Urban sustainable mobility indicators application in small cities: the case of Polykastro, Greece

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Abstract. The effective evaluation of the implementation of the strategies, policies, and actions toward a sustainable urban mobility system is based, among others, on the use of appropriate indicators that reflect the elements and dimensions of sustainable mobility (economic, social, and environmental). These indicators should be measurable, relevant to the target, and adapted to the scale of the city. In addition, this system of indicators should be equipped with valid and compatible data sets on transport in order to provide an effective tool for assessing the conditions of sustainable mobility in the study city. The methodology used was based on the integration of international experience in the sustainable urban mobility sector in the study area. Concluding, this paper examines the assumptions and perspectives of achieving a sustainable urban transport system in small cities, focusing on this methodology in the city of Polykastro. The paper can be used as an implementation guide for assessing the level of sustainable urban mobility in other small-sized provincial cities, such as Polykastro.

1 Introduction

The unregulated development of cities in the previous century in Greece, combined with the urbanization of a large part of the population and the ever-greater increase of private cars, led to bad living conditions in the cities of Greece, even the small ones that have the comfort of space to develop at a more smooth and "humane" pace. This problem naturally also concerns the cities abroad and especially the cities of Europe. The European Union (EU), in order to help alleviate the inequalities and distortions that have been created, tries to direct the policies of the member states through various papers, policies, announcements, actions, and directives that it issues and promotes.

In this light, Sustainable Urban Mobility, which aims at alternative means of transport, such as walking and cycling, and at strengthening mass transport by means of public transport, at appropriate spatial/urban planning and transportation planning and adequate traffic and parking management seems to be the best solution to the above concerns and negative findings [1].

One of the different ways to evaluate sustainable urban mobility is by using relevant indicators as they assess the current situation and demonstrate the perspectives and necessary directions of policy and actions.

The purpose of this paper is to investigate the concept, structure, and characteristics of an urban transport system in small cities in light of sustainability and sustainable transportation.

At the same time, it can be used as a comparative tool for the cities of corresponding size in Greece and other small-sized Mediterranean cities after the valuation of appropriate indicators, using the city of Polykastro, Greece, as a case study.

The paper's results include the recognition of the content and elements of an affordable, time-reliable, safe, and flexible urban transportation system, with optimal management of resources and improvement of the quality of life for small cities in Greece.

2 Literature review

Urban sustainable mobility is the result of an overall strategy based on sound spatial planning, effective traffic and parking management, functional and flexible urban public transport, the formation of appropriate infrastructure and conditions for the promotion of soft means of transportation, and the exploitation of new technologies with the aim of environmental protection, the reduction of pollutant emissions, and finally the improvement of the quality of life in the urban area [2].

The European Commission's definition of sustainable mobility is as follows: the term aims to meet the demand for mobility (from businesses and people) while at the same time recognizing the limits of resources and the impact of transport operations on the environment. In this definition, it is evident that no limit is placed on mobility. Unlimited mobility is taken for granted. We accept this principle at the city level [3].

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The term "sustainable mobility" emphasizes the goal of maintaining or even increasing the level of mobility in the city without, however, this increase in trips having environmental and social impacts. Mobility is sought to be protected because it is linked to the social dimension of the city [4].

Indicators can help urban societies identify important changes that need to be made at all levels of sustainability decisions, including land use, infrastructure, transportation, and not just economic policies [5].

Creating a single framework of sustainable urban mobility indicators to monitor the progress of transport systems is not possible due to the capacity and diversity of each system and urban environment. Thus, a multitude of studies have been developed, each one giving different weight to each dimension of sustainable development, using a different development methodology and ultimately ending up with different indicators [6].

Considering its interest in upgrading the quality of life in the urban area, the EU has published many papers, such as conclusions of consultations, committee conferences, green and white papers, directives, etc. With these papers, guiding policies are formulated regarding the development of transport at the national and European levels.

At the Greek level, in recent years, there has been an obvious attempt to integrate the issue of sustainable urban mobility into the priorities of politicians, at the regional and local level, such as the "Proposal for the strategy of urban mobility in matters of competence" of the Ministry of Internal Affairs and Communications of 2008. Especially for the preparation of Sustainable Urban Mobility Plans (SUMPs), the Green Fund of the Ministry of the Interior is expected to allocate approximately 9 million euros to fund SUMPs in approximately 150 Greek Municipalities.

In the context of supporting the sustainability of urban transport and mobility in the EU, several research programs and initiatives have been implemented and are still being implemented today, in the context of which several projects have been financed in the direction of sustainable urban mobility (e.g., CIVITAS Initiative, ELTISPLUS Program, Eco Mobility SHIFT Initiative, SOLUTIONS project, NICHES+ project, 2MOVE2 project, TRANSPOWER project, VIAJEO PLUS project, PLUME project, SMILE project, SUTRA project, etc.).

3 The city of Polykastro

Polykastro is the seat of the homonymous Municipal Unit of the Municipality of Paionia, a municipality of the Kilkis Regional Unit. The seat of the Municipality is Polykastro, with 6,497 inhabitants.

As an area, it is not so important to be studied per se, but the importance of this paper is the fact that there are many similar small-sized cities in Greece and in the Mediterranean for which this work could be used to develop relevant methodologies for comparative studies.

The city attracts the trips of the citizens of the entire Municipality in order to be served by its existing infrastructures.

There is intense business and commercial activity, a Health Center, as well as camps with a large number of soldiers and military personnel.

Around the city, there are crafts with a variety of activities, but also two large dairy industries.

To the west and at a distance of 500 meters from the center flows the Axios River, and the Athens-Skopje railway line passes through Polykastro (the new electric railway connection is also being built).

The existing routes of the KTEL Kilkis (the intercity bus operator) that serves Polykastro are the following: Polykastro-Thessaloniki and Polykastro-Evzonoi. There are also the Korona-Polykastro road axes and various complementary road axes that connect the settlements to each other. The Municipality of Paionia also has extensive rural road infrastructure.

Although most of the urban fabric is developed on flat ground, apart from the western area, which is built on the slopes of a hill, there is no network of cycle paths or public transport. As a result, the streets of Polykastro are full of cars and trucks serving the shops' commercial traffic. Also, to these trips are added the trips of the military in the region, often also the trips of military vehicles, the long-distance transport, and the trips of those who want to avoid the international road to Skopje due to the existence of tolls. Consequently, walking is not attractive and safe, and the use of bicycles is discouraged.

In Fig. 1, an indicative city map of the road network of the city of Polykastro is presented.

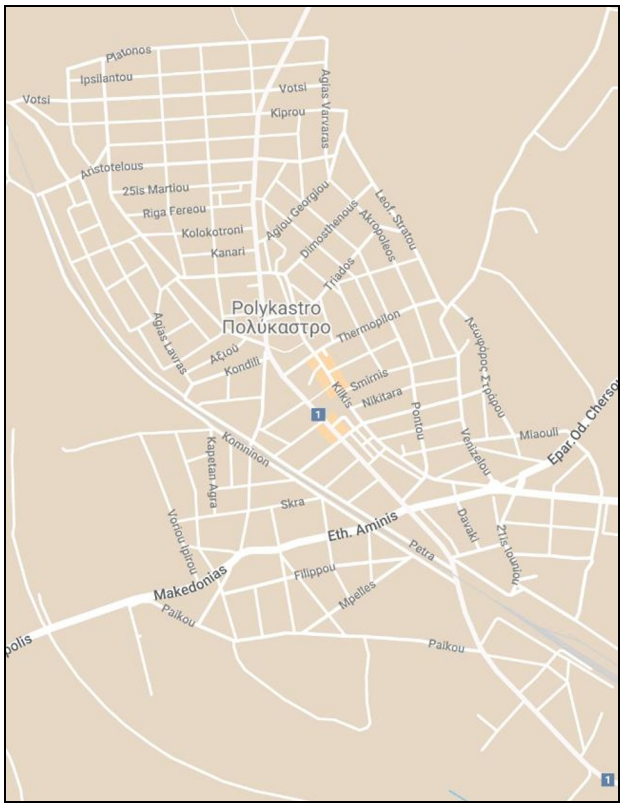

Fig. 1. Road network of the city of Polykastro [7].

4 Selection and calculation of indicators for the city of Polykastro

The selection of indicators must meet the following criteria:
1. Completeness: the indicators must cover the transport activities of the area under study but also reflect social, environmental, and economic impacts.
2. Data quality: data collection methods must ensure accuracy and follow valid standards.
3. Comparability: results must be comparable across groups and times [8].
4. Ease of understanding: indicators must be clear and understandable to every citizen.
5. Accessibility and transparency: all data must be available to stakeholders.
6. Cost-effectiveness: indicators must be cost-effective.
7. Clear results: indicators must differentiate overall effects from effects in different regions and time periods.
8. Performance targets: indicators should be suitable for setting targets.

The choice of the index system was made based on the basic characteristics of the city of Polykastro and its particularities after the examination of relevant literature [5-6], [8].

Sources of data and information were archives, studies, and services of the Municipality of Paionia, the Hellenic Statistical Authority (2011 census), the available literature, filled questionnaires by city inhabitants, and on-site indicative measurements of traffic volume.

It is noted that almost all Greek cities of the size of Polykastro do not have public transport, with the exception of the island regions, where urban transport is almost necessary to serve seasonal tourism. Therefore, the selection of indicators with reference to the characteristics of public transport was not considered necessary since they would have been zero. Also, the situation is similar for the network of cycle paths and pedestrian paths. In addition, due to the small population size, it is recommended that there is no question of traffic jams and corresponding delays.

Based on the above, the four (4) main axes of the strategy of the indicators that were selected are the following:
1. Unified spatial, urban, and transportation planning.
2. Traffic and parking management.
3. Promotion of alternative transportation.
4. Promotion of technologies and measures for the environment.

A total of twenty-one (21) indicators were selected, which are listed in Table 1, and grouped in the five (5) corresponding axes.

During the preparation of this research, 104 questionnaires were filled, which in relation to the above reference population corresponds to a confidence level of 90% and a margin of error of 8%. The reference population is considered to be the inhabitants of the city of Polykastro minus the percentage of people who could not express a reliable or important opinion, e.g., due to age.

Thus, the reference population will be considered the population at the last census (6,497 people) minus the percentage of people aged 0-15, which is around 15% (975 people), according to data from the Hellenic Statistical Authority, that is 5,522 people.

Table 1. Selection of indicators of sustainable urban mobility for the city of Polykastro.

Strategy	Goals	Indicators
Unified spatial, urban, and transportation planning.	• Improved access to services and goods	A1: GDP[1] per capita. A2: Area (km^2). A3: Population density. A4: % of population in less than 500 meters from services. A5: Private car ownership (vehicles/1,000 inhabitants).
Efficient traffic and parking management.	• Estimated travel time by all means. • Reduction of noise levels and pollutant emissions. • Improving road safety. • Enhancing multimodality.	B1: Distribution of trips per means (car, truck, bicycle, motorcycle). B2: Average vehicle occupancy. B3: Number of traffic accidents. B4: Feeling safe traveling by car. B5: Cost of commuting in relation to monthly income. B6: Percentage of annoyance from traffic noise during the day and night.
Promotion of alternative transportation.	• Improving the level of service of public transport, pedestrian, and cycle paths. • Shaping user behavior for sustainable mobility. • Redistribution of public space.	C1: Percentage of expression of interest in the creation of an urban public transport network and its use. C2: Density of cycling network (m/m^2). C3: Percentage of length of cycle paths in relation to the road network. C4: Percentage of road length with mild traffic measures. C5: Percentage of sidewalks, ramps, and parking spaces for disabled access. C6: Percentage of expression of interest in creating a network of cycle paths and bicycle use. C7: Percentage of interest in creating sidewalks and moving on foot. C8: Traffic accidents (number) involving pedestrians and cyclists.

4. Promotion of technologies and measures for the environment.	• Reduction of pollutant emissions and improvement of the quality of life of the inhabitants.	D1: Total annual emissions of CO, NO_X, PM. D2: Number of hybrid, electric, and gas vehicles.
1. Gross Domestic Product (GDP). 2. Liquefied Petrol Gas (LPG).		

5 Results

The values of the sustainable urban mobility indicators for the city of Polykastro are presented below:

A1. GDP per capita: Since there is no data for the Municipality of Paionia, we consider that the GDP per capita is the same as in the whole Prefecture of Kilkis, i.e., €11,379 per capita.

A2. Area (km^2): The area of the city of Polykastro is 45.78 km^2.

A3. Population density: The population of the city is 6,497 inhabitants, and its area is 45.78 km^2, so the density is 141.92 inhabitants/km^2.

A4. % of population in less than 500 meters from services: From relevant calculations on the urban planning map of Polykastro, the percentage is approximately 35%.

A5. Private car ownership (vehicles/1,000 inhabitants): The relative index, after calculations and deductions, is 296.38 vehicles/1,000 inhabitants.

B1. Distribution of trips per means (car, truck, bicycle, motorcycle): Traffic volumes were measured daily during peak hours (07:15-08:45 and 13:00-15:00) for a week in July. The modal share was found to be approximately as follows: Cars = 65%, Trucks = 15%, Bicycles = 5%, Motorcycles = 8%, and Walking = 7%.

B2. Average vehicle occupancy: Based on the responses to the questionnaire, the index was calculated at 1.56 people/vehicle.

B3. Number of traffic accidents: The data on the number of traffic accidents concern the entire Municipality of Paionia, as it was not possible to specify the data for the city of Polykastro. Their number for 2016 was equal to 34.

B4. Feeling safe traveling by car: According to the corresponding answers to the questionnaire, the following results were obtained regarding how safe the respondents feel while traveling by car: not at all safe = 18.27%, a little safe = 20.19%, quite safe = 29.81%, very safe = 25, 00%, too much safe = 6.73%.

B5. Cost of commuting in relation to monthly income: The results for this indicator were also derived from the answers given questionnaire survey: <10% = 67.30%, 10-25% = 32.70%, >25% = 0.00%.

B6. Percentage of annoyance from traffic noise during the day and night: The results were derived from the questionnaire survey, and more specifically from the question: Are you bothered by traffic noise during the day and at night? The results are as follows: Yes = 57.69%, No = 42.31%.

C1. Percentage of expression of interest in the creation of an urban public transport network and its use: The value of the index results from the answers given to the questionnaire. As can be seen from the results in the answers, the overwhelming percentage of citizens who were asked agree with the development and use of urban public transport: Yes = 83.65%, No = 16.35%.

C2. Density of cycling network (m/m^2): This index has the value zero (0) since there are no cycling paths in the city of Polykastro.

C3. Percentage of length of cycle paths in relation to the road network: As previously, this index has the value zero (0) since there are no cycling paths in the city of Polykastro.

C4. Percentage of road length with mild traffic measures: This index is estimated to have a value of <1% since the percentage of roads with light traffic measures in Polykastro is minimal. In particular, there are only two roads that are characterized as such, with one lane and wide sidewalks, and a speed limit of up to 30 km/h. Due to their geometry, they act as a deterrent to vehicle access.

C5. Percentage of sidewalks, ramps, and parking spaces for disabled access: The indicator was estimated at 35%, with on-site observation on almost all the sidewalks of the main streets as well as the side sidewalks. A large percentage of sidewalks have ramps accessible by people with disability and also a lane for people with impaired vision, while this percentage decreases as someone moves away from the city center. Unfortunately, there are not enough accessible parking spaces.

C6. Percentage of expression of interest in creating a network of cycle paths and bicycle use: The value of the index results from the relevant responses to the questionnaire: Yes = 73.08%, No = 26.92%.

C7. Percentage of interest in creating sidewalks and moving on foot: The value of the index results from the questionnaire: Yes = 78.84%, No = 21.16%.

C8. Traffic accidents (number) involving pedestrians and cyclists: After calculations, it was found that the index is equal to 8.9 accidents/year, of which 5.1 accidents involve pedestrians and 3.8 cyclists.

D1. Total annual emissions of CO, NO_X, and PM: It was not possible to find or calculate data for the emissions of pollutants: CO, NO_X, and PM.

D2. Number of hybrid, electric, and gas vehicles: Exact figures for the city of Polykastro could not be found. For this reason, European and national data were used, and relevant ratios were calculated: Hybrid vehicles = 56, Electric vehicles = 4, and Gas vehicles = 19.

From the values and the evaluation of the indicators, it seems that the city of Polykastro lags behind in quality in large part of them, constituting a relatively moderate, from the point of view of sustainability, urban mobility, and transportation system:

6 Discussion and proposals

The main issues of urban mobility and transport that need improvement and further research in the city of Polykastro were found to be the following:

• Lack of public transport or even Demand Responsive Transport (DRT) services, considering that a significant percentage of the population perceives positively the creation of a relevant network and the use of public means of transport.

• Absence of bicycle lanes: A significant percentage of the respondents responded positively to their use, provided there is relative availability. In this direction, relevant awareness-raising actions, as well as the preparation of a brief feasibility study, could highlight the dynamics of bicycle use, given the many successful examples internationally.

• Lack of planned and safe crossings and ramps for pedestrians and people with disability, as well as accessible parking spaces. The percentage of people with disability may seem to be small and not "visible" in the daily life of the city, but the improvement of its access and service infrastructure will immediately improve their quality of life, make them move more in the city, making them, thus, visible.

• Very high use of the car in local scale movements within the city, with the low occupancy of the vehicles being evident: The city today is a transit area for several through flows to and from the surrounding destinations, as well as internal private car trips that end up in the city center. The distances are short, but habits and attitudes have been formed regarding the movements that are harmful to the urban environment, and research has shown that mobility habits are difficult to change [9].

• Significant rate of road accidents, including vulnerable users: Awareness raising, tightening of police controls and fine tickets, appropriate signage, creation of light traffic zones, and pedestrian crossings are some of the measures in the right direction to mitigate this problem.

• Relatively high levels of traffic noise in the city center: Actions to limit vehicle use and their entry into the center can, among other things, contribute significantly to the reduction of emitted noise.

Based on the above, the main objectives that should govern the strategy for a sustainable urban transport and mobility system in the city of Polykastro are summarized as follows:

• To enhance its accessibility for residents and visitors, including people with disability.

• In strengthening the mobility of its inhabitants, which is a prerequisite for the development of the economy, primarily through the feasibility of operating urban municipal transport.

• It is pointed out that the proposed traffic "armoring" should not be considered as a police measure but as an intervention that will enhance the vitality of the city, fill the streets with pedestrians and cyclists, and make it more youthful, more human, happier, and more active, giving it, thus, real development prospects.

• Reducing the nuisance of the car in the center without affecting the access to the services, work, education, and supply areas of the stores.

• Reinforcement of smooth traffic conditions in the neighborhoods as well as on central roads.

• Promotion of modes of transportation that are friendly to the city's scale and environment, such as walking and cycling, which for the city of Polykastro could serve a significant percentage of the mobility needs in the general frame of the promotion of active mobility [10] by the EU.

• Investigating the possibility of organizing a municipal urban transport system, even in the form of DRT.

The research presented in this paper complements relevant research conducted in other small-sized Greek cities [11-15], and it can be used as a guide to evaluating the mobility and transportation systems of other similar small-sized provincial cities in Greece and abroad.

7 Conclusion and proposals for further research

In this paper, urban sustainable mobility indicators were applied in the case of the city of Polykastro, Greece. Polykastro is a small-sized provincial city in northern Greece. Despite the fact that the area is not so important to be studied per se, the importance of this paper is the fact that there are many similar small-sized cities in Greece and in the Mediterranean for which this work could be used to develop relevant methodologies for comparative studies.

In the frame of this research, relevant literature was reviewed. After examining the proposed indicators for small-sized cities, they were adapted to meet the peculiarities of the city of Polykastro. This is a required step in every application of sustainable transportation indicators in small-sized cities because most have peculiarities that big cities and metropolitan areas do not have. For example, small-sized cities may lack public transportation systems while giving more emphasis on active mobility (walking and cycling) compared to the bigger cities and metropolitan areas. Relevant literature should be considered in case the small-sized city gives more emphasis on cycling [16], walking [17-20], and public transportation [21-24] or even on more innovative approaches, such as carsharing [25-26], carpooling [27], and DRT [28]. Another aspect that should be considered is whether the small-sized city has a university campus or not, as in Greece, this is very common. In this case, special consideration should be given to the sustainable mobility of its university campus [29].

After all the aforementioned considerations, the city-specific list of sustainable mobility indicators can be derived. This or other similar research [14] can be used to evaluate the level of sustainable mobility of small-sized cities and even proceed with comparative studies.

Unfortunately, most sustainable mobility literature concerns big urban centers and metropolitan areas. At the same time, small-sized cities also face many challenges, for which there seems to be a lack of relevant research and literature. Our paper could make a small contribution towards enhancing the literature on sustainable mobility of small-sized cities in Greece and abroad.

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