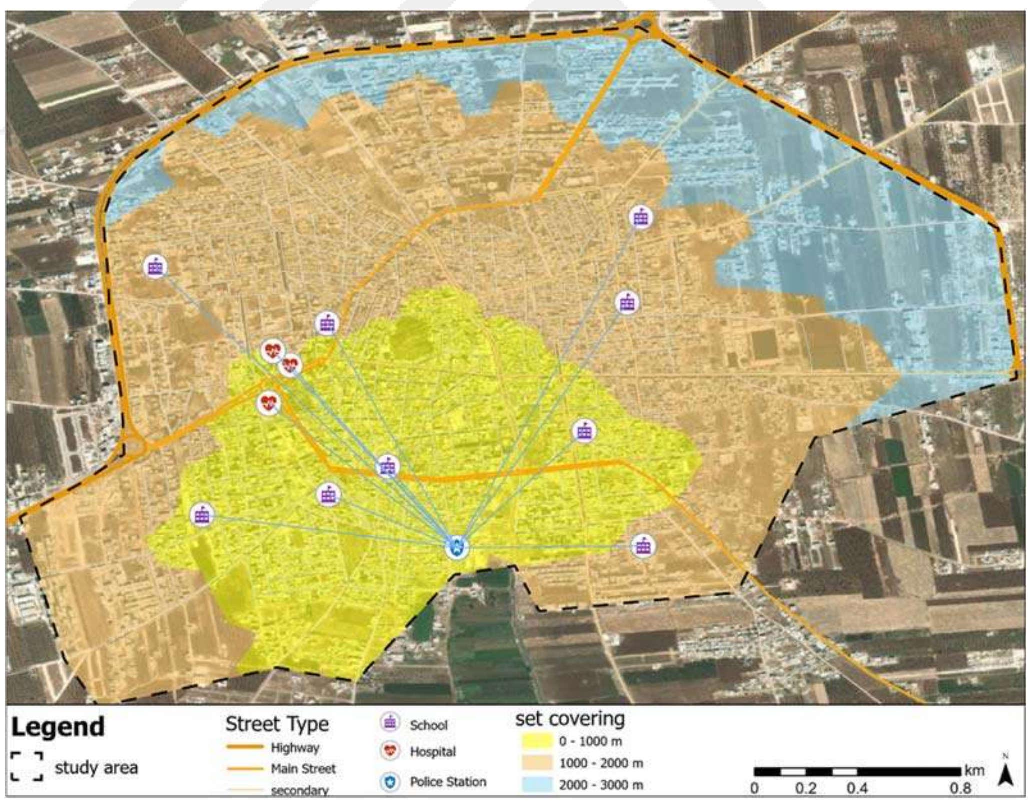

Figure 4.1. Service Area zones based on travel time from a police station.

4.1 Suggestion to Improve the Service

Based on the creation of a suitability map to prioritize alternative locations, overlaying aerial photographs to assess land availability, and conducting location-allocation analysis, the recommended location for a new police station is the northern side of Azaz (as shown in Figure 4.2). This suggested location should be in close proximity to the main road that connects the surrounding highway, ensuring good coverage for the northern side of the city. It is also crucial to take into account the anticipated city expansion over the next 10 years when considering the placement of the new police station.

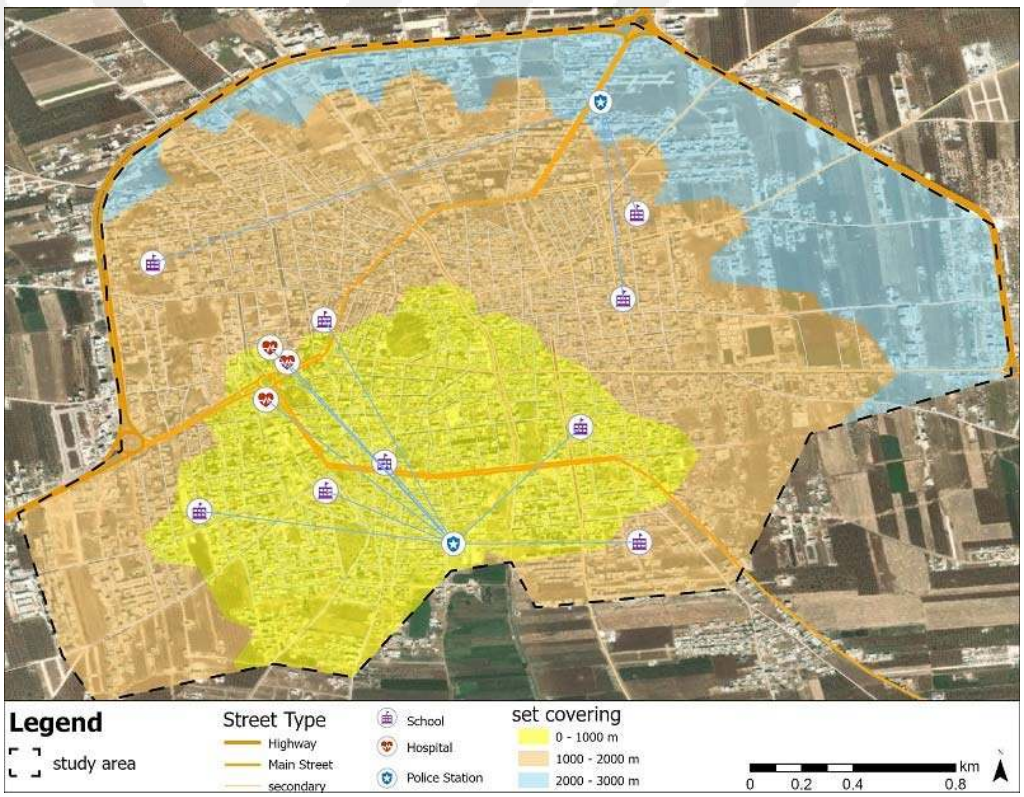

Figure 4.2. Finding the best location by Location-Allocation Analysis.

4.2 Comparison of Current State with The Suggested Map

The current situation in the city is characterized by the northern side being distant from the police station, leading to a lack of control in that area. To address this issue, we have resolved it by adding a new police station, reducing response times and instilling a sense of security across the entire city. This, in turn, has created a conducive environment for new investments in the city.

CHAPTER 5
CONCLUSION

5.1 Lessons to be Learned:

The presented study on risk-prone maps and their use in selecting optimal sites for new police stations offers several valuable lessons:

1. The Importance of GIS: GIS plays a crucial role in decision-making and optimal planning for various sectors, including public safety. This study underscores the significance of utilizing GIS tools to improve service delivery and enhance safety.

2. Consideration of Travel Time and Distance: Planners, insurers, and emergency services should consider travel time and distance from facilities when selecting new police station locations. These factors directly impact response times and, consequently, public safety.

3. Hotspot Trends in Crime: Analyzing hotspot trends of crime is essential for identifying high-risk areas. Incorporating this data into decision-making processes can lead to more effective site selection and improved law enforcement efforts.

4. Network Analysis and Multi-Criteria Analysis: The integration of service areas in network analysis and multi-criteria analysis provides a comprehensive understanding of high-risk zones and aids in candidate location selection.

5. Optimal Solutions through Location-Allocation Analysis: Applying location-allocation analysis, while considering cost and demand allocation, offers government agencies and planners optimal solutions for site selection, ensuring efficient resource allocation.

5.2 Implications for Policy Makers:

For policy makers, this study highlights several implications:

1. Informed Decision-Making: Policymakers should embrace GIS technology and the findings of this study to make informed decisions about police station locations. This will help maximize public safety and improve emergency response times.

2. Resource Allocation: The study's approach to location-allocation analysis can assist policymakers in efficiently allocating resources for police station construction, minimizing costs, and meeting demand.

Implications for Researchers:

5.3 Researchers can draw from this study in the following ways:

1. Spatial Considerations: Future research in the field of site selection should consider spatial factors, such as crime distribution, as essential components in decision-making.

2. Comprehensive Geographic Coverage: Expanding network analysis to cover larger areas, including suburbs and surrounding regions, can provide a more holistic understanding of potential site locations for police stations.

5.4 Future Research:

For future studies, it is recommended to:

1. Expand Geographic Scope: Extend the network analysis to cover the entire area around Azaz, including suburbs, to gain a more comprehensive understanding of the road network and potential site locations for police stations.

2. Incorporate Crime Data: Continue to incorporate crime information and its spatial distribution as effective factors in site selection to refine and enhance the decision-making process.

5.5 Drawbacks of the Study:

While this study offers valuable insights, it's important to acknowledge its limitations:

1. Geographical Scope: The study's focus on a specific area (Azaz) may limit the generalizability of its findings to other regions with different geographic and demographic characteristics.

2. Data Availability: The effectiveness of the study relies on the availability and accuracy of crime data, which may vary in different locations and over time.

3. Assumption of Stationary Crime Patterns: The study assumes that crime patterns remain stationary, which may not hold true in dynamic urban environments.

4. Socioeconomic Factors: The study does not extensively explore the influence of socioeconomic factors on crime patterns, which can be an important consideration in site selection.

By acknowledging these drawbacks and considering the lessons learned, implications for policy makers and researchers, and avenues for future research, stakeholders can make more informed decisions in the field of police station site selection.

REFERENCES

[1] Recasens, A.; Cardoso, C.; Castro, J.; Nobili, G. G. (2013). Urban security in southern Europe. European Journal of Criminology, 10(3), 368–382.

[2] Dongen, M. V., (2016). The Rocky Road to Postcolonial Stability: A Case Study of MINUSMA's Role in the Peace Process of Mali's Postcolonial Conflict. MA Thesis: Radboud University.

[3] Hampson, F. O. (2008). Human security. In P. Williams (Ed.), Security studies: An introduction. London: Routledge.

[4] Ratcliffe, Jerry H. (2004). Geocoding crime and a first estimate of a minimum acceptable hit rate. International Journal of Geographical Information Science, 18(1), 61–72.

[5] Attfield I, Tamiru M, Parolin B, De Grauwe A (2002) Improving micro-planning in education through a geographical information system: studies on Ethiopia and Palestine. School mapping and local-level planning. Paris, France.,

[6] Geoithub, (2017). Geoithub. Retrieved November 1, 2017, from http://geoithub.com/wpcontent/uploads/2017/01/GIS-INEDUCATION.pdf

[7] Huang, J.; Zhan, Y.; Cui, W.; Yuan, Y.; Qi, P.; (2010). Development of a Campus Information Navigation System Based on GIS, IEEE 2010 International Conference on Computer Design and Applications, V5-491–V5-494.

[8] Wendy L. Wallace, Ruijin Ma, Diana Stuart Sinton, (2010). A Major Individual Project submitted in partial satisfaction of the requirements for the degree of Master of Science in Geographic Information Systems, (Master's thesis, University of Redlands).

[9] Claiborn L. P.; Kumler M.; (2015). Quantitative School Bus Stop Risk Assessment of Redlands, California, (Master's thesis, University of Redlands).

[10] A. M. Azlan and N. Naharudin, (2020). Measuring Safety Index for Pedestrian Path by Using AHP-GIS, Built Environment Journal, Special Issue, 67 - 75, 2020.

[11] Lawrence W. Sherman; Patrick R. Gartin; Michael E. Buerger (1989). Hot Spots Of Predatory Crime: Routine Activities And The Criminology Of Place, 27(1), 27–56.

[12] Danielle M. Fenimore, M.A., B.A., B.S, (2020). Investigating The Spatiotemporal Distribution And Environmental Risk Factors Of Harm-Weighted Crime, (Doctor's thesis, Texas State University).

[13] R. F. A. Elsheikh and W. A. S. Hassan, (2016). Analysis of Least Cost Path by Using Geographic Information Systems Network and Multi Criteria Techniques, International Journal Of Multidisciplinary Sciences And Engineering, Vol. 7, No. 5.

[14] Nama, G. F.; Ulvan, M.; Ulvan, A.; Hanafi, A. (2015). Design and implementation web based geographic information system for public services in Bandar Lampung City - Indonesia, IEEE 2015 International Conference on Science in Information Technology (ICSITech), Indonesia, 270-275.

[15] Mohsin, M., Maraş H. H., (2015). An application of a GIS-based campus information system: Kirkuk University as an example, (Master's thesis, Çankaya University).

[16] D. N. Fadhil, R. Moeckel, R. Rothfeld, (2018). A GIS-based Analysis for Selecting Ground Infrastructure Locations for Urban Air Mobility, (Master's thesis, Technical University of Munich).

[17] Vogiatzaki, Maria; Zerefos, Stelios; Hoque Tania, Marzia (2020). Enhancing City Sustainability through Smart Technologies: A Framework for Automatic Pre-Emptive Action to Promote Safety and Security Using Lighting and ICT-Based Surveillance. Sustainability, 12(15), 6142–.

[18] M. Garramone, N. Moretti1, M. Scaioni1, C. Ellul2, F. Re Cecconi1, M. C. Dejaco, (2020). Bim And Gis Integration For Infrastructure Asset Management: A Bibliometric Analysis, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume VI-4/W1-2020, 2020.

[19] Anderson, R. (1990). The application of geographical information systems in the spatial analysis of crime. Geographical Information Systems for Urban and Regional Planning, 143–151.

[20] B. Sadoun; O. Al-Bayari (2007). Location based services using geographical information systems. , 30(16), 3154–3160.

[21] A. T. Pour, W. L. Yue (2012). The Role of Geographic Information Systems (GIS) in Road Emergency Services Location and Black Spot Studies. ATRF-Australasian Transport.

[22] E. Baloyi, V. Letsoko, W. Musakwa,(2019). Evaluating the location of fire stations using Geographic Information Systems GIS-based accessibility analysis: a case study in Ekurhuleni, (Master's thesis, The University Of Johannesburg).

[23] Indriasari, V.; Mahmud, A. R.; Ahmad, N.; Shariff, A. M. (2010). Maximal service area problem for optimal siting of emergency facilities. , 24(2), 213–230.

[24] Murray, A. T. (2016). Maximal Coverage Location Problem: Impacts, Significance, and Evolution. International Regional Science Review, 39(1), 5–27.

[25] Kermanshah, A.; Derrible, S. (2016). A geographical and multi-criteria vulnerability assessment of transportation networks against extreme earthquakes. Reliability Engineering & System Safety, 153, 39–49.

[26] Horner, M.; Downs, J., (2007). Testing a Flexible Geographic Information System-Based Network Flow Model for Routing Hurricane Disaster Relief Goods. Transportation Research Record: Journal of the Transportation Research Board, 2022, 47–54.

[27] Zhang, F.; Johnson, D.; Johnson, M.; Watkins, D.; Froese, R.; Wang, J. (2016). Decision support system integrating GIS with simulation and optimisation for a biofuel supply chain. Renewable Energy, 85, 740–748.

[28] Wey, Wann-Ming; Zhang, Heng; Chang, Yu-Jie (2016). Alternative transit-oriented development evaluation in sustainable built environment planning. Habitat International, 55, 109-123.

[29] Jelokhani-Niaraki, M.; Bastami M., R.; Yazdanpanah D., Q.; Hajiloo, F.; Sadeghi-Niaraki, A. (2019). A volunteered geographic information system for monitoring and managing urban crimes: a case study of Tehran, Iran. Police Practice and Research, 1–15.

[30] Achu A L, R S Suja Rose, (2016). GIS Analysis of Crime Incidence and Spatial Variation in Thiruvananthapuram City, International Journal of Remote Sensing Applications (IJRSA) Volume 6.

[31] F. Mohammed, Abbas; R. Baiee, Wadhah (2020). Analysis of Criminal Spatial Events in GIS for predicting hotspots. IOP Conference Series: Materials Science and Engineering, 928, 032071.

[32] Samuel, K. J., Agbola, S. B., & Olojede, O. A. (2022). The safety and security of urban households in South Africa: a geospatial exploration of the crimescape in the neighborhoods of Durban, South Africa. African Geographical Review, 1-16.

[33] M. EH Ong, Faith S. N., Jerry O., Susan Y., Derek A., David K. Y., Swee H. L., V Anantharaman, (2009). Geographic-Time Distribution of Ambulance Calls in Singapore: Utility of Geographic Information System in Ambulance Deployment, Annals Academy of Medicine.

[34] Lim Yu Liang, Dadang Mohamad Ma'some, Law Teik Hua, (2005). Traffic Accident Application Using Geographic Information System, Journal Of The Eastern Asia Society For Transportation Studies, Vol. 6, Pp. 3574 – 3589.

[35] Restrepo, J., (2012). Geographic information system for the management of traffic in the medellin's mobility department, IEEE Colombian Intelligent Transportation Systems Symposium, 1–5.

[36] Islam S, (2018). Community Policing (CP): Challenges on Preventing Crime and Human Security in Bangladesh, Review Pub Administration Manag 6: 253.

[37] Saraiva, M.; Matijošaitienė, I.; Mishra, S.; Amante, (2022). A. Crime Prediction and Monitoring in Porto, Portugal, Using Machine Learning, Spatial and Text Analytics. ISPRS Int. J. Geo-Inf. 2022, 11, 400.

[38] Mendoza, A.; Mayoral, E.; Vicente, J.; Quintero, F. (2001). Geographic Information System-Based Accident Data Management for Mexican Federal Roads, Transportation Research Record: Journal of the Transportation Research Board, 1746, 74–83.

[39] Jayvant C., Anurag O., Brind K., (2016). Spatial and statistical analysis of road accidents hot spots using GIS, 3rd Conference of Transportation Research Group of India, (3rd CTRG).

[40] Urban Research Center, Azaz's City Profile,(2016). https://www.urc-sy.com

[41] ELSHEİKH, R. (2022). GIS-based services analysis and multi-criteria for optimal planning of location of a police station. Gazi University Journal of Science, 35(4), 1248-1258.

[42] P. Nicoară and I. Haidu, (2014). A GIS Based Network Analysis For The Identification Of Shortest Route Access To Emergency Medical Facilities, Geographia Technica, Vol. 09, Issue 2, 2014, 60-67.

[43] Blanes i Vidal, Jordi and Kirchmaier, Tom (2018). The Effect of Police Response Time on Crime Clearance Rates. The Review of Economic Studies, 85(2), 855–891.

APPENDIX

Table 3.6. Land use data.

FID	Shape	type
0	Polygon	House
1	Polygon	House
2	Polygon	House
3	Polygon	House
4	Polygon	House
5	Polygon	House
6	Polygon	House
7	Polygon	Private property
8	Polygon	Public ownership
9	Polygon	Agricultural
10	Polygon	Industrial
11	Polygon	Public ownership
12	Polygon	Agricultural
13	Polygon	Agricultural
14	Polygon	Private property
15	Polygon	Private property
16	Polygon	Private property
17	Polygon	Private property
18	Polygon	Private property

Table 3.7. Road data.

Objected	Shape	code	class	one-way	bridge	tunnel	Shape Length
1	Polyline	5112	trunk	F	F	F	285.12092
2	Polyline	5121	unclassified	F	F	F	352.861733
3	Polyline	5115	tertiary	B	F	F	2085.697536
4	Polyline	5121	unclassified	B	F	F	239.096722
5	Polyline	5113	primary	B	F	F	590.419199
6	Polyline	5113	primary	F	F	F	411.787797
7	Polyline	5113	primary	B	F	F	169.782897
8	Polyline	5113	primary	F	F	F	169.841522
9	Polyline	5121	unclassified	B	F	F	815.875703
10	Polyline	5121	unclassified	B	F	F	761.454185
11	Polyline	5121	unclassified	B	F	F	580.949949

12	Polyline	5115	tertiary	B	F	F	710.240369
13	Polyline	5115	tertiary	B	F	F	640.395634
14	Polyline	5115	tertiary	F	F	F	196.130125
15	Polyline	5114	secondary	B	F	F	594.407306
16	Polyline	5121	unclassified	B	F	F	466.775851
17	Polyline	5122	residential	B	F	F	72.828048
18	Polyline	5115	tertiary	F	F	F	728.746053
19	Polyline	5121	unclassified	B	F	F	81.730749
20	Polyline	5121	unclassified	B	F	F	399.648749
21	Polyline	5121	unclassified	B	F	F	562.060437
22	Polyline	5115	tertiary	B	F	F	1010.830607
23	Polyline	5121	unclassified	B	F	F	300.187941
24	Polyline	5115	tertiary	B	F	F	310.218286
25	Polyline	5121	unclassified	B	F	F	1012.689464
26	Polyline	5115	tertiary	F	F	F	730.868961
27	Polyline	5121	unclassified	B	F	F	702.108394
28	Polyline	5121	unclassified	B	F	F	772.540088
29	Polyline	5121	unclassified	B	F	F	439.534137
30	Polyline	5121	unclassified	B	F	F	697.114123
31	Polyline	5121	unclassified	B	F	F	1114.143828
32	Polyline	5112	trunk	F	F	F	441.348077
33	Polyline	5121	unclassified	B	F	F	865.851317
34	Polyline	5121	unclassified	B	F	F	1113.553082
35	Polyline	5121	unclassified	B	F	F	426.670155
36	Polyline	5115	tertiary	B	F	F	1057.238022
37	Polyline	5122	residential	B	F	F	202.817119
38	Polyline	5121	unclassified	B	F	F	172.996569
39	Polyline	5122	residential	B	F	F	124.036606
40	Polyline	5121	unclassified	B	F	F	202.204018
41	Polyline	5121	unclassified	B	F	F	67.291334
42	Polyline	5122	residential	B	F	F	90.557531
43	Polyline	5122	residential	B	F	F	301.749519
44	Polyline	5122	residential	B	F	F	158.840873
45	Polyline	5122	residential	B	F	F	439.96127
46	Polyline	5121	unclassified	B	F	F	193.835117
47	Polyline	5121	unclassified	B	F	F	230.716184
48	Polyline	5121	unclassified	B	F	F	99.926055
49	Polyline	5122	residential	B	F	F	199.693268
50	Polyline	5122	residential	B	F	F	281.951071
51	Polyline	5121	unclassified	B	F	F	67.457556
52	Polyline	5122	residential	B	F	F	126.641822
53	Polyline	5122	residential	B	F	F	303.038854
54	Polyline	5121	unclassified	B	F	F	149.740074
55	Polyline	5122	residential	B	F	F	305.534823

56	Polyline	5121	unclassified	B	F	F	169.262101
57	Polyline	5122	residential	B	F	F	133.939111
58	Polyline	5121	unclassified	B	F	F	140.297145
59	Polyline	5122	residential	B	F	F	178.929776
60	Polyline	5121	unclassified	B	F	F	117.298661
61	Polyline	5122	residential	B	F	F	154.843153
62	Polyline	5121	unclassified	B	F	F	82.772363
63	Polyline	5122	residential	B	F	F	413.649832
64	Polyline	5121	unclassified	B	F	F	136.874528
65	Polyline	5121	unclassified	B	F	F	141.060187
66	Polyline	5121	unclassified	B	F	F	210.147096
67	Polyline	5122	residential	B	F	F	152.669176
68	Polyline	5121	unclassified	B	F	F	181.028699
69	Polyline	5121	unclassified	B	F	F	245.053168
70	Polyline	5122	residential	F	F	F	261.996288
71	Polyline	5122	residential	B	F	F	170.186877
72	Polyline	5121	unclassified	B	F	F	267.875304
73	Polyline	5121	unclassified	B	F	F	277.383887
74	Polyline	5121	unclassified	B	F	F	331.74662
75	Polyline	5121	unclassified	B	F	F	284.413441
76	Polyline	5121	unclassified	B	F	F	210.861276
77	Polyline	5121	unclassified	B	F	F	191.51492
78	Polyline	5122	residential	B	F	F	291.031254
79	Polyline	5122	residential	B	F	F	399.273822
80	Polyline	5121	unclassified	B	F	F	206.409499
81	Polyline	5121	unclassified	B	F	F	203.344739
82	Polyline	5122	residential	B	F	F	265.38858
83	Polyline	5121	unclassified	B	F	F	637.659072
84	Polyline	5121	unclassified	B	F	F	318.190874
85	Polyline	5121	unclassified	B	F	F	352.831853
86	Polyline	5121	unclassified	B	F	F	446.048063
87	Polyline	5121	unclassified	B	F	F	114.494288
88	Polyline	5122	residential	B	F	F	226.834434
89	Polyline	5121	unclassified	B	F	F	205.852522
90	Polyline	5121	unclassified	B	F	F	319.736962
91	Polyline	5121	unclassified	B	F	F	206.37962
92	Polyline	5121	unclassified	B	F	F	344.213769
93	Polyline	5121	unclassified	B	F	F	268.112365
94	Polyline	5121	unclassified	B	F	F	345.808553
95	Polyline	5121	unclassified	B	F	F	580.196466
96	Polyline	5121	unclassified	B	F	F	512.032484
97	Polyline	5121	unclassified	B	F	F	207.734391
98	Polyline	5121	unclassified	B	F	F	55.10316
99	Polyline	5122	residential	B	F	F	81.411102

100	Polyline	5122	residential	B	F	F	123.382589
101	Polyline	5121	unclassified	B	F	F	102.206988
102	Polyline	5122	residential	B	F	F	152.132673
103	Polyline	5121	unclassified	B	F	F	96.0621
104	Polyline	5121	unclassified	B	F	F	305.653924
105	Polyline	5122	residential	B	F	F	84.346958
106	Polyline	5121	unclassified	B	F	F	186.161203
107	Polyline	5121	unclassified	B	F	F	128.378539
108	Polyline	5122	residential	B	F	F	110.136835
109	Polyline	5121	unclassified	B	F	F	155.303117
110	Polyline	5121	unclassified	B	F	F	65.436518
111	Polyline	5122	residential	B	F	F	195.516696
112	Polyline	5121	unclassified	B	F	F	124.931551
113	Polyline	5121	unclassified	B	F	F	139.262685
114	Polyline	5121	unclassified	B	F	F	131.602792
115	Polyline	5121	unclassified	B	F	F	415.067658
116	Polyline	5121	unclassified	B	F	F	139.869939
117	Polyline	5121	unclassified	B	F	F	270.19494
118	Polyline	5121	unclassified	B	F	F	135.234201
119	Polyline	5121	unclassified	B	F	F	123.222693
120	Polyline	5121	unclassified	B	F	F	125.335949
121	Polyline	5121	unclassified	B	F	F	217.420939
122	Polyline	5121	unclassified	B	F	F	67.805276
123	Polyline	5121	unclassified	B	F	F	158.922449
124	Polyline	5121	unclassified	B	F	F	227.13043
125	Polyline	5122	residential	B	F	F	275.007321
126	Polyline	5121	unclassified	B	F	F	270.969776
127	Polyline	5121	unclassified	B	F	F	444.450594
128	Polyline	5121	unclassified	B	F	F	389.33568
129	Polyline	5122	residential	B	F	F	369.270708
130	Polyline	5121	unclassified	B	F	F	351.139887
131	Polyline	5121	unclassified	B	F	F	392.533897
132	Polyline	5121	unclassified	B	F	F	524.927999
133	Polyline	5122	residential	B	F	F	49.784773
134	Polyline	5122	residential	B	F	F	53.93861
135	Polyline	5122	residential	B	F	F	56.616647
136	Polyline	5122	residential	B	F	F	143.207183
137	Polyline	5122	residential	B	F	F	163.861431
138	Polyline	5122	residential	B	F	F	59.316256
139	Polyline	5122	residential	B	F	F	145.341346
140	Polyline	5122	residential	B	F	F	91.756071
141	Polyline	5122	residential	B	F	F	56.102319
142	Polyline	5122	residential	B	F	F	104.529023
143	Polyline	5122	residential	B	F	F	149.550756

144	Polyline	5122	residential	B	F	F	55.150397
145	Polyline	5122	residential	B	F	F	85.366849
146	Polyline	5122	residential	B	F	F	56.949794
147	Polyline	5141	service	B	F	F	71.555825
148	Polyline	5122	residential	B	F	F	106.851215
149	Polyline	5122	residential	B	F	F	46.528357
150	Polyline	5122	residential	B	F	F	89.734641
151	Polyline	5122	residential	B	F	F	119.843107
152	Polyline	5122	residential	B	F	F	166.553393
153	Polyline	5122	residential	B	F	F	37.752887
154	Polyline	5122	residential	B	F	F	49.190851
155	Polyline	5122	residential	B	F	F	63.724409
156	Polyline	5122	residential	B	F	F	81.155358
157	Polyline	5122	residential	B	F	F	107.22835
158	Polyline	5122	residential	B	F	F	39.513576
159	Polyline	5122	residential	B	F	F	60.562329
160	Polyline	5122	residential	B	F	F	71.968887
161	Polyline	5122	residential	B	F	F	44.463586
162	Polyline	5122	residential	B	F	F	129.680211
163	Polyline	5122	residential	B	F	F	75.114734
164	Polyline	5122	residential	B	F	F	345.974343
165	Polyline	5122	residential	B	F	F	65.0659
166	Polyline	5122	residential	B	F	F	34.954539
167	Polyline	5122	residential	B	F	F	52.110116
168	Polyline	5122	residential	B	F	F	38.906691
169	Polyline	5141	service	B	F	F	95.605629
170	Polyline	5122	residential	B	F	F	146.737712
171	Polyline	5122	residential	B	F	F	87.105079
172	Polyline	5122	residential	B	F	F	73.893182
173	Polyline	5122	residential	B	F	F	125.030549
174	Polyline	5122	residential	B	F	F	56.864881
175	Polyline	5122	residential	B	F	F	121.267558
176	Polyline	5122	residential	B	F	F	63.724333
177	Polyline	5122	residential	B	F	F	72.39036
178	Polyline	5122	residential	B	F	F	53.102392
179	Polyline	5122	residential	B	F	F	270.175221
180	Polyline	5122	residential	B	F	F	217.705678
181	Polyline	5122	residential	B	F	F	82.147517
182	Polyline	5121	unclassified	B	F	F	634.708487
183	Polyline	5121	unclassified	B	F	F	416.529859
184	Polyline	5122	residential	B	F	F	189.514075
185	Polyline	5122	residential	B	F	F	84.801177
186	Polyline	5122	residential	B	F	F	101.057753
187	Polyline	5122	residential	B	F	F	167.69594

188	Polyline	5122	residential	B	F	F	100.119913
189	Polyline	5122	residential	B	F	F	218.735052
190	Polyline	5122	residential	B	F	F	201.989832
191	Polyline	5122	residential	B	F	F	136.69796
192	Polyline	5122	residential	B	F	F	174.593573
193	Polyline	5141	service	B	F	F	114.045598
194	Polyline	5122	residential	B	F	F	67.339919
195	Polyline	5122	residential	B	F	F	53.115609
196	Polyline	5122	residential	B	F	F	166.56311
197	Polyline	5122	residential	B	F	F	257.185375
198	Polyline	5122	residential	B	F	F	100.795624
199	Polyline	5141	service	B	F	F	50.474077
200	Polyline	5122	residential	B	F	F	128.622513
201	Polyline	5122	residential	B	F	F	106.970602
202	Polyline	5122	residential	B	F	F	144.526194
203	Polyline	5122	residential	B	F	F	203.335308
204	Polyline	5122	residential	B	F	F	83.951015
205	Polyline	5122	residential	B	F	F	142.259537
206	Polyline	5122	residential	B	F	F	244.627619
207	Polyline	5122	residential	B	F	F	388.009202
208	Polyline	5122	residential	B	F	F	104.525205
209	Polyline	5122	residential	B	F	F	262.533735
210	Polyline	5122	residential	B	F	F	207.743112
211	Polyline	5122	residential	B	F	F	291.75432
212	Polyline	5122	residential	B	F	F	251.370636
213	Polyline	5122	residential	B	F	F	94.85142
214	Polyline	5113	primary	F	F	F	166.08696
215	Polyline	5122	residential	B	F	F	205.154602
216	Polyline	5122	residential	B	F	F	55.92261
217	Polyline	5122	residential	B	F	F	193.880701
218	Polyline	5122	residential	B	F	F	153.200883
219	Polyline	5122	residential	B	F	F	145.725602
220	Polyline	5122	residential	B	F	F	139.426935
221	Polyline	5122	residential	B	F	F	402.686328
222	Polyline	5122	residential	B	F	F	123.852332
223	Polyline	5122	residential	B	F	F	249.680134
224	Polyline	5122	residential	B	F	F	414.014423
225	Polyline	5122	residential	B	F	F	104.461747
226	Polyline	5122	residential	B	F	F	175.920443
227	Polyline	5122	residential	B	F	F	253.191409
228	Polyline	5122	residential	B	F	F	231.421951
229	Polyline	5122	residential	B	F	F	142.856421
230	Polyline	5122	residential	B	F	F	170.100342
231	Polyline	5122	residential	B	F	F	165.291913

232	Polyline	5121	unclassified	B	F	F	246.321037
233	Polyline	5122	residential	B	F	F	189.519935
234	Polyline	5121	unclassified	F	F	F	342.697465
235	Polyline	5154	path	B	F	F	125.650908
236	Polyline	5115	tertiary	F	F	F	1006.401412
237	Polyline	5115	tertiary	F	F	F	1013.914221
238	Polyline	5114	secondary	F	F	F	305.996777
239	Polyline	5122	residential	B	F	F	195.154591
240	Polyline	5122	residential	B	F	F	90.624509
241	Polyline	5122	residential	B	F	F	224.2764
242	Polyline	5121	unclassified	B	F	F	463.859891
243	Polyline	5122	residential	B	F	F	303.863684
244	Polyline	5113	primary	F	F	F	33.089393
245	Polyline	5121	unclassified	B	F	F	378.143203
246	Polyline	5121	unclassified	B	F	F	573.662537
247	Polyline	5122	residential	B	F	F	105.038792
248	Polyline	5122	residential	B	F	F	64.967748
249	Polyline	5122	residential	B	F	F	22.446219
250	Polyline	5114	secondary	F	F	F	325.271626
251	Polyline	5114	secondary	F	F	F	289.736654
252	Polyline	5121	unclassified	B	F	F	615.520677
253	Polyline	5113	primary	B	F	F	388.319431
254	Polyline	5122	residential	B	F	F	92.353429
255	Polyline	5115	tertiary	F	F	F	47.222391
256	Polyline	5115	tertiary	B	F	F	10.203048
257	Polyline	5115	tertiary	F	F	F	35.564908
258	Polyline	5115	tertiary	F	F	F	12.688065
259	Polyline	5114	secondary	F	F	F	235.172715
260	Polyline	5115	tertiary	F	F	F	13.100711
261	Polyline	5114	secondary	F	F	F	88.050667
262	Polyline	5121	unclassified	B	F	F	176.200137
263	Polyline	5114	secondary	F	F	F	232.640927
264	Polyline	5115	tertiary	F	F	F	47.079854
265	Polyline	5121	unclassified	B	F	F	611.494567
266	Polyline	5115	tertiary	F	F	F	44.580572
267	Polyline	5114	secondary	F	F	F	313.869787
268	Polyline	5114	secondary	F	F	F	289.91185
269	Polyline	5121	unclassified	B	F	F	60.40993
270	Polyline	5114	secondary	B	F	F	39.820944
271	Polyline	5114	secondary	F	F	F	326.930075
272	Polyline	5121	unclassified	F	F	F	235.628158
273	Polyline	5121	unclassified	B	F	F	631.162944
274	Polyline	5121	unclassified	F	F	F	236.468143
275	Polyline	5122	residential	B	F	F	35.506144

276	Polyline	5113	primary	F	F	F	56.443755
277	Polyline	5113	primary	B	F	F	6.653475
278	Polyline	5122	residential	B	F	F	8.526265
279	Polyline	5122	residential	B	F	F	146.972117
280	Polyline	5113	primary	F	F	F	458.457688
281	Polyline	5112	trunk	F	F	F	71.172063
282	Polyline	5112	trunk	F	F	F	162.713659
283	Polyline	5112	trunk	F	F	F	133.69865
284	Polyline	5112	trunk	F	F	F	390.130438
285	Polyline	5112	trunk	F	F	F	188.901796
286	Polyline	5112	trunk	F	F	F	109.540325
287	Polyline	5121	unclassified	B	F	F	168.397824
288	Polyline	5121	unclassified	B	F	F	487.795569
289	Polyline	5112	trunk	F	F	F	477.843915
290	Polyline	5112	trunk	F	F	F	362.533731
291	Polyline	5112	trunk	F	F	F	113.065655
292	Polyline	5121	unclassified	B	F	F	1.408142
293	Polyline	5112	trunk	F	F	F	355.652401
294	Polyline	5112	trunk	F	F	F	305.00898
295	Polyline	5112	trunk	F	F	F	211.237311
296	Polyline	5113	primary	F	F	F	736.766912
297	Polyline	5113	primary	F	F	F	729.566244
298	Polyline	5115	tertiary	F	F	F	190.593976
299	Polyline	5135	tertiary_link	B	F	F	10.916952
300	Polyline	5122	residential	F	F	F	253.766774
301	Polyline	5122	residential	B	F	F	17.728241
302	Polyline	5122	residential	B	F	F	17.352652
303	Polyline	5122	residential	B	F	F	147.236213
304	Polyline	5122	residential	F	F	F	89.460707
305	Polyline	5122	residential	F	F	F	89.261978
306	Polyline	5122	residential	B	F	F	88.811931
307	Polyline	5122	residential	B	F	F	206.525436
308	Polyline	5122	residential	B	F	F	18.65139
309	Polyline	5122	residential	B	F	F	14.770428
310	Polyline	5122	residential	B	F	F	90.542554
311	Polyline	5142	track	B	F	F	679.529964
312	Polyline	5121	unclassified	B	F	F	233.03465
313	Polyline	5122	residential	B	F	F	41.095863
314	Polyline	5141	service	B	F	F	223.113594
315	Polyline	5141	service	B	F	F	104.564247
316	Polyline	5121	unclassified	B	F	F	126.468467
317	Polyline	5122	residential	B	F	F	67.624989
318	Polyline	5122	residential	B	F	F	49.186062
319	Polyline	5122	residential	B	F	F	131.997536

320	Polyline	5122	residential	B	F	F	110.865543
321	Polyline	5122	residential	B	F	F	126.73881
322	Polyline	5122	residential	B	F	F	111.876469
323	Polyline	5122	residential	B	F	F	62.261291
324	Polyline	5122	residential	B	F	F	179.107883
325	Polyline	5122	residential	B	F	F	61.758225
326	Polyline	5121	unclassified	B	F	F	324.31586
327	Polyline	5122	residential	B	F	F	129.504169
328	Polyline	5121	unclassified	B	F	F	113.464633
329	Polyline	5122	residential	B	F	F	88.120794
330	Polyline	5122	residential	B	F	F	88.467355
331	Polyline	5122	residential	B	F	F	140.905424
332	Polyline	5121	unclassified	B	F	F	226.45906
333	Polyline	5122	residential	B	F	F	207.986529
334	Polyline	5122	residential	B	F	F	36.981804
335	Polyline	5112	trunk	F	F	F	86.57676
336	Polyline	5112	trunk	F	F	F	20.888255
337	Polyline	5112	trunk	F	F	F	741.833917
338	Polyline	5112	trunk	F	F	F	60.505057
339	Polyline	5115	tertiary	F	F	F	54.134511
340	Polyline	5115	tertiary	F	F	F	54.520976
341	Polyline	5132	trunk_link	F	F	F	78.698689
342	Polyline	5132	trunk_link	F	F	F	116.314929
343	Polyline	5121	unclassified	B	F	F	19.702505
344	Polyline	5113	primary	B	F	F	9.378305
345	Polyline	5121	unclassified	B	F	F	155.366524
346	Polyline	5115	tertiary	B	F	F	46.208742
347	Polyline	5121	unclassified	B	F	F	212.866413
348	Polyline	5121	unclassified	B	F	F	216.617049
349	Polyline	5113	primary	F	F	F	11.870456
350	Polyline	5113	primary	F	F	F	11.465055
351	Polyline	5121	unclassified	B	F	F	175.111333
352	Polyline	5121	unclassified	B	F	F	76.45392
353	Polyline	5114	secondary	F	F	F	78.822617

CURRICULUM VITAE

PERSONAL DETAILS

Name SURNAME: M.Radwan Mouket

EDUCATION

September 2019 – October 2023 **Gaziantep University, Gaziantep, Turkey**
Master's Degree in Industrial Engineering.

September 2000 - June 2006 **University of Aleppo, Aleppo, Syria**
Bachelor's Degree in Mechanical Engineering

September 1997 - June 2000 **Bassam Alomar High School, Aleppo, Syria**
High School Diploma

EXPERIENCE:

- Urban Research Center (URC), January 2016 – Till now – CEO.
- Chemtech - January 2014 - January 2016 – Deputy General Manager.
- Lafarge Cement Syria – November 2011- January 2014 – Maintenance Engineer.
- Krayem for metallic fabrication - November 2011- November 2009- Project Manager.