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Identifying Factors for the Development of Sustainable Urban Transport in the Context of Urban Sprawl – A Comparative Study among EU`s Capitals

Giani-Ionel GRĂDINARU[1], Alin-Cristian MARICUȚ[2*],
Ana-Maria DINU[3], Rareș BĂLĂUȚĂ[4]

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Abstract

Sustainable urban transport is one of the goals of the Sustainable Development Goal; 11 sustainable cities and communities. With the main purpose of sustainable urban development, the paper aims to identify related fields associated with sustainable urban transport and the principal factors that influence the development of sustainable transport in the urban environment. In order to achieve these objectives, in a first phase, a bibliometric analysis is carried out based on the theme of sustainable urban transport, then to achieve the second objective, a random forest algorithm is implemented at the level of the 27 capitals of the Member States of the European Union. The main results of the paper define the concept of sustainable urban transport from the perspective of noise pollution, transport policies, transport equity, urban planning, and the transport pattern of urban citizens.

Keywords: travel behaviour, noise pollution, travel policy, transport justice, urban planning.

JEL Classification: R41, R58.

1. Introduction

Urban transport sustainability is a critical issue in the development of modern cities, particularly in the context of urban sprawl (Banister, 2008). Urban sprawl refers to the uncontrolled expansion of urban areas into the surrounding rural land, leading to low-density, car-dependent communities (Ewing et al., 2014).

[1] Bucharest University of Economic Studies, Bucharest, Romania, giani.gradinaru@csie.ase.ro.
[2] Bucharest University of Economic Studies, Bucharest, Romania, alin.maricut@csie.ase.ro.
* Corresponding author.
[3] Bucharest University of Economic Studies, Bucharest, Romania, dinuana21@stud.ase.ro.
[4] Bucharest University of Economic Studies, Bucharest, Romania, balautarares21@stud.ase.ro.

This phenomenon poses significant challenges for sustainable urban transport, which aims to reduce environmental impact, enhance mobility, and improve the quality of life for city dwellers. Taking into account the desiderata of the European Green Deal on carbon neutrality in European cities, as well as those of the Sustainable Development Strategy, the paper aims to identify the directions for developing a sustainable policy for the development of public transport in urban areas. The second objective is to identify the factors that determine the increase in sustainability in the urban environment. To achieve these goals, scientific articles indexed in the Web of Science database were initially analysed, with the keyword "transport policy" as a keyword. Subsequently, on a sample of the 27 capitals of the Member States of the European Union, a random forest model was estimated to identify the importance of predictors at the level of cities that have implemented underground transport.

Until now, in the international scientific databases, no scientific work with a similar approach, which uses predictive techniques to identify the urban development pattern of cities in the context of the implementation of the subway, has been identified.

The originality elements of this paper consist of calculating new variables based on GIS technology, using coordinates from the Open Street Map platform.

The first chapter deals with literature review, the second chapter deals with working hypotheses, the third chapter presents the methods used and the description of variables, the fourth chapter presents the main results, while the last section, dedicated to conclusions, describes the main conclusions, the limits of the research, as well as the future directions of research development.

2. Problem Statement

The United Nations goal 11.2 is to provide an accessible, safe, and sustainable urban transport system for all citizens by 2030. There are a multitude of factors that can characterise a sustainable transport system, but this paper aims to focus on transport equity, noise pollution, transport policies, urban planning, and travel patterns.

Pereira et al. (2017) argue that a certain minimum level of accessibility to key destinations is a basic need that people must satisfy. Moreover, accessibility highlights the spatial dimension of equal opportunity concerns and is a necessary but insufficient condition for promoting these. In addition, all this plays a crucial role in people's personal development and allows them to pursue a life they consider meaningful. On the other hand, Karner et al. (2024) promote the concept of equity in transport to increase the social inclusion of all urban citizens and, implicitly, to reduce urban development gaps.

Shepherd et al. (2006) points out that optimal urban transport planning strategies involve reducing fares, increasing the frequency of public transport, and implementing road charges for efficiency and financial sustainability, with the need for careful assessment of the model used and impact on society before decisions are made. On the other hand, May et al. (2006) state that although synergy of policy instruments is frequently promoted in urban transport policy, it is rarely clearly defined and achieving it remains difficult.

Current demographic and socioeconomic changes present a very volatile and unpredictable pattern of urban development, and urban planning legislation needs to take these factors into account and adapt to the dynamism of the twenty-first century Korah et al. (2017). To meet these challenges, architects and city managers must have a solid foundation of up-to-date theoretical knowledge. However, Hurlimann et al. (2021) show that study programmes in the field do not address to a significant extent key concepts of climate change, such as greenhouse gas emissions, sea level rise or wildfires, or sustainable urban development.

Another problem identified in sustainable urban transport planning is noise pollution. The biggest impact on road noise is two-wheelers during the day and cars at night, the main sources of noise being honking and the speed at which vehicles are driving (Balaji et al., 2022). Traffic noise is a source of disturbance for city dwellers, especially when it interferes with sleep, degrading quality of life (Zannin & Bunn, 2014). Da Paz et al. (2005) argue that noise pollution in urban environments has harmful effects on human health, with the hearing comfort threshold being at 65 dB. Exceeding it can seriously harm health regardless of age. Also, the results of his research on urban noise in Curitiba, Brazil show a large difference between the values measured in sound-controlled areas (residential neighbourhoods) and uncontrolled areas (city centre), the latter being much larger.

There are different types of ways to achieve sustainable urban transport, including subways, walking, or cycling. Sun (2020) claims that, on average, the subway is used daily for about 31 minutes to get to work and about 17 minutes for personal travel. Other sustainable means of transport, such as walking or cycling, have decreased in frequency of use, and the reasons for this change are lack of infrastructure (sidewalks, cycle paths), bad weather, and the danger of collision with cars. These findings are also supported by Vos (2019), who states that in order to boost public transport use and active travel, policymakers need to invest in measures that improve the passenger experience, such as separate lanes for public transport and bicycles, aesthetically and functionally attractive walking environments, or improved conditions inside public transport.

3. Research Questions / Aims of the Research

With the main purpose of sustainable urban development, the paper aims to identify related fields associated with sustainable urban transport and the principal factors that influence the development of sustainable transport in the urban environment. In order to achieve these objectives, in a first phase, a bibliometric analysis is carried out based on the theme of sustainable urban transport, then to achieve the second objective, a random forest algorithm is implemented at the level of the 27 capitals of the Member States of the European Union. Then, to achieve these two objectives, the research has been started from two research hypotheses:

H1: there is an association between urban transport patterns and citizens' quality of life.

H2: There are significant differences regarding sustainable urban transport at the level of the capitals of the Member States of the European Union.

4. Research Methods

In order to achieve the first of the objectives of the paper, the Web of Science Collection to extract the metadate of the articles that have transport policy as a keyword. Later, the co-occurance network among key words of these article was analyzed using VOSviewer.

In order to achieve the second objective of the paper it was used Random Forest algorithm. Breiman (2001) created Random Forest, which is a member of the decision tree family. Decision tree models have a hierarchical structure similar to that of a tree and make predictions by dividing the prediction space into several subsections. There are two processes involved in the development of decision trees. First, divide the feature space (the range of values for each characteristic) into several different regions in each division. Second, the average values of the predicted variable are forecast for each observation falling within the same region. Finding value by dividing the prediction space more effectively is the challenge. The threshold value is determined to minimise the total sum of square errors (Kuhn & Johnson, 2013). As both a classifier and a regressor, Random Forest can quickly process large amounts of data to produce highly accurate results. Adjusting hyperparameters requires less work than with other machine learning models. The number of trees, maximum tree depth, and decision factors (such as sample division and criteria for leaf nodes) are hyperparameters of this model (Ahmad et al., 2017).

Table 1. Description of indicators

Acronym	Indicator	Unit of measures	Period of references	Source
ADE	Average Distance to Education	yards	2024	Open Street Map
ADPT	Average Distance to public transport	yards	2024	Open Street Map
ADMS	Average Distance to Medical Services	yards	2024	Open Street Map
GAC	Green Area per Capita	yards	2022	OECD
PK	Parking	Number of parking place	2024	Open Street Map
CPE	4 floors	Number of buildings	2024	Open Street Map
CZE	10 floors	Number of buildings	2024	Open Street Map
DGS	Density of Green Space	Percentage	2024	Open Street Map

Acronym	Indicator	Unit of measures	Period of references	Source
DCI	Density Commercial Industrial	Percentage	2024	Open Street Map
DPK	Density Park	Percentage	2024	Open Street Map
ADS	Average Distance Supermarket	yards	2024	Open Street Map
ADF	Average Distance Fuel	yards	2024	Open Street Map
GDPC	GDP Capita	Dolars per capita	2022	OECD
LPR	Labour Productivity	Dolars per employed persons	2022	OECD
UPE	Urban population exposed to harmful levels of long-term road traffic noise	%	2022	European Environment Agency

Source: own work.

The variables that have Open Street Map as a data source were calculated by the authors based on geospatial coordinates, which were taken in R, using the osmdata package. Distance variables (ADE, ADPT, ADMS, ADS, ADF) were calculated as average distances from residential buildings (apartments, residential blocks, residential houses) to schools, kindergartens, high schools, gas stations, supermarkets, public transport stations, hospitals, or doctor's offices (Table 1). To calculate these distances, the entire road network was entered for each statistical unit. In the case of ADE variables, ADPT distance was calculated using the entire road network allowing movement without a means of locomotion ("by foot"), while in the case of ADF, ADS, ADMS variables, the entire public road network was used, which can be used by transport by motor vehicle ("by motorcar"). These two approaches were chosen because it is important that access from residential buildings to public transport stations and educational establishments is achieved without using a vehicle, thus leading to traffic congestion relief.

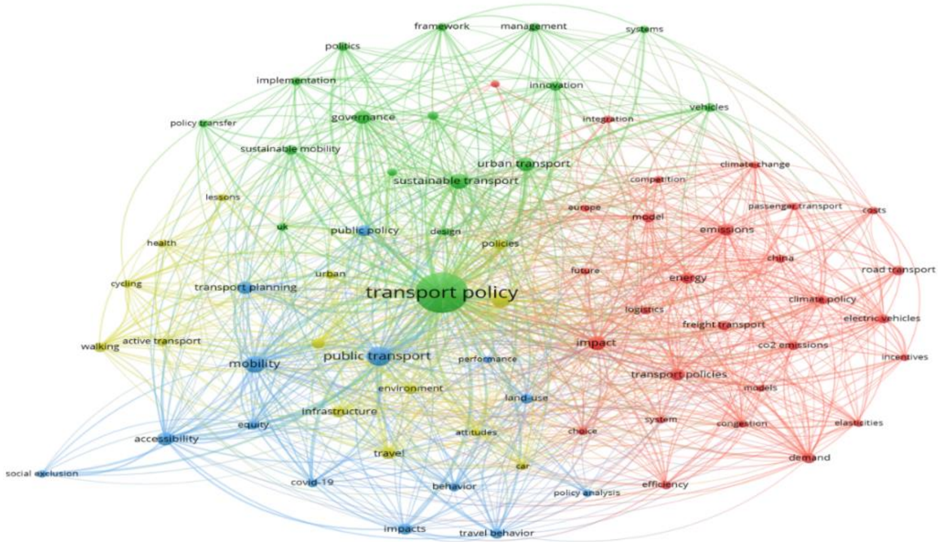
On the other hand, for the other distances, the distance travelled by a means of locomotion is much more relevant, because the frequency of these routes is lower, and, for example, in the case of access to medical services, in case of emergency, the trip is made by ambulance. All distances were calculated using the package dodgr from RStudio. The density variables are calculated as the share of the area of the units of interest (e.g., parks) in the total area of the statistical unit (Table 1).

These variables have been selected in accordance with the principle of completeness of data. Another important aspect regarding the quality of the data was their relevance, so variables were selected mainly in the urban mobility area, but also in the social / environmental area.

5. Findings

In a first phase, the network linking the keyword “transport policy” and the associated keywords was analysed.

Figure 1. Transport policy co-occurrence network

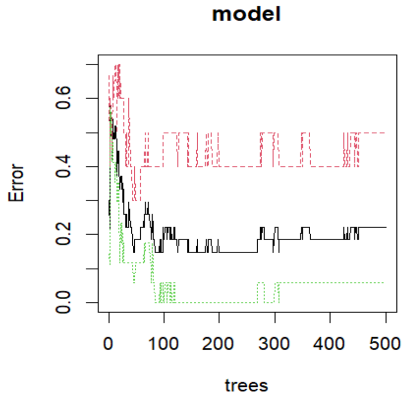


Source: own working using VOSviewer.

The transport policy process is defined by 4 clusters. The first cluster (blue) contains words such as public transport, transport planning, mobility, accessibility, equity, covid-19, which denotes that in these articles the emphasis is on unhindered access to public transport, but also on the Coronavirus pandemic, which suggests that they were written in the last 3-4 years. The second cluster (red) contains words such as electric vehicles, climate policy, emissions, impact, and climate change, which suggests that these articles address the impact of transport on the environment and climate change, offering the use of electric vehicles as a more environmentally friendly alternative. The third cluster (yellow) is made up of words such as cycling, walking, health, and active transport. Thus, these articles address healthy alternatives, both for people and the environment, to travel by car or public transport. In doing so, these modes of transport are effective in conserving fuel, reducing vehicle emissions, and improving individual and public health. The fourth cluster contains words such as sustainable transport, governance, implementation, management, and sustainable mobility, which suggests that these articles talk about how sustainable public transport policies must have the support of those in charge in order to be implemented.

As for the random forest model, the predicted variable is Metro (coded 0 for capitals that do not have subways and 1 for those that do), while the rest of the variables played the role of predictor.

Figure 2. Trees versus Errors



Source: own work using RStudio.

The algorithm used 500 decision trees, and three discriminating variables were used for each division. Given the randomness of the decision trees, the estimate with 300 trees did not give a classification error consistently less than if we took 500 trees (Figure 2). That is why we chose to use the latter value, noting that that is when the model stabilises.

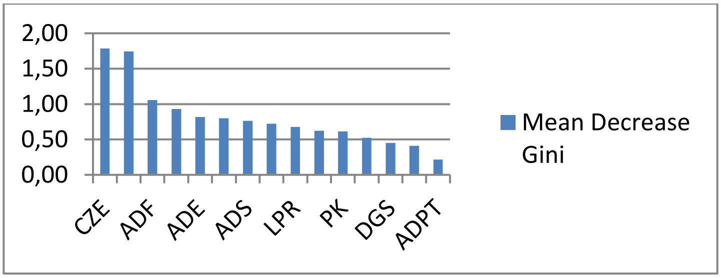
Table 2. Confusion matrix

Category	0	1	Error
0	5	5	50%
1	1	16	5,9%

Source: own work using RStudio.

The Random Forest model has a classification error equal to 22.22%, quite small, which brings into question the possibility of the existence of several capitals that did not correlate the existence of the subway with predictors. The algorithm classifies more efficiently the capitals that have a subway, having an error of only 5.88%, while those that do not have a subway classify them randomly, the error being 50%. Thus, it can be said that the model is suitable for cities that have implemented underground public transport. To better analyse the influence predictors have on the predicted variable, we need to look at their importance in classification.

Figure 3. Importance of predictors



Source: own work using Excel.

It can be stated that the predictors with the greatest influence on classification are: 4 and 10 floors buildings, density of parks and average distance to a gas station, while the least influence has GDP per capita and average distance to a public transport station (Figure 3). It follows that, mainly, the implementation of underground public transport does not depend fundamentally on economic development or on the infrastructure of public transport in a capital, but on the model of urban development, horizontally or vertically, on public places of agreement (parks) and the average distance to gas stations, confirming the idea stated by Sun (2020). Thus, the hypothesis is opened that vertical urban development would be beneficial for the implementation of the subway, because the population being more concentrated on a smaller area, not many lines and metro stations should be built to cover the entire city, resulting in lower costs. It is also interesting to note which capitals were misclassified. Thus, Athens behaves differently from capitals that use underground transport infrastructure, similar to Nicosia, Ljubljana, Luxembourg, Vilnius and Zagreb. On the other hand, Valletta, Tallinn, Dublin, Riga and Bratislava have a similar urban development pattern to cities that have metros, which opens the hypothesis for developing this means of transport in order to increase urban sustainability. Therefore, decision-makers in these cities should consider the concept of urban equality as defined by Karner et al. (2024).

6. Conclusions

Public transport policies focus on mobility, accessibility, public transport, transport planning, climate policy, road transport, and sustainable transport. Regarding the second objective, cities that develop vertically need underground urban transport, because there is an acute problem of lack of parking spaces and congestion of the city, and the implementation of underground transport would replace the need of residents to use the car and crowd traffic. The results of this study can contribute to the decision-making process at the level of local communities, in order to adopt the decision for the implementation of underground transport. In addition, the results of the study give a better understanding of the related concepts in the area of public policies in transport. H1 is therefore partially confirmed, as urban transport patterns influence citizens' quality of life from an urban mobility perspective. Regarding H2, the existence of significant differences in the development of sustainable urban transport (subway) is also confirmed.

There are some European capitals that have not yet implemented underground urban transport, but are sufficiently developed so that the natural step would be to build an underground public transport network. Among the limitations of research is the small sample volume. Also, data collected through the Open Street Map platform may have problems with the timeliness of the data, so there may be a potential gap in our results. Future research directions aim to add new predictors and also to enlarge the sample.

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