

Land Use around Metro Stations: A Case Study

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Abstract—Transport and land use are two systems that are mutually influenced. Their interaction is a complex process associated with continuous feedback. The paper examines the existing land use around an under construction metro station of the new metro network of Thessaloniki, Greece, through the use of field investigations, around the station's predefined location. Moreover, except from the analytical land use recording, a sampling questionnaire survey is addressed to several selected enterprises of the study area. The survey aims to specify the characteristics of the enterprises, the trip patterns of their employees and clients, as well as the stated preferences towards the changes the new metro station is considered to bring to the area. The interpretation of the inter-relationships among selected data from the questionnaire survey takes place using the method of Principal Components Analysis for Categorical Data. The followed methodology and the survey's results contribute to the enrichment of the relevant bibliography concerning the way the creation of a new metro station can have an impact on the land use pattern of an area, by examining the situation before the operation of the station.

Keywords—land use, metro station, questionnaire survey

I. INTRODUCTION

LAND use and transportation are two systems that are mutually influenced. According to Aravantinos [1], between the two systems there is a peculiar but decisive relationship; each one supplements and enhances, while at the same time degenerates, disrupts and disaggregates the other. The exact relationships that characterize this interaction are difficult to define sufficiently [2]. The investigation of the impact of a new transit station on the land use system of an area can be performed using two different categories of methods: the first one includes comparative empirical studies before and after the operation of the station and the other one involves the use of integrated land use – transport models [3]. The methodology followed in this paper belongs to the former category. In particular, this paper focuses on the analysis of the existing land use around an under construction metro station (Papafi Station) of the new metro network of Thessaloniki, Greece, through the use of field investigations, around the

station's predefined location. Thessaloniki is the second biggest city in Greece, covering an area of 6,038 Ha with a population of 790,824 inhabitants, according to 2011 census [4]. It is among very few European cities which, although their population is above 700,000 inhabitants, do not have any track based public transportation system. This situation is expected to change with the construction of a contemporary metro system, which is the largest on - going transport project in the country. The Thessaloniki basic metro line will have a length of 9.6 km, with 13 stations, crossing the city from the North - West to the South - East. The construction phase initiated in June 2006 and has not yet been completed until the moment this paper is being written (December 2011). It is estimated that after its completion, the line is going to carry 18,000 passengers/ hour/direction [5]. The research question that this paper approaches is whether the new metro line of Thessaloniki will affect the nature and function of the land use system around its stations. The objective of the paper is thus to capture the situation "before" the station becomes operational and the trends concerning its future impact on the land use pattern around it. It is estimated that the proposed research methodology could be used as a "pilot" for future studies before and after the launching of the metro system. The study of the impact of a transport system on land use patterns is useful, as transport planning should be integrated with land use policies with the aim of enhancing the role of public transport and promoting more environmental friendly, alternative means of transport. The paper is structured as follows: literature review concerning the impact of new transport infrastructure on land use, enriched by results of relevant case studies worldwide, description and analysis of the case study area, data collection and methodology, presentation and critical analysis of the results, conclusions drawn and ideas for further research on the topic.

II. LITERATURE REVIEW

A large number of studies have taken place attempting to describe the underlying relationship between increasing accessibility and changes in land use patterns of an area.

Exploring the impact the introduction of a new track based public transport network, or the extension of its existing infrastructure can have on the land use system has been the objective of several researches, with case studies in European and American cities. Knight and Trygg [6] examined the impact of a new metro station in Toronto, Canada, on residential density around it. According to their research's results, the first two years after the station's opening there was no particular change in density, whereas within the next five years important density increase was reported in the residential

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areas nearby in comparison with the areas that were not included in the station's influence zone. Similar results were found by Spengler [7] for New York's Metro, but this study revealed that changes in transport infrastructure are not likely to motivate urban development without the co - existence of other favorable factors. The impact of the BART (Bay Area Rapid Transit) system of San Francisco on land use system, twenty years after the start of its operation, was the objective of the research undertaken by Cervero and Landis (1997) [8]. The study concludes that the impact on land use is of local character and limited to the city centre, and there is minor impact around certain suburban stations. Therefore, the existence of the stations does not affect exclusively the land use system, but it is one of its main formation factors.

In Europe, the research of the impact of Munich's Metro on land use in 1978 shows that the high income classes tend to move to the suburbs, contributing to the spatial division of residential and work spaces and to the reduction of traffic congestion alongside major road axes [9]. Gentlemen et al. [10] examined the impact of new metro stations and the extension of a railway line in Glasgow on the land use system. The methodology used was the comparative analysis of empirical data collected before and one year after the transport innovations. An increase in trade and office uses, and storage spaces of the examined areas was detected. With regard to land values there was recovery of the previous years' decline in property prices. Small increases in the population were also reported.

A book by Hass - Klau et al. (2004), examines the effect of trams and light rail stations on residential property prices, office rents and retailing, in 15 cities in France, Germany, UK and Canada, covering developments since the late 1970s [11]. This study reveals that proximity to rail infrastructure has a positive impact on land value in the vast majority of case studies. These results are enhanced by a recent LSE research, with a case study of a German high speed rail track connecting Cologne and Frankfurt [12], presenting evidence which demonstrates that high speed rail systems sustainably promote economic activity within regions that enjoy an increase in accessibility. Moreover, Gibbons and Machin, [13] showed that an increase of almost 10% in property prices was experienced in places affected by the Jubilee's line extension, compared to those which remained unaffected in London.

The only experience in Greece so far about the impacts of a metro station to the transport and land use system comes from the city of Athens where there is an extensive metro network. A research study of this kind, which focuses on the city of Athens, has been undertaken by Tzouvadakis et al. [14] In particular, the researchers examined the effect of seven Athens metro stations within a buffer zone of 250 m. in order to test the relation between commercial land use and rail transport infrastructure innovation. An increase of the retail activity was reported at the non - residential properties located within 100 m. of the stations, while other positive results include growth of the pedestrians flow and the enhancement of employees' mobility, as well as general upgrade of the area's urban environment.

In February 2011, ATTIKO METRO S.A. announced the intention to update the Athens' Metro Development Study by analytical land use and job positions' recording and socio - economic characteristics estimation for the whole Attiki's region [5].

III. CASE STUDY AREA, DATA COLLECTION AND METHODOLOGY

Papafi station is situated in the area of East Thessaloniki, within a walking distance from the so - called "historic centre" of the city. It is the 7th station of the metro line. The buffer zone of the research was defined as the area included in a radius of 500 m around the location of the station's future infrastructure (Figure 1). The limits of the buffer zone are defined by the surrounding streets. The criteria for the choice of the Papafi Station as the case study of this research were the location of the station within the urban tissue of Thessaloniki, the existing transport connections of the area, as well as its urban character. The area is characterized by dense urban tissue, compact building activity, extended land segmentation and lack of open public spaces.



Fig. 1 Research buffer zone of 500 m. around Papafi Station (Google Earth, 2010)

The expected impact of the new Thessaloniki's Metro on land use was examined through detailed field work [15], by the gathering, elaboration and display of a significant volume of primary information concerning the nature and characteristics of the land use system. It comprises two parts: the first one includes the analytical recording of the land use type and attributes, covering the whole study area whilst the second one is a sampling questionnaire survey the objective of which is to specify the characteristics of the enterprises, the trip patterns of their employees and clients, as well as the stated preferences towards the changes the new metro station believed to bring to the area.

The questionnaire survey involved the preparation and distribution of questionnaires focused on the non - residential land use system of the zone and was addressed to employees and clients of various enterprises within the zone. The completion of the questionnaires took place by the use of the

method of personal interview. Both the land use recording and the questionnaire survey took place in February - March 2010.

The document that was used to record the land use of the zone includes characteristics such as the building's address, the number of floors, the type of the land use of the ground floor (there is provision for the potential existence of up to 5 different land use kinds for each building), the main (average) land use of the building's levels and the number of households (corresponding to the number of door bells). The coding was based on the official coding used by the Hellenic Statistical Authority (EL. STAT.), after making the necessary changes and adaptations in order to make it suitable for the area. In particular, 12 main categories were formed, 3 of which were analyzed further in 3 sub - categories each.

The questionnaire is separated in two parts, with the one describing the attributes of the enterprise and its staff, and the other part the stated preferences (SP) of the persons involved. More specifically, the first part records both quantitative and qualitative data such as the company's type, the state of ownership (rented or owned property), year and reason(s) of installation, number of employees and average number of clients daily, the transport mode that they use to reach the company etc. The second part consists of the interviewees' SP towards the potential increase of the volume of clients due to the operation of the metro station, the degree of the future development of the area and potential upgrade of the quality of life there. The questions have in their vast majority, predefined answer boxes that in some cases cover a range of potential answers (e.g. the question about the salary), in other cases, especially in the SP part, they indicate the degree of agreement with the statement. The questions that had "open type" answers were coded afterwards during office elaboration.

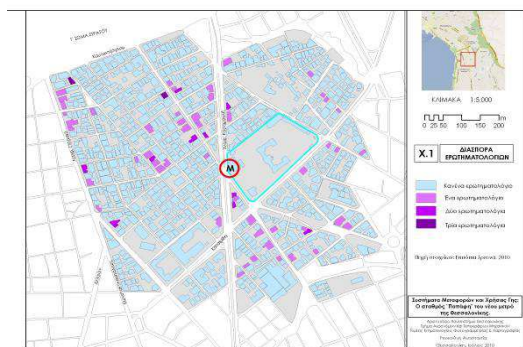


Fig. 2 GIS map illustrating the dispersion of enterprises' questionnaires

The dispersion of the enterprises within the buffer zone is indicated in Figure 2. The dark color shows that at this specific building 3 questionnaires were completed (3 different enterprises at the same building), the next one in the color scale shows that 2 questionnaires were completed, while the light one indicates the most common case of 1 questionnaire. The rest of properties (that were not examined in the sample survey) are not colored. The sampling survey provides good coverage of the examining area.

The collected data were introduced in digital databases and were connected with the corresponding spatial information;

thematic maps by the use of Geographical Information System technology were produced. The descriptive statistical analysis of all the variables took place in order to calculate the frequencies with which each variable appears in the sample. Pie charts and bar charts were formed in order to reach certain basic conclusions of the survey.

In order to achieve the effective interpretation of the inter - relationships that appear among the variables used at the questionnaires, the method of Principal Components Analysis for Categorical Data was used. This method revealed interesting correlations and contrasts that were not obvious by the simple descriptive analysis.

The Principal Components Analysis for Categorical Data is a non - linear technique of analysis in components; the relationships among the variables are represented by a small group of uncorrelated structures, usually two or three. Therefore, with the use of this method, a group of variables can be tested in order to find the principal dimensions of their variance. The initial variables are replaced with a lower number of new, uncorrelated variables, interpreting at the same time the highest possible percentage of the variance of the initial group of variables. The diagrammatic representation of the analysis' results is done using scatter plots that can either refer to the variables, the groups of variables or the objective items of the research (in this case the questionnaires) [16].

IV. RESULTS OF THE LAND USE RECORDING AND MAPPING REPRESENTATION

The detailed recording of the ground floor land use showed that within the buffer zone the existing land use system includes 1342 properties. The ground floor land use allocation is illustrated in the map of Figure 3. Commercial is the predominant land use category, covering 26.30 % of the total.. It is worth mentioning that the category with the second highest frequency is the "empty property", reaching the 21.24%. This observation is of particular interest, especially during the current financial circumstances. A significant portion of the ground floor land use (approximately 13.00%) consists of residential properties (parts of block of flats), followed by restaurants/cafes/bars and relaxation areas (5.00%). The category which includes personal services corresponds to 7.00% of the total. Two large hospitals, one children's welfare institution were recorded and 13 buildings that accommodate educational activities, which although comprising only 3.00% of the total land use, they occupy significant space and in addition to that, they are main trip generators. The spatial allocation shows that the commercial activity is mostly concentrated alongside the main road axes. The analysis of the dispersion of land use categories in the area was approached by forming zones of concentric circles starting from the radius of 100 m (and growing by 100 m. until 400 m.) around Papafi Station (Figure 3).

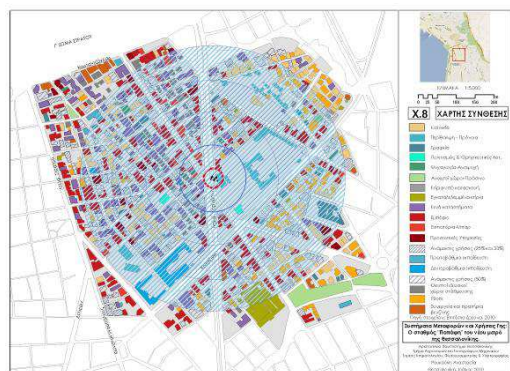


Fig. 3 GIS map showing the ground floor's land use allocation

In the internal zone, the major land use is “empty property”, southern of the principal road axis, while the following zone is characterized by the commercial use or combinations of land use spread all over the zone. In the other two external zones there is no predominant land use. Therefore, generally it can be argued that there is no over – concentration of certain activities in one or more specific zones, and thus no categorization of activities based on the distance from the station's location can be assumed safely.

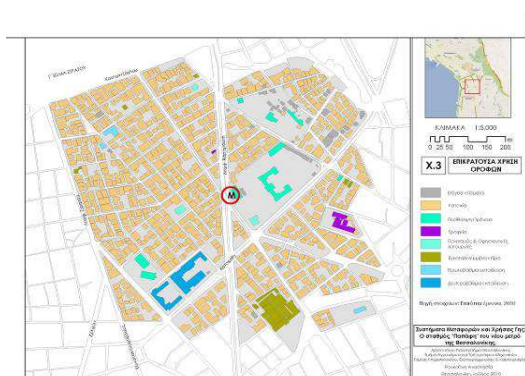


Fig. 4 GIS map showing the upper floors' main land use allocation

V. RESULTS OF THE QUESTIONNAIRE SURVEY

A total of 95 questionnaires were collected from the selected enterprises, from which 80 were considered valid to be used for the analysis. The proportion of the enterprises' type is representative of the corresponding proportion of the total study area's land use. Therefore, the predominant use belongs to the “commercial” category in this case as well. The answers were analyzed using descriptive statistical analysis.

The main results accrued by the answers of the questionnaire's first part which describes the characteristics of the enterprise and the persons related with it (employees and clients) are summarized below.

The majority of the enterprises are rented properties and their opening year lies in the '90s. The basic reason why the employers chose to establish their enterprise there is because of the advantages of the neighborhood. The rent or buying cost and the easy access by public transport were not considered to be important motivation for the enterprises' installation. The

average number of employees for each enterprise is 2 – 4 persons, whilst in many of them the owner is the only employee. The employees usually drive to work using their personal vehicle, spending approximately 6 – 15 minutes in parking search. The average number of daily clients is 1 – 20 persons for the majority of enterprises. Most of them are regular clients, pedestrians and the purpose of their trip is exclusively to visit the enterprise.

The answers of the stated preference part of the questionnaire revealed a very positive behavior towards the new Thessaloniki Metro and Papafi Station in particular. More than half of the interviewees consider that more clients are going to visit their company after the metro operation, but there is a 40% that does not think this is likely to happen. They argue that the urban environment is likely to be upgraded and there is going to be an increase in land value (rents and property prices); nevertheless 51% said that this increase is not going to be high and is more likely to range between 10 and 30% of the current prices.

In order to apply the method of Principal Components Analysis for Categorical Data, the variables of the questionnaires were divided in different groups. Each group was tested for the existence or not of correlation among its variables. The method was applied several times, using different combinations of variables each time. The main results of two applications are summarized below, accompanied by the corresponding scatter plots.

The first application includes the variables: Type of the enterprise (A1), State of ownership (A2 α), Number of employees (A5), Number of clients (A9), Regularity of clients (A10) (Figure 5). The interpretation of the scatter plot of Figure 5 shows that the enterprises that occupy only one employee and are owned and not rented properties are related with commercial or office use and with 1 – 20 average number of clients daily, while the rented properties appear to occupy more staff (2 - 20 persons) and have more visitors (20 – 500 persons), with their land use usually being leisure or personal services.

The second application includes the variables: Estimation of the area's visitors increase (B1 β), Estimation of the degree of change of consumers' behavior towards the area (B2 β), Estimation of the degree of urban environment's and quality's of life upgrade (B3 β) and Estimation of the percentage of increase in property and rent prices of the area (B4 β) (Figure 6). The interpretation of the scatter plot of Figure 6 indicates that there is a correlation between the interviewees who answered that the consumers' attitude towards the area will be subject to small or middle changes and those who think that the urban environment and quality of life will be enhanced a little or moderately, whilst there is partial correlation with the categories “increase of visitors and of property and rent prices by up to 10%”. In contrast, the category that includes those who answered that the estimated changes are expected to be experienced intensively comprises a different, clearly separated group.

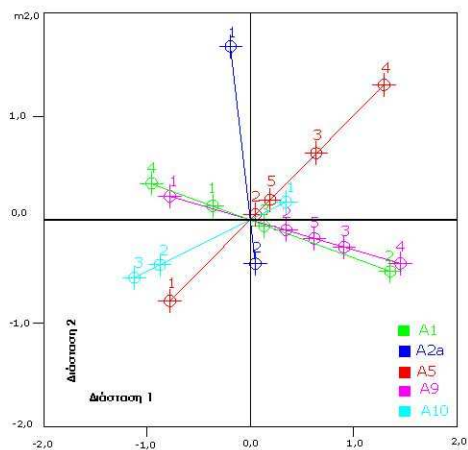


Fig. 5 Scatter plot of the first application

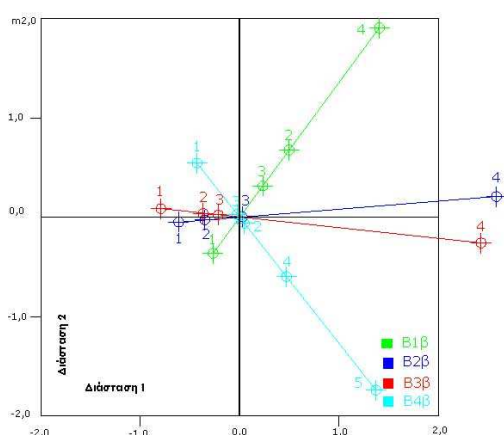


Fig. 6 Scatter plot of the second application

VI. CONCLUSION

A study that focuses on measuring the land use changes made by new transport infrastructure has not yet taken place with a wide coverage in Greece. The methodology followed and the corresponding results can contribute to the enrichment of the existing experience concerning the way a metro station affects the land use system as well as the trip characteristics in its area. A very interesting research question still to be approached is to repeat the survey after the operation of the metro line and station to compare the “before” and “after” land use and trip patterns. The paper strengthens the necessity of examining the effect of new transport infrastructure on land use in this country; plus it presents an additional to existing ones approach in order to achieve this target through the combination of land use recording, questionnaire-based survey and multivariable analysis.

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