Vrije Universiteit Amsterdam

Master Thesis

"Optimal location displacement for future ambulance stations in the city of Athens, Greece under the existence of traffic congestion (an attempt to understand the mechanisms of transport flow in an overcrowded urban environment)"

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To my Parents,

Nickolaos & Maria

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Abstract

According to 2021 European Emergency Numbers Association data, about 300.000 people suffer from a cardiac arrest while being out of Hospital where due to personnel immediate healthcare assistance can be administered, most of them happening while the victims are at home. From those only 8 to 10% survive, while the greater percentage of people are unable to administer first aid in the case of emergency to their close relatives in case of need. It takes only ten minutes for a person who has suffered from a cardiac arrest to fall into a permanent comma, and about fifteen minutes before he cannot be rejuvenated with technical means and lose his life, if CPR procedure does not begin immediately, and a device called electronic defibrillator is the only thing increasing his chances of surviving. A great number of countries belonging in the European Union have set up their ambulance dispatch centers in their cities in order for their paramedics to be able to reach cases like the above via ambulance within the critical ten-minute margin. System that experienced a serious stress test given the hospitalization needs due to the Covid-19 pandemic a few years back. In Athens, the capital of Greece, the above system is significantly underdeveloped with only one Ambulance Dispatch center with limited number of vehicles and paramedics working far beyond 9 to 5 schedules to cover the emergency needs of about 3,8 million people. The suboptimal use of financial support packages, and the general environment of the country lead to people dying waiting for an ambulance, while the few donations from shipowners are unable to prevent the inevitable, despite them exceeding tenths of millions of euros for new equipment and vehicles (ambulances). What outcome can road traffic congestion have to the latter mortality rates and vehicle travel times in an urban environment like the one of Athens?

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1. Introduction

1.1 Overview of Athens

In the south and Southwest part of Athens petroleum refineries along with their distribution and loading hubs are situated in the Industrial zones of Perama and Aspropyrgos. Namely companies like ETEKA, Hellenic Petroleum S.A. , Motor Oil S.A. (Owner of Shell Hellas plant). In the southern central part of Athens, the sub-industrial area of Agios Ioannis Rentis is situated where food and beverage suppliers with their distribution centers as well as their physical stores are situated. There are also several warehouses and distribution centers in the North-West part of Athens (the area of Ano Liosia).

The city of Athens is run through by an untolled highway E75 Starting from the North part , and diverging through the west midsection up until the South part of Athens where it is connected to the Municipality of Piraeus where one of the largest Mediterranean ports is placed, and in the opposite direction continuing into a high-speed road along the coastline. Following the previous road the last four lane high speed road Leoforos Syggrou , connects the Southern parts of Athens and neighboring municipalities with the city center. Starting from the city center and continuing through the Northeast a three-lane road, splits into two main highway avenues, Leoforos Kifissias which continues up North crossing the central-eastern part of Athens all the way to the North Suburbs before giving its place to smaller two-lane roads parallel to the entering to Athen's highway E75 (Kifisos). The other part of the center starting highway road follows a similar route before shifting to cover completely the East part of Athens giving its place to the tolled route 6 Attiki odos highway which finishes in a U-ring in the Athens International Airport. Driving the latter route towards the center of Athens, this highway splits again into two similar highways, the southern one covering the outer South – East ring of Athens and connecting it to the Southern Municipalities of Attica, and the Northern one which continues through the Northern part of Athens until it meets the main Ring, above E75 giving vehicles besides the roundabout routes, access to the center of Athens mainly through E75, but most importantly connecting all the previous through outer highway rings to the industrial areas and suburbs, located at the North, West and Southwest of the city (from top to bottom like Ano Liosia , Aspropyrgos, Perama, Rentis though entering highway Athens Avenue) and the port of Piraeus. The last main highway which also starts from the center of Athens called Athens Avenue, connects the eastern part of the city to downtown, and vice versa towards the industrial area of Aspropyrgos, which also happens to be the main road used by heavy transport vehicles from Peloponnese region to reach the east part of Athens and directly the port of Piraeus.

After all this complicated network the reason this paper focuses on describing it in detail is the fact that on morning weekdays when the city begins to wake, several vehicles carrying heavy loads such us fuel for gas stations and many more, F&B products for supermarkets and similar businesses, as well as industrial equipment and more, end up meeting on the road with smaller carriers and mostly individual commuters driving to their jobs from all around Attica, summing up for an average commuting distance reaching 40 kilometers in certain cases.

Here, a historical recap of the development of Athens Road network and agglomeration expansion is made in order to gain an understanding of how the city grow in its today form, which contributed heavily to the daily congestion patterns taking place.

1.2 Traffic in Theory and in Athens

In a road network a certain amount of traffic is expected and there are cases where it can also be beneficial (check source research project). However, the cause of traffic is the cost (extra minutes spend per trip) each user imposes on the rest of the users in a certain road network without wanting to or accounting for it, namely the marginal external cost. Pricing this externality under certain conditions can prove beneficial, since pricing a road when it is at full capacity will stop extra drivers entering, and will make users smoothen their departure times after and before the peak in order to avoid it (given of course that this pricing is not always the fairest policy, since the value of money and utility gained differentiates on the financial background of the user) as stated by Erik T. Verhoef & Keneth A. Small (2007). Alas in an environment like Athens, accounting for the lack of alternatives to commute and economic austerity currently present (among other factors like lack of education, trust in the justice system), which translates to inelastic demand for the use of car, despite the challenges in parking and reaching the expected travel times, and also the ellipse of organized reporting and data to monitor traffic congestion, although it would be welcome to have the opposite, designate limited exercise and explanatory power to pricing options up until the creation of this paper.

Specifically, in the early morning hours of the weekdays the highway, primary, secondary and lastly residential road links as well as their connecting ones are filled with traffic since people leave their resident either by car or with public transport flooding these streets with traffic. Residential roads exhibit some relaxed travelling times between 10 a.m. and 1 .p.m. (as exhibited by Tom-Tom Open GPS data) where only people that work in distribution, food delivery, public transport and a small portion of travelling people and leisure travelers are using the road network. This results at moderate traffic in the city center with lack of parking spots in it, while their availability becomes bigger the closer we are to the outer rim residential areas and the suburbs.

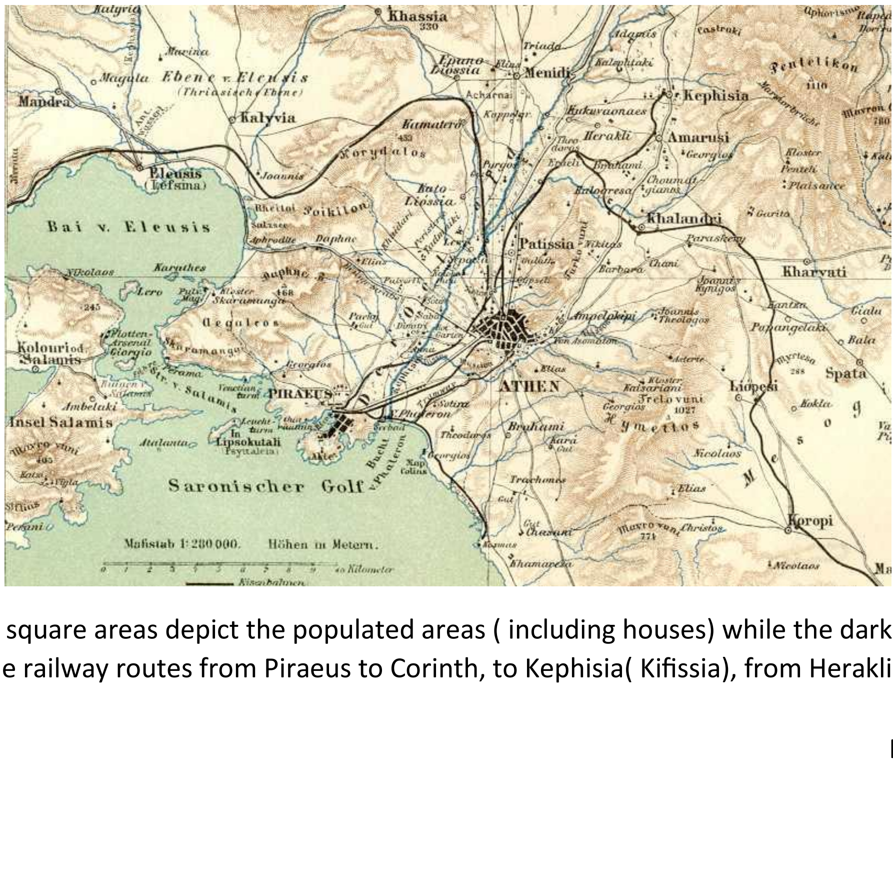
1.3 History of Athens

Originally Athens, being one of the most ancient preserved and gradually turned into modern cities, starting from a historical city center connected to the Piraeus port and expanding along this line. When the first railway network was introduced connecting the port with the Northern suburbs, put side to side to the main road network connecting the previous locations passing through the city center, and marking oldest occupied parts of the city. Access to this line network meant daily commuting for all sorts of workers and merchants of the time, since this trading route helped people connect to the rest of the city and have access to their necessities. Many of the roads connecting Piraeus to Athens center and from there to the Northern suburbs, where preexisting long before the independence of Greece and the creations of its nation. With the early occupation of Athens regions slowly expanded forcing these main arteries to stay active and self-created necessary smaller channel roads started appearing, not necessarily graveled, since most of the commuting was taking place either with horses or chariots drag by them, when talking about transporting goods apart from the traditional way of on foot carrying. The appearance of cars did not come until the first decades of the 20th century, up until which horses dragging carriages executed most of the goods and people delivery in soil paths or in very rare cases grated stone parts, in order to secure passage traction for those predecessors of modern vehicles. Since the city was slowly moving to the electricity era, electricity poles started appearing along the main commercial route, and reaching side roads and pedestrian paths. The latter construction gave more motives to people to build houses close to already preexisting ones, in order to gain access to these commodities (including early telephone lines sharing the same poles). This expansion from within the center of Athens to the outer rim was accompanied with the emergence of local merchant stores for daily groceries, educational facilities (mainly schools) and other infrastructure like police stations. The construction of the first organized water distribution and sewage system started in 1926 in Athens, while up until this point the Andrian aqueduct was the main source of water for the heart of Athens starting from springs of the Parnitha Mountain north of Athens reaching to its heart, the modern famous and expensive area of Kolonaki. During 1860 – 1930, four (4) main tanks, two in Kolonaki, an underwater one in Chalandri and the tank of the smaller Panormou aqueduct was the main source of water distribution for the city of Athens up until the creation of the Marathona Dam. Although not directly linked to our research, the main water network links played a significant road in the occupation and expansion of residential housing and of many industrial factories of the time.

The port of Piraeus, because of its location, was turned out to be the fastest growing industrial municipality and remained that way for several years. By 1880 it became the biggest port of Greece, housing both commercial and industrial shipping, which was followed by a geometric growth of the region's borders. The city of Athens and the port region of Piraeus reached their peak growth towards 1922, where immigrants from other cities of Greece and refugees from the genocide of the Greeks of Asia minor. Nowadays regions as Nea Ionia, Ampelokipoi, Kaisariani and Vironas in Athens central and east, Korydallos, Nikaia, Kokinia and Drapetsona next to Piraeus, Aigaleo and Peristeri in west Athens and finally Kolonaki and Exarcheia in the modern Athens center. It is worth mentioning that most of these refugees had lost almost all their belongings when they came to Athens, and they had to depend both on the state for housing and work, despite the fact that the early residents of Greece did not consider them as their own, something that is displayed both in their income records (the few that exist) as well as the areas they chose to occupy and build their homes. Notwithstanding the fact that the Greek state resulted in government finance in order to create homes for these people, during the time none of the government officials conducted top tier civil design in order to take full advantage of the geomorphological characteristics of the yet unoccupied areas, resulting in many dense square blocks, lack of pedestrian roads while the street dimensions remained narrow resulting in most of these areas keeping the same design until today. Limited to a one parked one moving vehicle road width, many of today's Athen's neighborhoods, have this design, which although vintage and stylish, created problems as congestion whenever people moved to new houses, whenever the water and electricity infrastructure needed replacement, maintenance or expansion, or simply when two vehicles like carriages and later on cars met. Certainly, for the era of the city roads with more width were considered unnecessary, since the main priority was to find home for the latter early residents, apart from costly to construct, mainly due to lack of funding and the elevation dissimilarities across the city of Athens (rocky soil, steep hills, lack of continuous field space of steady elevation coastal areas of Moschato excluded). The architects, Stamatis Kleanthis and Eduard Schaubert responsible for the design of the road network around the historic center of Athens back in the year 1833, succeeded in building a road network that would highlight the ancient monuments of Acropolis, Lycabetous Hill among many more. Most of the historic squares of the center where highlighted, as well as the main central roads were aligned with the ruins of the ancient city (that is the reason, Patision avenue, which crosses the heart of Athens from the area of Patissia up till the central Omonia square, provides clear view to Acropolis.

The population of Athens and its spatial expansion stood at a steady rate after 1922, since economic crisis, the events of the second world war followed by the Greek civil war and the decade of dictatorship in Greece right after, prohibited most of the people to have the motives to resettle in Athens and mitigated the expansion of houses to the preexisting residents of the municipalities of Attica.

<u>Image 1: The map of Athens 1894.</u>



The dark square areas depict the populated areas (including houses) while the dark red lines depict the railway routes from Piraeus to Corinth, to Kephisia(Kifissia), from Heraklion to

Koropi (later the route of the underground railway to Eleftherios Venizelos Athens Airport) and finally the costal line to what today is the Municipality of Glyfada

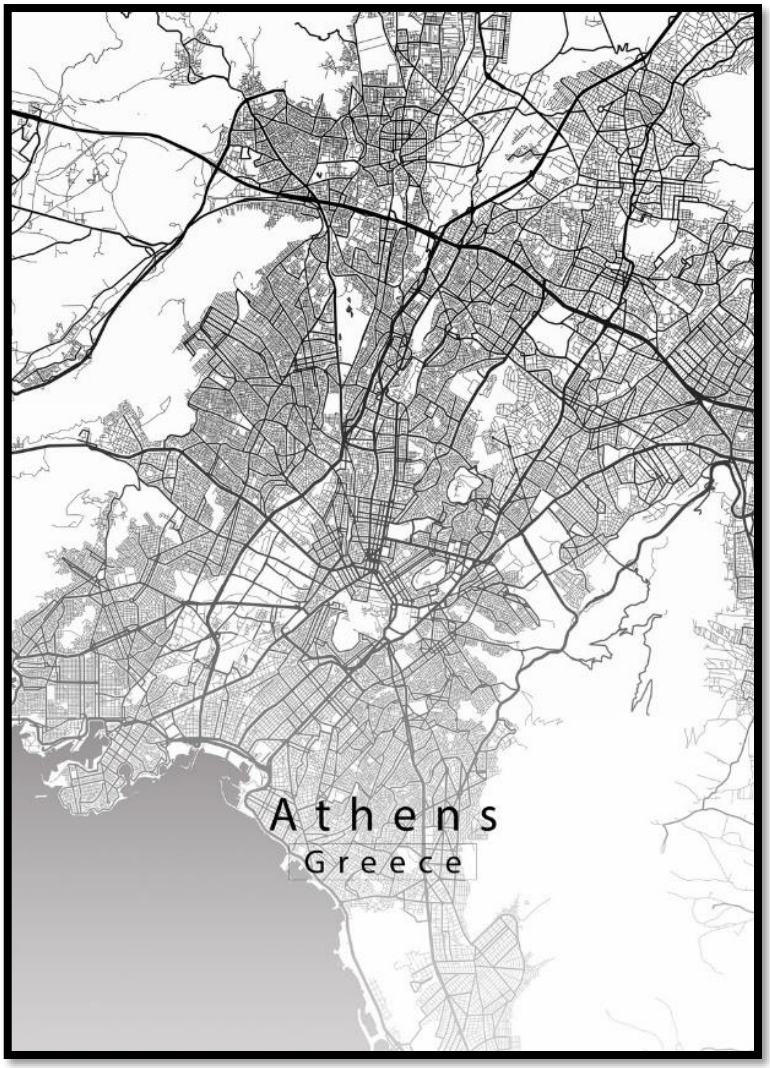
The first electricity factory was situated at Panepistimiou street in 1890, while the Kerameikos area housed a large lightgas production plant, which was the main method of illuminating public street lamps and certain houses. In the year 1902, The Faliro Hydroelectric power plant was operational, located at the area of Neo Faliro next to Piraeus, and alongside many local power plants by private holders, and the creation of a second electricity production factory at the area of Keratsini in 1926, where the main sources of electric power for the city of Athens (the first one also powering the electric Piraeus – Kifisia railway).

The industrial blocks of Metaxourgeio in the central Athens, housing a big tobacco processing factory, preceded the creation of large industrial zones with factories of many kinds throughout Athens and the port of Piraeus, mainly where the access to electric power plants, railway lines was minimized, but also where other manufacturing factories were already established (like the area of Keratsini). With a percent of difficulty in mapping, the early industrial zones of Attica, included the port of Piraeus up until the Drapetsona shipyards , Faliro and Keratsini, areas within small distance to port, access to railway and a variety of small factories present, Kerameikos next to the preexisting Thissio, both sides of the Piraeus avenue which connected the port to the heart of Athens chosen by many manufacturers given the easy access it provided, and finally smaller factories located either next to railway stations of Line 1 or the banks of Kifissos river in the west part of the central Attica.

Yet, the asphalt paving of the central Syntagma roads did not start until 1908 and was restricted to only the big scale connecting roads like Stadiou and Panepistimiou which connected Omonia square to Syntagma. The use of cars as means of transport was restricted to a few wealthy families, and apart from vehicles like buses used to travel either from other cities of Greece to Athens, or for public transport within Attica, that peaked up a bit faster, most households did not have a car to commute until the mid-90s. The turbulent history of Greece in the 20th century ranging from two world wars, to a civil one which was followed by roughly a decade of dictatorship (1967 – 1974), accompanied by the continuous loans Greece had to take to sustain its development as an addition to economic crisis (1891 bankruptcy of Argentina, world economic crisis of 1929, public debt deficit crisis of 1965, load debt crisis of 1985 – 1987, and most recent world crisis of 2009, 2010 ongoing economic crisis), left the developing city of Athens in the mercy of the manufacturers, shipowners and politicians in power, leading to frivolous urban development without limitations. The burst in migration that took place in the region of Attica during the 90s, led to the rapid expansion of the historic center and the line towards and including Piraeus, with countless new houses being built and roads paved without predicting the number of cars that eventually occupied them. The appearance of primary two-way roads and single direction residential roads wide enough for three cars (two parked to the sides and one moving in-between them) quickly overshadowed the neighboring central areas of the basin, without however putting limitations for parked cars, load unload zones for trucks and heavy vehicles, lack of pedestrian paths which was originally covering the most of the road surface. In an attempt to cover the transport demand of both individual commuters and professional carriers of all kinds, in conjunction with the ease of loan influx Greece had, once entering the European Union in 1981, large scale concrete highways and their interchanges were constructed in various parts of Athens. The motivation was not entirely faulty, since tradesmen needed to reach or start from the port of Piraeus and the manufacturing plants and shipyards needed their resources delivered to operate, along with the job of supplying with every possible product store and market of Athens, all done in the fastest and most efficient way possible, something that residential central roads could not provide, (Although Arthur Pigou, had already established his theory about the Braess Paradox (1920), meaning that adding more roads to an already preexisting network can reduce the speeds in the network since drivers will switch to the new route limiting its capacity, speeds and counterbalancing the positive effects from its creation).

Unfortunately, the gradual yet fast shift from production workers to services employees, in combination with the government law, forcing industries out of urban environment, and the unsupervised ease of loan hand out, resulted these large infrastructures today to be used in their greatest volume for individual commuting rather than smooth exploitation with heavy vehicles to maintain the advertised and originally promised travel times. Therefore, past few decades a densely populated city, with absolutely zero control on the height of the building being built, elastic legislation on efficient road use and little punishment for the non-law abiding, which relies heavily on car for commuting. While many attempts have been made from both the state and the organization for public transport in Athens (O.A.S.A.), to promote their use, the vast occupation and construction of new municipalities, (and the relaxed passenger control), have led many people to choose a private vehicle for their commuting, (in spite of the endless connectivity options offered). Congestion unfortunately affects both car driving road users as well as public transport passengers, and Athens is not exception to this modern urban environment observation, with many primary roads and central arteries pinned down at traffic congestion timeframes (7 to 9 a.m. , 2:30 to 4 p.m. , 5p.m. to 8 p.m.).

Image 2



Up: Bulk representation of today's road network of the biggest part of Athens

Down : Ring road intersection of the E75 highway entering Athens from the North suburbs and E94 bridging the city of Elefsina, with the Northern suburbs and finishing and the Athens International Airport "Eleftherios Venizelos" east of Athens.

2. Literature Review & Research Question

2.1 Purpose of Research

Apart from the scientific papers used to completing my research paper with focused on the phenomenon of congestion in urban environment and its possible solution, Grekousis (2014), Brent (2020) & Griffin (2013) was the motivation for the following pages. The first one highlights the added value of the spatial factors through GIS software in analysis and decision making in healthcare. This GIS, AI & Neural Networks approach focused on density utilizing multicriteria tools and different time periods. Ket difference with my paper is the accuracy used in the latter, since I only focus on increasing the probabilities of serving emergencies (this paper has simpler approach), looking one step further and drawing motivation for future analysis. In the second one, the authors highlight the higher value of time of the Emergency response vehicles, using an American State Size Dataset (far bigger than Attica where Athens is the capital). The focus is primarily on Fire Department response times and does not count loses for the Healthcare department, contradictory the focus here is on the last category (time losses that can be deadly). The last one focuses on a dataset extracted from a questionnaire towards Emergency Medical Service Workers; to draw the factors they consider most important in reduced travel times. This approach is not present here but it could only positively affect the validity of the results, since an expert's opinion is better in any profession. This is the first paper to my understanding that utilizes a simplified network analysis to illustrate congestion on the roads of Athens and trying to use information for all the people included to see (the) "If there is a second location and (the) where should it be to cover their healthcare needs?" Supplementary a regression analysis, aims to test "If socioeconomic factors contribute in the reasons people call the ambulance service for?

2.2 Emergency Ambulance service and the inhibitors of smooth operation

The service responsible for immediate response in life threatening situations in Athens is called E.K.A.B., which acronyms translates to Emergency Center of Rapid Assistance. Its base of operation is situated at the health district between metro stations Ethniki Amyna and Katechaki next to "Georgios Gennimatas" & "Sotiria" General Public Hospitals, at the Eastern central part of Athens, with direct access to Mesogeion Avenue, which passes through the eastern municipalities of Athens (Papagou, Psychiko, Holargos, Halandri,Gerakas), and through the latter to Katechaki Avenue which intersects with the Alimou Avenue after an junction to bridge the southern municipalities (the two first being three lane dual direction with limited traffic lights and the second one a two lane dual direction peripheral road). The total amount of available ambulance vehicles of EKAB is rounded to 90, however only 40 of them are operational (this should not be overlooked since this fleet is used for emergencies within the whole Attica and not only the demand of the capital).

Given the outcome of the recession in Greece, Athens houses 25 public hospitals (including military units that give priority to people working for government services like police, fire brigade, healthcare etc. , and the hospitals dedicated to children healthcare). The positive scenario would be all of them to be operational 24/7, but for reasons like cost reduction and lack of personnel, only maximum five (5) of them work this way per evening, and switch the day after. This being the primary limitation of the preceding network analysis, I am attempting to construct the basic idea that even with all hospitals open on a 24-hour basis (realistically unlikely scenario), there are still people that are left unserved in case of emergency. The initialization of the analysis lays on this spectrum, continuing with the addition of the factor of congestion limiting the road speeds per class to congestion realistic numbers, and comparing the optimal locations for a new station afterwards to summarize. The second limitation is the actual response time. To clarify, in real-life conditions an ambulance must be dispatched from its stand-by location which can be either parked in a hospital or a metro station, reach the incident address, park the vehicle (not as straightforward as it sounds), administer first aid to put the patient in a steady situation for transfer and then begin the final stage of transporting the patient to a proper healthcare facility (in reality the hospitals that work 24/7 shifts that day). Having access to the data of the real call locations, would aid significantly in building a historical map and actually putting to the test the effectiveness of the ambulances given all the conditions taking place. The latter info is scarce in general, and absent from this paper.

3. Part I: Network analysis for public hospitals

3.1 Network Analysis Introduction

The network analysis & the optimal location problem solving procedures presented below were created in the Spatial Analysis Platform QGIS, using the algorithm Network Analysis: Service Area (from layer), using the options both directions and topology value “1”, and was run (8) eight times in total. Prior to explain the technical details and planning it is considered of substance to highlight certain limitations of it, stated below :

1. It is assumed that all public Hospitals are operational and ready to receive patients at all times. In reality only 1/4 of the Hospitals in Attica is available every night
2. The actual emergency call locations were not supplied as data in this paper, therefore information about the residences and the interaction environment of the population of Athens is drawn from online databases
3. Athens, besides its beauty, is a very congested overpopulated city with poor public transport and very high percentage of car and taxi usage. Previous limitations as well as the lack of parking spots and load unload zones for trucks where not directly accounted for in the model
4. Local markets, municipality events, festivals and large-scale gigs can interfere with the vehicle flow alternating routes and travel times for all commuters including ambulances
5. Real accurate data about traffic on the road network are absent, and are replaced by average speeds per type of road
6. The coastal areas in East Attica are not taken under consideration, mainly due to small local population. These areas are getting busier during the seasonal summer months, where traffic also appears in the weekends. A review of all steps for the whole Attica would help better understand the Healthcare needs of these areas.
7. Economic crisis in Greece, and political turbulence have sadly led to many hospitals to stop operating. Especially when focusing on the core Public Hospitals, official update from the Ministry of Health should be consulted

Initially, a simulation the network coverage of Athens is attempted, assuming that the hospitals are stationed in all 25 Public Hospitals and their central dispatch center, for two time periods, one early in the morning where no congestion exists on the road and the second one in the morning hours where traffic is at its peak. Additionally, two types of incidents needing assistance will be added, class one (1) calls that exhibit emergency and need the ambulance to arrive within ten (10) minutes and class two (2) calls exhibiting less serious cases that still need the ambulance to arrive within thirty (30) minutes. The following table represents the kilometers per hour speed per type of road, for the network used :

Table 1.1 : Speeds set for Network Analysis[1] simulation[2]

Type of Road	Period	
	P1	P2
	Speed km/h	
motorway	60	140
primary	50	95
motorway_link	30	70
secondary	40	80
busway	30	60
tertiary	30	30
trunk_link	20	60
primary link	20	45
secondary link	20	45
residential	20	40
service	20	30
tertiary link	20	20
living_street	15	20

The Response times for serious events in countries in Europe is generally 10 minutes but each country has its own exception. For example, for an Emergency Medical Support (EMS) Ambulance crew , in Poland, the median time of arrival on a monthly basis is no longer than 8 minutes in a city with more than 10,000 inhabitants and 15 minutes outside a city with more than 10,000 inhabitants, while the maximum time of arrival cannot be longer than 15 minutes in a city with more than 10,000 inhabitants and 20 minutes outside a city with more than 10,000 inhabitants. This information serves to help set the time margins for the city of Athens and to highlight an actual problem of never reaching those in reality, mutually.

1.For the analysis below the non-congestion period is symbolized by P2, while the congestion period is symbolized by P1

2.The road network from OSM is filtered to include exclusively roads accessible by ambulances

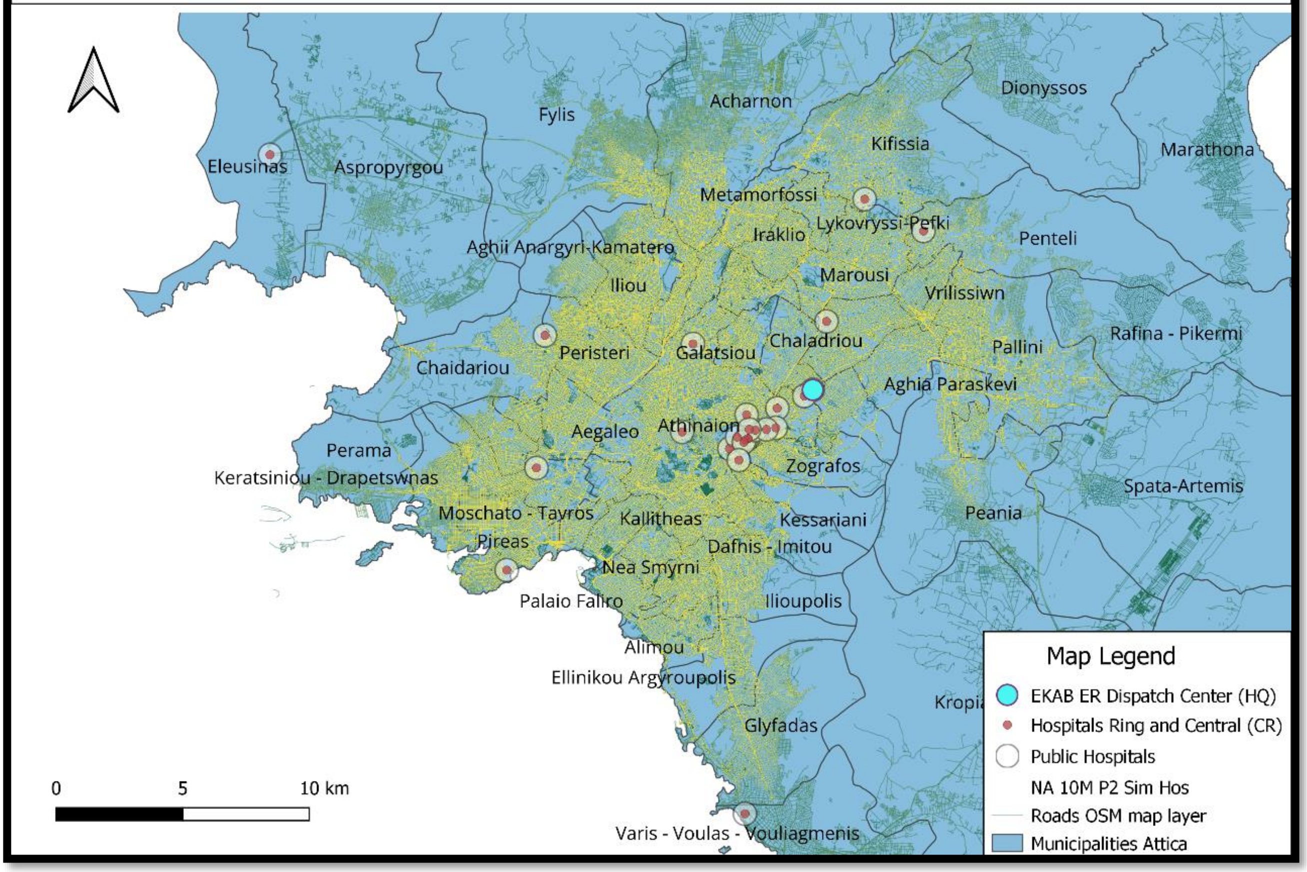
3.2 Network based on all Public Hospitals (Simulation Scenario)

3.2.1 Congestion Absent – Period 2

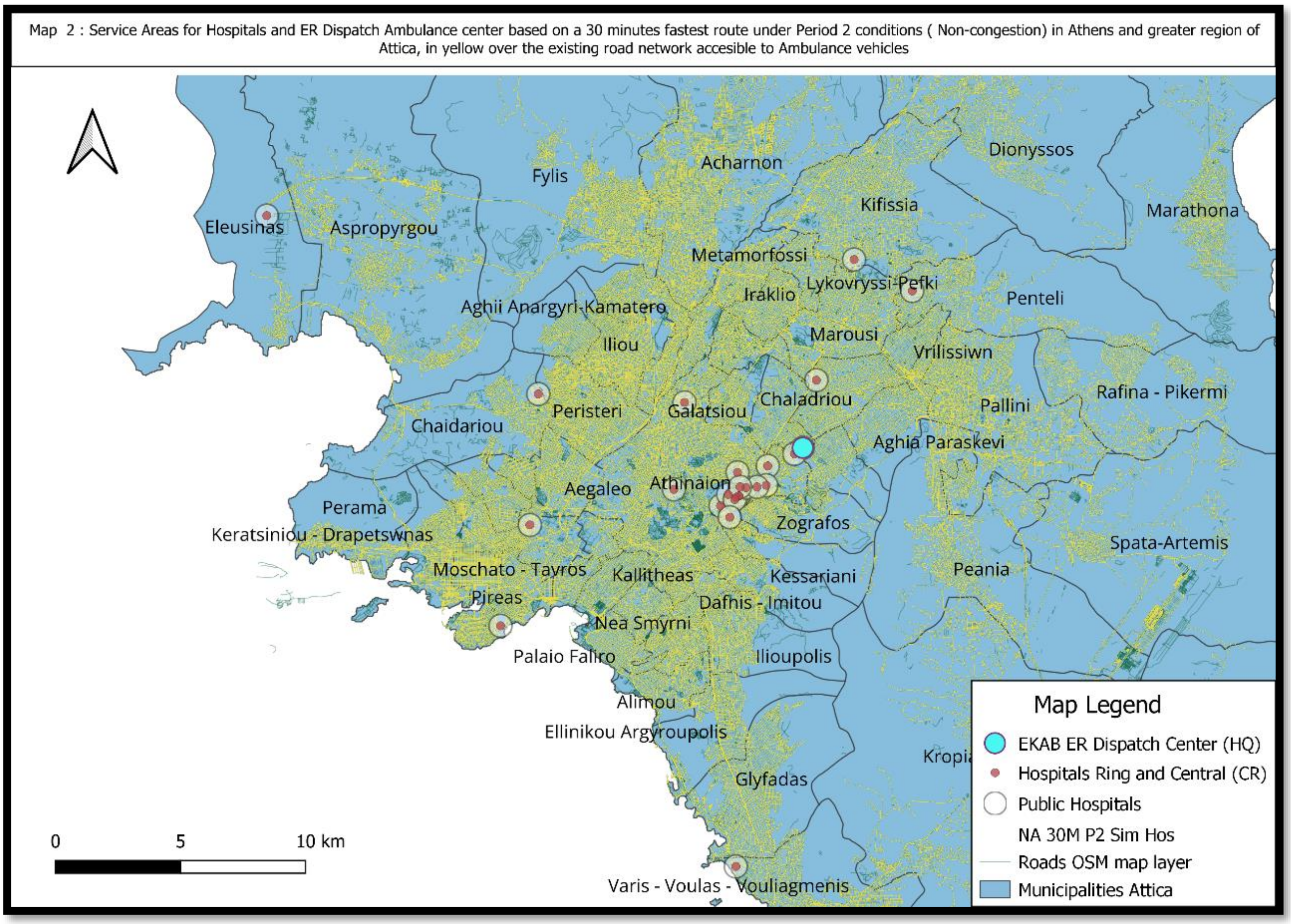
As seen from Map 1 below all of the Athens and Piraeus region municipalities can be reached, while few outer Attica municipalities remain inaccessible. The latter ones are completely reached when 20 minutes more are given to the ambulances to arrive, as seen from the following maps. The few green lines in the center of both maps are not included since they depict pedestrian roads or historic pave ways where access to vehicles is not possible.

Map 1

Map 1 : Service Areas for Hospitals and ER Dispatch Ambulance center based on a 10 minutes fastest route under Period 2 conditions (Non-congestion) in Athens and greater region of Attica, in yellow over the existing road network accesible to Ambulance vehicles



Map2

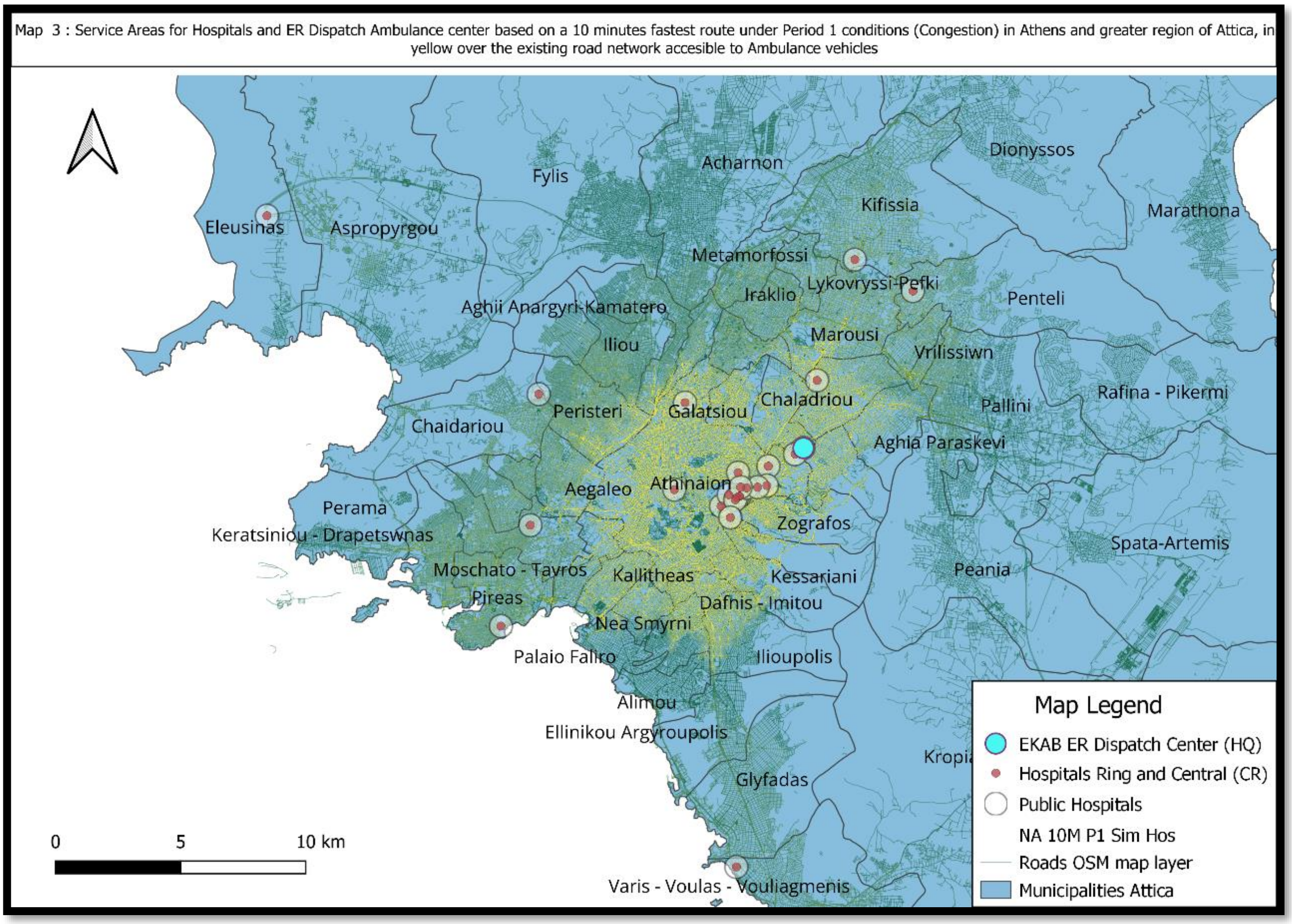


Map 2 displays the accessibility during the optimal non-congestion hours (f.e.5:00 a.m.), for thirty (30) minutes span incidents, where coverage is almost unison. Apart from highlighting the fact that when roads are at low capacity the later emergencies can be reached with ease. In contrast where congestion is introduced, with simulation values, network coverage is cut by almost 2/3 for the most serious incidents, with minor effects for the less serious ones, as Maps 2 & 4 below exhibit.

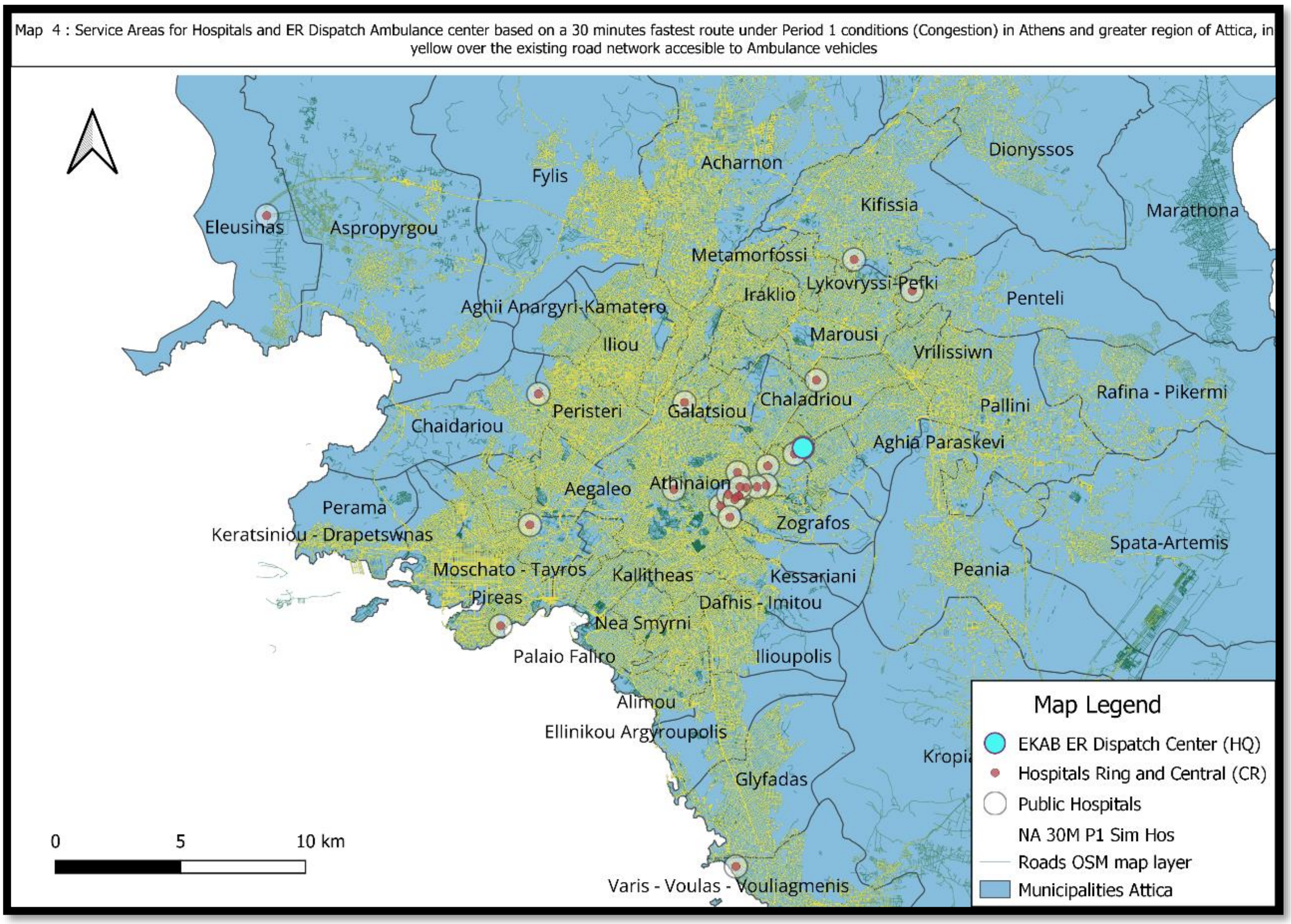
3.2.2 Congestion Present – Period 1

From the set of maps bellow it is in overall visible that, certain areas mainly municipalities at the North and East part of Athens along with almost two municipalities in the south and the coastal municipalities of Perama and part of Elefsina city remain significantly unserved. Lastly when the travel time is increased to 30 minutes only few municipalities in the East part of Athens remain unserved (Map 4).

Map 3



Map 4



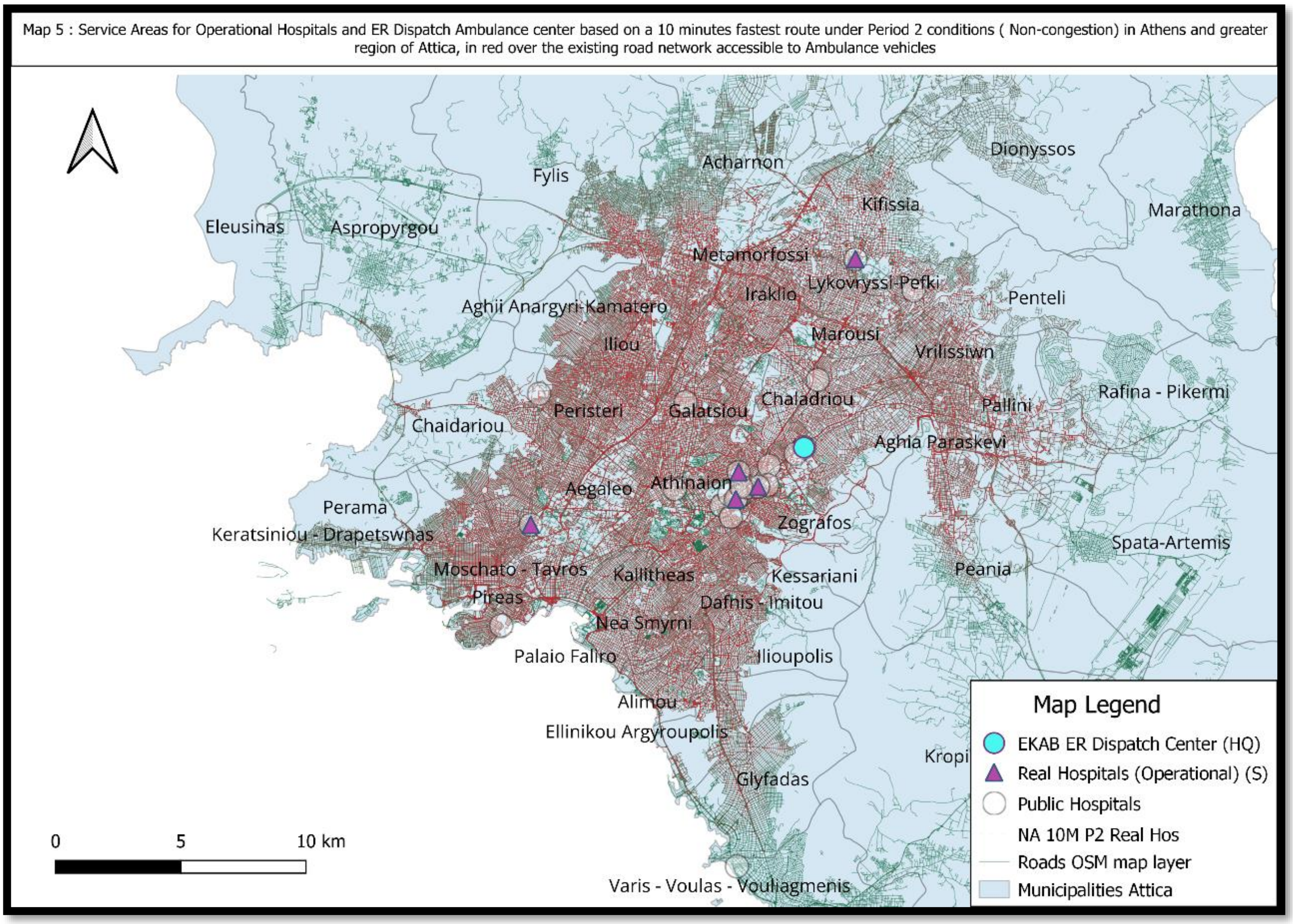
The above simplified simulation, given all hospitals are ready to serve patients, there are enough ambulances to reach the cases, direction of the road is not significant, tolerance is set to 1, shows that even in the perfect conditions some cases can be unreachable within the ten minutes critical time margin. It should not be overlooked that the objective of the ambulance crew is to reach the patient, park the vehicle, make sure it is safe to proceed, reach the patient, administer E.R., stabilize the victim and then start the route to the most appropriate hospital under the commands of the control center, which in many cases is not the nearest one. Below we will focus on a repetition of the exact same conditions, but with a small tweak, being the use of a real-life scenario of available hospitals, with realistically smaller number. The hospitals being used are all operational on Friday the 10th of May 2024 (all Units and Departments included) from 14:30 to 8:00 of the following day.

3.3 Network based on Operational Hospitals (Real Scenario)

3.3.1 Congestion absent – Period 2

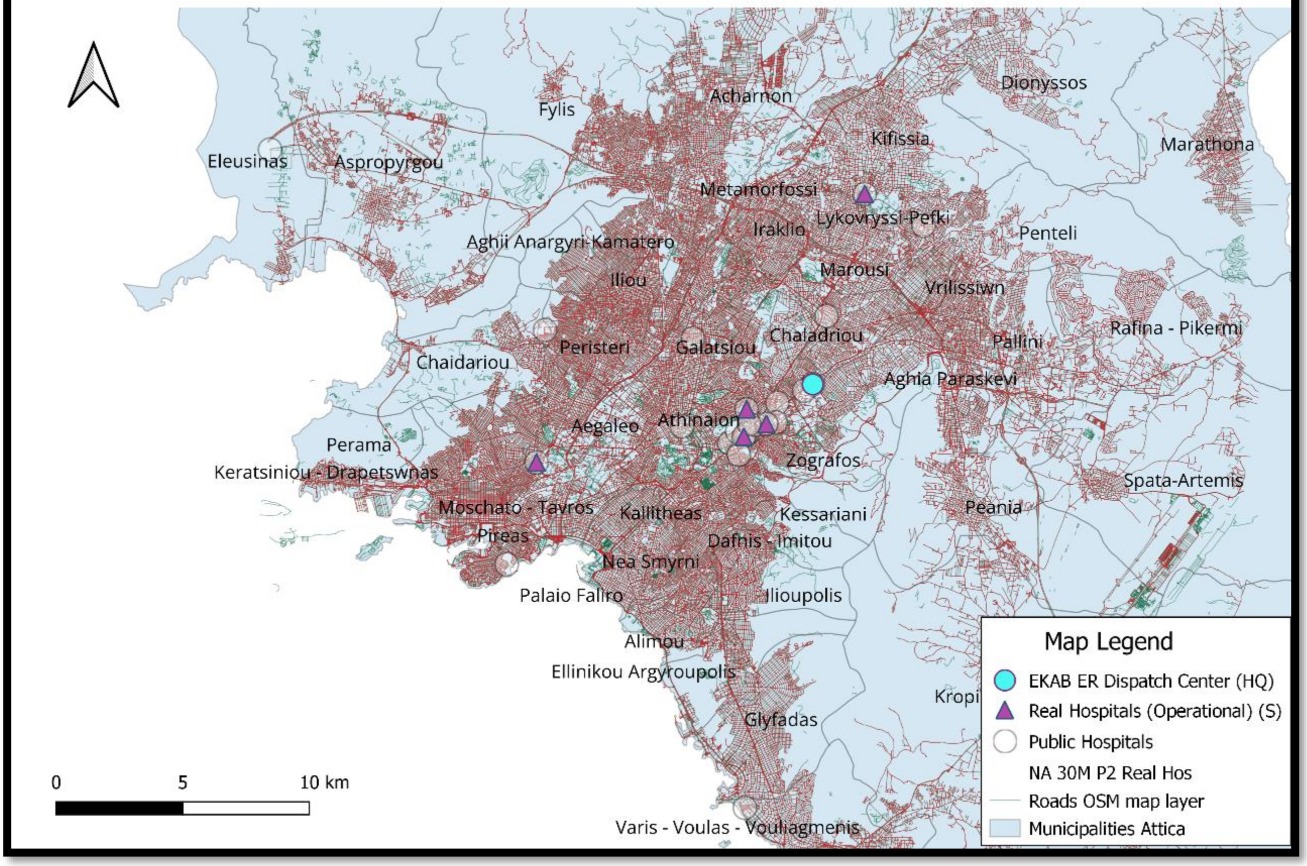
Map 5 shows the Service Areas for Operational Hospitals and ER Dispatch Ambulance center based on a 10 minutes fastest route under Period 2 conditions (Non-congestion) in Athens and greater region of Attica, in red over the existing road network accessible to Ambulance vehicles, while Map 6 below it displays the service Areas for Operational Hospitals and ER Dispatch Ambulance center based on a 30 minutes fastest route under Period 2 conditions (Non-congestion) in Athens and greater region of Attica, in red over the existing road network accessible to Ambulance vehicles. Considering only five (5) hospitals are operational the 10-minute network for the non-congestion period is significantly affected compared to the network coverage in Map 2.

Map 5



Map 6

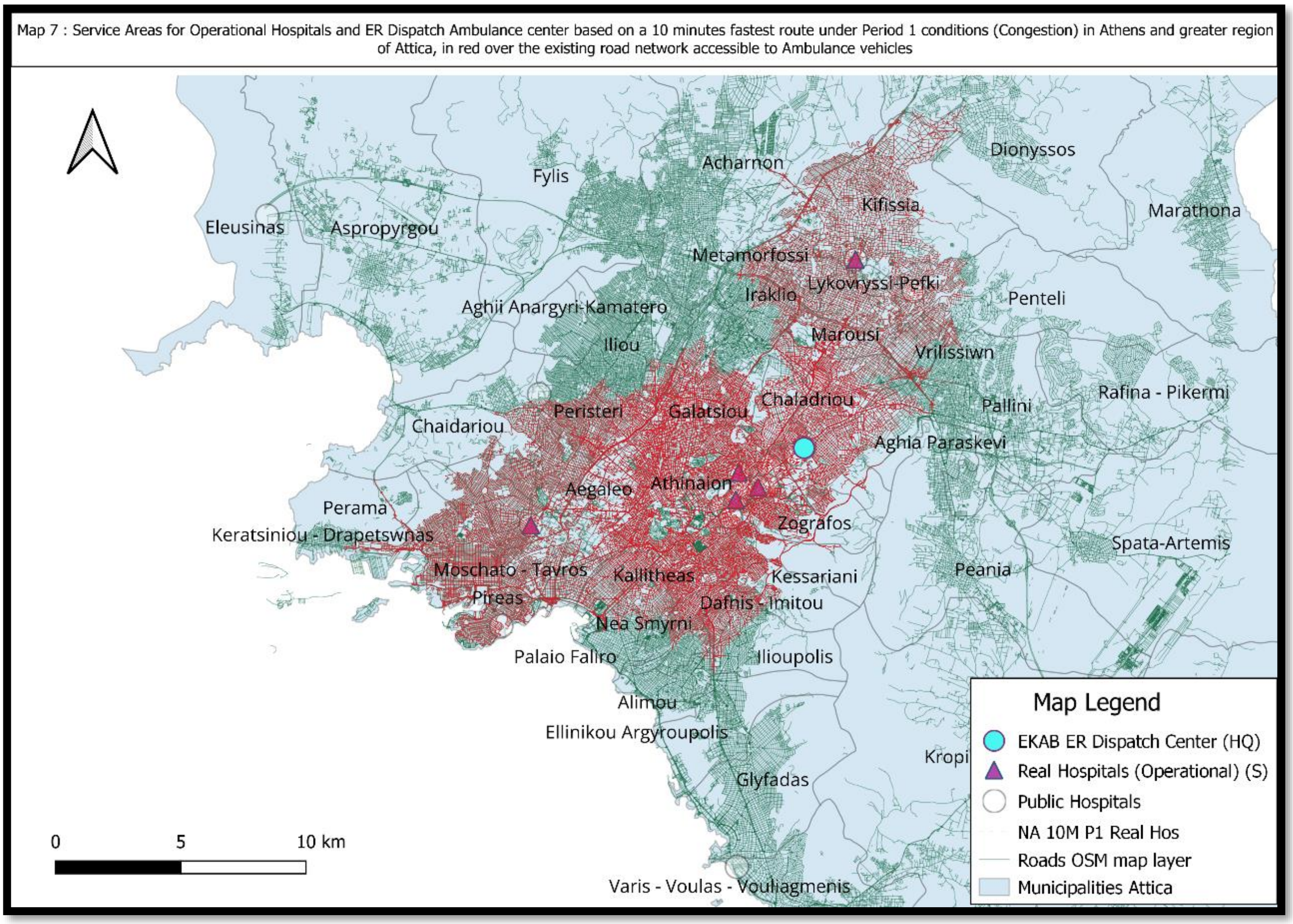
Map 6 : Service Areas for Operational Hospitals and ER Dispatch Ambulance center based on a 30 minutes fastest route under Period 2 conditions (Non-congestion) in Athens and greater region of Attica, in red over the existing road network accessible to Ambulance vehicles



3.3.2 Congestion Present – Period 1

Below on Maps 7 and 8, the true effect of our assumed values for speeds on the road is unveiled, where for the congested road network with Operating hospitals, the ten-minute margin map (Map 7) outputs the smaller coverage of all four (4) 10 minute fastest route and eight (8) networks coverage in general. The differences on the thirty (30) minute road network coverage links for operational hospitals are present in between map 8 & 6, but they are limited, therefore their explanatory power is of minor use. It would be interesting for future research to incorporate the locations the ambulances are on standby before receiving patients, in order to see if the 10-minute maps coverage is affected significantly (meaning the areas unserved plummet), and finally if the thirty minute maps outer rings remain the same or reach full coverage (100%) regardless of traffic conditions.

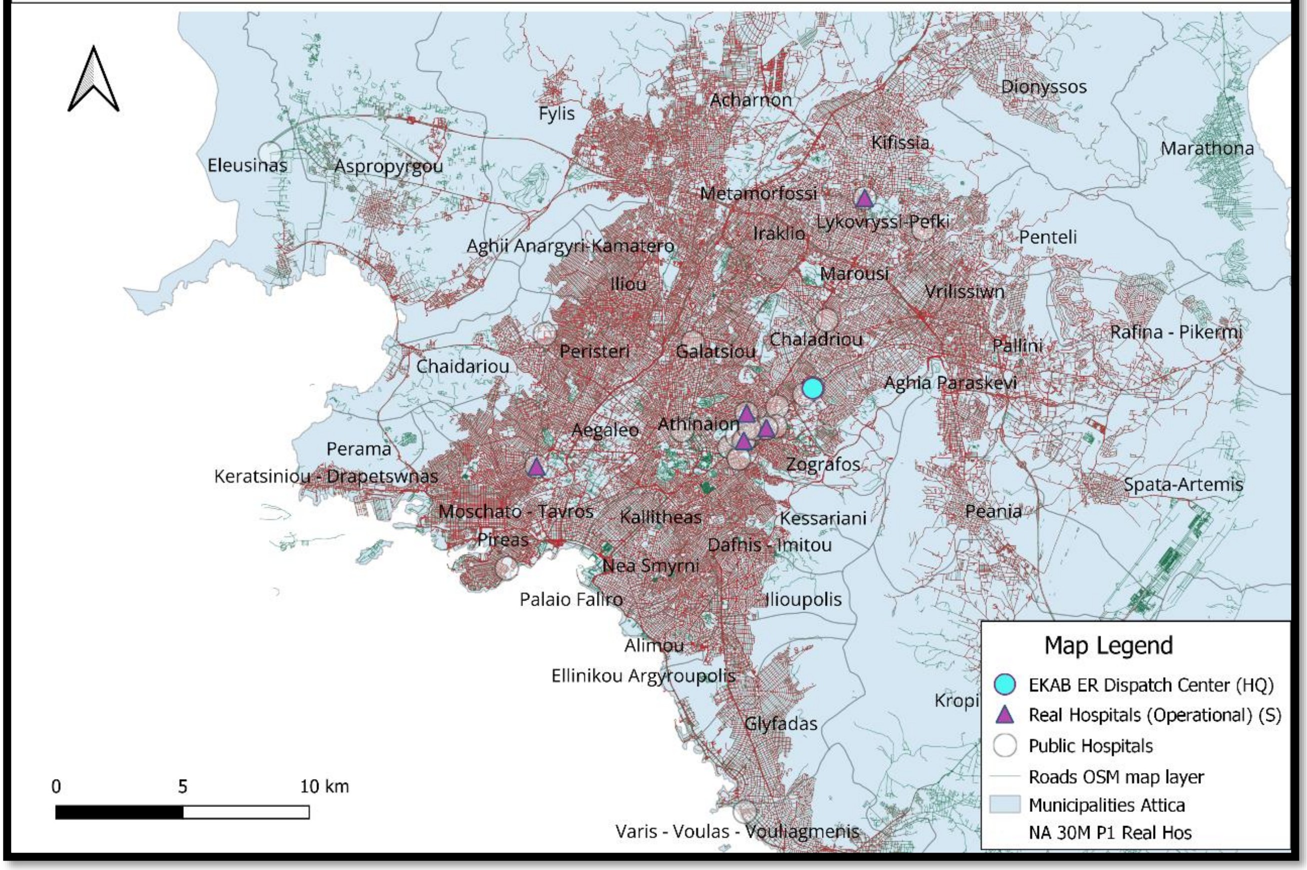
Map 7



Map 7 : Service Areas for Operational Hospitals and ER Dispatch Ambulance center based on a 10 minutes fastest route under Period 1 conditions (Congestion) in Athens and greater region of Attica, in red over the existing road network accessible to Ambulance vehicles
Dionyssos
Acharnon
Fylis
Kifissia
Marathona
Eleusinas
Aspropyrgou
Metamorfossi
Lykovryssi-Pefki
Iraklio
Penteli
Aghii Anargyri-Kamatero
Marousi
Iliou
Vrilissiwn
Chaladriou
Pallini
Rafina - Pikermi
Peristeri
Galatsiou
Chaidariou
Aghia Paraskevi
Athinaion
Aegaleo
Perama
Zografos
Keratsiniou - Drapetswnas
Spata-Artemis
Moschato - Tavros
Kallitheas
Kessariani
Peania
Pireas
Dafnis - Imitou
Nea Smyrni
Palaio Faliro
Ilioupolis
Alimou
Ellinikou Argyroupolis
Kropi
Glyfadas
Varis - Voulas - Vouliagmenis
0
5
10 km
Map Legend
EKAB ER Dispatch Center (HQ)
Real Hospitals (Operational) (S)
Public Hospitals
NA 10M P1 Real Hos
Roads OSM map layer
Municipalities Attica

Map 8

Map 8 : Service Areas for Operational Hospitals and ER Dispatch Ambulance center based on a 30 minutes fastest route under Period 1 conditions (Congestion) in Athens and greater region of Attica, in red over the existing road network accessible to Ambulance vehicles

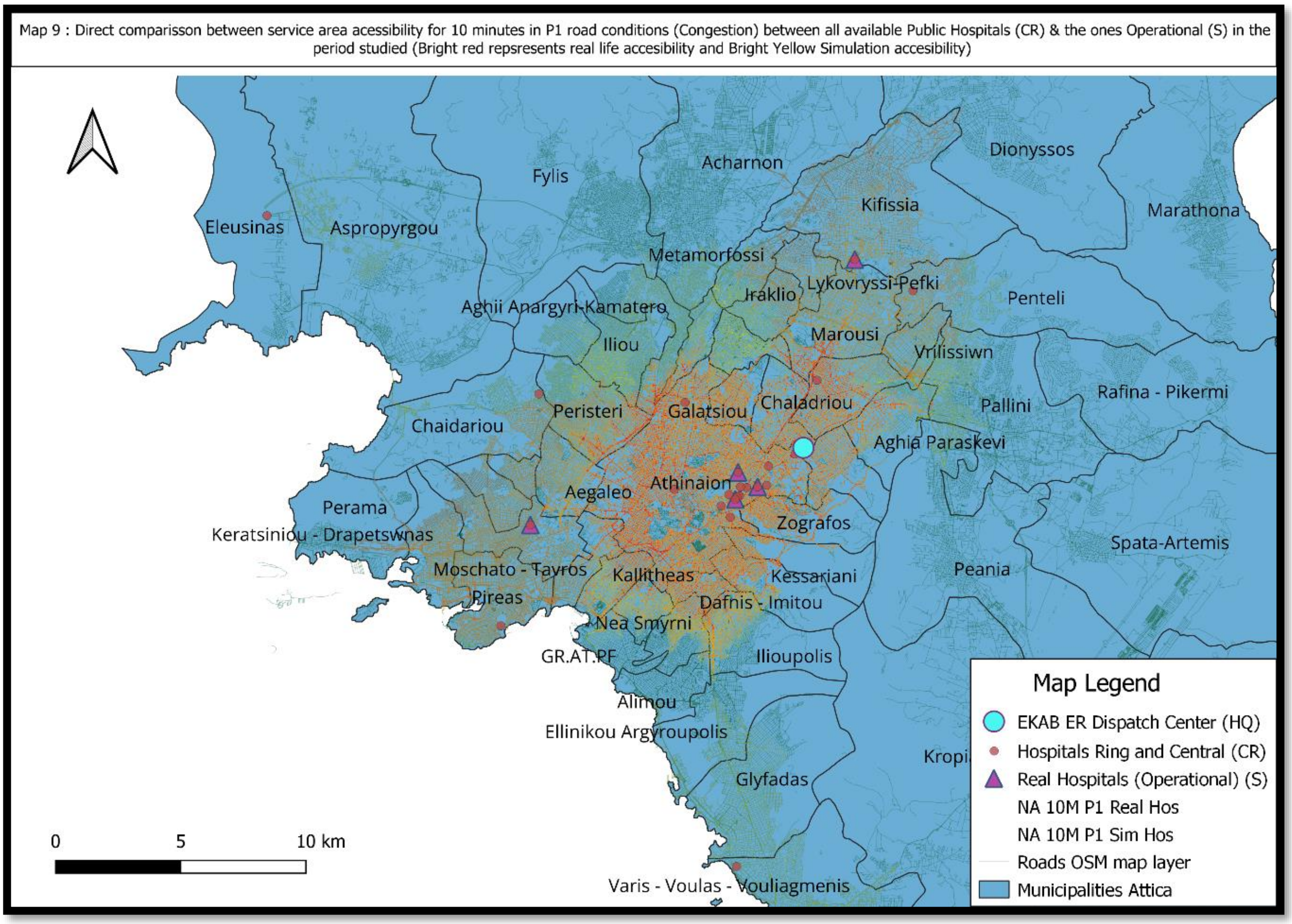


The below direct comparison between the two available hospital datasets, justifies the motivation for an expansion in the network since the green areas are the areas where if an emergency class 1 incident happened during congestion they cannot be reached (neither with all hospitals available nor with only the operational ones), and the yellow are the ones that cannot be reached with the real-life operational hospitals. Certainly, the choice of day as a typical Friday is totally random, and of course there can be days with more hospitals available, even so though a case where all hospitals can be open and ready to welcome patients are exceptionally rare.

3.3.3 Additional Network maps

Hereby two concluding additional maps are introduced, a 10 minute congested network of All Hospitals (NA 10M P1 Sim Hos) and Operational Hospitals (NA 10M P1 Real Hos) from map 3 and 7, per Municipality name, as well as a one for the above information in conjunction with historical traffic accident rates per 1000 residents per municipality (darker grey meaning higher) to acquire an idea of the worst areas a person could have been involved in a serious car accident (serious incident) needing immediate ambulance assistance, based on probabilities.

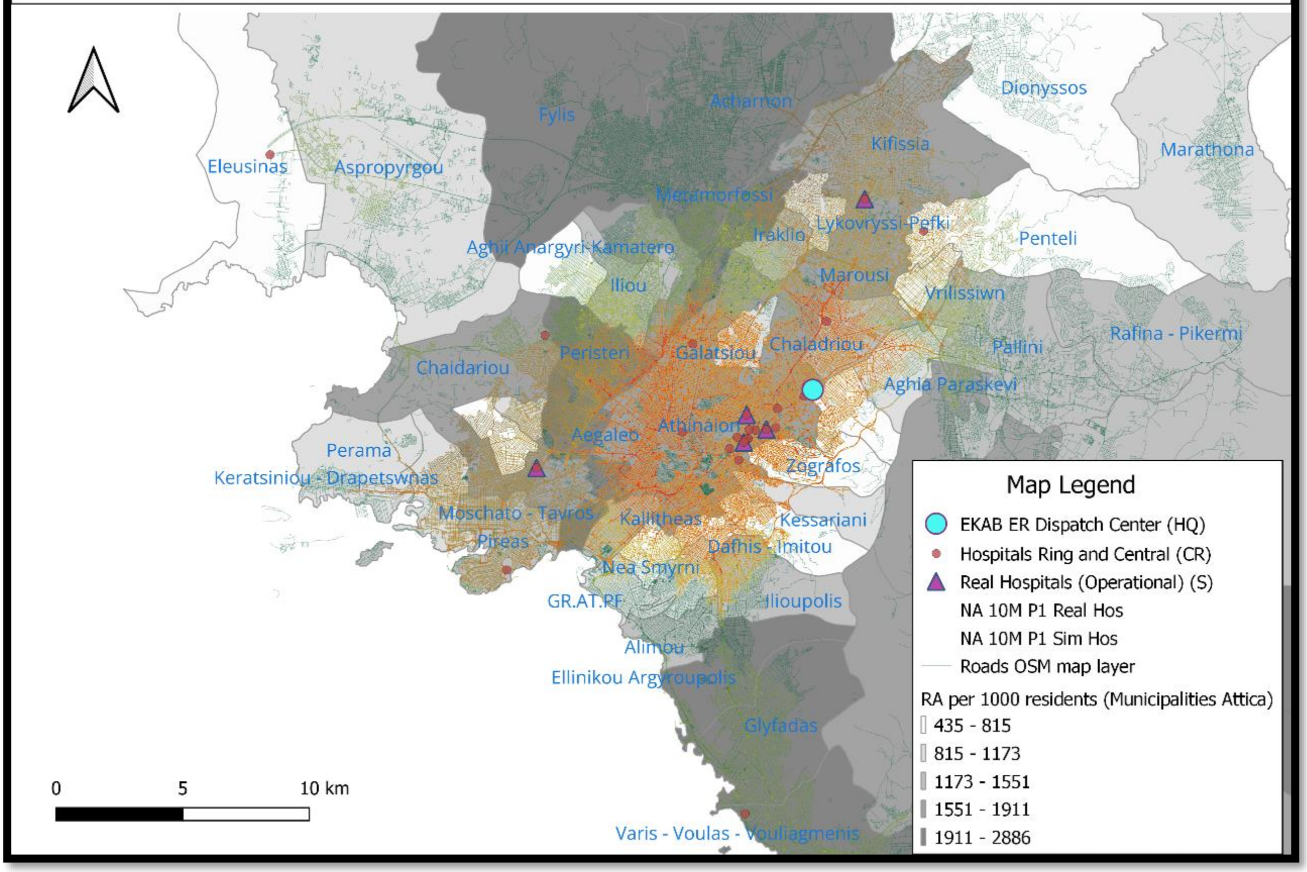
Map 9



Map 9 : Direct comparisson between service area acessibility for 10 minutes in P1 road conditions (Congestion) between all available Public Hospitals (CR) & the ones Operational (S) in the period studied (Bright red repsresents real life accesibility and Bright Yellow Simulation accesibility)

Also, from the following map (Map 10) there can be visible that areas with high historical probability of road accidents are left out of the 10-minute critical timeframe for both Hospital layers (Metamorfosi, Acharnai in north and Elliniko, Glyfadas, Voulas in the south).

Map 10



Map 10: Service areas within 10 minutes in simulation (Sim in yellow) and real - life (Real in red) networks, in period 1 conditions (Congestion) in side by side comparison with the probability for Road Accidents per 1000 people in each municipality of Attica (RA)

What is really interesting is to observe the 10 minutes network coverage difference for both hospital datasets above. Dark green represents the roads and subsequently the areas that cannot be reached within 10 minutes, no matter how many hospitals are operational. Bright hue camo green represents the most distant areas still reachable when traffic is present (P1) and all hospitals operate, while conclusively light red represents the areas reachable when traffic is present and only the realistically operational hospitals are incorporated (the worst-case scenario). Another key observation here, is that municipalities in the South and mid-west are proportionally out of reach when the hospitals at their municipalities (depicted by red dots) are not active.

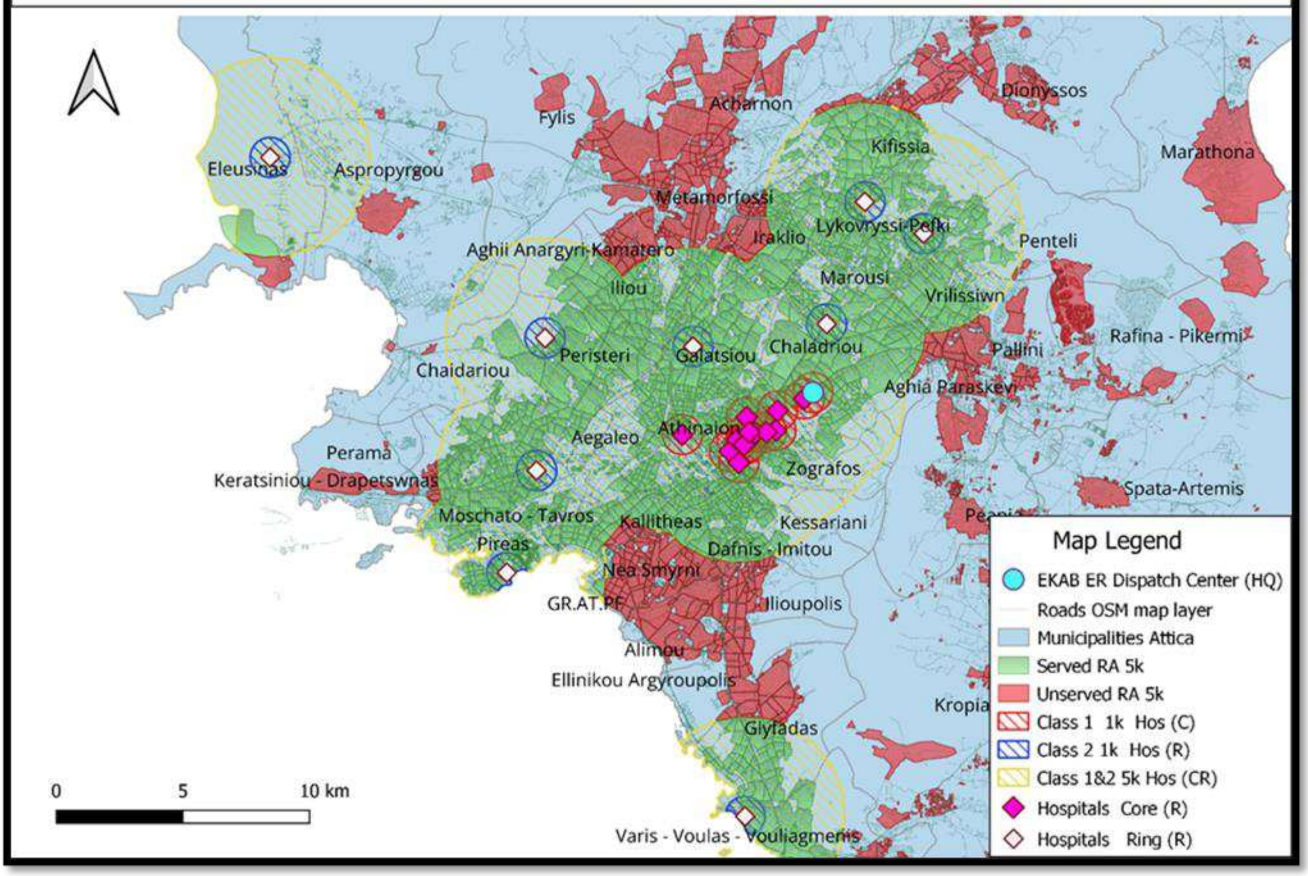
Hitherto, it is important to note that rarely do all hospitals operate at the same hours altogether, because in real life conditions cost reduction, excess supply for healthcare, but nonetheless, the way hospitals operate 24-hour timeframes prohibits this event. Hospitals remain operational for 24 hours at foul personnel capacity, after which stand by personnel takes over and any additional requests for new patients are sent to the remaining active hospitals, except for critically unstable patients that have already reached the building. Additionally, the argumentation that more available vehicles set at random locations could make these areas servable, is considered misleading, since traffic can obscure both the ongoing route to those stand by locations, but also stall the procedure of driving an occupied by patient vehicle to the hospital and back.

3.3.4 Abstract Maps

3.3.4.1 Euclidian distance Buffers for residential Areas in Athens

Provided that, all Hospitals are operational the following map simulates the accessibility residents of the city have to the latter facilities. What is fascinating about it overlooking the fact that the zones do not rely on the network is that, many residents are more than 5 km away from a hospital facility, and almost all the urban characterized city part is out of the 1km theoretically achievable walking distance for every citizen!

Map 11



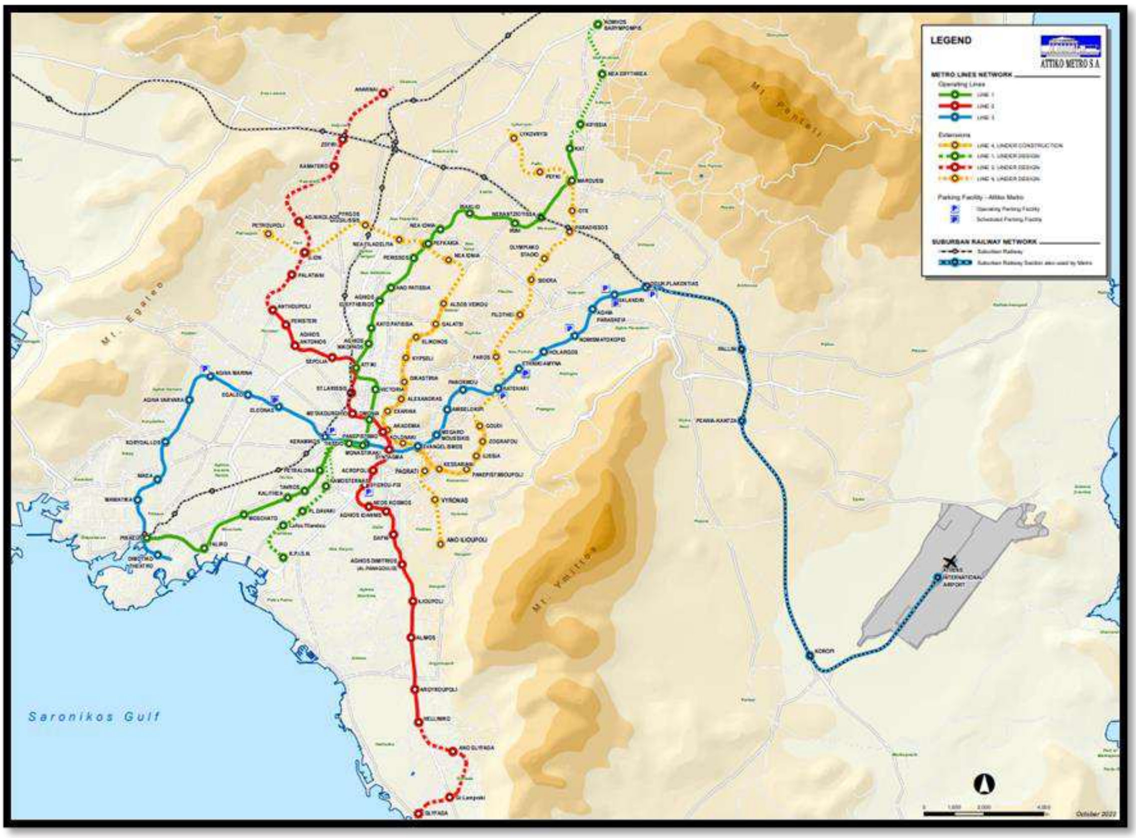
Map 11 : Euclidian Buffer of one (1) & (5) kilometer analysis of hypothetical catchment areas for all public hospitals in Attica (C &R) , with focus in the served (green) and unserved (red) residential areas, with the latter lacking access situated above five (5) kilometers away from any Healthcare facility (assuming all hospitals operate at the same time)

Apart from the intuitions, the above map is the reason for the weights (in the WLC-MCA) of to the closer to EKAB hospitals (Core Class 1 Hospitals), and their importance, since the possible second station needs to be as furthest away from this network in order to avoid the ambulances losing time passing from the same roads instead of minimizing the distance of their routes (for all and whenever this is possible).

3.3.4.2. Abstract regarding railway metro lines in Athens

As specific scientific papers focus on (Anuprija (2023), Hanseler (2018), Zhou (2019)), and real-life phenomenon observations declare, metro and railway stations are areas of congestion. Pedestrians, taxis, private cars and public transport all have as a final location or a stop, these facilities, the reason being the need to access a different area and the fastest, most convenient, and sometimes the only way is through the cities metro system. In Athens there are two underground metros (Line 2 [red] & 3 [blue] and one partially underground metro line (line 1 [green]), with one more underground being under construction (line 4 [orange]). These spots host a large number of people and vehicles and very limited time and space causing bottlenecks, aside from helping people reach their destination in time. The goal for the optimal locations below is that they can be close to metro for the workers to move fast and with ease, but not so close that they can be susceptible to limited travel times from traffic.

Image 3 : Metro and railway Network of Greece. The yellow line is the under-construction line 4 of the Athens metro system, where the continuous yellow part is already under construction and he yellow white part is under design



3.4 Limitations of the network Analysis

The main limitation of the above analysis is that it is dependent on a random set of Operational Hospitals. Since at a daily timeframe this combination changes there can be cases where the operational hospitals contain the ones closer to the outer rim municipalities, and may therefore achieve better coverage. Although when traffic is present it is unlikely to see improvement in the network length and subsequently coverage.

This simulation does not take into account traffic lights, road signs (like stops), and direction of the road, meaning one-way roads are represented being driven the other way round! A vehicle in motion does not have a constant driving speed (km/h) as assumed above, for the profound reason that vehicles start and stop within urban environment because there is a road sign commanding limiting speed or completely stopping, a roundabout circle junction, a traffic light shifting priority to other road users (red and green lights) . This simulation is based on average speeds. Interestingly though, considering the argumentation that a skilled driver that knows the routes can make the route in less time, seems obsolete since the variation in traffic is very dissimilar even for parallel roads, and bottlenecks can form really easily. Last but not least, for this point accidents or other sudden events like a double-parked car, or stopping for fuel can affect the travel times in a very unexpected manner, making the minutes in the road soar, as alternatives are likely unlikely (f.e. road accident in a residential area blocking main road used also by public transport, or vehicle crashing at the fast lane of a highway)

Furthermore, the assumption that the roads can be used interchangeably for the faster routes even though some of them are one way is way too auspicious to be true in real life. When an urban environment road network is built or extended lots of variables are involved (how water and electricity pipes form the surrounding building are built around it, how heavy loads can the road withstand, what commuting needs does it serve, will public transport go through it, is parking allowed and if so which vehicles fit to pass through and which ones have to maneuver to squeeze through. The assumption that all roads can be used both ways set by the QGIS Network Analysis Service Areas algorithm, is not a realistic one, since in this case for the results to be rigid the roads would need to contain no other vehicles but the ambulances, and the last ones never to meet each other. Travel times can only be higher in real life and network coverage smaller. One more factor that should not be overlooked is the road quality. In Athens, for a long time the rapid urbanization, and political turbulence and lack of control, have resulted in rapid expansion of roads without having engineers do the proper studies for the asphalt to withstand the pressures of the cars moving above it. The prior led to a road network with numerous potholes, furrows, and stacked layers (also private companies are responsible for this since many municipalities have allowed them to connect optic fiber cables to the layers under the roads, breaking them and not being able to layer them back properly), that force drivers to stop, damage the moving parts of the ambulance's tires, rims, suspension (and vehicles in general), and increase the probability of an accident (Pembuain 2018). That last factor negatively influencing speeds is also not taken into account in the Ambulance Coverage Network Analysis.

Certainly, there is a degree of disproportionality in the Network Analysis, since the speeds of the non-congestion period represents free flow at nighttime and are hardly close to their daytime speed limits and actual speeds (that does not change the fact that some areas are in reality still unreachable and the cohesion of arguments for a second future Ambulance Station).

Last in order, the ambulances are not always dispatched from a hospital, apart from when they are unloading patients, but always begin and stop at the ER Emergency Dispatch center in the mid-eastern part of Athens. The assumption that ambulances start covering service areas only from the hospitals is more of a conditional assumption, than a full-time event. A criticism on the verge that since the EKAB ambulance center has more vehicles therefore them starting from this location would give better coverage, is probably faulty, due to the fact that this would result in the close area being better covered, but the distant municipalities would be left unserved for more than the critical 10-minute margin for emergencies.

4. Part II : Optimal Ambulance Dispatch Station Location displacement utilizing Multiple Correspondence Analysis

4.1. Methodology : Software, Data & Framework

This section is dedicated to the process of utilizing QGIS[3] software, combining information such as population layers, road and rail metro layers[4], Municipalities, residential areas, Airbnb's and Hotels locations, EKAB[5] center and the Hospitals of the main center of Athens, in order to create a list of the possible locations for a new ambulance station in Athens in order to reduce travel times of these vehicles. The layers used to represent the final locations are chosen from two different sets of land areas, Brownfield[6] land layers and Industrial[7] land layers. The Coordinate reference system used is the WGS 84/ Pseudo – Mercator and the authority ID EPSG : 3857, and all the layers being used or created were transformed to this for consistency. On that matter, the layers of metro stations (used only as a separate content below) and the layers of EKAB, Hospitals and Airbnb's were Georeferenced using Google Maps and Airbnb public website (meaning they are original, apart from Hospitals which was created with a combination of overpass turbo data and georeferenced addition). The steps taken are the following :

1) The first step of the procedure started with collecting or creating all the necessary layers.
2) The second was transforming, adding, altering, characterizing all the necessary data to the layers.
3) The third step included creating availability layers using the raster calculator with the according weights to gain a first idea of where the final location will be, the MCA layers.
4) On the fourth step, the previous are combined (multiplied to be specific) with the land areas layers, and zonal statistics tool is being used to create the final weighted areas based on the criteria.

5) On the fifth and final step the areas are ranked from worse to best (in a scale of 4 to 1) and the final maps are created.

3.G.I.S. stands for Geographical Information System

The data/criteria being used are shown in table 1.2, below :

Table 1.2 : List of criteria utilized for the Optimal Location Problem procedure

Number	Criterion	Specification	Name in GIS
1	Main Roads	Motorways, primary, and their links	Proper Roads C2
2	Core Hospitals & EKAB	Class 1 Hospitals (15 in total) & EKAB center (1 in total)	IOS I1
3	Metro Railway	The four metro lines, including the part that connects the green to yellow lane (Neratziotissa – Doukisis Plakentias)	Metro Railway (Lines 1,2,3,4 under construction)
4	Population	Local population based on GHSL	GHSL pop
5	Hotels	Only hotel facilities in the Open Street map POI vector	Hotels and Airbnbs C1
6	Airbnb's	Georeferenced Airbnb's for Athens and regional areas without the coastal east Attica part	

4. All layers in vectors transformed to roasters of 500 by 500 meters cells and clipped by the Municipalities Attica layer before the MCA process

5.EKAB stands for emergency response ambulance dispatch center

6.Brownfields as defined by the Government of Canada are "abandoned, idle or underutilized commercial or industrial pieces of land where past actions have caused environmental contamination, but still are appropriate for redevelopment or other economic opportunities"

7.Industrial fields : pieces of land in or related to industry or/and having a lot of industry & factories

Note : In this paper Hospitals means Public Hospitals

Note : The raster normalizing for the final raster layers was done by dividing with the maximum of the layer for the ones needs to be close to and 1 – (layer/ min) for the ones deeded to be away from

4.2 Criteria and the reason for their use

- Roads : The choice of proximity close to highways and primary roads, was done in order for the ambulance cruisers to have direct access to the road network in all directions. Especially the proximity close to highways will reduce the time an ambulance needs to spent waiting in a road sign or a traffic light since the first contain this feature only in certain intersection crossroads. Primary roads of course have certain limitation in terms of speed and incorporation of traffic lights but, it is the second most accessible higher speed network with almost four lanes (two per direction) in all of its set up for the city of Athens. This ease to open road motivates the choice of this joint layer as the primary criterion with the greater weight.

- Hospitals & EKAB : Geographically it is straightforward that in Athens, the concentration of hospitals is greater in the midcentral eastern part where also the primary ambulance station is situated. Undoubtedly not all prior hospitals work at the same time but still, it is pointless to have a second station really close to them since ambulances will go there either way to drop of patients at some time. My approach in opting for a location to build a second ambulance station is that it will act as a supportive entity, limiting distance to the hospitals for the residents of the rest of the city, without the possibility of further expansion to a third one anytime soon, in line with the country's financial footprint. This is the intuition for separating the hospitals to a class 2 for the outer (R) and class 1 for the inner (C), and using the latter as a reverse proximity criterion.

- Justification for railway metro proximity : The healthcare workers deserve easy access to the facility given that they work long hours and under constant pressure. Proximity to the basic Metro lines of Athens is chosen as the third criterion given that depending on the Area being close to the Dispatch Center can help workers reach it faster, but again the weights make sure it is not too close to make the workers commuting with car susceptible to the phenomenon of lack of parking seats next to metro stations. Since congestion is a common phenomenon near metro stations (the greater the connectivity the more the users), and Athens is not an exception, a moderate distance between metro lanes (not stations, although the produced possible locations remained connected as the original EKAB station), was chosen. It should also be noted that the railway network used only contains metro infrastructure that belongs to Athens Public Transport company (in gr ΣΤΑΣΥ), and not the full extension of the network expanding to the jurisdiction of Hellenic Train (ΤΡΑΙΝΟΣΕ), because 1. the latter one operates in a different rail network with limited access between the two (exception Neratziotissa), 2. poor maintenance of wagons & network, and 3. the security measures of the company are very elastic (if not inexistent) and can and have led to accidents in the past. Therefore, without including the previous network in the MCA location analysis, it is suggested to be avoided. The modern metro of Athens is a fast well-connected network, currently under expansion. In the analysis the metro network contains in addition the newly constructed line 4 (howbeit not giving an optimal location ancylose for the Brownfields). In winding up, the Tram stations were also not involved since both in terms of low speeds, bounded network coverage and its routes stopping at traffic lights like a car make it an ineffective means for the goal (however the connectivity it provides for the Southern suburbs to the city center, undoubtedly make it a viable option tool for a future ambulance station located in the south of Athens), thus their network can be used if transformed in certain parts with cement or asphalt and be used to cut the travel times of ambulances, as it is being done in the capitals of progressive nations like the Netherlands.

- Population : We chose to give limited weight to this variable, because of the collinearity that exists between choosing maximum proximity to highways and primary roads, and the heterogeneity caused by it. Indeed, ambulances and healthcare in general is needed where people exist and demand should meet the supply and its needs. On the contrary, choosing to be close to highways and close to metro stations also includes the necessity and need for people to be well connected. Therefore, giving extra weight above else to this category would shift the final location close to residential areas, and this is not optimal nor welcome. The least importance is given in this criterion along with where possible tourists stay layer below.

- Airbnb's : This platform has become famous worldwide and has been offering houses as accommodation to tourists (data which is not included in any of the sources). Since the hotel's location where accessible by Open Street Map Data, but the Airbnb's not, the analysis was done with an own layer given the weight[8] of 0.1 over the 0.9 of the Hotels (and the resulting layer was multiplied by 0.08 for the criterion C5 to be constructed). The reason for the within weights lies in local population statistics and data for tourists arriving at Athens International Airport on May 2016).

- Hotels : Along with the Airbnb's this layer was used to represent the spatial distribution of tourists entering Athens, with the intuition to also spatially include them in the calculations, since in a case of emergency they will first need to use the local Healthcare Network.

8. The population of Attica on 1.1.2016 was 3.781.274 and the average of 7 years from 2008 to 2014 was 180.858, resulting in a 0,473-ratio tourist to locals. The focus here is also to the tourists that choose to stay in Attica but not all of them rent in vastly populated areas during their stay. Therefore, the weight of the tourists was doubled for a final of 0.9 for local population and 0.1 for accommodation for non-locals.

The dimensions of a typical ambulance in the Greek streets are similar to the Peugeot Boxer (one of the most used cars turned into ambulance to cover the emergency needs of Greece), meaning width of 2.05 meters and length of 1380 plus 4035, 5.42 meters, resulting to 11 square meters for one vehicle to park. For 100 cruiser ambulances 1.111,11 square meters would be necessary just for parking. Taking into account two times paved concrete road for the vehicles to maneuver in and out, of two times their parking space results in an area of 2.222,22 meters occupied. Now taking finally into account a very generous scenario of 1200 square meters building for changing uniforms, restocking ambulances and repairing them, leads us to a space of minimum 4.533.33 square meters is needed for a proper Emergency dispatch center facility. The filtering of the available brownfields layer area and industrial site area layer are executed upon this spectrum (areas above 4540). In facilities like these the advantage of space is always welcome, and bearing in mind that if a project like this is about to be constructed, Architects Engineers, Electricians and workers of all types are going to use the available space efficiently and the leftover land can have other uses (f.e. expansion) there is not a maximum limit set to available land for calculations.

4.3 Multiple Correspondence Analysis (MCA) and Weighted Linear Composition (WLC)

4.3.1 Execution of the Analysis in QGIS Environment

The MCA analysis taking place is broken into five (5) criteria using the Rank-Sum[9] Method:

I. (C1) proximity to motorways and primary roads (joined layer)
II. (C2) reverse proximity to class one hospitals & EKAB,
III. (C3) proximity to metro railway stations,
IV. (C4) Proximity to local population (GHSL pop layer)
V. (C5) Proximity to tourists (joint Hotels and Airbnb's Layer)

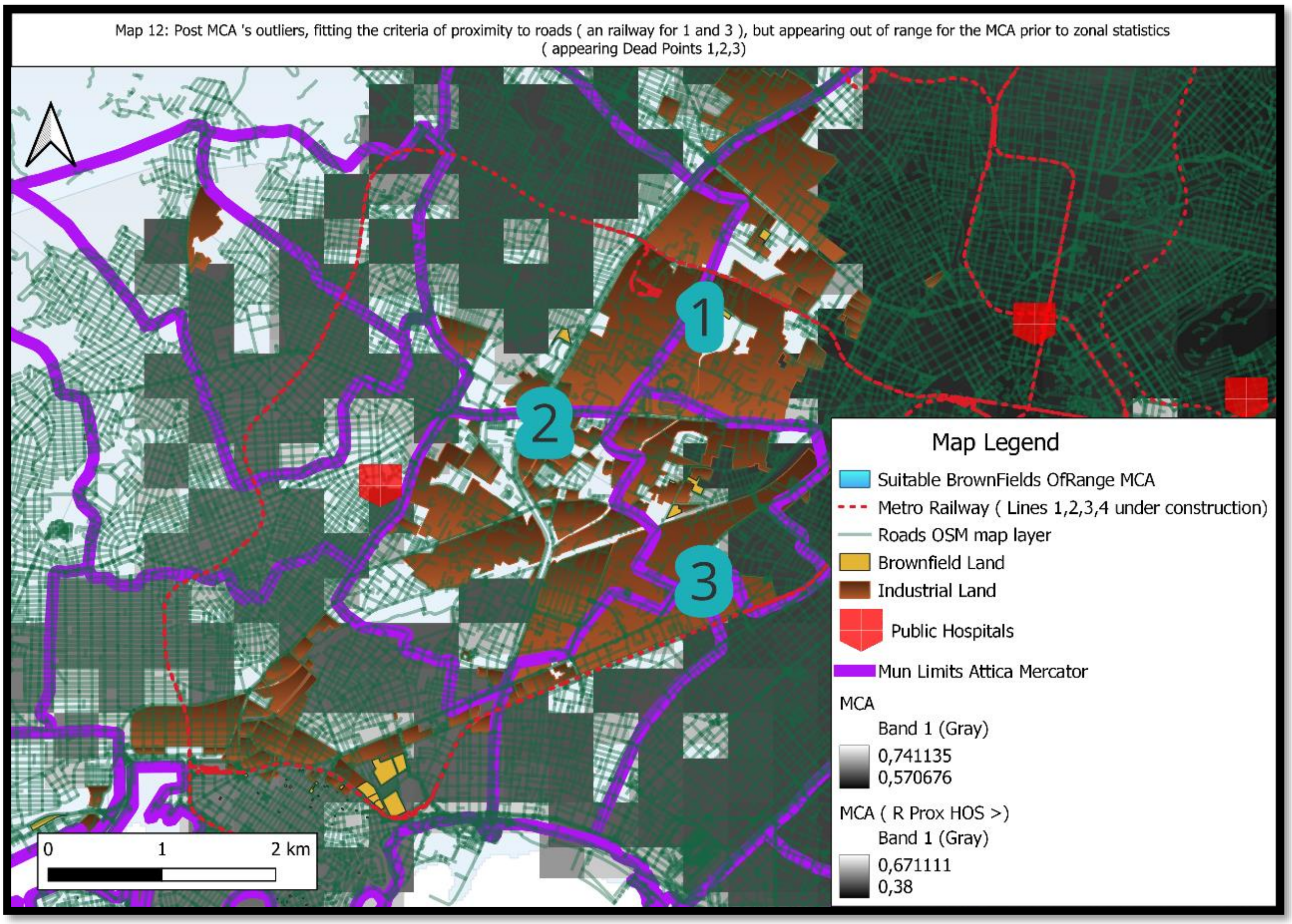
The above are used with an equivalent weight assigned to them to create the MCA layer that will then be used interchangeably for both brownfields and industrial fields. The optimal combination chosen for the MCA layer of this paper is the following :

MCA = [0.5*"Roads MCA@1" +0.3*"HOS I1 MCA@1"+ 0.12 * "Rail MCA@1" + 0.08*((0.9*"pop MCA@1") +(0.1 * "Hot & Airbnb MCA@1"))]

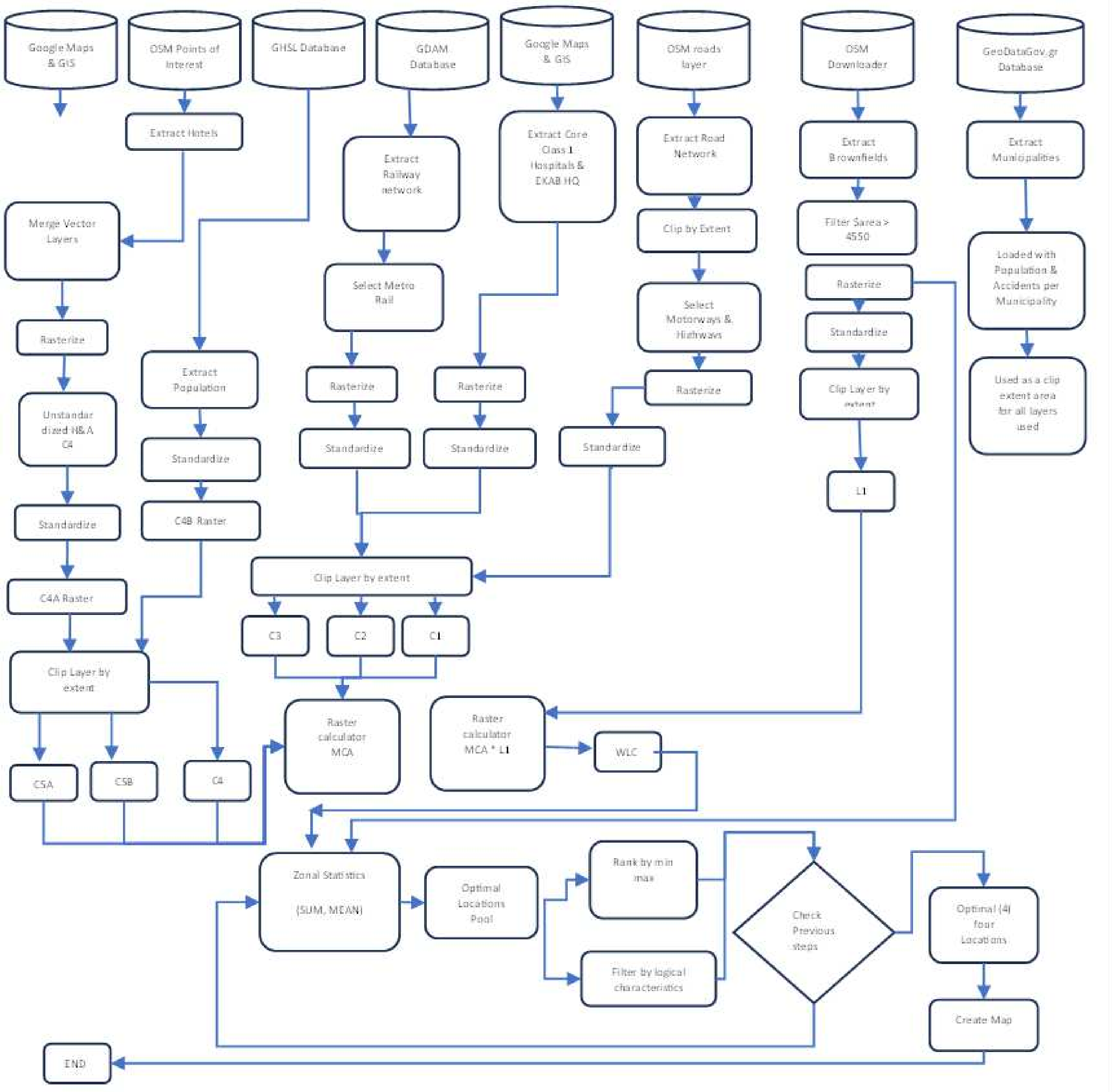
9. The Raster calculator is also sensitive on the order of the criteria as well as the weights, meaning that highest to lowest weight rank sum criteria analysis result layer is different from the ascending one.

The following map represents locations considered out of range after the MCA analysis and before the Zonal Statistics Analysis for the final locations of both land use categories (Dead Points Reference). Location 1 Brownfield is really close to the metro station of Elaionas (Line3), and has access to Kifissos Motorway (E75), and the area appears empty (the reason it is believed it went out of range is because it does not have **direct** access to the motorway and has to go through Iera Odos road (red dotted line above it is the metro and it is aligned underground with this road) to reach an interchange to enter. Location 2 is directly next to highway interchange, but in reality it is occupied by a McDonalds restaurant, along the fact that the MCA did not include the point at first. Location 3 appears empty on Google maps, is next to a primary road, but the MCA dropped it out for being to close to the Class One Core Hospitals (like the Polyclinic Athens University Hospital , nearly 4610,37 meters with Cartesian measurement) like Location 1.

Map 12


Map 12: Post MCA 's outliers, fitting the criteria of proximity to roads (an railway for 1 and 3), but appearing out of range for the MCA prior to zonal statistics
(appearing Dead Points 1,2,3)
1
2
3
Map Legend
Suitable BrownFields OfRange MCA
Metro Railway (Lines 1,2,3,4 under construction)
Roads OSM map layer
Brownfield Land
Industrial Land
Public Hospitals
Mun Limits Attica Mercator
MCA
Band 1 (Gray)
0,741135
0,570676
MCA (R Prox HOS >)
Band 1 (Gray)
0,671111
0,38
0
1
2 km

Flowchart 1.1 : The procedure of choosing the optimal locations (in Brownfields) for a future Ambulance station in the city of Athens, with the use of GIS software



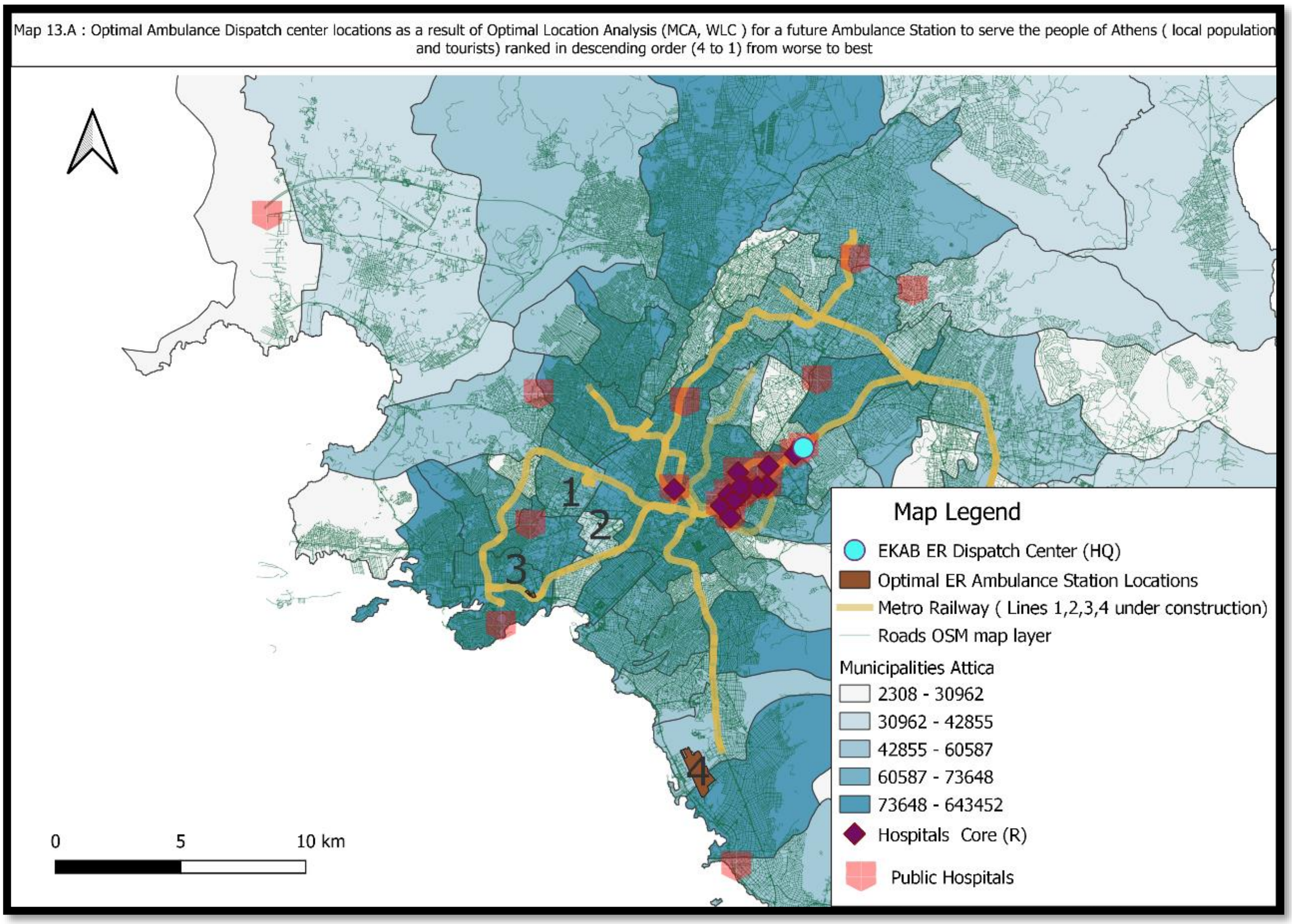
4.3.2 MCA of Brownfields areas

Motivation & Evaluation for Brownfield Areas

Brownfields are the perfect locations to build new infrastructures if the budget is not a limitation. Given that most of them used to be industrial sites they are well connected to the road network, most of them are bigger than the necessary square meters needed by the previous section (at least in the OSM dataset provided). Their accessibility is translated to ease of reach and parking for construction crews to operate, leading to smaller total time needed to build the facility. The only limitations that can occur are environmental hazards and difficulties in the building process because of possible soil contamination which can be costly and the fact that their state makes it easy for gas and electricity providers to build Power columns or pipelines through them. However, if money is not a limitation the previous setbacks can be dealt with. Apart from the latter the heavy industries in Athens were ordered by parliament act in the year 1980 to move their factories and plants out of the urban core of the capital. So environmental issues can only occur in extreme cases.

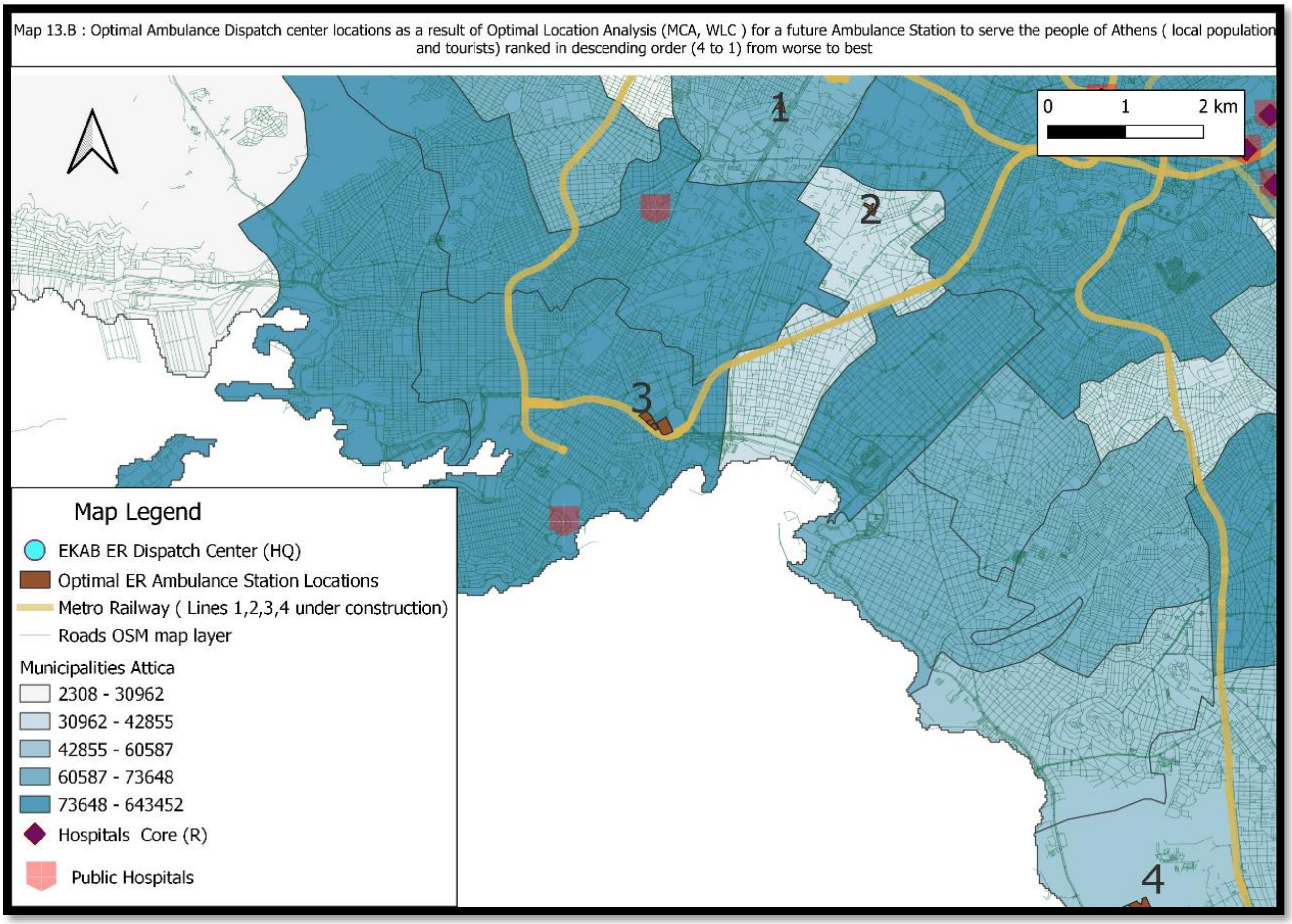
The result of the multicriteria analysis in a raster format is now multiplied by Brownfields (for entirely building an ambulance station from zero) and zonal statistics are used (similar to the previous GIS tools) to create the following suitability maps for the optimal Ambulance stations for this category of Land.

Map 13.A

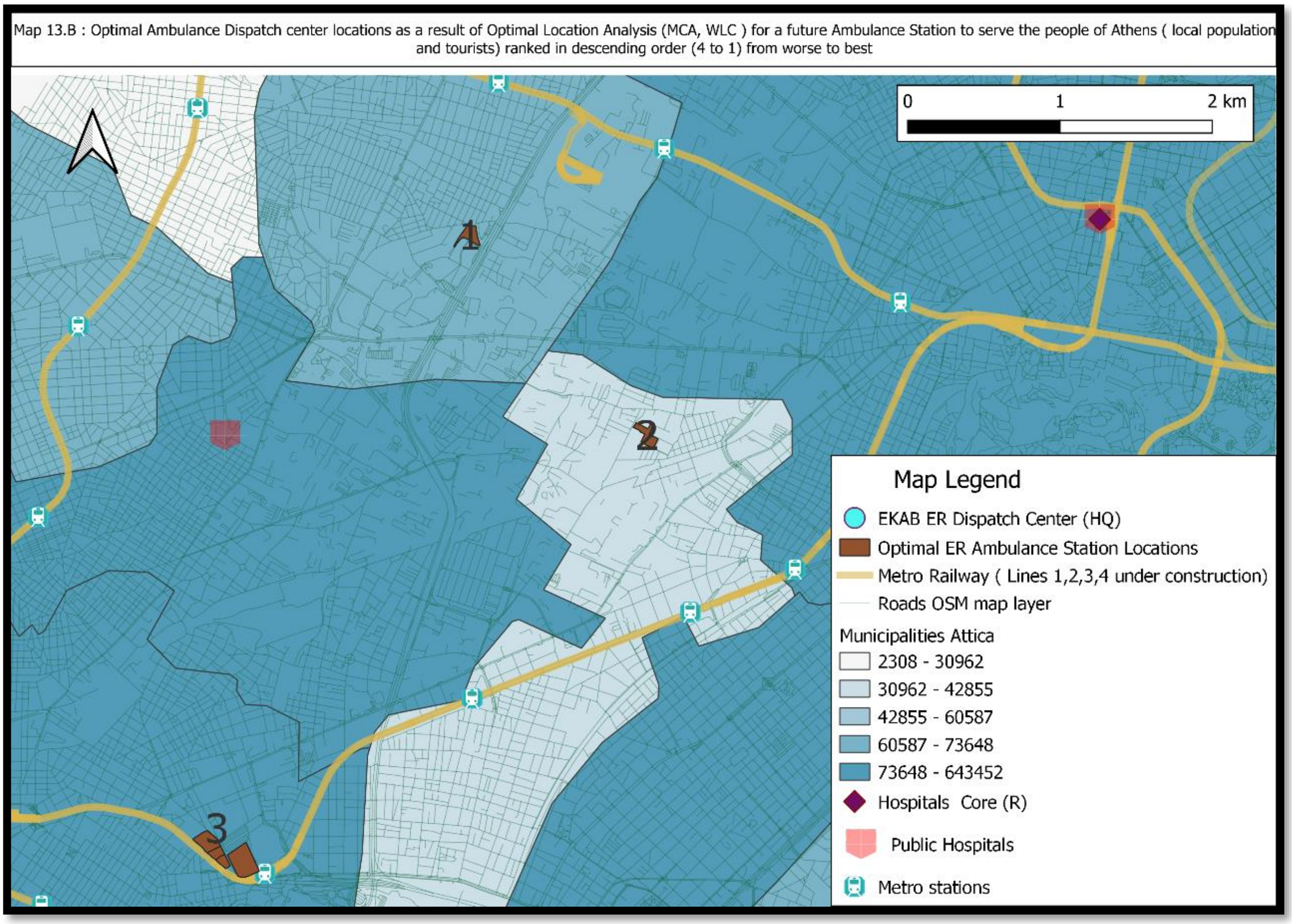


Map 13.A : Optimal Ambulance Dispatch center locations as a result of Optimal Location Analysis (MCA, WLC) for a future Ambulance Station to serve the people of Athens (local population and tourists) ranked in descending order (4 to 1) from worse to best
1
2
3
4
Map Legend
EKAB ER Dispatch Center (HQ)
Optimal ER Ambulance Station Locations
Metro Railway (Lines 1,2,3,4 under construction)
Roads OSM map layer
Municipalities Attica
2308 - 30962
30962 - 42855
42855 - 60587
60587 - 73648
73648 - 643452
Hospitals Core (R)
Public Hospitals
0
5
10 km

<u>Map 13.B</u>


Map 13.B : Optimal Ambulance Dispatch center locations as a result of Optimal Location Analysis (MCA, WLC) for a future Ambulance Station to serve the people of Athens (local population and tourists) ranked in descending order (4 to 1) from worse to best
0
1
2 km
1
2
3
4
Map Legend
EKAB ER Dispatch Center (HQ)
Optimal ER Ambulance Station Locations
Metro Railway (Lines 1,2,3,4 under construction)
Roads OSM map layer
Municipalities Attica
2308 - 30962
30962 - 42855
42855 - 60587
60587 - 73648
73648 - 643452
Hospitals Core (R)
Public Hospitals

Map 13.B (Zoomed in)

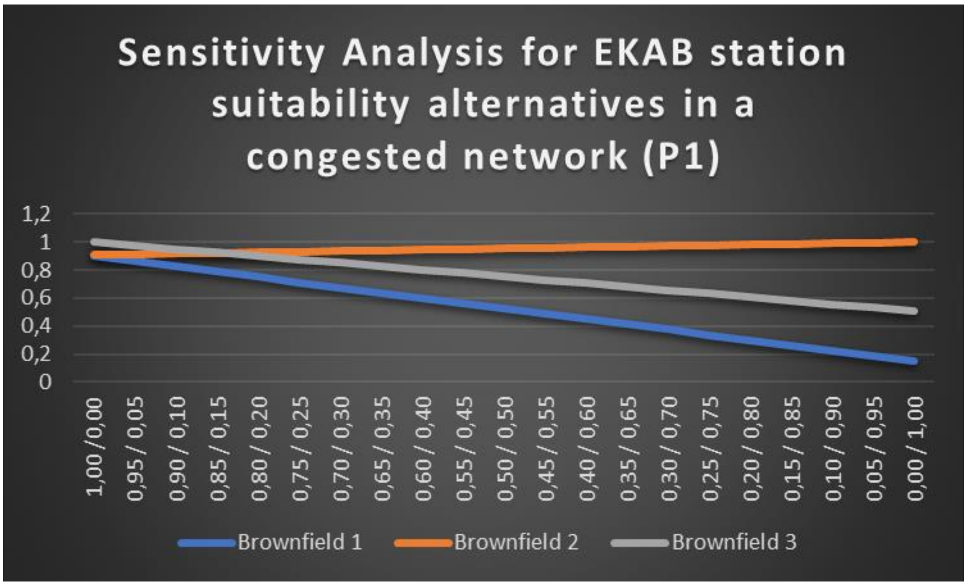


The resulting best ranked locations are presented above and belong at the Municipality of Aigaleo (1), Moschato (2) and Tavros (3). The location number 4 although reaching the highest score in the max category, is in real life occupied at a large extend by Lafarge's cement redistributing private company. Additionally, the WLC analysis overlearned towards furthest away from the core hospitals leaving this position with greater distances to cover in order to reach west Attica regions like Piraeus. Location 3 appears ideal, since it is located next to metro station Faliro and is also significantly close to E75 motorway, utilizing the parallel to metro line primary road Piraeus, and also through the coastal road towards Athens and Piraeus, apart from being connected to a 24-hour bus lane to the center of the former. The concern here appears whenever there is a football match of the Oympiakos football team, since the location in such cases will most certainly be congested, and moreover it is placed after the intersection with the Poseidonos Avenue (which leads to the center of Piraeus), meaning ambulances will have to do the circle of the stadium to go the same direction. These reasons justify the rank for Location 3. Now Location 2 is placed 1,7 kilometers from the closest metro, in an area with connectivity to also the bus network. But first and foremost, it offers two entrances to E75 in close distance. Finally, location 1 is considered to be the optimal station of all, is situated 1,3 kilometers from Aigaleo Metro line 3, 0,7 meters from an interchange and from there access to the main arteries leading to west, north and central municipalities. The only drawback is that electricity power lines, and white square areas that appear like ancient monument marble in Google Maps. The first one is a fire hazard, but under careful planning can be dealt with, the ancient monuments on the small square area can be transformed in an exhibition site, and the rest of the area can theoretically still function like a healthcare ambulance dispatch facility. The above ranking is also supported by Summary set of Maps 5, which also show that for 10 minutes available travel time in congestion environment, location 1 provides the biggest catchment area. For the above reason I support Area 1 as the optimal for ambulance station displacement.

4.3.3 Sensitivity Analysis of Optimal Brownfields

Since the previous part aided in pinpointing the available sites for the new ambulance station, a sensitivity analysis[10] is needed to see how robust is the order set beforehand. In order to complete this part two different networks where used (a 10-minute P1 congested and a similar 30 minute) using the population layer and the maximum from the MCA as two the two factors to see how the locations score. The results are given in the graph below, using the previous rankings :

Graph 1.1



Overall, the analysis for the choice of location two (2) is robust except for the first four categories leaning towards the population and not the MCA criteria. What can be extracted from this part of the analysis, is the quantitative result that besides the quality characteristics highlighted in the previous part of the analysis, the sensitivity approach shows that location 2 seems more optimal for the displacement of the ambulance station.

*10. In order to simulate the inverted distance matrix, the 60 kilometers per hour congestion speed for motorways was used, in 10 minutes 10 kilometers can be travelled while in 30 minutes 30 kilometers can be travelled. Regarding weighting for people in the previous radius I used the inverted distance matrix but instead of multiplying by it I multiplied the people from the pop layer by the inverted one (pop10 * 1/ (1/10^2) & pop10 * 1/ (1/30^2), to give greater importance to people in outer limit of the network.*

4.3.4 Cost Benefit Analysis and dynamics of an additional EMS Dispatch Station under Congestion

Creating a 10-minute congested network around the EKAB Ambulance Dispatch Center HQ, and removing the municipalities inaccessible to it, 3.412.261 people in the whole Attica remain unserved with the critical margin. By assuming that the value of life of a person is equal to the monetary cost value to its employer (1200 € for wage, 1800 € for the insurance of the worker) and taking into account the fixed and variable costs for the aforementioned Ambulance station (simplifying when possible and needed), a Cost Benefit Analysis is conducted. Below Table represents the cost for the first three years in future values:

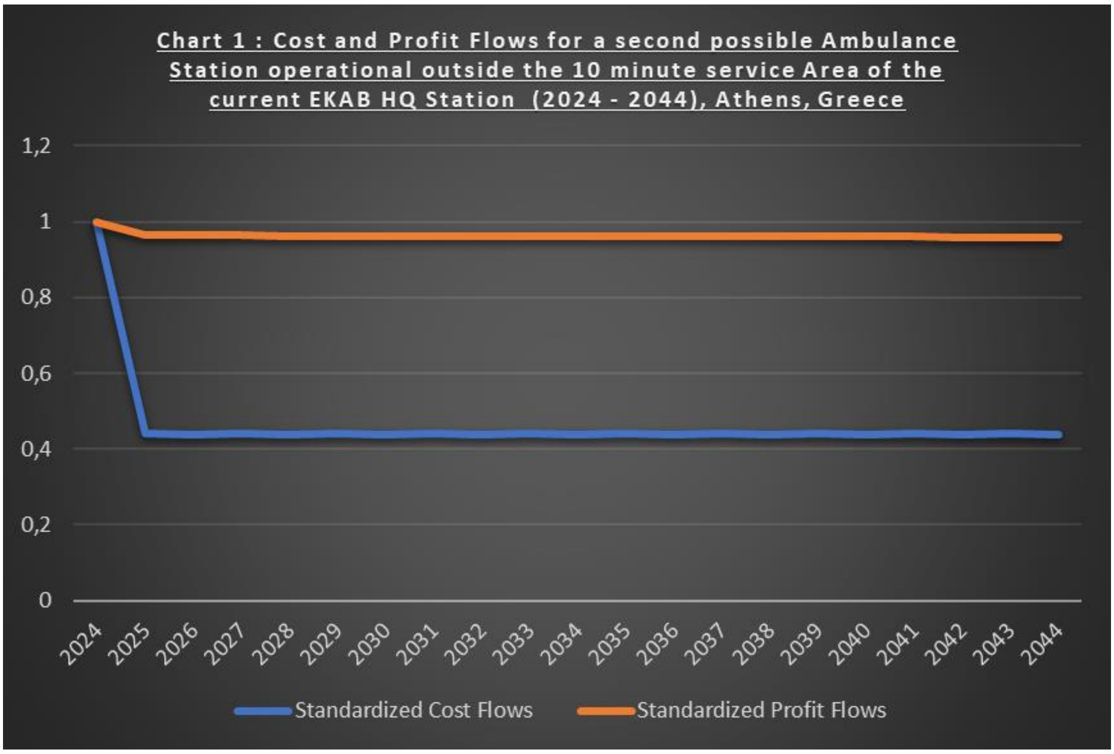
Table 1.3 : Fixed (FC) & Variable Cost of the Cost Benefit Analysis

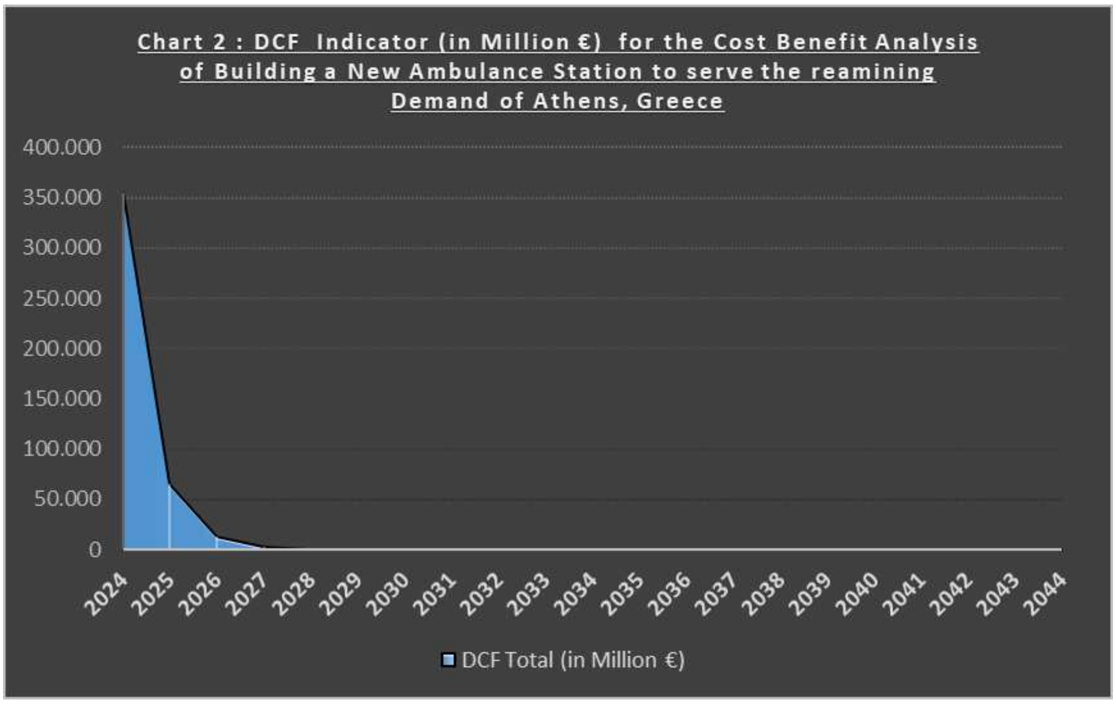
Cost Type	Cost Category	Frequency	2024	2025	2026
FC	Employees	once per year	13.986.000	13.986.000	13.986.000
FC	Water	once per year	9.000	9.000	9.000
FC	Vehicles	Only 1st year	20000000	-	-
FC	Electricity	once per year	8.954	8.954	8.954
VC	Fuel	once per year	1.490.076	1.490.076	1.490.076
VC	Security	once per year	2.500	2.500	2.500
VC	Maintenance	once per year	85.000	175.000	85.000
Totals			35.581.530	15.671.530	15.581.530

Among other assumptions it is set that the station works in three shifts in which all one hundred (100) vehicles utilized, with the workers working five days with two days off in a seven-day week and with thirty days off per year, bringing the total needed to run the ambulances to 318 paramedics serving one thousand calls per day for the whole year round (365 days). The value of the cars is set to 200.000 €, containing vehicle and necessary medical equipment, their fuel requirements is set to cover the above trips assuming 200 kilometers per day, and increased fuel consumption levels which represent realistic driving conditions (15 liters per 100km over the 9,93 liters per 100km for the Peugeot Boxer Van 2.2 HDi L2H2 diesel[11] ICE version). Electricity (and water consumption assumed equal in € values), represent overoptimistic billing (of 120 € per MWh for 55 of them consumed yearly in big industries), and maintenance includes all moving parts and two types of annual service procedures per vehicle (as appears in 2024 85.000 € for small service and in 2025). Lastly Security services are on yearly rate (given that this task is handed out to private professionals and not public, like the police), and all vehicles are depreciated completely at the end of this part, meaning 20 years after their original purchase they have zero monetary value for the NHS (National Health System).

11. Although diesel Internal Combustion Engines (ICE) exhaust fumes have proven to cause cancer in the past decades, the ability to cover the needs of the criteria and the models delivered being the latest Euro 6 approved filtered ones demanded by the EU, justify for the time of writing this paper this choice.

Using the DCF investment Index and calculating the Future Present Value (FPV) of the total costs of the Service Operation and the total Benefits of the Value of life of the people saved, the return of the investment is introduced (Interest Rate = 4,25 Fixed rate on the main refinancing operations set by the European Central Bank and years period is 20 (n)), The standardized cost and benefit flows as well as their output sum DCF Total (= DCF Costs + DCF profit) is given in the Charts below:





If accurate numbers are provided, with the oversimplification set aside followed by the will to provide to the Healthcare by covering the investment initial cost (36 million € if the building is built from zero with lots of financial headroom for extra expenses like buying the land setting asphalt to make the surface even & plant additional trees to limit temperatures in the summer, not shown here but none of the previous expenses can reduce the DCF more than couple of millions which is not even the 1/20th of yy axis Chart 2) avoiding corruption along the way, the construction of a new ambulance station in Athens cannot be anything but beneficial. Chart 2's positive Total DCF Index ultimately corroborates the pre stated.

Note : Even with those expenses added in the usual first period, the FPV multiplier being 1 and are overestimated to 20 million the DCF value of 2024 (Year zero) 354.780.000.000 is merely affected.

4.3.5. MCA of Industrial areas

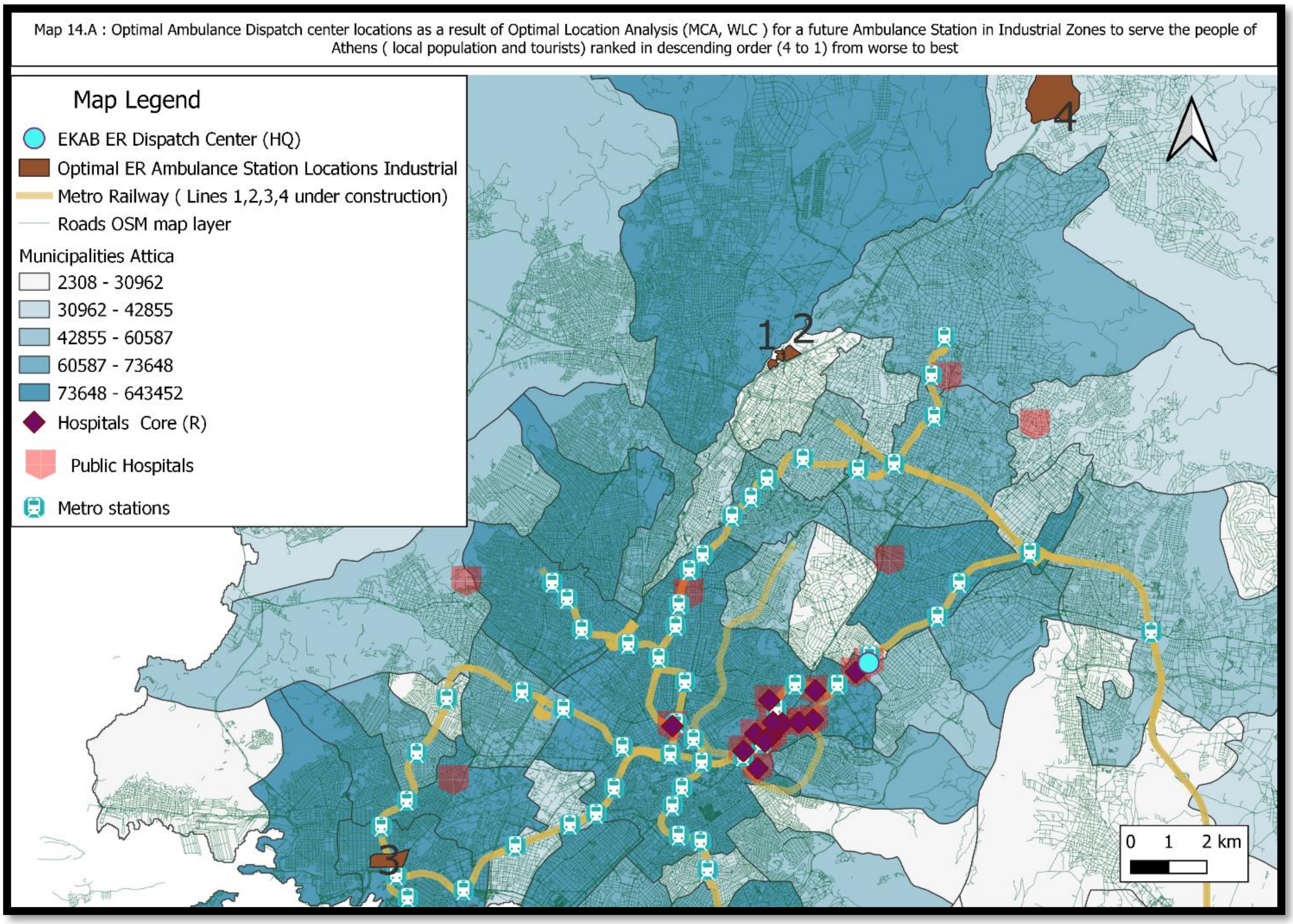
4.3.5.1 Motivation for Industrial Areas

Choosing the Industrial sites, is a viable option, since they are the cheapest to turn into dispatch centers, already have access to the street, and the infrastructure is built solid enough to withstand the weight of many tones more than capable of housing ambulance vans, 24-hour gas stations are nearby due to trucks loading and unloading needing easy access to refueling, and not to forget that vehicle spare parts are open close by. In terms of the financial aspect of the project Industrial sites strike as reasonable options of leasing space to the ER service to operate, in order to reduce costs. The creation of an ambulance stations from the building process, is actually a costly procedure with an ending deadline that continues to be shifting because of bureaucracy , technical issues, and political stability which deeply affects the Healthcare sector in Greece. Trailing comes the issue of when to actually order the ambulance cruisers, since having them arrive before the facility is ready to host them, will result in untimely depreciation of these vehicles.

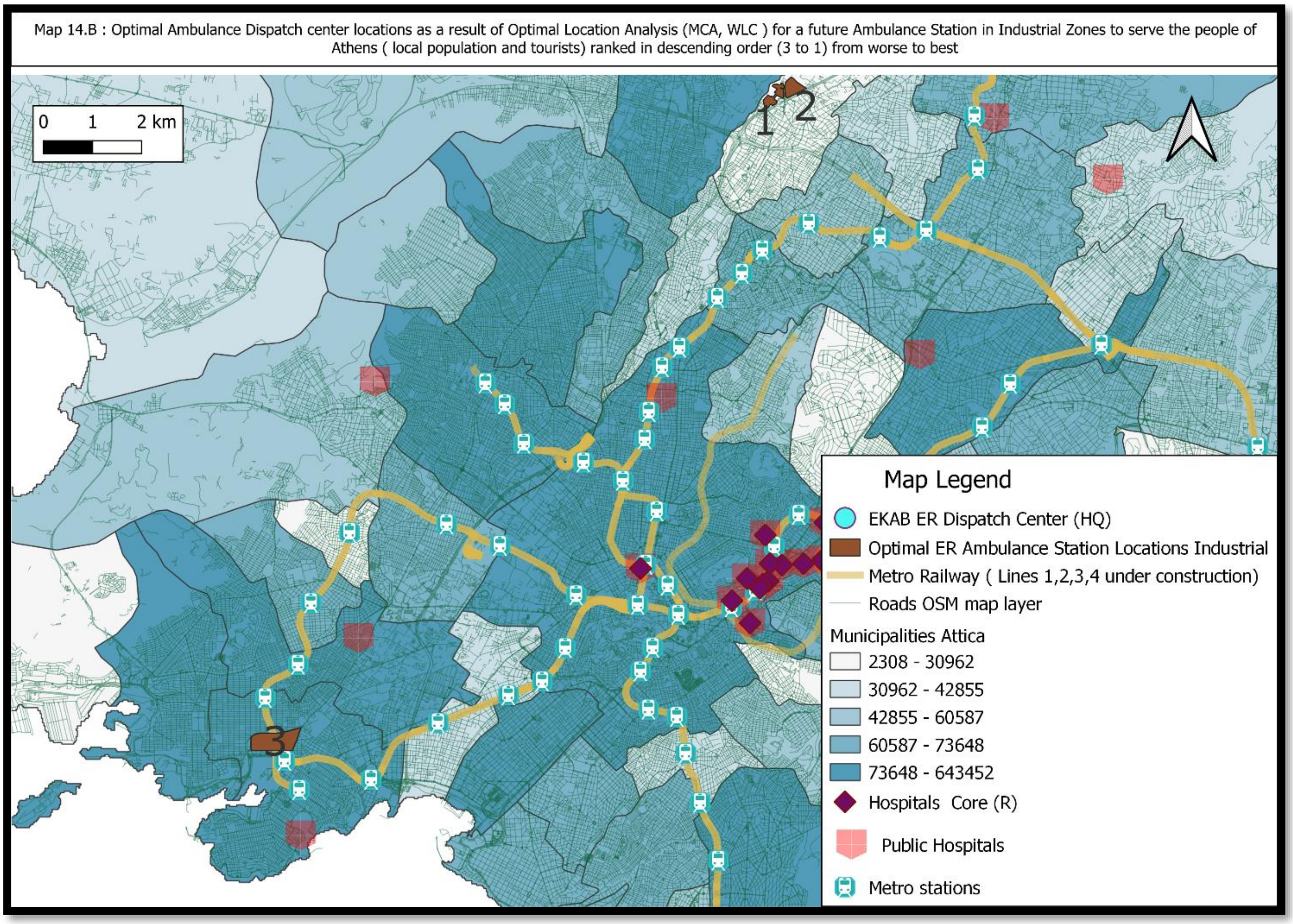
4.3.5.2 Evaluation for Industrial Areas

Similar to the previous part, the results for the optimal locations for industrial areas are represented in the following maps:

Map 14.A


Map 14.A : Optimal Ambulance Dispatch center locations as a result of Optimal Location Analysis (MCA, WLC) for a future Ambulance Station in Industrial Zones to serve the people of Athens (local population and tourists) ranked in descending order (4 to 1) from worse to best
Map Legend
EKAB ER Dispatch Center (HQ)
Optimal ER Ambulance Station Locations Industrial
Metro Railway (Lines 1,2,3,4 under construction)
Roads OSM map layer
Municipalities Attica
2308 - 30962
30962 - 42855
42855 - 60587
60587 - 73648
73648 - 643452
Hospitals Core (R)
Public Hospitals
Metro stations
1,2
3
4
0 1 2 km

Map 14.B



The resulting optimal locations for industrial areas belong to the Municipalities of Metamorfosi (1,2) and Piraeus. The choice of exclusion for location 4 stems from the fact that again the weighted analysis outputted an extreme far location, without access to metro network and far away from the city core (which also affected locations 1 &2). A key difference compared to the brownfields analysis result, is that the rankings here are in accordance with the mean values of the zonal statistics final layer (0.7091 for 1&2 and 0.7048 for 3). Locations 1 & 2 are right next to the highway E75 interchange, with location 1 seemingly from satellite image having more open cemented surface to work as a parking and also being directly on the right side of the road it is easier to enter the road, which is even so controlled by a traffic light as opposed to location 2. The area scored low on the metro accessibility criteria since it is 3 km away from the closest metro station Irakleio of Line 1 (Green)accessible by only two bus lanes, which is considered a basic limitation of the model. Perhaps a lower weight on the distance away from the core Class 1 Hospitals would output a f more accessible polygon. Location three although scoring the lowest of the three, is theoretically capable of covering the needs for ER services of west Attica. With the maximum distance from the Piraeus Metro lines 1 & 3 stations (the second one is newly built, underground and faster). Within the limits there are tons of industries occupying squares with seemingly lots of paved surface that can be used as a parking spot for ambulances. An interesting point is that the right upper corner of the Location 3 polygon is occupied by the Municipality of Piraeus as a municipal parking area, which can bring the leasing cost even lower. Diverging from the previous limits right next to the upper right side of the polygon there seem to be big abandoned fields with some scares housing towards the side of the road (not much is known for the area but theoretically it can be used as an expansion point). To conclude location 3 is in close distance to a junction that can lead to every direction (coastal primary road to west municipalities, northeast route of Thivon, Piraeus Road, Leoforos Posidonos). A drawback in the latter is that in heavily touristic months like May to September congestion will be present. One final key point is that using industrial space under leasing conditions, can sometimes be burdensome legally and financially (f.e. Who will be to blame if medical equipment or ambulance vehicles are stollen or damaged, what if the company owning the space decides to file for bankruptcy then, will the owners agree to a reasonable rent for the occupied space or will they demand above market price compensation for the used space, will the company agree lasing the space in the first place, are the infrastructures able to accommodate ambulance vehicles and medical crew in an efficient way, will the landlord provide 24-hour security).

4.4 Results

The congestion analysis begun in the network of Athens, in order to see if there are areas that are left unserved in the case of congestion[12] by the ambulance service. Eight different combinations were tested in total to result that when extreme congestion is present as exhibited by the Period 1 km/h for each category of road, the catchment areas for the ambulance cruisers shrunk significantly (Map 4 and Map7), in both scenarios of all Public Hospitals Operating and the realistically Operational ones in a past date. Proving that congestion can actually cause a serious threat to people needing immediate assistance that are out of reach, in all given setups, like cardiac arrests, strokes etc., the analysis resumed with the procedure of tracing locations that can be suitable for the ambulance center to expand. Utilizing a combination of WLC and MCA analysis, three (3) locations were chosen for Brownfields and three (3) locations for Industrial fields for a total of six (6) possible future ambulance station location in the city of Athens. These locations were combined with a sensitivity analysis for the first category making the second in rank (Location 2) more suitable for this category when taking into account population and the MCA result, while the preceding congested network maps show that Brownfield suitable location 1 can achieve maximal coverage, congestion present[13]. These locations for both Industrial and Brownfields, succeed maximizing proximity to motorways[14] and primary roads (followed by the rest three criteria), providing the best possible head start for the ER vehicles and their crew in their goal to save lives in the city[15], an aid more than necessary especially when they have to deal with congestion. Rooting for locations both close to motorways and primary roads reassures that the vehicles will always have a gateway faster route regardless of the intensity of the congestion in the previous two. Closing a simulative Cost Benefit Analysis shows the possible yielding investment in monetary values (€) based on values of life theory, accentuating that a second ambulance station is worth building from financial accounting perspective.

The impact of this analysis would hopefully help future planners (at the worst-case aid) choose the optimal locations for Ambulance stations in the making, taking into account traffic in the network and the indirect cost sustained by fuel usage, and depreciation to vehicles stuck in traffic. Even more, the availability of land to build or lease are taken into account, leading experts that want to approach an estimation about the cost of such an investment, more accurate intervals. The accessibility of the workers in this department of Healthcare are taken into account, in order for them to have a sustainable way to reach their job, like public transport or still be accessible on foot and hope that in the case of actually building the above, the state will consult the public transport organizations towards 24-hour lanes to this location in order to help this people in their attempt to save lives. The procedure of tracing these locations, was challenging given the availability of land for it, and will continue to be in a real-life scenario, however when consulting experts in planning solutions can be given to any limitation, financial and technical, besides my own approaches to the matter in each location and the possible benefits that come out of it. The analysis additionally incorporates the need to avoid the hospital field core of Athens and takes into account the places where people (locals and tourists) spend one third of their daily time (assuming they are sleeping 8 hours). To sum up the benefits of the analysis reflect the needs of all people within the study area like the expansion of the ER Service accessibility, taking into account the factors in the road network.

12. As stated in the beginning the roads in Athens can be very narrow, and the drivers are not always following the law, making it difficult for ambulances to save time using siren and lights

13. Summary maps 5.1 to 5.4 represent a 10-minute congestion present P1, period service areas for the current EKAB HQ and the three possible Brownfield Locations as operation Ambulance Stations. The surface Area covered by Location offers the most benefits, and should be built before the rest locations

14. Motorways and Highways are used interchangeably, and they represent 3 or/and 4 lane high speed roads not limited by traffic lights. It should be noted that all top three locations for both brownfields and industrial ones always appear in the top ten in terms of maximum and mean spatial statistics, and the rest of the locations are highly positively spatially correlated being next to one another. From the last the ones with the higher mean score were kept to make the final maps and set the results. Numbers may differ but the locations always exist no matter where I chose to filter for areas greater than 4540 square kilometers (pre or after the MCA and WLC multiplication part).

15. Congestion can be more intensive in urban environment, where if a main axis road used by both public transport and private vehicles is used, suffers congestion, this spreads to all the connecting residential roads, and given the dimensions of the ambulances, they cannot maneuver through that space

4.5 Limitations

- The primary limitation of the preceding analysis is the fact that many simplifying assumptions are used to calculate distances, speeds and in short network coverage. In real life when congestion is present the speed on the road's experiences great heterogeneity, and is far from the constant P1 congestion speeds set by category of road. The routes used although calculating both starting and ending points in the algorithms, makes the assumption that roads can be driven the opposite direction which is not the case in real life, even for government vehicles. To add traffic lights and traffic signs priorities are, as well as people violating them are not taken into account neither in the predefined speeds not the roads utilized network structure. Nevertheless, the travel times can only be worse than above and the network coverage smaller, which supports this paper's theory that traffic can reduce travel times for the ambulances (noting the underdeveloped healthcare coverage in terms of ambulance stations)

- The analysis does not take into account the proximity of the hospitals of Class 2 situated on the outer rim of the total public hospitals layer, as well as passing from the same routes twice which is inevitable if calls are made from certain locations away from both the possible ER ambulance station locations and the close hospitals, and the lack of other primary roads nearby. The argumentation that two stations is better than one is weak, when comparing to this outer layer. However, some locations being in the middle of these two layers like the locations of rank 1 and 2 of the Brownfield land use analysis appear to cover a large "star" area without needing to pass from the same road if incidents happen in the middle (provided all hospitals are operational)
- Another weakness is the fact that the goal is to build only one more ambulance station since from the results aforementioned, there seems to be the need for several more in order to cover the needs of Athens.
- Furthermore, the existence of private hospitals is not taken into account, which can be an option for certain individuals (however since public insurance is mandatory in Greece, most people use its convenience of visiting public hospitals, since in many cases it is cost effective)
- Elevation is something that is not taken into account and can significantly increase travel times on its own without the presence of congestion in certain areas, mainly the residential ones, given the geomorphological characteristics of Athens. Buildings in Athens are also old and space to park outside them is not available all the time. Parking an ambulance cruiser in tight spots can be challenging even for experienced paramedic crew. And then the fact that many of the buildings are old, without elevators or and/ with small crowded ones, overshadows lightly the proper travel times of ambulances.
- The given setup, necessary simplifying data for the analysis means the networks above can appear greatly bigger than they actually are in reality, meaning that if the extra stations are being built their efficiency will be cut down by the variables affecting the land road routes. The above choice of locations is in need of measures that will reduce traffic in general, like enforcing efficient public transport, limit car usage (for leasing users) and ownership, in order to help optimal displacement of (additional) ambulance stations reach its full potential which is to reach patients soon enough to attempt to save their lives. There is also the case of outliers, where even if everything goes perfect and paramedics how up in time, the patient is unable to recover, which no matter how macabre it appears, limits in theory the effectiveness of the station.
- The Coordinate system used for the creation of the above layers, has limited accuracy to at best 2 meters meaning that this area within and outside of the circumference of the optimal area polygons can actually be unavailable for use in the actual environment of the Earth.
- Last but not least the MAUP problem. The sensitivity of analytical result to altering shape and size of the Area Units is referred to as the modifiable area unit problem (Openshaw 1984, Wong 2009) as mentioned in Jacek Malczewski & Claus Rinner "

Multicriteria Decision Analysis in Geographic Information Science ". Given this fact, the models and the decisions based upon them than stem from the GIS-MCA procedure, are only valid for the specific scale and coordinate system being used to create them. Therefore, for any other scale than 500 by 500-meter cells and different coordinate system, the optimal locations can differ from those in this paper.

5. Part III : Road Accidents in Greece and Regression Analysis

5.1 Introduction

Certainly, it cannot directly be stated that traffic causes driving accidents, since most of the cars are moving very slow trying to find the faster way. In motorways and highways, there is not much room for argumentation. In fact, it is quite common an accident to cause the traffic in certain road networks. However, in urban environment traffic makes people patience less, one of the reasons they tend to violate traffic lights and stop signs, believing that this is the faster way for them to get to their destination. The data accessible , unfortunately do not segregate into type of road network to support the previous trail of thought. Instead, this is an effort to find a meaningful relationship between road accidents their victims (diseased, lightly & heavily wounded), and factors of the economy like unemployment, consumer power index (simulating how the availability or not of extra money leads to safer vehicles and/or more patience in driving due to the feeling of financial security), new vehicles registered, government expenditure for healthcare as percentage (%) of GDP, and petroleum origin fuel total imports without any spatial information about them. This part was partially inspired by Leigh (1991), Wegman (2017), Okui (2021) and Kpamma (2020) papers, where a variety of factors set the ground for further investigation. The data used belong in a combination of a 10-year monthly dataset[16] for a total of 132 lines of data and the S.T.A.T.A. statistics program is used for the regression analysis and the creation of the tables in this part. At this point an Ordinary Least Squares regression analysis will be attempted, about the traffic accidents taking place on the whole road network of Greece. The variables used are the following :

- Roadacc : total of all road accidents in GR per month
- Pcars : registration of new cars
- Trucks : registration of new heavy vehicles like trucks and lorries (term used interchangeably to represent heavy vehicles, which in the greatest percentage are Trucks of all kinds)
- Fatalities: total deaths caused by road accidents
- Heavwou : total heavily wounded caused by accidents
- Liwou : total lightly wounded caused by accidents
- Cpi : consumer price index (differences in this number reflect the inflation, and it also represents the actual cost of living for the local people)
- Une : unemployment rate (not seasonally adjusted)

Owing to an attempt to increase the explanatory power of the model, the following modified year to month dummies[17] are introduced:

- Damh: representing with 1 the months of the year when there was increase in % of GDP spent for Health and 0 otherwise
- Dampo : representing with 1 the months of the year when there was increase in total population and 0 otherwise
- DamFU: representing with 1 the months of the year when there was increase in total petroleum fuel tones consumed and 0 otherwise

16. An overview of the data Statistics is given at the Summary

17. The whole set of regressions was also run with the dummy variables having added the value of 1 to all lines and then turned to logarithm, in order to tackle the mathematical weakness. All regression results did not defer significantly from using them as is, being the reason there are none included in the results.

5.2 Ordinary Least Squares Regression

Using the above dataset, I performed Ordinary Least Squares regression in four (4) different sets :

1) $roadacc_i = \alpha_0 + \alpha_1 \cdot pcars_i + \alpha_2 \cdot trucks_i + \alpha_3 \cdot cpi_i + \alpha_4 \cdot une_i + \alpha_5 \cdot damh_i + \alpha_6 \cdot dampo_i + \alpha_7 \cdot damFU_i + \varepsilon_i$

   for i = 1,2,… 132

2) $liwou_i = \alpha_0 + \alpha_1 \cdot pcars_i + \alpha_2 \cdot trucks_i + \alpha_3 \cdot cpi_i + \alpha_4 \cdot une_i + \alpha_5 \cdot damh_i + \alpha_6 \cdot dampo_i + \alpha_7 \cdot damFU_i + \varepsilon_i$

   for i = 1,2,… 132

3) $heavwou_i = \alpha_0 + \alpha_1 \cdot pcars_i + \alpha_2 \cdot trucks_i + \alpha_3 \cdot cpi_i + \alpha_4 \cdot une_i + \alpha_5 \cdot damh_i + \alpha_6 \cdot dampo_i + \alpha_7 \cdot damFU_i + \varepsilon_i$

   for i = 1,2,… 132

4) $fatalities_i = \alpha_0 + \alpha_1 \cdot pcars_i + \alpha_2 \cdot trucks_i + \alpha_3 \cdot cpi_i + \alpha_4 \cdot une_i + \alpha_5 \cdot damh_i + \alpha_6 \cdot dampo_i + \alpha_7 \cdot damFU_i + \varepsilon_i$

   for i = 1,2,…,132

The explanation of the above variables is the following:

α_0 : the constant term, this term represents the value of the dependent variable (here $roadacc_i$), if all the independent variables are set to zero.

α_1 : the coefficient of the independent variable 1 (here $pcars_I$), α1 represents the unit change in the dependent variable (here roadaccidents), if the independent variable car registrations is increased by one unit, when all other independent variables remain constant. This value is statistically significant at a 5% level.

α_2 : the coefficient of the independent variable 2 (here $trucks_i$), α_2 represents the unit change in the dependent variable (here roadaccidents), if the independent variable truck registrations is increased by one unit, when all other independent variables remain constant.

α_3: the coefficient of the independent variable 3 (here cpi_i), α_3 represents the unit change in the dependent variable (here roadaccidents), if the independent variable consumer price index is increased by one unit, when all other independent variables remain constant.

α_4 : the coefficient of the independent variable 4 (here une_i), α_4 represents the unit change in the dependent variable (here roadaccidents), if the independent variable unemployment rate is increased by one unit, when all other independent variables remain constant.

α_5 : the coefficient of the independent dummy variable 5 (here $damh_i$), α_5 represents the unit change in the dependent variable (here roadaccidents), if the independent variable increase in expenditure on healthcare as percentage of GDP has the value of one (1), when all other independent variables remain constant.

α_6 : the coefficient of the independent variable 6 (here $dampo_i$), α_6 represents the unit change in the dependent variable (here roadaccidents), if the independent increase in total population has the value of one (1), when all other independent variables remain constant.

α_7 : the coefficient of the independent variable 7 (here $damFU_i$), α_7 represents the value of the dependent variable (here roadaccidents), if the independent variable increase in total petroleum fuels tones has the value of one (1), when all other independent variables remain constant.

ε_i : the error term represents all the variation in the dependent variable that is not explained by the independent variables.

<u>Table 2.1 Regressions OLS1,2,3 &4 with their results[18] are given below:</u>

	OLS Road accidents	OLS Lightly wounded	OLS Heavily wounded	OLS Fatalities
	(1)	(2)	(3)	(4)
VARIABLES	roadacc	liwou	heavwou	fatalities
pcars	0.00246	0.00406	9.40e-05	-0.000617
	(0.370)	(0.492)	(0.0629)	(-0.704)
trucks	-0.0453	-0.0583	-0.0329**	-0.0129
	(-0.531)	(-0.567)	(-2.105)	(-1.373)
cpi	20.33**	19.97*	-0.0297	-0.492
	(2.121)	(1.670)	(-0.0134)	(-0.378)
une	-13.83**	-17.08**	-3.100**	-2.384***
	(-2.309)	(-2.353)	(-2.286)	(-3.269)
damh	8.402	34.77	-3.332	2.713
	(0.112)	(0.387)	(-0.229)	(0.338)
dampo	93.56*	72.01	30.98**	12.45*
	(1.747)	(1.080)	(2.398)	(1.742)
damFU	-2.234	5.570	-12.11	-1.078
	(-0.0323)	(0.0670)	(-0.890)	(-0.142)
Constant	-736.8	-492.1	216.2	198.6
	(-0.676)	(-0.364)	(0.874)	(1.375)
Observations	132	132	132	132
R-squared	0.186	0.154	0.296	0.264

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

18. There are four independent variables being used here ($roadacc_i$, $liwou_i$, $heavwou_i$, $fatalities_i$), one per O.L.S. model

Table 2.2 Regressions OLS log 1,2,3 &4 with their results[19] are given below:

OLS log Road Accidents		OLS log lightly wounded		OLS log heavily wounded		OLS Log fatalities	
	(1)		(2)		(3)		(4)
VARIABLES	logroadacc	VARIABLES	logliwou	VARIABLES	logheavwou	VARIABLES	logfatalities
logpcars	0.0848	logpcars	0.101	logpcars	-0.0352	logpcars	-0.126
	(1.192)		(1.339)		(-0.217)		(-1.134)
logtrucks	-0.182	logtrucks	-0.194	logtrucks	-0.775***	logtrucks	-0.298
	(-1.245)		(-1.247)		(-2.725)		(-1.468)
logcpi	1.777	logcpi	1.532	logcpi	-1.039	logcpi	-1.004
	(1.608)		(1.263)		(-0.433)		(-0.569)
logune	-0.438***	logune	-0.468***	logune	-1.177***	logune	-0.888***
	(-2.941)		(-2.930)		(-3.588)		(-4.442)
damh	0.125	damh	0.158	damh	0.303	damh	0.244*
	(1.410)		(1.654)		(1.642)		(1.930)
dampo	0.0387	dampo	0.00619	dampo	0.200*	dampo	0.106
	(0.750)		(0.110)		(1.706)		(1.275)
damFU	0.106	damFU	0.122	damFU	0.214	damFU	0.194*
	(1.371)		(1.476)		(1.269)		(1.744)
Constant	0.473	Constant	1.763	Constant	18.58	Constant	14.71
	(0.0789)		(0.268)		(1.507)		(1.615)
Observations	132	Observations	132	Observations	132	Observations	132
R-squared	0.185	R-squared	0.165	R-squared	0.318	R-squared	0.244
Robust t-statistics in parentheses		Robust t-statistics in parentheses		Robust t-statistics in parentheses		Robust t-statistics in parentheses	
*** p<0.01, ** p<0.05, * p<0.1		*** p<0.01, ** p<0.05, * p<0.1		*** p<0.01, ** p<0.05, * p<0.1		*** p<0.01, ** p<0.05, * p<0.1	

19.There are four independent variables being used here ($logroadacc_i$,$logliwou_i$, $logheavwou_i$,$log\ fatalities_i$), one per O.L.S. model

From table 2.1 the variables are statistically accepted meaning each approaches the true value of the dependent variable when all the other are constant are: une for OLS1, une for OLS 2, une and dampo for OLS3 and finally une again for OLS4. When logarithmic[20] transformation is introduced using the natural logarithm (ln), the results from the table 2.2. are the following: logune for logOLS1 & logOLS2, logune and logtrucks for logOLS3 and finally logune for logOLS4. From the previous two tables it is obvious that the variable unemployment has strong explanatory power on all dependent variables (road accidents, lightly wounded, heavily wounded, fatalities). In the logarithmic transformation of this variable, logune, the coefficient which represents that if unemployment increases by 1% the independent variable will be decreased by (α_3)[21] % given the negative sign of all the coefficients. This coefficient is statistically significant in the 5% level for all four regressions, and so is the non-logarithmic one for the set of OLS regressions in Table 2.1 . The previous sentence means that unemployment actually is associated with all the dependent variables under analysis, and its relationship is inelastic for (1),(2) & (4) and elastic for (3), meaning that unemployment is increased the road accidents, lightly wounded from accidents, heavily wounded from accidents will decrease but with significantly lower rates than the decrease in the heavily wounded.

This is a rather unusual result since a (naïve) thinking mind would say that in a healthy economy it makes no sense wanting to make people lose their jobs in order to decrease their probability to get in a road accident, probability to become heavily or lightly wounded from it, and their probability to die. Accepting this result in real world conditions seems very offensive at first glance, but maybe this is not what the numbers tell. Greece's economy has been in recession since 2008, so technically people should have less money to buy cars, let alone drive them around for prolonged periods. Yet on the other side can ownership has not stopped during this period and neither have road accidents. People are used to commute by car in Greece which increases their probability for car accidents. What my opinion is on the matter is that the cpi showing the cost of life differences between periods and the unemployment rate describing people out of the job market interacts with the accidents in the following way : a portion of the employed people are causing accidents for various reasons (makes sense since having a car and paying for fuel requires a job), and if somebody wants to reduce them, he has to limit (or cut) the amount of money spent that lead to this people being able to drive their vehicles and crash them. The previous sentence quietly exhibits a congested road network for certain moments in the given time period[22]. No matter how intriguing the above information may sound, both quarters of regressions suffer from omitted variable bias error in the estimates, since unemployment rates can long term affect the purchasing power index, the increase in cpi can affect both cars and trucks registrations (trailing purchases), but also the purchase of a car can lead someone to higher cost of living not being able to maintain it therefore losing his/hers job. To avoid this inevitable interaction between variables an instrumental variables approach is used.

20.For S.T.A.T.A. using log represents the use of the natural logarithm , therefore from this point onwards all variables that have the log in front of them represent logarithmic transformations using the natural logarithm ln (fe. log(liwou) is the value of ln(liwou))

21.The a3 represents the value on the right of logune in the Table 2.2 , is different one for each of the four logols regressions and represents the a3 % change in the dependent variable (logroadacc, logliwou, logheavwou, logfatalities) if unemployment increases by 1%

22.The above argumentation cannot take into account nor the people committing fraud to own vehicles neither the ones that are unemployed but regardless own a vehicle and use it to commute. For them to be traced bank records, tax office extraits and vehicles registered on family would be needed to run additional analysis.

5.3 Instrumental Variables Two Stage Ordinary Least Squares Regression

In this part, the cpi is used as an instrument on the independent variables registered cars (pcars)and registered trucks (trucks), in order to attract endogenous variation in the latter and avoid omitted variable bias. In this way the independent variables for cars and truck registrations are instrumented and then used to produce the final regressions given in the tables below. In the final path of this section, an F statistics test is included for the 2SLS IV regressions with the most statistically acceptable coefficients ($|p| < 0.05$), in order to determine if the instrument used is weak or strong. When these coefficients are accepted statistically, the true value of the independent variable, all else variables constant, lies within the confidence interval. Finally, the economic significance of the variables is checked to see if the results are meaningful in real life conditions.

Instruments must be both strong (not weak $F>10$) and exogenous[23]. The first condition represents whether or not the independent variables used as instruments are relevant enough to extract endogenous variation from the instrumented independent variables, and make them exogenous like the remaining independent ones in the second and final stage of the IV OLS process. For the second one (the exogeneity assumption), it has to be argued if the instruments used are also exogenous. The instrument used here is the log of cpi, and it is used to instrument both car and trucks registrations (and consequently purchases) . The argumentation about the exogeneity of the exogenous independent variables and the instrument is the following : unemployed people do not commute by car, or have them in the name of relatives, consumer price index affects the population growth but only short term since people who want to have family have children anyway. The state rarely cares for the purchasing power of the people since it is not taken into account when spending for healthcare,(rather population coverage metrics are used). Demand for fuel is mostly inelastic due to lack of alternatives all around Greece for people to go to work, but by car. When importers buy fuel they do not care if the cost of living went up, as long as they keep their margin, that's why CNG are brought to the market. Small period switch to electric does not affect Greece, since such vehicles fully electric started becoming more popular from 2021 afterwards for commercial users, most companies have not switched to electric for the study period. Government spending for healthcare can be argued that is affected by amounts of patients received, thus it is usually the numbers regarding the previous year period, so a direct affect from those dependent variables (liwou, heavwou) is unlikely since decisions for the budget take place yearly and are also affected by the presence of European Financial Support Packages. Road accidents appear way to specialized to be included in the % of healthcare spending, and so are the actual deaths, since this deceased people cannot be helped, so increased healthcare cannot do something about them. The previous lines focused on the exogenous independent variables and dummies. For the instrument and the instrumented variables, new car or truck ownership does not increase the consumer price index directly, maybe in time it can prove costly if the model is faulty, but most of the time it affects the consumption directly and not the income. By instrumenting new car and truck registrations, the other factors that would lead to these purchases are minimized and the effect of those who are not affected by inflation changes represented by the option to won a new vehicle become visible. In this paper all instruments are relevant (F >10) and the argumentation for their exogeneity is listed above. This part continues with the results of the coefficients of the IV regressions (Tables 2.3 – 2.6) and a summarized comparison of them.

23.For that the IJ-Sargan test of overidentifying assumptions can be used, but more strongly argumentations at towards why the instruments are exogenous which the approach chosen here.

The Instrumental Variable (IV) Two Stage O.L.S. regressions[24] with the variables as they were given in data files are listed below in tables 2.3 & 2.4 :

Table 2.3 Instrumental Variable TSLS Regression utilizing cpi as an instrument on pcars

	IV1	IV2	IV3	IV4
	(1)	(2)	(3)	(4)
Variables	roadacc	liwou	heavwou	fatalities
pcars	-0.049	-0.049	-0.008	-0.003
une	-51.894	-56.022	-6.729	-3.025
damh	245.821	279.212	22.957	8.265
dampo	-98.268	-123.487	14.532	9.994
damFU	224.078	239.084	14.168	4.730
Intercept	2377.925	2601.202	290.484	156.700
Number of Observations	132			
R - squared	0.00001	0.00001	0.1247	0.2292

Table 2.4 Instrumental Variable TSLS Regression utilizing cpi as an instrument on trucks

	IV5	IV6	IV7	IV8
	(5)	(6)	(7)	(8)
Variables	roadacc	liwou	heavwou	fatalities
trucks	-0.197	-0.201	-0.032	-0.011
une	-29.829	-33.545	-3.121	-1.743
damh	86.326	116.736	-3.125	-1.005
dampo	1.882	-21.465	30.910	15.815
damFU	64.761	76.790	-11.885	-4.530
Intercept	1905.935	2120.391	213.299	129.268
Number of Observations	132			
R - squared	0.0765	0.753	0.2959	0.2519

The IV regressions with the variables transformed to natural logarithms (ln) are listed below in tables 2.5 & 2.6 :

Table 2.5 Instrumental Variable TSLS Regression utilizing cpi as an instrument on pcars

	IVLOG1	IVLOG2	IVLOG3
	(1)	(2)	(3)
Variables	logroadacc	logheavwou	logliwou
logpcars	-0.049	-0.901	-0.384
logune	-1.098	-1.405	-1.074
damh	0.369	0.215	0.383
dampo	-0.076	-	-0.098
damFU	0.352	-	0.350
Intercept	13.764	16.699	13.463
Number of Observations	132		
R - squared	0.00001	0.1012	0.00001
First Stage F-statistic	27.16	28.13	27.16

Table 2.6 Instrumental Variable TSLS Regression utilizing cpi as an instrument on logtrucks

	IVLOG4	IVLOG5	IVLOG6	IV7
	(4)	(5)	(6)	(7)
Variables	logroadacc	logroadacc	logheavwou	logliwou
logtrucks	-0.337	-0.347	-0.667	-0.296
logune	-0.725	-0.760	-1.000	-0.705
damh	0.211	0.227	0.249	0.226
dampo	-	0.207	0.160	-
damFU	0.195	-0.032	0.240	0.198
Intercept	11.404	11.577	12.155	1.172
Number of Observations	132			
R - squared	0.1120	0.1079	0.3128	0.1101
First Stage F-statistic	45.18	41.80	41.80	45.18

24 All combinations of regression variables not included are in the most part not statistically significant, meaning that there is not 95% chance the true value of the independent variable lies within individual confidence intervals. 2SLS IV regressions for the independent variable logfatalities are not presented since in almost all regressions tested, the majority if not all the coefficients are rejected statistically.

Below lies an aggregated table of the two stage Instrumental Variables regressions for the independent variables (8) and the regressions of their logarithmic transformations (6)

Table 2.7 : Aggregated[25] IV regressions :

i	Y	IM	I	X1	XD1	XD2	XD3	R^2	F	Regression
1	roadacc	pcars	cpi	une	damh	dampo	damFU	0.000001	26.56	IV1
2	roadacc	trucks	cpi	une	damh	dampo	damFU	0.0765	43.18	IV5
3	liwou	pcars	cpi	une	damh	dampo	damFU	0.000001	26.56	IV2
4	liwou	trucks	cpi	une	damh	dampo	damFU	0.0753	43.18	IV6
5	heavwou	pcars	cpi	une	damh	dampo	damFU	0.1247	26.56	IV3
6	heavwou	trucks	cpi	une	damh	dampo	damFU	0.2959	43.18	IV7
7	fatalities	pcars	cpi	une	damh	dampo	damFU	0.2292	26.56	IV4
8	fatalities	trucks	cpi	une	damh	dampo	damFU	0.2519	43.18	IV8
9	logroadacc	logpcars	logcpi	logune	damh	dampo	damFU	0.000001	27.16	IVLOG1
10	logroadacc	logtrucks	logcpi	logune	damh	-	damFU	0.01120	45.18	IVLOG4
11	logroadacc	logtrucks	logcpi	logune	damh	dampo	damFU	0.1079	41.80	IVLOG5
12	logliwou	logpcars	logcpi	logune	damh	dampo	damFU	0.000001	27.16	IVLOG3
13	logliwou	logtrucks	logcpi	logune	damh	-	damFU	0.1101	45.18	IVLOG7
14	logheavwou	logpcars	logcpi	logune	damh	-	-	0.1012	28.13	IVLOG2
15	logheavwou	logtrucks	logcpi	logune	damh	dampo	damFU	0.3128	41.8	IVLOG6

25.Y : Dependent Variable. X : Independent Variable. $XD_{i=1,2,3}$: Independent Dummy Variable. IM : = Instrumented Variable used in the second and final stage of the IV 2SLS procedure. I : Instrument used to extract exogenous variations from the instrumented variable in the first stage of IV 2SLS procedure. R^2: R-squared indicator for the result of the second and final stage of the IV 2SLS procedure. F : first stage F-statistic used to check for the exogeneity of the instruments (indicate if the instruments are strong or weak). Green represents the statistically only accepted coefficients for the independent variables IM to XD3 per line/regression.

5.4 Results

Shifting from OLS to IV approach, there are several compelling points emerging. In IV-log approach (last five lines on the table before), all separate instrumental variables logcars's and logtrucks 's coefficients, and logune's ones, are all statistically significant, showing per each ceteris paribus, the true value of each dependent variable Y lies within their 95% confidence intervals. Utilizing logarithmic transformation IVLOGS[26] , the coefficients for the dummies damh & damFU become statistically significant, indicating a strong explanatory relationship statistically. The damh coefficients are acceptable is all but IVLOG7. In IVLOG5 the coefficient of damFU has a negative sign, as opposed to all other five regressions containing it (IVLOG) being statistically acceptable. Finally, the IV approach with the given values of the independent variables (non-ln) outputted sparse statistically significantly coefficients for trucks, une and dampo leaving all else coefficients unacceptable. Yet in the latter all instruments are relevant, having first stage F value higher than 10 and even in the lV7 & IV8 the R^2 reach their highest values, highlighting the fit of the data to the regression setup (lamentably not generating any useful results). An extension to the previous data may in the future bring a more meaningful statistical model.

All in all, the second half of Table 2.7, pinpoints that the car & truck registrations and unemployment levels can affect the number of road accidents, and the numbers of lightly wounded and heavily wounded stemming from them in the Greek road network. Increases in Healthcare budget as a percentage of GDP can supplementarily affect the latter three dependent variables (except from IVLOG 6) and so can the increase of total petrol fuel tones except from the heavily wounded. Population soar does not affect any of the Y's according to log IVOLS. The coefficients for the instrumented independent variables (IM) are all negative which is also the case for the X1 in both categories of IV regressions. This translates to an 1% increase in any of the latter (say pcars in IVLOG1) will result in an 0.049 % decrease in the expected road accidents, highlighting the possible beneficial effects of importing cars with advanced safety characteristics (fe. collision warning systems, better brakes etc.),ceteris paribus. Similarly, in IVLOG4, an 1% increase in heavy vehicles like trucks results in an 0,337 decrease in road accidents. It is interesting that the coefficients of both instrumented variables logpcars and logtrucks, are all below one in absolute values and have negative sign, meaning the elasticity of road accidents, lightly wounded, heavily wounded towards the according (IM9 to IM15) is inelastic. The prior sentence means that one can try to decrease any of the Y(Y9 – Y15) by increasing the percentage of cars or trucks imported. Of course, the previous result does not have economic significance since even if it made sense to do so, the gains from the reduced accidents and their product patients would not be enough to counterbalance the cost of importing them.

It goes without saying that constantly importing vehicles is very bad for the environment due to exhaust fumes pollution, when there is no large-scale program to recycle the old fleets, let alone that in long term it can cause congestion as well, even more intensely in urban environments, apart from the effect on urban traffic congestion (Gomez et al 2024). Contradictory, half the coefficients for unemployment the log regressions (IVLOGi i =1,2,3), implies an elastic relationship. In IVLOG1, an 1% increase in unemployment would result in an 1,098 % decrease in roadaccidents. Despite the fact that the rational for why this might seem reasonable has been explained in previous paragraphs, there is not any accurate way of pinpointing which are the employed people that cause the accidents and the routes they take. Therefore, although statistically unemployment is an acceptable coefficient, its realistic use is limited if not insignificant without extra data, apart from the fact that the numbers economically cannot sufficiently support a car usage policy for the employed.

Further down, the coefficients for damh and damFU, the population and fuel import increase dummies are statistically acceptable. In IVLOG4, when this month belongs in a year where increase in healthcare budget as percentage of GDP is observed, the number of the total road accidents is increased by 100 * 0,211% = 211%. The only reason the previous sentence would make sense is if people are indifferent between the possibility of having or not an accident, and in that case believing that the healthcare is very high or that it should be making them drive recklessly. Clearly the latter is a wrong way of explaining the reality, especially in Greece. This dummy variable does not provide useful information in this setup. Finally, the coefficient of damFU in IVLOG5 indicates that, when the month is in a year where the total imports in petrol fuel were increased, taking the value of 1, there will be a 100*(0,032)% = 3,2 % decrease in accidents. However, in all else IV log regressions this coefficient is positive meaning that when fuel import increase, so does the according accidents, lightly and heavily wounded from them. For example, in INVLOG4, if damFU is 1 then the expected accidents should be increased by (0.195)*100% = 19,5%. More kilometers driven the more fuel burnt and the higher the chance of an accident, therefore this variable is meaningful. Dampo is the indicator for if there was an increase in population from the last year, its coefficients are mostly rejected, which is in line with the fact that new babies born obviously do not start driving and causing road accidents, that is why it is not so meaningful apart from its statistical insignificance. The standard errors increase when moving from IV to the IV with logarithms approach which is also visible by the R^2 smaller values (except from IVLOG 6, the last one), but this is to be expected given the mechanisms of the Instrumental variable regression. Overall, there is definitely a relationship between the accidents on the road , the injured they produce and the car and truck registration as well as unemployment , and it is believed that a bigger richer sample containing more variables, in short information, will clear out the sign and the magnitude of it.

26. The log Y = α_1 log X setup, where Y dependent X independent variable, means the coefficient (α_1) of the independent variable is the percentage change that will happen to the Y (increase if the sign is positive "+", decrease if the sign is negative "-") if X increases by 1% . Additionally in the log Y = α_1 XD (dummy of 1 or 0), the coefficient of the dummy independent variable is in the 100(α_1) % percentage change in Y similar to above when the dummy independent variable has the value of 1.*

5.5 Limitations – Criticism

- Urban and suburban residential networks used with all magnitudes of cities, have motorcycles and scooters moving around them, since this means of transportation is versatile in terms of parking and relatively cheap in terms of fuel usage. These vehicles more often than not are involved in road accidents, for which unfortunately no data is available for none of the cities of Greece, and especially the capital which is under study in part one. Although the wounded and the deceased are added to the bulk database, having the extra information on how they affect these accidents can help broaden the usage or the road network system, predict traffic and congestion models, and possibly result to legislation to avoid accidents caused by and/or evolving them.

- Comparably, the type of road network, if it is motorway, primary or residential, if it is placed within or outside urban environment, the number of accidents that have taken place at it and their geographic location can all assist in building statistical or GIS models, to change the laws or build new beneficial facilities that will limit the accidents and the congestion caused before and after them.
- Co2 and NOx emissions caused by human activity, manufacturing and of course driving can affect the quality of the air in big cities especially when they are surrounded mountains limiting the amount of cubic feet that can be drawn away from a city, like Athens. These emissions are caused by internal combustion engines of all types, including cars, motorcycles, trucks etc. Accessing however the effect these gases can cause in urban environment is limited to assumptions when the data are yearly counted or when there are not enough historic records to run analysis (data for NOx emissions in Athens exist from 1/1/2018, therefore limiting the regression to 24 lines of data to run which is far from enough for a decent small analysis. Alas the analysis cannot be used for environmental purposes directly.
- Reason for the accident as well as the time period would also help identify seasonality patterns, given that the month level is too broad of a period to find repetition. In the above part the focus was not on the phenomenon of the congestion. That is because outliers for crashes that happen at night when in some streets there is no congestion cannot be linked to the latter phenomenon. Supplementary factors like, car condition, car category (small, sedan or SUV), if the drivers where under the influence of substances (alcohol or drugs), if their residence is nearby, and if they know the network being locals or they were driving in it for the first time like tourists.
- The Instrumental Variable Two Stage Ordinary Least Squares Method approach helps limit exogeneity and omitted variable bias, with the countereffect of increasing standard errors. The results from this analysis showed that many of the coefficients where statistically insignificant ,and may of the ones that were not were not economically significant and/or had a sign that can only be acceptable conditionally in realistic environment

6. Discussion

Using simple tools and logical thinking, the construction of an extensive network analysis and Optimal location problem was solved for different two factors regarding ground availability. But is the solution to reduce response times putting more vehicles on the street? Certainly, the chances of people living after an emergency are increased if an ambulance reaches them within a certain timeframe. But unmeasured factors like age of victim, severity of injury or disease (ex-heart attack), if the surrounding people can administer first aid, and do it effectively (which is a factor of both people knowing what they are doing, but also depends on the incident, for example in a heart attack, cardiopulmonary resuscitation cannot help if there is no defibrillator available, which is an expensive device mostly available at hospitals and ambulances). A great example can be set once more, by the Netherlands, with the availability of these devices ranging from train stations to even public squares. More vehicles are more than welcome, given the financial state of Greece and also the deficiencies of the Health System in Greece, but first there is the more severe issue of traffic that has to be dealt with in order to give such a high-cost investment the ground to meet its full potential.

Educating drivers to provide priority to ER vehicles and heavily fine or strip them of their licenses when they are using the Emergency Lane(in Greek Λ.Ε.Α.), to avoid traffic (quite common sight in both Urban and Motorway Road network). The more realistic solution though would be to make people use public transport, as a safe and effective means of transport. Giving refugees, immigrants and financially hurt social groups easier access to public transport cards, forcing security measures to avoid free riders, and design the routes of buses and trolleys in a way that would make people travel efficiently parallel to adopting the pedestrian usage of certain roads would significantly reduce traffic, and plumet travel times for all vehicles. Lastly Public hospitals, are facilities where workers (including Ambulance paramedics) operate under very difficult conditions, and yet they provide excellent for the country's state Healthcare and attention to the accuracy of the tests and operations, something that private sector hospitals cannot be motivated or forced by nature to provide, and need to be supported to continue to do so.

7. Summary

7.1 General Information about the paper

The Geographic Limits of the GIS Analysis in Attica contain all the sectors of Athens (North, East, West, South), Piraeus and Glyfada zones. The map coverage stops at the geographical longitude of Marathona city in the Northeast, Elefsina Hospital in the West, and in the Latitude of the southeast part of the Voulas-Varis–Vouliagmenis Municipality South. The Mercator projection has the disadvantage that areas away from the Earth's equator appear distorted pointing the differences of the distances in sizes with reality, with the advantage however that the directions and shapes are kept intact as appears from the figure below :

Summary Figure 2 : Mercator Earth Projection Distortion Range

The QGIS version used is the 3.28.0-Firenze with the Python version 3.9.5, run on Windows 10 Version 2009. List of Layers used in GIS with sources below:

- Open Street Map/ Geofabrik.de : Road, Railway, land use, Residential Areas, Industrial Areas
- Open Street Map/ Geofabrik.de : Land Use in Attica
- OSM QGIS Plugin Layer Downloader : Brownfields in Attica
- Overpass Turbo : Hospitals in Attica
- Google Maps and QGIS : Georeferenced Hospitals, Airbnb's, ER dispatch center (EKAB)
- Gov.gr municipalities and their limits
- NTUA Lab Traffic Accidents per Municipality Map used as a base to enrich the Municipalities Layer with Accident Data
- Population GHSL

In order to standardize the criteria, the Raster Calculator procedure was done for all five raster layers. For (C3) , (C4) , (C5) the calculation of the standardized layers was done by diving with the maximum of the layer, while for (C2) the raster was standardized by multiplying with (1 – (Core HOS layer)/ Max (Core HOS layer)), to represent that the furthest away from this area the more optimal the location. The same was used for criterion (C1) in order for the final layer to be close to motorways and primary roads. Whenever the option was available when calculating layers the Municipality Attica Layer was used to avoid having values where there is no land, while {Clip vector by extent} and {Difference} was used to isolate the areas of interest. In order to create the service areas in the Network analysis, the values of 0.167 and 0.5 were used to simulate 10 minutes and 30 minutes for ‘’Travel Cost” and fastest for “Path Type”

All regressions and confidence intervals, and inferentially the acceptance or not of the coefficients are measured at the 5% level (O.L.S. , log O.L.S. , IV 2SLS , log-log IV2SLS).

All Instrumental Variable regressions where run in both stages to ensure the results of the F statistic are Robust.

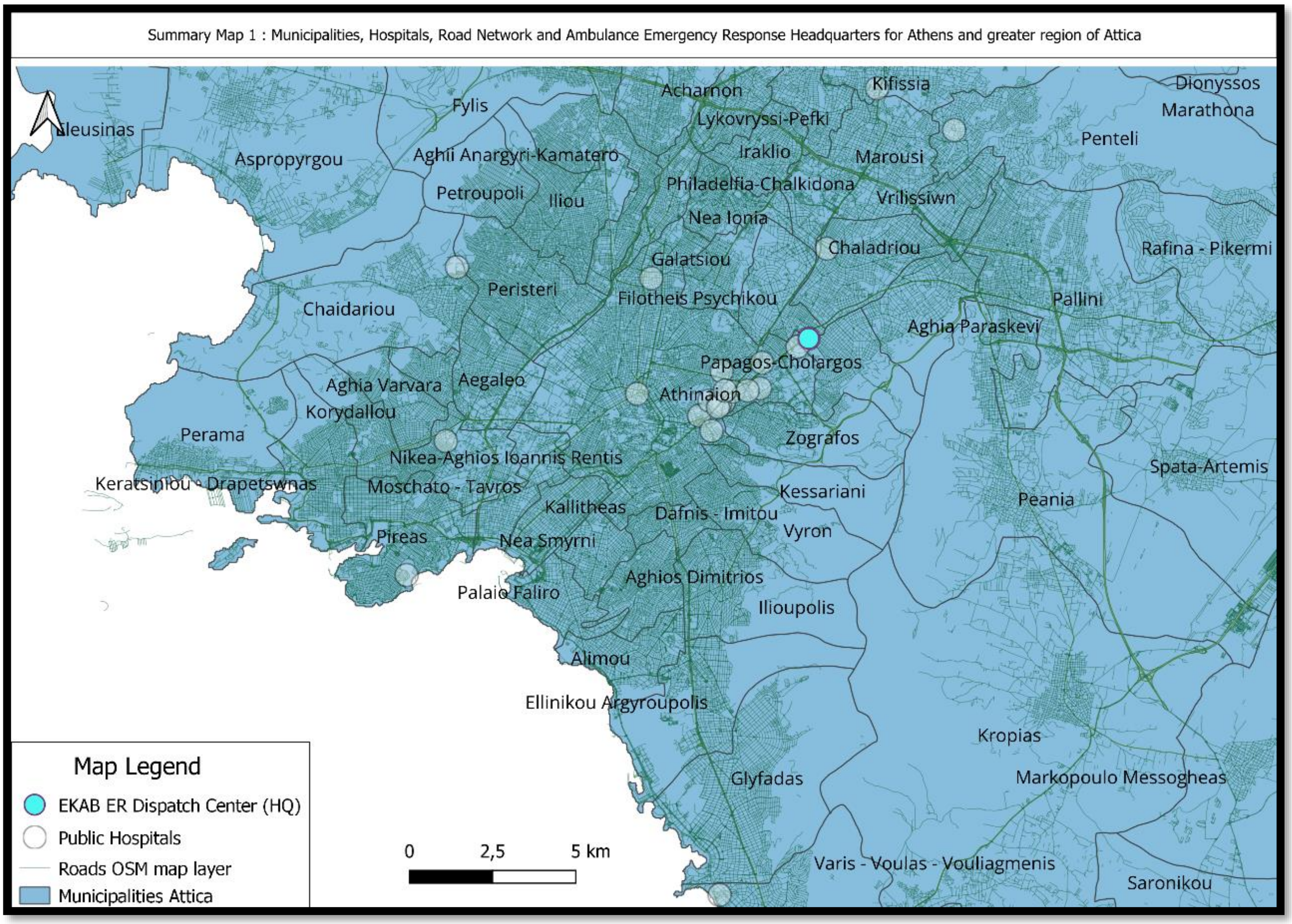
All regressions were originally performed in Stata Version 17, and then rerun on Version 18. The results remained at their first performed levels.

Summary Maps and Tables:

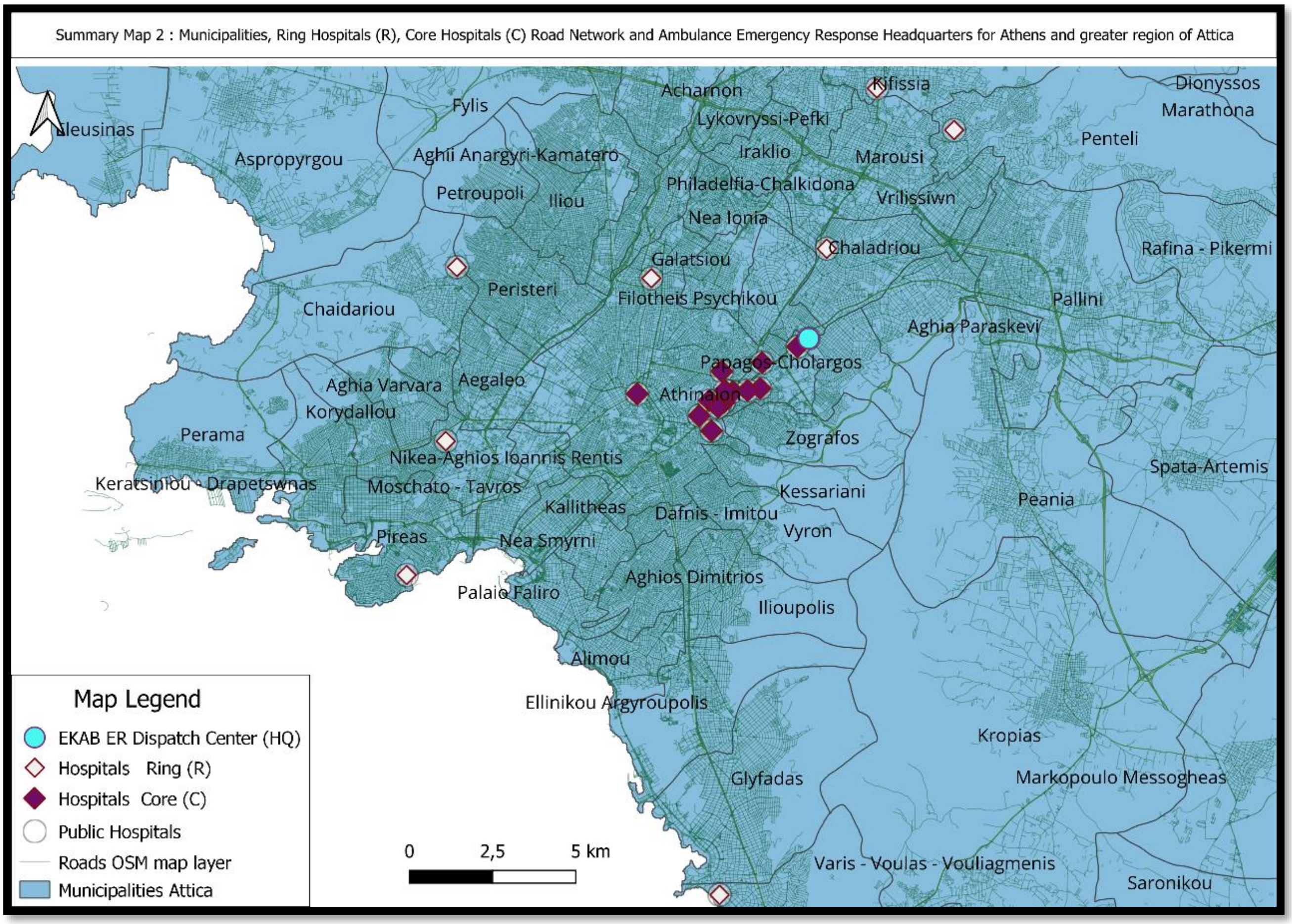
Summary Table 1 : (25) Hospitals of Athens utilized in Part 1

id	Hospital Class	Hospital Name	Hospital Category	Real Hospitals Operational (S)	Type
1	2	Sismanogleio	Ring (R)	No	Public
2	2	Amalia Fleming	Ring (R)	No	Public
3	2	Pammakaristos Hospital of Divine Providence	Ring (R)	No	Public
4	2	Naval Piraues Military Hospital	Ring (R)	No	Public
5	2	Asklipiio Voulas	Ring (R)	No	Public
6	2	Attikon University	Ring (R)	No	Public
7	2	Thriasio General Hospital of Elefsina	Ring (R)	No	Public
8	2	KAT	Ring (R)	Yes	Public
9	2	Agios Panteleimonas of Nikaia	Ring (R)	Yes	Public
10	2	Konstantopoulio	Ring (R)	No	Public
11	1	Alexandra Public Hospital (Geogrios Gennhmatas Charter)	Core (C)	No	Public
12	1	Korgialeneio - Benakeio Hellenic Red Cross	Core (C)	No	Public
13	1	Evagelismos	Core (C)	No	Public
14	1	Sotiria	Core (C)	No	Public
15	1	Athens Naval Hospital	Core (C)	No	Public
16	1	Alexandra Public Hospital	Core (C)	No	Public
17	1	Children's Hospital Agia Sophia	Core (C)	No	Public
18	1	Alexandra	Core (C)	No	Public
19	1	Aretaieion University	Core (C)	Yes	Public
20	1	Polyclinic Athens University	Core (C)	No	Public
21	1	Ippokrateio	Core (C)	No	Public
22	1	Laiko	Core (C)	No	Public
23	1	Andreas Syggros Venereal & Dermatological	Core (C)	Yes	Public
24	1	Elpis	Core (C)	Yes	Public
25	1	Spiliopoulio - Agia Eleni	Core (C)	No	Public

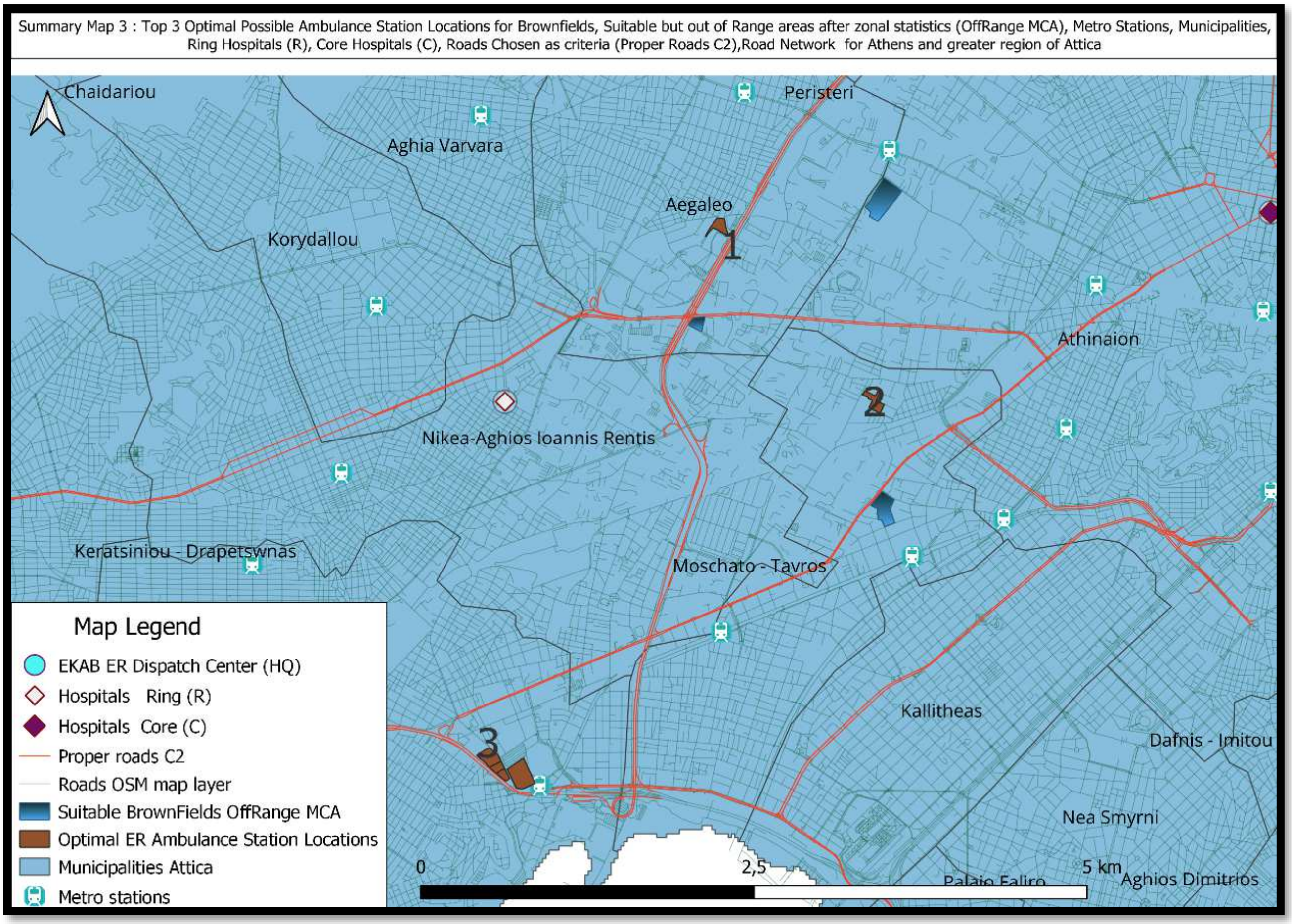
Summary Map 1



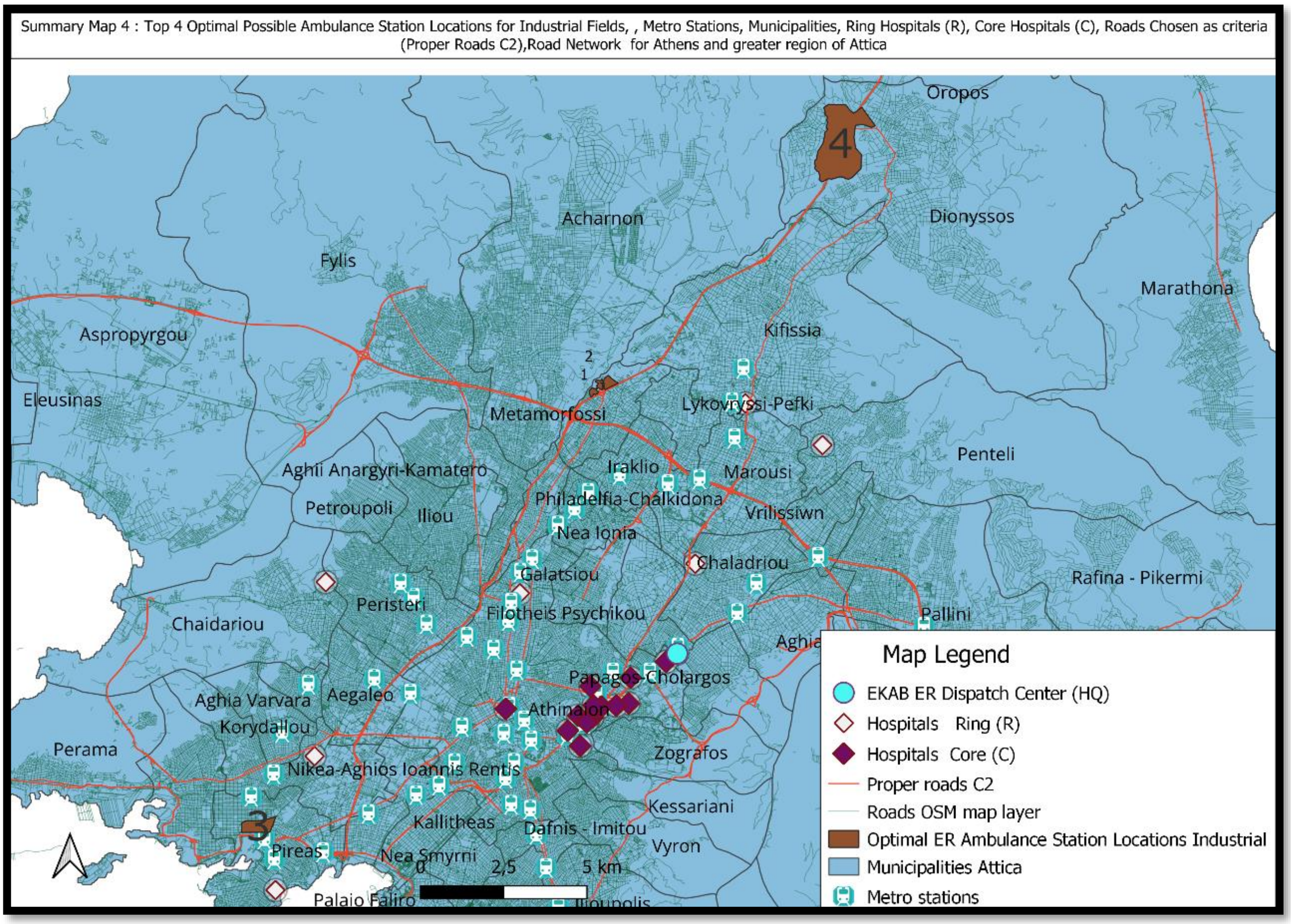
Summary Map 2



Summary Map 3

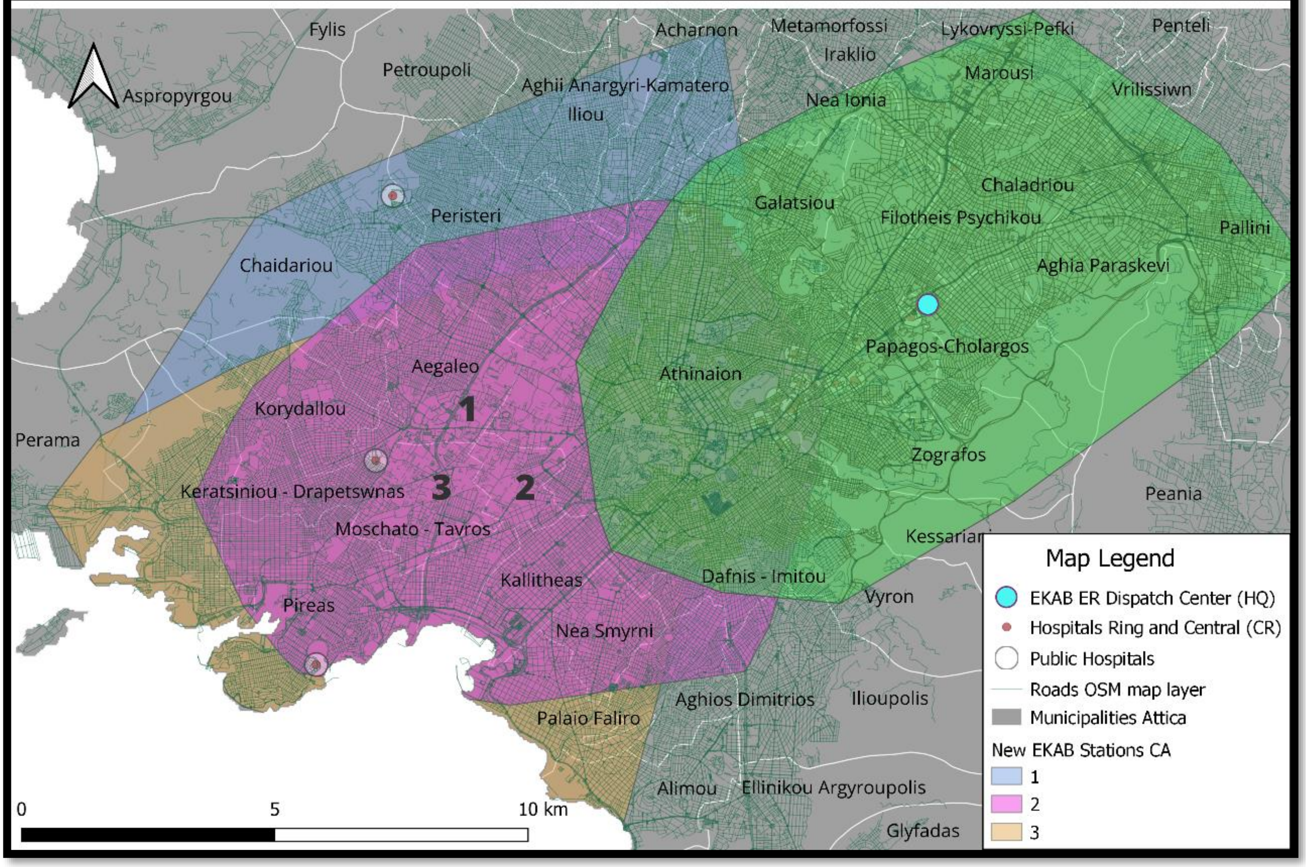


Summary Map 4



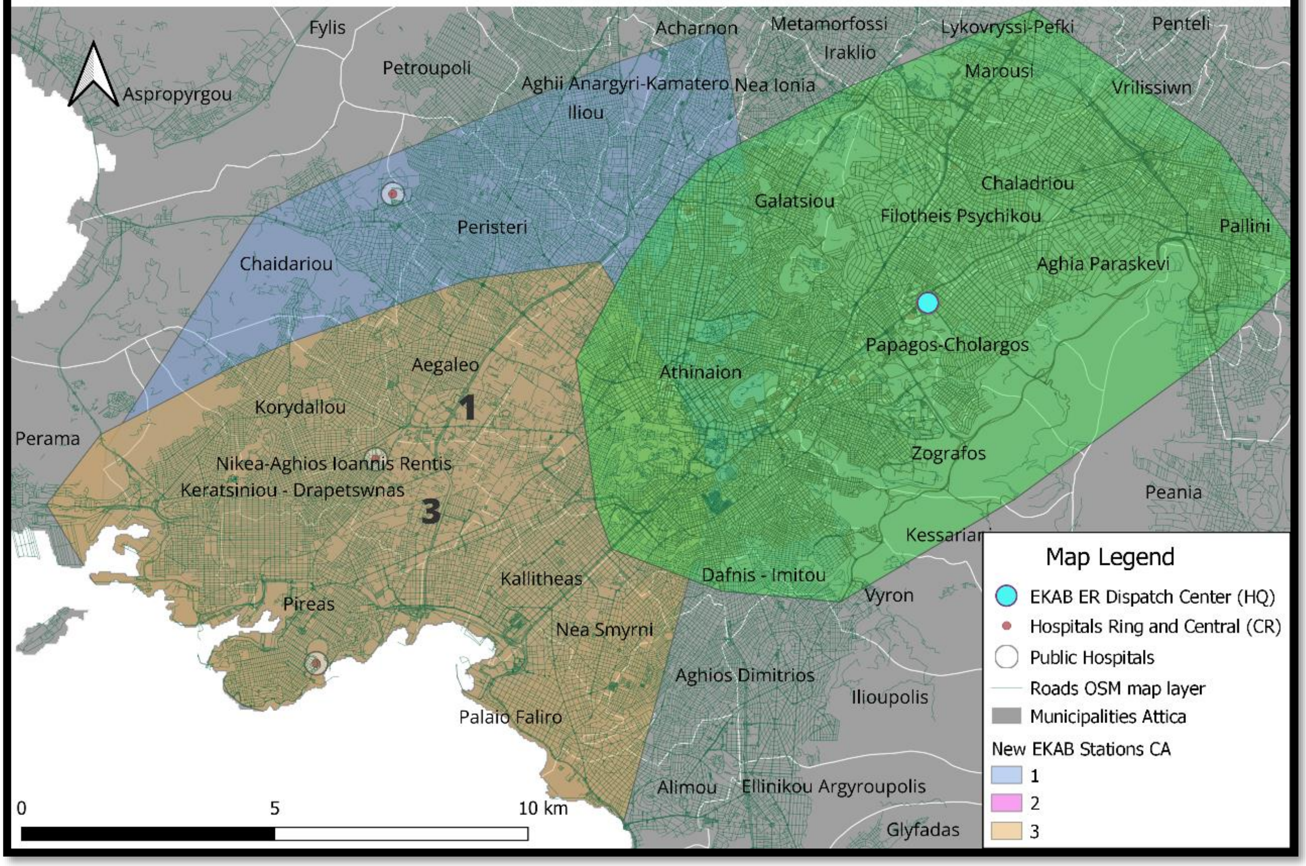
Summary Map 5.1

Summary Map 5.1 : Service Areas for Ambulance Stations (Existing EKAB and Possible Expansion Locations 1,2,3) on a 10 minutes fastest route under Period 1 conditions (Congestion) in Athens



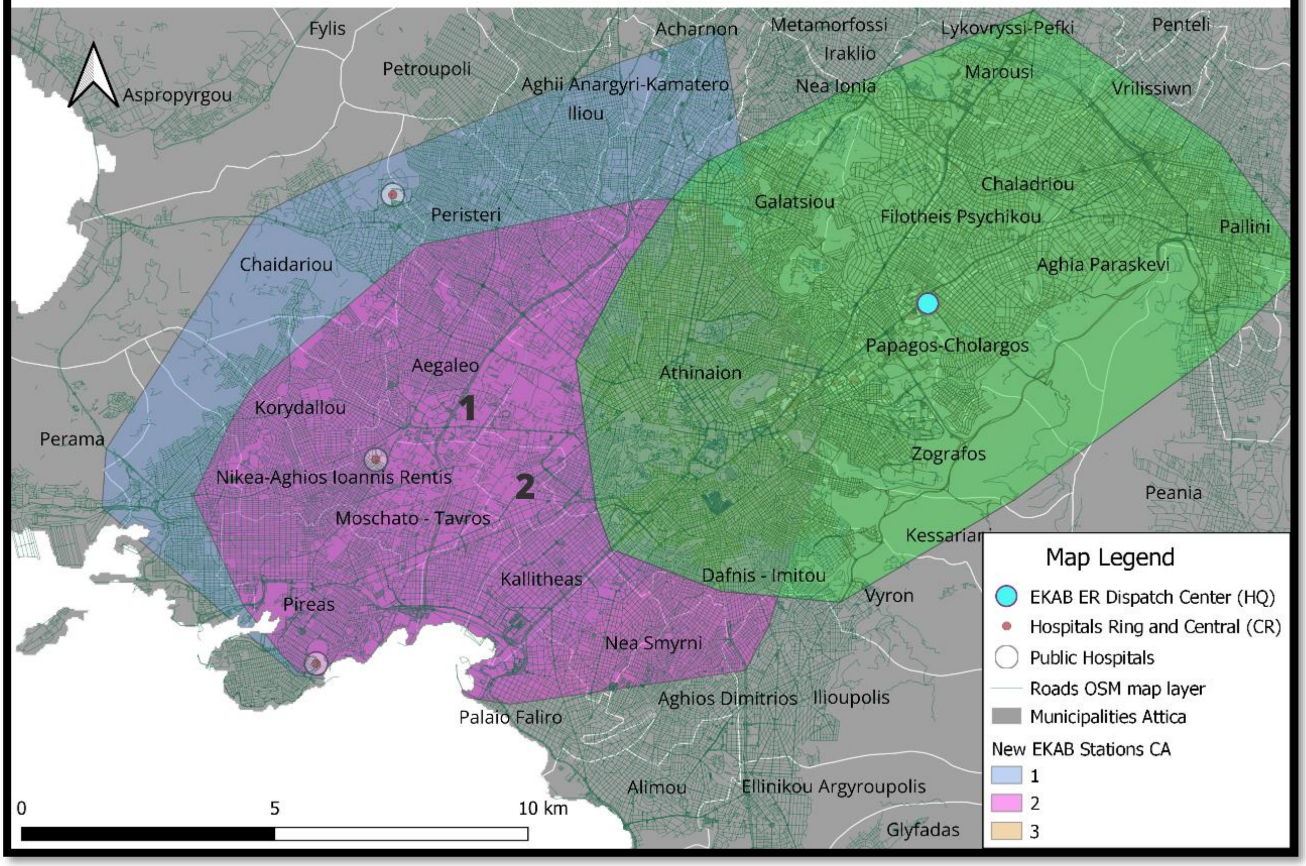
Summary Map 5.2

Summary Map 5.2 : Service Areas for Ambulance Stations (Existing EKAB and Possible Expansion Locations 1,3) on a 10 minutes fastest route under Period 1 conditions (Congestion) in Athens

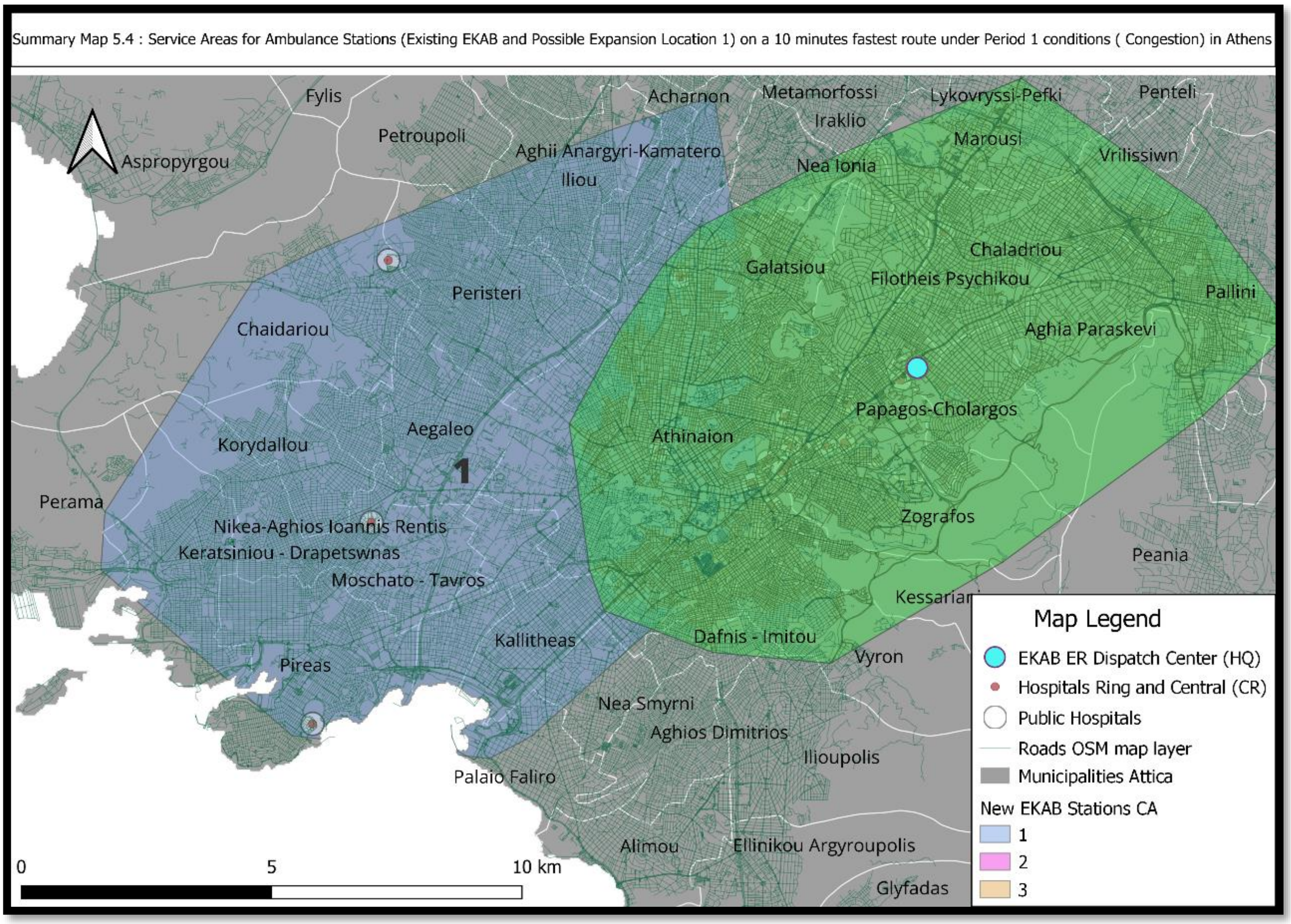


Summary Map 5.3

Summary Map 5.3 : Service Areas for Ambulance Stations (Existing EKAB and Possible Expansion Locations 1,2) on a 10 minutes fastest route under Period 1 conditions (Congestion) in Athens



Summary Map 5.4



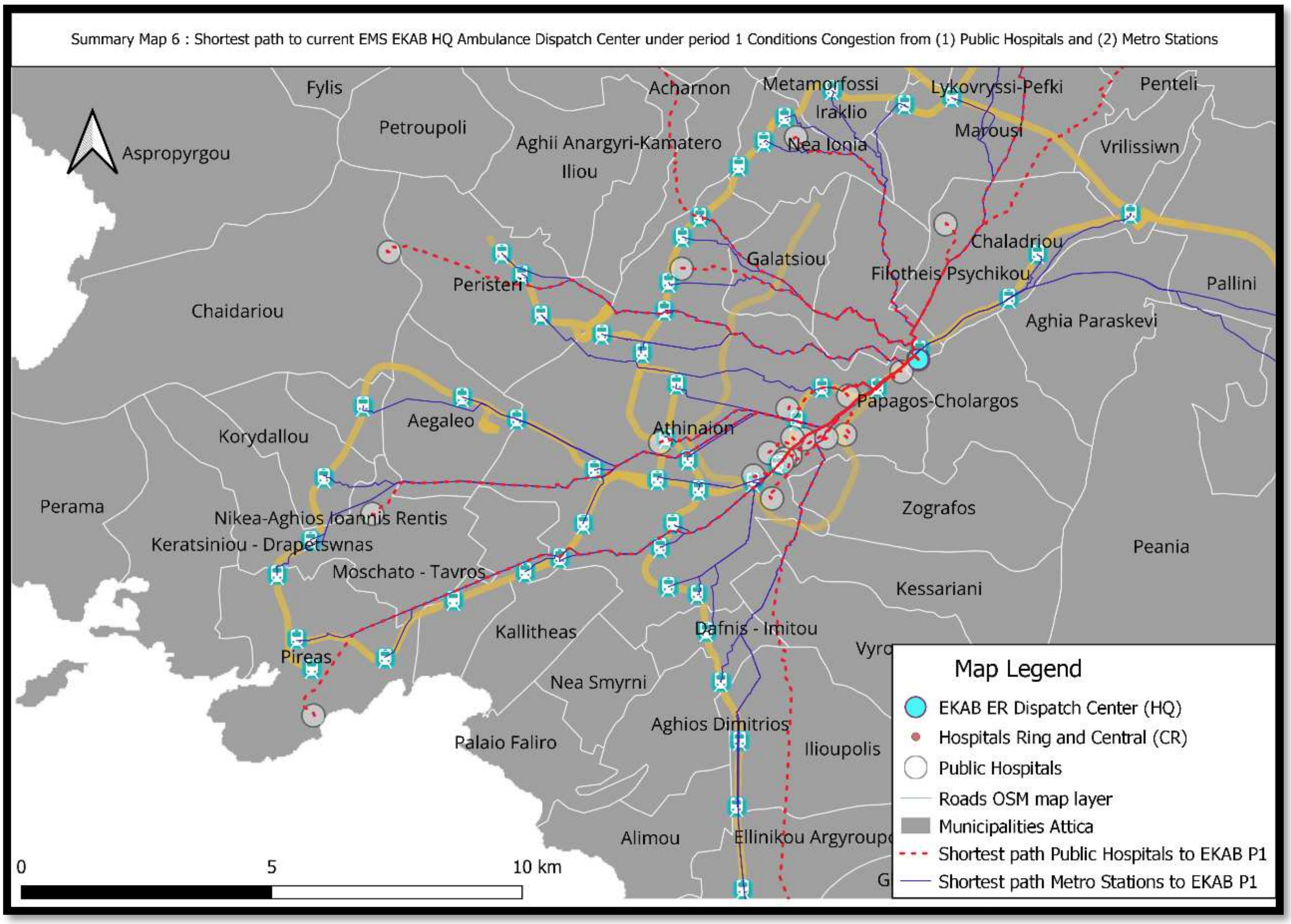
Summary Figure 2 : Optimal Brownfields from Satellite Perspective :

Summary Figure 3 : Optimal Industrial Aerias from Satellite Perspective :

Areas to the right of the left photo are taken off since from satellite pictures there are already buildings there, whereas to the left the existence of open fields (concrete or soil) is present, and also connectivity to motorway is excellent to both directions.

7.2 Possible Extensions Part I & II “Ambulance on rails”

<u>Summary Map 6</u>

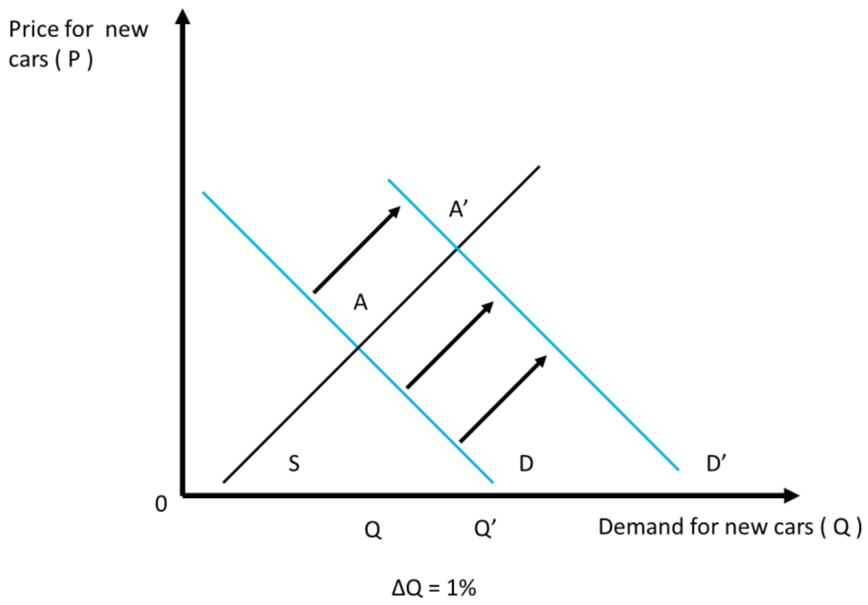


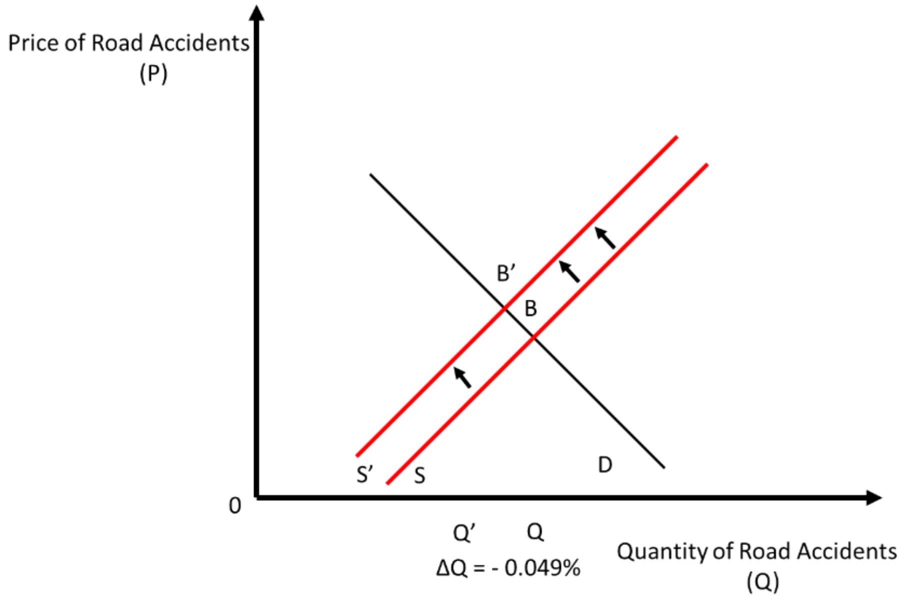
In the shortest path map for distances from Public Hospitals (1) to EKAB HQ and Metro Stations (2) to EKAB HQ, the networks converge, meaning the same routes ambulances use to go back to base from metro stations is the same they use to go from hospitals back to base, if they want to cover the shortest distance.

What if the metro had special ambulance wagons to transport patients to Hospitals? If the infactructure allows it these wagons can move patients around with a top speed of 80 km/h, faster than any land road using vehicle ambulance. Of course this is a costly project requiring to redisgn the whole network and is limited if the tracks used for this purpose are the same used to commute by metro by the public. But newly built lines of Metro Line 4 can take this as a consideration. If an extra set of metro tracks can move patients to the hospital, which is easy given that the core hospitals are built right next to metro lines, using the metro, system congestion on the roads effect on patients trying to get to a hospital will be diminished. The idea is that maybe ambulances can reach high risk patients faster, stabilize them and get them to the closer metro station, for the “metro ambulance crew” to load and take them by ambulance wagon to the hospital. This project except from costly and complicated to build has only limited value in the current network, considering this accomulation of Hospitals is only observed at the core Class 1 of Athens. In order for this to be meaningful, the travel times of using the above network must be faster than the ones ambulances take patients to the hospital by road vehicles (Only lines 2&3 can reach top speed), which is hard since the ambulances may find it hard to park right next to metro stations (parking zones can help though), and they will face congestion when departing from them to respond to the next patient. Yet as a last addition the networks on the road for the purposes of reaching the EKAB HQ Dispatch Center from all Public Hospitals and Metro Stations are almost dentical for the city center, and the benefits of this spatial relastionship should be searched after.

7.3 Possible Extensions Part III "What is the relationship between demand and supply of road accidents and the demand for cars (and trucks)?"

<u>Summary Graph 1.1 IVLOG 1 effect of the result of demand for new cars in the expected road accidents</u>





The summary Graph 1.1 represents the effect of registering new cars in the roads of Greece. The smaller (inelastic) effect on the expected road accidents reflects the motives of these drivers to drive more careful as well as the technological features of those. The Demand Curve in the Road Accidents Market (down figure), is the one the Emergencyy Healthcare System uses to operate hospitals. The closer to national days off and holidays the higher the expected frink and driving, and traffic on the road movin the demand curve to the right. The Supply curve moves to the right-down when the previous events actually lead to road accidents, and upper – left when the traffic on the road is reduced (like the Covid 19 pandemic mandatory homestaying restrictions), or when new educated drivers are introduced in the road network keepin the road network speeds low. The according unemployment graphs have a similar graph (for the unempolynment demand and supply), with the difference that in the second one the reduction in roadaccidents, lightly wounded and heavy wounded demands is of higher percentage than the initial percentage (%) growth in uneployment as the regression analysis shows.

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