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School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

A Study to evaluate the Public Transport Travel-Time Variability in Metropolitan Athens

Ioannis Loizos

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences

SUPERVISOR :

Prof. dr. ir. Tom BELLEMANS

MENTOR :

De heer Muhammad Wisal KHATTAK

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Preface

This study was conducted as part of the thesis for the Master of Transportation Sciences degree and its purpose was to evaluate the effectiveness of the design of the Public Transport system of Athens by evaluating the Public Transport Travel-time Variability using General Transit Feed Specification (GTFS) data. Ninety-three (93) origin points were defined in the different suburbs and neighborhoods of Athens and the travel times for accessing the city center by Public Transport were measured and analyzed.

The GTFS data files were obtained by the Public Transport Agency of Athens and were analyzed using a router software using several parameters like the specific day, the time of the day, and the departure time.

The most important finding was that the introduction of a new metro station to a suburb can drastically reduce the travel times and create new demand over a period of time thus making the Public Transport system not only effective but also a driver of economic growth.

The author also wishes to express his gratitude to Professor dr. ir. Tom Bellemans who as his supervisor developed the script and the necessary parameters for the router software that was used to conduct the research and provided valuable guidance throughout the research.

Initially, the problem statement is analyzed and the methodology of the research is introduced followed by the research questions and a thorough literature review. Then, Metropolitan Athens and its PT system are analyzed along with the specifics on the methodology of the research including the selection of the time periods, and of the origin and destination points. Finally, the results of the research are presented followed by the discussion of the results and the conclusions. The report finishes by listing the limitations of the research and the author’s proposals for future research.

Summary

The purpose of this study was to assess the effectiveness of the design of the Public Transport (PT) system in Athens, which is the capital of Greece, by evaluating the Public Transport Travel-time Variability (PTTTV). To achieve this, the Minimum and the Maximum travel times, and the PTTTV, using General Transit Feed Specification (GTFS) data, were measured from when traveling from ninety-three origin points in the suburbs of Metropolitan Athens to the city center for years 2024 and 2015.

The problem that this study attempted to analyze was the current situation of PT services in Athens, while the PT agency is in the process of constructing a new metro system during the last decades, targeting to reduce road traffic congestion, the travel times, the air pollution, and to encourage a modal switch to make mobility sustainable. Suburbs that are served by the new metro system are mainly benefited by the increased service frequencies and accessibility to the other suburbs and mainly the city center.

To define the origin points for the research, initially the area of study was defined at a radius of twenty-five kilometers (25 km) away from Syntagma Square that was the destination point in the city center. Then, the land uses in every suburb and neighborhood within this range was researched to identify the most appropriate point that generated the most demand for travel. Key transportation nodes like "Athens International Airport" (AIA) and the Piraeus seaport were also included.

An analysis to define the time periods of the measurements was also undertaken and it was decided to focus on the morning peak and the afternoon off-peak of weekdays. Two (2) hours were analyzed for each time period of every year with departures at every minute from every origin point to the city center.

As part of the study a thorough analysis on the PT system of Athens with several historical parameters was also conducted and it was revealed that since year 2010, when the Greek Financial Crisis started, several budget cuts were taken and the PT offering was significantly reduced. Frequencies in year 2024 remained in general below the 2009 service-levels across the PT system of Athens.

To obtain the results from the GTFS files, a router software named "r5py" was used where the parameters of the measurements were set and it was run in Python create the file with the results. Following some necessary adjustments to the results of year 2024, the analysis was made. The findings included that in general PTTTV had slightly improved compared to year 2015. Suburbs which gained new metro stations in years 2020 and 2022 benefited the most which also underlined the significant benefits of the construction of the metro system. These findings were also in-line with those of the literature review. To further analyze the differences, a comparison of the changes in the population was also conducted but without any direct cause-and-effect relationship being identified.

The conclusions that were drawn included that the budget cuts and the population change did not seem to have any significant effect on PTTTV with the most

significant effect being caused by the introduction of the new metro stations. The PT system in general was evaluated to be effective because of its low PTTTV and offering to the citizens and visitors of Athens the ability to satisfy their transportation needs.

Proposals to improve the current situation until the construction of the metro system is completed were formulated according to the findings in literature. They included the introduction of express bus services, and the investment in more frequent bus services by reversing the service cuts to proportionally benefit the whole area of study from the increased service levels regardless if they are served by a metro or a bus line. Furthermore the "smoothing" of the demand was also proposed with the most important proposal being to enable the travelers to be informed in real-time about PT services to increase reliability.

Finally, the limitations of the research included the bias that despite a low PTTTV, the specific PT services may be crowded thus unable to attract passengers. A further bias was the lack of recent data about the need for transportation in Athens, and finally the finding that some results may not include the fastest transportation option but the extent of the effects of this bias could not be evaluated.

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List of Abbreviations

AIA	Athens International Airport
BRT	Bus Rapid Transit
csv	Comma-separated values
CTA	Commercial Triangle of Athens
DEV	Standard Deviation
GTFS	General Transit Feed Specification
HIT	Hellenic Institute of Transportation
id	Identity
ITS	Intelligent Transport System
KM	Kilometer(s)
KPIs	Key Performance Indicators
MAX	Maximum Travel Time
MIN	Minimum Travel Time
MINU	Minute
N/A	Non-Applicable
No	Number
OASA	Athens Urban Transport Organization
OCT	October
PT	Public Transport
PTTTV	Public Transport Travel-time Variability
vs.	Versus
WT	Waiting Time
WTs	Waiting Times
WWF	World Wide Fund for Nature

I. Introduction

The idea to conduct this study as part of the thesis for the Master of Transportation Sciences degree was generated by the author's personal experiences using Public Transport (PT) multiple times daily in the large and densely-populated city of Athens, which is the largest city and capital of Greece.

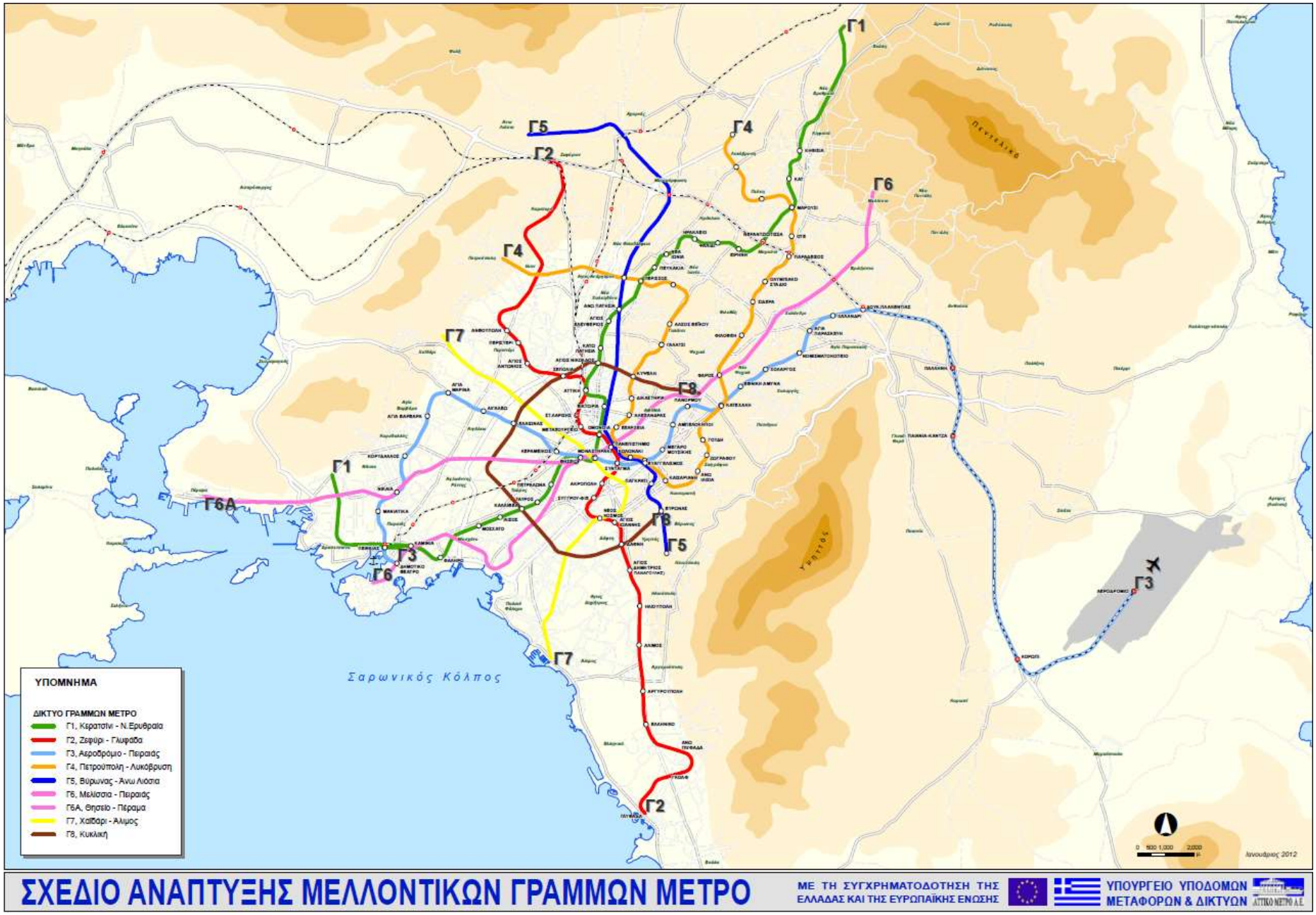
Since year 1991, the Greek government has initiated in stages the construction of a dense metro system in Athens with eight (8) metro lines, to connect the city center with the suburbs replacing bus and trolleybus lines targeting to reduce road traffic congestion and make mobility sustainable (see Picture 1 on page 10) (Elliniko Metro, n.d.a). The construction is ongoing and it requires decades of planning and construction combined with billions of euros in financing. Consequently, today only some suburbs are served by the metro system (Elliniko Metro, n.d.b).

The PT system has been transformed gradually with several bus and trolleybus lines operating as feeders of the new metro stations penetrating the nearby neighborhoods and suburbs which are not served by the metro system. These lines are prone to delays because of the varying road traffic conditions which increase travel times especially during the peak hours. The results of the research confirmed that the travel time when originating from suburbs without a metro service, has a higher Standard Deviation compared to the suburbs with a metro service. Examples include suburbs like Acharnai and Filothei (see Appendix B on pages 85-105).

Thus because of the aforementioned varying travel times, the traveling public prefers to use the metro system wherever this is available and even takes odd routes to commute to other suburbs through the city center. The main reason is because of its high frequency of services regardless of a possible slight increase in the total travel time (Centre for Renewable Energy Sources and Saving, 2014). Regarding the suburbs which are not served by the metro system, the World Wide Fund for Nature (WWF) found that the use of private vehicles is preferred over the use of buses and trolleybuses by the traveling public (In.gr Newsroom, 2014).

The aim of this study was to quantitively evaluate the effectiveness of the PT system's design in providing access to the socioeconomic activities of Athens. This has been evaluated by identifying the Public Transport Travel-time Variability (PTTTV) today and comparing it to that of year 2015, before the introduction of six (6) new metro stations. This study highlights the benefits that a metro service can bring to the traveling public by reducing the travel time and the PTTTV compared to bus services. It can also be used as reference for future research regarding the transformation of PT in Athens as the metro system is currently under construction.

Initially, the problem statement is analyzed and the methodology of the research is introduced followed by the research questions and a thorough literature review. Then, Metropolitan Athens, its PT system and the specifics on the methodology are analyzed. Finally, the results of the research are presented followed by the discussion of the results and the conclusions. The report finishes by listing the limitations of the research and the author's proposals for future research.



PICTURE 1: Map of all eight (8) metro lines that are planned to be built. Today only parts of lines 1 (green) and 2 (red) and the whole line 3 (light blue) are operational. Part of line 4 (orange) is under construction.

(Picture taken from Attiko Metro (2012))

II. Problem Statement

Today because of the effects of the climate change, the need for switching to using sustainable means of transportation has become more vital than ever. The continuous evaluation of PT services is a key issue for ensuring their competitiveness thus improving the quality of life. PT services need to be competitive to attract more passengers and to encourage a modal switch from private vehicles to PT. Among the different Key Performance Indicators (KPIs), reliability, frequency of services, load factors, and even transfer possibilities through central PT hubs are included (Hluško et al., 2024).

Apart from the aforementioned KPIs which evaluate the operational efficiency of PT, a further important parameter refers to the effectiveness of the system's design in terms of enabling its potential users to participate in the city's socioeconomic activities. Specifically, according to Rodrigue (2024) the need for transportation is derived from three (3) distinct types of activity: working, shopping, and social/recreation.

In case the PT system provides all its potential users with an as equal as possible chance to participate in the aforementioned activities then the PT system's design can be evaluated as effective and it can be assumed that it is a driver of economic growth (ibid.). To assess this, the study has focused in analyzing the PTTTV.

According to Kieu et al. (2015), PTTTV is defined as *"the variance in travel times of vehicles travelling similar trips"* with the analysis focusing in evaluating the operational efficiency of the timetables targeting to optimize scheduling. Both Kieu et al. (2015) and Noland & Polak (2002) have defined three (3) different types of PTTTV: day-to-day that focuses on the time variability between different days, period-to-period that focuses on the time variability between different periods of the day, and vehicle-to-vehicle that focuses on the time variability between different vehicles on the same day during the same period.

During the selection process for choosing a means of transportation, PTTTV is important for its perception by the traveling public. The perception of a high PTTTV minimizes the possibility of PT services to be selected by the traveling public (Chatzidouros, 2011).

A further crucial factor for selecting a PT service is the Waiting Time (WT). According to Ansari Esfeh et al. (2020), the WT is defined as the time that elapses from when a passenger enters the PT system at origin until the start of the trip combined with the Waiting Times (WTs) at transfer points for continuing the trip. Even though PT agencies worldwide undertake great efforts to successfully match supply with demand, a PT service that operates at a low frequency, for example at every thirty (30) minutes, may increase the WT disproportionally to the actual travel time thus further minimizing the possibility of the traveling public selecting PT.

An example is that in Athens for year 2022 the average total commute time by PT including walking, waiting, and the actual travel time was calculated to be forty-

seven (47) minutes (Moovit, n.d.). Remarkably, this value is in-line with the results of the research as it is shown in Appendix Table B1 (see page 85-87) that for year 2024 the average Maximum travel time including WTs and walking stood at fifty (50) minutes. This justifies the reason why the minimum acceptable regular service frequency of PT worldwide has been defined to be that of every thirty (30) minutes (Chatzidouros, 2011).

This is further justified by the results of the transportation study that was conducted as part of the "Sustainable Urban Mobility Plan" for the Municipality of Rafina-Pikermi (2021) which is in the area of Meshogheia. The plan used the below service-level categories to assess the effectiveness of the bus lines that serve the Municipality based on their frequency intervals (see Table 1). The categories have been defined by the "Hellenic Institute of Transportation" (HIT) in year 2005:

SERVICE LEVEL	FREQUENCY INTERVALS	COMMENTS
A	<10′	Passengers do not need the timetable
B	10-14′	Frequent services, passengers may advise the timetable
C	15-20′	Maximum desired waiting time if a service is missed
D	21-30′	Service not attractive to most passengers
E	31-60′	Service available for once every hour
F	>60′	Service not attractive to all passengers

TABLE 1: PT service levels defined by HIT based on frequency intervals
(Table taken from Municipality of Rafina-Pikermi (2021))

It is remarkable that for any frequency interval that is equal to or higher than twenty-one (21) minutes, the service becomes unattractive to the traveling public because of the long WTs which are expected when they wish to use it.

The magnitude of the effects of PTTTV and WT is further stressed by the fact that the city center and the suburbs of Athens that have been studied as part of the research have almost three-and-a-half (3.5) million inhabitants (Hellenic Statistical Authority, 2023) and it is estimated that Athens was visited in year 2023 by approximately six-and-a-half (6.5) million tourists with the city center being their main point of interest (OT.gr Newsroom, 2024).

In a large and densely populated city like Athens, it is more complicated for PT services to match their supply with the demand especially since the urban spatial structure has progressively changed to a decentralized-one with the creation of local clusters making transportation flows more complicated and difficult for a centralized hub-to-spoke PT system to cope with (Rodrigue, 2024).

III. Methodology of the Research

The study has focused on the period-to-period PTTTV type with an additional examination of the changes over the course of nine (9) years. The possible causes that have been examined include the change in the number of inhabitants according to the censuses of years 2011 and 2021 and the opening of new metro stations in years 2020 and 2022. The parameters of the research are briefly presented in this chapter and in detail in the next chapters.

It is important to note that a major difference, compared to other studies found in literature, is that this study did not focus on evaluating the operational efficiency of the timetable at unforeseen events like road traffic congestions but rather on its design so as to evaluate the PTTTV according to the planners' decisions when the timetable was compiled. This justifies the fact that the effectiveness of the PT system was evaluated by analyzing PTTTV while arguably if the focus was on the operation of the timetable, this would have led to an evaluation of its efficiency and not of its effectiveness.

Additionally, even though the PTTTV categories that were mentioned in Chapter II are not related to the WT, it is evident that for assessing the effectiveness of the PT system correctly, the WTs needed to be calculated in combination with the respective travel times. The result was the successful calculation of the total time that a passenger needs to spend inside the PT system for each trip to make the comparisons between the different time periods. Thus, for the purpose of this study, the calculation of the PTTTV has also incorporated the WT at each origin and transfer point.

Regarding the means of transportation, all with the exception of the suburban railway lines were included. The suburban railway services were excluded from the research, despite the fact that the three (3) suburban railway lines serve eighteen (18) suburbs, because their timetables are not compiled nor coordinated by "Athens Urban Transport Organization" (OASA). OASA is the responsible agency for providing PT services in Metropolitan Athens, but the suburban railway services are coordinated by the "Hellenic Railways Organization" independently and they operate at low frequencies of one to three (1-3) trains per hour. Since the aim of the study is to evaluate the effectiveness of the PT system's design as a system, they were excluded because they are not part of design of the PT system of Athens which is managed by OASA.

The PTTTV was evaluated for accessing the city center of Athens from multiple suburbs by PT. By using General Transit Feed Specification (GTFS) datasets for two (2) different years, specifically years 2015 and 2024, two (2) distinct two-hour time periods have been analyzed for each year: the morning peak and the afternoon off-peak (see Table 2 on page 14).

DATASET	TIME PERIOD	DURATION	FREQUENCY
No 1: year 2015	Morning Peak	120 minutes	at every minute
	Afternoon Off-Peak	120 minutes	at every minute
No 2: year 2024	Morning Peak	120 minutes	at every minute
	Afternoon Off-Peak	120 minutes	at every minute

TABLE 2: The scope of data collection

For these time periods, the Minimum and Maximum travel times for each trip, and the Standard Deviation have been calculated depending on the minute that the traveler decides to start the trip during the specific time period. The frequency of calculations has been selected to be at every minute having taken under consideration the fact that PT services operate at high frequencies.

To conduct the research, initially the GTFS files were gathered. OASA publishes GTFS files at least twice per year. The file that was used for year 2015 was downloaded by the "Transit Feeds" website which stores historical GTFS data (Transit Feeds, 2015). The file included the timetables for all metro, tram, bus, and trolleybus lines. For year 2024 the two files were downloaded from the digital platform which is named "O2hub" of the "Growthfund". The "Growthfund" is a government-owned fund that owns and manages OASA. The first file included the timetables for all metro and tram lines, and the second for all bus and trolleybus lines (O2hub, 2024).

To process the GTFS files, a router software named "r5py" was used. Professor dr. ir. Tom Bellemans developed a script that was run in Python. The script used three (3) sources of data:

- an "Open Street Map" of Athens file that was taken from Geofabrik (n.d.),
- the GTFS file or files for the year under study, and
- the list of points as they were plotted by the author in "QGIS".

Then the specific departure date and time were set in the script and it was run to produce the results of the travel times. The results were provided in minutes between all points in the form of a csv (comma-separated values) file. The results did not refer to the specific means of transportation that were to be used for the trip but they included the fastest option combining PT services and walking.

It is significant to mention that regarding the 2024 results, the results from some origin points seemed to include only walking times. Following a thorough search by the author, it was identified that this error could be attributed to the fact that during the last months OASA had introduced private operators to some bus lines and the timetables of these lines were only partially included to the GTFS files. To overcome this, it was verified by the author that the GTFS files that had been loaded by OASA to "Google Transit" included the timetables for all lines thus for twenty-four (24) origin points the data was received by "Google Transit". These origin points were: Acharnai (no 2), Ano Liosia (no 10), Anthousa (no 11), Aspropyrgos (no 13), Fyli (no 21), Gerakas (no 23), Glyfada (no 24), Glyka Nera (no 25), Koropi (no 34),

Nea Erythraia (no 43), Paiania (no 50), Pallini (no 52), Spata (no 62), Voula (no 64), Zefyri (no 68), Dionysos (no 70), Drosia (no 71), Ekali (no 72), Elefsina (no 73), Pikermi (no 74), Thrakomakedones (no 75), Vari (no 76), Varympompi (no 77), and Vouliagmeni (no 78).

Regarding the selection of the day for obtaining the data, a typical weekday and specifically a Monday that was not a holiday was selected for both datasets, specifically October 5th 2015 and May 13th 2024. Both dates were within OASA's Winter Timetable Period which is valid from September until June.

Furthermore, in order to better understand the operation of the router software, it is important to mention that according to its specifications, it measures travel times based on a specified departure time window. To provide results at every minute, it calculates the median value of the next ten (10) minutes after the specified departure time. For example, if the departure time has been set at 07:00, the median value between 07:00 and 07:09 will be calculated (r5py, 2023). It can be assumed that the use of median values might have affected the ability of the router software to calculate effectively the actual Minimum and Maximum travel times for some origin points but still it has been possible to make comparisons between the results and draw conclusions.

Finally, it is noted that for measuring the straight-line distance between every origin point and the destination point, the tool of the "National Hurricane Center and Central Pacific Hurricane Center" (n.d.) has been used, which was retrieved from the web.

IV. Research Questions

The below research questions were formulated to analyze the results of the research and evaluate the PTTTV for traveling from the suburbs to the city center of Athens:

1. Are the Maximum and Minimum travel times and the Standard Deviation different for each time period? Do they change?
    a. Is the PTTTV during each time period comparable equal for all suburbs?
    b. Which differences in the travel times and the PTTTV from year 2015 to year 2024 are significant and why?
    c. Has the opening of new metro stations in years 2020 and 2022 changed the travel times and the PTTTV for some suburbs between years 2015 and 2024?
    d. Have the budget cuts affected the travel times and the PTTTV between years 2015 and 2024?
2. Do the specific means of transportation (buses, metro, trolleybuses, and trams) that serve each suburb affect the PTTTV? How? Have the means of transportation for a specific trip changed from year 2015 to year 2024?
    a. Do routes share parts of the same PT services like for example the same metro line? Is there any relation to the PTTTV?
3. Can any relation be identified by comparing the differences in the travel times and the PTTTV between the two (2) different datasets to the change of the population of each suburb by using data from the censuses of years 2011 and 2021?
4. Is the PT system's design assessed to be effective in providing all its potential users with an as equal as possible chance to participate in the activities that create the need for transportation? Have any corrective actions that can be taken to minimize the effects of PTTTV in the current situation, before the construction of the metro system is completed, be identified?

V. Literature Review

Effects of Travel-time variability

Kim & Chung (2018) studied for the city of Seoul, which is the capital of South Korea, the travel-time variability on an origin-destination basis. They selected two (2) commercial business districts as destination points and seven (7) origin points in residential areas. The specific points were situated at either a metro station or the city hall. The source of data was from the web-based sources which provide real-time information on the estimated travel times and road traffic congestion. They identified a direct relationship between the mean and the Standard Deviation of the travel time with higher travel-time variability occurring during peak hours which may be even more than fifty percent (50%) higher than the off-peak hours.

The importance of the travel-time variability to travelers is emphasized by Abdel-Aty et al. (1995) who investigated the effects of the perceived travel-time variability on route choices made by travelers who use their private vehicles and they concluded after repeated measurements that there is a direct relation of cause and effect between them. Travelers tended to avoid routes where they had either the knowledge or the perception of uncertainty regarding the travel time.

Fosgerau et al. (2010) further analyzed the differences in the choice behavior of PT and private vehicle users. The result was that their main driver, when disposable income was excluded, was the perception that by using their private vehicles, the travel-time variability was lower. This underlines the fact that PT needs to be competitive not only in terms of cost but also in terms of operational efficiency and design effectiveness in order to attract more passengers.

In turn, Braga et al. (2023) analyzed the socioeconomic impact of travel-time variability on different social groups of people. The result was that the higher the travel-time variability, the higher the transportation cost is both in financial- and time-efficiency terms. Thus, an area with a higher travel-time variability than another is negatively affected because the other area is more privileged and its residents have more options to participate in the city's socioeconomic activities.

This is further supported by Durán-Hormazábal & Tirachini (2016) who studied the travel-time variability for trips by PT and cars in the city of Santiago de Chile. The conclusion was that the most efficient PT means is the metro because of its high service frequency and distinct right-of-way. Thus, a suburb which is served by a metro line is more privileged compared to a suburb which is not.

Effects of a distinct right-of-way, service reliability, and crowding

The importance of the distinct right-of-way was also supported by Yetiskul & Senbil (2012) who studied PTTTV in the city of Ankara, which is the capital of Turkey. They focused on the bus lines that do not operate in a distinct right-of-way and concluded that they are more prone to high PTTTV rates becoming unreliable.

Chakrabarti & Giuliano (2015) studied the negative effects of unreliability in the Bus Rapid Transit (BRT) system of the city of Los Angeles which is in the state of

California of the United States of America. It was determined that reliability is a determinant of patronage thus when services do not operate reliably patronage decreases. Examples from patronage rates of the Los Angeles BRT system supported this finding.

A further example of the consequences of unreliable PT services, is the operational meltdown of the "S-Bahn" rapid transit system in the city of Berlin that started in year 2009 and lasted for two (2) years. Because of substandard maintenance, services were severely reduced and many lines closed in order for technical checks on the rolling stock to be conducted, forcing travelers to find alternative ways of commuting to work between the remote suburbs of Berlin, which is the capital of Germany. This hampered their employability prospects and reduced their disposable income (Hasselmann, 2019).

For passengers who use unreliable services, this causes an increase in their indirect travel cost in terms of lost customer hours. Xiao & Fukuda (2015) attempted to estimate the cost of misperception of the travel time that causes travelers to depart earlier than required in order to ensure that they will arrive on-time. The cost was estimated to be one to eight percent (1-8%) in additional time spent for commuting.

Ansari Esfeh et al. (2020) specifically analyzed the PTTTV of bus services in the Klang Valley in Malaysia. Their findings were that the Burr distribution was the most effective model for analyzing the PTTTV, and that in the Central Business District during weekdays under severe road traffic congestion the addition of one (1) stop at a traffic signal increased the PTTTV by fifty percent (50%). This high rate led frequently to buses catching-up enroute a preceding bus thus increasing crowding and causing an underutilization of resources. This further underlines the benefit of operating at a distinct right-of-way.

Regarding crowding, an additional factor that increases travel times was analyzed by Chen et al. (2023). It is about the choice of passengers to delay boarding a metro train because of crowding. This delay affects their perception of reliability especially if it occurs repeatedly.

An additional cause of crowding was studied by Moller & Raveau (2024) in Santiago de Chile. It referred to the railcar choice of passengers in the metro system. Passengers who travel during peak times are frequent users and they choose to board a railcar based on their experience and knowledge of the nearest exit at a station's platform. The findings showed that passengers tended to prefer boarding on the third and the fourth railcar of the eight-railcar metro trains causing congestion in central stations and increasing the dwell times and consequently the travel times and the PTTTV during peak times.

Effects on accessibility to jobs

Nichols et al. (2024) analyzed the impact on the accessibility to jobs as a result of repeated PT delays by measuring and comparing the scheduled timetable to the operation of the timetable in the Swedish region of Scania by using GTFS data. The result was that repeated delays can lead to a four to nine percent (4-9%) reduction

in the accessibility to jobs. The less the number of households in the area, the biggest the consequences are.

Arbex & Cunha (2020) also analyzed the impact of crowding and PTTTV on the accessibility to jobs in the PT system of the city of Sao Paulo in Brazil. The source of data was big-data of smart card users and GTFS files. The result was that during the morning peak the accessibility to jobs is severely impacted by the crowding and PTTTV. This was determined by comparing the calculated demand, with data taken from smart card users, to the estimated capacity with data taken from GTFS files. Areas without metro stations were impacted more but the distance from the city center had proportionally the same impact on areas with and without metro stations.

Effects by the construction of new metro stations

Deng & Zhao (2022) conducted a large-scale study to assess the impact that is caused by the introduction of new metro stations, to the habits of the traveling public in the city of Shenzhen in China. They used mobile phone data of almost eight thousand (8,000) residents to assess the impact in different catchment areas. The result was that for residents living in a radius of three kilometers (3 km) away from the new stations, the number of trips increased because the new metro stations caused a modal shift from using buses and private vehicles to using the metro. For those living within a radius of one kilometer (1 km) away from the new stations, the frequency of the trips also increased thus underlining that on top of the modal shift, new demand can be generated too.

Lin et al. (2024) analyzed the impact that is caused by the introduction of metro systems in general, and underlined that the improvement of reliability in the PTTTV is one of the major benefits combined with the travelers' perception that a metro system is associated with a travel time that can change only slightly.

Quezada Larriva et al. (2023) further supported this finding by analyzing the impact that would be caused by the introduction of the first metro line in the city of Quito, which is the capital of Ecuador, to the accessibility of the traveling public to the city's socioeconomic activities. The study was conducted before the introduction of the metro system and it anticipated that its launch would reduce the accessibility gap depending on the distance of a residence from a metro station. On trips of up to thirty (30) minutes, it was estimated that accessibility would increase by eight to eleven percent (8-11%) for those who reside near a metro station.

Solutions proposed in literature

To address the aforementioned issues different solutions have been proposed in literature:

First, regarding solutions on infrastructure planning, Yetiskul & Senbil (2012) concluded based on the results of their research that the provision of bus lanes can decrease PTTTV and increase the reliability of PT services. On the contrary, Braga et al. (2023) determined that a distinct and segregated right-of-way is more effective than bus lanes and decreases PTTTV more drastically. Yazici et al. (2013) who

analyzed and evaluated the "Metrobüs" BRT system of the city of Istanbul in Turkey also supported this view. The conclusion of their research was that the success of the system is based on its distinct right-of-way which allows for higher speeds and lower travel-time variability.

Second, regarding improved timetable planning, Low et al. (2022) used statistical tools like Burr distribution to model day-to-day PTTTV and they proposed several operational solutions including the introduction of tripper buses, which start picking up passengers midway on a line at congested parts. This relieves other congested buses by allowing them to only disembark passengers. A further solution are buses that skip stops (express services) thus traveling faster between the terminals of a line.

Third, regarding the choices made by the travelers, De Palma et al. (2004) conducted research to analyze the departure-time variability of workers during the afternoon peak in the city of Brussels, which is the capital of Belgium. The result of the survey amongst commuters proved that workers with flexible working plans preferred to depart at times of lesser congestion so as to reduce their expected travel time and be less prone to travel-time variability. Thus, a solution would be to reduce the number of travelers in the peak times so as to reduce the travel-time variability through less congestion for both PT services and other means of transportation.

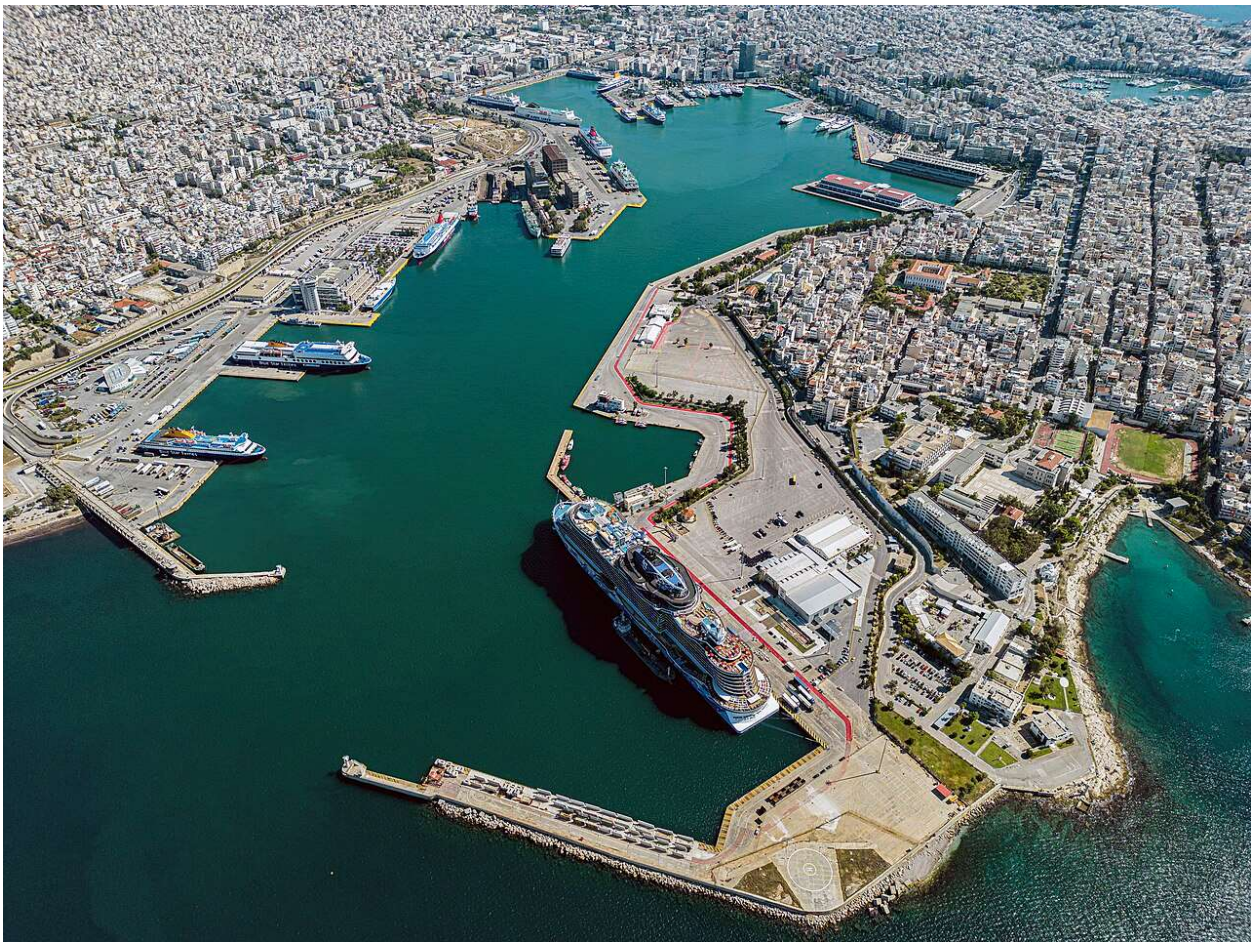
Li et al. (2016) also analyzed several models for studying travel-time variability and concluded that a "smoothing" of the peak-time demand will lead to an increase in the off-peak demand. If the reduced demand is within the capacity that is provided either by the road network or by PT, congestion and travel-time variability can be reduced drastically.

Russ & Gust (2023) analyzed almost twenty (20) years after De Palma et al. (2004) the effectiveness of reliable route planning software for achieving time savings in day-to-day intermodal transportation in Hamburg, a city of Germany. One of the conclusions was that empowering travelers to know their expected travel times for each of the different travel options in real-time, can reduce the number of congestions and subsequently the travel-time variability. It can lead to an instant "smoothing" of the demand as the capacity is better utilized. This is also supported by Kim & Chung (2018) who argued that the identification of alternative travel paths reduces congestion thus the travel-time variability and that real-time information is the most effective way to promote them.

Finally, the use of an Intelligent Transport System (ITS) providing real-time information to the traveling public can also provide valuable information to PT route planners for adjusting the timetable when scheduled services are consistently not operated as planned (Nuzzolo & Comi, 2016).

VI. Introduction to Metropolitan Athens

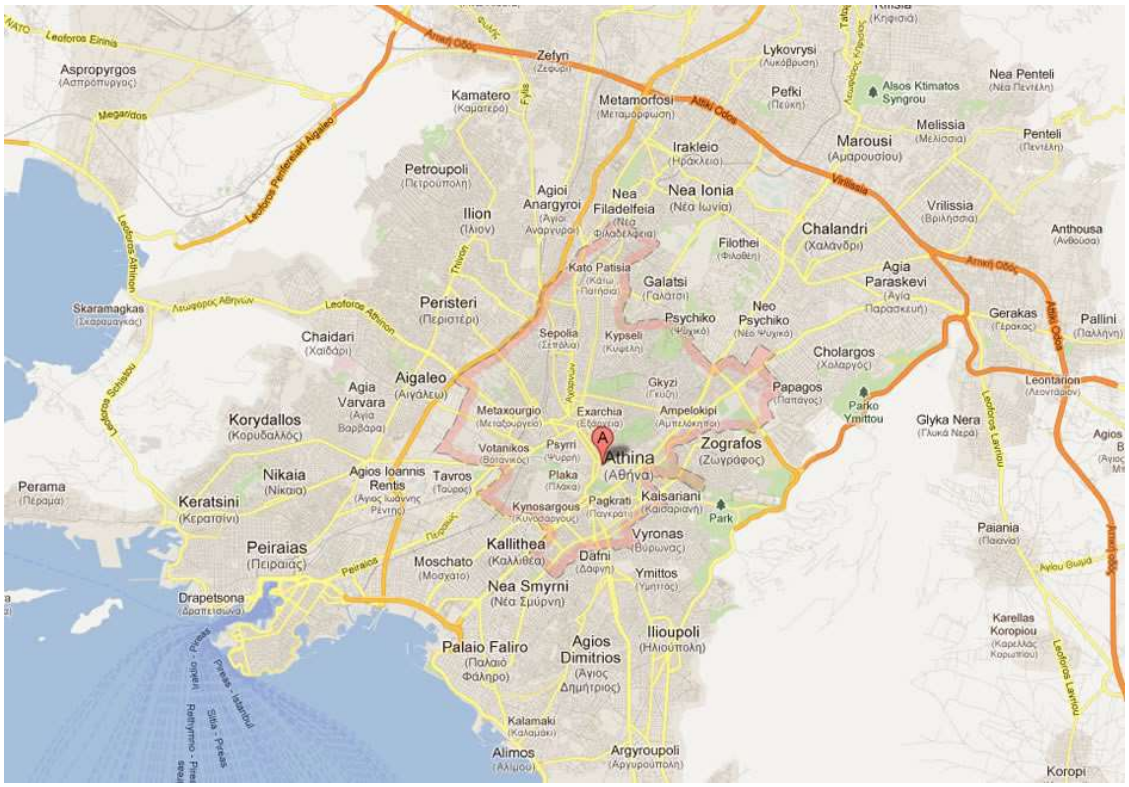
Athens has been continuously inhabited for more than five-thousand (5,000) years, a characteristic that makes it one of the world's oldest cities (Tung, 2003). Today it has approximately three-and-a-half (3.5) million inhabitants and Metropolitan Athens consists of eighty-four (84) suburbs (Hellenic Statistical Authority, 2023). The urban area of Athens expanded rapidly after the Second World War because of urbanism and Greece's rapid economic development (Elliniko Metro, n.d.a). Athens has been built in the Attica basin which is surrounded by mountains to its north, east, and west and by the Saronic gulf to the south where Piraeus, the third busiest seaport of Europe, is located (see Picture 2) (Eurostat, 2023). Initially, Athens expanded around the city center and within the Attica basin but during the last decades, Athens expands mainly to the east of the basin in the area of Meshogheia (see Pictures 3-4 on page 24) (Kotzamanis, 1997).



PICTURE 2: The passenger and cruise terminals of the Piraeus seaport. The seaport extends approximately 2 km when measured from the inner edge to the outer edge.
(Picture taken from "Google Images")

PICTURE 3: Satellite picture of Attica. The Attica basin where most of the suburbs of Athens are, is marked in red. The Meshogheia area is located to the right of the red line.

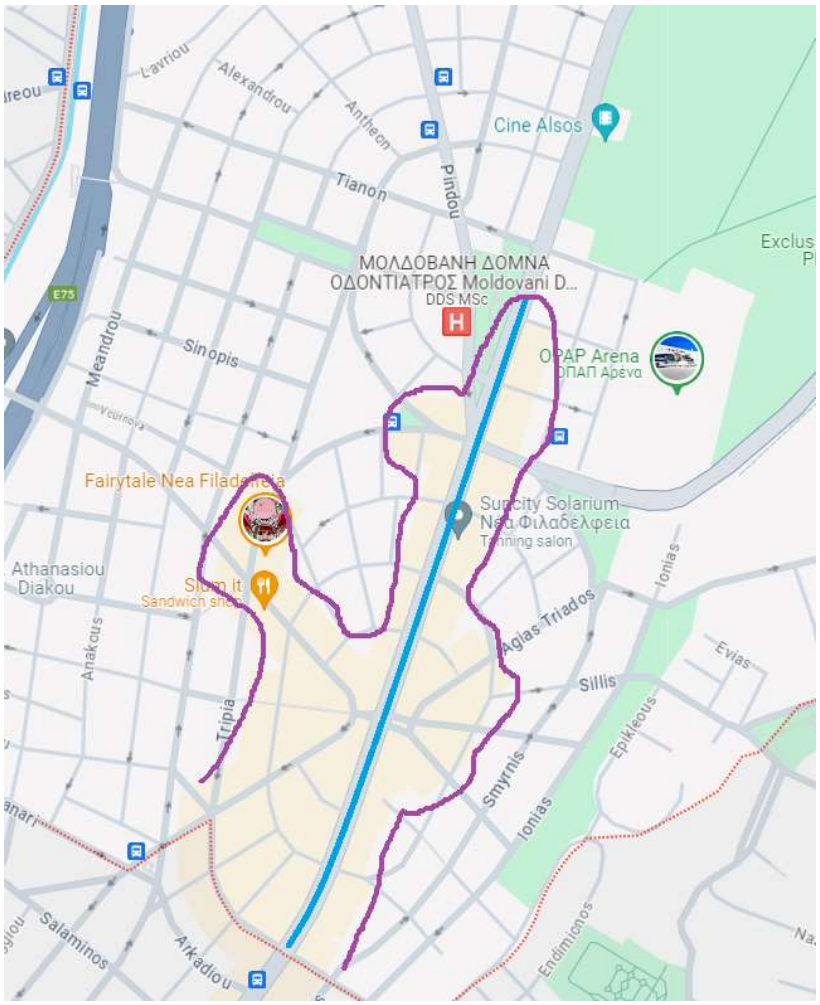
(Picture taken from "Google Maps" and edited by the author)



PICTURE 4: Map of the core of the suburbs of Athens. Syntagma Square in the city center is marked as point A.

(Picture taken from "Google Maps")

A study of the land uses of the suburbs through "Google Maps" revealed that they do not vary greatly across the different suburbs. All have residential areas and most of them commercial areas consisting mainly of small retail shops. Commercial areas in "Google Maps" are highlighted in yellow color. The road network structure of most suburbs can be described as having one main avenue that connects them with the city center which also has a cluster of retail shops, businesses, and cafeterias. The cluster is usually the center of the suburb and the residences have been built around it. An example is that of the suburb of Nea Filadelfeia (see Picture 5). Dekeleias Avenue which connects the suburb with the city center to the south is marked in light blue and the commercial area is marked in purple. The residences have been developed around the cluster.



PICTURE 5: Street Map of the suburb of Nea Filadelfeia. Dekeleias Avenue is marked in light blue, the commercial area is marked in purple.
(Picture taken from "Google Maps" and edited by the author)

Regarding the street network types, it is noteworthy that even though Nea Filadelfeia has a curvilinear loop pattern, the vast majority of suburbs feature a "disturbed" grid pattern like for example the suburb of Aghia Paraskevi (see Picture 6 on page 26). This is justified by the fact that Athens has been historically developed

without a prior city plan thus roads had to be designed after the construction of the first properties (Kotzamanis, 1997). This hampers the task of bus services to effectively penetrate the neighborhoods of the suburbs without making deviations.

PICTURE 6: Street Map of the suburb of Aghia Paraskevi
(Picture taken from "Google Maps")

The city center of Athens, as it is shown in Picture 4 (see page 24), is located in the center of the Attica basin and it has been built around the Acropolis hill. The area of the city center hosts a variety of ministries and governmental agencies, the parliament building, the old city which is known as Plaka, a park, numerous shops, offices of small, medium, and large enterprises, museums and archaeological sites, theaters, cinemas, many hotels and cafeterias. The city center also has long pedestrian areas that create a circle around the Acropolis hill (Zitouni-Petrogianni et al., 2022). Finally, the city center is the heart of the night life of Athens making it constantly "alive". The aforementioned activities attract both tourists and locals who live in the suburbs thus creating the need for transportation.

The most important area in the city center that provides a wide variety of commercial activities, is the so-called "Commercial Triangle of Athens" (CTA) which is defined as the area within Ermou, Athinas, and Praksitelous streets. Zitouni-Petrogianni et al. (2022) conducted research in year 2019 to identify the land uses within this area. In the past, the CTA used to host mainly retail shops while during the last decades, this trend has shifted to hosting leisure activities like bars and cafeterias (ibid.). Picture 7 (see page 27) presents the leisure activities in the CTA as they were mapped in year 2019.

Picture 8 (see page 28) presents the activities which are conducted in the upper floors of the buildings in the CTA. On the ground floor, most buildings host a retail shop or simply an entrance to the upper floors while the upper floors themselves may host multiple activities. The most popular are retail shops which are marked in red, offices which are marked in green, and hotels which are marked in rose. These activities generate the need for transportation.

PICTURE 7: Map of leisure activities in the CTA in year 2019

(Picture taken from Zitouni-Petrogianni et al. (2022) and edited by the author)

PICTURE 8: Map of activities conducted in the upper floors of buildings in the CTA in year 2019

(Picture taken from Zitouni-Petrogianni et al. (2022) and edited by the author)

VII. The Public Transport System of Athens

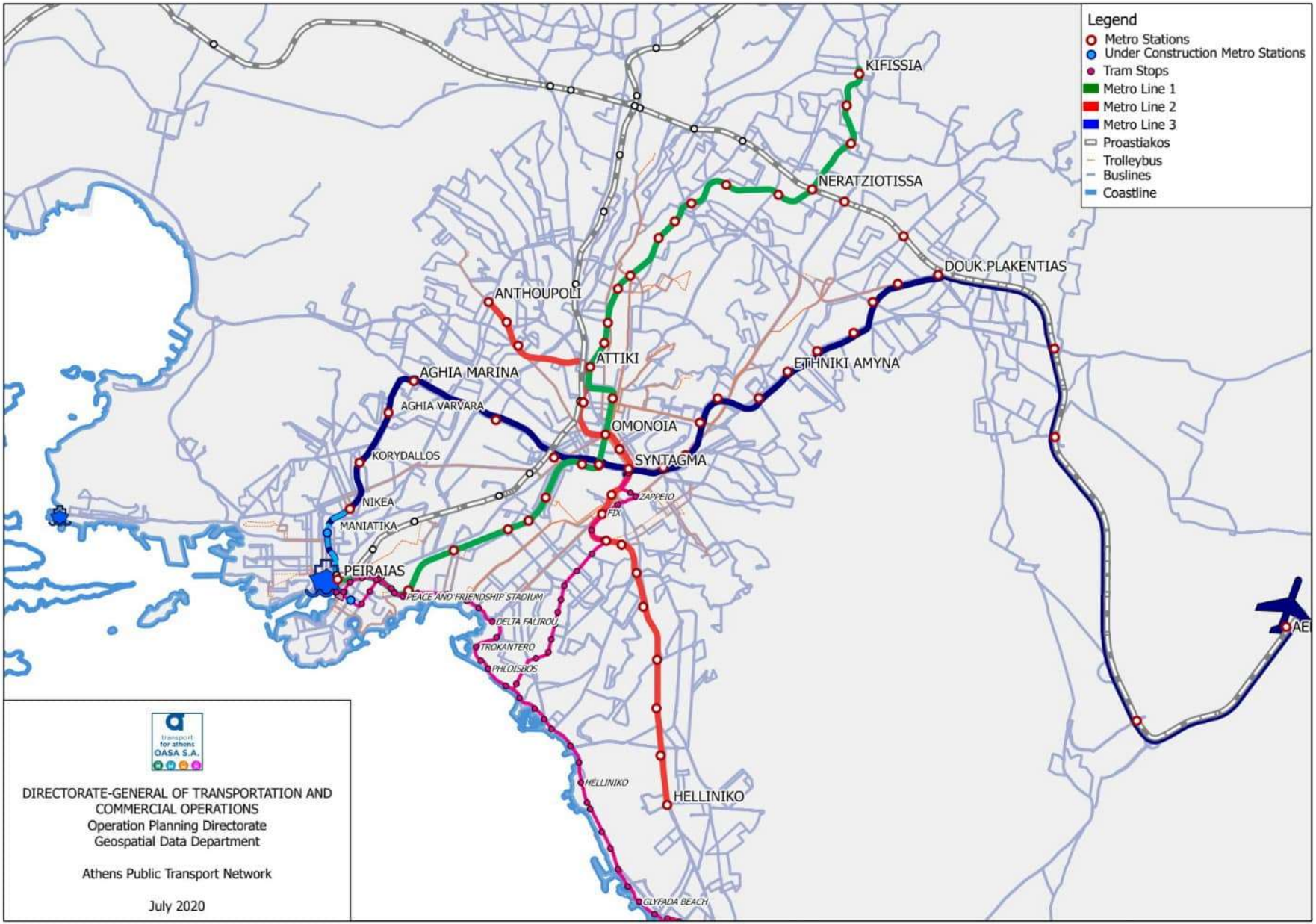
As of May 2024, the PT system of Athens consisted of three (3) metro lines, two (2) tram lines, twenty (20) trolleybus lines, and two-hundred-and-sixty-three regular (263) bus lines (see Picture 9 on page 30). The network design is that of a hub-and-spoke type. The metro lines are used as the core because all three (3) serve the city center forming a triangle with four (4) key stations (see Picture 10 on page 33). Several metro stations in the suburbs are hubs for bus and trolleybus lines that penetrate the residential areas of neighboring suburbs. Some core bus lines connect densely-populated suburbs with the city center directly while trolleybus lines also connect the city center with the suburbs (OASA Telematics, 2024).

The importance of the city center to the PT network is further underlined by the fact that for east-to-south or west-to-north trips, passengers may have to pass through or connect in the city center. The reason is because intermunicipal bus lines that do not serve the city center have low frequencies and are unreliable (ibid.). Using the metro which has higher frequencies leads to lower PTTTV thus the arrival times can be better estimated (Centre for Renewable Energy Sources and Saving, 2014).

The whole PT system during the last fifteen (15) years has been subject to several service cuts especially during off-peak hours as a result of the Greek Financial Crisis that started in year 2010 and the large decrease in the budget of OASA (OASA S.A., 2016). Table 3 (see page 31) presents a list with the changes of the service frequencies in the morning peak on weekdays between 07:00 and 08:59 of select lines that serve the city center compared to years 2009, before the cuts started, and to year 2015. Data has been taken from the author's personal archive.

It is important to mention that none of the tram and bus lines that were included serve suburbs that had new metro stations introduced during the past fifteen (15) years with the exception of bus lines 040 and 049. The selection was made on lines that did not have any change of route with the exception of the metro lines 2 (red) and 3 (blue) that were extended to the suburbs. It is important to note that for some lines, the service frequency for the core part of the line that serves the city center is presented. Less frequent services operated on other parts of the line. The results showed that when comparing year 2024 to year 2009, the service frequency on nine (9) out of a total of eleven (11) services had decreased. One (1) service had the same service frequency while one (1) service had an increased service frequency. When comparing year 2024 to year 2015, four (4) services had a decrease in their service frequency, two (2) had it unchanged, and five (5) showed increases.

An analysis of the data that has been provided by OASA S.A. (2016) for year 2015 showed that the vehicle-kilometers of PT in Athens stood at approximately one-hundred-and-forty-one (141) million. In year 2022 that is the latest year for which data could be obtained, it had dropped to approximately one-hundred-and-thirty-nine (139) million but for buses it remained unchanged (OASA S.A., 2023). It is noteworthy that in year 2009 it stood at approximately one-hundred-and-sixty-eight (168) million (OASA S.A., 2010).



PICTURE 9: Map of the PT system of Athens as of July 2020. Metro lines are marked in green, red and blue. Metro stations that are shown to be under construction opened in year 2023. Tram lines are marked in rose, bus lines in light blue, and trolleybus lines in yellow.

(Picture taken from OASA S.A. (2020))

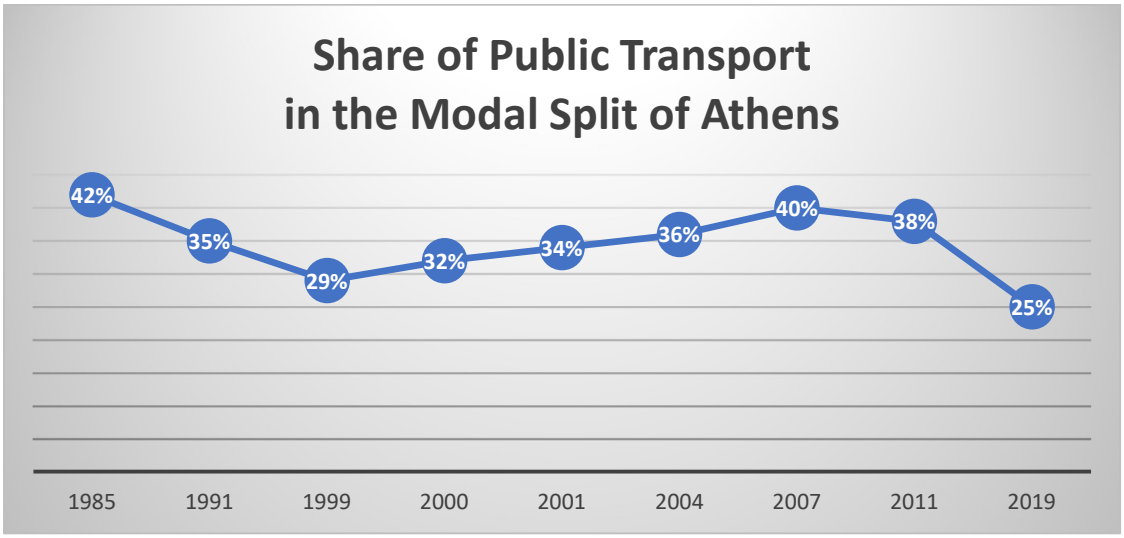
SERVICE	2009 AVERAGE INTERVAL	2015 AVERAGE INTERVAL	2024 AVERAGE INTERVAL
Metro line 1 (green)*	3’30’’	6’	6’
Metro line 2 (red)	3’15’’	4’	4’30’’
Metro line 3 (blue)*	4’30’’	4’30’’	4’
Tram lines 4 & 5*	7’30’’	7’30’’	N/A
Tram line 6	N/A	N/A	9’
Bus line 040	8’	10’	8’
Bus line 049	10’55’’	13’20’’	15’
Bus lines 220 & 221*	6’19’’	6’40’’	6’40’’
Bus line 608	6’	7’30’’	7’04’’
Bus lines A7 & B7*	8’	13’20’’	15’
Bus lines A8 & G8*	9’14’’	13’20’’	12’
Bus lines A9 & B9*	10’	17’08’’	13’20’’

*Frequencies for the core part of the line that serves the city center.
Less frequent services operate on other parts of the line.

TABLE 3: List of average morning-peak frequency intervals in minutes on select lines

(Data taken from the author’s personal archive)

The aforementioned data showed that PT service levels have not recovered from the budget cuts but OASA had managed to increase the services on some lines by year 2024 compared to year 2015. This was also been confirmed by the results of the research. Despite the increases, according to the Ministry of Infrastructure and Transport, the aforementioned reduction of PT services has been reflected in the modal split which for year 2019, just before the restrictions of the COVID-19 pandemic, stood at twenty-five percent (25%), the lowest share since year 1999 just before the opening of two (2) new metro lines (red and blue) (see Graph 1).



GRAPH 1: Data taken from Anastasopoulos (2003), OASA S.A. (2008), IBM (2015), and Liliopoulou (2021)

It is noteworthy that the aforementioned infrastructure investments that have been made during the last decades to expand the metro system, are promoted as offering the major benefit of lowering PTTTV (Elliniko Metro, n.d.a). In the past the vast majority of suburbs were served by buses which used the already congested avenues thus PTTTV depended on the road traffic congestion reducing both the efficiency and the effectiveness of the PT system (ibid.).

It can be argued though that a reduction in the service frequency of the metro system as a result of budget cuts, has a greater impact in the PTTTV compared to the reduction of the service frequency of a bus line, because of the role that metro lines perform in the PT system's design and the greater capacity they offer. Klontza (2024) mentioned in her news article that because of crowding, OASA will attempt during the summer period of year 2024 to increase the service frequencies of metro line 3 (blue) to better cater the increased demand during the tourist season.

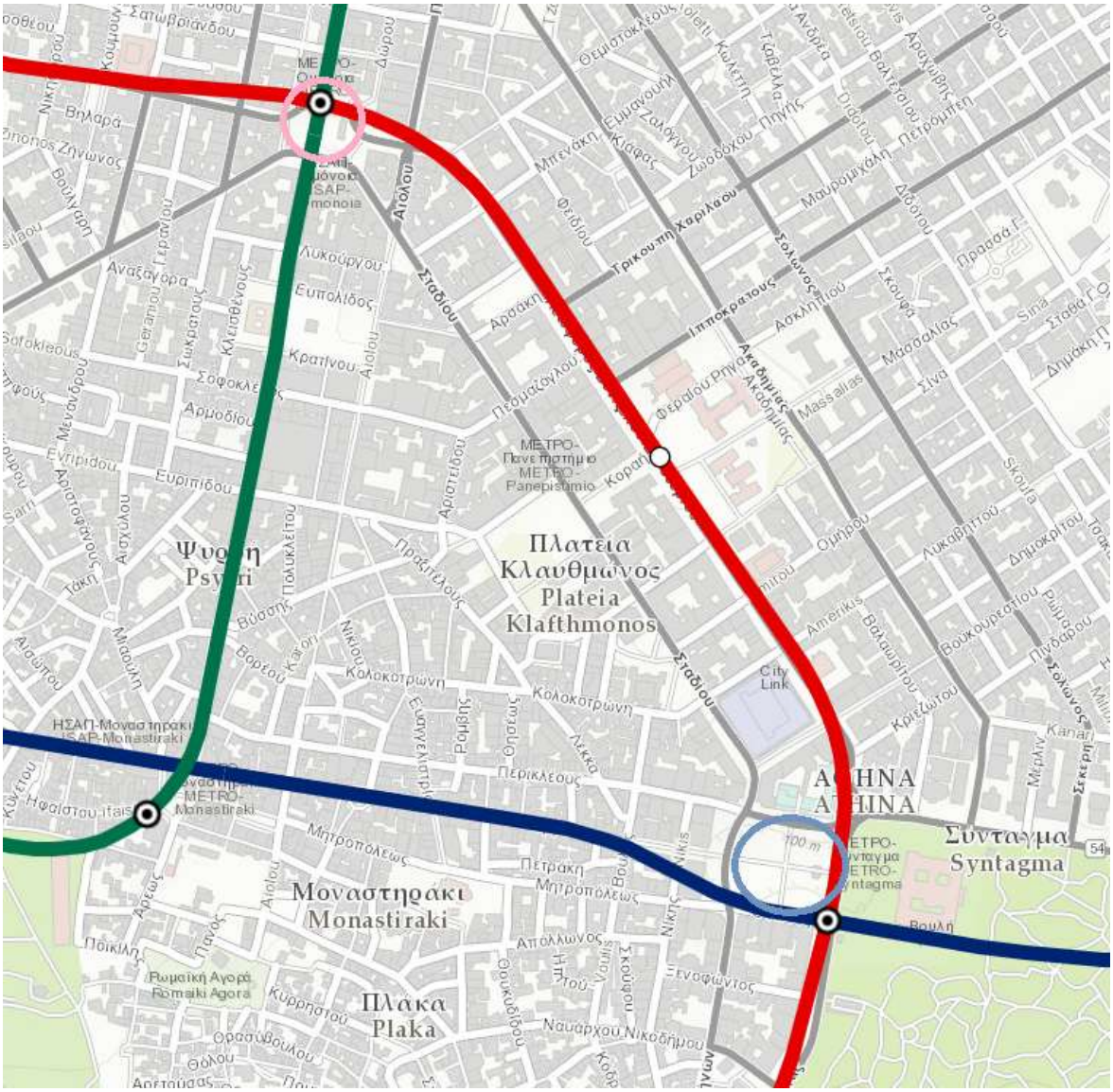
Interestingly, the struggle to match supply with demand comes from the past. According to Kotzamanis (1997), it is estimated that the first time, since its creation in year 1869, when the PT system of Athens overcame its stress point was during the 1930s after the city's population doubled in less than ten (10) years because of refugees from Asia Minor settling in Athens and inhabiting new suburbs. At that time, the PT system consisted of twenty (20) tram lines connecting the then inhabited suburbs of Athens with the city center, and one (1) metro line (green) connecting the city center with the Piraeus seaport. The newly inhabited suburbs were never connected to the city's tram network but they were the first suburbs to be served by bus lines which connected them with the city center (Research history team of Athens public transport, 2007).

After the Second World War and the city's rapid expansion, the tram network was gradually replaced by buses and trolleybuses to release road space for private cars (ibid.). The Athens PT system patronage peaked during the 1960s and then it started to decline as the number of private vehicles continued to increase (Elliniko Metro, n.d.a). The newly-constructed suburbs had to be connected with the city center through new or avenues that were expanded in order to provide adequate capacity for private vehicles. To achieve this, several homes needed to be demolished. Despite the increased road capacity, traffic congestion levels worsened and reached their peak during the 1980s and 1990s only to be relieved by the introduction of the new metro lines (red and blue) in year 2000 (Research history team of Athens public transport, 2007).

The aforementioned chain of events proves that the PT infrastructure in Athens expands at a slower pace than the city's growth thus affecting PTTTV negatively.

VIII. The Selection of Syntagma Square as the Destination Point

Despite the fact that the city center of a city like Athens has various attractions and that it consists of various squares, pedestrian ways, and neighborhoods, for the purpose of this study a single destination point was selected. After the Second World War and until the 1990s, Omonoia Square was considered the most central point of Athens because it was the only central square that was served by a metro line (green) and it was in the northern corner of the CTA having itself several retail and department stores. Instead, Syntagma Square which is located in the southeastern corner of the CTA and was not served by any metro line but featured cafeterias, was a popular square for leisure activities (see Picture 10).



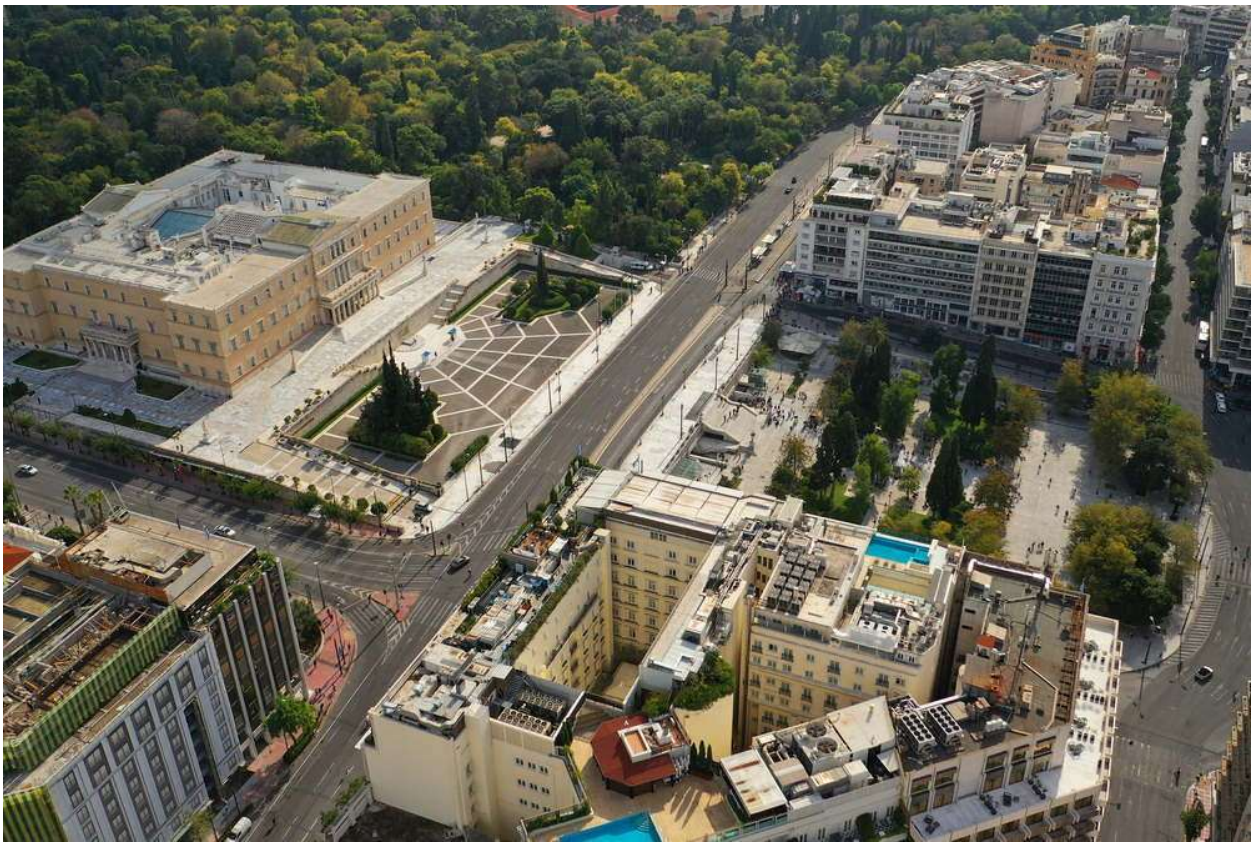
PICTURE 10: Map of the city center including metro lines and stations. Omonoia Square is marked in rose, Syntagma Square in light blue.

(Picture taken from OASA S.A. (n.d.) and edited by the author)

Since year 2000 when the two new metro lines (red and blue) serving Syntagma Square opened, the central point began to shift from Omonoia Square to Syntagma Square. Syntagma Square is closer to Plaka which is popular to tourists and to the northern end of Ermou street which has been converted to a pedestrian way leading to the opening of new retail shops. Due to its position, Syntagma Square serves as an entrance point to the CTA. In Plaka and the southern part of the CTA new restaurants, bars, and cafeterias have opened and new hotels are still inaugurated around Syntagma Square (OT.gr Newsroom, 2023).

The square itself hosts concerts, parades, events, and is visited by many tourists who take photographs of the parliament building and the prestigious hotel buildings which are located around the square, making it synonymous to the true central point of Athens and the second most famous and recognizable point in Athens internationally after the Acropolis (see picture 11).

The aforementioned characteristics and the development of Syntagma Square during the last years make it the ideal point of interest for travelers to visit in the city center thus the ideal destination point for the purpose of this research.

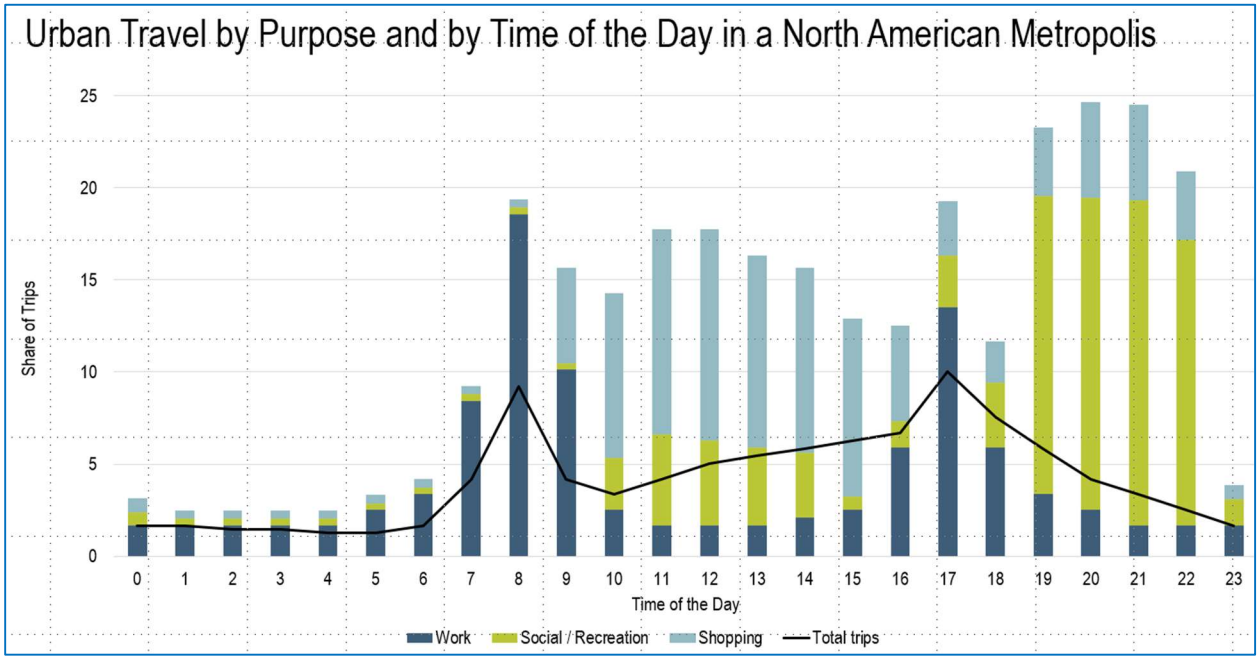


PICTURE 11: A view of Syntagma Square

(Picture taken from "Google Maps")

IX. The Selection of the Time Periods

It was significant to carefully select the specific time periods that the research would focus in order for the study to have representative results of PTTTV at times that are most popular for transportation. The general operating hours of the PT system in Athens during weekdays are from 05:00 to 00:30 (OASA S.A., 2015). During this almost twenty-hour (20) time period, multiple transportation needs are satisfied which are derived from all three (3) activities that were analyzed in Chapter II, at varying intensity. An example of this varying intensity has been provided by Rodrigue (2024) regarding the number of trips sorted by the time of the day and activity in a North American Metropolis on a typical weekday (see Graph 2).



GRAPH 2: Number of trips sorted by the time of the day and activity in a North American Metropolis

(Graph taken from Rodrigue (2024))

From the results of the research that was conducted by Rodrigue (2024), it is determined that from 07:00 to 08:00 most trips derive from the need of commuting to work while from 09:00 to 15:00 most trips are for shopping followed by social/recreation activities. Between 16:00 and 18:00 commuting from work is the major activity and from 19:00 to 22:00 most trips occur to satisfy the activity of social/recreation followed by shopping.

This approach is justified by the fact that the typical working hours across Europe and North America are from 09:00 to 17:00 thus the rest hours of the day are typically devoted to social/recreation and shopping activities while midday, travelers are mostly people who are not part of the labor force thus they satisfy their need for shopping during the morning hours. The activity of commuting to and from work creates two peak periods: one in the morning and one in the afternoon

(Rodrigue, 2024) (Chatzidouros, 2011). Furthermore, according to Glover (2000) since the 1980s, the number of passengers riding the "London Underground" during the off-peak hours and especially during the afternoon off-peak and in the evening has increased significantly and this has been attributed to the increased needs of transportation which are derived from the needs of social/recreation activities. This trend has continued after the end of the restrictions of the COVID-19 pandemic with demand in New York City being higher during the non-peak hours than before the pandemic (Walker, 2023). Such variations have led PT agencies worldwide to divide their operating hours to multiple time periods to better reflect the service requirements according to the projected demand (Chatzidouros, 2011).

The specific time periods that have been defined by OASA could not be identified. After a detailed analysis of the timetables, it has been determined that each metro line has different although similar peak and off-peak hours. Thus, it was decided to review the timetable of metro line 3 (blue) (see Table 4) which has the highest frequency of all metro lines and of bus line 608 (see Table 5 on page 37), which has the highest frequency of all bus lines (OASA Telematics, 2024). Subsequently, seven (7) time periods have been defined (see Table 6 on page 38).

DAY	TIME	SERVICE FREQUENCY
		DOUK. PLAKENTIAS - DIM. THEATRO
MONDAY - THURSDAY	05:30 - 06:00	9'
	06:00 - 06:30	5'
	06:30 - 10:00	4'
	10:00 - 13:30	5'
	13:30 - 17:30	4'
	17:30 - 20:00	6'
	20:00 - 22:00	7'
	22:00 - 00:20	9'
FRIDAY	05:30 - 06:00	9'
	06:00 - 06:30	5'
	06:30 - 10:00	4'
	10:00 - 13:30	5'
	13:30 - 17:30	4'
	17:30 - 20:00	6'
	20:00 - 22:00	7'
	22:00 - 00:20	9'
	00:20 - 01:30	15'

TABLE 4: Scheduled service frequencies of metro line 3 between Doukissis Plakentias and Dimotiko Theatro stations on May 13th, 2024

(Screenshot taken from STASY S.A. (n.d.))

Timetable For Return										
05	05:00	05:15	05:30	05:40	05:50					
06	06:00	06:10	06:20	06:30	06:40	06:50				
07	07:00	07:08	07:16	07:23	07:31	07:38	07:46	07:53		
08	08:00	08:07	08:14	08:22	08:29	08:36	08:42	08:49	08:55	
09	09:02	09:08	09:15	09:21	09:27	09:33	09:39	09:45	09:51	09:57
10	10:03	10:09	10:16	10:23	10:31	10:39	10:47	10:55		
11	11:02	11:10	11:17	11:24	11:31	11:38	11:45	11:52	11:59	
12	12:05	12:12	12:18	12:25	12:31	12:37	12:43	12:49	12:55	
13	13:01	13:07	13:13	13:19	13:25	13:31	13:37	13:43	13:49	13:55
14	14:01	14:08	14:14	14:21	14:27	14:34	14:40	14:47	14:53	
15	15:00	15:06	15:12	15:18	15:24	15:30	15:36	15:42	15:48	15:54
16	16:00	16:06	16:12	16:18	16:24	16:30	16:36	16:42	16:48	16:54
17	17:00	17:06	17:12	17:18	17:24	17:30	17:36	17:42	17:48	17:54
18	18:00	18:06	18:12	18:19	18:26	18:33	18:40	18:47	18:54	
19	19:01	19:08	19:15	19:22	19:29	19:37	19:44	19:52	19:59	
20	20:06	20:13	20:20	20:28	20:36	20:44	20:52			
21	21:00	21:08	21:16	21:24	21:32	21:40	21:50			
22	22:00	22:15	22:25	22:35	22:45					
23	23:00	23:15	23:35							

TABLE 5: Scheduled departures of bus line 608 from Zografou destined to Galatsi on May 13th, 2024

(Screenshot taken from OASA Telematics (2024))

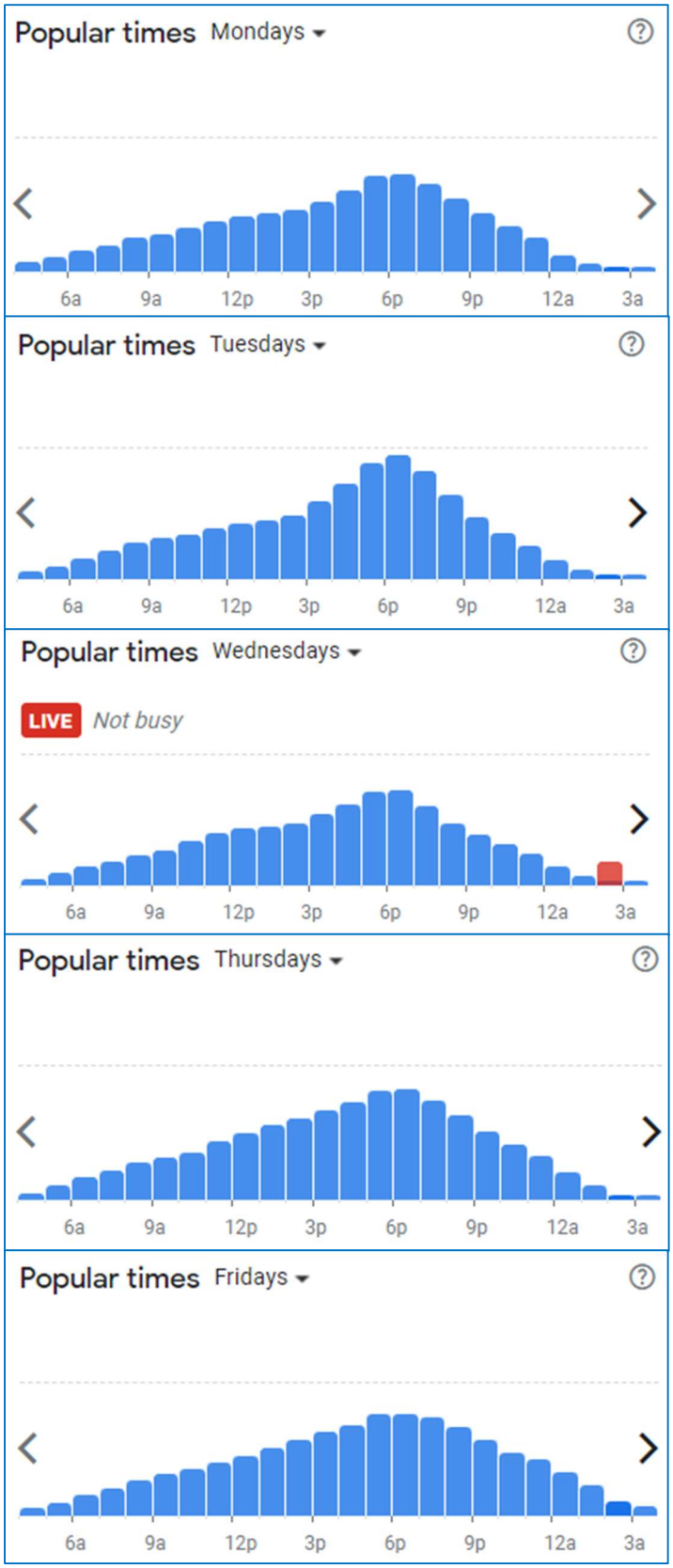
NO	TIME PERIOD	NAME	SPECIFIC PERIOD TO BE STUDIED
1	05:00-06:29	Early Morning	
2	06:30-09:29	Morning Peak	07:00-08:59
3	09:30-13:29	Morning Off-Peak	
4	13:30-17:29	Afternoon Peak	
5	17:30-19:29	Afternoon Off-Peak	17:30-19:29
6	19:30-21:59	Evening	
7	22:00-00:30	Late Evening	

TABLE 6: Weekday time periods of Athens PT services.
Time periods that were studied have been marked in yellow.

Table 6 shows that services start at low frequencies which gradually increase towards the start of the morning peak (second time period) when services operate at the highest frequency. The third time period follows with lower service frequencies but in any case, higher than these of the early morning. In the early afternoon, the afternoon peak starts with services operating at high frequencies comparable to these of the morning peak. The afternoon off-peak follows with service frequencies comparable to these of the morning off-peak. At 19:30 the evening time period starts with lower service frequencies than both off-peak time periods reflecting the decreasing number of trips as the end of the day approaches combined with the fact that the general closure time of retail shops is at 21:00 (Athens Development and Destination Management Agency, n.d.). The late evening time period is the final one reflecting on the considerably fewer trips with service frequencies comparable to these of the early morning.

Out of the aforementioned seven (7) time periods, two (2) hours in the morning peak and two (2) hours in the afternoon off-peak were selected to be studied. The morning peak was selected because it is the time period with the highest number of trips thus also when the highest levels of road traffic congestion are expected. The afternoon off-peak was selected because it is the time period that according to Glover (2000) and Walker (2023), shows the highest increase in the number of trips during the last decades, because of the increasing transportation needs to satisfy the social/recreation activities combined with the fact that the need for shopping trips to the city center is also satisfied during this time period. The direction of travel was from the suburbs to the city center since especially during the morning peak this is the direction of travel that has the most trips.

It is significant to mention that it was a matter of careful analysis whether to select the afternoon off-peak or the evening time period as the second time period to study. The afternoon off-peak period was ultimately selected because according to the "Popular Times" data for Syntagma metro station which are provided by "Google" (see Picture 12 on page 39), during the afternoon off-peak the station has more visits compared to the evening time period. Finally, it is important to mention that the importance of Syntagma Square for the shopping and social/recreation activities is underlined by the fact the station is more popular during the afternoon hours.



PICTURE 12: Visits to Syntagma metro station per day and time of the day

(Screenshots taken from "Google Maps" on May 2nd, 2024)

X. The Selection of the Area of Study and its Population

Following the selection of Syntagma Square as the destination point in the city center, it is essential to define the area of study and the origin points in the suburbs. To define the area, "QGIS" software was used (see Picture 13 on page 42). An "Open Street Map" of Athens was loaded and Syntagma Square was marked in dark red and around it a twenty-five-kilometer (25 km) radius was plotted and colored in light red.

This area includes the core of the suburbs of Athens and most distant suburbs to the west and the east including a total of seventy-five (75) suburbs (see Picture 14 on page 43). In order for an area to constitute a suburb for the purposes of this study, it needed to be defined as a Municipal Unit forming part of a Municipality according to the Greek law no 3852/2010 of local governance. The only exception was the suburb of Varympompi that had been only recently attached to the Municipal Unit of Acharnai but for the purposes of this study it constituted a standalone suburb because of its geographical position (Government Gazette of the Hellenic Republic, 2010).

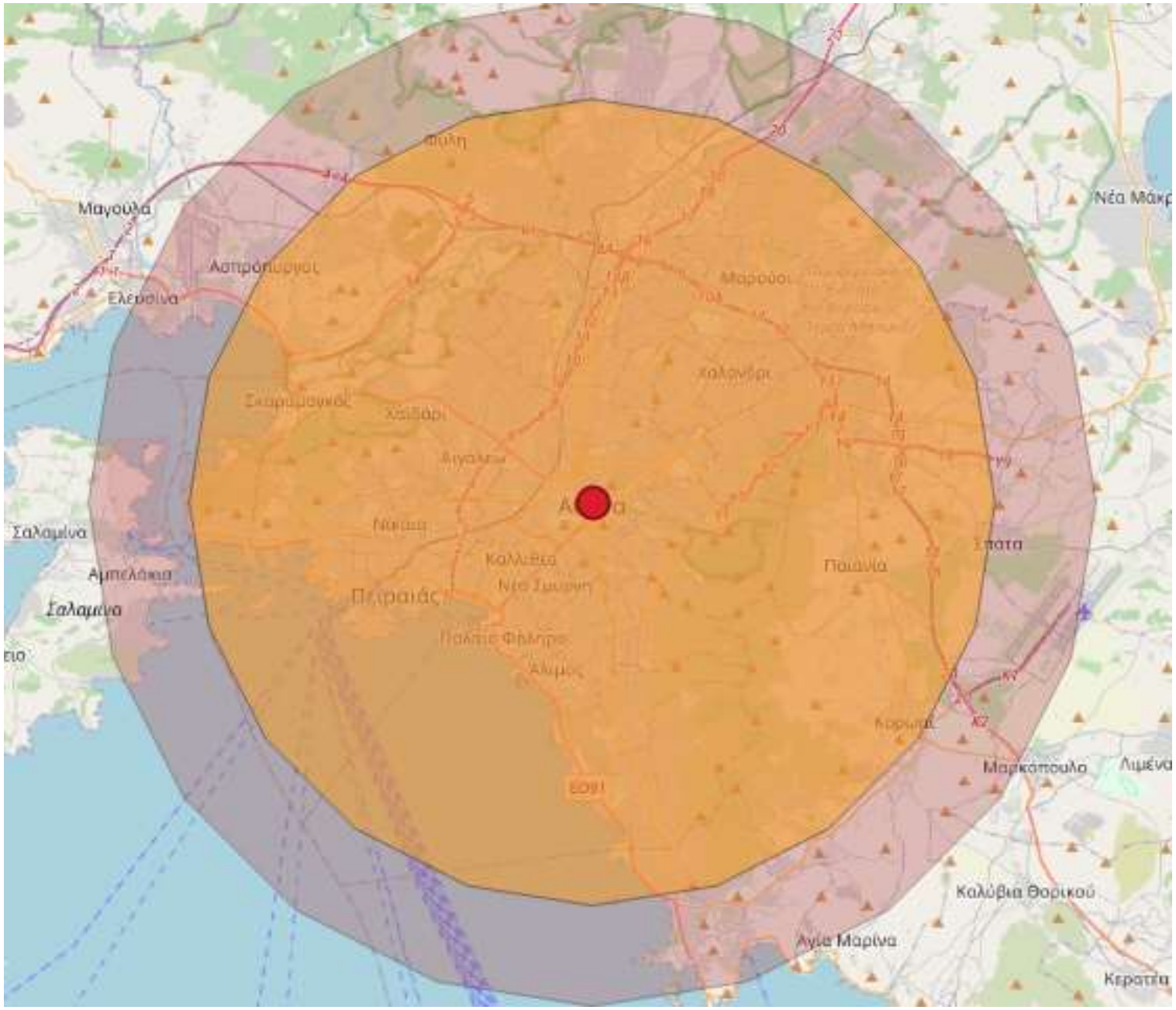
To the south, the area of study ends in the coastline and does not extend to the island of Salamina which is accessible only by ferry from the suburb of Perama. Ferries depart every fifteen (15) minutes from 06:00 to 22:00 thus the travel time for reaching Salamina by PT is directly related to the time that is required for reaching Perama (Perama-odigos, 2018).

It is worth mentioning that the initial plan was to plot a radius of twenty-kilometers (20 km) around Syntagma Square but this area would exclude several inhabited suburbs which are located by the sea and to the north along with "Athens International Airport" (AIA) in Spata.

To clearly comprehend the extent of the area, Table 7 (see pages 44-45) has been compiled reporting the population per suburb for years 2011 and 2021. The suburbs have been listed alphabetically. Suburb no 0 is the Municipality of Athens that includes the city center. The suburbs that were added as part of the area's extension from twenty-kilometers (20 km) to twenty-five-kilometers (25 km) are numbered separately and were included at the end of the list. The results of the censuses that were conducted in years 2011 and 2021 along with the change from year 2011 to year 2021 are presented in the table's columns.

Appendix Table A1 (see pages 83-84) presents the same data but suburbs are sorted by the largest percentage change in the population. It is worth noticing that most suburbs which were added as part of the area's extension are placed on the top of this list thus justifying the extension of the area of study.

From studying the data, it is concluded that the population of the area showed a slight decrease during the past decade of less than half percent (0.5%) on average with suburbs located closer to the city center showing the largest decreases, like Aigaleo and Peristeri while the largest increases were found in suburbs away from the city center like Thrakomakedones, Gerakas, and Voula.



PICTURE 13: Syntagma Square is marked in dark red, the 20-km radius is colored orange, and the 25-km radius is colored light red

(Picture created by the author in "QGIS")

PICTURE 14: The map of the area divided per suburb with the Suburb No

(Picture takes from the author's personal archive and edited by the author)

SUBURB NO	SUBURB	POPULATION 2011	POPULATION 2021	CHANGE	
0	ATHENS	664,046	643,452	(20,594)	-3.15%
1	Acharnai*	100,743	100,857	114	0.11%
2	Aghia Paraskevi	59,704	62,147	2,443	4.01%
3	Aghia Varvara	26,550	26,759	209	0.78%
4	Aghioi Anargyroi	34,168	32,283	(1,885)	-5.67%
5	Aghios Dimitrios	71,294	71,664	370	0.52%
6	Aghios Ioannis Rentis	16,050	15,411	(639)	-4.06%
7	Aigaleo	69,946	65,831	(4,115)	-6.06%
8	Alimos	41,720	43,174	1,454	3.43%
9	Ano Liosia	33,565	35,047	1,482	4.32%
10	Anthousa	2,132	2,158	26	1.21%
11	Argyroupoli	34,097	33,312	(785)	-2.33%
12	Aspropyrgos	30,251	31,381	1,130	3.67%
13	Chaidari	46,897	47,051	154	0.33%
14	Chalandri	74,192	77,102	2,910	3.85%
15	Cholargos	30,840	31,304	464	1.49%
16	Dafni	22,913	23,431	518	2.24%
17	Drapetsona	13,968	13,815	(153)	-1.10%
18	Elliniko	17,259	16,715	(544)	-3.20%
19	Filothei	7,302	7,370	68	0.93%
20	Fyli	2,946	3,209	263	8.55%
21	Galatsi	59,345	57,909	(1,436)	-2.45%
22	Gerakas	29,939	33,856	3,917	12.28%
23	Glyfada	87,305	89,597	2,292	2.59%
24	Glyka Nera	11,049	11,877	828	7.22%
25	Ilion	84,793	84,004	(789)	-0.93%
26	Ilioupoli	78,153	76,730	(1,423)	-1.84%
27	Irakleio	49,642	50,494	852	1.70%
28	Kaisariani	26,458	26,269	(189)	-0.72%
29	Kallithea	100,641	97,616	(3,025)	-3.05%
30	Kamatero	28,361	29,179	818	2.84%
31	Keratsini	77,077	75,721	(1,356)	-1.77%
32	Kifissia	47,332	48,700	1,368	2.85%
33	Koropi	30,307	30,817	510	1.67%
34	Korydallos	63,445	61,248	(2,197)	-3.52%
35	Lykovrysi	9,738	9,705	(33)	-0.34%
36	Marousi	72,333	71,830	(503)	-0.70%
37	Melissia	22,741	23,618	877	3.78%
38	Metamorfosi	29,891	30,174	283	0.94%
39	Moschato	25,441	25,322	(119)	-0.47%
40	Nea Chalkidona	9,822	9,760	(62)	-0.63%
41	Nea Erythraia	18,038	18,604	566	3.09%
42	Nea Filadelfeia	25,734	25,198	(536)	-2.10%
43	Nea Ionia	67,134	64,611	(2,523)	-3.83%
44	Nea Penteli	7,198	6,916	(282)	-4.00%
45	Nea Smyrni	73,076	72,853	(223)	-0.31%
46	Neo Psychiko	10,137	10,671	534	5.13%
47	Nikaia	89,380	88,077	(1,303)	-1.47%

SUBURB NO	SUBURB	POPULATION 2011	POPULATION 2021	CHANGE	
48	Paiania	15,619	16,159	540	3.40%
49	Palaio Faliro	64,021	64,863	842	1.31%
50	Pallini	22,344	23,445	1,101	4.81%
51	Papagou	13,699	13,962	263	1.90%
52	Pefki	21,415	21,293	(122)	-0.57%
53	Penteli	4,995	5,076	81	1.61%
54	Perama	25,389	25,628	239	0.94%
55	Peristeri	139,981	133,630	(6,351)	-4.64%
56	Petroupoli	58,979	60,146	1,167	1.96%
57	Piraeus	163,688	168,161	4,473	2.70%
58	Psychiko	9,529	9,595	66	0.69%
59	Spata	12,333	12,991	658	5.20%
60	Tavros	14,972	14,339	(633)	-4.32%
61	Voula	28,364	31,497	3,133	10.47%
62	Vrilissia	30,741	32,417	1,676	5.31%
63	Vyronas	61,308	59,134	(2,174)	-3.61%
64	Ymittos	10,715	10,455	(260)	-2.46%
65	Zefyri	9,454	9,901	447	4.62%
66	Zografou	71,026	69,874	(1,152)	-1.64%
67-25KM	Dionysos	6,458	7,021	563	8.35%
68-25KM	Drosia	7,186	7,837	651	8.67%
69-25KM	Ekali	5,889	5,574	(315)	-5.50%
70-25KM	Elefsina	24,910	24,971	61	0.24%
71-25KM	Pikermi	7,175	7,707	532	7.15%
72-25KM	Thrakomakedones	6,200	7,312	1,112	16.46%
73-25KM	Vari	15,855	16,717	862	5.29%
74-25KM	Varympompi*	N/A	N/A	N/A	N/A
75-25KM	Vouliagmeni	4,180	4,332	152	3.57%
TOTAL		**3,491,518**	**3,478,866**	**(12,652)**	**-0.36%**

*The population of Varympompi is included in the population of Acharnai

TABLE 7: List of the population per suburb within the area of study. The suburbs are sorted alphabetically while the nine (9) suburbs that were added as part of the extension of the area of study have been added in a separate alphabetical order.

XI. The Selection of the Origin Points in the Suburbs

After defining the area of study, it is purposeful to list the specific origin points that were used for collecting the data and the justification for selecting them. Furthermore, it is significant to mention that Tables 8-11 (see pages 48-54) include the same Point Numbers that have been used to compile the tables in Appendix B (see pages 85-105). This numbering is different to the numbering in the preceding Chapter X. Point no 1 is Syntagma Square.

For every suburb one (1) origin point was designated with the exception of the suburbs of Marousi and Peristeri which had two (2) origin points because of their larger extent thus giving a total of seventy-seven (77) origin points (see Table 8 on pages 48-51). The origin points that were added as a result of the extension of the area to a twenty-five-kilometer (25 km) radius are marked in light red color.

A second set of five (5) origin points which are key transportation nodes throughout the area was added including the AIA and the Piraeus seaport (see Table 9 on page 51).

Finally, it is important to indicate that the Municipality of Athens itself which includes Syntagma Square, extends to a large area and includes densely-populated neighborhoods which may be located even five kilometers (5 km) away from Syntagma Square like Patissia. For this purpose, eleven (11) more origin points were added as origins within the Municipality of Athens (see Table 10 on page 51).

To select the origin points for every suburb and neighborhood, a thorough examination of the buildings in each area was undertaken. Each origin point is within or close to the commercial area of a suburb or neighborhood where more demand for transportation is generated compared to the residential areas. To assess this, data from "Google Maps" about the buildings that host retail shops or cafeterias was used. In residential suburbs where no commercial area could be identified, a key point like a square or a grove was selected as origin points. All origin points are close to PT stops or are PT stops themselves. Finally, Table 11 (see pages 52-54) presents the coordinates of all points.

POINT NO	SUBURB	POINT	JUSTIFICATION
2	Acharnai	Acharnon Square	Central square of suburb and commercial area
3	Aghia Paraskevi	Aghia Paraskevi Square	On key Athenian Avenue, central square of suburb, and lowest point of commercial area
4	Aghia Varvara	Aghia Varvara Square	Key point of suburb and highest point of commercial area
5	Aghioi Anargyroi	Aghioi Anargyroi Square	On key Athenian Avenue, central square of suburb, and commercial area
6	Aghios Dimitrios	Athens Metro Mall	On key Athenian Avenue and largest shopping center in southern suburbs
7	Aghios Ioannis Rentis	Village Shopping Center	On intersection of three key Athenian Avenues and largest shopping center in western suburbs
8	Aigaleo	Eleftherias Square	On intersection of two key Athenian Avenues, commercial area, and near Baroutadiko Grove
9	Alimos	Kalamaki Beach	On key Athenian Avenue, beach, and commercial area
10	Ano Liosia	Iroon Square	Central square of suburb and commercial area
11	Anthousa	Anthousa Square	Central square of suburb
12	Argyroupoli	Iroon Polytechneiou Square	Central square of suburb and commercial area
13	Aspropyrgos	Dimarcheio Square	Central square of suburb and commercial area
14	Chaidari	Chaidari Memorial Park	Near key Athenian Avenue and highest point of commercial area
15	Chalandri	Chalandri Square	Central square of suburb and commercial area
16	Cholargos	Cholargos Metro Station	On key Athenian Avenue and commercial area
17	Dafni	Kolokotroni Square	On key Athenian Avenue and commercial area
18	Drapetsona	Aghios Fanourios Square	Central square of suburb and commercial area
19	Elliniko	Elliniko Metro Station	On key Athenian Avenue and lowest point of commercial area
20	Filothei	Drosopoulou Square	Key point of suburb
21	Fyli	Fyli Town Hall	Key point of suburb and commercial area
22	Galatsi	Galatsiou Avenue and Veikou Avenue Intersection	Key point of suburb and lowest point of commercial area
23	Gerakas	Gerakas Square	Near key Athenian Avenue, central square of suburb, and commercial area
24	Glyfada	Glyfada Square	On key Athenian Avenue, central square of suburb, commercial area, and near beaches
25	Glyka Nera	Lavriou Avenue and Korytsas Intersection	On key Athenian Avenue and commercial area

POINT NO	SUBURB	POINT	JUSTIFICATION
26	Ilion	Eleftherias Square	Commercial area
27	Ilioupoli	Ethnikis Antistaseos Square	Central square of suburb and commercial area
28	Irakleio	Irakleio Square	Central square of suburb and commercial area
29	Kaisariani	Aghios Nikolaos Square	Lowest point of commercial area
30	Kallithea	Davaki Square	On key Athenian Avenue and commercial area
31	Kamatero	Dimokratias Square	Central square of suburb and commercial area
32	Keratsini	Nikis Square	Near key Athenian Avenue and highest point of commercial area
33	Kifissia	Platanou Square	On key Athenian Avenue, commercial area, and Kifissia Grove
34	Koropi	Koropi Square	Central square of suburb and commercial area
35	Korydallos	Eleftherias Square	Central square of suburb and commercial area
36	Lykovrysi	Church of Aghia Varvara	On key Athenian Avenue and commercial area
37	Marousi I	Efterpis Square	Central square of suburb and commercial area
38	Marousi II	The Mall Athens	Largest shopping center in Athens
39	Melissia	Eleftheriou Venizelou and Panagi Tsaldari Intersection	Key point of suburb and lowest point of commercial area
40	Metamorfosi	Iroon Polytechneiou Square	Central square of suburb and commercial area
41	Moschato	Metamorfoseos Sotiros Square	Commercial area
42	Nea Chalkidona	Acharnon and Dekeleias Intersection	On key Athenian Avenue and lowest point of commercial area
43	Nea Erythraia	Eleftheriou Venizelou and Strofyliou Intersection	On key Athenian Avenue and commercial area
44	Nea Filadelfeia	Patriarchou Square	On key Athenian Avenue and commercial area
45	Nea Ionia	Nea Ionia Post Office	On key Athenian Avenue and commercial area
46	Nea Penteli	Iroon Polytechneiou Square	Central square of suburb and commercial area
47	Nea Smyrni	Nea Smyrni Square	Central square of suburb and commercial area
48	Neo Psychiko	Faros Psychikou	On key Athenian Avenue and commercial area
49	Nikaia	Laodikias and Gemelou Intersection	On key Athenian Avenue and commercial area
50	Paiania	Panagiotou Davari Square	Central square of suburb and commercial area

POINT NO	SUBURB	POINT	JUSTIFICATION
51	Palaio Faliro	Ethnikis Antistaseos Square	On key Athenian Avenue, beach, lowest point of commercial area, and near Flisvos Park and Marina
52	Pallini	Koimiseos Theotokou Church	On key Athenian Avenue and commercial area
53	Papagou	Papagou Grove	Key attraction of the suburb
54	Pefki	Sofokli Venizelou Square	On key Athenian Avenue and commercial area
55	Penteli	Charavgis Square	Central square of suburb and commercial area
56	Perama	Iroon Square	On key Athenian Avenue and commercial area
57	Peristeri I	Bournazi Square	Central square of suburb and commercial area
58	Peristeri II	Dimokratias Square	On key Athenian Avenue and commercial area
59	Petroupoli	Petroupoli Square	Key point of suburb and highest point of commercial area
60	Piraeus	Dimotiko Theatro Square	On key Athenian Avenue, central square of suburb, and commercial area
61	Psychiko	28is Oktovriou and Dafnis Intersection	Commercial area
62	Spata	Palaio Dimarcheio Square	Central square of suburb and commercial area
63	Tavros	Ethnikis Antistaseos Square	On key Athenian Avenue and commercial area
64	Voula	Aghios Ioannis Church	Key point of suburb and highest point of commercial area
65	Vrilissia	Analipseos Square	Central square of suburb and commercial area
66	Vyronas	Ethnikis Antistaseos Square	Commercial area
67	Ymittos	Ymittos Square	Central square of suburb and commercial area
68	Zefyri	Zefyri Park	Commercial area
69	Zografou	Iroon Square	Commercial area
70	Dionysos	Dionysou Avenue and Mitropolitou Kydonion Grigoriou Avenue Intersection	On key Athenian Avenue and key point of suburb
71	Drosia	Drosia Square	On key Athenian Avenue and commercial area
72	Ekali	Vasileos Pavlou Square	On key Athenian Avenue and central square of suburb
73	Elefsina	Elefsina Square	On key Athenian Avenue and commercial area
74	Pikermi	Aghios Christoforos Church	On key Athenian Avenue and commercial area
75	Thrakomakedones	Aristotelous Square	Central square of suburb

POINT NO	SUBURB	POINT	JUSTIFICATION
76	Vari	Isodia Theotokou Church	On key Athenian Avenue and commercial area
77	Varympompi	Varympompi Square	Central square of suburb
78	Vouliagmeni	Nymfon Square	On key Athenian Avenue, beach, and commercial area

TABLE 8: List of the origin points identified in each suburb.
The origin points that were added as a result
of the extension of the area are marked in light red color.

POINT NO	NODE	POINT	JUSTIFICATION
79	Athens International Airport	Departures Level	
80	Athens Train Station (Larissa Station)	Station Building	
81	Kifissos Bus Station	Station Building	
82	Liosion Bus Station	Station Building	
83	Piraeus seaport	Odissos Square	Almost equal walking distance from the edges of the port

TABLE 9: List of the origin points identified as transportation nodes

POINT NO	NEIGHBORHOOD	POINT	JUSTIFICATION
84	Girokomeio	Kifissias Avenue and Panormou Intersection	On key Athenian Avenue, hospitals, and commercial area
85	Gkizi	Argentine Republic Square	On key Athenian Avenue, hospitals, and commercial area
86	Goudi	Aghiou Thoma Square	Hospital and commercial area
87	Koukaki	Gargaretta Square	Near key Athenian Avenue and commercial area
88	Kypseli	Fokionos Negri and Ioannou Drosopoulou Intersection	Near key Athenian Avenue and lowest point of commercial area
89	Neos Kosmos	Neos Kosmos Metro Station	Commercial area
90	Pagkrati	Pagkrati Square	Commercial area and Pagkrati Park
91	Patissia	Ano Patissia Metro Station	On key Athenian Avenue, hospital, and highest point of commercial area
92	Petralona	Petralona Metro Station	Commercial area
93	Plateia Amerikis	Amerikis Square	On key Athenian Avenue and commercial area
94	Sepolia	Sepolia Metro Station	Commercial area

TABLE 10: List of the origin points identified in the Municipality of Athens

POINT NO	SUBURB / NODE / NEIGHBORHOOD	POINT	LATITUDE	LONGITUDE
1	Athens	Syntagma Square	37.9755606182858	23.7348883490646
2	Acharnai	Acharnon Square	38.0806969779182	23.7362570424136
3	Aghia Paraskevi	Aghia Paraskevi Square	38.0130761554146	23.8205470792514
4	Aghia Varvara	Aghia Varvara Square	37.9899480634912	23.6596341807851
5	Aghioi Anargyroi	Aghioi Anargyroi Square	38.0271479590500	23.7179710500258
6	Aghios Dimitrios	Athens Metro Mall	37.9394544465875	23.7400120218203
7	Aghios Ioannis Rentis	Village Shopping Center	37.9749071518255	23.6683635253032
8	Aigaleo	Eleftherias Square	37.9920997513302	23.6783065037067
9	Alimos	Kalamaki Beach	37.9091155183311	23.7129377287659
10	Ano Liosia	Iroon Square	38.0790285738350	23.7022839213530
11	Anthousa	Anthousa Square	38.0266152085335	23.8737226492514
12	Argyroupoli	Iroon Polytechneiou Square	37.9059807541903	23.7503849487210
13	Aspropyrgos	Dimarcheio Square	38.0617981515659	23.5891348498446
14	Chaidari	Chaidari Memorial Park	38.0028386896432	23.6633548889346
15	Chalandri	Chalandri Square	38.0218167396019	23.7978584885452
16	Cholargos	Cholargos Metro Station	38.0045552857723	23.7948279987189
17	Dafni	Kolokotroni Square	37.9498126344429	23.7373808041211
18	Drapetsona	Aghios Fanourios Square	37.9473729395801	23.6296255236876
19	Elliniko	Elliniko Metro Station	37.8921783293030	23.7472934244525
20	Filothei	Drosopoulou Square	38.0221569730674	23.7848912814113
21	Fyli	Fyli Town Hall	38.1027094518420	23.6695350475202
22	Galatsi	Galatsiou Avenue and Veikou Avenue Intersection	38.0130041691160	23.7530451033883
23	Gerakas	Gerakas Square	38.0092151078544	23.8579129592677
24	Glyfada	Glyfada Square	37.8639830071145	23.7467891572807
25	Glyka Nera	Lavriou Avenue and Korytsas Intersection	37.9874125510016	23.8505377675292
26	Ilion	Eleftherias Square	38.0320289628319	23.7078976464968
27	Ilioupoli	Ethnikis Antistaseos Square	37.9319483663717	23.7561463464906
28	Irakleio	Irakleio Square	38.0464243123579	23.7666883265848
29	Kaisariani	Aghios Nikolaos Square	37.9697799000072	23.7532484216368
30	Kallithea	Davaki Square	37.9557426672346	23.7031659652126
31	Kamatero	Dimokratias Square	38.0589890597865	23.7114946466691
32	Keratsini	Nikis Square	37.9706357766361	23.6218657689889
33	Kifissia	Platanou Square	38.0725233818595	23.8116655577613
34	Koropi	Koropi Square	37.9002925906107	23.8729624507255

POINT NO	SUBURB / NODE / NEIGHBORHOOD	POINT	LATITUDE	LONGITUDE
35	Korydallos	Eleftherias Square	37.9770854554514	23.6504579575201
36	Lykovrysi	Church of Aghia Varvara	38.0691872110394	23.7814662597735
37	Marousi I	Efterpis Square	38.0560769236877	23.8050530338333
38	Marousi II	The Mall Athens	38.0445921759931	23.7904729827071
39	Melissia	Eleftheriou Venizelou and Panagi Tsaldari Intersection	38.0518328442432	23.8387499677529
40	Metamorfosi	Iroon Polytechneiou Square	38.0616843082973	23.7611336529304
41	Moschato	Metamorfoseos Sotiros Square	37.9539076333040	23.6818578639832
42	Nea Chalkidona	Acharnon and Dekeleias Intersection	38.0262466819388	23.7314488243119
43	Nea Erythraia	Eleftheriou Venizelou and Strofyliou Intersection	38.0889814387277	23.8182921175796
44	Nea Filadelfeia	Patriarchou Square	38.0339994107170	23.7380392147203
45	Nea Ionia	Nea Ionia Post Office	38.0426730577949	23.7533048651108
46	Nea Penteli	Iroon Polytechneiou Square	38.0580024915533	23.8579791376698
47	Nea Smyrni	Nea Smyrni Square	37.9467569060369	23.7139816984885
48	Neo Psychiko	Faros Psychikou	38.0048739550131	23.7758216724447
49	Nikaia	Laodikias and Gemelou Intersection	37.9688751660902	23.6450266077577
50	Paiania	Panagiotou Davari Square	37.9542362486417	23.8532436441686
51	Palaio Faliro	Ethnikis Antistaseos Square	37.9256846499716	23.6915102378775
52	Pallini	Koimiseos Theotokou Church	38.0038845307859	23.8811739864809
53	Papagou	Papagou Grove	37.9934101079394	23.7936785641492
54	Pefki	Sofokli Venizelou Square	38.0589996862568	23.7926787768756
55	Penteli	Charavgis Square	38.0485339907336	23.8678652631243
56	Perama	Iroon Square	37.9643359970347	23.5687009622294
57	Peristeri I	Bournazi Square	38.0126992836085	23.7065974114613
58	Peristeri II	Dimokratias Square	38.0128623899075	23.6954244293464
59	Petroupoli	Petroupoli Square	38.0424819642885	23.6837492677015
60	Piraeus	Dimotiko Theatro Square	37.9429445714656	23.6476338482153
61	Psychiko	28is Oktovriou and Dafnis Intersection	38.0055230546907	23.7667303356122
62	Spata	Palaio Dimarcheio Square	37.9619449128584	23.9143027082876
63	Tavros	Ethnikis Antistaseos Square	37.9681096186832	23.6952535345774
64	Voula	Aghios Ioannis Church	37.8414681232284	23.7658431304246
65	Vrilissia	Analipseos Square	38.0362994938110	23.8272418800697
66	Vyronas	Ethnikis Antistaseos Square	37.9598473223260	23.7528593235135
67	Ymittos	Ymittos Square	37.9548312700229	23.7462320910016
68	Zefyri	Zefyri Park	38.0653762230143	23.7152525461202
69	Zografou	Iroon Square	37.9782565770504	23.7689362424672

POINT NO	SUBURB / NODE / NEIGHBORHOOD	POINT	LATITUDE	LONGITUDE
70	Dionysos	Dionysou Avenue and Mitropolitou Kydonion Grigoriou Avenue Intersection	38.1017792103233	23.8833857116582
71	Drosia	Drosia Square	38.1204990918822	23.8586304386480
72	Ekali	Vasileos Pavlou Square	38.1103641173750	23.8418608770479
73	Elefsina	Elefsina Square	38.0431395323765	23.5418765686406
74	Pikermi	Aghios Christoforos Church	38.0018822348041	23.9411591126166
75	Thrakomakedones	Aristotelous Square	38.1296739187192	23.7574765087933
76	Vari	Isodia Theotokou Church	37.8331318841491	23.8026933297566
77	Varympompi	Varympompi Square	38.1299805359336	23.7893879879795
78	Vouliagmeni	Nymfon Square	37.8129638338954	23.7828822422099
79	Athens International Airport	Departures Level	37.9360180284240	23.9470649065501
80	Athens Train Station (Larissa Station)	Station Building	37.9925778185292	23.7205309974592
81	Kifissos Bus Station	Station Building	37.9976310173687	23.6990684387432
82	Liosion Bus Station	Station Building	38.0100490743543	23.7225058680524
83	Piraeus seaport	Odissos Square	37.9477474654814	23.6432315582766
84	Girokomeio	Kifissias Avenue and Panormou Intersection	37.9930231893286	23.7666040266040
85	Gkizi	Argentine Republic Square	37.9894048371987	23.7441392579990
86	Goudi	Aghiou Thoma Square	37.9823743025368	23.7648901738199
87	Koukaki	Gargaretta Square	37.9658906623658	23.7252914944345
88	Kypseli	Fokionos Negri and Ioannou Drosopoulou Intersection	38.0008371147923	23.7348838989178
89	Neos Kosmos	Neos Kosmos Metro Station	37.9575815630983	23.7283830780127
90	Pagkrati	Pagkrati Square	37.9676531218278	23.7472003689791
91	Patissia	Ano Patissia Metro Station	38.0236584978915	23.7361619012093
92	Petralona	Petralona Metro Station	37.9684517109686	23.7089073942471
93	Plateia Amerikis	Amerikis Square	38.0024539359957	23.7336040498021
94	Sepolia	Sepolia Metro Station	38.0026067390361	23.7140461823631

TABLE 11: List of the coordinates of all points

XII. The Results of the Research

The results of the travel times from each origin point to Syntagma Square were compiled to four (4) tables, one for each time period (see Annex C on pages 107-131). Data from these tables was used to compile Appendix Tables B1-B7 (see pages 85-105). Each line presents the results of the travel times from an origin point to Syntagma Square. All results are presented in minutes and the Standard Deviation results have been rounded.

The grey color on the column of a table denotes that the values on this column have been sorted from highest-to-lowest or lowest-to-highest along with the rest of the data on the line. The columns that are colored light red present the results of year 2015 and those that are colored light blue present the results of year 2024. The green-colored columns present the differences between the data of multiple columns as denoted in the title of the column. Positive differences are written in black and negative differences in red. The contents of each table are presented below:

- Appendix Table B1 (see pages 85-87) presents the results of the research sorted by the number of the point along with the Maximum and Minimum travel times for every time period of each year and the Standard Deviation. The green-colored columns indicate the difference between the two (2) time periods of the same year.
- Appendix Table B2 (see pages 88-90) presents the results sorted by the number of the point but the green-colored columns indicate the difference between years 2015 and 2024 for the same time period indicating if the travel time has improved by year 2024.
- Appendix Table B3 (see pages 91-93) is a variation of Table B2 presenting the results sorted by the highest improvement in the Minimum travel time for each origin point during the morning peak compared to year 2015.
- Appendix Table B4 (see pages 94-96) is also a variation of Table B2 presenting the results sorted by the highest Standard Deviation in the travel time for each origin point during the morning peak for year 2024.
- Appendix Table B5 (see pages 97-99) presents the results of the morning peak for both years combined with the rounded distance in km and the distance traveled per minute in km for the Minimum travel time for both years. The results are sorted by the longest distance traveled in km per minute for year 2024 and these values have been rounded to four (4) decimal places. The difference compared to year 2015 is also presented in the green-colored column combined with the last column which indicates the existence of a metro station at the maximum walking distance of fifteen (15) minutes.
- Appendix Table B6 (see pages 100-102) is a variation of Table B5 presenting the results sorted by the longest distance in km.
- Appendix Table B7 (see pages 103-105) is also a variation of Table B5 presenting the results sorted by the highest improvement in the distance traveled in km per minute for the Minimum travel time compared to year 2015.

XIII. Discussion of the Results

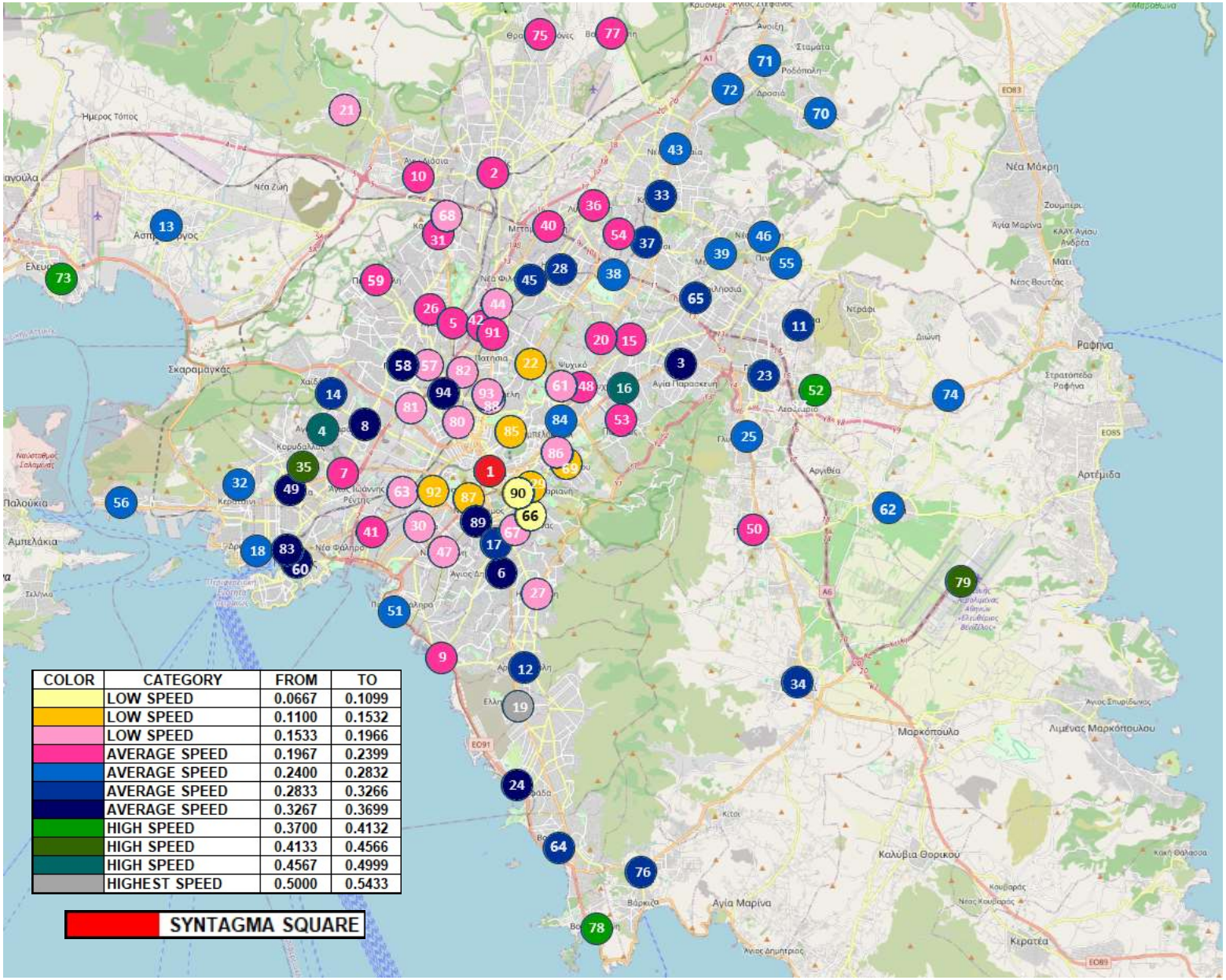
The below findings were identified regarding PTTTV in Athens after analyzing the tables of the results. Picture 15 (see page 58) was created by the author in "QGIS" and it displays the positions of the origin points on map along with their point no. The average distance traveled per km has been categorized to eleven (11) distinct ranges each associated to a different color. The categories have been further grouped as Low speed, Average speed, High speed, and Highest speed.

The first finding from the analysis of Appendix Table B1 (see pages 85-87) was that on average the Maximum travel times during the afternoon off-peak for both years were slightly longer than the ones of the morning peak, but still the difference was insignificant of just one (1) minute. The Minimum travel times remained the same on average with a difference of zero (0) minutes for both years. This is a first indication that there are no significant differences between the two (2) time periods for both years.

Specifically, the differences in the Maximum travel times for year 2015 for the majority of origin points had none to only marginal differences. The highest was of twelve (12) minutes for the suburb of Nea Erythraia (point no 43) indicating that during the afternoon off-peak it would take twelve (12) more minutes to reach Syntagma Square compared to the morning peak. Interestingly, for twelve (12) origin points the results indicated that it would need less time to reach Syntagma Square (point no 1) during the afternoon off-peak compared to the morning peak. The highest gain was of seven (7) minutes for the suburb of Pallini (point no 52) indicating that during the afternoon off-peak it would take seven (7) minutes less to reach Syntagma Square compared to the morning peak.

In year 2024 there were more suburbs that showed differences. The highest was that of forty (40) minutes for the suburb of Varympompi (point no 77) while the highest gain was of forty-seven (47) minutes for the suburb of Fyli (point no 21). It is important to mention that both Varympompi and Fyli are remote suburbs in Northwest Attica, each of which is served by a bus line that connects with another bus line to reach the city center. These large differences have been both attributed to the low frequency of bus services since especially the suburb of Varympompi, according to the timetable for May 13th 2024 with data being extracted from "Google Transit", was served by one to two (1-2) buses per hour.

The second finding that was derived from the analysis of Appendix Table B2 (see pages 88-90) was that the Maximum travel times for the majority of origin points during both time periods had decreased by year 2024 compared to year 2015. Specifically, they decreased on average by one (1) minute during the morning peak and by two (2) minutes during the afternoon off-peak. During the morning peak, four (4) origin points showed decreases of more than twenty (20) minutes, and five (5) of ten to nineteen (10-19) minutes, while during the afternoon off-peak four (4) origin



PICTURE 15: Map showing all origin points displaying their point no and colored according to the distance traveled per km for year 2024 for the Minimum travel time during the morning peak

(Picture created by the author in "QGIS")

points showed decreases of more than twenty (20) minutes, and eight (8) of ten to nineteen (10-19) minutes.

The highest decrease during the morning peak was for the suburb of Korydallos (point no 35) by twenty-eight (28) minutes that was attributed to the introduction of a new metro station in the suburb in year 2020, and during the afternoon off-peak for the suburb of Paiania (point no 50) by twenty-seven (27) minutes that was attributed to increased frequencies of bus services. The highest increase during the morning peak was for the suburb of Fyli by fifty-two (52) minutes, and during the afternoon off-peak for the suburb of Varympompi by fifty-seven (57) minutes. They were both attributed to the low frequency of bus services (OASA Telematics, 2024).

The third finding that was derived from examining Appendix Table B3 (see pages 91-93) was that the suburbs which gained new metro stations showed considerable decreases in the Minimum travel times during peak times, like Aghia Varvara (point no 4) and Nikaia (point no 49) of eighteen (18) minutes, Korydallos of twenty-three (23) minutes, and Piraeus (point no 60) of fourteen (14) minutes.

Suburbs that are located close to these metro stations but did not gain a metro station themselves had also showed decreases, like Keratsini (point no 32) of fifteen (15) minutes, Perama (point no 56) of eleven (11) minutes, Aghios Ioannis Rentis (point no 7) of seven (7) minutes, and Drapetsona (point no 18) of six (6) minutes. These suburbs were benefited by their bus lines operating as feeders to the new metro stations. This finding underlines the positive impact of the construction of the new metro stations.

A detailed analysis of the third finding led to the fourth finding by examining the differences of Appendix Tables B3-B4 (see pages 91-96) with regards to the Minimum travel times for suburbs which had metro stations in year 2015, and by year 2024 they had benefited from more frequent metro services. Specifically, suburbs like Cholargos (point no 16) and Ilioupoli (point no 27) showed decreases of nine (9) minutes, Argyropouli (point no 12) and Elliniko (point no 19) of eight (8) minutes.

At this point it is also important to note that although compared to year 2015 the frequency of metro services decreased in the core sections of most lines, as it has been presented in Chapter VII, it had increased in the outer sections in order to satisfy the increasing demand from the suburbs (information taken from the author's personal archive). An example is the Aghios Dimitrios-Elliniko section of metro line 2 (red) where services increased from eight-minute intervals to four-and-a-half-minute intervals.

Moreover, suburbs which were served by bus lines that operate as feeders to metro stations had benefited indirectly from the aforementioned increased frequencies like Glyfada (point no 24) and Vouliagmeni (point no 78) by fifteen (15) minutes, and Papagou (point no 53) by nine (9) minutes. These findings further

underline the impact that an increase in the service frequency of a metro service or of a PT service in general may have to the accessibility of an area.

The fifth finding that was noticeable by analyzing Appendix Table B3 (see pages 91-93), was that in the area of Meshogheia many suburbs seemed to have benefited from an increase in the frequency of bus services with decreased Minimum travel times during the morning peak like: Glyka Nera (point no 25) by twenty-three (23) minutes, Koropi (point no 34) and Paiania (point no 50) by twenty (20) minutes, Anthousa (point no 11) by thirteen (13) minutes, and Spata (point no 62) by nine (9) minutes.

Finally, it is remarkable that during the morning peak of year 2024 only four (4) origin points showed increases in the Minimum travel time compared to year 2015. The increases ranged from three to six (3-6) minutes while all of them were remote suburbs that were served only by buses. The increases were attributed to either frequent road traffic congestions that led to longer trip times or a decrease in the service frequency of bus services.

The sixth finding that was derived from examining Appendix Table B4 (see pages 94-96) was that PTTTV was indeed higher in remote suburbs which were served by low frequency services. For example, Varympompi and Fyli for year 2024 showed a very high Standard Deviation during the morning peak of nineteen to twenty (19-20) minutes. Specifically, for Fyli it decreased significantly during the afternoon off-peak to eight (8) minutes while for Varympompi it increased to thirty-three (33) minutes. This was attributed to the fact that the service frequency was very low thus the time period of two (2) hours was not enough to provide with a holistic picture of the PTTTV for these specific suburbs (OASA Telematics, 2024).

The seventh finding that was evident by analyzing Appendix Tables B5-B6 (see pages 97-102) was that out of the nine (9) distant suburbs that were added as part of the extension of the area of study to twenty-five (25) km, all but (2) suburbs had Minimum travel times which were very competitive compared to the travel times of origin points closer to the city center.

To reach Syntagma Square from the suburb of Vouliagmeni (point no 78), which is located nineteen (19) km away, with a travel time of fifty (50) minutes, the distance traveled per minute was three-hundred-and-eighty meters (0.38 km). To reach Syntagma Square from the neighborhood of Pagkrati (point no 90) which is located only two (2) km away, the distance traveled per minute was only seventy meters (0.07 km) while the travel time was just fifteen (15) minutes.

Furthermore, out of all fifteen (15) origin points with a distance of less than or equal to three (3) km away from Syntagma Square, thirteen (13) were ranked below the average in terms of the distance traveled per minute with the exceptions of Neos Kosmos (point no 89) and Dafni (point no 17). This variation was attributed to the

fact that roads are more congested near the city center than in the outer suburbs thus causing a reduction to the speed of buses and trolleybuses.

A further important note is that these distances are straight-line distances while PT routes operate around mountains or serve other areas first because of their route design thus making deviations. An interesting example is that of the origin points of Elliniko (point no 19) and Piraeus seaport (point no 83). Both origin points are located nine (9) km away from Syntagma Square (point no 1) but the distance traveled per minute from Elliniko was five-hundred meters (0.50 km) for eighteen (18) minutes, and from Piraeus seaport it was three-hundred-and-sixty meters (0.36 km) for twenty-five (25) minutes. Each origin point offers connection to Syntagma Square by a single metro line and while the metro line 2 (red) travels from Elliniko in almost a straight line, line 3 (blue) that serves Piraeus seaport goes through a west curve to reach Syntagma Square from the west instead of the south (see Picture 9 on page 30).

This was also important for some suburbs in the area of Meshogheia like Koropi (point no 34), Spata (point no 62), and Paiania (point no 50) which although they are located to the east, all the PT routes that serve them travel around Mount Hymettus. First, they travel to the northwest to reach the northern edge of the mountain and then to the south to reach each suburb.

Picture 15 (see page 58) shows clearly that the Lowest speeds were valid for origin points closer to the city center than the origin points categorized in Average and High speeds. The points that are colored dark blue, thus in the upper level of the Average speeds, depict in some cases the trails of the three (3) metro lines on the map which indicates the benefit that the metro lines have provided to these suburbs. The High and Highest speeds were mostly valid for origin points away from the city center like AIA. This can be also justified by the fact that these origin points were connected to highways that offered the chance of bus services operating at a high speed and then passengers connected to a metro line to reach the city center. Examples include the distant suburbs of Elefsina (point no 73) in the west and Vouliagmeni (point no 78) in the south.

The eighth finding that was evident after analyzing Appendix Table B7 (see pages 103-105) was that the distance traveled per minute had improved in year 2024 for eighty-nine (89) origin points compared to year 2015. The average improvement was of sixty meters (0.06 km). Out of the four (4) origin points that showed reductions in the distance traveled per minute, the worse was for the suburb of Acharnai (point no 2) with a reduction of thirty meters (0.30 km). The reductions ranged from ten to thirty meters (0.10-0.30 km).

The highest improvement was for the suburb of Korydallos (point no 35) at two-hundred-and-sixty meters (0.26 km) per minute followed by the suburb of Aghia Varvara (point no 4) at two-hundred-and-fifty meters (0.25 km) per minute. The improvement is attributed to the introduction of metro stations in both suburbs in year 2020.

The ninth finding concerned the remarkable results of the origin point of AIA (point no 79). According to Appendix Table B7 (see pages 103-105), the distance traveled per minute for year 2015 was two-hundred-and-ninety meters (0.29 km) and it improved significantly by year 2024 at four-hundred-and-thirty meters (0.43 km). A logical explanation would be that either the means of transportation changed or that the service frequency improved significantly.

Even though the specific means of transportation are not revealed by the results of the router software, it was assumed that the metro is the means that provided the faster option of traveling to Syntagma Square because of its high service frequency. The metro service to AIA was introduced in year 2004 operating at intervals of every thirty (30) minutes. Since year 2022 this has been reduced to intervals of every thirty-six (36) minutes (STASY S.A., n.d.).

This reduction would lead to the conclusion that the Maximum travel time would have increased by year 2024 while the Minimum travel time normally would have remained unchanged. On the contrary, the Minimum travel time during the morning peak decreased from sixty-six (66) minutes to forty-four (44) minutes showing a great improvement.

According to the company that operates the metro system, the trip from AIA to Syntagma Square lasts for thirty-eight (38) minutes which was in line with the aforementioned forty-four (44) minutes of Minimum travel time (ibid.). Regarding the results of year 2015, the logical explanation would be that they did not take into account the metro trips to AIA and only the bus lines that served AIA. An analysis of the GTFS file for year 2015 revealed that it contained the metro services to AIA thus the assumption that was made was that as it has been reported in Chapter III, the router software used the median values of the next ten (10) minutes thus affecting the calculation of the actual Minimum and Maximum travel times.

XIV. Conclusions

After the analysis of the results of the research, it is purposeful to attempt to answer the research questions that were presented in Chapter IV. Every question is presented below followed by the answer that has been formulated as the result of the research.

1. *Are the Maximum and Minimum travel times and the Standard Deviation different for each time period? Do they change?*

   According to the Appendix Table B1 (see pages 85-87), the average Maximum travel times for year 2015 ranged from fifty-one to fifty-three (51-53) minutes, and for year 2024 from fifty to fifty-one (50-51) minutes.

   The average Minimum travel time for year 2015 stood for both time periods at forty-two (42) minutes and for year 2024 at thirty-four (34) minutes.

   Finally, the Standard Deviation for year 2015 stood for both time periods at three (3) minutes and for year 2024 at four (4) minutes.

   When comparing values of the same year for different time periods, it is evident that the difference was small or non-existent.

   When comparing values of the same time period for different years, it is evident that apart from the significant improvement of the Minimum travel times in year 2024, the rest of the differences were insignificant or non-existent. This leads to the conclusion that with the exception of the improved Minimum travel times by year 2024, all other values are not different when compared to the other year or the other time period.

   a. *Is the PTTTV during each time period comparably equal for all suburbs?*

      According to the first finding, it is evaluated that the PTTTV was comparable equal for all suburbs considering that the average Standard Deviation for year 2024 stood at only four (4) minutes for both time periods. During the morning peak the Standard Deviation ranged from one to twenty (1-20) minutes and during the afternoon off-peak from one to thirty-three (1-33) minutes. This justifies the fact that during the afternoon off-peak services are less frequent compared to the morning peak.

      Even though the Standard Deviation per suburb can be quite high, even at thirty-three (33) minutes, the average Standard Deviation has been considered as a justifiable metric to evaluate the situation in the whole area of study.

b. *Which differences in the travel times and the PTTTV from year 2015 to year 2024 are significant and why?*

Since the highest decreases occurred in the Minimum travel times, the below differences in the morning peak were marked as significant:

According to the fifth finding, the decreases in several suburbs which are situated in the area of Meshogheia, like Glyka Nera (point no 25), Koropi (point no 34), Paiania (point no 50), Anthousa (point no 11), and Spata (point no 62). Since no new metro stations had been constructed in Meshogheia, the improvement was attributed to higher frequencies of bus services. Furthermore, all of these suburbs showed an increase in their population at the census of year 2021 compared to that of year 2011 thus further justifying an improvement of the bus services as a purposeful action.

Moreover, according to the second and third findings, the suburbs that gained new metro stations or the ones that benefited from having bus lines that operate as feeders to the new stations, showed significant decreases in their Minimum travel times. The differences are presented in question 1c.

c. *Has the opening of new metro stations in years 2020 and 2022 changed the travel times and the PTTTV for some suburbs between years 2015 and 2024?*

According to the second and third findings, the below improvements have occurred to the Minimum travel time during the morning peak of the suburbs that gained new metro stations:

- Aghia Varvara (point no 4) by eighteen (18) minutes,
- Korydallos (point no 35) by twenty-three (23) minutes,
- Nikaia (point no 49) by eighteen (18) minutes, and
- Piraeus (point no 60) by fourteen (14) minutes.

Regarding the PTTTV, all these suburbs showed a decrease in their Standard Deviation by one (1) minute with the exception of Aghia Varvara, for which it remained unchanged. The distance traveled per minute in km also improved according to the eighth finding.

Furthermore, the below suburbs benefited from the opening of the new stations in nearby suburbs:

- Aghios Ioannis Rentis (point no 7) by seven (7) minutes,
- Keratsini (point no 32) by fifteen (15) minutes,
- Drapetsona (point no 18) by six (6) minutes, and
- Perama (point no 56) by eleven (11) minutes.

Regarding the PTTTV, all these suburbs showed an increase in their Standard Deviation by one (1) minute with the exception of Drapetsona that showed a decrease of one (1) minute. This was attributed to the fact that these suburbs are served by bus and trolleybus lines.

Consequently, it is evaluated that the new metro stations have led to a significant change in the travel times and to a minimal change in the PTTTV.

d. *Have the budget cuts affected the travel times and the PTTTV between years 2015 and 2024?*

The budget cuts did not seem to have drastically affected the travel times and the PTTTV for the nine-year period that was under study. The fact that the Minimum travel times showed significant improvements, justifies the data of Chapter VII where it is shown that service frequencies for some services had slightly increased compared to year 2015. This is opposite to the fact the vehicle-kilometers as they were reported by OASA had decreased significantly. It can be assumed that the cuts have affected most services during the evening and not during the morning peak or the afternoon off-peak. It is also assumed that if the data of year 2024 was compared to data of year 2009, the changes in the service frequencies would be significantly larger.

2. *Do the specific means of transportation (buses, metro, trolleybuses, and trams) that serve each suburb affect the PTTTV? How? Have the means of transportation for a specific trip changed from year 2015 to year 2024?*

The router software did not provide information on which specific PT means were included at each result. Judging from the reduction in the travel time for the suburbs that gained new metro stations, the travel means for traveling from these suburbs to Syntagma Square must have changed with regards to using only the metro service and not a combination of metro and bus services. This change refers to the suburbs of Aghia Varvara (point no 4), Korydallos (point no 35), Nikaia (point no 49), and Piraeus (point no 60).

a. *Do routes share parts of the same PT services like for example the same metro line? Is there any relation to the PTTTV?*

An essential comparison that can be made is between origin points that are located close to metro stations which are served by the two (2) metro lines (2-red and 3-blue) that also serve Syntagma Square.

The western branch of the line 3 (blue) serves successively the stations of Aghia Varvara, Korydallos, and Piraeus seaport (point no 83) where the respective origin points are also located. A further characteristic is that the

three (3) stations opened in years 2020 and 2022 thus making a comparison with year 2015 possible. In year 2024 all three (3) points had the same Standard Deviation of one (1) minute for both time periods while each had a different Standard Deviation in year 2015. This highlights a connection between PTTTV and a PT service that serves multiple points. This has been also visually depicted in Picture 15 (see page 58) where the trail of metro line 3 (blue) in the western suburbs is formed by the origin points that share similar distances traveled per km.

3. *Can any relation be identified by comparing the differences in the travel times and the PTTTV between the two (2) different datasets to the change of the population of each suburb by using data from the censuses of years 2011 and 2021?*

The comparison that was made, was for suburbs that had a population increase of more than eight percent (8%) in the 2021 census compared to the 2011 census. The results of the censuses were presented in Chapter X.

- Thrakomakedones with approximately a sixteen percent (16%) population increase had a higher than the average increase in the travel times for year 2024 while the Standard Deviation decreased but it still remained above the average.
- Gerakas with approximately a twelve percent (12%) population increase had a decrease in the travel times equal to the average but the Standard Deviation increased though it still remained below or equal to the average.
- Voula with approximately a ten percent (10%) population increase had a decrease in the travel times equal to the average but the Standard Deviation increased and continued to remain above the average.
- Drosia with approximately a nine percent (9%) population increase had a decrease in the travel times equal or higher to the average with the exception of the Maximum travel times during the morning peak but the Standard Deviation increased and continued to remain above the average.
- Fyli with approximately a nine percent (9%) population increase had an increase in the travel times during the morning peak and a marginal decrease during the off-peak period though still below the average. Subsequently, the Standard Deviation greatly increased during the morning peak and marginally decreased during the afternoon off-peak and continued to remain above the average.
- Dionysos with approximately an eight (8%) population increase had a decrease in the travel times equal or higher to the average with the exception of the Maximum travel times during the morning peak.

Subsequently the Standard Deviation increased during the morning peak and marginally decreased during the afternoon off-peak but continued to remain above the average.

The aforementioned changes show that most suburbs had a decrease in the travel times, which considering the fact that all of them are remote could be explained by an increase in the block times of their respective PT services. The fact that the Standard Deviation mostly increased leads to the conclusion that the frequency of services must had remained unchanged or that it changed only slightly. Consequently, it is evaluated that the censuses did not have any significant impact to the choice of the network design. This could be further attributed to the fact that these suburbs are remote and their inhabitants could use their private vehicles to satisfy their transportation needs.

Interestingly, as it was discussed in question 1b, the suburbs of Glyka Nera, Koropi, Paiania, Anthousa, and Spata in the area of Meshogheia seemed to have had changes that were in line with a change in the population but they all had increases of less than eight percent (8%). A possible explanation could also be the fact the OASA, as it was mentioned in Chapter III, assigned the operation of the bus lines that serve these suburbs to new operators which might have led to the compilation of an improved timetable.

4. *Is the PT system's design assessed to be effective in providing all its potential users with an as equal as possible chance to participate in the activities that create the need for transportation? Have any corrective actions that can be taken to minimize the effects of PTTTV in the current situation, before the construction of the metro system is completed, be identified?*

It is evaluated that the PT system of Athens in general provides its users with an as equal as possible chance to participate in the activities that create the need for transportation with regards to accessing the city center. PTTTV when measured as Standard Deviation remains low thus the PT system is evaluated as effective. Despite this, suburbs which are served by metro lines are more "privileged" because their commuters enjoy higher distances traveled per minute, especially because of its distinct right-of-way and high frequency of services, as it has been also mentioned in literature and as it has been presented by the seventh finding.

First, because of the metro system, the PT system is also a driver of economic growth as it has been proved by the selection of the origin point in the suburb of Cholargos that was Cholargos metro station itself. The station opened in year 2010 and around it a commercial area has been developed as the research for choosing an origin point in Cholargos proved. This is also

supported by the literature review which revealed that a metro station can also create new demand. Furthermore, the increase in the frequency of the metro services after some years according to the fourth finding supports the existence of such unexploited opportunities that after their exploitation lead to an increase in demand.

In fact, the parameter where most differences occurred is the travel times. Suburbs with metro stations have more competitive travel times compared to suburbs that do not. On Appendix Table B5 (see pages 97-99), it is shown that forty-one (41) points had a metro station at a walking distance of fifteen minutes. Twenty-three (23) of them had an above-the-average distance traveled per minute and eighteen (18) below-the-average.

Second, this proves the fact that metro stations can significantly reduce the travel times to the suburbs they serve and also positively affect the travel times to other suburbs when bus lines operate as feeders to the metro stations. It is expected that after the construction of the metro system is completed, the Minimum travel times will be further lowered for the whole area of study while PTTTV will be also lowered further as this study has proven thus increasing the attractiveness of the PT system.

The impact of bus, trolleybus, and tram lines is less significant as it has been proven that higher service frequencies can reduce PTTTV but when compared to the other suburbs that are served by the metro system, their disadvantage in speed is evident.

This disadvantage leads to the crucial question of which actions can be taken to improve the current situation before the completion of the construction of the metro system. It also needs to be underlined that metro stations operate as local hubs in parallel with others PT means thus creating a single PT system. Even after the completion of the construction of the metro system, buses will be in most cases the last-mile PT means that will be able to penetrate the neighborhoods and “feed” the metro system.

First, real-time information needs to be provided to reduce PTTTV and transform uncertainty to certainty by reducing the lost customer hours drastically as it is mentioned in literature. Currently only buses and trolleybuses have empowered travelers to travel as such and it is vital for the metro system and the tram lines to be also included (OASA Telematics, 2024). This ITS solution can also reduce crowding which is a major factor that leads the traveling public to avoid PT services as it has been also found in literature.

This change will be a vital driver in restoring the share of PT in the modal split to the level it had before the Greek Financial Crisis that started in year 2010. It can also increase the accessibility to jobs as it has been proven in literature since increased reliability leads to an increase in the accessibility to jobs.

Second, it would be ideal if cuts could be reversed because as table of PT service levels of HIT has shown, services that operate on intervals equal to or higher than twenty-one (21) minutes are unattractive to the traveling public because of the long WTs. Especially considering that the suburbs of Thrakomakedones and Fyli that have had high population increases are served by bus lines with low services frequencies as shown by the sixth finding, services on these suburbs could be evaluated as inadequate. This finding makes the investment in more frequent bus services crucial in order for the whole area of study to be benefited proportionally with better PT service levels.

It could be argued that the decreases in the service frequencies of some PT services since year 2009 may have been caused by a reduction in their patronage. If this is true for some cases, it should be studied if it would be purposeful to make targeted increases in the PT offering to encourage the modal switch and achieve the target of sustainable mobility.

A point that requires attention is according to the literature review, the significant increase of the demand during the off-peak hours during the last decades and OASA needs to ensure that PT services will be sufficient to cater for this demand.

Third, the introduction of BRT lines should also be considered as an interim measure before the construction of the metro system is completed. On avenues without metro stations, like Kifissias Avenue, the distinct right-of-way could lead to a significant improvement in the travel time and the reduction in the PTTTV. This would benefit the suburbs of Filothei, Psychiko, and Neo Psychiko significantly. Especially the suburb of Neo Psychiko (point no 48), hosts many corporate offices on Kifissias Avenue which have many commuters daily.

Alternatively, an easy and more cost-effective measure would be the introduction of the express bus services on key avenues to reduce the travel time between the two ends of an avenue. As the literature has proven, this is already applied in other cities and even Athens has just an express bus line on Kifissias Avenue, namely bus line E14 (OASA Telematics, 2024). Other avenues without metro stations could be also served by express bus services.

Finally, the ”smoothing” of the peak can be an effective measure as it was found in literature. It can be effective for the suburb of Zografou which hosts the campuses of two Athenian universities. The campuses are currently served by the most frequent bus lines, like line 608, and a “moving” time of start and end of the classes would help to reduce crowding on these bus lines.

XV. Limitations to the Research

During the course of this study, the below limitations were identified:

According to Braga et al. (2023) and Nichols et al. (2024), using GTFS data just to analyze scheduled services and not the actual operation of the timetable for evaluating the accessibility to a place, like the city center of Athens, can lead to an over or underestimation of accessibility by a significant amount. This can indeed cause a bias in case the operation of the timetable differs greatly from the planned timetable. For the purpose of this study, the target was to evaluate the planners' network design through the planned PTTTV to establish if the system was effective thus the impact of this bias on this research is judged to be minimal.

An additional limitation is a bias regarding the results of the research. The Maximum and Minimum travel times have been calculated and the Standard Deviation was used as an indicator of the PTTTV for each origin point. These results have been used to assess the effectiveness of the PT system design based on comparisons between the routes from every origin point. The PTTTV may show to be low for such comparisons but the actual services may be highly crowded. It can be argued that crowding refers to the assessment of the efficiency of the PT system, but the evolution of the results of this research, which could be assessing metrics like crowding, could prove if the PT services are indeed effective with regards to offering adequate capacity to satisfy demand. For example, if all PT services are crowded then despite the low PTTTV, the PT system cannot attract more passengers. The effects of this bias to the study cannot be evaluated since no patronage data has been used.

A further limitation was the lack of recent data about the need for transportation in Athens. OASA used to conduct a large-scale research every ten (10) years. The latest was conducted in year 2005 and after nineteen (19) years it is outdated. The research that was scheduled to be conducted in year 2015 was not conducted because of budget cuts and currently in year 2024 research is being conducted but no preliminary results have been released. If the data of year 2015 was available, it would have been possible to analyze the effects of the Greek Financial Crisis on the need for transportation combined with the effects of the budget cuts in the PT system of Athens.

A final bias refers to the ninth finding of the research regarding the PT services of AIA. Since the research's findings did not reveal the specific reasons of these peculiar results, it can be assumed that such peculiar results may also be present in the results of other origin points and may have influenced the result towards showing that an improvement has occurred by year 2024. The extent of the effects of this bias cannot be evaluated.

XVI. Proposals for future Research

As it was mentioned in Chapter XV, an evolution would be to use primary data to measure the crowding of the PT services to better assess the effectiveness of the design of the PT system. This could also provide with a solid basis for the evaluation by OASA of the design of the PT system.

Moreover, research on the Minimum and Maximum travel times and the PTTTV for year 2009 before the budget cuts occurred and the comparison to the present-day situation would help to better assess the effects of the service cuts and if they have caused any changes to the traveling habits of the traveling public.

A final research proposal is the regular assessment of the PTTTV using the results of this study as a comparison to assess any future changes and mainly the effects by the introduction of new metro stations. The results could be used to assess the possible effects of the construction of a metro system in larger cities in Africa or Asia which are not served by a metro system and their population size would justify its construction.

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XVIII. Appendices

Appendix A:

SUBURB NO	SUBURB	POPULATION 2011	POPULATION 2021	CHANGE	
72-25KM	Thrakomakedones	6,200	7,312	1,112	16.46%
22	Gerakas	29,939	33,856	3,917	12.28%
61	Voula	28,364	31,497	3,133	10.47%
68-25KM	Drosia	7,186	7,837	651	8.67%
20	Fyli	2,946	3,209	263	8.55%
67-25KM	Dionysos	6,458	7,021	563	8.35%
24	Glyka Nera	11,049	11,877	828	7.22%
71-25KM	Pikermi	7,175	7,707	532	7.15%
62	Vrilissia	30,741	32,417	1,676	5.31%
73-25KM	Vari	15,855	16,717	862	5.29%
59	Spata	12,333	12,991	658	5.20%
46	Neo Psychiko	10,137	10,671	534	5.13%
50	Pallini	22,344	23,445	1,101	4.81%
65	Zefyri	9,454	9,901	447	4.62%
9	Ano Liosia	33,565	35,047	1,482	4.32%
2	Aghia Paraskevi	59,704	62,147	2,443	4.01%
14	Chalandri	74,192	77,102	2,910	3.85%
37	Melissia	22,741	23,618	877	3.78%
12	Aspropyrgos	30,251	31,381	1,130	3.67%
75-25KM	Vouliagmeni	4,180	4,332	152	3.57%
8	Alimos	41,720	43,174	1,454	3.43%
48	Paiania	15,619	16,159	540	3.40%
41	Nea Erythraia	18,038	18,604	566	3.09%
32	Kifissia	47,332	48,700	1,368	2.85%
30	Kamatero	28,361	29,179	818	2.84%
57	Piraeus	163,688	168,161	4,473	2.70%
23	Glyfada	87,305	89,597	2,292	2.59%
16	Dafni	22,913	23,431	518	2.24%
56	Petroupoli	58,979	60,146	1,167	1.96%
51	Papagou	13,699	13,962	263	1.90%
27	Irakleio	49,642	50,494	852	1.70%
33	Koropi	30,307	30,817	510	1.67%
53	Penteli	4,995	5,076	81	1.61%
15	Cholargos	30,840	31,304	464	1.49%
49	Palaio Faliro	64,021	64,863	842	1.31%
10	Anthousa	2,132	2,158	26	1.21%
38	Metamorfosi	29,891	30,174	283	0.94%
54	Perama	25,389	25,628	239	0.94%
19	Filothei	7,302	7,370	68	0.93%
3	Aghia Varvara	26,550	26,759	209	0.78%
58	Psychiko	9,529	9,595	66	0.69%
5	Aghios Dimitrios	71,294	71,664	370	0.52%
13	Chaidari	46,897	47,051	154	0.33%
70-25KM	Elefsina	24,910	24,971	61	0.24%

SUBURB NO	SUBURB	POPULATION 2011	POPULATION 2021	CHANGE	
1	Acharnai*	100,743	100,857	114	0.11%
45	Nea Smyrni	73,076	72,853	(223)	-0.31%
35	Lykovrysi	9,738	9,705	(33)	-0.34%
39	Moschato	25,441	25,322	(119)	-0.47%
52	Pefki	21,415	21,293	(122)	-0.57%
40	Nea Chalkidona	9,822	9,760	(62)	-0.63%
36	Marousi	72,333	71,830	(503)	-0.70%
28	Kaisariani	26,458	26,269	(189)	-0.72%
25	Ilion	84,793	84,004	(789)	-0.93%
17	Drapetsona	13,968	13,815	(153)	-1.10%
47	Nikaia	89,380	88,077	(1,303)	-1.47%
66	Zografou	71,026	69,874	(1,152)	-1.64%
31	Keratsini	77,077	75,721	(1,356)	-1.77%
26	Ilioupoli	78,153	76,730	(1,423)	-1.84%
42	Nea Filadelfeia	25,734	25,198	(536)	-2.10%
11	Argyroupoli	34,097	33,312	(785)	-2.33%
21	Galatsi	59,345	57,909	(1,436)	-2.45%
64	Ymittos	10,715	10,455	(260)	-2.46%
29	Kallithea	100,641	97,616	(3,025)	-3.05%
0	ATHENS	664,046	643,452	(20,594)	-3.15%
18	Elliniko	17,259	16,715	(544)	-3.20%
34	Korydallos	63,445	61,248	(2,197)	-3.52%
63	Vyronas	61,308	59,134	(2,174)	-3.61%
43	Nea Ionia	67,134	64,611	(2,523)	-3.83%
44	Nea Penteli	7,198	6,916	(282)	-4.00%
6	Aghios Ioannis Rentis	16,050	15,411	(639)	-4.06%
60	Tavros	14,972	14,339	(633)	-4.32%
55	Peristeri	139,981	133,630	(6,351)	-4.64%
69-25KM	Ekali	5,889	5,574	(315)	-5.50%
4	Aghioi Anargyroi	34,168	32,283	(1,885)	-5.67%
7	Aigaleo	69,946	65,831	(4,115)	-6.06%
74-25KM	Varympompi*	N/A	N/A	N/A	N/A
TOTAL		**3,491,518**	**3,478,866**	**(12,652)**	**-0.36%**

*The population of Varympompi is included in the population of Acharnai

APPENDIX TABLE A1:

List of the population per suburb within the area of study. The suburbs are sorted by the largest percentage change between years 2011 and 2021.

Appendix B:

		MONDAY, OCTOBER 5TH 2015						MONDAY, MAY 13TH 2024						DIFFERENCES OFF-PEAK vs. PEAK			
		MORNING PEAK			AFTERNOON OFF-PEAK			MORNING PEAK			AFTERNOON OFF-PEAK			2015		2024	
	From Point	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	Acharnai	62	50	3	66	51	4	70	56	3	71	54	4	4	1	1	(2)
3	Aghia Paraskevi	36	31	1	37	32	1	34	25	2	36	25	3	1	1	2	0
4	Aghia Varvara	38	33	1	39	33	2	20	15	1	24	15	2	1	0	4	0
5	Aghioi Anargyroi	40	32	2	39	34	1	43	28	3	41	29	2	(1)	2	(2)	1
6	Aghios Dimitrios	23	22	0	23	22	0	17	12	1	17	12	1	0	0	0	0
7	Aghios Ioannis Rentis	44	35	2	45	35	3	42	28	3	47	29	4	1	0	5	1
8	Aigaleo	22	21	0	22	21	0	20	15	1	25	15	2	0	0	5	0
9	Alimos	50	44	1	51	44	2	52	37	3	50	36	3	1	0	(2)	(1)
10	Ano Liosia	76	66	2	79	64	4	83	60	5	79	56	5	3	(2)	(4)	(4)
11	Anthousa	85	54	9	83	56	9	87	41	11	83	42	10	(2)	2	(4)	1
12	Argyroupoli	39	35	1	40	35	1	32	27	1	32	27	1	1	0	0	0
13	Aspropyrgos	81	65	5	83	63	7	75	57	4	72	52	5	2	(2)	(3)	(5)
14	Chaidari	32	27	1	32	28	1	27	22	1	31	22	2	0	1	4	0
15	Chalandri	46	40	2	46	40	2	46	34	3	48	32	3	0	0	2	(2)
16	Cholargos	23	22	0	23	23	0	18	13	1	20	13	2	0	1	2	0
17	Dafni	18	17	0	18	17	0	14	10	1	14	10	1	0	0	0	0
18	Drapetsona	52	44	2	54	45	3	44	38	1	48	37	2	2	1	4	(1)
19	Elliniko	29	26	1	30	27	1	23	18	1	23	18	1	1	1	0	0
20	Filothei	46	42	1	47	41	1	48	34	3	51	37	3	1	(1)	3	3
21	Fyli	104	78	7	110	76	10	156	83	19	109	75	8	6	(2)	(47)	(8)
22	Galatsi	46	38	2	45	39	2	52	35	4	52	37	4	(1)	1	0	2
23	Gerakas	51	42	2	52	45	2	52	35	4	50	37	3	1	3	(2)	2
24	Glyfada	60	50	3	64	50	4	59	35	6	51	34	4	4	0	(8)	(1)
25	Glyka Nera	81	61	5	85	57	7	57	38	5	60	38	5	4	(4)	3	0
26	Ilion	43	35	2	41	36	2	48	31	4	47	31	4	(2)	1	(1)	0
27	Ilioupoli	42	36	1	43	37	2	31	27	1	31	27	1	1	1	0	0
28	Irakleio	37	34	1	38	34	1	42	28	3	38	28	2	1	0	(4)	0
29	Kaisariani	25	23	1	28	24	1	24	17	1	27	17	2	3	1	3	0
30	Kallithea	31	27	1	33	28	1	34	24	2	35	25	2	2	1	1	1
31	Kamatero	67	50	5	68	51	5	64	44	4	63	47	4	1	1	(1)	3
32	Keratsini	62	52	2	65	52	3	50	37	3	53	37	4	3	0	3	0

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
33	Kifissia	56	53	1	57	53	1	58	44	3	54	44	2	1	0	(4)	0
34	Koropi	98	68	8	92	68	8	89	48	11	95	52	10	(6)	0	6	4
35	Korydallos	49	39	2	51	39	3	21	16	1	25	16	2	2	0	4	0
36	Lykovrysi	66	55	3	69	59	3	72	54	4	73	54	4	3	4	1	0
37	Marousi I	43	40	1	44	40	1	49	35	3	45	35	2	1	0	(4)	0
38	Marousi II	44	41	1	45	41	1	48	34	3	44	34	2	1	0	(4)	0
39	Melissia	65	50	4	68	54	5	68	46	5	77	47	7	3	4	9	1
40	Metamorfosi	63	50	4	67	53	4	65	47	4	81	52	7	4	3	16	5
41	Moschato	32	29	1	33	29	1	31	22	2	35	21	3	1	0	4	(1)
42	Nea Chalkidona	35	30	1	37	32	2	41	29	3	39	29	2	2	2	(2)	0
43	Nea Erythraia	68	61	2	80	61	5	74	55	4	74	54	4	12	0	0	(1)
44	Nea Filadelfeia	40	33	2	41	35	2	43	32	2	42	32	2	1	2	(1)	0
45	Nea Ionia	42	39	1	45	39	2	42	28	3	38	28	2	3	0	(4)	0
46	Nea Penteli	73	58	5	77	59	5	73	53	5	78	52	6	4	1	5	(1)
47	Nea Smyrni	26	23	1	26	23	1	30	22	2	34	22	3	0	0	4	0
48	Neo Psychiko	33	30	1	35	29	1	35	24	2	34	25	2	2	(1)	(1)	1
49	Nikaia	52	42	2	54	43	3	28	24	1	33	24	2	2	1	5	0
50	Paiania	90	70	7	99	69	10	70	50	5	72	51	5	9	(1)	2	1
51	Palaio Faliro	44	37	2	48	35	4	45	25	5	46	27	5	4	(2)	1	2
52	Pallini	66	43	5	59	43	4	60	35	5	60	36	5	(7)	0	0	1
53	Papagou	41	36	2	41	37	1	33	27	1	35	28	2	0	1	2	1
54	Pefki	60	52	2	61	52	2	66	47	3	62	48	3	1	0	(4)	1
55	Penteli	76	63	4	87	66	5	76	51	6	85	50	7	11	3	9	(1)
56	Perama	74	64	2	73	65	2	65	53	3	74	53	4	(1)	1	9	0
57	Peristeri I	36	29	2	37	31	2	30	26	1	31	26	1	1	2	1	0
58	Peristeri II	23	22	0	23	23	0	19	14	1	20	15	1	0	1	1	1
59	Petroupoli	54	48	2	57	50	2	60	38	5	61	40	5	3	2	1	2
60	Piraeus	44	37	2	45	38	2	27	23	1	32	23	2	1	1	5	0
61	Psychiko	38	29	2	40	32	3	39	23	3	38	25	3	2	3	(1)	2
62	Spata	84	71	4	85	70	4	83	62	5	78	59	5	1	(1)	(5)	(3)
63	Tavros	40	34	1	42	32	2	41	24	4	43	25	4	2	(2)	2	1
64	Voula	76	56	5	74	58	5	71	49	6	70	50	4	(2)	2	(1)	1
65	Vrilissia	57	42	5	58	45	4	59	37	5	72	36	8	1	3	13	(1)
66	Vyronas	31	25	2	32	25	2	35	22	3	35	22	3	1	0	0	0
67	Ymittos	30	25	2	30	24	2	28	16	2	28	19	2	0	(1)	0	3
68	Zefyri	70	52	5	71	53	5	67	51	4	65	48	4	1	1	(2)	(3)
69	Zografou	29	26	1	30	26	1	29	21	2	28	20	2	1	0	(1)	(1)

	From Point	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
70	Dionysos	110	89	7	112	87	8	127	78	12	104	77	6	2	(2)	(23)	(1)
71	Drosia	98	79	5	98	78	6	107	72	8	95	60	7	0	(1)	(12)	(12)
72	Ekali	89	74	3	93	73	6	88	66	5	88	65	5	4	(1)	0	(1)
73	Elefsina	72	64	3	78	59	5	66	48	5	68	46	5	6	(5)	2	(2)
74	Pikermi	95	70	7	94	69	7	102	67	8	97	64	7	(1)	(1)	(5)	(3)
75	Thrakomakedones	103	81	6	112	78	9	107	84	5	111	84	6	9	(3)	4	0
76	Vari	79	52	8	78	54	8	73	55	4	77	58	4	(1)	2	4	3
77	Varympompi	142	87	17	142	88	18	159	83	20	199	85	33	0	1	40	2
78	Vouliagmeni	88	65	6	86	65	6	76	50	7	72	51	5	(2)	0	(4)	1
79	Athens International Airport	86	66	7	82	66	6	79	44	10	79	44	11	(4)	0	0	0
80	Athens Railway Station	18	17	0	18	18	0	16	11	1	17	12	1	0	1	1	1
81	Kifissos Bus Station	39	36	1	40	39	0	32	23	2	36	26	2	1	3	4	3
82	Liosion Bus Station	29	25	1	30	26	1	34	23	2	34	25	2	1	1	0	2
83	Piraeus seaport	31	28	1	32	28	1	30	25	1	35	26	2	1	0	5	1
84	Girokomeio	19	18	0	19	19	0	17	12	1	19	12	2	0	1	2	0
85	Gkizi	25	22	1	28	23	1	27	16	2	30	18	2	3	1	3	2
86	Goudi	29	26	1	29	26	1	26	19	2	27	19	2	0	0	1	0
87	Koukaki	14	13	0	14	13	0	13	8	1	13	8	1	0	0	0	0
88	Kypseli	29	25	1	30	26	1	30	19	2	30	21	2	1	1	0	2
89	Neos Kosmos	14	13	0	14	13	0	11	6	1	11	6	1	0	0	0	0
90	Pagkrati	21	16	1	22	17	1	25	15	2	25	15	2	1	1	0	0
91	Patissia	28	25	1	29	25	1	35	21	3	31	21	2	1	0	(4)	0
92	Petralona	20	17	1	21	17	1	25	16	2	28	15	3	1	0	3	(1)
93	Plateia Amerikis	26	23	1	28	24	1	26	18	2	32	19	3	2	1	6	1
94	Sepolia	17	16	0	17	17	0	16	11	1	17	12	1	0	1	1	1
AVERAGE		**51**	**42**	**3**	**53**	**42**	**3**	**50**	**34**	**4**	**51**	**34**	**4**	**1**	**0**	**1**	**0**

APPENDIX TABLE B1: List of the results of the research also indicating the difference between the two time periods for each year

		MONDAY, OCTOBER 5TH 2015						MONDAY, MAY 13TH 2024						DIFFERENCES 2024 vs. 2015			
		MORNING PEAK			AFTERNOON OFF-PEAK			MORNING PEAK			AFTERNOON OFF-PEAK			MORNING PEAK		AFTERNOON OFF-PEAK	
	From Point	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	Acharnai	62	50	3	66	51	4	70	56	3	71	54	4	8	6	5	3
3	Aghia Paraskevi	36	31	1	37	32	1	34	25	2	36	25	3	(2)	(6)	(1)	(7)
4	Aghia Varvara	38	33	1	39	33	2	20	15	1	24	15	2	(18)	(18)	(15)	(18)
5	Aghioi Anargyroi	40	32	2	39	34	1	43	28	3	41	29	2	3	(4)	2	(5)
6	Aghios Dimitrios	23	22	0	23	22	0	17	12	1	17	12	1	(6)	(10)	(6)	(10)
7	Aghios Ioannis Rentis	44	35	2	45	35	3	42	28	3	47	29	4	(2)	(7)	2	(6)
8	Aigaleo	22	21	0	22	21	0	20	15	1	25	15	2	(2)	(6)	3	(6)
9	Alimos	50	44	1	51	44	2	52	37	3	50	36	3	2	(7)	(1)	(8)
10	Ano Liosia	76	66	2	79	64	4	83	60	5	79	56	5	7	(6)	0	(8)
11	Anthousa	85	54	9	83	56	9	87	41	11	83	42	10	2	(13)	0	(14)
12	Argyroupoli	39	35	1	40	35	1	32	27	1	32	27	1	(7)	(8)	(8)	(8)
13	Aspropyrgos	81	65	5	83	63	7	75	57	4	72	52	5	(6)	(8)	(11)	(11)
14	Chaidari	32	27	1	32	28	1	27	22	1	31	22	2	(5)	(5)	(1)	(6)
15	Chalandri	46	40	2	46	40	2	46	34	3	48	32	3	0	(6)	2	(8)
16	Cholargos	23	22	0	23	23	0	18	13	1	20	13	2	(5)	(9)	(3)	(10)
17	Dafni	18	17	0	18	17	0	14	10	1	14	10	1	(4)	(7)	(4)	(7)
18	Drapetsona	52	44	2	54	45	3	44	38	1	48	37	2	(8)	(6)	(6)	(8)
19	Elliniko	29	26	1	30	27	1	23	18	1	23	18	1	(6)	(8)	(7)	(9)
20	Filothei	46	42	1	47	41	1	48	34	3	51	37	3	2	(8)	4	(4)
21	Fyli	104	78	7	110	76	10	156	83	19	109	75	8	52	5	(1)	(1)
22	Galatsi	46	38	2	45	39	2	52	35	4	52	37	4	6	(3)	7	(2)
23	Gerakas	51	42	2	52	45	2	52	35	4	50	37	3	1	(7)	(2)	(8)
24	Glyfada	60	50	3	64	50	4	59	35	6	51	34	4	(1)	(15)	(13)	(16)
25	Glyka Nera	81	61	5	85	57	7	57	38	5	60	38	5	(24)	(23)	(25)	(19)
26	Ilion	43	35	2	41	36	2	48	31	4	47	31	4	5	(4)	6	(5)
27	Ilioupoli	42	36	1	43	37	2	31	27	1	31	27	1	(11)	(9)	(12)	(10)
28	Irakleio	37	34	1	38	34	1	42	28	3	38	28	2	5	(6)	0	(6)
29	Kaisariani	25	23	1	28	24	1	24	17	1	27	17	2	(1)	(6)	(1)	(7)
30	Kallithea	31	27	1	33	28	1	34	24	2	35	25	2	3	(3)	2	(3)
31	Kamatero	67	50	5	68	51	5	64	44	4	63	47	4	(3)	(6)	(5)	(4)
32	Keratsini	62	52	2	65	52	3	50	37	3	53	37	4	(12)	(15)	(12)	(15)
33	Kifissia	56	53	1	57	53	1	58	44	3	54	44	2	2	(9)	(3)	(9)

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
34	Koropi	98	68	8	92	68	8	89	48	11	95	52	10	(9)	(20)	3	(16)
35	Korydallos	49	39	2	51	39	3	21	16	1	25	16	2	(28)	(23)	(26)	(23)
36	Lykovrysi	66	55	3	69	59	3	72	54	4	73	54	4	6	(1)	4	(5)
37	Marousi I	43	40	1	44	40	1	49	35	3	45	35	2	6	(5)	1	(5)
38	Marousi II	44	41	1	45	41	1	48	34	3	44	34	2	4	(7)	(1)	(7)
39	Melissia	65	50	4	68	54	5	68	46	5	77	47	7	3	(4)	9	(7)
40	Metamorfosi	63	50	4	67	53	4	65	47	4	81	52	7	2	(3)	14	(1)
41	Moschato	32	29	1	33	29	1	31	22	2	35	21	3	(1)	(7)	2	(8)
42	Nea Chalkidona	35	30	1	37	32	2	41	29	3	39	29	2	6	(1)	2	(3)
43	Nea Erythraia	68	61	2	80	61	5	74	55	4	74	54	4	6	(6)	(6)	(7)
44	Nea Filadelfeia	40	33	2	41	35	2	43	32	2	42	32	2	3	(1)	1	(3)
45	Nea Ionia	42	39	1	45	39	2	42	28	3	38	28	2	0	(11)	(7)	(11)
46	Nea Penteli	73	58	5	77	59	5	73	53	5	78	52	6	0	(5)	1	(7)
47	Nea Smyrni	26	23	1	26	23	1	30	22	2	34	22	3	4	(1)	8	(1)
48	Neo Psychiko	33	30	1	35	29	1	35	24	2	34	25	2	2	(6)	(1)	(4)
49	Nikaia	52	42	2	54	43	3	28	24	1	33	24	2	(24)	(18)	(21)	(19)
50	Paiania	90	70	7	99	69	10	70	50	5	72	51	5	(20)	(20)	(27)	(18)
51	Palaio Faliro	44	37	2	48	35	4	45	25	5	46	27	5	1	(12)	(2)	(8)
52	Pallini	66	43	5	59	43	4	60	35	5	60	36	5	(6)	(8)	1	(7)
53	Papagou	41	36	2	41	37	1	33	27	1	35	28	2	(8)	(9)	(6)	(9)
54	Pefki	60	52	2	61	52	2	66	47	3	62	48	3	6	(5)	1	(4)
55	Penteli	76	63	4	87	66	5	76	51	6	85	50	7	0	(12)	(2)	(16)
56	Perama	74	64	2	73	65	2	65	53	3	74	53	4	(9)	(11)	1	(12)
57	Peristeri I	36	29	2	37	31	2	30	26	1	31	26	1	(6)	(3)	(6)	(5)
58	Peristeri II	23	22	0	23	23	0	19	14	1	20	15	1	(4)	(8)	(3)	(8)
59	Petroupoli	54	48	2	57	50	2	60	38	5	61	40	5	6	(10)	4	(10)
60	Piraeus	44	37	2	45	38	2	27	23	1	32	23	2	(17)	(14)	(13)	(15)
61	Psychiko	38	29	2	40	32	3	39	23	3	38	25	3	1	(6)	(2)	(7)
62	Spata	84	71	4	85	70	4	83	62	5	78	59	5	(1)	(9)	(7)	(11)
63	Tavros	40	34	1	42	32	2	41	24	4	43	25	4	1	(10)	1	(7)
64	Voula	76	56	5	74	58	5	71	49	6	70	50	4	(5)	(7)	(4)	(8)
65	Vrilissia	57	42	5	58	45	4	59	37	5	72	36	8	2	(5)	14	(9)
66	Vyronas	31	25	2	32	25	2	35	22	3	35	22	3	4	(3)	3	(3)
67	Ymittos	30	25	2	30	24	2	28	16	2	28	19	2	(2)	(9)	(2)	(5)
68	Zefyri	70	52	5	71	53	5	67	51	4	65	48	4	(3)	(1)	(6)	(5)
69	Zografou	29	26	1	30	26	1	29	21	2	28	20	2	0	(5)	(2)	(6)
70	Dionysos	110	89	7	112	87	8	127	78	12	104	77	6	17	(11)	(8)	(10)

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
71	Drosia	98	79	5	98	78	6	107	72	8	95	60	7	9	(7)	(3)	(18)
72	Ekali	89	74	3	93	73	6	88	66	5	88	65	5	(1)	(8)	(5)	(8)
73	Elefsina	72	64	3	78	59	5	66	48	5	68	46	5	(6)	(16)	(10)	(13)
74	Pikermi	95	70	7	94	69	7	102	67	8	97	64	7	7	(3)	3	(5)
75	Thrakomakedones	103	81	6	112	78	9	107	84	5	111	84	6	4	3	(1)	6
76	Vari	79	52	8	78	54	8	73	55	4	77	58	4	(6)	3	(1)	4
77	Varympompi	142	87	17	142	88	18	159	83	20	199	85	33	17	(4)	57	(3)
78	Vouliagmeni	88	65	6	86	65	6	76	50	7	72	51	5	(12)	(15)	(14)	(14)
79	Athens International Airport	86	66	7	82	66	6	79	44	10	79	44	11	(7)	(22)	(3)	(22)
80	Athens Railway Station	18	17	0	18	18	0	16	11	1	17	12	1	(2)	(6)	(1)	(6)
81	Kifissos Bus Station	39	36	1	40	39	0	32	23	2	36	26	2	(7)	(13)	(4)	(13)
82	Liosion Bus Station	29	25	1	30	26	1	34	23	2	34	25	2	5	(2)	4	(1)
83	Piraeus seaport	31	28	1	32	28	1	30	25	1	35	26	2	(1)	(3)	3	(2)
84	Girokomeio	19	18	0	19	19	0	17	12	1	19	12	2	(2)	(6)	0	(7)
85	Gkizi	25	22	1	28	23	1	27	16	2	30	18	2	2	(6)	2	(5)
86	Goudi	29	26	1	29	26	1	26	19	2	27	19	2	(3)	(7)	(2)	(7)
87	Koukaki	14	13	0	14	13	0	13	8	1	13	8	1	(1)	(5)	(1)	(5)
88	Kypseli	29	25	1	30	26	1	30	19	2	30	21	2	1	(6)	0	(5)
89	Neos Kosmos	14	13	0	14	13	0	11	6	1	11	6	1	(3)	(7)	(3)	(7)
90	Pagkrati	21	16	1	22	17	1	25	15	2	25	15	2	4	(1)	3	(2)
91	Patissia	28	25	1	29	25	1	35	21	3	31	21	2	7	(4)	2	(4)
92	Petralona	20	17	1	21	17	1	25	16	2	28	15	3	5	(1)	7	(2)
93	Plateia Amerikis	26	23	1	28	24	1	26	18	2	32	19	3	0	(5)	4	(5)
94	Sepolia	17	16	0	17	17	0	16	11	1	17	12	1	(1)	(5)	0	(5)
AVERAGE		**51**	**42**	**3**	**53**	**42**	**3**	**50**	**34**	**4**	**51**	**34**	**4**	**(1)**	**(7)**	**(2)**	**(8)**

APPENDIX TABLE B2: List of the results of the research also indicating the differences for each time period between years 2015 and 2024

		MONDAY, OCTOBER 5TH 2015						MONDAY, MAY 13TH 2024						DIFFERENCES 2024 vs. 2015			
		MORNING PEAK			AFTERNOON OFF-PEAK			MORNING PEAK			AFTERNOON OFF-PEAK			MORNING PEAK		AFTERNOON OFF-PEAK	
From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	Glyka Nera	81	61	5	85	57	7	57	38	5	60	38	5	(24)	(23)	(25)	(19)
35	Korydallos	49	39	2	51	39	3	21	16	1	25	16	2	(28)	(23)	(26)	(23)
79	Athens International Airport	86	66	7	82	66	6	79	44	10	79	44	11	(7)	(22)	(3)	(22)
34	Koropi	98	68	8	92	68	8	89	48	11	95	52	10	(9)	(20)	3	(16)
50	Paiania	90	70	7	99	69	10	70	50	5	72	51	5	(20)	(20)	(27)	(18)
4	Aghia Varvara	38	33	1	39	33	2	20	15	1	24	15	2	(18)	(18)	(15)	(18)
49	Nikaia	52	42	2	54	43	3	28	24	1	33	24	2	(24)	(18)	(21)	(19)
73	Elefsina	72	64	3	78	59	5	66	48	5	68	46	5	(6)	(16)	(10)	(13)
24	Glyfada	60	50	3	64	50	4	59	35	6	51	34	4	(1)	(15)	(13)	(16)
32	Keratsini	62	52	2	65	52	3	50	37	3	53	37	4	(12)	(15)	(12)	(15)
78	Vouliagmeni	88	65	6	86	65	6	76	50	7	72	51	5	(12)	(15)	(14)	(14)
60	Piraeus	44	37	2	45	38	2	27	23	1	32	23	2	(17)	(14)	(13)	(15)
11	Anthousa	85	54	9	83	56	9	87	41	11	83	42	10	2	(13)	0	(14)
81	Kifissos Bus Station	39	36	1	40	39	0	32	23	2	36	26	2	(7)	(13)	(4)	(13)
51	Palaio Faliro	44	37	2	48	35	4	45	25	5	46	27	5	1	(12)	(2)	(8)
55	Penteli	76	63	4	87	66	5	76	51	6	85	50	7	0	(12)	(2)	(16)
45	Nea Ionia	42	39	1	45	39	2	42	28	3	38	28	2	0	(11)	(7)	(11)
56	Perama	74	64	2	73	65	2	65	53	3	74	53	4	(9)	(11)	1	(12)
70	Dionysos	110	89	7	112	87	8	127	78	12	104	77	6	17	(11)	(8)	(10)
6	Aghios Dimitrios	23	22	0	23	22	0	17	12	1	17	12	1	(6)	(10)	(6)	(10)
59	Petroupoli	54	48	2	57	50	2	60	38	5	61	40	5	6	(10)	4	(10)
63	Tavros	40	34	1	42	32	2	41	24	4	43	25	4	1	(10)	1	(7)
16	Cholargos	23	22	0	23	23	0	18	13	1	20	13	2	(5)	(9)	(3)	(10)
27	Ilioupoli	42	36	1	43	37	2	31	27	1	31	27	1	(11)	(9)	(12)	(10)
33	Kifissia	56	53	1	57	53	1	58	44	3	54	44	2	2	(9)	(3)	(9)
53	Papagou	41	36	2	41	37	1	33	27	1	35	28	2	(8)	(9)	(6)	(9)
62	Spata	84	71	4	85	70	4	83	62	5	78	59	5	(1)	(9)	(7)	(11)
67	Ymittos	30	25	2	30	24	2	28	16	2	28	19	2	(2)	(9)	(2)	(5)
12	Argyroupoli	39	35	1	40	35	1	32	27	1	32	27	1	(7)	(8)	(8)	(8)
13	Aspropyrgos	81	65	5	83	63	7	75	57	4	72	52	5	(6)	(8)	(11)	(11)
19	Elliniko	29	26	1	30	27	1	23	18	1	23	18	1	(6)	(8)	(7)	(9)

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
20	Filothei	46	42	1	47	41	1	48	34	3	51	37	3	2	(8)	4	(4)
52	Pallini	66	43	5	59	43	4	60	35	5	60	36	5	(6)	(8)	1	(7)
58	Peristeri II	23	22	0	23	23	0	19	14	1	20	15	1	(4)	(8)	(3)	(8)
72	Ekali	89	74	3	93	73	6	88	66	5	88	65	5	(1)	(8)	(5)	(8)
AVERAGE		**51**	**42**	**3**	**53**	**42**	**3**	**50**	**34**	**4**	**51**	**34**	**4**	**(1)**	**(7)**	**(2)**	**(8)**
7	Aghios Ioannis Rentis	44	35	2	45	35	3	42	28	3	47	29	4	(2)	(7)	2	(6)
9	Alimos	50	44	1	51	44	2	52	37	3	50	36	3	2	(7)	(1)	(8)
17	Dafni	18	17	0	18	17	0	14	10	1	14	10	1	(4)	(7)	(4)	(7)
23	Gerakas	51	42	2	52	45	2	52	35	4	50	37	3	1	(7)	(2)	(8)
38	Marousi II	44	41	1	45	41	1	48	34	3	44	34	2	4	(7)	(1)	(7)
41	Moschato	32	29	1	33	29	1	31	22	2	35	21	3	(1)	(7)	2	(8)
64	Voula	76	56	5	74	58	5	71	49	6	70	50	4	(5)	(7)	(4)	(8)
71	Drosia	98	79	5	98	78	6	107	72	8	95	60	7	9	(7)	(3)	(18)
86	Goudi	29	26	1	29	26	1	26	19	2	27	19	2	(3)	(7)	(2)	(7)
89	Neos Kosmos	14	13	0	14	13	0	11	6	1	11	6	1	(3)	(7)	(3)	(7)
3	Aghia Paraskevi	36	31	1	37	32	1	34	25	2	36	25	3	(2)	(6)	(1)	(7)
8	Aigaleo	22	21	0	22	21	0	20	15	1	25	15	2	(2)	(6)	3	(6)
10	Ano Liosia	76	66	2	79	64	4	83	60	5	79	56	5	7	(6)	0	(8)
15	Chalandri	46	40	2	46	40	2	46	34	3	48	32	3	0	(6)	2	(8)
18	Drapetsona	52	44	2	54	45	3	44	38	1	48	37	2	(8)	(6)	(6)	(8)
28	Irakleio	37	34	1	38	34	1	42	28	3	38	28	2	5	(6)	0	(6)
29	Kaisariani	25	23	1	28	24	1	24	17	1	27	17	2	(1)	(6)	(1)	(7)
31	Kamatero	67	50	5	68	51	5	64	44	4	63	47	4	(3)	(6)	(5)	(4)
43	Nea Erythraia	68	61	2	80	61	5	74	55	4	74	54	4	6	(6)	(6)	(7)
48	Neo Psychiko	33	30	1	35	29	1	35	24	2	34	25	2	2	(6)	(1)	(4)
61	Psychiko	38	29	2	40	32	3	39	23	3	38	25	3	1	(6)	(2)	(7)
80	Athens Railway Station	18	17	0	18	18	0	16	11	1	17	12	1	(2)	(6)	(1)	(6)
84	Girokomeio	19	18	0	19	19	0	17	12	1	19	12	2	(2)	(6)	0	(7)
85	Gkizi	25	22	1	28	23	1	27	16	2	30	18	2	2	(6)	2	(5)
88	Kypseli	29	25	1	30	26	1	30	19	2	30	21	2	1	(6)	0	(5)
14	Chaidari	32	27	1	32	28	1	27	22	1	31	22	2	(5)	(5)	(1)	(6)
37	Marousi I	43	40	1	44	40	1	49	35	3	45	35	2	6	(5)	1	(5)
46	Nea Penteli	73	58	5	77	59	5	73	53	5	78	52	6	0	(5)	1	(7)
54	Pefki	60	52	2	61	52	2	66	47	3	62	48	3	6	(5)	1	(4)
65	Vrilissia	57	42	5	58	45	4	59	37	5	72	36	8	2	(5)	14	(9)
69	Zografou	29	26	1	30	26	1	29	21	2	28	20	2	0	(5)	(2)	(6)
87	Koukaki	14	13	0	14	13	0	13	8	1	13	8	1	(1)	(5)	(1)	(5)

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
93	Plateia Amerikis	26	23	1	28	24	1	26	18	2	32	19	3	0	(5)	4	(5)
94	Sepolia	17	16	0	17	17	0	16	11	1	17	12	1	(1)	(5)	0	(5)
5	Aghioi Anargyroi	40	32	2	39	34	1	43	28	3	41	29	2	3	(4)	2	(5)
26	Ilion	43	35	2	41	36	2	48	31	4	47	31	4	5	(4)	6	(5)
39	Melissia	65	50	4	68	54	5	68	46	5	77	47	7	3	(4)	9	(7)
77	Varympompi	142	87	17	142	88	18	159	83	20	199	85	33	17	(4)	57	(3)
91	Patissia	28	25	1	29	25	1	35	21	3	31	21	2	7	(4)	2	(4)
22	Galatsi	46	38	2	45	39	2	52	35	4	52	37	4	6	(3)	7	(2)
30	Kallithea	31	27	1	33	28	1	34	24	2	35	25	2	3	(3)	2	(3)
40	Metamorfosi	63	50	4	67	53	4	65	47	4	81	52	7	2	(3)	14	(1)
57	Peristeri I	36	29	2	37	31	2	30	26	1	31	26	1	(6)	(3)	(6)	(5)
66	Vyronas	31	25	2	32	25	2	35	22	3	35	22	3	4	(3)	3	(3)
74	Pikermi	95	70	7	94	69	7	102	67	8	97	64	7	7	(3)	3	(5)
83	Piraeus seaport	31	28	1	32	28	1	30	25	1	35	26	2	(1)	(3)	3	(2)
82	Liosion Bus Station	29	25	1	30	26	1	34	23	2	34	25	2	5	(2)	4	(1)
36	Lykovrysi	66	55	3	69	59	3	72	54	4	73	54	4	6	(1)	4	(5)
42	Nea Chalkidona	35	30	1	37	32	2	41	29	3	39	29	2	6	(1)	2	(3)
44	Nea Filadelfeia	40	33	2	41	35	2	43	32	2	42	32	2	3	(1)	1	(3)
47	Nea Smyrni	26	23	1	26	23	1	30	22	2	34	22	3	4	(1)	8	(1)
68	Zefyri	70	52	5	71	53	5	67	51	4	65	48	4	(3)	(1)	(6)	(5)
90	Pagkrati	21	16	1	22	17	1	25	15	2	25	15	2	4	(1)	3	(2)
92	Petralona	20	17	1	21	17	1	25	16	2	28	15	3	5	(1)	7	(2)
75	Thrakomakedones	103	81	6	112	78	9	107	84	5	111	84	6	4	3	(1)	6
76	Vari	79	52	8	78	54	8	73	55	4	77	58	4	(6)	3	(1)	4
21	Fyli	104	78	7	110	76	10	156	83	19	109	75	8	52	5	(1)	(1)
2	Acharnai	62	50	3	66	51	4	70	56	3	71	54	4	8	6	5	3

APPENDIX TABLE B3: List of the results of the research indicating the difference between years 2015 and 2024 sorted by the highest Minimum travel time reduction in year 2024 during the morning peak

		MONDAY, OCTOBER 5TH 2015						MONDAY, MAY 13TH 2024						DIFFERENCES 2024 vs. 2015			
		MORNING PEAK			AFTERNOON OFF-PEAK			MORNING PEAK			AFTERNOON OFF-PEAK			2015		2024	
From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
77	Varympompi	142	87	17	142	88	18	159	83	20	199	85	33	17	(4)	57	(3)
21	Fyli	104	78	7	110	76	10	156	83	19	109	75	8	52	5	(1)	(1)
70	Dionysos	110	89	7	112	87	8	127	78	12	104	77	6	17	(11)	(8)	(10)
11	Anthousa	85	54	9	83	56	9	87	41	11	83	42	10	2	(13)	0	(14)
34	Koropi	98	68	8	92	68	8	89	48	11	95	52	10	(9)	(20)	3	(16)
79	Athens International Airport	86	66	7	82	66	6	79	44	10	79	44	11	(7)	(22)	(3)	(22)
74	Pikermi	95	70	7	94	69	7	102	67	8	97	64	7	7	(3)	3	(5)
71	Drosia	98	79	5	98	78	6	107	72	8	95	60	7	9	(7)	(3)	(18)
78	Vouliagmeni	88	65	6	86	65	6	76	50	7	72	51	5	(12)	(15)	(14)	(14)
24	Glyfada	60	50	3	64	50	4	59	35	6	51	34	4	(1)	(15)	(13)	(16)
55	Penteli	76	63	4	87	66	5	76	51	6	85	50	7	0	(12)	(2)	(16)
64	Voula	76	56	5	74	58	5	71	49	6	70	50	4	(5)	(7)	(4)	(8)
39	Melissia	65	50	4	68	54	5	68	46	5	77	47	7	3	(4)	9	(7)
52	Pallini	66	43	5	59	43	4	60	35	5	60	36	5	(6)	(8)	1	(7)
59	Petroupoli	54	48	2	57	50	2	60	38	5	61	40	5	6	(10)	4	(10)
72	Ekali	89	74	3	93	73	6	88	66	5	88	65	5	(1)	(8)	(5)	(8)
75	Thrakomakedones	103	81	6	112	78	9	107	84	5	111	84	6	4	3	(1)	6
65	Vrilissia	57	42	5	58	45	4	59	37	5	72	36	8	2	(5)	14	(9)
51	Palaio Faliro	44	37	2	48	35	4	45	25	5	46	27	5	1	(12)	(2)	(8)
62	Spata	84	71	4	85	70	4	83	62	5	78	59	5	(1)	(9)	(7)	(11)
46	Nea Penteli	73	58	5	77	59	5	73	53	5	78	52	6	0	(5)	1	(7)
10	Ano Liosia	76	66	2	79	64	4	83	60	5	79	56	5	7	(6)	0	(8)
50	Paiania	90	70	7	99	69	10	70	50	5	72	51	5	(20)	(20)	(27)	(18)
25	Glyka Nera	81	61	5	85	57	7	57	38	5	60	38	5	(24)	(23)	(25)	(19)
73	Elefsina	72	64	3	78	59	5	66	48	5	68	46	5	(6)	(16)	(10)	(13)
76	Vari	79	52	8	78	54	8	73	55	4	77	58	4	(6)	3	(1)	4
13	Aspropyrgos	81	65	5	83	63	7	75	57	4	72	52	5	(6)	(8)	(11)	(11)
31	Kamatero	67	50	5	68	51	5	64	44	4	63	47	4	(3)	(6)	(5)	(4)
43	Nea Erythraia	68	61	2	80	61	5	74	55	4	74	54	4	6	(6)	(6)	(7)
AVERAGE		**51**	**42**	**3**	**53**	**42**	**3**	**50**	**34**	**4**	**51**	**34**	**4**	**1**	**0**	**1**	**0**
40	Metamorfosi	63	50	4	67	53	4	65	47	4	81	52	7	2	(3)	14	(1)

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
36	Lykovrysi	66	55	3	69	59	3	72	54	4	73	54	4	6	(1)	4	(5)
23	Gerakas	51	42	2	52	45	2	52	35	4	50	37	3	1	(7)	(2)	(8)
22	Galatsi	46	38	2	45	39	2	52	35	4	52	37	4	6	(3)	7	(2)
26	Ilion	43	35	2	41	36	2	48	31	4	47	31	4	5	(4)	6	(5)
63	Tavros	40	34	1	42	32	2	41	24	4	43	25	4	1	(10)	1	(7)
68	Zefyri	70	52	5	71	53	5	67	51	4	65	48	4	(3)	(1)	(6)	(5)
54	Pefki	60	52	2	61	52	2	66	47	3	62	48	3	6	(5)	1	(4)
9	Alimos	50	44	1	51	44	2	52	37	3	50	36	3	2	(7)	(1)	(8)
7	Aghios Ioannis Rentis	44	35	2	45	35	3	42	28	3	47	29	4	(2)	(7)	2	(6)
32	Keratsini	62	52	2	65	52	3	50	37	3	53	37	4	(12)	(15)	(12)	(15)
45	Nea Ionia	42	39	1	45	39	2	42	28	3	38	28	2	0	(11)	(7)	(11)
28	Irakleio	37	34	1	38	34	1	42	28	3	38	28	2	5	(6)	0	(6)
38	Marousi II	44	41	1	45	41	1	48	34	3	44	34	2	4	(7)	(1)	(7)
37	Marousi I	43	40	1	44	40	1	49	35	3	45	35	2	6	(5)	1	(5)
91	Patissia	28	25	1	29	25	1	35	21	3	31	21	2	7	(4)	2	(4)
20	Filothei	46	42	1	47	41	1	48	34	3	51	37	3	2	(8)	4	(4)
2	Acharnai	62	50	3	66	51	4	70	56	3	71	54	4	8	6	5	3
66	Vyronas	31	25	2	32	25	2	35	22	3	35	22	3	4	(3)	3	(3)
61	Psychiko	38	29	2	40	32	3	39	23	3	38	25	3	1	(6)	(2)	(7)
56	Perama	74	64	2	73	65	2	65	53	3	74	53	4	(9)	(11)	1	(12)
5	Aghioi Anargyroi	40	32	2	39	34	1	43	28	3	41	29	2	3	(4)	2	(5)
15	Chalandri	46	40	2	46	40	2	46	34	3	48	32	3	0	(6)	2	(8)
33	Kifissia	56	53	1	57	53	1	58	44	3	54	44	2	2	(9)	(3)	(9)
42	Nea Chalkidona	35	30	1	37	32	2	41	29	3	39	29	2	6	(1)	2	(3)
44	Nea Filadelfeia	40	33	2	41	35	2	43	32	2	42	32	2	3	(1)	1	(3)
82	Liosion Bus Station	29	25	1	30	26	1	34	23	2	34	25	2	5	(2)	4	(1)
67	Ymittos	30	25	2	30	24	2	28	16	2	28	19	2	(2)	(9)	(2)	(5)
88	Kypseli	29	25	1	30	26	1	30	19	2	30	21	2	1	(6)	0	(5)
48	Neo Psychiko	33	30	1	35	29	1	35	24	2	34	25	2	2	(6)	(1)	(4)
47	Nea Smyrni	26	23	1	26	23	1	30	22	2	34	22	3	4	(1)	8	(1)
3	Aghia Paraskevi	36	31	1	37	32	1	34	25	2	36	25	3	(2)	(6)	(1)	(7)
30	Kallithea	31	27	1	33	28	1	34	24	2	35	25	2	3	(3)	2	(3)
92	Petralona	20	17	1	21	17	1	25	16	2	28	15	3	5	(1)	7	(2)
41	Moschato	32	29	1	33	29	1	31	22	2	35	21	3	(1)	(7)	2	(8)
85	Gkizi	25	22	1	28	23	1	27	16	2	30	18	2	2	(6)	2	(5)
93	Plateia Amerikis	26	23	1	28	24	1	26	18	2	32	19	3	0	(5)	4	(5)
81	Kifissos Bus Station	39	36	1	40	39	0	32	23	2	36	26	2	(7)	(13)	(4)	(13)

From Point		MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	DEV	MAX	MIN	MAX	MIN
90	Pagkrati	21	16	1	22	17	1	25	15	2	25	15	2	4	(1)	3	(2)
69	Zografou	29	26	1	30	26	1	29	21	2	28	20	2	0	(5)	(2)	(6)
86	Goudi	29	26	1	29	26	1	26	19	2	27	19	2	(3)	(7)	(2)	(7)
80	Athens Railway Station	18	17	0	18	18	0	16	11	1	17	12	1	(2)	(6)	(1)	(6)
94	Sepolia	17	16	0	17	17	0	16	11	1	17	12	1	(1)	(5)	0	(5)
58	Peristeri II	23	22	0	23	23	0	19	14	1	20	15	1	(4)	(8)	(3)	(8)
18	Drapetsona	52	44	2	54	45	3	44	38	1	48	37	2	(8)	(6)	(6)	(8)
89	Neos Kosmos	14	13	0	14	13	0	11	6	1	11	6	1	(3)	(7)	(3)	(7)
16	Cholargos	23	22	0	23	23	0	18	13	1	20	13	2	(5)	(9)	(3)	(10)
6	Aghios Dimitrios	23	22	0	23	22	0	17	12	1	17	12	1	(6)	(10)	(6)	(10)
19	Elliniko	29	26	1	30	27	1	23	18	1	23	18	1	(6)	(8)	(7)	(9)
53	Papagou	41	36	2	41	37	1	33	27	1	35	28	2	(8)	(9)	(6)	(9)
57	Peristeri I	36	29	2	37	31	2	30	26	1	31	26	1	(6)	(3)	(6)	(5)
12	Argyroupoli	39	35	1	40	35	1	32	27	1	32	27	1	(7)	(8)	(8)	(8)
87	Koukaki	14	13	0	14	13	0	13	8	1	13	8	1	(1)	(5)	(1)	(5)
84	Girokomeio	19	18	0	19	19	0	17	12	1	19	12	2	(2)	(6)	0	(7)
17	Dafni	18	17	0	18	17	0	14	10	1	14	10	1	(4)	(7)	(4)	(7)
27	Ilioupoli	42	36	1	43	37	2	31	27	1	31	27	1	(11)	(9)	(12)	(10)
35	Korydallos	49	39	2	51	39	3	21	16	1	25	16	2	(28)	(23)	(26)	(23)
29	Kaisariani	25	23	1	28	24	1	24	17	1	27	17	2	(1)	(6)	(1)	(7)
8	Aigaleo	22	21	0	22	21	0	20	15	1	25	15	2	(2)	(6)	3	(6)
4	Aghia Varvara	38	33	1	39	33	2	20	15	1	24	15	2	(18)	(18)	(15)	(18)
14	Chaidari	32	27	1	32	28	1	27	22	1	31	22	2	(5)	(5)	(1)	(6)
83	Piraeus seaport	31	28	1	32	28	1	30	25	1	35	26	2	(1)	(3)	3	(2)
49	Nikaia	52	42	2	54	43	3	28	24	1	33	24	2	(24)	(18)	(21)	(19)
60	Piraeus	44	37	2	45	38	2	27	23	1	32	23	2	(17)	(14)	(13)	(15)

APPENDIX TABLE B4: List of the results of the research indicating the difference between years 2015 and 2024 sorted by the highest Standard Deviation of the travel time in year 2024 during the morning peak

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	✓
19	Elliniko	29	26	1	23	18	1	9	0.5000	0.3462	0.1538	✓
4	Aghia Varvara	38	33	1	20	15	1	7	0.4667	0.2121	0.2545	✓
16	Cholargos	23	22	0	18	13	1	6	0.4615	0.2727	0.1888	✓
35	Korydallos	49	39	2	21	16	1	7	0.4375	0.1795	0.2580	✓
79	Athens International Airport	86	66	7	79	44	10	19	0.4318	0.2879	0.1439	✓
78	Vouliagmeni	88	65	6	76	50	7	19	0.3800	0.2923	0.0877	
73	Elefsina	72	64	3	66	48	5	18	0.3750	0.2813	0.0938	
52	Pallini	66	43	5	60	35	5	13	0.3714	0.3023	0.0691	✓
94	Sepolia	17	16	0	16	11	1	4	0.3636	0.2500	0.1136	✓
3	Aghia Paraskevi	36	31	1	34	25	2	9	0.3600	0.2903	0.0697	✓
83	Piraeus seaport	31	28	1	30	25	1	9	0.3600	0.3214	0.0386	✓
58	Peristeri II	23	22	0	19	14	1	5	0.3571	0.2273	0.1299	✓
60	Piraeus	44	37	2	27	23	1	8	0.3478	0.2162	0.1316	✓
24	Glyfada	60	50	3	59	35	6	12	0.3429	0.2400	0.1029	
6	Aghios Dimitrios	23	22	0	17	12	1	4	0.3333	0.1818	0.1515	✓
8	Aigaleo	22	21	0	20	15	1	5	0.3333	0.2381	0.0952	✓
49	Nikaia	52	42	2	28	24	1	8	0.3333	0.1905	0.1429	✓
89	Neos Kosmos	14	13	0	11	6	1	2	0.3333	0.1538	0.1795	✓
14	Chaidari	32	27	1	27	22	1	7	0.3182	0.2593	0.0589	✓
11	Anthousa	85	54	9	87	41	11	13	0.3171	0.2407	0.0763	
23	Gerakas	51	42	2	52	35	4	11	0.3143	0.2619	0.0524	
37	Marousi I	43	40	1	49	35	3	11	0.3143	0.2750	0.0393	✓
34	Koropi	98	68	8	89	48	11	15	0.3125	0.2206	0.0919	
76	Vari	79	52	8	73	55	4	17	0.3091	0.3269	(0.0178)	
64	Voula	76	56	5	71	49	6	15	0.3061	0.2679	0.0383	
17	Dafni	18	17	0	14	10	1	3	0.3000	0.1765	0.1235	✓
65	Vrilissia	57	42	5	59	37	5	11	0.2973	0.2619	0.0354	
12	Argyroupoli	39	35	1	32	27	1	8	0.2963	0.2286	0.0677	✓
33	Kifissia	56	53	1	58	44	3	13	0.2955	0.2453	0.0502	✓
28	Irakleio	37	34	1	42	28	3	8	0.2857	0.2353	0.0504	✓
45	Nea Ionia	42	39	1	42	28	3	8	0.2857	0.2051	0.0806	✓

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
56	Perama	74	64	2	65	53	3	15	0.2830	0.2344	0.0486	
13	Aspropyrgos	81	65	5	75	57	4	16	0.2807	0.2462	0.0345	
51	Palaio Faliro	44	37	2	45	25	5	7	0.2800	0.1892	0.0908	
55	Penteli	76	63	4	76	51	6	14	0.2745	0.2222	0.0523	
43	Nea Erythraia	68	61	2	74	55	4	15	0.2727	0.2459	0.0268	
72	Ekali	89	74	3	88	66	5	18	0.2727	0.2432	0.0295	
32	Keratsini	62	52	2	50	37	3	10	0.2703	0.1923	0.0780	
74	Pikermi	95	70	7	102	67	8	18	0.2687	0.2571	0.0115	
38	Marousi II	44	41	1	48	34	3	9	0.2647	0.2195	0.0452	✓
46	Nea Penteli	73	58	5	73	53	5	14	0.2642	0.2414	0.0228	
71	Drosia	98	79	5	107	72	8	19	0.2639	0.2405	0.0234	
18	Drapetsona	52	44	2	44	38	1	10	0.2632	0.2273	0.0359	
25	Glyka Nera	81	61	5	57	38	5	10	0.2632	0.1639	0.0992	
39	Melissia	65	50	4	68	46	5	12	0.2609	0.2400	0.0209	
62	Spata	84	71	4	83	62	5	16	0.2581	0.2254	0.0327	
AVERAGE		**51**	**42**	**3**	**50**	**34**	**4**	**9**	**0.2545**	**0.1990**	**0.0555**	--
84	Girokomeio	19	18	0	17	12	1	3	0.2500	0.1667	0.0833	✓
70	Dionysos	110	89	7	127	78	12	19	0.2436	0.2135	0.0301	
91	Patissia	28	25	1	35	21	3	5	0.2381	0.2000	0.0381	✓
59	Petroupoli	54	48	2	60	38	5	9	0.2368	0.1875	0.0493	
15	Chalandri	46	40	2	46	34	3	8	0.2353	0.2000	0.0353	✓
54	Pefki	60	52	2	66	47	3	11	0.2340	0.2115	0.0225	
41	Moschato	32	29	1	31	22	2	5	0.2273	0.1724	0.0549	✓
26	Ilion	43	35	2	48	31	4	7	0.2258	0.2000	0.0258	
53	Papagou	41	36	2	33	27	1	6	0.2222	0.1667	0.0556	✓
50	Paiania	90	70	7	70	50	5	11	0.2200	0.1571	0.0629	
77	Varympompi	142	87	17	159	83	20	18	0.2169	0.2069	0.0100	
9	Alimos	50	44	1	52	37	3	8	0.2162	0.1818	0.0344	
2	Acharnai	62	50	3	70	56	3	12	0.2143	0.2400	(0.0257)	
5	Aghioi Anargyroi	40	32	2	43	28	3	6	0.2143	0.1875	0.0268	
7	Aghios Ioannis Rentis	44	35	2	42	28	3	6	0.2143	0.1714	0.0429	
40	Metamorfosi	63	50	4	65	47	4	10	0.2128	0.2000	0.0128	
48	Neo Psychiko	33	30	1	35	24	2	5	0.2083	0.1667	0.0417	

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
42	Nea Chalkidona	35	30	1	41	29	3	6	0.2069	0.2000	0.0069	✓
20	Filothei	46	42	1	48	34	3	7	0.2059	0.1667	0.0392	
31	Kamatero	67	50	5	64	44	4	9	0.2045	0.1800	0.0245	
36	Lykovrysi	66	55	3	72	54	4	11	0.2037	0.2000	0.0037	
75	Thrakomakedones	103	81	6	107	84	5	17	0.2024	0.2099	(0.0075)	
10	Ano Liosia	76	66	2	83	60	5	12	0.2000	0.1818	0.0182	
68	Zefyri	70	52	5	67	51	4	10	0.1961	0.1923	0.0038	
57	Peristeri I	36	29	2	30	26	1	5	0.1923	0.1724	0.0199	✓
44	Nea Filadelfeia	40	33	2	43	32	2	6	0.1875	0.1818	0.0057	✓
67	Ymittos	30	25	2	28	16	2	3	0.1875	0.1200	0.0675	
27	Ilioupoli	42	36	1	31	27	1	5	0.1852	0.1389	0.0463	✓
47	Nea Smyrni	26	23	1	30	22	2	4	0.1818	0.1739	0.0079	
80	Athens Railway Station	18	17	0	16	11	1	2	0.1818	0.1176	0.0642	✓
21	Fyli	104	78	7	156	83	19	15	0.1807	0.1923	(0.0116)	
61	Psychiko	38	29	2	39	23	3	4	0.1739	0.1379	0.0360	
81	Kifissos Bus Station	39	36	1	32	23	2	4	0.1739	0.1111	0.0628	
82	Liosion Bus Station	29	25	1	34	23	2	4	0.1739	0.1600	0.0139	✓
30	Kallithea	31	27	1	34	24	2	4	0.1667	0.1481	0.0185	✓
63	Tavros	40	34	1	41	24	4	4	0.1667	0.1176	0.0490	✓
93	Plateia Amerikis	26	23	1	26	18	2	3	0.1667	0.1304	0.0362	✓
86	Goudi	29	26	1	26	19	2	3	0.1579	0.1154	0.0425	✓
88	Kypseli	29	25	1	30	19	2	3	0.1579	0.1200	0.0379	
69	Zografou	29	26	1	29	21	2	3	0.1429	0.1154	0.0275	
85	Gkizi	25	22	1	27	16	2	2	0.1250	0.0909	0.0341	✓
87	Koukaki	14	13	0	13	8	1	1	0.1250	0.0769	0.0481	✓
92	Petralona	20	17	1	25	16	2	2	0.1250	0.1176	0.0074	✓
29	Kaisariani	25	23	1	24	17	1	2	0.1176	0.0870	0.0307	
22	Galatsi	46	38	2	52	35	4	4	0.1143	0.1053	0.0090	
66	Vyronas	31	25	2	35	22	3	2	0.0909	0.0800	0.0109	
90	Pagkrati	21	16	1	25	15	2	1	0.0667	0.0625	0.0042	

APPENDIX TABLE B5: List of the travel times during the morning peak of each year along with the distance of each route in km sorted by the longest distance traveled per minute for the Minimum travel time in year 2024. The difference in the distance traveled is also indicated along with the existence of a metro station.

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	✓
79	Athens International Airport	86	66	7	79	44	10	19	0.4318	0.2879	0.1439	✓
78	Vouliagmeni	88	65	6	76	50	7	19	0.3800	0.2923	0.0877	
71	Drosia	98	79	5	107	72	8	19	0.2639	0.2405	0.0234	
70	Dionysos	110	89	7	127	78	12	19	0.2436	0.2135	0.0301	
73	Elefsina	72	64	3	66	48	5	18	0.3750	0.2813	0.0938	
72	Ekali	89	74	3	88	66	5	18	0.2727	0.2432	0.0295	
74	Pikermi	95	70	7	102	67	8	18	0.2687	0.2571	0.0115	
77	Varympompi	142	87	17	159	83	20	18	0.2169	0.2069	0.0100	
76	Vari	79	52	8	73	55	4	17	0.3091	0.3269	(0.0178)	
75	Thrakomakedones	103	81	6	107	84	5	17	0.2024	0.2099	(0.0075)	
13	Aspropyrgos	81	65	5	75	57	4	16	0.2807	0.2462	0.0345	
62	Spata	84	71	4	83	62	5	16	0.2581	0.2254	0.0327	
34	Koropi	98	68	8	89	48	11	15	0.3125	0.2206	0.0919	
64	Voula	76	56	5	71	49	6	15	0.3061	0.2679	0.0383	
56	Perama	74	64	2	65	53	3	15	0.2830	0.2344	0.0486	
43	Nea Erythraia	68	61	2	74	55	4	15	0.2727	0.2459	0.0268	
21	Fyli	104	78	7	156	83	19	15	0.1807	0.1923	(0.0116)	
55	Penteli	76	63	4	76	51	6	14	0.2745	0.2222	0.0523	
46	Nea Penteli	73	58	5	73	53	5	14	0.2642	0.2414	0.0228	
52	Pallini	66	43	5	60	35	5	13	0.3714	0.3023	0.0691	✓
11	Anthousa	85	54	9	87	41	11	13	0.3171	0.2407	0.0763	
33	Kifissia	56	53	1	58	44	3	13	0.2955	0.2453	0.0502	✓
24	Glyfada	60	50	3	59	35	6	12	0.3429	0.2400	0.1029	
39	Melissia	65	50	4	68	46	5	12	0.2609	0.2400	0.0209	
2	Acharnai	62	50	3	70	56	3	12	0.2143	0.2400	(0.0257)	
10	Ano Liosia	76	66	2	83	60	5	12	0.2000	0.1818	0.0182	
23	Gerakas	51	42	2	52	35	4	11	0.3143	0.2619	0.0524	
37	Marousi I	43	40	1	49	35	3	11	0.3143	0.2750	0.0393	✓
65	Vrilissia	57	42	5	59	37	5	11	0.2973	0.2619	0.0354	
54	Pefki	60	52	2	66	47	3	11	0.2340	0.2115	0.0225	
50	Paiania	90	70	7	70	50	5	11	0.2200	0.1571	0.0629	

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
36	Lykovrysi	66	55	3	72	54	4	11	0.2037	0.2000	0.0037	
32	Keratsini	62	52	2	50	37	3	10	0.2703	0.1923	0.0780	
18	Drapetsona	52	44	2	44	38	1	10	0.2632	0.2273	0.0359	
25	Glyka Nera	81	61	5	57	38	5	10	0.2632	0.1639	0.0992	
40	Metamorfosi	63	50	4	65	47	4	10	0.2128	0.2000	0.0128	
68	Zefyri	70	52	5	67	51	4	10	0.1961	0.1923	0.0038	
19	Elliniko	29	26	1	23	18	1	9	0.5000	0.3462	0.1538	✓
3	Aghia Paraskevi	36	31	1	34	25	2	9	0.3600	0.2903	0.0697	✓
83	Piraeus seaport	31	28	1	30	25	1	9	0.3600	0.3214	0.0386	✓
38	Marousi II	44	41	1	48	34	3	9	0.2647	0.2195	0.0452	✓
59	Petroupoli	54	48	2	60	38	5	9	0.2368	0.1875	0.0493	
31	Kamatero	67	50	5	64	44	4	9	0.2045	0.1800	0.0245	
AVERAGE		**51**	**42**	**3**	**50**	**34**	**4**	**9**	**0.2545**	**0.1990**	**0.0555**	--
60	Piraeus	44	37	2	27	23	1	8	0.3478	0.2162	0.1316	✓
49	Nikaia	52	42	2	28	24	1	8	0.3333	0.1905	0.1429	✓
12	Argyroupoli	39	35	1	32	27	1	8	0.2963	0.2286	0.0677	✓
28	Irakleio	37	34	1	42	28	3	8	0.2857	0.2353	0.0504	✓
45	Nea Ionia	42	39	1	42	28	3	8	0.2857	0.2051	0.0806	✓
15	Chalandri	46	40	2	46	34	3	8	0.2353	0.2000	0.0353	✓
9	Alimos	50	44	1	52	37	3	8	0.2162	0.1818	0.0344	
4	Aghia Varvara	38	33	1	20	15	1	7	0.4667	0.2121	0.2545	✓
35	Korydallos	49	39	2	21	16	1	7	0.4375	0.1795	0.2580	✓
14	Chaidari	32	27	1	27	22	1	7	0.3182	0.2593	0.0589	✓
51	Palaio Faliro	44	37	2	45	25	5	7	0.2800	0.1892	0.0908	
26	Ilion	43	35	2	48	31	4	7	0.2258	0.2000	0.0258	
20	Filothei	46	42	1	48	34	3	7	0.2059	0.1667	0.0392	
16	Cholargos	23	22	0	18	13	1	6	0.4615	0.2727	0.1888	✓
53	Papagou	41	36	2	33	27	1	6	0.2222	0.1667	0.0556	✓
5	Aghioi Anargyroi	40	32	2	43	28	3	6	0.2143	0.1875	0.0268	
7	Aghios Ioannis Rentis	44	35	2	42	28	3	6	0.2143	0.1714	0.0429	
42	Nea Chalkidona	35	30	1	41	29	3	6	0.2069	0.2000	0.0069	✓
44	Nea Filadelfeia	40	33	2	43	32	2	6	0.1875	0.1818	0.0057	✓
58	Peristeri II	23	22	0	19	14	1	5	0.3571	0.2273	0.1299	✓

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
8	Aigaleo	22	21	0	20	15	1	5	0.3333	0.2381	0.0952	✓
91	Patissia	28	25	1	35	21	3	5	0.2381	0.2000	0.0381	✓
41	Moschato	32	29	1	31	22	2	5	0.2273	0.1724	0.0549	✓
48	Neo Psychiko	33	30	1	35	24	2	5	0.2083	0.1667	0.0417	
57	Peristeri I	36	29	2	30	26	1	5	0.1923	0.1724	0.0199	✓
27	Ilioupoli	42	36	1	31	27	1	5	0.1852	0.1389	0.0463	✓
94	Sepolia	17	16	0	16	11	1	4	0.3636	0.2500	0.1136	✓
6	Aghios Dimitrios	23	22	0	17	12	1	4	0.3333	0.1818	0.1515	✓
47	Nea Smyrni	26	23	1	30	22	2	4	0.1818	0.1739	0.0079	
61	Psychiko	38	29	2	39	23	3	4	0.1739	0.1379	0.0360	
81	Kifissos Bus Station	39	36	1	32	23	2	4	0.1739	0.1111	0.0628	
82	Liosion Bus Station	29	25	1	34	23	2	4	0.1739	0.1600	0.0139	✓
30	Kallithea	31	27	1	34	24	2	4	0.1667	0.1481	0.0185	✓
63	Tavros	40	34	1	41	24	4	4	0.1667	0.1176	0.0490	✓
22	Galatsi	46	38	2	52	35	4	4	0.1143	0.1053	0.0090	
17	Dafni	18	17	0	14	10	1	3	0.3000	0.1765	0.1235	✓
84	Girokomeio	19	18	0	17	12	1	3	0.2500	0.1667	0.0833	✓
67	Ymittos	30	25	2	28	16	2	3	0.1875	0.1200	0.0675	
93	Plateia Amerikis	26	23	1	26	18	2	3	0.1667	0.1304	0.0362	✓
86	Goudi	29	26	1	26	19	2	3	0.1579	0.1154	0.0425	✓
88	Kypseli	29	25	1	30	19	2	3	0.1579	0.1200	0.0379	
69	Zografou	29	26	1	29	21	2	3	0.1429	0.1154	0.0275	
89	Neos Kosmos	14	13	0	11	6	1	2	0.3333	0.1538	0.1795	✓
80	Athens Railway Station	18	17	0	16	11	1	2	0.1818	0.1176	0.0642	✓
85	Gkizi	25	22	1	27	16	2	2	0.1250	0.0909	0.0341	✓
92	Petralona	20	17	1	25	16	2	2	0.1250	0.1176	0.0074	✓
29	Kaisariani	25	23	1	24	17	1	2	0.1176	0.0870	0.0307	
66	Vyronas	31	25	2	35	22	3	2	0.0909	0.0800	0.0109	
87	Koukaki	14	13	0	13	8	1	1	0.1250	0.0769	0.0481	✓
90	Pagkrati	21	16	1	25	15	2	1	0.0667	0.0625	0.0042	

APPENDIX TABLE B6: List of the travel times during the morning peak of each year along with the longest distance traveled per minute for the Minimum travel time in year 2024. Data sorted by the distance in km.

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
1	Syntagma Square	--	--	--	--	--	--	--	--	--	--	✓
35	Korydallos	49	39	2	21	16	1	7	0.4375	0.1795	0.2580	✓
4	Aghia Varvara	38	33	1	20	15	1	7	0.4667	0.2121	0.2545	✓
16	Cholargos	23	22	0	18	13	1	6	0.4615	0.2727	0.1888	✓
89	Neos Kosmos	14	13	0	11	6	1	2	0.3333	0.1538	0.1795	✓
19	Elliniko	29	26	1	23	18	1	9	0.5000	0.3462	0.1538	✓
6	Aghios Dimitrios	23	22	0	17	12	1	4	0.3333	0.1818	0.1515	✓
79	Athens International Airport	86	66	7	79	44	10	19	0.4318	0.2879	0.1439	✓
49	Nikaia	52	42	2	28	24	1	8	0.3333	0.1905	0.1429	✓
60	Piraeus	44	37	2	27	23	1	8	0.3478	0.2162	0.1316	✓
58	Peristeri II	23	22	0	19	14	1	5	0.3571	0.2273	0.1299	✓
17	Dafni	18	17	0	14	10	1	3	0.3000	0.1765	0.1235	✓
94	Sepolia	17	16	0	16	11	1	4	0.3636	0.2500	0.1136	✓
24	Glyfada	60	50	3	59	35	6	12	0.3429	0.2400	0.1029	
25	Glyka Nera	81	61	5	57	38	5	10	0.2632	0.1639	0.0992	
8	Aigaleo	22	21	0	20	15	1	5	0.3333	0.2381	0.0952	✓
73	Elefsina	72	64	3	66	48	5	18	0.3750	0.2813	0.0938	
34	Koropi	98	68	8	89	48	11	15	0.3125	0.2206	0.0919	
51	Palaio Faliro	44	37	2	45	25	5	7	0.2800	0.1892	0.0908	
78	Vouliagmeni	88	65	6	76	50	7	19	0.3800	0.2923	0.0877	
84	Girokomeio	19	18	0	17	12	1	3	0.2500	0.1667	0.0833	✓
45	Nea Ionia	42	39	1	42	28	3	8	0.2857	0.2051	0.0806	✓
32	Keratsini	62	52	2	50	37	3	10	0.2703	0.1923	0.0780	
11	Anthousa	85	54	9	87	41	11	13	0.3171	0.2407	0.0763	
3	Aghia Paraskevi	36	31	1	34	25	2	9	0.3600	0.2903	0.0697	✓
52	Pallini	66	43	5	60	35	5	13	0.3714	0.3023	0.0691	✓
12	Argyroupoli	39	35	1	32	27	1	8	0.2963	0.2286	0.0677	✓
67	Ymittos	30	25	2	28	16	2	3	0.1875	0.1200	0.0675	
80	Athens Railway Station	18	17	0	16	11	1	2	0.1818	0.1176	0.0642	✓
50	Paiania	90	70	7	70	50	5	11	0.2200	0.1571	0.0629	
81	Kifissos Bus Station	39	36	1	32	23	2	4	0.1739	0.1111	0.0628	
14	Chaidari	32	27	1	27	22	1	7	0.3182	0.2593	0.0589	✓

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
53	Papagou	41	36	2	33	27	1	6	0.2222	0.1667	0.0556	✓
AVERAGE		**51**	**42**	**3**	**50**	**34**	**4**	**9**	**0.2545**	**0.1990**	**0.0555**	--
41	Moschato	32	29	1	31	22	2	5	0.2273	0.1724	0.0549	✓
23	Gerakas	51	42	2	52	35	4	11	0.3143	0.2619	0.0524	
55	Penteli	76	63	4	76	51	6	14	0.2745	0.2222	0.0523	
28	Irakleio	37	34	1	42	28	3	8	0.2857	0.2353	0.0504	✓
33	Kifissia	56	53	1	58	44	3	13	0.2955	0.2453	0.0502	✓
59	Petroupoli	54	48	2	60	38	5	9	0.2368	0.1875	0.0493	
63	Tavros	40	34	1	41	24	4	4	0.1667	0.1176	0.0490	✓
56	Perama	74	64	2	65	53	3	15	0.2830	0.2344	0.0486	
87	Koukaki	14	13	0	13	8	1	1	0.1250	0.0769	0.0481	✓
27	Ilioupoli	42	36	1	31	27	1	5	0.1852	0.1389	0.0463	✓
38	Marousi II	44	41	1	48	34	3	9	0.2647	0.2195	0.0452	✓
7	Aghios Ioannis Rentis	44	35	2	42	28	3	6	0.2143	0.1714	0.0429	
86	Goudi	29	26	1	26	19	2	3	0.1579	0.1154	0.0425	✓
48	Neo Psychiko	33	30	1	35	24	2	5	0.2083	0.1667	0.0417	
37	Marousi I	43	40	1	49	35	3	11	0.3143	0.2750	0.0393	✓
20	Filothei	46	42	1	48	34	3	7	0.2059	0.1667	0.0392	
83	Piraeus Port	31	28	1	30	25	1	9	0.3600	0.3214	0.0386	✓
64	Voula	76	56	5	71	49	6	15	0.3061	0.2679	0.0383	
91	Patissia	28	25	1	35	21	3	5	0.2381	0.2000	0.0381	✓
88	Kypseli	29	25	1	30	19	2	3	0.1579	0.1200	0.0379	
93	Plateia Amerikis	26	23	1	26	18	2	3	0.1667	0.1304	0.0362	✓
61	Psychiko	38	29	2	39	23	3	4	0.1739	0.1379	0.0360	
18	Drapetsona	52	44	2	44	38	1	10	0.2632	0.2273	0.0359	
65	Vrilissia	57	42	5	59	37	5	11	0.2973	0.2619	0.0354	
15	Chalandri	46	40	2	46	34	3	8	0.2353	0.2000	0.0353	✓
13	Aspropyrgos	81	65	5	75	57	4	16	0.2807	0.2462	0.0345	
9	Alimos	50	44	1	52	37	3	8	0.2162	0.1818	0.0344	
85	Gkizi	25	22	1	27	16	2	2	0.1250	0.0909	0.0341	✓
62	Spata	84	71	4	83	62	5	16	0.2581	0.2254	0.0327	
29	Kaisariani	25	23	1	24	17	1	2	0.1176	0.0870	0.0307	
70	Dionysos	110	89	7	127	78	12	19	0.2436	0.2135	0.0301	

		MONDAY, OCT 5TH 2015			MONDAY, MAY 13TH 2024			DISTANCE IN KM	KM PEN MINU 2024	KM PER MINU 2015	DIFFERENCE 2024 vs. 2015	15 MINU WALK TO METRO STATION
		MORNING PEAK			MORNING PEAK							
From Point		MAX	MIN	DEV	MAX	MIN	DEV					
72	Ekali	89	74	3	88	66	5	18	0.2727	0.2432	0.0295	
69	Zografou	29	26	1	29	21	2	3	0.1429	0.1154	0.0275	
43	Nea Erythraia	68	61	2	74	55	4	15	0.2727	0.2459	0.0268	
5	Aghioi Anargyroi	40	32	2	43	28	3	6	0.2143	0.1875	0.0268	
26	Ilion	43	35	2	48	31	4	7	0.2258	0.2000	0.0258	
31	Kamatero	67	50	5	64	44	4	9	0.2045	0.1800	0.0245	
71	Drosia	98	79	5	107	72	8	19	0.2639	0.2405	0.0234	
46	Nea Penteli	73	58	5	73	53	5	14	0.2642	0.2414	0.0228	
54	Pefki	60	52	2	66	47	3	11	0.2340	0.2115	0.0225	
39	Melissia	65	50	4	68	46	5	12	0.2609	0.2400	0.0209	
57	Peristeri I	36	29	2	30	26	1	5	0.1923	0.1724	0.0199	✓
30	Kallithea	31	27	1	34	24	2	4	0.1667	0.1481	0.0185	✓
10	Ano Liosia	76	66	2	83	60	5	12	0.2000	0.1818	0.0182	
82	Liosion Bus Station	29	25	1	34	23	2	4	0.1739	0.1600	0.0139	✓
40	Metamorfosi	63	50	4	65	47	4	10	0.2128	0.2000	0.0128	
74	Pikermi	95	70	7	102	67	8	18	0.2687	0.2571	0.0115	
66	Vyronas	31	25	2	35	22	3	2	0.0909	0.0800	0.0109	
77	Varympompi	142	87	17	159	83	20	18	0.2169	0.2069	0.0100	
22	Galatsi	46	38	2	52	35	4	4	0.1143	0.1053	0.0090	
47	Nea Smyrni	26	23	1	30	22	2	4	0.1818	0.1739	0.0079	
92	Petralona	20	17	1	25	16	2	2	0.1250	0.1176	0.0074	✓
42	Nea Chalkidona	35	30	1	41	29	3	6	0.2069	0.2000	0.0069	✓
44	Nea Filadelfeia	40	33	2	43	32	2	6	0.1875	0.1818	0.0057	✓
90	Pagkrati	21	16	1	25	15	2	1	0.0667	0.0625	0.0042	
68	Zefyri	70	52	5	67	51	4	10	0.1961	0.1923	0.0038	
36	Lykovrysi	66	55	3	72	54	4	11	0.2037	0.2000	0.0037	
75	Thrakomakedones	103	81	6	107	84	5	17	0.2024	0.2099	(0.0075)	
21	Fyli	104	78	7	156	83	19	15	0.1807	0.1923	(0.0116)	
76	Vari	79	52	8	73	55	4	17	0.3091	0.3269	(0.0178)	
2	Acharnai	62	50	3	70	56	3	12	0.2143	0.2400	(0.0257)	

APPENDIX TABLE B7: List of the travel times during the morning peak of each year along with the longest distance traveled per minute for the Minimum travel time in year 2024.
Data sorted by the largest difference in distance traveled in km per minute.

Appendix C:

id_name	point_name
1	Athens
2	Acharnai
3	Aghia Paraskevi
4	Aghia Varvara
5	Aghioi Anargyroi
6	Aghios Dimitrios
7	Aghios Ioannis Rentis
8	Aigaleo
9	Alimos
10	Ano Liosia
11	Anthousa
12	Argyroupoli
13	Aspropyrgos
14	Chaidari
15	Chalandri
16	Cholargos
17	Dafni
18	Drapetsona
19	Elliniko
20	Filothei
21	Fyli
22	Galatsi
23	Gerakas
24	Glyfada
25	Glyka Nera
26	Ilion
27	Ilioupoli
28	Irakleio
29	Kaisariani
30	Kallithea
31	Kamatero
32	Keratsini
33	Kifissia
34	Koropi
35	Korydallos
36	Lykovrysi
37	Marousi
38	Marousi
39	Melissia
40	Metamorfosi
41	Moschato
42	Nea Chalkidona
43	Nea Erythraia
44	Nea Filadelfeia
45	Nea Ionia
46	Nea Penteli
47	Nea Smyrni
48	Neo Psychiko
49	Nikaia
50	Paiania
51	Palaio Faliro
52	Pallini
53	Papagou
54	Pefki
55	Penteli
56	Perama
57	Peristeri I
58	Peristeri II
59	Petroupoli
60	Piraeus
61	Psychiko
62	Spata
63	Tavros
64	Voula
65	Vrilissia
66	Vyronas
67	Ymittos
68	Zefyri
69	Zografou
70	Dionysos
71	Drosia
72	Ekali
73	Elefsina
74	Pikermi
75	Thrakomakedones
76	Vari
77	Varympompi
78	Vouliagmeni
79	Athens International Airport
80	Athens Train Station (Larissa Station)
81	Kifissos Bus Station
82	Liosion Bus Station
83	Piraeus Port
84	Girokomeio
85	Gkizi
86	Goudi
87	Koukaki
88	Kypseli
89	Neos Kosmos
90	Pagkrati
91	Patissia
92	Petralona
93	Plateia Amerikis
94	Sepolia

APPENDIX TABLE C1: List of the ID and points names for the research as they were created in "QGIS"

AM	7:00	7:01	7:02	7:03	7:04	7:05	7:06	7:07	7:08	7:09	7:10	7:11	7:12	7:13	7:14	7:15	7:16	7:17	7:18	7:19	7:20	7:21	7:22	7:23	7:24	7:25	7:26	7:27	7:28	7:29	7:30	7:31	7:32	7:33	7:34	7:35	7:36	7:37	7:38	7:39
from_id	travel_time_to_id_1																																							
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	56	56	56	56	55	55	54	54	53	53	52	52	51	50	50	50	50	50	50	52	52	52	52	52	52	52	52	52	52	53	53	53	53	53	53	53	53	53	53	52
3	34	34	33	33	33	33	33	34	35	35	34	34	34	34	33	33	32	32	31	31	31	31	31	32	32	32	33	33	33	33	33	33	33	32	32	32	32	32	32	32
4	36	36	36	36	36	35	35	35	35	35	35	36	36	35	35	35	35	35	34	34	34	34	34	34	33	34	35	36	37	36	36	35	36	36	36	36	36	36	36	35
5	34	33	33	32	32	32	32	32	32	32	32	32	33	34	34	35	35	35	35	35	34	34	34	34	34	34	34	35	36	37	37	38	39	39	39	39	39	38	38	37
6	22	22	22	22	23	23	22	22	22	22	22	22	23	23	22	22	22	23	22	22	23	23	22	22	22	22	22	22	22	23	22	22	22	22	22	22	23	23	22	22
7	35	35	35	35	35	35	39	40	41	42	42	42	41	41	41	41	41	40	40	39	39	38	38	38	39	40	39	39	38	38	38	39	39	39	39	39	38	39	40	41
8	22	22	21	21	22	22	21	21	21	22	21	21	21	22	21	21	21	22	21	21	21	22	22	21	21	22	22	21	21	22	22	21	21	21	22	22	21	21	21	21
9	50	49	48	47	46	45	45	45	45	45	45	45	45	45	46	47	47	46	46	45	45	45	46	47	47	46	46	45	45	46	47	47	46	46	45	45	45	46	47	47
10	69	69	69	68	68	67	67	67	67	67	67	67	67	67	69	69	69	69	69	69	69	69	69	69	71	71	71	71	71	71	71	71	71	70	70	69	69	69	69	68
11	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	54	54	54	54	54	76	76	77	78	79	82	82	82	83	84	84	84	84	83	83	84	84	85	85
12	37	37	38	38	37	37	37	37	36	36	36	37	37	37	38	38	37	37	37	37	37	37	37	37	36	36	36	37	38	39	38	38	37	37	38	39	39	39	38	38
13	76	76	76	75	74	73	72	71	71	70	70	69	69	68	68	67	66	65	65	65	65	65	65	81	81	81	81	81	80	79	78	77	76	75	75	74	74	73	73	72
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AM	8:20	8:21	8:22	8:23	8:24	8:25	8:26	8:27	8:28	8:29	8:30	8:31	8:32	8:33	8:34	8:35	8:36	8:37	8:38	8:39	8:40	8:41	8:42	8:43	8:44	8:45	8:46	8:47	8:48	8:49	8:50	8:51	8:52	8:53	8:54	8:55	8:56	8:57	8:58	8:59
from_id	travel_time_to_id_1																																								
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APPENDIX TABLE C2: List of the results for the morning peak on Oct 5th, 2015. All values are in minutes.

PM	5:30	5:31	5:32	5:33	5:34	5:35	5:36	5:37	5:38	5:39	5:40	5:41	5:42	5:43	5:44	5:45	5:46	5:47	5:48	5:49	5:50	5:51	5:52	5:53	5:54	5:55	5:56	5:57	5:58	5:59	6:00	6:01	6:02	6:03	6:04	6:05	6:06	6:07	6:08	6:09
from_id	travel_time_to_id_1																																							
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3	32	32	33	34	34	34	35	37	37	37	37	37	36	35	34	34	34	33	33	33	33	33	34	35	35	35	35	35	35	34	34	34	34	34	34	34	34	34	34	35
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from_id	travel_time_to_id_1																																							
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APPENDIX TABLE C3: List of the results for the afternoon peak on Oct 5th, 2015. All values are in minutes.

AM	7:00	7:01	7:02	7:03	7:04	7:05	7:06	7:07	7:08	7:09	7:10	7:11	7:12	7:13	7:14	7:15	7:16	7:17	7:18	7:19	7:20	7:21	7:22	7:23	7:24	7:25	7:26	7:27	7:28	7:29	7:30	7:31	7:32	7:33	7:34	7:35	7:36	7:37	7:38	7:39
from_id	travel_time_to_id_1																																							
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	60	64	63	62	61	60	59	58	57	56	65	64	63	62	61	60	59	63	62	61	60	59	67	66	65	64	63	62	61	60	59	58	66	65	64	63	62	61	60	64
3	30	29	28	27	26	30	29	28	27	32	31	30	29	28	27	31	30	29	28	27	31	30	32	33	32	31	30	29	28	27	26	25	32	31	30	29	28	27	26	30
4	17	16	20	19	18	17	16	15	19	18	17	16	15	19	18	17	16	15	19	18	17	16	15	19	18	17	16	15	18	17	16	15	18	17	16	15	18	17	16	15
5	32	31	30	37	36	35	34	33	32	31	35	34	33	37	36	35	34	43	42	41	40	39	38	37	36	35	34	33	32	36	35	34	33	32	31	30	29	38	37	36
6	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	16	15	14	13
7	37	36	35	34	38	37	36	39	38	37	36	35	34	33	32	31	30	33	32	31	42	41	40	39	38	37	36	35	34	37	36	35	34	33	32	31	30	41	40	39
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9	45	44	43	42	41	40	39	38	37	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	45	44	43	42	50	49	48	47	46	45	44	43	42	41	40
10	67	66	65	64	63	62	61	60	72	71	70	69	68	67	66	65	64	63	62	70	69	68	67	66	65	64	63	62	61	74	73	72	71	70	69	68	67	66	65	73
11	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	72	71	74	73	72	71	70	69	68	67	66	65	64	87	86	85	84	83	82
12	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	31	30	29	28	27	31	30	29	28	31	30	29	28	27	31	30	29	28	31
13	70	69	68	67	66	69	68	67	66	65	64	63	62	61	60	59	66	65	64	63	62	61	60	71	70	69	68	67	66	65	64	63	62	61	60	59	75	74	73	72
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15	46	45	44	43	42	41	40	39	38	37	41	40	39	38	37	46	45	44	43	42	41	40	39	38	37	36	35	34	41	45	44	43	42	41	40	39	38	37	36	40
16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	18	17	16	15	14	18	17	16	15	14	18	17	16	15	14	13	17
17	13	12	11	10	14	13	12	11	10	14	13	12	11	10	14	13	12	11	10	14	13	12	11	10	14	13	12	11	10	14	13	12	11	10	14	13	12	11	10	13
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20	41	40	39	38	37	36	36	35	34	42	41	45	44	43	42	41	40	39	38	37	41	40	47	46	45	44	43	42	41	40	39	38	45	44	43	42	41	40	46	45
21	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95
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AM	7:40	7:41	7:42	7:43	7:44	7:45	7:46	7:47	7:48	7:49	7:50	7:51	7:52	7:53	7:54	7:55	7:56	7:57	7:58	7:59	8:00	8:01	8:02	8:03	8:04	8:05	8:06	8:07	8:08	8:09	8:10	8:11	8:12	8:13	8:14	8:15	8:16	8:17	8:18	8:19
from_id	travel_time_to_id_1																																							
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	63	62	61	60	59	58	61	60	59	63	62	65	64	63	62	61	60	59	58	57	65	64	63	62	61	69	68	67	66	65	64	63	62	61	60	64	63	62	61	60
3	34	33	32	31	30	29	28	27	26	30	29	28	32	31	30	34	33	32	31	30	33	32	31	30	29	28	27	26	25	31	30	34	33	32	31	30	29	28	27	30
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6	12	16	15	14	13	16	15	14	13	12	16	15	14	13	16	15	14	13	12	16	15	14	13	16	15	14	13	12	16	15	14	13	16	15	14	13	12	16	15	14
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11	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	58	57	56	55	54
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19	21	20	19	18	22	21	20	19	22	21	20	19	18	22	21	20	19	22	21	20	19	18	22	21	20	19	22	21	20	19	18	22	21	20	19	22	21	20	19	18
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21	94	93	92	91	90	89	88	87	86	85	84	83	156	155	154	153	152	151	150	149	148	147	146	145	144	143	142	141	140	139	138	137	136	135	134	133	132	131	130	129
22	44	46	45	44	43	42	47	46	45	44	43	42	41	40	39	38	37	49	48	47	46	45	44	43	43	42	41	40	39	40	39	38	37	36	35	44	52	51	50	49
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40	58	57	56	55	54	62	61	60	59	58	57	56	55	54	53	52	51	50	49	57	56	55	54	53	52	56	55	54	53	65	64	63	62	61	60	59	58	57	65	64
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90	20	19	20	19	18	19	18	17	16	20	19	22	21	20	22	22	21	20	19	18	19	18	17	16	21	20	21	20	19	20	22	21	20	19	18	19	18	17	16	22
91	23	26	25	24	23	22	21	29	28	27	26	25	24	28	27	26	25	24	23	26	25	24	23	22	21	29	28	27	26	25	24	28	27	26	25	24	23	26	25	24
92	22	21	20	19	18	21	20	19	18	17	16	23	22	21	20	19	18	21	20	19	18	17	16	23	22	21	20	19	18	21	20	19	18	17	16	23	22	21	20	19
93	24	23	26	25	24	23	22	21	21	20	25	25	26	25	24	23	22	21	21	20	25	24	26	25	24	23	22	21	21	20	25	26	25	24	24	23	22	21	21	20
94	14	13	12	15	14	13	12	11	15	14	13	12	15	14	13	12	11	15	14	13	12	15	14	13	12	11	15	14	13	12	15	14	13	12	11	15	14	13	12	15

APPENDIX TABLE C4: List of the results for the morning peak on May 13th, 2024. All values are in minutes.

PM	5:30	5:31	5:32	5:33	5:34	5:35	5:36	5:37	5:38	5:39	5:40	5:41	5:42	5:43	5:44	5:45	5:46	5:47	5:48	5:49	5:50	5:51	5:52	5:53	5:54	5:55	5:56	5:57	5:58	5:59	6:00	6:01	6:02	6:03	6:04	6:05	6:06	6:07	6:08	6:09
from_id	travel_time_to_id_1																																							
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	60	59	68	67	66	65	64	63	62	61	55	54	69	68	67	66	65	64	63	62	61	60	68	67	66	65	64	63	62	61	71	70	69	68	67	66	65	64	63	62
3	31	30	29	28	33	32	31	30	29	34	33	32	31	30	35	34	33	32	31	30	29	28	27	26	31	30	29	28	27	26	31	30	29	28	34	33	32	31	30	35
4	20	19	18	17	16	15	18	17	16	15	18	17	16	15	19	18	17	16	15	24	23	22	21	20	19	18	17	16	15	19	18	17	16	15	20	19	18	17	16	15
5	35	34	33	32	31	30	29	33	32	41	40	39	38	37	36	35	34	33	37	36	35	34	38	37	36	35	34	33	32	36	35	34	33	37	36	35	34	33	37	36
6	13	12	16	15	14	13	16	15	14	13	12	16	15	14	13	16	15	14	13	12	16	15	14	13	16	15	14	13	12	16	15	14	13	16	15	14	13	12	16	15
7	33	32	41	40	39	38	37	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	34	38	37	36	35	34	33	45	44	43	42	41	40	39
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9	45	44	43	42	41	40	39	38	37	50	49	48	47	46	45	44	43	42	41	40	39	43	42	41	40	39	38	47	46	45	44	43	42	41	40	39	43	42	41	40
10	65	64	63	62	61	60	59	58	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	68	67
11	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	77	76
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16	13	17	16	15	14	13	18	17	16	15	14	13	19	18	17	16	15	14	13	18	17	16	15	14	13	18	17	16	15	14	13	18	17	16	15	14	13	18	17	16
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20	43	42	41	40	39	38	43	42	41	40	39	38	37	42	41	46	45	44	43	42	41	40	39	45	44	43	42	41	40	39	38	43	42	41	40	44	43	48	47	46
21	96	95	94	93	92	91	90	89	88	87	86	85	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	94	93	92	91	90	89	88	87	86	85	84	83	82
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23	43	42	41	40	39	50	49	48	47	46	45	44	43	42	41	40	39	38	50	49	48	47	46	45	44	43	42	41	40	39	44	43	42	46	45	44	43	42	41	40
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26	35	34	33	32	31	35	34	43	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	35	34	43	42	41	40	39	43	42	41	40	39	38	37	36
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31	50	49	48	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	58	57	56	55	54	53	52
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39	55	54	53	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	52	51	50	49	53	52	77	76	75	74	73	72	71	70	69	68	67	66
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42	35	34	33	32	36	35	34	33	32	31	35	34	33	32	31	30	34	33	32	31	30	29	38	37	36	35	34	33	32	36	35	34	33	32	31	30	29	38	37	36
43	65	64	63	62	61	60	59	58	57	56	55	54	63	62	61	60	65	64	63	62	61	60	59	58	57	65	64	63	62	61	60	65	74	73	72	71	70	69	68	67
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45	35	34	33	32	31	35	34	33	32	31	30	34	33	32	31	30	29	33	32	31	30	29	28	37	36	35	34	33	32	31	35	34	33	32	31	30	29	28	37	36
46	55	54	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	62	61	60	59	58	57	56	55	54	53	78	77	76	75	74	73	72	71	70	69	68	67	66
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PM	6:10	6:11	6:12	6:13	6:14	6:15	6:16	6:17	6:18	6:19	6:20	6:21	6:22	6:23	6:24	6:25	6:26	6:27	6:28	6:29	6:30	6:31	6:32	6:33	6:34	6:35	6:36	6:37	6:38	6:39	6:40	6:41	6:42	6:43	6:44	6:45	6:46	6:47	6:48	6:49
from_id	travel_time_to_id_1																																							
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	61	60	64	63	62	66	65	64	63	62	71	70	69	68	67	66	65	64	63	62	61	60	69	68	67	66	65	64	63	62	56	55	64	63	62	61	60	59	58	57
3	34	33	32	31	30	29	28	27	26	30	29	28	27	26	25	30	29	28	27	32	31	30	29	28	33	32	31	30	29	36	35	34	33	32	31	30	29	28	27	31
4	20	19	18	17	16	15	19	18	17	16	15	19	18	17	16	15	22	21	20	19	18	17	16	15	20	19	18	17	16	15	20	19	18	17	16	15	20	19	18	17
5	41	40	39	38	37	36	35	34	33	37	36	35	39	38	37	36	35	34	41	37	36	35	34	33	32	31	30	34	33	37	36	35	34	38	37	36	35	34	38	37
6	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15	14	13	17	16	15
7	38	37	36	35	34	33	38	37	42	41	40	39	38	37	36	35	34	39	38	37	36	35	34	33	32	31	40	39	38	37	36	35	34	41	40	39	38	43	42	41
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9	39	38	47	46	45	44	43	47	46	45	44	43	42	41	40	39	43	42	41	40	39	38	47	46	45	44	43	47	46	45	44	43	42	41	40	39	39	38	37	45
10	66	65	64	63	62	61	60	59	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	73	72	71	70	69	68	67	66	65	64	63	62	61	60	79	78	77
11	75	74	73	72	71	70	69	68	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	73	72
12	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30	29	28	32	31	30
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15	39	38	37	36	35	40	39	38	37	42	41	40	39	38	37	42	41	40	39	38	37	44	43	42	41	40	39	38	37	41	40	39	38	37	36	40	39	38	37	42
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18	44	43	42	41	46	45	44	43	42	41	46	45	44	43	42	41	40	39	38	41	46	45	44	43	42	41	48	47	46	45	44	43	42	41	46	45	44	43	42	41
19	19	23	22	21	20	19	23	22	21	20	19	23	22	21	20	19	23	22	21	20	19	23	22	21	20	19	23	22	21	20	19	23	22	21	20	19	23	22	21	20
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21	81	80	79	78	77	76	75	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77
22	45	44	43	42	41	40	39	38	50	49	49	48	47	46	45	44	43	42	41	46	45	44	43	42	41	40	39	38	43	42	41	50	49	48	52	51	50	49	49	48
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83	26	33	32	31	30	29	28	27	26	31	30	29	28	27	26	31	30	29	28	27	26	31	30	29	28	27	26	29	28	27	26	31	30	29	28	27	26	33	32	31
84	17	16	15	14	13	12	19	18	17	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12	17	16	15	14	13	12	17	16	15	14	13	12	17	16	15	14
85	25	24	23	22	21	20	24	23	22	21	21	29	29	28	27	26	25	24	23	22	21	20	24	24	23	22	21	20	25	24	23	22	21	20	19	18	30	29	28	27
86	24	23	22	27	26	25	24	23	22	21	20	24	23	22	21	20	25	24	23	22	21	23	22	23	22	21	21	24	23	22	23	22	21	24	23	22	21	23	22	21
87	9	12	12	11	10	9	13	12	11	10	9	13	12	11	10	9	13	12	11	10	9	13	12	11	10	9	12	12	11	10	9	13	12	11	10	9	13	12	11	10
88	26	30	29	28	27	26	27	26	25	24	23	22	21	28	27	26	30	29	28	27	26	29	28	28	27	26	25	24	23	22	21	30	29	28	27	26	29	28	27	26
89	9	8	7	11	10	9	8	7	11	10	9	8	7	11	10	9	8	7	11	10	9	8	7	11	10	9	8	7	11	10	9	8	7	11	10	9	8	7	11	10
90	20	19	18	17	21	20	25	24	23	22	21	20	19	21	20	19	18	17	16	17	16	15	18	17	21	20	19	20	24	23	22	21	20	19	18	17	16	22	21	21
91	26	25	29	28	27	26	25	24	23	22	30	29	28	27	26	25	24	29	28	27	26	25	24	23	22	31	30	29	28	27	26	25	29	28	27	26	25	24	23	22
92	20	19	18	23	22	21	20	19	18	17	16	23	22	21	20	19	18	17	28	27	26	25	24	23	22	21	26	25	24	23	22	21	20	23	22	21	20	19	18	17
93	30	32	31	30	29	28	27	26	25	24	23	22	21	20	32	31	30	29	28	27	30	29	28	27	27	26	25	24	23	22	21	20	19	28	27	30	29	28	27	26
94	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12	16	15	14	13	12

APPENDIX TABLE C5: List of the results for the afternoon peak on May 13th, 2024. All values are in minutes.