# IS A NEW METRO LINE A MEAN FOR SUSTAINABLE MOBILITY AMONG COMMUTERS? THE CASE OF THESSALONIKI CITY

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**Abstract:** No one can argue that fix route transport systems, like metro, can significantly contribute to the target of sustainable mobility by shifting a large number of persons from their current transport mode of choice – in most cases private cars. However, the individual characteristics of the traveller (like the trip purpose and the socioeconomic background) can affect the demand for such a transport mode. In this context, the paper aims to develop a methodology for the investigation of the impact of these characteristics on the potential use of the new Metro System of Thessaloniki by daily commuters. More specific, a questionnaire survey based on stated preference techniques is developed and a pilot application is conducted at the area of three future metro stations with different geographic location and economic profile. The pilot application showed daily commuters of middle and high income are more frequent users of private cars. Approximately the ¾ of commuters with destination to the city centre are expected to shift to the metro, while the corresponding share for through traffic commuters is diminished due to the dependence on the private car for large distance work trips.

**Keywords:** urban transport, sustainable mobility, metro system, stated preference, questionnaire survey.

## 1. Introduction

Nowadays, almost 60% of the European citizens are living in cities and approximately 85% of the European GDP is produced within urban areas. Despite their specific features, the European cities have to face and overcome similar problems (congestion, pollution, threats on public health, safety and security issues), with road traffic pertaining to be one of the main contributors. The delays and the greater negative impacts due to traffic congestion cost over 1% of the European GDP (Commission, 2001). In addition, the ongoing urban sprawl causes the following vicious cycle: The increase of car dependency increases the demand for new road infrastructure, which leads to the growth of new activities and the increase of the number and distance of trips, leading to the increase of car dependency and so on. The main objective of policy makers and transport planners is to abolish this cycle, or at least to delay it, by introducing initiatives that can alter not only the supply side of the transport system (e.g. new tram or metro line), but also to affect the demand for travel (such as decreasing the frequency of trips and the mode selection).

The demand of urban transport is spatially distributed and it is vital for the transport planner to detect areas presenting common travel, behavioural and socioeconomic

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characteristics. The current paper attempts to identify the factors of potential demand for a new transport mode by taking into account the above specific characteristics, which can have an impact on travellers' choice. In this context, the paper aims at the development of a methodological approach and a pilot application for the estimation of the potential use of the Thessaloniki's Metro System.

## 2. The City of Thessaloniki and the New Metro System

Thessaloniki is the largest city of Northern Greece with a population of approximately 1,000,000 inhabitants. The road network of the city centre is congested and delays are presented during peak periods mainly due to commuters' traffic. According to the General Transportation Study of the Thessaloniki metropolitan area, approximately 1,600,000 trips are made daily in the city. Almost 25% of these trips use the city centre as their origin or destination (or both) (O.M.P.The., 2000). As a result, traffic and associated environmental problems related with delays, vehicle queues,

energy consumption and pollutants emissions are observed.

The public transport system of Thessaloniki comprises the urban bus system operated by the Urban Transport Organisation (OASTH). The number of passengers annually served by this fleet is 180,000,000 approximately with a mean occupancy of 42% (Gavanas, 2005).

Currently, a metro system is under construction in the city (its completion date is foreseen for the year 2014), which is expected to serve 250,000 passengers daily (Attiko Metro, 2011). The main line of the metro (Line 1) has a total length of 9.5 km and is expected to cost approximately 1 billion euros. In addition, public funds of 400 million euros have been secured for the extension of the metro system to Kalamaria (Line 2). The master plan of the city betoken that an extensive metro network will cover the city sprawl for the next 20 years (Fig. 1). Table 1 presents the main technical and operational characteristics for the two lines that are under construction (Attiko Metro, 2011).



**Fig. 1.**
*Network Extension Plan of Thessaloniki Metro System*

**Table 1**

*Technical and Operational Characteristics of Metro System*

| Characteristic | Value |
|---|---|
| **Vehicle Capacity** | 450pas/train |
| **Density** | 5 pas/m2 |
| **Max Speed** | 80 km/h |
| **Commercial Speed** | 30 km/h |
| **Frequency** | 1min 30 sec (peak hours) - 2 min (off-peak hours) |
| **Daily Passengers** | 250,000 (Line 1) - 300,000 (Line 1+2) |
| **Max Hourly Capacity** | 18,000 pas |

It is estimated that the new metro system will have a positive impact in terms of transportation and environmental benefits. Regarding the transportation indices, it is calculated that due to the diversion of preference from the bus to the new metro Line 1, the net benefits will be approximately 68.5 million euros (values 2004), derived just from the first year of operation. These benefits were calculated to reach 188 million euros until 2036 (Papaioannou, 2007). As far as the environmental benefits are concerned, it is estimated that the operation of Line 1 within the period 2012-2041 will decrease the $CO_2$ emissions approximately by 1.25 million tones and the CO emissions by 25 thousands tones mainly due to the diminishment of road traffic volumes and congestion.

Taking all the above into account, it can be argued that the new metro system can play a key role towards the vision of sustainable mobility. However, certain questions emerge in respect to the fulfillment of the target of sustainability: How sure is it that all potential users are attracted by the new metro system? What are the individual characteristics that can act as barriers to adopt sustainable behaviour? In the context of this paper some of these questions are examined through the development of a stated preference questionnaire survey for the examination of the potential of five modes (car, motorcycle, taxi, bus, metro) for through and towards the centre commuting and a pilot application focused on three future metro station areas.

## 3. The Stated and Revealed Preference Techniques

The stated and revealed preference surveys are being used for decades in order to value nonmarket public goods. Nonmarket goods are those not exchanged in markets, such as the environmental quality and the improvement of transportation systems and services. Most of the methods are specifically designed to estimate individuals' "Willingness to Pay" (WTP) for certain improvements and services, or their "Willingness to Accept" (WTA), where the accepted (or not accepted) paying value for the improvement (or respectively worsening) of a transportation index (e.g. deaths related to road accidents) is calculated (Politis et al., 2009).

In stated preference (SP) surveys responders are asked to rate, rank or choose between different hypothetical product/service scenarios made up of different attribute

mixes. The choices made by the responders can be used to infer how they value different attributes (Abley, 2010). The methodological framework of the SP analysis is based on the random utility theory, which assumes that each consumer (the user of a new road facility or service for transport studies) is a rational decision maker, aiming to maximize his personal utility when making choices. Two of the most spread methods that are being used in SP analysis are the Contingent Valuation Method and the Conjoint Analysis Method (Sanko, 2002).

Revealed preference (RP) theory is a method by which it is possible to discern consumer behaviour on the basis of variable prices and incomes (Samuelson, 1938). A consumer with a given income will buy a mixture of products, as his income changes the mixture of goods and services will also change. It is assumed that the consumer will never select a combination which is more expensive than that which was previously chosen. RP theory deliberately ignores measures of utility and indifference. RP data are gathered either through direct observation or in surveys asking about actual behaviour. The most commonly used revealed preference method is the Hedonic Price Method (HPM).

## 4. Methodological Approach

For the purposes of the study, a questionnaire survey was conducted using SP techniques. The first part of the questionnaire comprises four sections. At the first section, a number of questions regarding the way people are moving from/to their work were asked. The second section includes questions about the household characteristics like the number of persons and the income level as it is perceived by the members of the household. The third section aims at the identification of the

personal characteristics of the responder (e.g. age and gender) and finally the last section of the revealed part is aiming to identify the current travel patterns of the interviewed persons, such as the current travel mode choice, the average travel time for commuting trips etc.

At the second part of the survey, a stated preference survey was conducted. At this part, the responders were asked to state their preference, between two (binary) preselected travel modes (car, motorcycle, taxi, bus and metro). The attributes of the choice based SP game were two: the cost of travel and the travel time. Table 2 presents an example of the cards of the SP game.

**Table 2**
*Example of the Choice Based Stated Preference Game*

| Attribute | Bus | Metro |
|-----------|-----|-------|
| Travel Cost | 0,50 euro | Increase by 0.50 euro |
| Time Cost | 30 min | Decrease by 12.2 min |

## 5. Pilot Application and Discussions of Results

In order to test the applicability of the proposed methodological approach, a pilot application was conducted comprising: the conduction of a questionnaire survey, the collection of data, the management of results and the extraction of conclusions and proposals. The questionnaire survey was conducted within a radius of 200 m (walking distance) around the area of three future metro stations for a sample of 105 commuters. Each of the station areas is characterized by a different geographic

location and income level (Gavanas, 2005): Kalamaria (east end of the city/high income), Fleming (east side of city center/medium income) and Lagada (west side of the city center/low income). In Fig. 1 it is illustrated the station areas (orange circles) and the city centre (green rectangular). The presentation of results involves the development of a series of thematic diagrams and tables for: a) each of the three metro station areas, b) the synthetic analysis, including total values for the pilot application area, c) the comparative analysis between the three areas in respect to their location and income level.

The questionnaire survey showed that the 75.2% of the responders come from households of medium income level while the percentage of both low and high income level households was found equal to 12.4%. In Fig. 2 it is presented the current mode choice for commuting in relation to the household income level, where it is evident the dominance of the private car for commuters of medium and high income. The percentage of commuters using the public bus is high for the groups of low and medium income while the percentage of taxi is relatively high (15.3%) only for the group of high income.
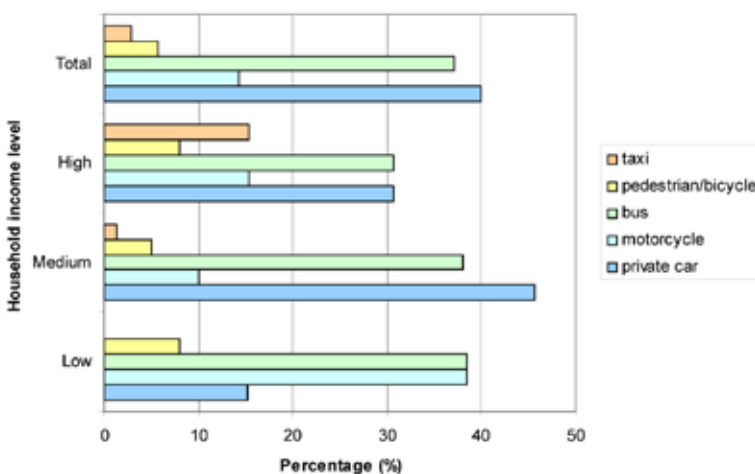


**Fig. 2.**
*Current Transport Mode Choice for Commuting in Relation to the Household Income Level*

According to the pilot application results, 70 out of the total of 105 responders are expected to shift from the current transport mode to the metro for their daily work trips. The 84.3% of these commuters are of the age groups of 18-35 (40%) and 35-55 (44.3%) while the commuters of older age seem more reluctant to change their current choice of mode. Furthermore, according to the *current mode*

*choice in relation to age and sex*, the percentage of male commuters of all age groups (18-35, 35-55 and over 55 years old) using private cars for their daily work trips is approximately 60% while the corresponding percentage for female commuters is less than 15%. On the contrary, the 58.6% of women commuters prefer the bus whereas the corresponding percentage of male commuters varies from

15.8% (18-35 years old) to 22,2% (over 55 years old).

In Table 3 there is a presentation of the *current mode choice for commuting* and the *potential shift to metro* that is expected to take place after its operation. From the Table 3 it can be observed for the Kalamaria metro station area the relatively high percentage of commuters that use private cars for their daily work trips. This is due to their higher income level and also to the comparatively larger distance that they have to travel in order to reach their destination (either towards or through the city centre). For the whole of the pilot application area, the percentage of commuters that are expected to shift from the private car to the metro after its operation is 57% with small variations among the three areas. It should also be noticed that the majority of motorcycle users in the areas which are closer to the city centre are not expected to shift from the motorcycle to the metro mainly because of the low cost, the flexibility and the door to door service provided by the specific transport mode.

**Table 3**

*Current Transport Mode Selection for Commuting and Potential Shift to Metro by Transport Mode*

| Metro station area | Transport mode | Before metro | After metro | |
|---|---|---|---|---|
| | | Current selection (%) | Current selection (%) | Shift to metro (%) |
| Kalamaria | private car | 51.4 | 22.8 | 28.6 |
| | motorcycle | 20.0 | 5.7 | 14.3 |
| | Bus | 20.0 | 2.9 | 17.1 |
| | pedestrian/bicycle | 2.9 | 2.9 | 0.0 |
| | Taxi | 5.7 | 2.8 | 2.9 |
| | **Total** | **100** | **37.1** | **62.9** |
| Fleming | private car | 34.3 | 14.3 | 20.0 |
| | motorcycle | 8.6 | 8.6 | 0.0 |
| | Bus | 45.7 | 0,0 | 45.7 |
| | pedestrian/bicycle | 5.7 | 5.7 | 0,0 |
| | Taxi | 5.7 | 2.8 | 2.9 |
| | **Total** | **100** | **31.4** | **68.6** |
| Lagada | private car | 34.3 | 14.3 | 20.0 |
| | motorcycle | 14.3 | 11.4 | 2.9 |
| | Bus | 45.7 | 5.7 | 40.0 |
| | pedestrian/bicycle | 5.7 | 0.0 | 5.7 |
| | Taxi | 0.0 | 0.0 | 0.0 |
| | **Total** | **100** | **31.4** | **68.6** |

As far as the *distribution of work trips according to destination* is concerned, the pilot application showed that 51.4% of the commuters originated from the Kalamaria metro station area have to reach a destination within the city centre and 40% conduct a through traffic work trip. The corresponding values for the Fleming and Lagada metro station areas are 54.3% and 51.4% with destination to the city centre and 28.5% and 25.7% for through traffic respectively.

In Fig. 3 and Fig. 4 it is illustrated the *transport mode choice for commuting towards* and *through the city centre* respectively. In these Figures, each pair of bars represents the *current transport*
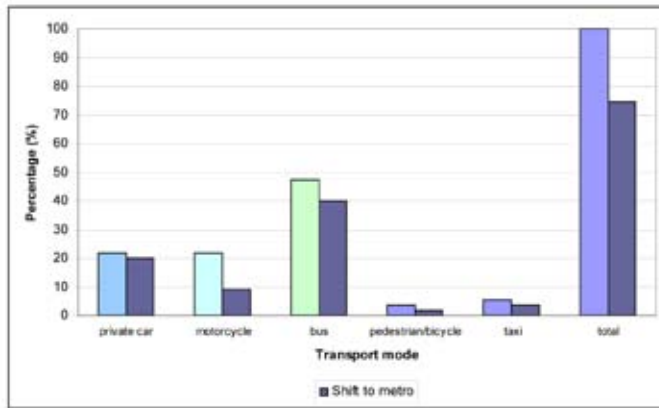


**Fig. 3.**
*Current Transport Mode Choice and Potential Shift from Each Mode to the Metro as a Percentage of Total Commuters with Destination to the City Centre*
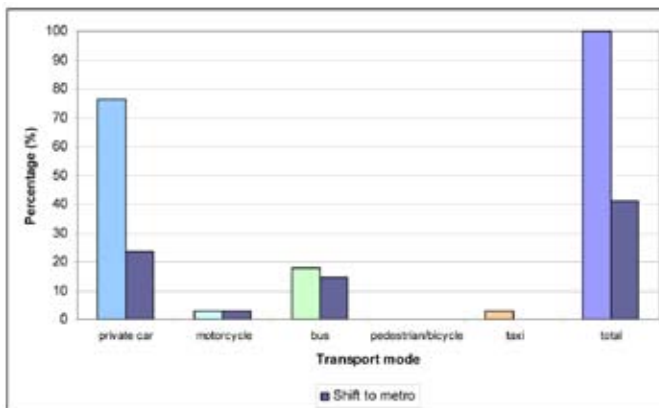


**Fig. 4.**
*Current Transport Mode Choice and Potential Shift from Each Mode to the Metro as a Percentage of Total Commuters with Destination Through the City Centre*

*mode choice* and the *potential shift from the specific mode to the metro* as percentage (%) of the total number of commuters using all modes. Fig. 3 shows that 47.3% of the commuters towards the city centre chose the bus for their daily work trips. After the operation of the metro, the commuters that are expected to shift from the bus to the new mode represent the 40% of the total number of commuters with destination to the city centre. The 74.5% of the total number of commuters with destination to the city centre are willing to shift from their current mode choice to the metro. In Fig. 4 it can be observed that 76.5% of the commuters that conduct through traffic currently use private cars and only 30.7% of them are willing to shift from this mode to the metro. An overall of 41.2% of the through traffic commuters are expected to shift from their current mode choice to the metro. In this percentage it is included the combined use of metro for the initial part of the trip and other modes (bus and rail mainly) for the final part.

## 6. Conclusive Remarks

In the current study it is presented a methodological approach (based on a stated preference questionnaire survey) for the ex ante evaluation of potential demand for the Thessaloniki Metro System. The study aims at the investigation of the role of the new transport mode for the promotion of sustainable mobility in the city of Thessaloniki. More specific, it is examined how the new transport mode will affect the mode choice of daily commuters towards and through the city centre, thus alleviating congestion from the road network during peak periods. The proposed methodological approach was tested by a pilot application which led to a series of interesting findings:

There is a strong dependency on private car use at the current situation for daily work trips and especially for trips through the city centre. The survey showed that the majority of through traffic commuters will use their cars even after the operation of the metro. Furthermore, the commuters that use motorcycles to reach their work places in the city centre appear satisfied with the level of service provided by the specific mode and are not willing to shift to the new transport mode. The greatest share of the metro users is expected to come from commuters that currently use the Thessaloniki public bus system. This is due to the fact that the main routes of the public bus network today are parallel to the under construction metro lines. Finally, it was also observed that in the current situation there is almost no use of combined transport for commuting through the city centre.

Thus, in order to further reduce the use of the private car it is proposed the promotion of the combined use of public transport modes and more specific: the provision of vertical connections to the main metro lines by the public bus system and the complementary use of the metro with other fixed route systems (such as suburban railway) in order to service long distance trips. At the same time, the metro's park & ride services is expected to contribute towards this direction. Furthermore, the operation of the metro system should be combined with measures for the restriction of the private car use and the promotion and extensive use of bicycle networks, bus lanes and pedestrian ways in the wider area of the city centre and other areas. Thus, the new transport mode will provide the opportunity of radically change the profile of the Thessaloniki transport system and upgrade the quality of the urban environment.

## Acknowledgments

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## DA LI JE NOVA LINIJA METROA NAČIN ZA POSTIZANJE ODRŽIVE MOBILNOSTI DNEVNE MIGRACIJE PUTNIKA? SLUČAJ SOLUNA

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**Sažetak:** Ne može se osporiti da podsistemi javnog masovnog linijskog transporta, poput metroa, mogu značajno da doprinesu održivoj mobilnosti, preusmeravajući veliki broj putnika koje se trenutno, u većini slučajeva, opredeljuju za privatne automobile, na drugi vid prevoza. Međutim, i individualne odlike putnika (kao što su svrha putovanja i socioekonomske karakteristike) mogu da utiču na potražnju za jednim takvim vidom transporta. Shodno tome, cilj ovog rada je da razvije metodologiju za istraživanje uticaja ovih karakteristika stalnih korisnika na potrebu uvođenja podsistema metroa u Solunu. Definisan je upitnik koji se zasniva na tehnikama iskazane preferencije i sprovedeno je pilot istraživanje u zonama tri buduće stanice metroa sa različitim geografskim lokacijama i ekonomskim profilom korisnika. Pilot istraživanje je pokazalo da stalni putnici sa srednjim i visokim primanjima češće koriste privatne automobile. Očekuje se da bi oko ¾ stalnih putnika, čije je krajnje odredište centar grada, trebalo da promeni vid kretanja i da svoje putovanje realizuje metroom, dok se očekuje da će udeo ovog vida transporta kod stalnih putnika sa dijametralnim karakteristikama putovanja biti znatno niži, usled korišćenja privatnih automobila za duga dijametralna putovanja do posla.

**Ključne reči:** javni gradski transport, održiva mobilnost, sistem metroa, iskazane preferencije, anketa.