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Smart Cities Concept- Smart Mobility Indicator

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ABSTRACT

This work attempts to analyze problems resulting from the lack of possibility to assess the effectiveness of the implementation of 'Smart Mobility' solutions, which represent one of the cornerstones of Smart Cities, from the point of view of city hall offices. The work presents existing Smart Mobility evaluation solutions, discusses their drawbacks, and then proposes a new indicator. The final part of the work presents assumptions with regard to the verification of the indicator and research work planned for the future.

KEYWORDS

smart cities; smart city; smart mobility

Introduction

The objective of this study is to develop an indicator which will evaluate the level of 'Smart Mobility' solutions implemented in cities. This subject seems to be extremely important in view of the growing importance of cities and their progressive growth in recent years. The 'Smart Mobility' area is particularly visible from the perspective of residents and visitors due to problems related to the transport of people, goods and information.

It has been decided that there is a need for an indicator – due to the fact that in the few studies currently in existence on 'Smart Mobility' issues the analysis is

overly general and there is a lack of detailed information on the assessment of specific ratings of the studies.

The indicator that is being developed under this study is aimed at making it possible for the officials of city halls, residents and investors to analyze situations related to the mobility of people, goods and information within the city in line with the ‘Smart Cities’ concept. The systematic application of the indicator will allow for ongoing verification of the above-mentioned issues, which will enable the more effective implementation of beneficial changes in the functioning of the city. Moreover, using the indicator on a wider scale will facilitate a comparison of situations in different cities and, inter alia, identify best practices in other, better-rated cities, thus contributing to their development.

Smart Cities Concept

The Smart City concept has been developed in relation to progressing urban development and the resulting increase in the needs of local communities, and also in relation to increasing financial and environmental costs. It is very difficult to clearly and precisely define what a Smart City is, because the term encompasses such domains as, for example, technology, communication, ecology and sociology. The literature contains numerous definitions of a Smart City, which vary one from another, depending on the author's area of interest. An example of a diverse approach to the subject of Smart Cities may be the concepts presented in the following paragraph.

One of them was formulated by the mayor of the city of Bilbao – Iñaki Azkuna, who, together with members of the Committee of Digital Knowledge-based Cities (2012), focused mainly on the necessity to utilize Information and Communication Technologies (ICT) in Smart Cities for the purpose of

achieving greater effectiveness and productivity, while at the same time raising awareness of these technologies among residents. All of these aspects are to have a real impact on the development of the entire city. A Smart City, understood in this way, also includes, among others, the need to make investments in human and socio-cultural capital, and to reasonably manage natural resources; however, these aspects bear less emphasis than the aforementioned ICT.

William J. Mitchell (2007) played an important role in the development of the Smart Cities programme at the Massachusetts Institute of Technology (MIT) Media Lab. In one of his papers, he compared a Smart City to a fully formed human organism in which information and communication technologies are equivalent to the nervous system. In this developed entity, all elements are connected and interact with each other, so that the organism's performance is stable, and possible problems are immediately solved. Such functioning is also conducive to further, faster development of cities of this type. This concept, similarly to the previous one, shows how important the appropriate use of ICT technology is, as without ICT the correct operation of the ‘organism’ would be impossible. Analyzing the different approaches to the Smart Cities concept, mentioned above, one may notice that definitions range from those whose authors are mainly focused on the technology aspect, through those where the main emphasis is put on social values, and ending with those that try to provide a holistic view of the issue. The variety of approaches to the Smart Cities concept brings with it many problems, which may be best observed when comparing and evaluating specific cities from the perspective of criteria that might classify them as Smart Cities. Depending on the adoption of a definition

focusing on a given aspect, the same city may receive completely different ratings. Even more diverse results may be obtained when comparing different cities if the analysis is geared towards a completely different aspect. At this point there is a danger that, for example, city authorities will use only those definitions which give the most favourable evaluation to the city they represent; consequently, for the average citizen this information may lead to erroneous conclusions and, above all, may prevent the effective implementation of technological solutions most necessary from the viewpoint of the city. The fact that the definitions vary so much also creates problems with regard to further research into cities of this type or their development. Fruitful collaboration between cities or academic centers is hard in the absence of a clear and uniform definition basis, which may provide a springboard for further investigation of the subject – especially one that is developing so dynamically. At the same time, the fact that there are such varied approaches to the Smart City concept indicates how important the concept currently is, and how great the need is for making it more uniform. Therefore, in the following paragraphs of this work, the authors will consider (Orlowski, Marc, Namiesnik, Tobiszewski 2017) that in Smart Cities technology is but a tool geared towards making the life of the residents of the city easier.

Aspects of Smart Cities

In order to better understand the essence of a Smart City, it is necessary to analyze the components of which it is comprised. The most widespread division of a Smart City into specific areas was presented by a team of academics from the Department of Spatial Planning of the Vienna University of Technology. According to the Vienna scientists (Giffinger, Kramar, Haindlmaier, Strohmayer, 2007) these areas are - the economy & competitiveness (Smart

Economy), transport (Smart Mobility), natural resources (Smart Environment), social & human capital (Smart People), standard and quality of life (Smart Living), administration & participation (Smart Governance). Determining the areas listed above made it possible to compare cities in terms of selected aspects, which formed a basis for the creation of various classifications. Rankings of this type provide city authorities with the opportunity to evaluate their own actions, and to indicate what types of action should be pursued to implement the idea of Smart Cities as effectively as possible.

The division into separate areas within a Smart City also makes it possible to take a better look at a specific city, due to the strengths, weaknesses, opportunities and threats specific to each area. Not only is this important from the viewpoint of the authorities – as it enables them to become more aware with regard to the city they manage – but it also makes it easier for investors and residents to assess whether the image of the city, created by the authorities, actually fits the vision resulting from the analysis of specific areas.

Smart Mobility Ascpect

Smart Mobility – means the area of a Smart City representing mobility, broadly defined, the components which comprise not only the traditionally understood transport of people and goods, but also the dissemination of information by digital means. The main role of the Smart Mobility area is to connect all the city's resources – people, goods and information. The easiest and quickest way to observe the level of development of a Smart City is from the perspective of this aspect, because every resident, and also visitor, will constantly come into contact with it. This area is enormously important when it comes to the competitiveness and degree of development of a city, where the

necessity to move between increasingly distant districts of the urban area becomes a real problem.

The basis for Smart Mobility is Information and Communication Technology (ICT), which currently plays a key role in the area of mobility (Stawasz, Sikora-Fernandez, 2015). According to the definition of the Ministry of Transport, Construction and Maritime Economy (2013), ICT comprises "all technologies capable of manipulating and transmitting information". Therefore, ICT includes, inter alia: the Internet, mobile and landline telephony, wireless networks, and television – along with the infrastructure required to operate these channels and simultaneously record data, such as computers, portable drives and servers. Moreover, applications and extensive IT systems which make it possible to collect, analyze and transmit data also include ICT in their scope.

If mobility is to be 'smart', it should not be limited to individual behaviors, because Smart Mobility is a set of multiple and varied initiatives that can represent different levels of ICT use. Taking into account the degree of implementation of specific actions, there are three phases of Smart Mobility (Benevolo, Dameri and D'Auria, 2016):

- starting phase – only a small number of activities, which are usually not coordinated with each other, and cover only a small portion of the urban area;
- intermediate phase – a number of wider-aiming activities, pursued by the city authorities, and the introduction of pilot projects and the measuring of results;

- mature phase – the integration of Smart Mobility solutions, the use of Intelligent Transport Systems, the collecting and sharing of data, i.e. open data.

Regardless of the presented level of Smart Mobility development, all initiatives concerning mobility should aim at the fulfilment of at least one key requirement. In their paper entitled "Smart Mobility in Smart City. Action Taxonomy, ICT Intensity and Public Benefits" (2016), Benevolo, Dameri and D'Auria specify the following key objectives that are to guide the implementation of Smart Mobility solutions:

- reducing mobility costs;
- reducing air pollution;
- reducing noise pollution;
- reducing traffic congestion;
- increasing safety;
- improving the speed of mobility.

Therefore, when speaking of Smart Mobility, reference is made to Intelligent Transportation Systems (ITS), municipal public transport, bicycle systems, and car sharing and car-pooling.

From the viewpoint of city authorities, indicators and rankings have very many uses. First of all, they help in the identification of the strengths and weaknesses of the city, thanks to which directions of future development may be more easily defined. Over a longer time period, the possibility to compare changes in indicator values makes it possible to control the actual effects of activities implemented. Rankings that evaluate individual areas of the city also

make it possible to check whether the development of the entire urban organism is carried out in a sustainable manner, which is extremely important for its proper functioning, in accordance with the assumptions of the Smart City concept. Moreover, thanks to rankings it is possible to compare one city with another. This, among other things, provides the opportunity to learn and borrow ready-made solutions from better-rated cities, whose strengths are easier to diagnose, and about which more information can be derived from individual indicators. In success cases, a comparison between specific cities is also beneficial in terms of the marketing value. It makes it possible to differentiate one city from others thanks to its implementation of best practices, which directly translates into an increase in positive attitudes among local activists. Moreover, a favourable presentation of the city attracts investors and new residents, and this affects the status of the city and its budget. Additionally, by having indicators and rankings at their disposal, city authorities can influence local communities, aiming to convince them to pursue changes.

From the perspective of the residents, indicators and rankings are first and foremost of an informative nature. They allow residents to get acquainted with the actual results reflecting the state of the city, and draw attention to individual problems, which are not always visible at first glance. Learning about this information can stimulate a broader discussion on further development strategies and mobilize the population to take action for the city. At the same time, from the viewpoint of citizens, it is very important that they are aware of the existence of tools which evaluate authorities. These tools force local authorities to carry out transparent dealings, because the community is able to verify such actions.

When analyzing the benefits of indicators and rankings for investors, at the forefront is the possibility to compare different cities according to their business profile and the ability to select the most appropriate place in this respect. Indicators and rankings make it much easier to see actual results reflecting the state of the city. This may influence the way in which extra allowances on salaries are granted to persons staying in a given city, depending on the assessment of the conditions prevailing in that city. It may also help to convince employees to change their place of residence within the framework of their job.

Developing a set of indicators for the assessment of Smart Mobility

To sum up the information from the previous sub-chapters, one may notice that:

- the use of indicators and rankings is highly beneficial for all: the authorities, investors and citizens. Appropriate use thereof may be conducive to the further development of urban areas and, consequently, the whole country;
- the most promising indicators and rankings concerning Smart Cities fail to present the entirety of information on the way in which individual components are evaluated. This prevents the full understanding and thus improvement of the individual elements influencing the performance of the cities concerned;
- some of these evaluation criteria could be improved or clarified and new evaluation components could be added to ensure that the indicators are more accurate and more reliable in relation to the actual development of the city;

- data on some of the indicators and rankings are subject to payment, which prevents a wider audience from familiarizing themselves with the information they present. This poses a major problem from the point of view of the residents of the evaluated cities, as they do not have access to information that also concerns them.

At the same time, the indicators used so far are very general in nature, as they consider the entirety of Smart Cities or, if detailed (like that developed by the Vienna University of Technology) they are based purely and solely on statistical data. On the one hand, this is due to both a lack of data from residents and vague data from authorities (e.g. on experiences), while at the same time, it forces the use of statistical data, the usefulness of which seems debatable (e.g. the number of sunny days in the solution proposed by the Vienna University of Technology).

The proposed new Smart Mobility Indicator (SMI), discussed in this work, would be developed in order to meet its original objectives – contributing to the further development of urban areas, and should be made publicly available. It is suggested that each municipal authority create an annual analysis for the city they manage. This will enable systematic control of the activities implemented, while bearing in mind that the main objective is to improve the living conditions of residents, and not for marketing purposes. The correctness of the assessment will be assured by the complete transparency of the data used to measure the characteristics, thanks to which any ambiguities can be verified by residents and competing urban units. The uniform system of assessment, applied within the

indicators, will make it possible for cities to compare to one another, which will obviously contribute to their development.

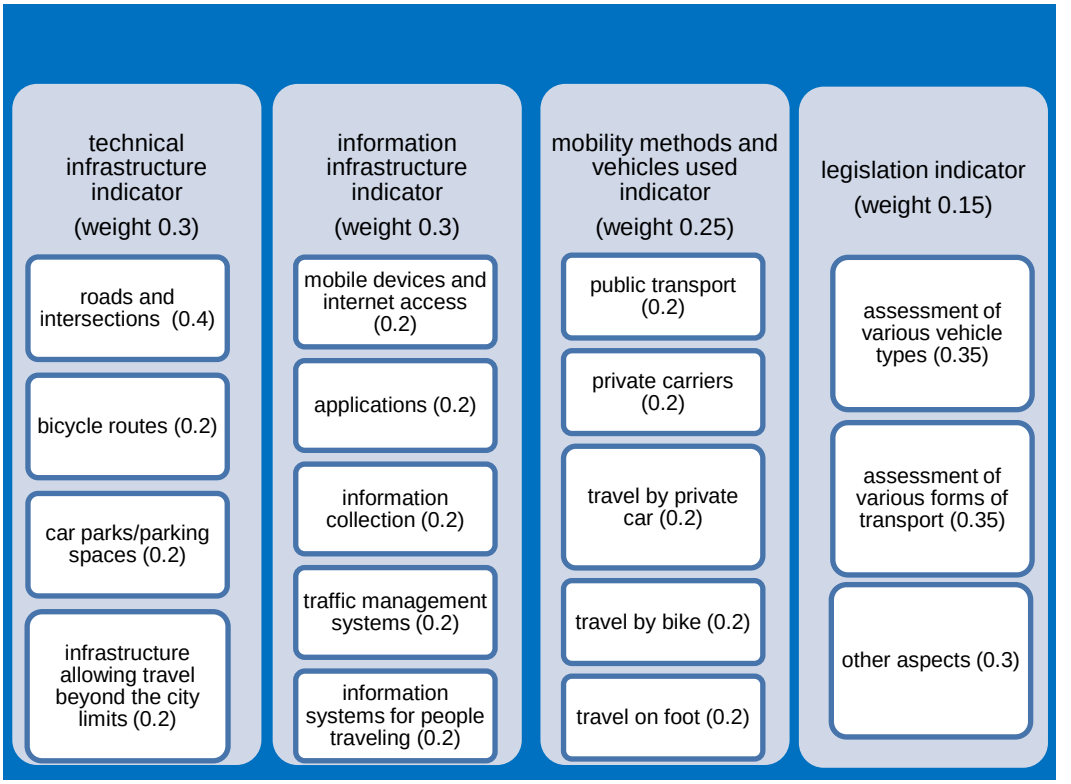
In order to develop the most optimized indicator to assess cities from the Smart Mobility viewpoint, one needs to precisely analyze the issues that impact mobility in urban areas. For this purpose, one needs to subdivide the whole area into domains which will encompass the following aspects:

- technical infrastructure,
- information infrastructure,
- mobility methods and vehicles used for this purpose,
- legislation.

The domain-based division indicated above is a result of analyses concerning attempts made so far at such a division and research carried out in the ten biggest cities in Poland. The decision to apply this division was made because it makes it possible to unequivocally define borders between these domain-based areas, which are in fact dependent on each other. Because they are closely interlinked, all of these domains should be developed in a balanced way so as to achieve the correct functioning of the entire Smart Mobility area. At the same time, it should be acknowledged that in the absence of appropriate solutions with regard to both technical and information infrastructure, no effective actions are possible in the field concerning mobility methods and vehicles used for that purpose. In addition, it should be noted that despite the fact that legislation may considerably contribute to the development of all the domains listed above, legislative action is to a large extent just a response to the current situation in specific domains. With these comments in mind, it has been decided that specific weights be assigned to the individual domain-based

evaluation factors (table 1), namely: technical infrastructure – 0.3; information infrastructure – also 0.3; mobility methods and vehicles used for this purpose – 0.25; and legislation – 0.15. Weight selection, crucial from the viewpoint of the model construction, was based on assessments by external experts with at least five years of experience in the area of Smart Cities. It should at the same time be pointed out that the weight values depend significantly on the market (country) where the model will be used. The model has been developed for the Polish market. For other markets it will be advisable to adapt the weights to local conditions (e.g. local legislative conditions related to the competencies of city authorities in a given country).

Table 1. Indicators for the SMI model.



Each of the indicators presented above was assigned specific factors – in total, 108 dedicated factors. Next, each of the 108 factors was assigned with a set of research questions, along with weights assigned to them. Due to the volume

restrictions of this article, the next part will present one selected set of factors, so that the process of creating the SMI indicator can be illustrated. At the same time, this study is supplemented by an annex which presents all 108 indicators and illustrates all of the interrelationships between them.

It was decided that factors based on the opinions of residents should be introduced, due to the residents' day-to-day contact with the analyzed issues. In this context, it is even more important to compare the observations of residents with the data obtained from city officials.

The minimum number of respondents required to carry out a study depends on the number of residents in the city in question. In order to obtain credible results (with an assumed confidence level of 95% and a maximum error of 3%) one should use the formula 1.1.

$$Nmin = \frac{0.9604 \cdot Np}{0.0009 \cdot Np + 0.9604} \qquad (1.1)$$

where:

N_{min}- minimum number of respondents in the survey

N_p – number of residents in the analyzed city.

Moreover, it is assumed that the distribution of respondents will reflect the distribution of residents with regard to the city districts in which they live. This is necessary as the objective is to run an opinion survey that will provide a basis for the evaluation of the entire city. In the event of a disproportionately high or low number of respondents from a given district, the whole survey loses its reliability.

The residents to whom the questions are directly asked will have to respond to the questions by marking the statement they most strongly agree with. Each of

these statements will be assigned a specific number of points. Upon the collection of all questionnaires from the respondents, the mean number of points will be calculated for each question. In this way, a final result will be obtained evaluating the examined factor.

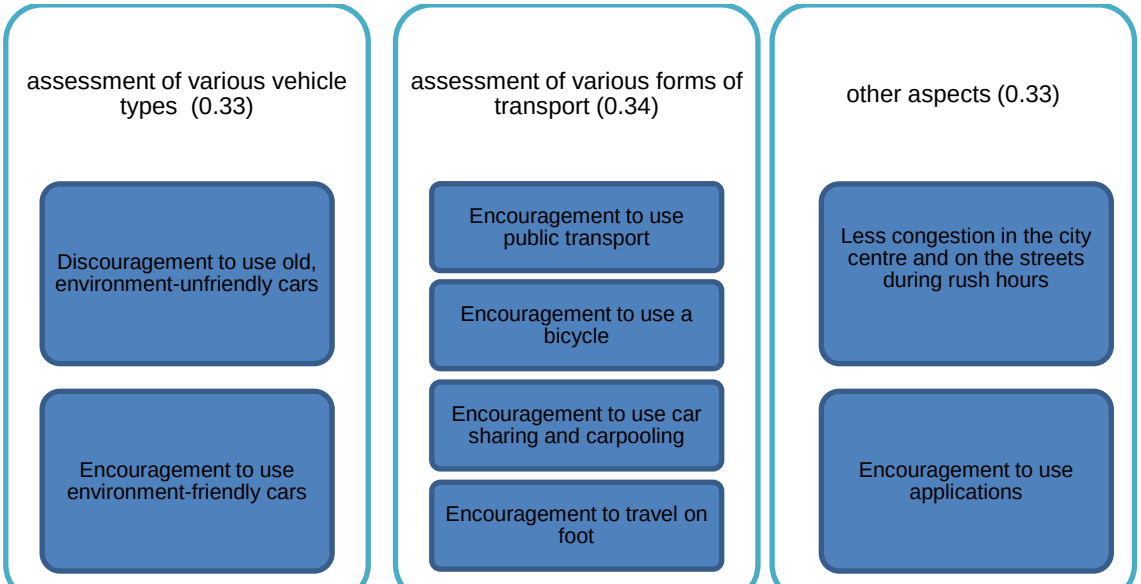
As far as questions addressed to the city hall (or its subordinate units) are concerned, there will be two types of questions – open-ended ones, requiring a specific numerical value to be supplied, or closed-ended ones, where city officials will have to mark the response that best fits the situation in the city. In the case of open-ended questions, the numerical values will be used to calculate a ratio, which will provide an evaluation of a given factor. As mentioned earlier, results closer to 1 are rated best, and those closer to 0 are rated worst. If the ratio is above 1, it will be assigned the value of 1 anyway (i.e. the maximum). On the other hand, in closed-ended questions, as in the case of questions addressed to residents, the possible answers will have an assigned point value, which at the same time will provide input towards an assessment of the underlying general issue. In the case where the question refers to obtaining information from several different sources, for example, data on public transport managed by different institutions (e.g. separately responsible for trams, buses, the underground), open-ended questions will require the aggregation of individual values (e.g. the number of vehicles in the fleet), and closed-ended questions – the average of points from answers to these questions (e.g. how to respond to significant delays in fleet vehicle timetables).

Forms of transportation

As mentioned before in the study, due to its volume limitations a decision was made to show a specific fragment of work concerning the development of the

SMI indicator. The category related to forms of transport will, according to the authors, provide the best presentation of what the proposed SMI indicator looks like. The 'Forms of Transportation' category falls into the group of legislative solutions. When examining the 'legislation' solutions, a division was applied concerning vehicle types, forms of transport and other aspects related to Smart Mobility activities, as shown in Table 2. All the factors assessed within the legislation domain have a significant impact on improving conditions within the Smart Mobility area, and their application may considerably speed up the development of the city in this respect.

Table 2. Categories and their components impacting the assessment of the indicator concerning legislation.



The exact location of the categories within the indicator as a whole is shown in Appendix 1.

When analyzing the category of Forms of Transportation, the decision was made to examine ways in which residents are encouraged to use forms of transport considered to have a positive impact on Smart Mobility. This was divided into the following solutions:

- public transport;
- bicycle;
- car sharing and carpooling;
- traveling on foot.

Each of these components is assessed by way of a questionnaire (Tables 3, 4, 5 and 6) in which the task of city officials is to indicate specific types of action taken up by the city. Each response is assigned a specific point value. The sum total of all points represents the assessment of the component analyzed by the questionnaire. The assessment of the category as a whole is in turn presented as the mean of the results obtained for specific components.

Table 3. Questionnaire exploring ways to encourage residents to use public transport.

What actions are used to encourage residents to use public transport?	points
Emphasis is placed on increasing the competitiveness of traveling time, e.g. through the creation of bus lanes.	0.15
There are low fares for public transport tickets - tickets are free of charge or their prices do not exceed the cost of traveling by car.	0.15
There are discounts on tickets or other incentives for car owners upon presentation of a valid car registration document and third-party liability insurance.	0.15
In collaboration with companies or schools, various incentives are provided for users of public transport.	0.15
Public transport vehicles are allowed to enter zones with restricted or excluded traffic.	0.15
Marketing/informational campaigns are carried out.	0.15
Other activities are carried out.	0.10

Source: own research

Table 4. Questionnaire exploring ways to encourage residents to use bicycles.

What actions are used to encourage residents to use bicycles?	points
It is possible to deduct tax for the purchase of a bicycle.	0.092
Visually attractive bicycle routes, which are the urban equivalents of tourist routes, are marked out.	0.092
Information courses/forums are offered to improve cycling in the city, discussing, for example, the most effective methods of protecting bicycles against theft, safe cycling in the city, the rights and obligations of a cyclist in relation to other road users, etc.	0.092
It is possible for the city (or other entities) to provide financial support for a charitable/social cause selected by a cyclist in return for covering a specific distance by bicycle.	0.092
In collaboration with companies or schools, various incentives are provided for people who commute by bicycle.	0.092

Educational activities related to cycling are carried out in schools at least once every three years.	0.092
Access to free-of-charge maintenance points is provided.	0.092
When renting a bicycle, there is a period of time for which there is no charge.	0.092
It is possible for city residents to rent a bicycle free of charge or on preferential terms.	0.092
Marketing/informational campaigns are carried out.	0.092
Other activities are carried out.	0.08

Source: own research

Table 5. Questionnaire exploring ways to encourage residents to use carpooling and car sharing solutions.

What actions are used to encourage residents to use carpooling?	points
Reduction in car parking fees if all the seats in the car are used.	0.085
Entry fees to special traffic zones are reduced or completely eliminated in the event of full use of the seats in the car.	0.085
Bus lanes can be used by cars in which all the seats are used.	0.085
In collaboration with companies, notice boards shall be promoted to help select co-passengers within the organization.	0.085
Marketing/informational campaigns are carried out.	0.085
Other activities are carried out.	0.075
What actions are used to encourage residents to use car sharing?	
The use of bus lanes is made possible.	0.085
Entry fees to special traffic zones are reduced or completely eliminated.	0.085
There are discounts for companies that operate in the car sharing business.	0.085
Companies are required to use only environment-friendly cars.	0.085
Marketing/informational campaigns are carried out.	0.085
Other activities are carried out.	0.075

Source: own research

Table 6. Questionnaire exploring ways to encourage residents to travel on foot.

What actions are used to encourage residents to travel on foot?	points
Regulations are introduced whereby the pedestrian is the most protected/privileged road user.	0.125
Systematic care is taken of the condition of sidewalk surfaces.	0.125
The scope of the pedestrian space is systematically increased (e.g. wider sidewalks, complete exclusion of road traffic from some streets).	0.125
In new developments, plans are made so as to ensure the shortest distance for pedestrians to walk, without the need to excessively “walk around”.	0.125
Vehicle traffic is totally or partially (e.g. during certain hours) excluded from the city centre.	0.125
Visually attractive pedestrian routes are created.	0.125
Marketing/informational campaigns are carried out.	0.125
Other activities are carried out.	0.125

Source: own research

Factors and research questions for the remaining categories were prepared in the same way. The next stage of work is the validation process of the developed indicator. It is planned that validation will be carried out for all areas of Smart

Cities; however, currently, the indicators that are ready are the Smart Environment indicator and the SMI (the latter being presented in this study). The two already developed indicators will be tested in a pilot study carried out in two city halls (which have already been selected; the test will start after the conclusion of the current election campaign). Following the pilot study, necessary corrections in the two already developed indicators will be introduced, and then they will be subject to further testing (a group of ten city halls, cities with more than 100k residents). The authors have already conducted research in these cities on their readiness to be 'Smart' and initially confirmed the interest of these cities in participating in the validation of the new indicator.

Conclusions

The objective of this study, which has been the development of an indicator which will evaluate the level of 'Smart Mobility' solutions implemented in cities, has been achieved. An indicator has been developed, based on the analysis of 108 factors, concerning issues within the scope of the following areas: transport infrastructure, information infrastructure, mobility methods and vehicles used, and legislation.

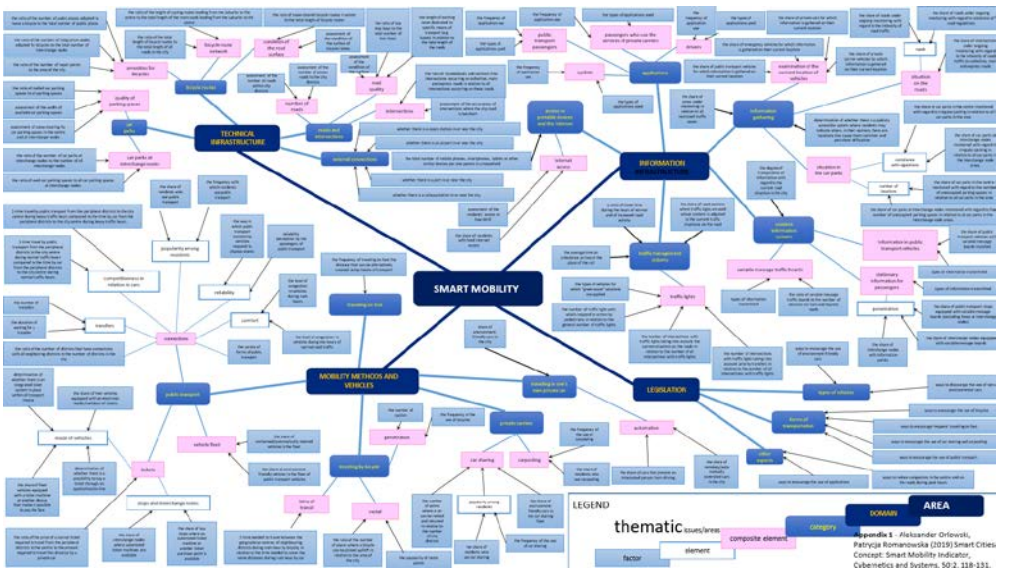
Sources determined to be the sources of information necessary for factor assessment are city hall officials and residents. For both these groups, data were acquired using questionnaires including closed-ended and open-ended questions.

In order to fully use the potential of the indicator, it should be applied to assess the largest possible number of cities and the results should be made public. It is important to present not only the final value of the indicator, but also the whole assessment of its components, including the factors and summarized information used in the calculations. Such full transparency will

enable residents and investors to become familiar with the actual level of solutions used, and will allow for the verification of calculations made. It will also provide city authorities with the opportunity to make a more detailed comparison of various urban units. The benefit lies mainly in the fact that this provides an opportunity to more easily identify model practices, which – as a whole – will translate into the development of cities.

This work has also suggested a method for the validation of a developed indicator before it is presented to the public.

Considering that the indicator in question covers only one of the Smart City areas, there is a need to develop other indicators to evaluate other areas, i.e. Smart Economy, Smart Environment, Smart People, Smart Living, Smart Governance. Thanks to this, it will be possible to assess the urban unit as a whole, which is important as, for the proper functioning of the city, each of the above areas should be developed proportionally to the others, due to the close interrelations between areas.



App1: Appendix 1, presenting the structure of the SMI (full version presented after References)

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Appendices

Appendix 1, presenting the structure of the SMI (you can find it in "linked data" category: appendix1 (2).pdf)