Dorota PERŁO, PhD
Faculty of Economics and Finance, University of Bialystok
e-mail: dorota.perlo@uwb.edu.pl
ORCID: 0000-0002-3815-1715

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THE IMPORTANCE OF SUSTAINABLE URBAN MOBILITY IN SHAPING THE QUALITY OF LIFE OF THE INHABITANTS OF FUNCTIONAL URBAN AREAS[1]

Summary

Purpose – The aim of this article is to examine the impact of sustainable urban mobility on the quality of life of inhabitants of functional urban areas. A thesis has been posed about the important relationship between them.

Research method – The article uses the method of soft modelling, which enables the study of the relationships between the hidden variables. Statistical data used in the empirical study concerns the Bialystok Functional Area.

Results – As a result of the conducted research and analyses, key determinants of sustainable urban mobility and quality of life were determined, the most important threats related to environmental degradation were identified as well as innovative solutions for sustainable urban mobility that should be implemented in order to effectively manage resources and protect them for the future generations were found.

Originality /value – Key research results can be useful in the process of developing Sustainable Urban Mobility Plans.

Keywords: quality of life, sustainable urban mobility, soft model, urban functional area

JEL Classification: C31, R12, R41, R58

1. Introduction

Contemporary theories of regional development presently place more emphasis on the usage and activation of endogenic potential in accordance with the concept of sustainable development. Such approach appears to be adequate, especially in the context of the hazard related to the depleting natural resources, negative consequences (both economic and social) of the environment degradation as well as negative demographic trends. On one hand, the effect of the aforementioned processes may be the depopulation of many areas, but on the other hand, there may

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be observed the densification of other areas, mainly the urban ones. In 2018 the inhabitants of cities amounted to 55.3% of the population worldwide. In accordance with the forecasts for 2030, this indicator will have increased to 60%, whereas in 2050 – to 70% [*World Urbanization …,* 2019, p. 3]. Another important aspect is also the approach to the way cities are defined: whether it is proper to focus the analyses on the administrative borders of cities or whether it is necessary to concentrate on cities and their functional areas; or, even further, it is crucial to decide if cities and their metropolitan areas ought to be concentrated on [*World Urbanization …,* 2019, p. 3]. Naturally, a proper approach is the resultant of the size and role of the analyzed cities. In the context of the functional relationships between cities and their external zones and in connection with the progressing and irreversible process of suburbanization, it is difficult to define a modern city in its administrative borders. It is more reasonable to base and forecast strategic development on urban functional areas (UFA), i.e. core cities along with municipalities located nearby that constitute the external zone. The internal potential of towns – cores is incomparably larger than the potential of municipalities that surround it. Therefore, the users of public services created by them (e.g. connected with education, health, culture and transport) are also the inhabitants of the municipalities creating their external zone which is frequently the place of residence of many employees of core cities. The number of inhabitants and their enterprises decide about the level of own incomes of local territorial units (LTU) to a large degree, especially the shares in taxes that constitute the incomes of the state budget, i.e. PIT or CIT. It means that the development possibilities of cities and their neighborhood are the resultant of the aforementioned stimulants and to a large extent depend on finding the right proportion between them. Therefore, a considerable role in the development of UFA is played by the preservation of the seeds of cooperation between UFA, which may result in the achievement of the synergy effect by means of accurate diagnosis and exploring collectively the opportunities of satisfying the needs of inhabitants and both more efficient and consistent management of the entire functional area which, as a consequence, will result in higher living standards.

The aim of the paper is to analyse the impact of sustainable urban mobility on the living standard of the inhabitants of urban functional areas. Contemporary cities compete for inhabitants by striving for development and, in some situations, also for the survival. Many cities become depopulated. Presently it is not sufficient to concentrate solely on increasing the level of infrastructural and economic development or to search for external investors who will ensure well paid workplaces. An important magnet that attracts inhabitants is the suitable living standard, owing to which the management of a modern city ought to concentrate also on seeking organizational, technological or investment solutions that will facilitate the achievement of this objective. An essential factor which shapes the living standard in urban functional areas is sustainable urban mobility. An instrument that serves the verification of such thesis is the soft model, which makes it possible to show the relationships between the non-observable phenomena. Bialystok Functional Area (BFA) [www1], which is composed of ten local territorial units: Białystok (as the

core) and nine muncipalities creating the external zone, including six having both urban and rural character: Choroszcz, Czarna Białostocka, Łapy, Supraśl, Wasilków, Zabłudów and three rural municipalities: Dobrzyniewo Duże, Juchnowiec Kościelny and Turośń Kościelna will be used as the example for the empirical analysis. BFA is located in Podlaskie voivodeship. It realizes mutual tasks on the basis of the strategy, the main aim of which is the development of BFA as the attractive place to work and live in. The concern for the living standard is the key to the development of this area – therefore, it is a good example that will serve the verification of the thesis posed. The calculations were made on the basis of statistical data from the years 2014-2018 which are available at the level of the administrative unit in the database of public statistics and local administration by using PLS program created by Rogowski.

2. The delimitation of urban functional areas in Poland – legal grounds

On 1 January 1999 three-tier administrative division of the territory of Poland into voivodeships, powiats and muncipalities was organized[2]. Urban functional areas do not constitute one of the units of the country's administrative division. As a consequence of the association of LTU in connection with the intensifying process of urban sprawl (especially as regards the capital cities of voivodeships) there emerge new mutual challenges, as a response to the downward need to create partner-like cooperation of local territorial units[3]. In order to encourage LTU to initiate such cooperation in the European Union in the years 2014-2020 a new financial instrument of the cohesion policy – Integrated Territorial Investments (ITI) was implemented. The legal basis of implementing this instrument was specified at the European and national level. At the European level the key role was played by the regulations of the European Parliament and Council (EU) [Rozporządzenie, 2013a, 2013b, 2013c]. In accordance with the bequests of the National Urban Policy 2023 (*Krajowa Polityka Miejska 2023)* [2015, p. 106] "the condition of obtaining support within the instrument of Integrated Territorial Investments (addressed at the functional areas of voivodeship centers) is to document the willingness of LTU to cooperate, which is connected with initiating the institutionalized form of partnership, and later on with preparing LTU Strategy – the document pointing at mutual challenges, objectives as well as proposals of certain projects". The requirement to elaborate the ITI strategy was also included in the document that specifies the

[2] In the first stage (by the virtue of the act of 8 March 1990 on territorial self-government [Act, 1990] introduced municipalities' self-governments were introduced, while in the act of 24 July 1998 on the implementation of the fundamental three-tier territorial division of the country [Act, 1998] the division into: municipalities, poviats and voivodships was determined.

[3] At the level of national regulations the possibility of local territorial units to form associations results from art. 172 of the Constitution of the Republic of Poland [Act, 1997], while at the level of international regulations the local communities' right of association is guaranteed by the European Charter of Local Self-government prepared in Strasbourg on 15 October 1985 [Act, 1994].

strategy concerning the interventions of European funds within three EU policies: cohesion policy, common agricultural policy and common fisheries policy, i.e. in the Partnership Agreement [*Programowanie perspektywy…,* 2014, pp. 213-215]. At the voivodeship level the provisions regarding the preparation and implementation of this instrument were specified in regional operational programs, while the delimitation of urban functional areas was formalized by the decisions of voivodeship boards. The basis for the delimitation of voivodeship centers of urban functional areas (MFA VC) was the expertise prepared by Śleszyński who presented their possible composition made on the basis of functional, socio-economic and morphological criteria [Śleszyński, 2013, pp. 173-197]. In the years 2014-2020 the ITI instrument was implemented by 17 MFA VC and 7 sub-regional centers of urban functional areas (MFA SC).

Bialystok Functional Area initiated the institutionalized form of cooperation by establishing the association of municipalities in 2013. The legal basis for the activity of BFA association is included in art. 84 of the act of 8 March 1990 on the self-government of municipalities [Act, 1990] as well as the act of 7 April 1989 – The Association Law [Act, 1989] and the statute. The substantial basis for the realization of BFA tasks is "The Strategy of Integrated Territorial Investments of Bialystok Functional Area for the years 2014-2020" [www 2].

In the EU financial perspective for the years 2021-2027 a plan to continue support by means of territorial instruments which should mobilize LTU to preserve cooperation is included. These are: integrated territorial investments (ITI), local development managed by the local community (RLKS)[4] and other territorial instruments [*Wniosek Rozporządzenie…,* 2018]. They are supposed to enable the achievement of the strategic objective no. 5: *Europe closer to inhabitants by supporting sustainable and integrated development of urban, rural and coastal areas within local initiatives* [*Dokument roboczy…,* 2019]. In accordance with the bequests of the Project of the so-called implementation act at the national level the necessary condition of continuing joint actions of MFA VC by means of ITI instrument will be the elaboration of the strategy of supra-local development [*Projekt ustawy…,* 2020]. The implementation of territorial instruments in a similar formula as in the years 2014-2020 is justified because it will enable the already formed inter-municipal associations to continue joint actions and consolidate cooperation, while the newly formed associations will be able to make use of good practices elaborated in the years 2014-2020.

[4] The pilot instrument realized in the years 2014-2020 in two voivodeships in Poland: Kujawsko-pomorskie and Podlaskie.

2. The specification of the soft model of the impact of sustainable urban mobility on the quality of life of UFA inhabitants

Soft modelling enables the analysis of the relationships between the directly non-observable variables: *sustainable urban mobility* (SUM) and the *quality of life* (QL). The soft model is composed of: the external (theoretical) model and the external (measurement) model [Joreskog, Wold, 1982, pp. 1-54; Kock, Mayfield, 2015, pp. 113-130; Lee et al., 2013, pp. 170-1722; Rogowski, 1990; Rogowski, 2002, pp. 23-34; Servera-Francés et al., 2013; Tenenhaus et al., 2005, pp. 159-205; Wold, 1980]. These models are used at the same time in the process of estimating parameters – they are interrelated. The internal model describes the relations between the non-observable variables, in other words, it describes the theoretical relations resulting from the adopted theory. In the constructed soft model, two non-observable (hidden) variables which create the internal model were adopted: sustainable urban mobility (SUM) and the quality of life (QL). The theoretical model is used for analyzing the impact of sustainable urban mobility on the quality of life. Hidden variables were defined on the basis of the potential collection of indicators (observable variables). The relations between non-observable variables and the observable ones constitute the measurement model which shows in which way indicators reflect their hidden variables, i.e. it includes the definitions of theoretical variables. As regards the soft model it is assumed that hidden variables are the linear combinations of their indicators.

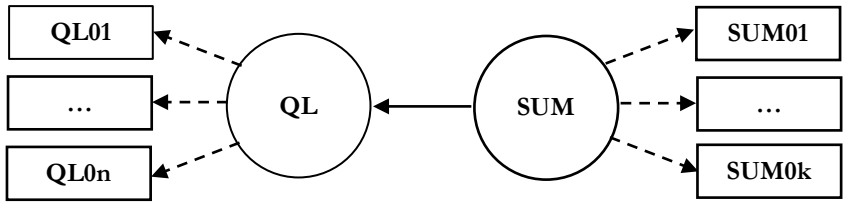
In the soft modelling method, the non-observable variables may be defined in two ways: deductive ad inductive. Depending on the adopted approach there are differences in the manner and results of the estimate. In the paper the deductive approach which implies that the hidden variable (as the theoretical approach) is the starting point for seeking empirical data (the transition from theoretical concepts to indicators) was adopted, which means that it is the primary variable in relation to a certain indicator. The indicators of such non-observable variables are referred to as reflecting (or reflective) indicators. In principle, reflective indicators ought to be characterized by high correlation between them, as a consequence of which during the selection of variables one needs to take into consideration the substantial aspects instead of basing on the classical selection methods. The classical methods imply insignificant correlation between the explanatory variables [Kuszewski, 2000, pp. 14-16]. The scheme of the internal and external model is presented in chart 1.

The soft model is estimated using the method of *partial least squares* (PLS). This method is used to estimate the parameters of the measurement model and the theoretical model at the same time. As the result of the estimate, apart from these parameters the estimation of the value of the hidden variable that can be treated as the synthetic measure is obtained. These values depend not only on the external relations, but also on the relations between complex phenomena included in the internal model. It means that the process of cognition is dependent on the theoretical description. The estimates of non-observable variables do not have substantial interpretation, but it is possible to interpret the changes of their values.

The variables analysed in soft modelling are referred to as either stimulants or destimulants. If the estimators of weights and factor loadings for the indicators being the stimulants of a certain observable variable are positive (while for destimulants they are negative), the higher value of this variable indicates a higher level of the analysed phenomenon in a given object. By interpreting the order of these numbers, it is possible to make the comparative analysis.

CHART 1

The scheme of the soft model showing the impact of sustainable urban mobility on the quality of life



where:

internal relation,

external relation,

hidden variable,

indicator.

Source: own elaboration.

The internal model presents the following linear equation:

$$\mathbf{QL_t} = \alpha_1 \mathbf{SUM_t} + \alpha_2 + \varepsilon_\mathbf{t}, \tag{1}$$

where:

$\mathbf{QL}_t$ – hidden endogenous variable in t moment,

$\mathbf{SUM}_t$ – hidden exogenous variable in t moment,

α_i –structural parameters of the model, i = 1, 2,

ε_t – random component.

In accordance with the stages of the classical econometric modelling, it is necessary to verify them before starting to analyse the results. The substantial verification ought to be made at the beginning, while the statistic verification should take place later on. The assessments of the parameters of both external and internal relations must be consistent with the adopted theoretical description. In order to check the quality of the soft model measures known as the classical elements of econometrics are used, which are based on the estimated values of hidden variables as the values observed in reality. These are the squared coefficients of multiple correlation (R^2) or standard deviations of parameter estimators.

The statistic properties of the soft model are checked mainly on the basis of Stone-Geisser test (S-G test), which is the measure of accuracy of prediction made on the basis of the model in relation to the "trivial" prediction and the so-called Tuckey method [Wold, 1980; Rogowski, 1990]. These methods are specific for soft modelling. The S-G test, which was named Wold, is not a typical statistic test because it does not include hypotheses, statistics or critical value. The procedure of analyzing the relevance of variables is completely different because it constitutes a certain test, but it is not a statistic test. The values of S-G test are not limited from below, while the upper limit amounts to 1. If the test's value is negative, the soft model has worse predicting properties in comparison with the trivial prognosis. As regards the test's value amounting to 1, the prognoses are unfailing, while for the value amounting to 0, the quality of the model prognoses and the trivial prognosis is identical.

In order to determine the value of the S-G test it is necessary to estimate the parameters of the soft model L-times. For each parameter of the external and internal relation one should determine the standard deviation of the obtained L of its estimators: b_1, b_2, ... ,b_L in accordance with the following formula:

$$\mathbf{s}_{\beta} = \sqrt{\frac{\sum_{l=1}^{L}(\mathbf{b}_l - \overline{\mathbf{b}})^2}{\mathbf{L}}}, \quad \text{where} \quad \overline{\mathbf{b}} = \frac{\sum_{l=1}^{L}\mathbf{b}_l}{\mathbf{L}} \tag{2}$$

Then the assessment of the relevance of the model's parameters is made using the "2s" rule. This method is known as the Tukey's range test.

3. The definition of hidden variables of the soft model showing the impact of sustainable urban mobility on the quality of life of UFA inhabitants

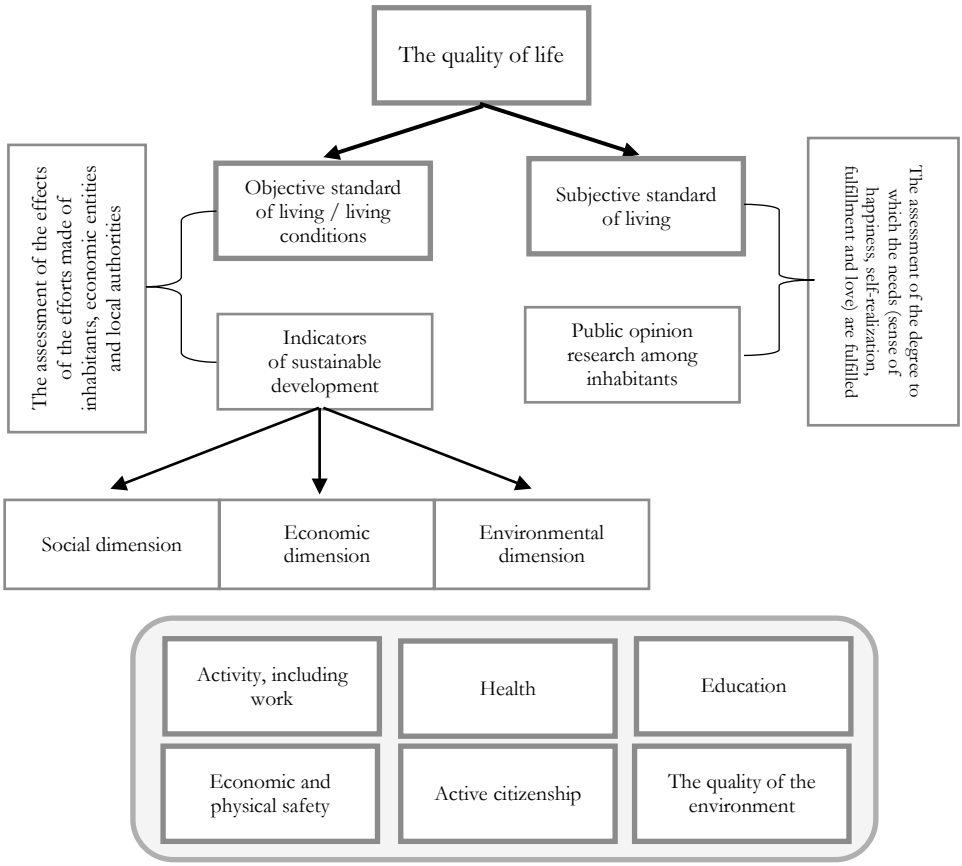
The quality of life is a multi-dimensional and interdisciplinary concept. Scientists focus their research on its various aspects that highlight various spheres of the reality. Most frequently, the quality of life includes the analysis of three approaches: subjective, objective and the approach combining the two perspectives [*Jakość życia*…, 2008, pp. 13-14].

The objective aspect points at the quantity approach to the analysis of the level of the quality of life (chart 2). It comprises mainly the indicators that define the conditions and the standard of living which are constructed on the basis of the available data and statistic research (e.g. public statistics, administrative databases). They are analysed in three dimensions of sustainable development: social, economic and environmental. They concern, among others: the possibility of educational and professional development, available technical, economic and social infrastructure, the quality of the natural environment or the existing seeds of constructing the social capital. The subjective aspect of the quality of life is analysed in quality terms on the basis of the opinion of inhabitants. It includes the feelings of inhabitants

towards the elements which frequently depend more on more personal factors than those offered by the city and its resources. These are: the sense of happiness, self-realization, fulfilment and love.

CHART 2

The approach to defining the quality of life – key elements



Source: author's own elaboration based on: [*Jakość życia*…, 2008, pp. 13-14; Petelewicz, Drabowicz, 2016, pp. 30-32; Rutkowski, 1988, pp. 42-48].

The research includes the objective approach to defining the quality of life. The hidden variable known as the "quality of life" (QL) was defined on the basis of available statistic information (at the level of a basic local territorial unit) which was aggregated at the level of Bialystok Functional Area in the years 2014-2018. Several dozens of observable variables were subject to initial analysis in the social, economic and environmental dimension. Ultimately, it comprises data included in table 1.

TABLE 1

The list of indicators of the hidden variable QL

Symbol	The name of the observable variable
QL01	Shares in taxes that constitute state budget incomes in total per 1 inhabitant in municipalities including cities with county rights [in PLN]
QL02	Children in pre-school education institutions per 1,000 children aged 3-5
QL03	Forest cover (in %)
QL04	Flats commissioned to use per 1000 people
QL05	The number of foundations, associations and social organizations per 10,000 inhabitants

Source: author's own elaboration.

These indicators were selected on the basis of the substantial and statistic criterion and then positively verified in the last stage of constructing the soft model. The quality of life is a multi-dimensional phenomenon that is difficult to define in a homogenous way and it is even more difficult to measure it. Consequently, it should be noted that the ultimate set of observable variables (which includes a small number of indicators) presents just the idea of the quality of life rather than examines all the elements having an impact on its level in a complementary way. It illustrates the most important components serving the estimation of the analysed relation and the direction of changes in the quality of life in the analysed period. The number of observable variables used to define QL results also from the method of soft modelling that reduces the composition of the indicators of the latent variable to the number of the analysed objects to the maximum level.

Sustainable urban mobility was defined on the basis of three concepts: sustainable development, sustainable transport and sustainable mobility, which constitutes the development and continuation of their selected elements [Wołek, 2014, p. 393]. In 2001 in Göteborg the European Council adopted the sustainable development strategy which has become the pillar for the development goals of the European Union [*Komunikat Komisji*…, 2005, p. 4]. All the subsequent strategic documents were based on it, while the original provisions were clarified. Sustainable transport was specified at the European Conference of Ministers of Transport in 2003 as the transportation system based on climate protection, regional and local air quality, which [*Assessment and*… 2004, p. 227-228]:

- ensures the realization of basic needs and the availability of communicative objectives in a secure way in accordance with the idea of sustainable development,
- offers services to the society at an affordable price, functions in an effective and fair way, offers the possibility of selecting transportation mean and supports competitive economy,
- reduces the emission of the air pollution.

According to the PWN Dictionary of Polish language, mobility means the population's ability to move in space or in the social system [www3]. Almost 50 years ago

mobility was viewed as a more complex process taking into account socio-technical system that was composed of: infrastructure, transportation technology as well as people and their behaviors [Wołek, 2014, p. 392]. Sustainable urban mobility is a multi-threaded concept that is of particular importance in the conditions of increasing urbanization processes causing such problems as: traffic congestion, poor air quality, noise emissions or high levels of CO_2 emission. The intensification of negative phenomena at the local scale results in the problems with sustainable development at the regional and national level and, consequently, also at the global level. Therefore, the local and supra-local level (the development of cities and their functional areas) has become priority in the cohesion policy of the European Union. The necessity to adopt a new approach to planning and organizing urban mobility was included in the Urban Mobility Package approved by the European Commission in 2013, but the instrument that serves comprehensive programming of this approach is the *Sustainable Urban Mobility Plan* (SUMP)) [*Wspólne…*, 2013]. "The plan of sustainable urban mobility is the strategic plan which aims at satisfying the mobility needs of people and enterprises in cities and in their vicinity as regards better quality of life. It is based on the existing planning practices and adequately considers the principles of integration, participation and assessment" [*Guidelines for …,* 2019 p. 10]. SUMP is the mechanism which, in combination with the possibility of obtaining financial support, effectively encourages the authorities of urban areas to undertake complex comprehensive actions connected with shaping urban mobility. It should be an interdisciplinary document that comprises the issues related to transport, land use and environmental protection, economic and social development and road safety [*Wspólne*…, 2013]. The achievement of more sustainable urban mobility is closely related to economic growth and reducing the environment pollution [*Zrównoważona*…, 2020, p. 4]. The actions aimed at the diversification of transport that is more adjusted to the principles of sustainable development are crucial from the perspective of the overarching objective – i.e. the quality of life.

TABLE 2

The list of indicators of the hidden variable SUM

Symbol	The name of the observable variable
SUM01	Bike paths in total per 100 km^2
SUM02	The number of times urban bicycles BiKeR were rented per 100,000 inhabitants
SUM03	The length of bus lanes in km per 100 km^2
SUM04	The mileage of buses per tone-kilometer in total in thousands per 100 km^2
SUM05	The number of passengers using public transport in persons per 100,000 inhabitants

Source: author's own elaboration.

Consequently, in the empirical research the hidden variable SUM – sustainable urban mobility, was defined by means of the aggregate of specific indicators that

decide about the usage of various types of low-emission transport. During the selection of indicators the substantial reasons and the availability of statistic data were taken into account, i.e. the adequate conditions as the ones that determined the selection of observable variables of the QL indicator (table 2).

4. The analysis of the results of the soft model – the impact of sustainable urban mobility on the quality of life of UFA inhabitants

As the result of estimating the parameters of soft model, the estimates of the internal and external relation are obtained. The estimated parameters were verified positively on its merits and in statistic terms – as a result, it is possible to interpret them. In the process of soft modelling a deductive approach was adopted, owing to which the analysis concerns factor loadings which are the correlation coefficients between the explanatory variables and the hidden variable. All the indicators of the hidden variable QL have very strong impact on it because their values oscillate between 0.85 and 0.99 (table 3).

TABLE 3

The results of the estimates of the parameters of the external model and errors in the estimates made using Tukey's range test

Variable	Weights	Loading factor	Free expression	R^2
	(Error)	(Error)		
QL01	0.2643	0.8621	-22174.5391	0.7432
	(0.1100)	*(0.2464)*		
QL02	0.2536	0.9949	-624.9984	0.9898
	(0.1076)	*(0.3415)*		
QL03	0.1823	0.9309	29.8152	0.8666
	(0.0729)	*(0.2361)*		
QL04	0.1999	0.8456	-84.3232	0.7150
	(0.1107)	*(0.4199)*		
QL05	0.1929	0.9386	-414.8270	0.8810
	(0.0780)	*(0.2722)*		
SUM01	0.2384	0.9885	-15.0476	0.9772
	(0.0015)	*(0.0029)*		
SUM02	0.2696	0.9888	-542600.6261	0.9776
	(0.0048)	*(0.0023)*		
SUM03	0.1763	0.8960	-1.0192	0.8029
	(0.0091)	*(0.0090)*		
SUM04	0.2829	0.8065	651.5642	0.6504
	(0.0181)	*(0.0125)*		
SUM05	0.1374	0,8129	-65239682.9391	0.6608
	(0.0109)	*(0.0117)*		

Source: author's own elaboration based on the results of soft modeling.

In Bialystok Functional Area the number of children in pre-primary education institutions per 1 thousand children aged 3-5 (QL02 – 0.9949) has the greatest impact on the quality of life. In the years 2014-2018 this indicator was on an upward trend and in 2018 it achieved the value of 97%, which means that almost 100% children aged 3-5 years were attending pre-primary education institutions. It results from the realization of integrated projects by BFA in terms of the improvement of pre-primary education infrastructure situated near the local community of LTU. This positive tendency indicates increasingly better availability of this infrastructure and pre-primary care. The development of urban centres depends to a large degree on the number of inhabitants and the direction of the change. It is also the derivative of the age structure of the population, while the demographic potential of BFA is its strong point. The number of BFA inhabitants increases from year to year, including the number of people in pre-production age, which is also the evidence of beneficial development possibilities of Bialystok Functional Area. Not all BFA municipalities can be characterized by positive trends in this aspect. Among 10 municipalities creating Bialystok Functional Area, in two municipalities (Czarna Białostocka and Łapy) the number of inhabitants marginally decreases (by 2.2% and 1.5% respectively in 2018 in comparison with 2014). Furthermore, in the structure of BFA population there is the increase in the participation of people in post-production age, which is consistent with the global trend connected, among others, with increasing the average life span, but may also constitute a certain development trend. Therefore, it requires shaping appropriate public services addressed to this group of population which will have beneficial influence on the quality of their life. At the same time, there is the increase in the participation of persons in pre-production age, which, in turn, gives the chance for the development of BFA and determines actions addressed to young people which will encourage them to develop and remain in their place of residence, including, among others, housing development. The development possibilities of BFA also depend municipalities own resources which they have at their disposal. The structure of personal incomes is to the largest degree composed of shares in taxes that constitute the incomes of the state budget – personal income taxes and corporate tax. One can observe very strong impact of this variable on the living standard of BFA inhabitants (QL01 – 0.8621). In the analysed period this indicator was characterized by positive dynamics in all the municipalities of BFA. However, the present economic situation, which is connected with economic slowdown caused by the COVID-19 pandemics, has negative influence on the labour market, development possibilities of enterprises and, as the consequence, on the wealth of the inhabitants. Additionally, considerable financial outlays, which LTU need to make in order to reinforce the safety of both inhabitants and tourists of BFA, reduce its investment possibilities.

Support instruments, which are developed at the European, national, regional and local level, do not cover the losses incurred as the consequence of the epidemic threat. Furthermore, it is difficult to estimate the time of economic slowdown which adopted global dimensions. Very careful prognosis of development are required in light of such threats as COVID-19. Another indicator that has strong impact on QL

variable is the number of foundations, associations and social organizations per 10,000 inhabitants (QL05 – 0.9386), which indicates the construction of social capital of BFA. The sense of identification with the surroundings and cooperation for solving social problems, or the involvement in the development of BFA municipalities constitute important elements of the quality of life. Podlaskie voivodship (the capital city of which is Białystok) is the region with relatively lower level of economic growth, but at the same time its advantage is the natural environment. An important role in shaping the quality of life is also played by legally protected areas, especially forests that occupy a considerable part of BFA areas and have good impact on the air quality (QL03 – 0.9309). Pure air is a rare good in the contemporary world and attracts both inhabitants and tourists. The loss of this advantage may result in depopulation and loss of development possibilities. Therefore, it is important to take steps reinforcing this side which are connected, among others, with the production of energy from renewable sources, the elimination of cauldrons for renewable fuels, the development of clean business that does not cause the environment degradation and with the development of sustainable urban mobility.

The indicators of hidden variable are characterized by equally strong impact as QL variable. Factor loadings oscillate from 0.81 to 0.99. All the observable variables are connected with the development of low-emission transport - in BFA it regards public transport and bike rides. Sustainable urban mobility of Bialystok Functional is to the largest degree determined by the development of BiKeR city bike which over the last years has become also the bike of the entire agglomeration (SUM02 – 0.9888). The number of rentals of BiKeR bikes in the years 2014-2018 almost doubled, which was, among others, the consequence of developing bike paths in BFA (SUM01 – 0.9885), the number of which (per 100 km^2) increased more than two times. However, it does not mean that the investment needs in this area were exhausted. On the contrary, the increased interest in bike mobility in BFA means that the network of bike paths and the system of city bikes should be still developed in order to improve road traffic safety and quality and in this way encourage even larger number of people to use this source of communication. Furthermore, a bike is a safe means of transport during the epidemic threat. Additionally, it is more ecological than passenger cars, which also predestines this type of low-emission transport to further development. Public transport, which in Bialystok Functional Area means mostly MPK buses, also plays an essential role in shaping sustainable urban mobility. This is facilitated both by the development of bus lanes in Bialystok (SUM03 – 0.8960), the increased number of communication lines, as well as vehicle kilometers travelled in muncipalities creating the external sphere of BFA (SUM04 – 0.8065). Unfortunately, so far it is not synonymous with the increased interest in the means of transport. Admittedly, the usage of public transport in BFA has strong impact on the hidden variable SUM (SUM05 – 0,8129), but the indicator (despite the development of road infrastructure and low-emission buses) still shows the downward trend. Additional limitations in the carriage of passengers by public transport (which are connected with the pandemic) show downward trend in these

terms. Białystok is a compact city that occupies the second position in Poland in terms of the population density (after Warsaw). However, its external zone is characterized by extensive construction of single-family houses. The newly created lines of the public transport do not satisfy all the needs of the neighborhood of Białystok. There are still visible huge needs in this sphere, but not all of them may be satisfied owing to the cost intensity of such a solution. This is the sphere for the development of new business models that specify "mobility as the service", such as car-pooling, or car-sharing. It is necessary to create proper instruments to support their development and include these services as the element of a complementary system of sustainable urban mobility of BOF programmed within SUMP.

The results of the estimate of the internal model are visible in the following equation (3).

$$\underset{(0,0205)}{\hat{\mathbf{QL}}_t = 0,8858\mathbf{SUM}_t} \underset{(24,0575)}{+185,3625} \qquad \mathbf{R}^2 = 0,7847 \tag{3}$$

TABLE 4

The results of Stone-Geisser test (SG)

Variable	SG test
QL01	0.2450
QL02	0.1688
QL03	0.0785
QL04	0.0123
QL05	0.0711
Overall test SG	0.2448

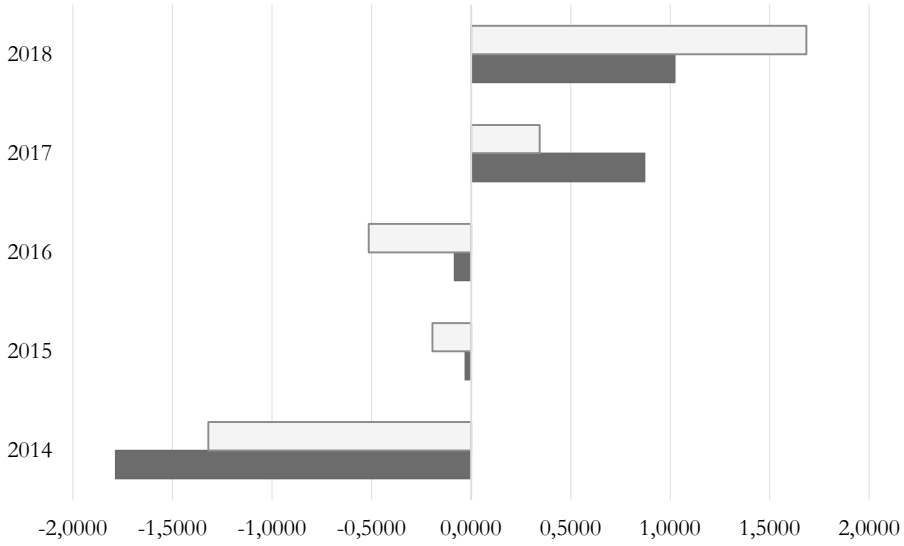
Source: author's own elaboration based on the results of soft modeling.

The quality of the internal model is good, the sign of which is the determination coefficient amounting to 0.7847. Additionally, it is possible to positively assess the estimated parameters – in accordance with the rule of the so-called Tukey ranges, the doubled value of their standard deviations is lower than the value of the estimated structural parameters. The model has also beneficial prognostic properties, the evidence of which is the positive value of Stone-Geisser test, both the general value and in terms of particular indicators of the endogenic variable QL (table 4). In accordance with the adopted thesis, sustainable urban mobility of BFA has a strong impact on shaping the quality of life in this area (0.8858). It is the indispensable element that specifies the priorities of the development of municipalities of Białystok Functional Area to create an attractive place to work and live in.

As the result of estimating the internal model the estimated values of hidden variables that serve the ordering of objects (years) while pointing at the direction of changes in the analysed values are also obtained. As regards two analysed hidden variables (QL and SUM), their values increase from year to year, which means

a positive tendency both in terms of shaping sustainable urban mobility and the increased level of the quality of life the in municipalities of Bialystok Functional Area (chart 3). Although the direction of the changes is proper, the analysis of individual statistic data points at the necessity of further investment and constructing the system of organizing and implementing intelligent solutions in this area which ought to be specified and described in a comprehensive and participatory way in the elaborated "Plan of Sustainable Urban Mobility of BFA" and then efficiently implemented.

CHART 3
The estimated values of QL and SUM hidden variables in the years 2014-2018



	2014	2015	2016	2017	2018
SUM	-1,3200	-0,1946	-0,5144	0,3449	1,6841
QL	-1,7838	-0,0302	-0,0826	0,8722	1,0245

Source: author's own elaboration based on the results of soft modelling.

The advantage of Bialystok Functional Area is its experience in terms of an institutionalized form of cooperation of municipalities in the form of LTU association and the realization of the common strategy of development. It creates the origins of the trust capital that enables BFA municipalities to seek common, more effective solutions in terms of improving the quality of life instead of competing for inhabitants, entrepreneurs and new business partners. The priority of BFA municipalities is to integrate activities in order to shape sustainable urban mobility that takes into consideration economic, social and environmental aspects.

5. Conclusions

The thesis that sustainable urban mobility has an impact on the quality of life of the inhabitants of urban functional areas was positively verified. This is indicated both by the global trends related to the need to protect the climate and by the necessity of systemic and complex approach to sustainable development at all its levels and local activities in urban centres. Education of the society and increasing the awareness of the hazards connected with the environment degradation and the air pollution change the attitudes of population. The inhabitants of urban and rural centers notice the need to take care of the natural environment and view it as common good that should be preserved in order to keep the future generations in good health in accordance with the concept of sustainable development. This moment is right for a more complex and systemic approach of urban functional areas to the development of sustainable urban mobility. Technological development also promotes such activities. COVID-19 pandemic showed how quickly society can adjust to using digital tools for remote working and how many activities can be performed without the need to move. The pandemic is also the reminder of the importance of safe population migration. Sustainable urban mobility includes all the elements that have an impact on the quality of life. On one hand, it includes urban logistics, ecologically sustainable transport (low-emission transport, autonomous cars, car-pooling, car-sharing), intelligent transportation systems which (thanks to using IT and communication technologies in transport) enable more effective usage of the possessed infrastructure resources and stocks. On the other hand, it also regards public space planning in accordance with the needs of its inhabitants, the availability of "low-emission zones" in urban areas that are more frequently used by cities as the instrument for shaping sustainable mobility, improving safety and dealing with noise.

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