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System Dynamics Analysis of the Relationship between Urban Transportation and Overall Citizen Satisfaction: A Case Study of Patras City, Greece

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Abstract: The main objective of this research is to evaluate how the transport sector affects the satisfaction of citizens. The model developed aims both at assessing the satisfaction of citizens and using it as a tool to measure the change in citizens' satisfaction resulting from new mobility practices or policies. The developed scenarios are based on the principles of sustainability and the action plans concern: better accessibility conditions for alternative means of transport; improving travel safety; reducing air pollution, greenhouse gas emissions and energy consumption; increasing efficiency and effectiveness in the movement of people and goods; and enhancing the attractiveness and quality of the urban environment. The results reveal that it is necessary for local decision makers to take further measures to increase the overall satisfaction of citizens with the aim of prosperity and happiness of citizens within their city, and the proposed model can support the decision-making process. Utilizing the developed system dynamics model, it is possible to make simulations with new data and at the same time to evaluate the change they bring to the individual sectors and to the overall satisfaction of the citizens.

Keywords: urban transportation; satisfaction level; sustainability; system dynamics; transport indicators; SUMI; Vensim

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1. Introduction

Today, people prefer and seek to live in cities rather than in smaller societies because they provide more opportunities. According to the U.S. Census Bureau, the world's population is an estimated 7.6 billion, of which 50% is living in cities. More specifically, in 1950, the urbanization rate was at 30%, in 2014 it was almost double, and in 2050 it is estimated to reach 68%. Hence, the constant migration of people to cities makes smart cities an increasingly attractive solution, but it also poses a sustainability challenge for city managers, where human-centered urban planning becomes vital in every project. The effective organization of cities is therefore imperative. There is a general belief that the implementation of the smart city concept will provide ways for cities to better able to address residents' demands and pursue sustainable development. Adopting novel technologies that enable stakeholders to redefine the notion of urbanization and development through the creation of a smart and sustainable city would help achieve this.

Literature Review

According to Batty, M. [1], who used the systems theory to explain the change in how cities have evolved, cities are complex systems that naturally develop through a bottom-up dynamic as opposed to a top-down approach [2]. While the adoption of the smart city concept is worldwide, there is currently no reliable existing indicator model to measure the impact of the smart city or how intelligent cities have become, nor has there been any research summarizing existing models [3]. In recent years, happiness and well-being have been used as primary indicators of the quality of human life and development. Since

2012, aligned with the United Nations and the OECD, a World Happiness Report has been published with resonance to implemented policies and government meetings [4]. However, happiness and well-being are subjective and complex concepts to calculate. There are several possible methods and sample data to measure them. Some data are objective, such as unemployment rate, distance from services, school dropout rate, etc. Others are subjective, such as perceived educational conditions (which may be higher or lower than actual educational conditions). The OECD, Eurostat, and the World Happiness Report use different ways of measuring and dividing happiness and well-being into different categories [4]. The development of frameworks that examine the dynamic and interrelated impacts of smart city key elements to support early decisions among stakeholders remains, until today, an open research topic.

Investigating the systems approach as outlined in several articles [5,6] that argue that the performance of cities can be efficiently achieved via the modeling of the fundamental subsystems of a city in order to simplify the intricate systems. As planners and environmental evaluators, Lombardi et al., in their work [7] on modeling the performance of smart cities, argued that a city is a complex system and complexity is the result of some unpredictable interactions. According to these authors, complex urban systems exhibit unpredictable behaviors, from which, when certain actions are taken, feedback can be generated. Complexity, according to [5], increases with diversity, and these authors consider approaches to be adaptive and collaborative in nature. Moreover, the complex system of a city is a valuable insight when related to the evolution of information systems [6]. Therefore, evaluating the performance of smart cities requires a complex model that can analyze the core components of cities for effective decision making. It is interesting to note that systems science experts [8] advocate using dynamic modeling to simplify complicated processes and improve response times. Sterman [8] suggested adopting modeling in addition to other tools rather than as an alternative. It is suggested that the demand for new decisions exposes a gap in the search for models that explore and explain correlations between subsystems and patterns of functional behavior. Therefore, the Dynamic System approach is a useful modeling tool that produces an open, thorough framework that enables decision makers to pinpoint the connections between various variables as well as the effects of changes on any of these variables [9–11].

The indicators of a smart city can contribute to the assessment of the achievement of the goal of sustainability, the analysis of the relationship between human activities and environmental change, and the broad participation of citizens in decision making, and their results can feed back to the political process so that the necessary adjustments and corrections can be made. By adopting indicators, priority issues can be more easily identified so that data and information collection can be directed [12]. The key areas into which smart city performance indicators can be categorized are economy, governance, people, environment, mobility, and lifestyle. In recent years, another indicator of smart cities has been added to the list, which is related to the happiness-satisfaction of the residents of each smart city. Alonso et al. [13] define indicators for measuring the economic, social and environmental sustainability of passenger transport systems in a group of cities. Toth-Szabo et al. [14] propose a framework and indicator list that puts weight on subjective indicators, i.e., how the population experiences the sustainability of transport, their satisfaction with the transport system, and its effects on the environment and social issues.

The use of divergent indicators for evaluating sustainable urban transportation has emerged as a core of urban studies [15]. Transport sustainability (environmental, social, and economic) has become a central concern of urban design in the past decade. Reisi et al. [16] provided a comparative analysis of different Melbourne statistical local areas in terms of transport sustainability in environmental, social, and economic aspects. Kutty et al. [17] examine the dependency of key transportation sustainability indicators on United States economic productivity. The econometric model consisted of performance indicators: a portion of the budget devoted to transportation, per capita traffic congestion delay, and efficient pricing for transportation as the independent variable with per capita GDP as the dependent variable. The results show a strong correlation between the indicators chosen, highlighting their role in contributing towards overall sustainability. A set of 20 indicators are selected in [18] and used as an example to evaluate their applicability to monitoring the lines of action regarding transportation in the Rio de Janeiro State Climate Plan. The results indicate that certain objectives cannot be monitored from the perspective of the sustainability criteria and signal the importance of establishing monitoring criteria previously of public policy elaboration process. Commute satisfaction, neighborhood satisfaction, and housing satisfaction can be used as indicators of urban quality of life and livability due to their potential contribution to subjective wellbeing [19]. In their article, Zenker, S. and Rutter, N. [20] refer to a survey conducted in Germany aiming to distinguish the degree of urban satisfaction and how it relates to other areas. Specifically, 765 citizens participated in this survey and Zenker's Citizen Satisfaction Index (CSI) measurement was used, highlighting its strong influence on adherence to the place and positive behavior of the citizen. Through this research, it seems that the satisfaction index of citizens significantly influences the attachment to a place, its evaluation, as well as the intention to abandon it. Van Ryzin [21] finds that citizen expectations, and especially the disconfirmation of expectations, play a fundamental role in the formation of satisfaction judgments regarding the quality of urban services. Interestingly, the modeling results suggest that urban managers should seek to promote not only high-quality services, but also high expectations among citizens.

An integral part of measuring a citizen's satisfaction index is the ability to model the dynamic system of a city. One software purposed to extract the satisfaction index is the Vensim software [22]. Makhdum et al. [23] describe a system of interaction between citizens and the local government. It is a process used for organizational development based on the interactive design approach, where the citizen and the local government adopt more effective and efficient ways of cooperation and communication. Thus, the "System of systems" theory is applied in each city. The problem arises when a city presents a lack of interaction between the citizen and the local government. The digitalization of various processes in public services to facilitate citizens is an initial solution for better cooperation. It presents the mentality of smart citizens, aiming to upgrade the quality of their life [23]. Nunes et al. [24] try to provide decision makers with an analysis system that reflects smart cities as a whole, taking into account objective and subjective variables in a range of areas. The methodology used in this study was the Strategic Opinion Development and Analysis (SODA) based on cognitive maps, as well as the SD approach. Diemer et al. [25] present a dynamic system for sustainable urban planning. In particular, their urban approach can explain the complex behavior and demand of urban areas. Through repeated simulations, an analysis was carried out regarding critical urban developing indicators such as population size, building stock, and manufacturing inventory, and how changes in these sizes affect the development of a city.

At the same time, there is a strong interest in the developing potential between the social, economic, and environmental footprints that define an urban area and how it can be modeled. It is suggested that urban areas are a key driver of climate change [26]. The case study in [26] concerned the city of Vienna, where expert interviews and qualitative quantitative data analyses were conducted to extract models. The resulting simulations represent possible negative consequences if stakeholders do not understand the basic dynamics in a given urban area and do not take into account any feedback. Transport is widely considered as a sector with significant positive and negative externalities affecting society, the environment and the economy. The fact of incorporating the main principles of sustainable development into transport planning is of prime importance to social and economic activities, while also having a big impact on the environment [27,28]. Transport is also one of the important features of urban life affecting sustainability issues relating to air pollution, traffic safety, urban development patterns, and car dependency attracting the attention of policy makers [29]. Citizens of urban areas expect the highest possible outcomes in all measured aspects from public services, territorial planning and viability, as well as environmental experiences. If the transport sector improves, the experience of establishing their residence in an urban area can be maximized. This means that having satisfied urban citizens and well-being becomes one of the main actors in attracting and retaining people in urban areas [30].

The aim of this research is to assess citizens' satisfaction regarding transport, as this sector seems to have a significant influence on the daily lives of citizens. For this purpose, a pilot model was created to measure and quantify the satisfaction of residents of an urban area. The case study is the city of Patras. The evaluation is carried out regarding transport and how this sector can be affected by the key areas of sustainability, which are the environment, society, and the economy. The model is based on the concept of a System Dynamics concept and is developed by using the Vensim software. The indicators used to implement this model are the Sustainable Urban Mobility Indicators (SUMI) proposed by the European Union [31]. The model for measuring citizens' satisfaction is a model that could easily be applied in various cities and municipalities by entering the data concerning the area of application based on its needs and specific characteristics. Results reveal that it is necessary for the local decision makers to take further measures to increase the overall satisfaction of citizens with the aim of prosperity and happiness of citizens within their city, and the proposed model can support the decision-making process.

This paper is structured as follows. The Section 1 refers to the system dynamics model development, where the case study and the indicators used in the model are presented. The Section 2 introduces the casual loop modeling used for the purposes of this research. In order to create a model that will respond to real data, a process which aims at a more realistic approach to the problem, as well as the equations of the different variables used in the model, are presented in the next section. Having completed the process by defining the equations and calculating the values of each variable, the dynamic model is completed. In the next section, the simulated model will demonstrate how people's satisfaction with transport changes over time with current data. The baseline scenario as well as some indicative scenarios are developed in order to assess the citizen's satisfaction over some measures taken by the local authorities. Finally, the results and conclusions are presented and some future extensions which may be applied are mentioned.

2. Materials and Methods

2.1. System Dynamics Model Development

Efficient transportation and mobility are essential for a city to function properly. A smart city should be easily accessible for visitors and residents and commuting around the city should be uninterrupted. A smart city should provide a multifaceted, efficient, secure, and comfortable transport system, linked to information and communication technology (ICT) and open data infrastructures. The need to make new decisions highlights a gap in the search for models that examine and explain patterns of functional behaviors and correlations between subsystems [7–9]. Four phases of the methodology applied in this study are highlighted in [32–34];

i. Model Representation: The first phase is the identification of the problem, the related needs, the desired results of its solution, as well as the determination of the variables under consideration and the lifetime of the system.
ii. Casual Loop Modelling: The second phase is the development of a model by identifying the cause-and-effect relationships between the variables and constructing diagrams.
iii. Dynamic Modelling: The third phase presents the method deployed, which aims to adopt a more concrete approach to the matter since it will produce both quantitative and qualitative outcomes in addition to qualitative relationships. Additionally, it concludes the validation of the model, which facilitates the assessment of whether the results obtained are consistent with reality.
iv. Scenario planning and Modelling: The last phase provides guidelines based on the assessment and analysis of the procedures to be followed to improve this situation.

The model developed in this paper concerns a tool for assessing citizens' satisfaction with transport and how their satisfaction is affected by various sectors. In addition, it suggests an innovative way of assessing the various changes resulting from new mobility practices or policies with regard to citizens' satisfaction and can play an important role in the decision-making procedure. This model can be easily applied to any municipality or city by entering the appropriate data each time. In this study, the city of Patras was selected as a case study. In order to achieve the above task, it is considered that the transport sector is a dynamic system consisting of individual interdependent subsystems, which are the environment, the economy and society. These subsystems are also divided into other subsystems. For modeling and simulations, the System Dynamics Vensim PLE software application was used. Vensim is a simulation software that provides a graphical modeling interface with flowcharts and causal bronchus, on top of a text-based equation system in a declarative programming language. A Data Flow Chart is presented in Figure 1 describing all the methodological steps of this research, followed from the literature review to the conclusions.

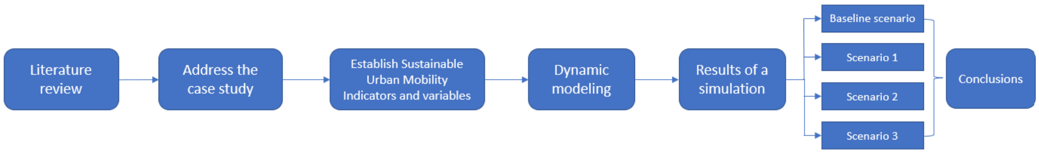

Figure 1. Data Flow Chart.

Case Study

Patras is the third largest city in Greece, with a population of 167,446 inhabitants, while the population of the Municipality of Patras amounts to 213,984 inhabitants according to the official census of 2011. The transport sector within Patras is divided into: Road & Public Transport, Rail, Air, Sea. In the context of this research, an evaluation was made only for the road, urban, as well as for the railway transport of the city of Patras.

Unlike data collected at the country level, there is no institute in Greece, such as Eurostat, that collects urban data and systematically places it in a database. For this reason, much of the data used in this paper were extracted through a specific questionnaire created for this research (S1) (sample size, n = 100) and its analysis. Other data are reasonable assumptions after research and evaluation of bibliographic references. Finally, some data were also obtained from statistical authorities, e.g., ELSTAT [35], if available.

In addition, most indicators related to the assessment of sustainable urban mobility as defined by the European Council (SUMI) were selected and used. The Scientific Committee on Environmental Problems (SCOPE) argues that the two main characteristics of the indicators are that they quantify information to make its importance clearer, and that they simplify information on complex phenomena by improving communication [36]. The indicators are presented as an integrated set covering the three dimensions of sustainable mobility. The dimensions are inspired by the pillars of sustainable development and refer to the sustainable use of resources and the impact of mobility on cities. The indicator set is a tool for cities to assess the current situation, understand the natural evolution of sustainable mobility (business as usual, or BAU) and assess the impact of selected solutions. The indicators to measure citizens' satisfaction with the transport system were grouped into three categories based on the triptych of sustainability: social, economic and environmental. It is noted that this grouping is not absolute, because many indicators can be integrated into more than one sector. Table 1 provides an overview of the Sustainable Urban Mobility Indicators (SUMI) used in this paper and their grouping.

Table 1. SUMI indicators and their grouping.

No	Group	Index	Definition
1	Economy	Affordability of public transport	Percentage of the population that uses public transport cards (unlimited monthly) in the urban area where they live.
		Access to mobility services	Percentage of population with appropriate access to mobility services (public transport).
		Opportunity for active mobility	Infrastructure for active mobility, i.e., walking and cycling.
		Quality of public spaces	Perceived satisfaction from public spaces.
2	Environment	Emissions of air pollutants	Emissions of air pollutants from all modes of passenger and freight transport (exhaust gases and non-exhaust gases for PM2.5) in the urban area.
		Greenhouse gas (GHG) emissions	Greenhouse gas emissions from all modes of transport of passengers and goods in the urban area.
		Energy efficiency	Total energy use by urban transport per passenger-kilometer and tons-kilometer.
3	Society	Road deaths	Road deaths from all road accidents in the urban area on an annual basis.
		Congestion and delays	Delays in road traffic and public transport during peak hours compared to off-peak travel (private road traffic) and optimal travel time by public transport.
		Satisfaction with public transport	Perceived satisfaction with the use of public transport.
		Active modes of operation for traffic safety	Deaths of users of active traffic modes in road accidents in the city in relation to their exposure to traffic.
		Travel time	Duration of travel to and from work or the educational institution, using any type of means of transport.
		Safety	The perceived risk of crime and the safety of passengers in urban transport.

The calculation of the above parameters was implemented through data collection by ELSTAT, Eurostat, as well as citizens' responses through corresponding questions (Appendix A). In cases where data were not sufficient, reasonable assumptions were made.

2.2. Casual Loop Modeling

The dynamic system analyzed in this paper is how the satisfaction of citizens regarding the transport sector in the Municipality of Patras is affected and changed compared to the sectors of society–economy–environment (Figure 2).

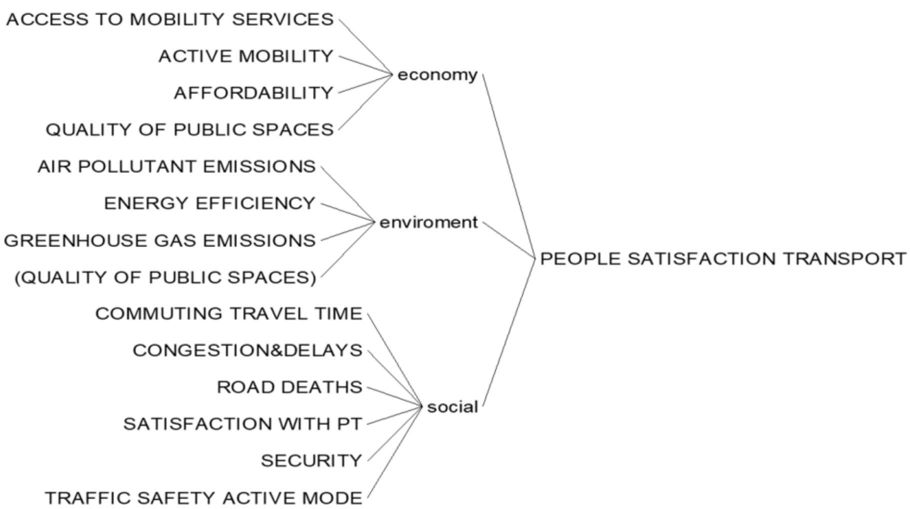

Figure 2. Citizens' satisfaction Causes Tree regarding transport.

The four variables chosen to formulate the equations of the model are environment, economy and society, as they constitute the triptych of sustainability, as well as the population. The equations of the individual variables (indicators) underpinning the model are those proposed by the EU for sustainable urban transport (Figure 3). More specifically:

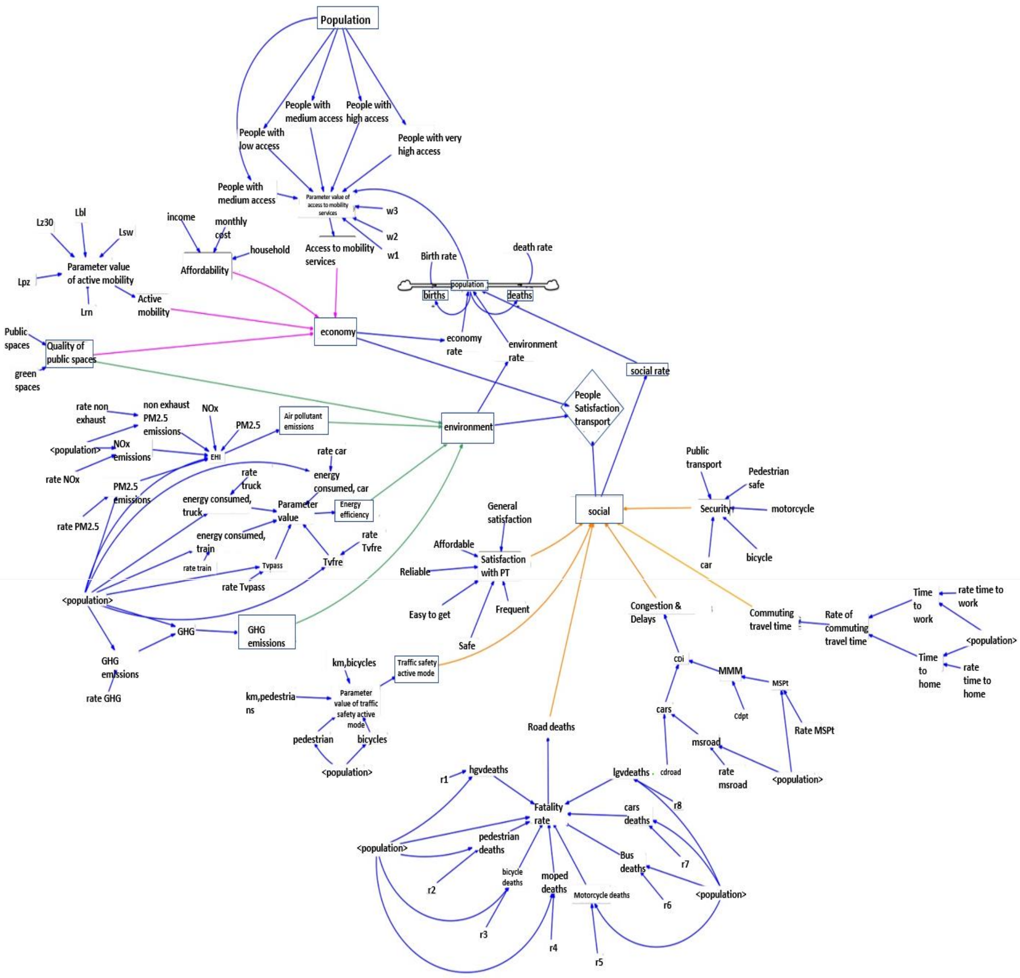

Figure 3. Visualized system based on the pillars of economy, environment and society as an index of Citizen Satisfaction regarding the transport sector in the Municipality of Patras (Vensim).

Economy: The indicators falling under this category are accessibility, affordability of public transport, quality of public spaces, as well as the possibility of active mobility. These indicators reflect the general satisfaction of citizens in matters relating to the financial capacity of the municipality in terms of construction costs, maintenance, and redevelopment costs and operating costs of public transport.

Environment: This category includes indicators of air pollution, greenhouse gas (GHG) emissions, energy efficiency and quality of public and green spaces. Citizens' satisfaction with the urban environment is directly linked to its quality and it is these indicators that assess the impact of transport on the environment.

Society: The indicators of this category are road deaths, congestion and delays, satisfaction with public transport, active modes of operation for traffic safety, travel time, and safety. The indicators were selected to meet the criteria of assessing citizens' satisfaction with social cohesion, human security, and health and well-being.

2.3. Dynamic Modeling

In order to create a model that will respond to real data, it was deemed necessary to introduce into the Vensim software appropriate equations that will indicate with mathematical relationships of the interaction between the variables. This process aims at a more realistic approach to the problem, as in addition to qualitative relationships, it will also provide quantitative results. In order to capture the interrelationships between the variables and to obtain the mathematical relationships of the model, four variables (stocks) were selected, as well as the demographic characteristics, as mentioned above. These variables are the population of the case study, the economy, the society, the environment, and the satisfaction of citizens.

2.3.1. Population Variables

In order to be able to carry out the level of satisfaction of the citizens of the Municipality of Patras, regarding the transport sector, it was considered necessary to introduce into the model variables referring to the total number of citizens per year, as well as to the changes that appear in this number. Table 2 presents the equations and values of the variables used in Vensim.

Table 2. List of population variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
population	Level	births-deaths + (economy rate + environment rate + social rate) × population	215,000	capita	CENSUS 2011 (ELSTAT)
births	Auxiliary	Population × birth rate/100	n.a	capita	EQUATION
birth rate	Constant	0.0096	0.096	Dnml	POPULATION/BIRTHS (year 2011)
deaths	Auxiliary	population × death rate/100	n.a	capita	EQUATION
death rate	Constant	0.01	0.01	Dnml	POPULATION/DEATHS (year 2011)
economy rate	Level	IF THEN ELSE (economy > 6.5, SMOOTH (0.01, 10), IF THEN ELSE (economy < 5, SMOOTH (−0.01, 10),0))/100	0	Dnml	ASSUMPTIOM
environment rate	Level	IF THEN ELSE (environment > 7, SMOOTH (0.008, 10), IF THEN ELSE (environment < 5, SMOOTH (−0.008, 10), 0))/100	0	Dnml	ASSUMPTIOM
social rate	Level	IF THEN ELSE (social > 6, SMOOTH (0.009, 10), IF THEN ELSE (social < 5, SMOOTH (−0.009, 10), 0))/100	0	Dnml	ASSUMPTIOM

The birth rate and death rate variables represent the rate of births and deaths, respectively, in Greece and therefore the way in which the population is affected. According to the 2011 census, the population of the Municipality of Patras was about 215,000 (rounded up to facilitate the analysis), while based on ELSTAT, the number of births was 9.6 per 1000 people, while the number of deaths was 10 per 1000 people in Greece in 2021. It was assumed that these percentages also apply to the Municipality of Patras. However, the population in one area is not only affected by births and deaths, but also by the transportation of people from one region to another. For this reason, the variables economy rate, environment rate, and social rate were created, which symbolize the extent to which the population is affected according to the level of satisfaction of citizens by the sectors economy, environment, and society, respectively. At this point, it was assumed that if the satisfaction of citizens at the economical level exceeds the grade 6.5 (rating scale 0–10) then the population growth rate of the Municipality of Patras will increase with a grade/step of 0.01, while if this value falls below 5.5 then the citizens will choose another area with a greater economic satisfaction index and it will decrease at a corresponding rate. Respectively, for the environmental level, if the level of satisfaction is above 7, then there will be an increase in the population growth rate, while if it is below 5, there will be a decrease. Finally, for social level, 6 and 5 were chosen as the limits, respectively. These values are an assumption.

2.3.2. Environmental

At first, certain variables that affect citizens' satisfaction regarding the environmental level should be calculated in order to define the final equation that will give the level of satisfaction of citizens in this area. More specifically, the variables are:

B1. Energy efficiency

Definition:Total energy use by urban transport (annual average for all modes of transport).

Parameter:

$$E = \frac{(\Sigma ij * Aij(\Sigma k * Sjk * Ijk * ECk))}{TVpass + (TVfre)/8} = Parameter\ value, \quad (1)$$

where:

E = Energy consumption [MJ/km]
TVpass = Passenger transport volume [passenger kilometers]
TVfre = Volume of goods transport [million tons km]
Sjk = Fuel type *k* per vehicle type *j*
Ijk = Energy intensity per distance travelled for vehicle type *j* and fuel type *k* [L/km or MJ/km or Wh/km]
Aij = Activity volume (distance travelled by mode *I* and vehicle type *j*) [million km per year]
ECk = Fuel energy content for fuel *k* [MJ/L or MJ/kg]
k = Fuel type (gasoline, diesel, natural gas, electric, etc.)
i = mode of transport (passenger car, tram, bus, train, motorcycle, freight train, truck, etc.)
j = Euro vehicle category (euro 0, euro 1, euro 2, euro 3, euro 4, euro 5, euro 6)

The values of the above variables used in the energy efficiency equation are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S1a,b) based on the analysis of the data obtained from the questionnaire responses.

The numerator of the above equation was calculated as the sum of three sub-variables, which are: energy consumed—car, energy consumed—train/bus, energy consumed—truck.

In particular, for the calculation of the variable energy consumed by car, the kilometers per car, the percentages of fuel types per car, and the percentages of the euro category per car are multiplied by the energy consumption per fuel type and per euro category for cars and by the energy content per fuel type. The final price of the variable energy consumed by car is calculated by summing up the above consumptions for all citizens who use a car. The energy consumption per fuel type and per euro category is automatically calculated from the excel spreadsheet (Supplementary Materials, Figure S1), while the energy content is constant per fuel type and is 34.2 MJ/L for Gasoline, 38.5 MJ/L foe Diesel and 25.1 for LPG. In the same way, the variables energy consumed—rain/bus, and energy consumed—truck, are calculated. The variables *Tvpass* and *Tvfre* are logical assumptions.

In order to calculate the change in the variables by vehicle type according to the changes occurring in the population, *Tvpass* (Volume of passenger transport) and *Tvfre* (Volume of freight transport) were created as an assumption, and they determine at what rate the population growth changes in any decrease. Appendix A—Table A1 presents the equations and values of the variables used in Vensim.

B2. Air pollutant emissions

Definition: Emissions of air pollutants from all modes of passenger and freight transport (exhaust and non-exhaust gas for PM2.5) in the urban area.

Parameter:

$$EHI = \frac{(\Sigma s * Eeqs * (\Sigma ij * Aij * (NEi + \Sigma ck * Sck * Eijkcs * Ik)) * 1000}{cap}, \quad (2)$$

where:

EHI = Harmful emissions equivalent index [kg PM2.5 equivalent/yearly *cap*]
Eeqs = Emissions of a substance type PM2.5 equivalent value of health effects
Eijkcs = Pollutant emissions per vkm resulting from transport mode *i* and vehicle type *j* for fuel type *k*, emission class *c* (g/km)
Aij = Activity volume (distance travelled by mode i and vehicle type *j*) [million vkm per year]
Sijk = Total fuel type *k* by vehicle type *j* and by mode of transport *i*
Cijkc = Total emission class *c* by fuel type *k* by vehicle type *j* and by mode of transport *i*
NEsi = Non-exhaust pollutant emissions *i* per distance travelled [g/km] (=0 for NOx)
cap = Number of inhabitants in the urban area [#]
k = Energy type (gasoline, diesel, natural gas, electricity, etc.)
i = Vehicle type (passenger car, tram, bus, train, motorcycle, inland waterway ship, freight train, truck, etc.)
j = Vehicle category.
s = Substance type limited to NOx and PM2.5
c = Emission class (euro)

The values of the above variables used in the equation of air pollutant emissions are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S2a,b) based on the analysis of the data obtained from the questionnaire answers.

The numerator of the above equation is equal to the sum of the variables; NOx emissions, PM2.5 emissions, and non-exhaust PM2.5 emissions multiplied by 1000.

More specifically, the variable NOxemissions is calculated by multiplying the kilometers per mode of transport, the percentages of fuel types per mode of transport, and the percentages of the euro category mode of transport by the constant NOxEijkc referring to pollutant emissions. The final value of the variable NOxemissions is calculated by summing up all the products for all the vehicles of the Municipality of Patras.

To calculate the variable PM2.5 emissions, the variables of mode of transport, the percentages of fuel types per mode of transport, and the percentages of the euro mode of transport are multiplied with the constant PM 2.5 *Eijkc*. Summing up the above result for all modes of transport, the final value of the variable PM2.5 emissions is calculated. The values of the constants NOx*Eijkc* and PM2.5 *Eijkc* are 0.064 and 1 accordingly (source: TSAP report 15, IIASA http://ec.europa.eu/environment/air/pdf/TSAP-15.pdf, accessed on 13 January 2023).

To calculate the variable non-exhaust PM2.5 emissions, the variables mode of transport, the percentages of fuel types per mode of transport, and the percentages of the euro mode of transport category are multiplied with the constant PM2.5 *NEsi*. Summing up the above result for all modes of transport, the final value of the non-exhaust variable PM2.5 emissions is calculated. Appendix A—Table A2 presents the equations and values of the variables used in Vensim.

B3. Greenhouse gas emissions (GHG emissions)

Definition: Greenhouse gas emissions from all modes of transport of passengers and goods in the urban area.

Parameter:

$$GHG = \frac{(\Sigma ij * Aij * (\Sigma ck * Sijk * Cijkc + Ijk * (Tk + Wk) * (1 + Fijk))) * 1000}{cap}, \quad (3)$$

where:

G = Greenhouse gas emissions [tons CO_2/*cap.*/year]
Tk = CO_2 emissions per unit of considered energy type [kg/L or kg/kWh]
Wk = Equivalent CO_2 emission per unit of considered energy type
Aij = Activity volume (distance travelled by mode *i* and vehicle type *j*) [million vkm per year]

Sijk = Total fuel type *k* per vehicle type *j* and per mode of transport *i* [fraction]
Cijkc = Total emission class *c* per fuel type *k* per vehicle type *j* and per mode of transport *i* [fraction]
Ijk = Energy intensity per distance travelled for vehicle type *j* and fuel type *k* [L/km or MJ/km or kWh/km]
Cap = Resident or number of inhabitants in the urban area [#]
Fijk = GHG correction without CO_2 (CO_2 equivalent)
k = Energy type (gasoline, diesel, natural gas, electricity, etc.)
i = mode of transport (passenger car, tram, bus, train, motorcycle, inland waterway vessel, freight train, lorry, etc.)
j = Category of vehicle

The values of the above variables used in the equation of greenhouse gas emissions are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S3a) based on the analysis of the data obtained from the questionnaire replies.

The numerator of Equation (3) is calculated as the sum of the GHG emissions for all vehicles in the Municipality of Patras multiplied by 1000. For the calculation of the variable GHG emissions, the kilometers, the percentages of fuel types, the percentages of the euro category per car and the energy intensity, with the sum of the CO_2 emissions and the equivalent emission, are multiplied. CO_2 is calculated as the sum of the constant 1 with the correction GHG without CO_2 (Supplementary Materials, Figure S3b). Appendix A—Table A3 presents the equations and values of the variables used in Vensim.

B4. Quality of public spaces

Definition: Citizens' satisfaction with public spaces.

Parameter:

$$\overline{SAT} = \frac{\Sigma m * \overline{ASPECT_m}}{m}\ m \text{ being the number of aspects (dimensions)}, \tag{4}$$

where:

$\overline{ASPECT_m} = \sum_h \overline{AGREE_{h,m}}$ *h* being the four replies of the agreement scale: (strongly agree, somewhat agree, somewhat disagree, strongly disagree)
and

$$\overline{AGREEh,m} = \frac{\#\text{times agreement } h \text{ was used in sample for aspect } m}{\#\text{people sample of aspect } m - \#\frac{\text{DK}}{\text{NA}} \text{ answers in sample } m} \times \text{C}h$$

where: C*h* = strongly agree = 10, C*h* = somewhat agree = 6.66, C*h* = somewhat disagree = 3.33, C*h* = strongly disagree = 0.

The data collection of this indicator was carried out using the questionnaire (S1). The methodology and analysis are presented in detail in Supplementary Materials, Figure S4.

More specifically, the variable "satisfied" equals the number of citizens who answered "satisfied" to the questionnaire divided by the sum of the citizens who answered "Rather satisfied", "Rather unsatisfied" and "Not at all satisfied" multiplied by the constant C*h* = 10. The variable "Rather satisfied" equals the number of citizens who answered "Rather satisfied" to the questionnaire divided by the sum of the citizens who replied "Satisfied", "Rather unsatisfied" and "Not at all satisfied' multiplied by the constant C*h* = 6.66. The variable "Rather unsatisfied" equals the number of citizens who answered "Rather unsatisfied" to the questionnaire divided by the sum of citizens who replied "Satisfied", "Rather satisfied" and "Not at all satisfied" multiplied by the constant C*h* = 3.33. The variable "Not at all satisfied" equals the number of citizens who answered "Not at all satisfied" to the questionnaire divided by the sum of the citizens who answered "Satisfied", "Rather satisfied" and "Rather unsatisfied" multiplied by the constant C*h* = 0.

Finally, the sum of all the above values gives the value of the final satisfaction for the variable public spaces. Following the same methodology, the variable green spaces is calculated. Appendix A, Table A4 presents the equations and values of the variables used in Vensim.

In the field of the environment, it is assumed that all the individual variables have the same weight in terms of citizens' satisfaction. Hence, the equation of Environmental Satisfaction is:

Environmental Satisfaction = (Air Pollutant Emissions + Energy Efficiency + Greenhouse Gas Emissions + Quality of Public Spaces)/4 = 5818 (5)

2.3.3. Social Variables

In this subsection, the variables referring to the satisfaction of citizens with society are calculated. Through the determination of these variables, the corresponding equation of overall satisfaction in the field of society will also be developed.

C1. Security

Definition: The perceived crime risk and passenger safety in urban transport.

Parameter:

$$\overline{SEC} = \frac{\Sigma m * \overline{SECm}}{m},\ m \text{ being the number of aspects (dimensions)}, \tag{6}$$

where:

$\overline{SECm} = \sum_h \overline{SECh, m}$, h being the four replies on the perception of crime related security: (Very safe, safe, unsafe and very unsafe)

and:

$$\overline{SECh, m} = \frac{\#\text{times agreement } h \text{ was used in sample for aspect } m}{\#\text{people sample of aspect } m - \#\frac{\text{DK}}{\text{NA}} \text{ answers in sample } m} \times Ch$$

where: Ch = Very safe = 10, Ch = safe = 6.66, Ch = unsafe = 3.33, Ch = Very unsafe = 0

The values of the above variables used in the equation of the security variable are derived from the completion of the excel auxiliary spreadsheet (Supplementary Materials, Figure S5) based on the analysis of the data obtained from the questionnaire answers.

The variable "Very safe" is equal to the number of citizens who answered "Very safe" to the questionnaire, divided by the sum of the citizens who replied "Safe", "Unsafe", and "Very unsafe", multiplied by the constant Ch = 10. The variable "Safe" is equal to the number of citizens who answered "Safe" to the questionnaire, divided by the sum of the citizens who answered "Very safe", "Unsafe" and "Very unsafe", multiplied by the constant Ch = 6.66. The variable "Unsafe" is equal to the number of citizens who replied "Unsafe" to the questionnaire, divided by the sum of the citizens who replied "Very safe", "Safe" and "Very unsafe", and multiplied by the constant Ch = 3.33. The variable "Very unsafe" is equal to the number of citizens who replied "Very unsafe" to the questionnaire, divided by the sum of the citizens who replied "Very safe", "Safe" and "Unsafe", multiplied by the constant Ch = 0.

Finally, the average value of the sum of all the above values gives the final satisfaction for the variable car. (Feeling safe regarding the use of the car). In the same way, the variables public transport, pedestrian safe, motorcycle, and bicycle are calculated (Feeling safe regarding each mode of transport). Appendix A, Table A5 presents the equations and values of the variables used in Vensim.

C2. Traffic safety active modes

Definition: Deaths of users of active modes of mobility in urban traffic accidents in relation to their exposure to traffic.

Parameter:

$$RF = \frac{\Sigma_i * K_i * 1000}{Exp_i}, \tag{7}$$

where:

RFi = Risk factor for mode *i*
Ki = Number of people killed within 30 days after the road accident as a consequence of the incident in a pedestrian mode (motorcycles) [# simple average over the last 3 years for which data are available]
Expi = Report, defined as number of trips (in millions) [# per year]
i = Mode of transport (pedestrian, bicycle)

The values of the above variables used in the equation of the security variable are derived from the completion of the excel auxiliary spreadsheet (Supplementary Materials, Figure S6) based on the analysis of the data obtained from the questionnaire answers. Appendix A—Table A6 presents the equations and values of the variables used in Vensim.

C3. Road deaths

Definition: Road deaths in the urban area on an annual basis.

Parameter:

$$FR = \frac{\Sigma_i * K_i * 1000}{cap}, \tag{8}$$

where:

FR = Mortality rate [# per 100,000 inhabitants of the region per year]
Ki = Number of people killed per mode of transportation *I* (Pedestrian, Bicycle, Moped, Motorcycles, Cars, HGV—Trucks, LGV, Bus) [# per year]
Cap = Number of urban area inhabitants [#]
i = mode of transport

The values of the above variables used in the equation of the road deaths variable are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S7) based on statistical data of ELSTAT. Appendix A, Table A7 presents the equations and values of the variables used in Vensim.

With the change in population growth rate in the region, road deaths per mode of transportation will be affected accordingly. For this reason, rate variables (r*i*) have been created to show the rate of change in deaths by mode of transportation. The rates are an assumption of this research.

C4. Satisfaction with Public Transportation (PT)

Definition: The perceived satisfaction with the use of public transportation.

Parameter:

$$\overline{SAT} = \frac{\Sigma m * \overline{ASPECT_m}}{m},\ m \text{ being the number of aspects (dimensions)}, \tag{9}$$

where:

$\overline{ASPECT_m} = \sum_h \overline{AGREE_{h,m}}$, *h* being the four replies of the agreement scale: (strongly agree, somewhat agree, somewhat disagree, strongly disagree)

$$\overline{AGREEh, m} = \frac{\#\text{times agreement } h \text{ was used in sample for aspect } m}{\#\text{people sample of aspect m} - \#\frac{\text{DK}}{\text{NA}} \text{ answers in sample } m} \times Ch$$

where: C*h* = strongly agree = 10, C*h* = somewhat agree = 6.66, C*h* = somewhat disagree = 3.33, C*h* = strongly disagree = 0

The values of the above variables used in the equation of the variable "Satisfaction with PT" are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S8) based on the analysis of the data obtained from the questionnaire responses. The variable "strongly agree" is equal to the number of citizens who answered "strongly agree" to the questionnaire, divided by the sum of the citizens who answered "somewhat agree", "somewhat disagree" and "strongly disagree", multiplied by the constant C*h* = 10. The variable "somewhat agree" equals the number of citizens who answered, "somewhat agree" to the questionnaire, divided by the sum of the citizens who answered "strongly agree", "somewhat disagree" and "strongly disagree", multiplied by the constant C*h* = 6.66. The variable "somewhat disagree" equals the number of citizens who answered "somewhat disagree" to the questionnaire, divided by the sum of the citizens who answered "strongly agree", "somewhat agree" and "strongly disagree", multiplied by the constant C*h* = 3.33. The variable "strongly disagree" is equal to the number of citizens who answered "strongly disagree" to the questionnaire, divided by the sum of the citizens who answered "strongly agree", "somewhat agree" and "somewhat disagree", multiplied by the constant C*h* = 0.

Finally, the sum of all the above values gives the final satisfaction for the variable General Satisfaction. In the same way, the variables General Satisfaction, Affordable, Reliable, Easy to Get, Frequent, and Safe are calculated. The variable "Satisfaction with PT" is calculated as the average value of the sum of the variables General Satisfaction, Affordable, Reliable, Easy to Get, Frequent, as well as Safe. Appendix A, Table A8 presents the equations and values of the variables used in Vensim.

C5. Commuting travel time

Definition: Duration of commuting to and from work or an educational institution, using any mode of transportation.

Parameters:

$$\overline{T_{com}} = \sum_i \frac{Tout_i}{n} + \sum_i \frac{Treturn_i}{n}, \quad (10)$$

where:

Tcom = Average commute time [minutes/day]
Touti = Commute time at work/school per person *I* [minutes/day]
Treturni = Commute time at home per person *i* [minutes/day]
n = number of people in the survey

The values of the above variables used in the equation of the "Commuting travel time" variable are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S9). Appendix A, Table A9 presents the equations and values of the variables used in Vensim.

With the change in population growth rate in the region, travel time will be affected accordingly. For this reason, "rate to home" and "rate to work" variables were created, which show the rate of change. The equations as well as the initial values of these variables are an assumption of the research.

C6. Congestion and delays

Definition: Delays in road traffic and public transportation during peak hours compared to non-peak hours travel (private road traffic) and optimal travel time on public transportation (public transport).

Parameter:

$$CD_{ij} = MS_{road} * \frac{(\sum_{i=1}^{10}((CTi * PHTiFFT_i)))}{\sum_{i=1}^{10} CT_i} + MS_{pt} * \frac{(\sum_{j=1}^{10}((PTj * PTPHTjPTOT_j)))}{\sum_{j=1}^{10} PT_j}, \quad (11)$$

where:

CDij = Congestion and delay index (percentage of delay during peak hours)
CTi = Number of car trips during peak hours on the main road corridor *i*
PHTi = Travel time by car during peak hours on the main road corridor *i* [minutes]
FFTi = Off-peak travel time by car on main road corridor *i* [minutes]
PTj = Number of journeys by public transport to travel during peak hours on the transit corridor *j* [#]
PTPHTj = Travel time on public transport during peak hours on the main road corridor *i* [minutes]
PTOTj = Optimal travel time on public transport on the main road corridor *i* [minutes]
MSroad = Road traffic share [%]
MSpt = Share of public transport [%]

The values of the above variables used in the equation of the variable "Congestion and delays" are derived from the completion of the excel spreadsheet (Supplementary Materials, Figure S10) based on the analysis of the data obtained from the questionnaire answers, as well as from reasonable assumptions made for traffic on 10 roads of the city of Patras at peak and non-peak hours. Appendix A, Table A10 presents the equations and values of the variables used in Vensim. The variables rate MSpt and rate MSroad were created as an assumption and are used to show the change in the respective variables in relation to the population.

It is assumed that all the individual variables have the same weight in terms of citizens' satisfaction in the field of society. The final equation concerning the social satisfaction of citizens is defined as:

$$\textbf{Social Satisfaction} = (\textbf{Commuting Travel Time} + \textbf{Security} + \textbf{Road Deaths} + \textbf{Satisfaction With Pt} + \textbf{Traffic Safety Active Mode} + \textbf{Congestion \& Delays})/6 = 5448, \quad (12)$$

2.3.4. Economic Variables

In a similar way, in the third area of the research, which concerns the satisfaction of citizens in the field of the economy, the calculation of the individual variables is first conducted so that the final equation can be determined.

D1. Access to mobility services

Definition: Total population with appropriate access to mobility services (public transport).

Parameter:

$$Accl = \frac{\Sigma i * (PRi) * Wi}{cap}, \quad (13)$$

where:

Accl = Appropriate Access Index

PRi = Number of people living in the access typology zone *i*, determined by the combination of the level of accessibility PT (public transport).

Wi = Weight to determine if accessibility to mobility services is appropriate/good (depending on the combination of the PT accessibility level).

Supplementary Materials, Figure S11 contains the calculation of the indicator. The weight varies for small (i.e., less than 100,000 inhabitants) or large urban areas. The Municipality of Patras is classified as a large urban area.

The *Wi* weight is preset and determines if accessibility is appropriate (or good) as follows:

1. *i* = 1 where absolutely appropriate
2. *i* = 0.5 where not fully appropriate
3. *i* = 0 where not appropriate
4. *Cap* = A number of inhabitants in the urban area [#]

For the calculation of the above indicator, an analysis of the answers to the questionnaire has already been made. More specifically, the calculation of the variable "people with no access" is calculated as the product of people without any access multiplied by the weight w1. The calculation of the variable "people with low access" is calculated as the product of people with low access multiplied by weight w1. The variable "people with medium access" is calculated as the product of people with moderate access multiplied by weight w2. The variable "people with high access" is calculated as the product of people with high access multiplied by weight w3. Similarly, the variable "people with very high access" is calculated as the product of people with very high access multiplied by the weight of w3.

Finally, the variable "parameter value of access to mobility services" is calculated as the sum of all the above, divided by the total population. Appendix A, Table A11 presents the equations and values of the variables used in Vensim.

D2. Public transport affordability

Definition: Share of the population using public transport cards (PTCs) (unlimited monthly trips or equivalent) in the urban area.

Parameter:

$$Affordability = \frac{Value\ of\ PTC\ per\ month\ * Average\ population\ of\ household}{Average\ household\ income}, \quad (14)$$

Supplementary Materials, Figure S12 details the calculation of the indicator. Appendix A, Table A12 presents the equations and values of the variables used in Vensim.

D3. Quality of public spaces

This indicator, apart from the field of the environment, was also chosen in the field of economy, as the development of public and green spaces requires infrastructure, the cost of which is borne by the municipality.

D4. Active Mobility

Definition: Infrastructure for active mobility, in particular walking and cycling.

Parameter:

$$Ram = \frac{(Lpv + Lbl + Lz30 + Lpz)}{Lprn}, \quad (15)$$

where:

Ram = Share of road length adapted for active mobility [*n*]
Lpv = Length of road network with sidewalks (not if on a pedestrian street) [km]
Lbl = Length of road network with cycle paths (not if in a zone of 30 km/h) [km]
Lz 30 = Length of road network in a zone of 30 km/h [km]
Lpz = Length of pedestrian zone [km]
Lrn = Total length of city road network (excluding motorways) [km]

For the calculation of this indicator, data were collected from GOOGLE EARTH, while at the same time, some reasonable assumptions were made. Supplementary Materials, Figure S12 details the calculation of the indicator. Appendix A, Table A13 presents the equations and values of the variables used in Vensim.

After calculating the above variables, it follows that:

Economic Satisfaction = (Affordability + Active Mobility + Quality of Public Spaces + Access to Mobility Services)/4 = 5162, (16)

2.4. General Satisfaction of Citizens Regarding the Transport Sector (People Satisfaction in Transport)

At this point, having calculated the values of satisfaction of citizens regarding the environment, society and the economy, the general satisfaction of citizens with regard to transport will be calculated. It was considered, in the present research, that satisfaction in transport is a function of the satisfaction of citizens in the above three areas. However, each sector affects the final satisfaction with a different weight. Appendix A, Table A14 presents the equations and values of the variables used in Vensim.

In order to find out the importance of each sector, the participants were asked a question in which it was requested to prioritize the three sectors according to how much each one affects their overall satisfaction in the transport sector. Figure 4 shows the analysis of the results.

Consequently, based on the answers of the questionnaire, the weights are as follows: Weco = 110/100 = 1.1, Wcc = 100/100 = 1.0, Wapprox = 90/100 = 0.9.

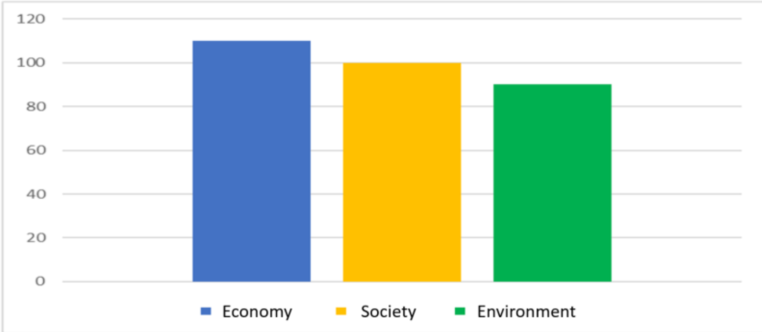

Figure 4. Weight by sector (Economy, Society, Environment).

3. Results

Having completed the process by defining the equations and calculating the values of each variable, the dynamic model is completed. In this section, the results of a simulation of the aforementioned model at the end of the 10th year are presented, based on current data. These demonstrate how people's satisfaction regarding transport changes over time.

3.1. Initial Situation—Baseline Scenario

During the simulation, the citizens' satisfaction of the Municipality of Patras is calculated equal to 5.45 and remains stable for the next 10 years. As satisfaction is an indicator with values from 0 to 10, we conclude that the value of 5.45 indicates that citizens are not satisfied enough with the current conditions, while at the same time the situation does not seem to improve in the future. More specifically, the subsystem variables of economic, environmental, and social satisfaction of citizens also show stability for the next 10 years (Table 3).

Table 3. Initial values for the subsystem variables of economic, environmental and social satisfaction of citizens over 10 years (Initial Situation—Baseline scenario).

Group	Level of Satisfaction	Variable	Value
Economy	5.16 [Equation (5)]	Access to mobility services	5.70
		Affordability	6.75
		Active mobility	4.00
Environment	5.81 [Equation (12)]	Energy efficiency	6.39
		Air pollutant	7.91
		Greenhouse Gas emissions	4.77
		Quality of public spaces	4.20
Society	5.44 [Equation (16)]	Traffic safety active mode	8.72
		Satisfaction with PT	4.15
		Road deaths	2.24
		Congestion and delays	5.01
		Commuting travel time	7.37
		Security	5.18

Appendix A, Figures A1 and A2 present the graphs of the initial situation, where the above variables show a stable value in relation to time.

The level of satisfaction of citizens in relation to the economy, the environment and society shows a stability over the years, with initial values of 5.16, 5.81 and 5.44, respectively (Equations (5), (12) and (16)). These values are considered moderate (rating scale 0–10) and, as a result, they do not meet the requirements for the economy ≤ 6.5, the environment ≤ 7, and society ≤ 6. As a result, the Municipality of Patras does not attract new citizens who wish to live in this area. However, the evaluation is not below average to lead residents to leave the area. The population prediction shows a slight decrease within the next 10 years, as does the general population of Greece, as the number of births is less than that of deaths (Appendix A, Figure A3).

In conclusion, it is necessary for the Municipality of Patras to take further measures to increase the satisfaction of citizens with the aim of prosperity and happiness of citizens within their city. This dynamic model plays an important role in taking the appropriate measures. Utilizing this dynamic system as a tool, it is possible to make simulations with new data and, at the same time, to evaluate the change they bring to the individual sectors and to the overall satisfaction of the citizens.

Following the research, some scenarios were performed, three of which are presented in the present study as they have the greatest impact. These scenarios present possible measures that the municipality could implement, aiming to increase citizens' satisfaction.

3.2. Scenario 1

In Scenario 1, it was assumed that in order to improve citizens' satisfaction in transport, it is important to increase bus numbers and generally improve public transport, as quality sustainable transport is central to sustainable urban mobility.

This alteration brings about changes in some of the variables of the dynamic system. More specifically, the increase in the number of buses and public transport infrastructure will result in better access for people, greater satisfaction with the use of public transport, reduction in individual car use (car, motorbike), reduction in traffic congestion, as well as reduction in road deaths as a safer means. Appendix A, Table A15 details the values used in Scenario 1 as a logical assumption, compared to those in the initial situation.

By performing the simulation in the Vensim software, citizens' satisfaction with the transport sector seems to show a slight increase (Figure 5).

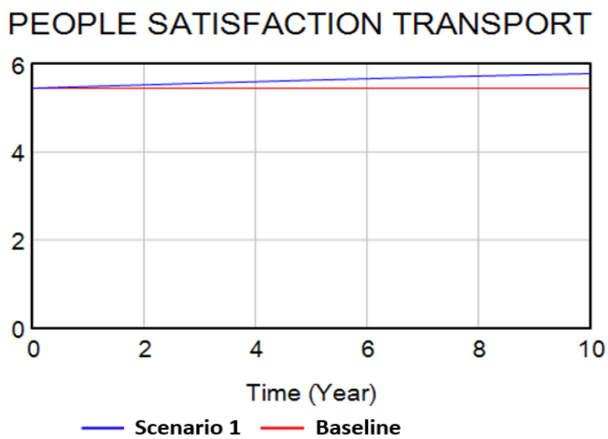

Figure 5. Citizens' satisfaction regarding transport in relation to time (Scenario 1).

More specifically, the general satisfaction of the citizens having an initial value of 5.44, over time shows a slight increase and fetches up at the price of 5.78. This increase is due to the improvement of citizens' satisfaction in the sectors of society, as well as the economy, as these sectors presented an increase. In contrast, the environmental sector decreased as the increase in the number of buses entails an increase in pollutants.

It is worth noting that in this scenario, the satisfaction of the citizens in the social sector exceeded the value 6, as a result of which the city began to attract people due to the good social conditions prevailing in it. Thus, the total population shows a slight increase compared to the initial (current) situation.

3.3. Scenario 2

Active mobility is one of the most important sustainable modes of transport. For this reason, most European countries are constantly improving their infrastructure and urging citizens in various ways to enhance this type of transport. That is why in Scenario 2, it was chosen to assess the satisfaction of citizens in a possible increase in the use of bicycles and the creation of appropriate/good infrastructure. Appendix A, Table A15 presents the assumptions made for the values of variables affected by the improvement in active mobility.

Performing the simulation of Scenario 2, it is observed that, indeed, the overall satisfaction of citizens regarding transport has been on the rise over the years. Starting with an initial value of the baseline scenario (5.45), citizens' satisfaction reaches a value equal to 6064 on the 10th year (Figure 6).

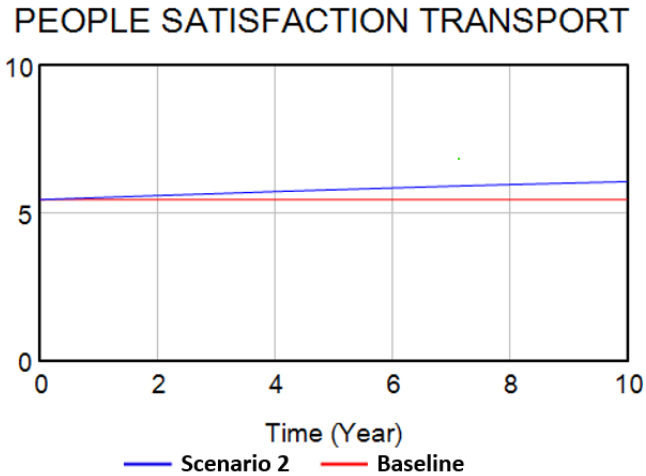

Figure 6. Citizens' satisfaction regarding transport in relation to time (Scenario 2).

In this scenario, the social sector is of particular interest. With the new measures proposed, citizens' satisfaction in this area exceeds the value of 6. This has resulted in the transformation of the Municipality of Patras into an accessible area for citizens, attracting more and more people to choose it as a permanent place of residence.

3.4. Scenario 3

Given the impact of urban mobility on both economic growth and the environment, the EU promotes sustainable urban mobility, which is about developing strategies that promote the transition towards cleaner and more sustainable modes of transport, such as walking, cycling, public transport and towards new standards for the use and ownership of cars. Thus, the latter scenario consists of the promotion of active mobility, the use of public transport, the improvement of the infrastructure, as well as the increase in electromobility in both private cars and public transport.

Another consideration taken into account during the development of Scenario 3 is the results of the previous simulations. It was believed that in order to achieve an even greater increase in satisfaction, the best scenarios of this study should be combined together. Appendix A, Table A15 details the values used in Scenario 3 as a logical assumption, compared to those applicable in the baseline scenario/initial situation. Appendix A, Table A16 presents in detail the change in the values of the variables of Scenario 3 for electromobility.

Understandably, citizens' satisfaction regarding transport shows a significant improvement based on the results of the last analysis. More specifically, satisfaction reaches the value of 7.15 after 10 years, marking an increase of 17% (Figure 7). Therefore, among the scenarios presented, Scenario 3 appears to be the most promising.

The diagrams of the individual sectors of the economy, environment, society, and the population are of particular interest. In the field of the economy, the increase in citizens' satisfaction is the result of the reduction in public transport ticket prices and the improvement in their infrastructure. More and more citizens will make use of public transport due to the affordability of their prices and easy access. Additionally, the development of public and green spaces is something that has a positive effect on the satisfaction of citizens. The fact that the municipality creates new infrastructure and improves existing ones, while providing more opportunities for mobility, makes the city sustainable and people's standard of living better.

Figure 7. Citizens' satisfaction regarding transport in relation to time (Scenario 3).

The improvement in public transport in terms of fuel type but also of cars (electromobility versus other types of fuel), the reduction in private vehicle use over public transport, and means of active mobility lay the foundations for a sustainable environment. Reducing air pollution and gas emissions create a healthier environment for citizens, which increases their satisfaction. Finally, at the level of society, reducing congestion and travel delays, reducing road accidents, and increasing transport safety improve the living conditions of the urban environment (Figure 8).

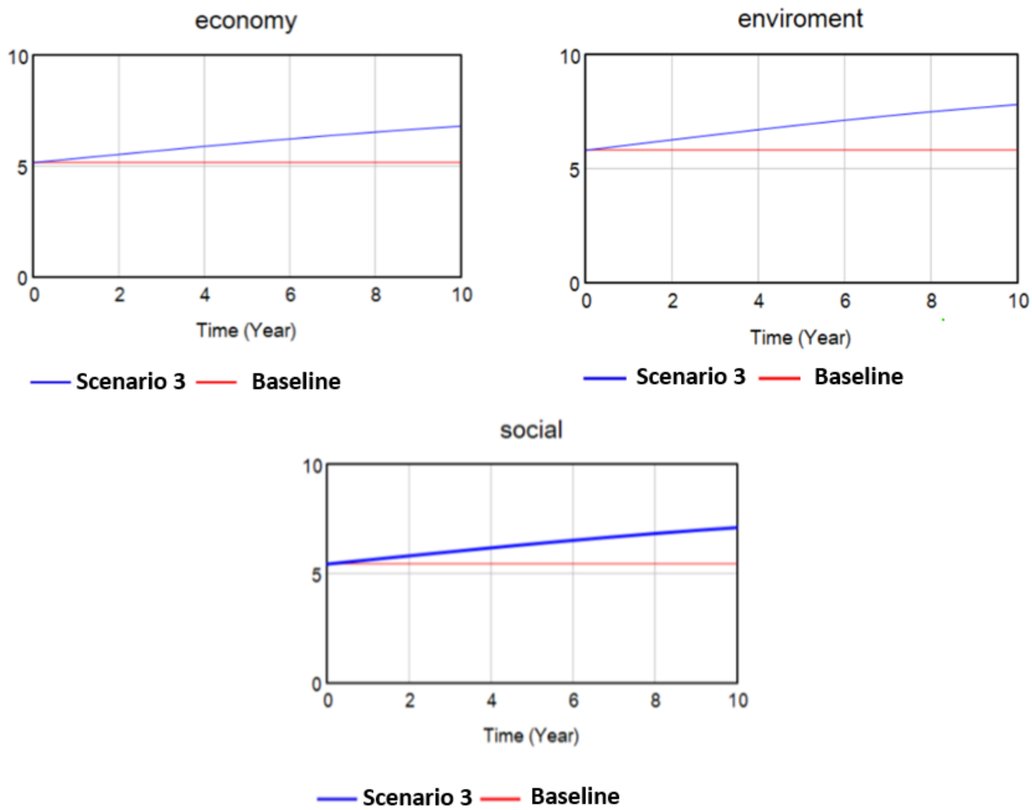

Figure 8. Citizens' satisfaction regarding economy, environment, society in relation to time (Scenario 3).

The increase in citizens' satisfaction with transport and individual sectors makes the Municipality of Patras a suitable place of residence with a high standard of living. This is also reflected in the graph of the population growth rate per year that emerged from the simulation of Scenario 3 using Vensim (Figure 9), in which it appears that as citizens' satisfaction increases, so does the population that chooses the Municipality of Patras as part of their permanent residence.

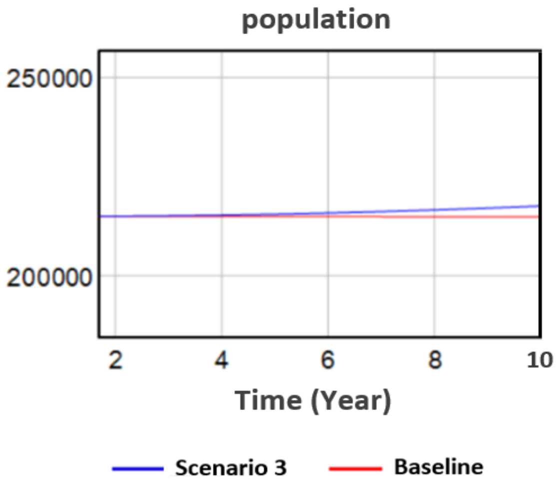

Figure 9. Population growth rate per year (Scenario 3).

Table 4 presents the results of the analysis of Scenario 3 for the individual variables of each subsystem, which show a gradual increase over the ten years. Appendix A, Figures A3 and A4 show the diagrams of the individual variables of each subsystem.

Table 4. Values of certain variables for economy, environment and society over ten years (Scenario 3).

Group	Variable	Baseline	Scenario 3
Economy	Access to mobility services	5.70	7.40
	Affordability	6.75	7.72
	Active mobility	4.00	4.87
Environment	Energy efficiency	6.38	8.02
	Air pollutant	7.91	8.29
	Greenhouse gas emissions	4.77	6.94
	Quality of public spaces	4.20	7.30
Society	Traffic safety active mode	8.72	9.56
	Satisfaction with PT	4.15	6.02
	Road deaths	2.24	5.03
	Congestion and delays	5.01	7.94
	Commuting travel time	7.37	8.12
	Security	5.18	6.68

Another simulation was made on Scenario 3 concerning how the satisfaction of citizens will change in more than 10 years and, specifically, in the next 30 years.

Satisfaction increases up to the twentieth year, reaching a value of 7.81, while in the next 10 years it decreases until year 30, where it reaches a value of 7.56 (Figure 10). The reason is due to the constant growth of the population. The measures taken in time 0 have a positive effect, but when the population increases too much, a redefinition and review of some measures is required to keep pace with the data that will arise in the future.

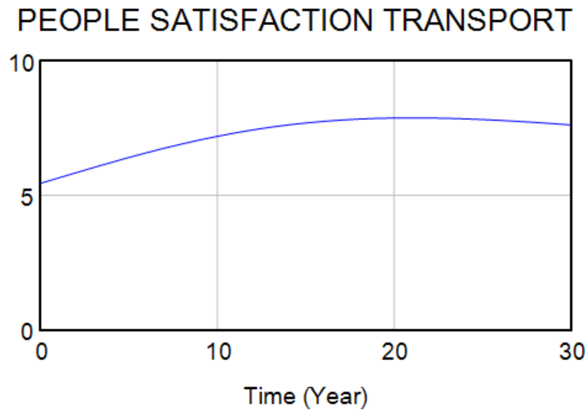

Figure 10. Citizens' satisfaction over 30 years.

4. Discussion

Cities are complex social ecosystems in which ensuring sustainability and optimal quality of life are important issues. For this reason, many smart cities today around the world define people's happiness in their development strategies, to the point that the goal of being a happy city is imperative to being smart. Happiness depends on daily variables ranging from stress-free mobility to trust in governance, as well as access to a clean environment and generally easy safe living.

In this research, it was chosen to evaluate how the transport sector affects the satisfaction of citizens. The transportation sector can be seen as a crucial element of the economy and the indicators used as a building block for productive outcomes [17]. The aim was to create a model to measure the satisfaction of the inhabitants of an urban area with regard to transport and how it can be influenced by the main principles of sustainability, which are the environment, society, and the economy. Citizens demand a high level of satisfaction, which means that the expectations of the citizens are fulfilled only if they express the highest satisfaction level [37]. The application based on the concept of System Dynamics and Vensim software was used for its implementation. System dynamics modelling has demonstrated considerable value across a number of different fields to help decision makers understand and predict the dynamic behavior of complex systems in support of the development of effective policy actions [38]. The indicators used to implement the above model are the Sustainable Urban Mobility Indicators (SUMI) proposed by the European Union. The current research illustrates the linkages among the sustainability pillars and the selected sustainable transport indicators [27]. The Municipality of Patras was chosen as the case study in this research.

The model developed in Vensim software aims both at assessing the satisfaction of citizens based on the current situation: baseline scenario and the use of it by the stakeholders or local government, as a tool to measure the change in citizens' satisfaction resulting from new mobility practices or policies. Therefore, after assessing the current situation, some scenarios were conducted for the measures that could be taken to improve the satisfaction of the residents regarding the transport sector. The scenarios were based on the principles of sustainability and the action plans concern: better accessibility conditions for alternative means of transport; improved travel safety; reduced air pollution, greenhouse gas emissions and energy consumption; increased efficiency and effectiveness in the movement of people and goods; and enhanced attractiveness and quality of the urban environment. The values of the variables of this model predominantly represent real data. However, several assumptions were also made where real-time data could not be found; this is a general problem in Greece, for which the EU takes care to create open databases but also to update them on a regular basis. Consequently, the usefulness of this model is predicted to be greater in the future with the input of real-world data.

The results of this study indicate that the three main pillars of sustainability (environment, economy, society) are almost of equal importance. The current situation of the case study denotes that people are not sufficiently satisfied with the situation of the transport sector as it is, while also not expecting an improvement in the near future. As quality sustainable transport is central to sustainable urban mobility, this research recommends (i) an improvement in public transport and transport infrastructure, (ii) the use of more sustainable means of transport (i.e., bicycles), and (iii) the use of electromobility. Potential stakeholders are the government, decision makers, local communities, and operators/investors. The dynamic process of opinion convergence can be observed in real-time by monitoring (1) the level of consensus and (2) the stakeholders' "satisfaction" with the perceived utility because of the simulated policy. This allows for the derivation of a subset of policy packages that perform well in terms of agreement and utility and are, hence, more likely to be adopted by stakeholders, i.e., with a high level of "satisfaction".

It is important to mention that in this paper, the presented model has replicability, as it could easily be applied in various cities and municipalities by entering each time the data concerning the area of application based on its needs and specific characteristics. A stated in [29], the transport sustainability index can be used by policy makers to evaluate the effect of their policies on transport sustainability in different ways. Other studies [39] also underscore the need for local government officials to manage citizen satisfaction in accordance with citizen expectations. Understanding and managing citizen expectations may help address citizen dissatisfaction and improve the overall public perception of the government. In any case, it is important to highlight the human-centric nature of the model. That is why the participation of citizens in the process of obtaining the data is also necessary. This can be achieved through questionnaires that will be posted on various platforms, or by holding conferences and carrying out other participatory actions.

5. Conclusions

It is worth noting that the pilot model presented in this paper is a dynamic system that can be further expanded by adding other sectors besides the economy, society and the environment, which underlines its extensibility. It can also delve deeper into each sector by taking into account additional indicators. Further research should involve the introduction of the cost equation into the model. The cost variable plays an important role both in the satisfaction of the citizen and in the decision making of the local authorities. Consequently, its introduction into the model is imperative to create a more accurate system for assessing citizens' satisfaction.

It could be argued that achieving transport sustainability should not focus on finding an ideal universal approach but rather on choosing the most appropriate yet compatible and scientifically valid methods for each unique case, considering the great variability in initiatives as well as in indicators, which has been highlighted by the current research. The added benefit of the current study is that its findings could serve as a strong foundation for advancement in the measurement of transport sustainability. Relevant stakeholders can use these findings as their main operational tool in two directions: (a) towards the development of a new sustainable transport indicator initiative tailored to the unique characteristics of the study area; and (b) towards an effective process for comparing transportation options.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/systems11030112/s1, Figure S1a. Energy efficiency excel spreadsheet, Figure S1b. Energy efficiency excel spreadsheet, Figure S2a. Air pollutant emissions excel spreadsheet, Figure S2b. Air pollutant emissions excel spreadsheet, Figure S3a. GHG emissions excel spreadsheet, Figure S3b. Air pollutant emissions excel spreadsheet, Figure S4. Quality of public spaces spreadsheet, Figure S5. Security spreadsheet, Figure S6. Traffic safety active modes spreadsheet. Figure S7. Traffic safety active modes spreadsheet, Figure S8. Satisfaction with PT spreadsheet, Figure S9. Commuting travel time spreadsheet, Figure S10. Congestion and delays spreadsheet, Figure S11. Access to mobility services spreadsheet, Figure S12. Affordability of public transport spreadsheet, Figure S13. Af-fordability of public transport spreadsheet.

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Appendix A

Table A1. Values of energy efficiency variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
ENERGY EFFICIENCY	Level	((parameter value − 3.5)/(0.5–3.5)) × 10	6.387	Dnml	-
Parameter value	Auxiliary	(energy consumed, car + energy consumed, train/bus + energy consumed, truck)/((Tvfre/8) + Tvpass)	1.584	Dnml	-
energy consumed, car	Auxiliary	SUM (energy consumed, car)	1769.2	(Million MJ)	Supplementary Materials
rate car	Level	rate car × 0.002	0.0082287	#	ASSUMPTION
energy consumed, truck	Auxiliary	SUM (energy consumed, truck)	1043,0	(Million MJ)	Supplementary Materials
rate truck	Level	rate truck × 0.0001	0.00485102	#	ASSUMPTION
energy consumed, train/bus	Auxiliary	SUM (energy consumed, train/bus)	454.8	(Million MJ)	Supplementary Materials
rate train/bus	Level	rate train × 0.0001	0.002115	#	ASSUMPTION
Tvpass	Auxiliary	rate *Tvpass* × population	2000	(in millions passenger km)	Supplementary Materials
rate *Tvpass*	Level	rate *Tvpass* × 0.0001	0.00930233	#	ASSUMPTION
Tvfre	Auxiliary	rate *Tvfre* × population	500	(Millions ton km)	Supplementary Materials
rate *Tvfre*	Level	rate *Tvfre* × 0.001	0.00232558	#	ASSUMPTION

Table A2. Values of air pollutant emissions variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
AIR POLLUTAN EMISSIONS	Auxiliary	((EHI-2.15)/(0–2.15)) × 10	7.91	Dnml	Supplementary Materials
EHI	Auxiliary	((NOx emissions × NOx) + (PM2.5 emissions × PM2.5) + (non-exhaust PM2.5 emissions × PM2.5) × 1000/population	0.448	Dnml	Supplementary Materials

Table A2. *Cont.*

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
Non-exhaust PM2.5 emissions	Auxiliary	SUM (non-exhaust PM2.5 emissions)	15.139	(tons)	Appendix A
rate non-exhaust	Level	rate non-exhaust × 0.001	7.0414×10^{-5}	#	ASSUMPTION
NOx emissions	Auxiliary	SUM (NOx Emissions)	836.48	(tons)	Supplementary Materials
rate NOx	Level	rate NOx × 0.0003	0.00389063	#	ASSUMPTION
PM2.5 emissions	Auxiliary	SUM (PM2.5 Emissions)	25.338	(tons)	Supplementary Materials
rate PM2.5	Level	rate PM2.5 × 0.001	0.000117853	#	ASSUMPTION
PM2.5	Constant	1	1	Dnml	Appendix A
NOx	Constant	0.067	0.067	Dnml	Supplementary Materials

Table A3. Values of GHG variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
GREENHOUSE GAS EMISSIONS	Auxiliary	((GHG-2.75)/(0–2.75)) × 10	4.77	Dnml	Supplementary Materials
GHG	Auxiliary	(GHG emissions × 1000)/population	1.43	Dnml	Supplementary Materials
GHG emissions	Auxiliary	SUM (GHG emissions)	308.98	Mio × kg	Supplementary Materials
rate GHG	Level	rate GHG × 0.001	0.00143712	#	ASSUMPTION

Table A4. Values of quality of public spaces variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
QUALITY OF PUBLIC SPACES	Auxiliary	(public spaces + green spaces)/2	4.2	Dnml	Supplementary Materials
public spaces	Constant	SUM (Satisfied + Rather satisfied + Rather unsatisfied + Not at all satisfied)	5	Dnml	Supplementary Materials
green spaces	Constant	SUM (Satisfied + Rather satisfied + Rather unsatisfied + Not at all satisfied)	3.4	Dnml	Supplementary Materials

Table A5. Values of security variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
SECURITY	Auxiliary	(car + motorcycle + public transpport + pedestrian safe + bicycle)/5	5.18	Dnml	Supplementary Materials
car	Constant	AVERAGE (SUMcars (very safe, safe, unsafe, very unsafe))	5.5	Dnml	Supplementary Materials

Table A5. *Cont.*

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
public transport	Constant	AVERAGE (SUM public transport (very safe, safe, unsafe, very unsafe))	5.9	Dnml	Supplementary Materials
pedestrian safe	Constant	AVERAGE (SUM pedestrian (very safe, safe, unsafe, very unsafe))	5.5	Dnml	Supplementary Materials
motorcycle	Constant	AVERAGE (SUM motorcycle (very safe, safe, unsafe, very unsafe))	5.4	Dnml	Supplementary Materials
bicycle	Constant	AVERAGE (SUM bicycle (very safe, safe, unsafe, very unsafe))	3.6	Dnml	Supplementary Materials

Table A6. Values of traffic safety active mode variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
TRAFFIC SAFETY ACTIVE MODE	Auxiliary	IF THEN ELSE (parameter value of traffic safety active mode > 2000, 0, ((parameter value of traffic safety active mode-2000)/(0–2000)) $\times$ 10)	8.72	Dnml	Supplementary Materials
parameter value of traffic safety active mode	Auxiliary	((bicycles + pedestrian)/(km, bicycles + km, pedestrian)) $\times$ 1000	254.93	Dnml	Supplementary Materials
bicycles	Auxiliary	(0.0028 $\times$ population)/100	6	#	ELSTAT
pedestrian	Auxiliary	(0.0055 $\times$ population)/100	11	#	ELSTAT
km, bicycles	Constant	40	40	Number of trips in million/year	ELSTAT
km, pedestrian	Constant	30	30	Number of trips in million/year	ELSTAT

Table A7. Values of road deaths variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
ROAD DEATHS	Auxiliary	IF THEN ELSE (FATALITY RATE $\geq$ 15, 0, IF THEN ELSE (FATALITY RATE = 0, 10, (FATALITY RATE-15)/(0–15) $\times$ 10))	3.20	Dnml	Supplementary Materials
FATALITY RATE	Auxiliary	((bicycle deaths + bus deaths + cars deaths + hgv deaths + lgv deaths + moped deaths + motorcycle deaths + pedestrian deaths)/population) $\times$ 100,000	10.20	Dnml	Supplementary Materials
Pedestrian	Auxiliary	r2 $\times$ population	4	#	ELSTAT
r2	Level	r2 $\times$ 0.003	1.8×10^{-5}	#	ASSUMPTION
Bicycle (including regular bicycle, e-bike, etc.)	Auxiliary	r3 $\times$ population	4	#	ELSTAT

Table A7. *Cont.*

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
r3	Level	r3 × 0.003	1.8×10^{-5}	#	ASSUMPTION
Moped	Auxiliary	r4 × population	1	#	ELSTAT
r4	Level	r4 × 0.003	4.7×10^{-6}	#	ASSUMPTION
Motorcycles	Auxiliary	r5 × population	8	#	ELSTAT
r5	Level	r5 × 0.002	3.8×10^{-5}	#	ASSUMPTION
Cars	Auxiliary	r7 × population	4	#	ELSTAT
r7	Level	r7 × 0.002	2×10^{-5}	#	ASSUMPTION
HGV—Trucks (≥3.5 tons)	Auxiliary	r1 × population	1	#	ELSTAT
R1	Level	r1 × 0.003	4.7×10^{-6}	#	ASSUMPTION
LGV (<3.5 tons)	Auxiliary	r8 × population	1	#	ELSTAT
r8	Level	r8 × 0.003	4.7×10^{-6}	#	ASSUMPTION
Bus	Auxiliary	r6 × population	0	#	ELSTAT
r6	Level	r6 × 0.0001	4.7×10^{-6}	#	ASSUMPTION

Table A8. Values of satisfaction with PT variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
SATISFACTION WITH PT	Auxiliary	(Reliable + Safe + Easy to get + Affordable + Frequent + General satisfaction)/6	4.15	Dnml	Supplementary Materials
General satisfaction	Constant	SUM (strongly agree, somewhat agree, somewhat disagree, strongly disagree)	3.9	Dnml	Supplementary Materials
Affordable	Constant	SUM (strongly agree, somewhat agree, somewhat disagree, strongly disagree)	2.3	Dnml	Supplementary Materials
Reliable	Constant	SUM (strongly agree, somewhat agree, somewhat disagree, strongly disagree)	4.2	Dnml	Supplementary Materials
Easy to get	Constant	SUM (strongly agree, somewhat agree, somewhat disagree, strongly disagree)	5.1	Dnml	Supplementary Materials
Frequent	Constant	SUM (strongly agree, somewhat agree, somewhat disagree, strongly disagree)	4.4	Dnml	Supplementary Materials
Safe	Constant	SUM (strongly agree, somewhat agree, somewhat disagree, strongly disagree)	5	Dnml	Supplementary Materials

Table A9. Values of commuting travel time variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
COMMUTING TRAVEL TIME	Auxiliary	IF THEN ELSE (rate of commuting travel time > 90, 0, 10 × (rate of commuting travel time-90)/(10–90))	7.37	Dnml	Supplementary Materials
rate of commuting travel time	Auxiliary	time to home + time to work	30.99	Dnml	Supplementary Materials
time to work	Auxiliary	AVERAGE (time to work)	15.53	min	Supplementary Materials
time to home	Auxiliary	AVERAGE (TIME TO HOME)	15.46	min	Supplementary Materials
rate time to work	Level	rate time to work × 0.0002	7.1907×10^{-5}	min	ASSUMPTION
rate time to home	Level	rate time to home × 0.0002	7.223×10^{-5}	min	ASSUMPTION

Table A10. Values of congestion and delays variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
CONGESTION & DELAYS	Auxiliary	IF THEN ELSE (CDi ≥ 3, 0, IF THEN ELSE(CDi < 1, 10, ((CDi-3)/(1–3)) × 10))	5.01	Dnml	Supplementary Materials
CDi	Auxiliary	cars + MMM	1.99	Dnml	Supplementary Materials
cars	Auxiliary	Cdroad × msroad	15.53	#	Supplementary Materials
MMM	Auxiliary	Cdpt × MSpt	15.46	#	Supplementary Materials
cdroad	Constant	1.79	1.79	#	Supplementary Materials
msroad	Constant	0.48	0.48	#	Supplementary Materials
rate msroad	Level	rate msroad × 0.0002	2.22×10^{-6}	#	Supplementary Materials
Cdpt	Constant	2.19	2.19	#	Supplementary Materials
MSpt	Constant	0.52	0.52	#	Supplementary Materials
ratemspt	Level	ratemspt × 0.0001	2.42×10^{-6}	#	ASSUMPTION

Table A11. Values of access to mobility services variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
ACCESS TO MOBILITY SERVICES	Auxiliary	IF THEN ELSE (parameter value of access to mobility services < 0, 0, IF THEN ELSE (parameter value of access to mobility services ≥ 100, 10, (parameter value of access to mobility services × 10)))	5.7	Dnml	Supplementary Materials

Table A11. *Cont.*

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
parameter value of access to mobility services	Auxiliary	(w1 × people with no access + w1 × people with low access + w2 × people with medium access + w3 × people with high access + w3 × people with very high access)/population	0.57	Dnml	Supplementary Materials
people with no access	Auxiliary	0.03 × population	6.450	#	Supplementary Materials
people with low access	Auxiliary	0.1 × population	21.500	#	Supplementary Materials
people with medium access	Auxiliary	0.6 × population	129.000	#	Supplementary Materials
people with high access	Auxiliary	0.2 × population	43.000	#	Supplementary Materials
people with very high access	Auxiliary	0.07 × population	15.050	#	Supplementary Materials

Table A12. Values of affordability variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
AFFORDABILITY	Auxiliary	(100 − ((household × monthly cost/income) × 100))/10	6.75	Dnml	Supplementary Materials
income	Constant	800	800	€	ASSUMPTION
monthly cost	Constant	100 (Bus card 70€) (Train card 30€)	100	€	Public Transport of Patras
household	Constant	2.6	2.6	#	ELSTAT

Table A13. Values of active mobility variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
ACTIVE MOBILITY	Auxiliary	MIN (10, (parameter value of active mobility/2) × 10)	4	Dnml	Supplementary Materials
parameter value of active mobility	Auxiliary	(Lbl + Lpz + Lz30 + Lsw)/Lrn	0.8	Dnml	ASSUMPTION
Lsw	Constant	500	500	km	ASSUMPTION
Lbl	Constant	200	200	km	ASSUMPTION
Lz30	Constant	600	600	km	ASSUMPTION
Lpz	Constant	300	300	km	ASSUMPTION
Lrn	Constant	2000	2000	km	ASSUMPTION

Table A14. Values of people satisfaction transport variables.

Variable	Variably Type	Equation	Initial Value	Measurement Units	Calculation
PEOPLE SATISFACTION TRANSPORT	Level	SMOOTH (((((1 × social + 1.1 × economy + 0.9 × enviroment)/3)-PEOPLE SATISFACTION TRANSPORT)/9), 10)	5.45448	Dnml	EQUATION
economy	Auxiliary	(AFFORDABILITY + ACTIVE MOBILITY + QUALITY OF PUBLIC SPACES + ACCESS TO MOBILITY SERVICES)/4	5.162	Dnml	EQUATION
environment	Auxiliary	(AIR POLLUTANT EMISSIONS + ENERGY EFFICIENCY + GREENHOUSE GAS EMISSIONS + QUALITY OF PUBLIC SPACES)/4	5.818	Dnml	EQUATION
social	Auxiliary	(COMMUTING TRAVEL TIME + SECURITY + ROAD DEATHS + SATISFACTION WITH PT + TRAFFIC SAFETY ACTIVE MODE + CONGESTION & DELAYS)/6	5.448	Dnml	EQUATION

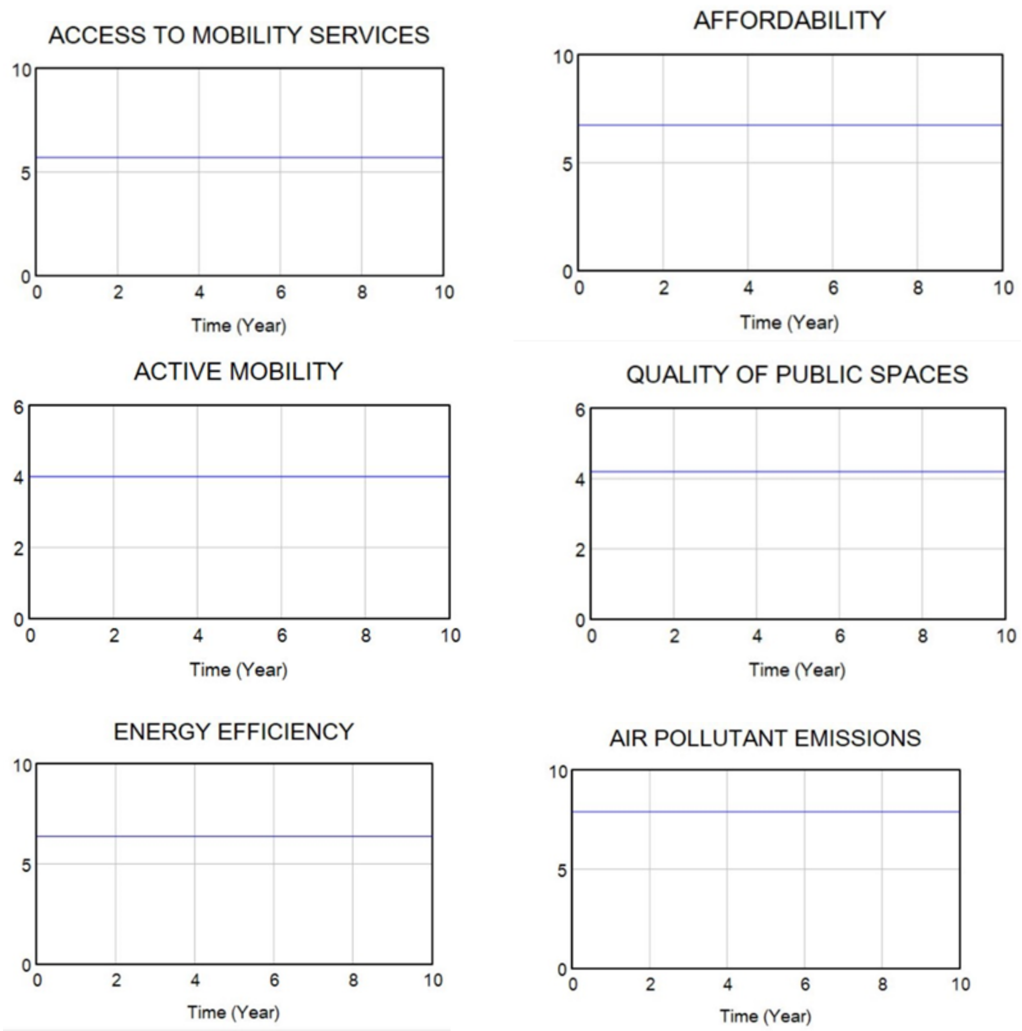


Figure A1. *Cont*.

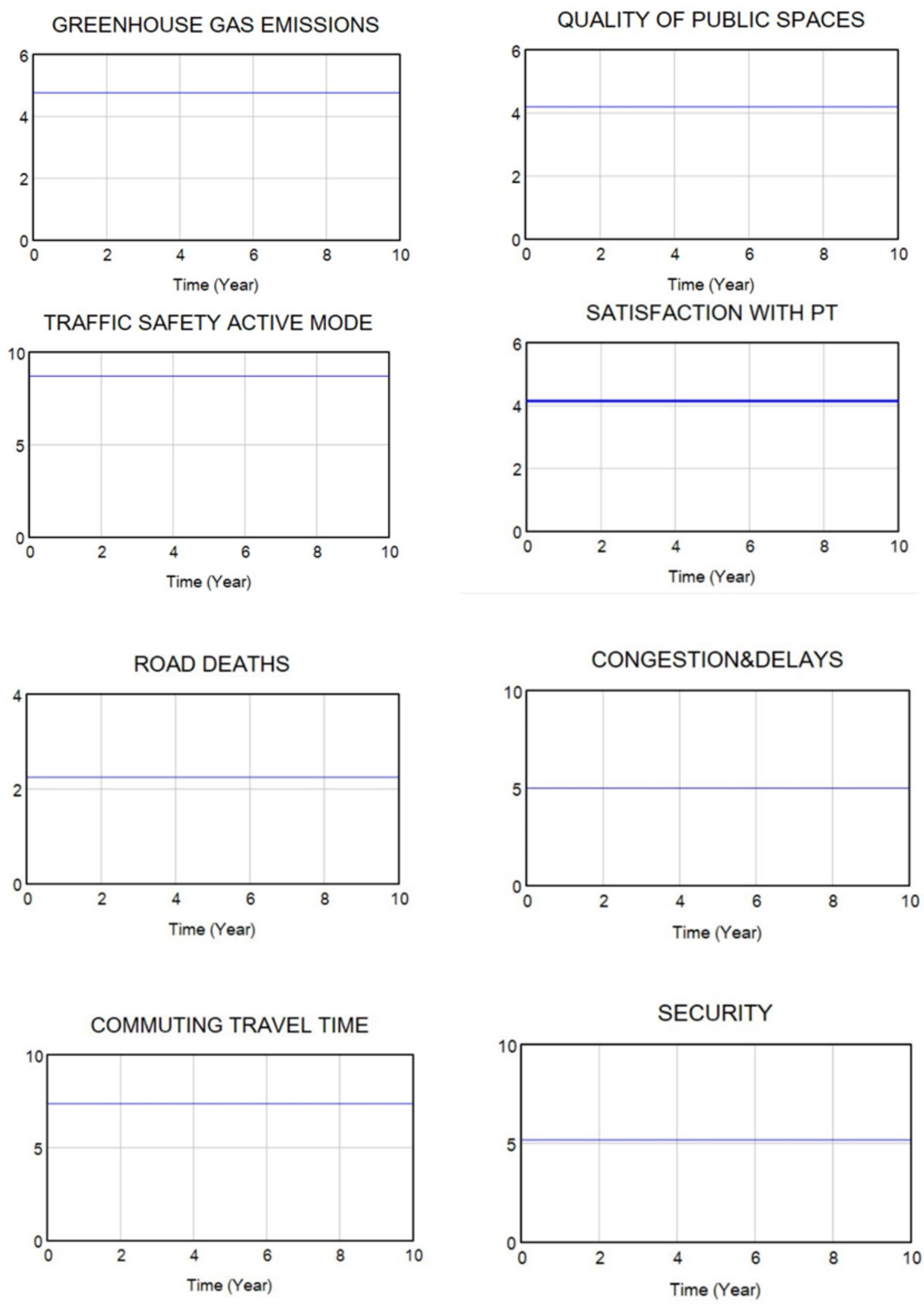


Figure A1. Graphs of individual variables in the field of economy, environment, society (Baseline scenario).

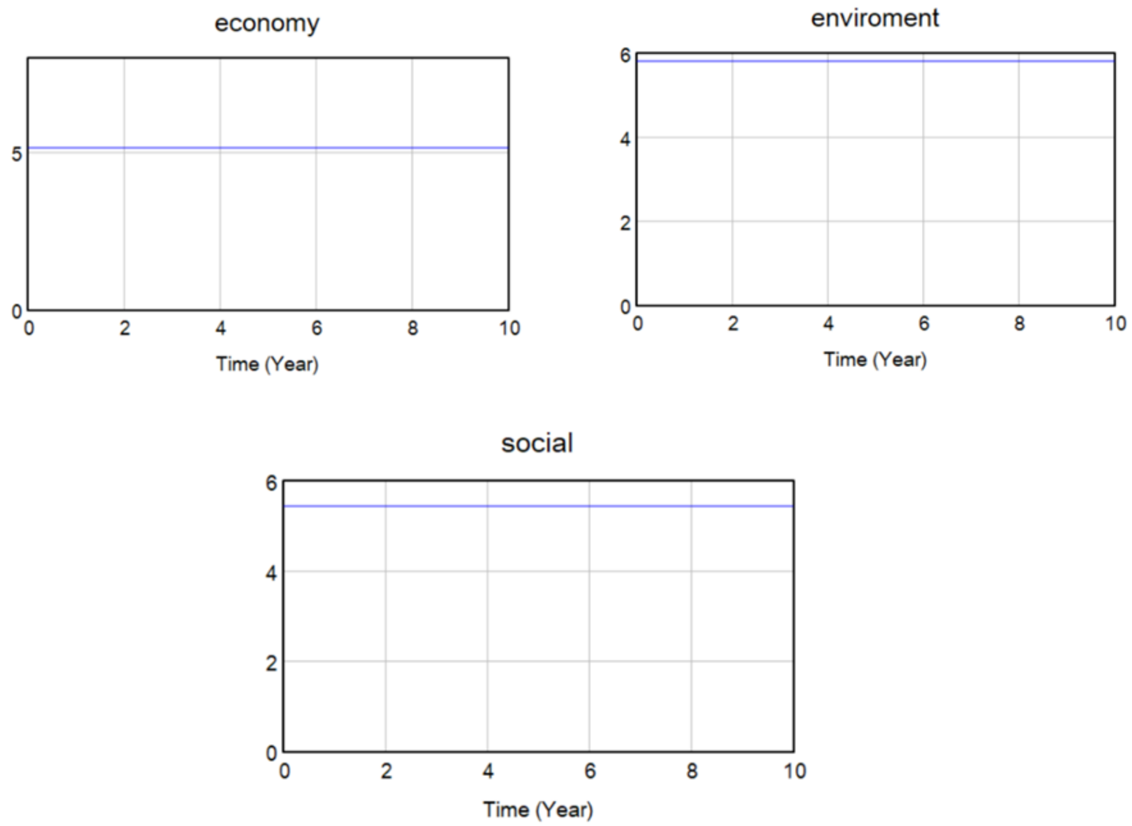
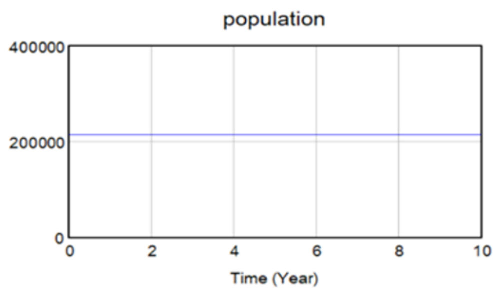


Figure A2. Graphs of the satisfaction regarding each field; economy, environment, social over 10 years (Baseline scenario).



Year	Population
0	215,000
1	214,999
2	214,998
3	214,997
4	217,997
5	214,996
6	214,995
7	214,994
8	214,993
9	214,992
10	214,991

Figure A3. Population growth rate over 10 years (Baseline scenario).

Table A15. A list of the change in the values of the variables in scenarios 1, 2, 3 compared to the baseline—current situation.

Variable	Initial Scenario	Scenario 1	Scenario 2	Scenario 3
		Quality of public spaces		
Public Spaces	5	-	7.2	7.6
Green Spaces	3.4	-	-	7

Table A15. *Cont.*

Variable	Initial Scenario	Scenario 1	Scenario 2	Scenario 3
		Active Mobility		
Lsw	500	-	600	600
Lpz	300	-	400	400
Lbl	200	-	350	350
		Access to mobility services		
No access	6.450	4.000	-	4.000
Low access	21.500	19.000	-	19.000
Medium access	129.000	70.000	-	70.000
High access	43.000	91.000	-	91.000
Very high access	15.050	31.000	-	31.000
		Affordability		
Monthly cost	100	-	-	60
		Air pollutant, energy efficiency, GHG		
car	650	500	640	500
Bus	8	30	6	30
Bus M3	5	8	4	8
Coach	2	3	1	3
Motorcycle	65	60	50	60
Train	2	2	2	2
		Traffic safety active mode		
Bicycle	11.82	-	3.22	3.22
pedestrian	6.23	-	6.45	6.45
		Security		
public transport	5.9	6.5	6.5	6.5
bicycle	3.6	-	-	6.5
pedestrian	5.5	-	-	7
		Road deaths		
car	4	3	-	3
Motorcycles	8	5	-	5
Bicycle	3.6	-	6.5	2
pedestrian	5	-	7	2
		Satisfaction with PT		
General satisfaction	3.9	5.2	-	6.0
Reliable	4.2	5.8	-	5.8
Easy to get	5.1	6.5	-	6.5
Affordable	2.3	-	-	6
Frequent	4.4	6.9	-	6.9
		Commuting travel time		
Time to work	15.53	14.00	13.00	13.00
Time to home	15.46	13.00	12.00	12.00

Table A16. List of recording the change in the values of the variables of Scenario 3 for electromobility.

Vehicle Fleet (%)	Gasoline	Diesel	CNG	LPG	Ethanol	Bio-Ethanol	Bio-Diesel	Hydrogen	Electricity	Gasoline Hybrid	Diesel Hybrid	Check
Car (M1)	12%	20%	0%	1.60%	0%	0%	0%	0%	65%	0%	1.6%	100%
Bus (M2)	n.a.	30%	0%	0%	n.a	n.a	0%	0%	70%	n.a.	0%	100%
Bus (M3)	n.a.	30%	0%	0%	n.a	n.a	0%	0%	70%	n.a.	0%	100%
Coach (M2/M3)	n.a.	30%	0%	0%	n.a	n.a	0%	0%	70%	n.a.	0%	100%
Motorycle	88.8%	11.11%	n.a.	n.a.	n.a	n.a	n.a	n.a	0%	n.a.	n.a.	100%
Train	n.a.	100%	n.a.	n.a.	n.a	n.a	0%	0%	0%	n.a.	n.a.	100%
LGV (<1305 kg)	10%	60%	0%	0%	n.a	n.a	0%	0%	0%	30%	0%	100%
LGV (1305–1760 kg)	8%	62%	0%	0%	n.a	n.a	0%	0%	0%	30%	0%	100%
LGV (>1760 kg)	1%	79%	0%	0%	n.a	n.a	0%	0%	0%	20%	0%	100%
HGV	n.a.	100%	n.a.	n.a	n.a	n.a	0%	0%	n.a.	n.a.	n.a.	100%

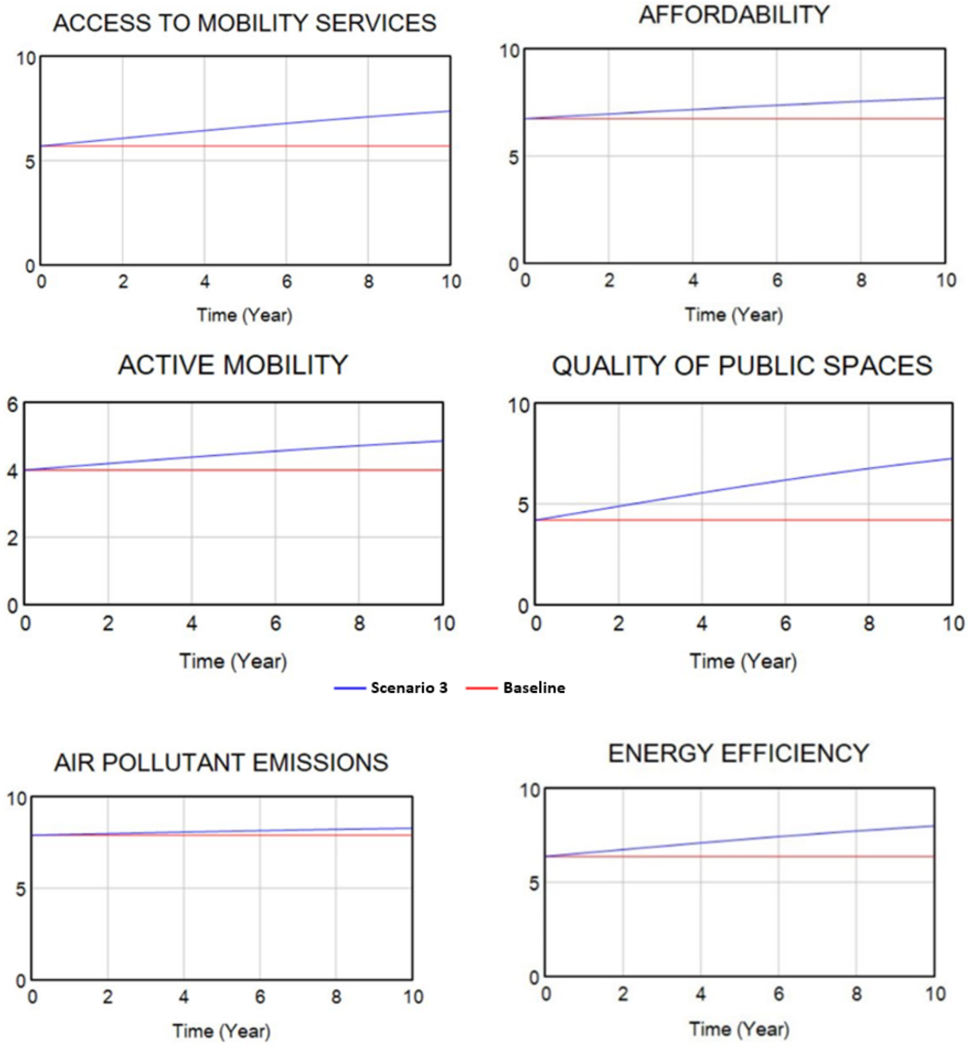


Figure A4. *Cont.*

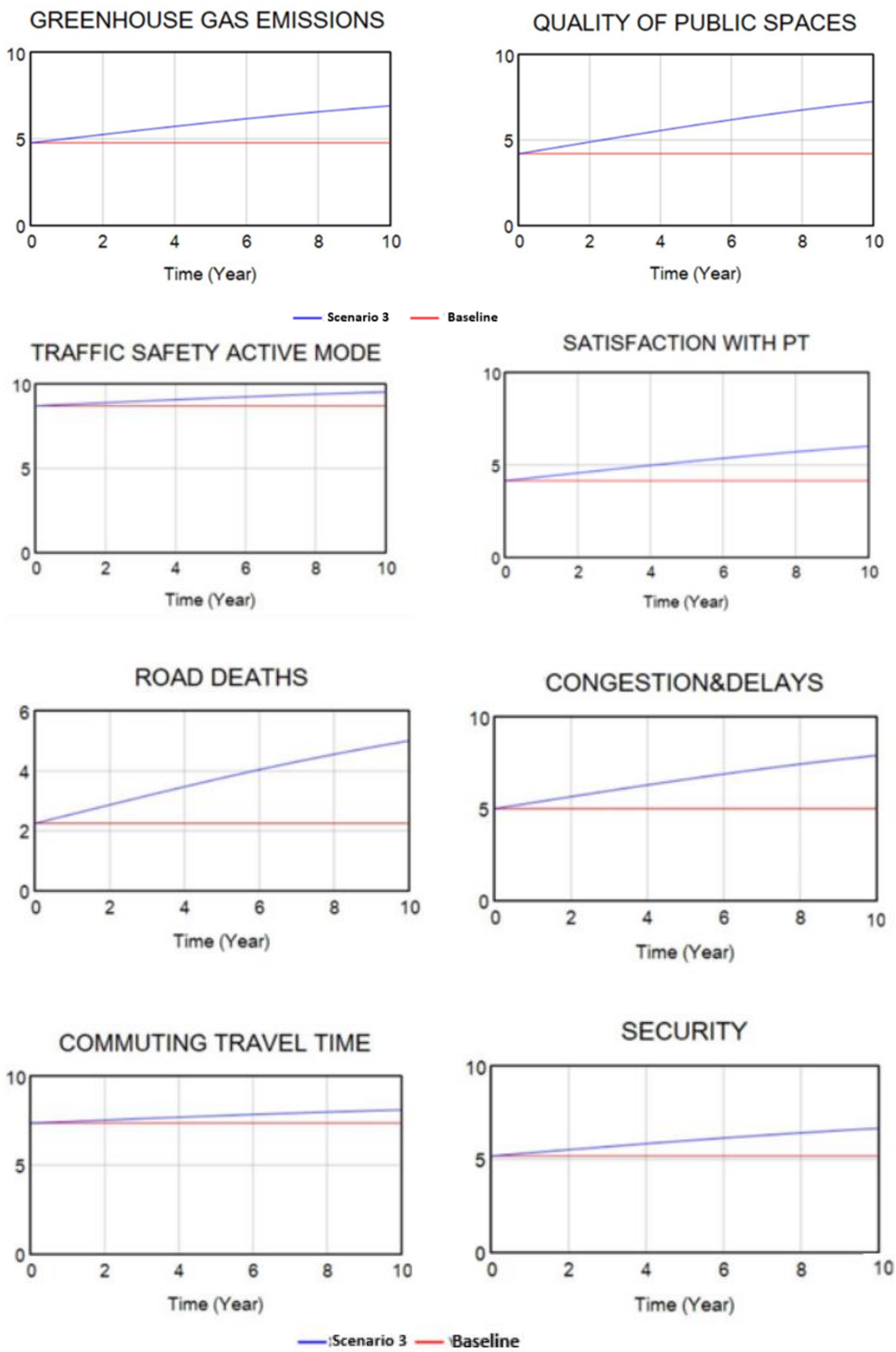


Figure A4. Graphs of individual variables in the field of economy, environment, society (Scenario 3).

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