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The challenge for the development of Smart City Concept in Bratislava based on examples of smart cities of Vienna and Amsterdam

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Abstract

A smart city in general is a very wide socio-economic-urban-technical phenomenon that inherently represents an increase certain quality of the urban environment and organism. It is not only a technical and technological level of development of infrastructure of a city, but constitutes mainly intellectual maturity and awareness of all stakeholders of the urban organism. Topic of Smart Cities is gaining exponentially in importance, as the socio-economic and demographic changes creating new trends, needs, requirements and challenges for existing urban areas, inner urban processes and their management. There are already a number of applied strategies, which proves the efficiency and sustainability of the solutions. In this contribution authors are trying to outline the problematic areas of Bratislava to achieve Smart City concept, whereby they take inspiration from the neighbouring city of Vienna and Amsterdam, which in turn are considered as some of the top smart cities in Europe.

Keywords: smart city, framework strategy, renewal, Bratislava, Vienna, Amsterdam,

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1. Introduction

With the development and change in society, particularly with changes in the manufacturing sectors of the economy is changing not only the economic structure, but also the environment of the city. Cities in the past responded to the industrialization of the construction of industrial buildings and entire structures, thus changed functional, respectively the spatial arrangement (mostly) rural zone of sites. Today needs to reflect the opposite trend-deindustrialisation, thus changing the use of functional areas and industry objects to other functions. It may be a manufacturing, services, logistics, research / development, or even housing and recreation. For the past 20 years also Bratislava has undergone many dynamic changes. Disordered and uncontrollable new construction of buildings and renovation of existing housing stock without comprehensive strategy or insufficient implementation support system, both static and dynamic transport should be the main reasons such as these developing processes should be started to meet the highest requirements of contemporary modern European cities.

Bratislava as a sister city of Vienna, from which it is located approximately 64 km could thus in its direction just to take an example from Vienna which is considered among the top European and world smart cities for several years. To achieve this state could be helpful, inter alia, also a project EU-GUGLE and also prepared several concepts such as “Methodology for complex renewal of housing estates with a focus on housing reconstruction” or

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still uncompleted implementation of transport policy of the city of Bratislava.

2. Definitions of Smart Cities

The concept of "smart city" has become more and more popular in scientific literature and international policies. To understand this concept it is important to recognize why cities are considered key elements for the future. Cities play a prime role in social and economic aspects worldwide, and have a huge impact on the environment. [1, 2] Table 1 reports some of the definitions of "smart city" proposed in the literature, providing an idea of the many meanings that has a smart city. Many definitions of smart cities exist. A range of conceptual variants is often obtained by replacing "smart" with alternative adjectives, for example, "intelligent" or "digital". The label "smart city" is a fuzzy concept and is used in ways that are not always consistent. [3,4]

Table 1. Some selected definitions of "smart city".

Definition	Source
A Smart City is a city well performing in a forward-looking way in six "smart" characteristics, built on the "smart" combination of endowments and activities of self-decisive, independent and aware citizens.	www.smart-cities.eu [4]
A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens	Giffinger et al. (2007)[5]
"[…] two main streams of research ideas: 1) smart cities should do everything related to governance and economy using new thinking paradigms and 2) smart cities are all about networks of sensors, smart devices, real time data and ICT integration in every aspect of human life." p. 57	Gabriel Cretu 2012) [6]
Smart cities "are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities)." p. 93	Kourtit and Nijkamp (2012) [7]

For better understanding of what all is in the concept "smart" necessary to redefine, a model (Figure 1) can be used. The model is based on a definition of Giffinger, who defined "smart degree" of 70 medium-sized European cities focusing not only on digital data and information, but on 6 dimensions: smart mobility, smart environment, smart governance, smart economy, smart people, smart living. [5, 8]

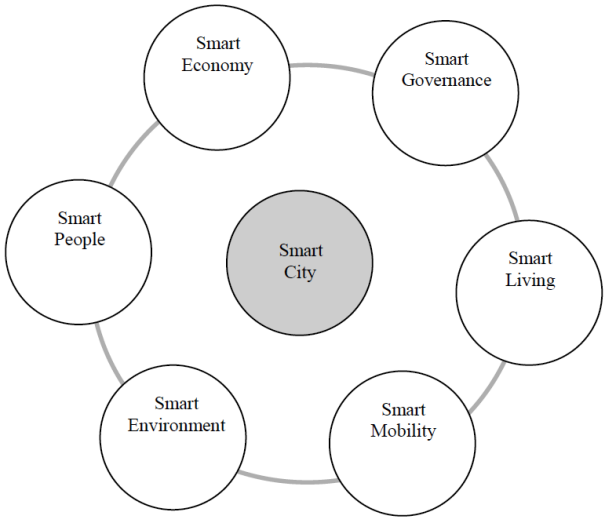


Figure 1. Six components of smart city [8]

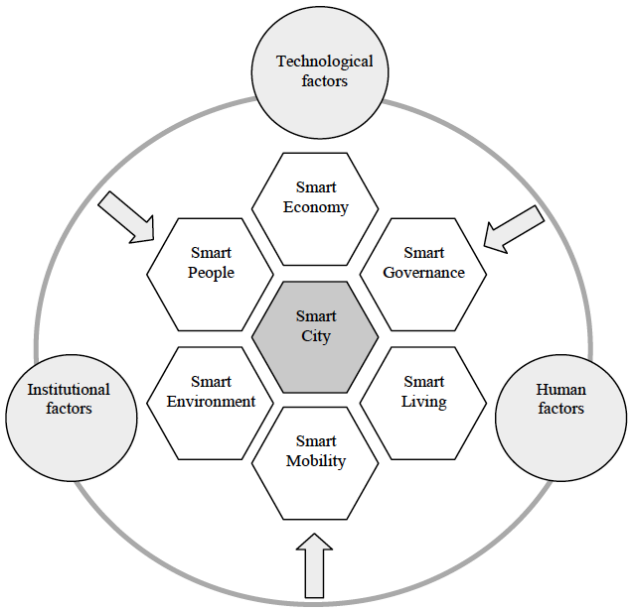


Figure 2. The relationship between components and characteristics of smart cities [8]

According to De Santis, Fasano, Mignolli and Villa (2014b) especially six dimensions of smart city categorize the conception between neoclassical theory of regional and city development. Actual study of the European Parliament Mapping smart cities in the EU (2014) supplements the scheme of six smart city characteristics by three components – technological, human, institutional (Figure 2). [8]

2.1. Vienna Smart City

The "smartness" of a city describes its ability to bring together all its resources, to effectively and seamlessly achieve the goals and fulfil the purposes it has set itself. In other words, it describes how well all the different city systems, and the people, organizations, finances, facilities and infrastructures involved in each of them, are: individually working efficiently; and acting in an integrated way and coherent way, to enable potential synergies to be exploited and the city to function holistically, and to facilitate innovation and growth. [9]

Recent years Vienna has become a leading smart and sustainable European city. The Austrian capital differs from most other metropolises through its good performance in so many areas: housing, public transport and other infrastructure services (e.g. waste separation, Spring Water Mains), education and universities as well as vast urban green spaces. [10] Vienna is the city with the world's best quality of living, according to the Mercer 2014 Quality of Living rankings, in which European cities dominate. [11]

For the city of Vienna has been prepared a framework urban development strategy with a view into the 2050. The present Smart City Vienna framework strategy is directed at all target groups of the city: Vienna's citizens, enterprises, non-profit institutions and, last but not least, the public sector itself. [10] Smart City Vienna comprises first and foremost the aim of resource preservation. Development and modification processes in the sectors of energy, mobility, and infrastructure and building management are to dramatically reduce CO2 emissions by 2050. [10]

In fact Vienna recently created a public private entity, TINA Vienna which is tasked with co-developing smart city strategies and solutions for the city. Nowadays there are prepared more than 100 smart cities projects being developed throughout the city. [12] For example one of the mentioned projects is Citizen Solar Power Plant. With a goal of obtaining 50% of their energy from renewables by 2030, the city partnered with the local energy provider, Vienna Energy, they developed a crowd-funding model whereby individual citizens can buy half or whole panels and receive a guaranteed return of 3.1% annually. [13]

Vienna is also testing out a range of electric mobility solutions from expanding their charging network from 103 to 440 stations by 2015 to testing EV car sharing and electric bike rentals. Vienna bike sharing program is fully accessible to visitors, not just residents. [14] Another important innovation has been in rezoning dense neighbourhoods allowing for zero-parking residential buildings. Residents in these communities commit to not owning a personal vehicle.

Finally, Vienna is renovating a 40 hectare former slaughterhouse district and turning it into a much smarter use: an innovation district focused on media science and technology. By 2016, the city expects 15,000 people to working on start-ups in the Neu Marx Quarter district. [13] Furthermore, Vienna took the extra step of incorporating the strategy into law to minimize the risk of future mayors throwing the plan out to start over. [14]

Smart City Vienna framework strategy

The key goal for 2050 of Smart City Vienna is to offer optimum quality of living, combined with highest possible resource preservation, for all citizens. This can be achieved through comprehensive innovations (shown on Fig. 3).

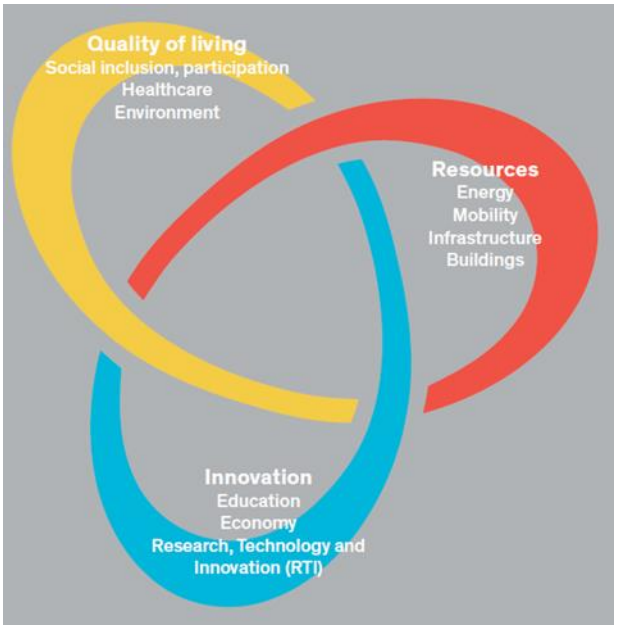


Figure 3. The Smart City Vienna principle [10] p. 17

The present framework strategy describes the key goals and principal approaches chosen to attain them. It represents guidelines for the numerous important specialised strategies of the city that define concrete multiyear plans for such areas as urban planning, climate protection, the future of energy supply or Vienna as an innovation hub. [10]

The Smart City Vienna framework strategy is more comprehensive (but not exhaustive), pursues a long-term horizon (2050) and does not offer detailed packages of measures. However, concrete sub-projects with a shorter timeframe will definitely be formulated and implemented. [10]

2.2. Amsterdam Smart City

The city of Amsterdam is ranked third in the European rankings by Cohen. Amsterdam set out its goals for sustainability in the Structural Vision 2040 and the Energy Strategy 2040 follows [15]:

- 40% reduction in CO2 emissions in 2025, compared with 1990 levels,
- 75% reduction in CO2 emissions by 2040,
- Climate-neutral municipal organisation in 2015.

To help achieve these targets, the Amsterdam Innovation Motor (AIM), now Amsterdam Economic Board, the city of Amsterdam, net operator Liander and telecom provider KPN started the Amsterdam Smart City platform in 2009 [15].

The Amsterdam Smart City (ASC) platform is a partnership between businesses, authorities, research institutions and the people of Amsterdam that initiates, stimulates and advances Smart City projects in Amsterdam. The main objective of the ASC platform is to help to achieve the targets set out in the Energy Strategy 2040 and to reduce carbon emissions in Amsterdam. ASC believes in a habitable city where it is pleasant to both live and work. In 2015 this platform has have into a partnership with over 100 partners, which are involved in more than 90 innovative projects. These Smart City projects deal with a variety of topics and cover all characteristics of a Smart City including energy transition, Smart Living, Smart Society, Smart Areas, Smart Economy, Smart Mobility solutions and open connectivity. The Amsterdam Smart City platform is aware of the many different ideas that can be applied to the city and the challenges that the city faces. By challenging parties to submit and execute innovative solutions to urban issues, ASC connects and accelerates this progress. ASC also addresses the possibilities to strengthen previous activities. This advances the development of new markets and profits for innovative solutions. Where possible, these solutions are replicated elsewhere in the city (shown on Figure. 4). [15]

Figure 4. The Amsterdam Smart City platform [15]

Inspirational projects from Amsterdam to Bratislava

Smart Parking - Mobypark

Parking in big cities is becoming more and more difficult. Many drivers spend on average 20 minutes per time while looking for a parking spot. This increases CO2 emissions and most important of all; people waste their time. Mobypark, a sharing parking platform, will make parking easier and more efficient. Private parking lots, public parking garages, hotels, and hospitals: they make their unoccupied parking spots available for drivers through this app. Mobypark offers all the available places on a platform where it's possible to see real time availability and book these parking spots ahead. As a result, drivers spend less time searching for a single spot and reduce CO2 emissions. In her turn, ensures that you can easily rent a parking place for several days of a private individual, hotel or another institution. The service of Mobypark consists of a website and an app (Android and iOS). It offers parking opportunities in more than twelve cities in the Netherlands (2014) and makes it possible in more than five countries to share your parking space and to rent your parking places for a short or long term. Its aims to, among others in collaboration with Amsterdam Smart City, enlarge the amount of parking places and partner up with different with public and private organizations. [16]

Smart Living – City-zen

In the City-zen project several innovative solutions are demonstrated in the field of smart grid, heat networks and sustainable housing in Nieuw-West in Amsterdam. The residents and users have a central position in all the solutions. The changes give the users more choice in the ways they use energy. The project is developing a positive energy district by implementing a variety of measures such as sustainable transport, smart parking systems and car sharing. The City-zen projects provide a major boost to the energy ambitions. In Amsterdam, the following projects are being implemented: Intelligent net, Sustainable heat network, Drinking Water used for cooling of business area, Energy saving by residents, Testing Living Lab, Serious Gaming and Roadmap to City Zero Energy. [17]

3. Methodology for Smart Cities

According global advisory committee for Smart Cities Benchmarking was developed 62 indicators across the Smart Cities Wheel (shown on Figure 5).

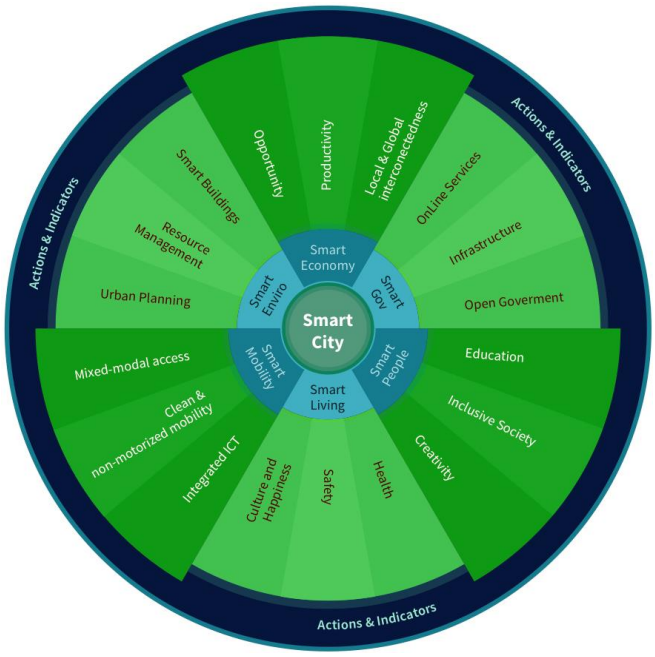


Figure 5. Smart Cities Wheel [14]

Each of the six components of the Smart Cities Wheel are assigned a set of indicators reflect an attempt to create a proxy for measuring each of the sub-components of the Wheel. Each component contains 3 subcomponents. Therefore there are 18 total subcomponents in the model, and with 62 indicators, that leaves an average of almost 3.5 indicators per subcomponent (shown on Appendix A. Smart Cities benchmarking indicators). The data were transformed by using a mathematical formula called a z-score, which permits the comparison of data in different units (e.g. %, tons of GHG emissions, etc.). Each of the 6 components is then assigned a maximum of 15 points and the results are transformed in a way that the highest performing city in each category is assigned 15 points. Thus, if one city were to lead in each of the six components, the city would obtain a maximum score of 90 points. Of the 62, 16 of them are also directly mapped to the new sustainable cities ISO standard (ISO 37120). [14]

3.1. Mercer's Quality of Living

Mercer's Quality of Living reports provide valuable information and hardship premium recommendations for over 460 cities throughout the world, the ranking covers 223 of these cities. [11]

Living conditions are analyzed according to 39 factors, grouped in 10 categories [11]:

- Political and social environment (political stability, crime, law enforcement, etc.)
- Economic environment (currency exchange regulations, banking services)
- Socio-cultural environment (media availability and censorship, limitations on personal freedom)
- Medical and health considerations (medical supplies and services, infectious diseases, sewage, waste disposal, air pollution, etc.)
- Schools and education (standards and availability of international schools)
- Public services and transportation (electricity, water, public transportation, traffic congestion, etc.)
- Recreation (restaurants, theatres, cinemas, sports and leisure, etc.)
- Consumer goods (availability of food/daily consumption items, cars, etc.)
- Housing (rental housing, household appliances, furniture, maintenance services)
- Natural environment (climate, record of natural disasters)

The scores attributed to each factor, which are weighted to reflect their importance to expatriates, allow for objective city-to-city comparisons. The result is a quality of living index that compares relative differences between any two locations evaluated. For the indices to be used effectively, Mercer has created a grid that allows users to link the resulting index to a quality of living allowance amount by recommending a percentage value in relation to the index. [11]

4. Bratislava

Until the fall of former political regime in 1989 was in Slovakia, including Bratislava for several years realized mass production of affordable housing. This construction was marked by the poor quality of buildings, especially as regards their energy performance. This poor technical condition mainly of prefabricated apartment buildings in many cases persists to these days, also thanks to still unrealized coherent concept of housing estates renewal. Renovation of buildings in Bratislava is provided on individual and un-conceptual basis. Renewal is performed only on separate apartment blocks, without connectivity to their immediate surroundings (shown on Fig. 6). Despite to this state for Ministry of Transport, Construction and Regional Development has been developed a comprehensive study of housing estate renewal in the recent past: "Methodology for complex renewal of housing estates with a focus on housing reconstruction".

Figure 6. Prefabricated Apartments Building in Bratislava [18]

Within this study was developed analysis of the current state of housing estates renewal in Slovakia - architectural, urban, administrative aspects and existing planning tools of complex housing estates renewal. There were analysed European documents in the field of urban development (Leipzig Charter, Toledo Declaration, the Territorial Agenda 2020, the Europe 2020 Strategy) as well as the research was performed on the selected model of foreign examples. Finally was realized the draft of methodology process of preparing strategic documents for housing estates renewal with emphasis on housing reconstruction at urban level, with an emphasis on an integrated approach and feasibility plans. [19] It should be added that putting this methodology into practice is heavily dependent on a momentary political will.

Now, the Slovak capital has a chance to move forward within a project aimed at demonstrating the feasibility of nearly-zero energy building renovation models. Bratislava is the only eastern European city to participate in the EU-GUGLE project, which stands for European cities serving as a Green Urban Gate towards Leadership in sustainable Energy. The aim of the project is to create a concept of energy performance and securing the energy efficiency of buildings when using them, as well as the reduction of energy intensity within the city's district in which the building is located. In other words, the project will take into consideration not only the reduction of energy consumption in the buildings, but will simultaneously deal with other aspects of a sustainable environment, like the interconnection of the building with public space, green areas and sustainable forms of mobility. The latter includes mass public transport, bicycles and moving on foot. Bratislava was chosen in a strong competition of 45 European cities and the city is cooperating with Vienna in this project, while the Austrian capital is serving as a district leader. Over the five years of the project (2013-2018) Bratislava with other European cities will join efforts to combine the latest research results in smart renovation of groups of buildings at the district level and use this knowledge to renovate the living space. The main task of this project is to bring to Bratislava new, sustainable technologies that will reduce emissions caused especially by heating apartment blocks. Within this project, Bratislava can receive up to €2 million to renovate 40,000 square meters of total floor area, i.e. up to €50 per square meter to cover the costs of the renovation. Out of the total floor area, 20,000 square meters should account for buildings owned by the Bratislava municipality, while the remaining 20,000 square meters should account for privately owned housing represented by owners' associations or apartment block administrators. The European Commission will refund the renovation costs only after the works are completed and have achieved the target parameters. [20]

"The apartment buildings, selected for the project EU-GUGLE demonstration are located in two districts: the wider city centre and the western part of Bratislava city (shown on Figure 7). A wide range of different building types from different construction systems and construction materials were selected for the EU-GUGLE project demonstration and are representing the typical city´s building composition. Almost all of the selected buildings are characterized by high energy demands and present diverse typical technical difficulties. The buildings, in current stage, have very poor thermal protection of the envelope and require high amount of energy for space heating and domestic hot water preparation. Most of the buildings are connected to a district heating network. The selection of pilot private apartment buildings is aimed to identify the wide spectrum of issues and problems that could prospectively occur in the renovation process of housing stock in the city. Between 60's and early 90's, due to city expansion and lack of housing units, many prefabricated concrete apartment blocks were built. The exemplary renovation of the municipal social housing is expected (the municipal Lodging-house for disadvantaged families and the House for elderly people)". [21]

- Total floor area to be renovated: ≈ 40,000m²
- Type of buildings: Both private apartment buildings and buildings own by community used for housing.
- Primary energy savings target: up to 60-75%.

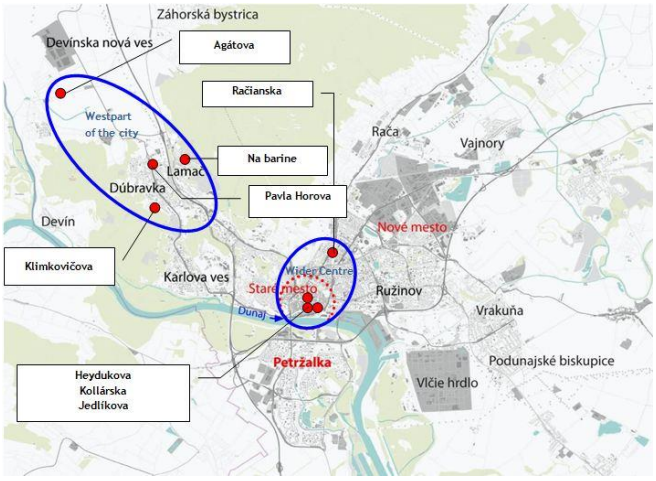


Figure 7. EU-GUGLE districts in Bratislava – demonstrations in red [21]

The energy saving measures outlined below will result in 60 to 75 % reduction of energy use in buildings compared to present state. The proposed measures will be replicated in other apartment buildings, located in different city districts, which are constructed in the same or have very similar construction systems. The actions are focussed on following technical and non-technical measures [21]:

Technical measures [21]:

- Improvement of the energy performance of buildings through renovation and retrofitting measures (thermal protection of peripheral constructions, roofs, replacement of existing windows with triple-glazed windows,)
- Implementation of renewable energy sources in district heating systems (eventually disconnection of buildings)
- Retrofitting of building technical system components and thermal insulation of distribution system pipes; reduction of energy use through technical measures
- Renewal of elevators, increasing of energy and transport efficiency (duplex elevator group control system)
- Replacing of fossil energy sources by several innovative technologies (application of heat recovery from the sewage, and air, heat pumps integrated in a low energy heat network, PV, cogeneration systems)

Non-technical measures [21]:

- Introduction of metering and regulation control systems • Motivation of tenants (metering), communication measures and advisory activities to reduce energy consumption through user's behavior
- Energy efficiency rental fee and other agreements with tenants

Also very important is the issue of transport infrastructure. Physical lifetime of transport infrastructure depends primarily on the building materials and old design of transport capacities. The materials that were used for its construction currently do not meet the quality requirements due to the infrastructure was not subject to more fundamental recovery process during its lifetime. Moreover, the infrastructure lifetime is significantly influenced by the intensity of its use. Its implementation largely falls within the period of implementation of residential buildings and public facilities in housing estates, when at least in a position of static transport capacitively was sufficient for the then demands.

The issue of parking in Slovakia is a long-term problem, whether in existing buildings or with new development projects where parking costs are only kind of forced expenditure on which developers often want to save money. Bratislava is one of the European metropolises, which seeks for the solution for several decades (shown on Figure 8). Problem that Bratislava was not ready for, is a major building boom which caused a further increase in both passenger and freight transport in the city center. This means that the constantly increasing level of motorization brings to Slovakia and especially in densely populated urban areas around the capital - Bratislava even higher space requirements. That becomes the most valuable quantities especially in the inner-city environment. This fact makes new demands on the urbanization of our cities, the professionalism of solutions to traffic problems and high standards to ensure a quality environment. One of the most serious current problems closely related to urban space in Bratislava is the traffic situation, especially the issue of static traffic. [22]

Figure 8. Parking in Bratislava [23]

Another important issue in the field of comprehensive transport solutions in Bratislava is the fact that there is insufficient traffic data database and the city does not have sufficient details of current conditions of its urban road network. City of Bratislava is lacking the scheduled surveys and their results, which would be able to determine the disproportion of the current state and predict its development. [24]

The list of projects that have an ambition to contribute to the solution of traffic problem in Bratislava is quite long. Solving problems with static traffic in Bratislava could be implemented using comprehensive regulation through traffic signs. In practice this means charging for parking at a time of increased congestion and the designation of paid parking zones with the road signs. Paid parking zones could improve the environment and conditions for non-motorized road users, as well as improving the quality of transport services. One of the solutions to the problems with static traffic could be building a semi recessed and recessed parking, garage houses, increase recessed parking with one or two floors.

Addressing of static traffic in different districts of the city lies in cooperation with the magistrate of the capital. Cooperation includes the selection of appropriate areas that would capacitive mean an increase in parking areas for individual districts. Solution of this complex issue could be also implemented through PPP projects. Another solution is a free parking not only on the borders of the city, but also outside, for example in Malacky, Pezinok or Senec. The condition is to create high quality service suburban bus line, which will operate at appropriate intervals. Another solution of problem of static transport in Bratislava could be seen in the construction of smart parking spaces by installing smart parking sensors placed directly on the parking places. Drivers would be allowed to easily find a free parking place and would contribute significantly to the reduction of emissions in the city. [22]

Another important issue is the participatory budget of the city and the city districts. Bratislava as the first Slovak city began experimenting with the introduction of participatory budgeting since 2011. Citizens were given the opportunity to decide directly on the reallocation of public finances and on the form of public space and services. Participatory budgeting process takes place throughout the year and is open to all citizens. In the first phase are collected suggestions and ideas from people on the use of public finances. They are then sorted and processed into projects. Since the idea is always more than a means to implement them, citizens must also decide which of their ideas are supported and which are not. [25]

It took place at participatory budgeting at the city level for a number of deficiencies and irregularities in recent years. They arise in the event of a communication strategy that would attract as many residents into the process; or administrative support, which would work systematically on the involvement of citizens and work on the drafts; and especially mismatch about the rules for the conduct of participatory budgeting process.

Municipality of Bratislava launches e-governance project in 2015. It is a project of electronic council, which contributes to saving the environment and optimizes the work of the City Office. The official website of the city will be available invitations and materials for meetings, profiles of deputies and information about their individual vote, or resolution of the City Council. The new application will serve all - as citizens, as well as local authorities and the deputies. [26]

4. Smart Living: The concept of low-carbon housing solutions for the selected urban zone in Bratislava

Defining of the solved area

The area of interest falls within the city district of Petrzalka in the capital Bratislava. Extent the solved area covers an area about the size of 1,096,348 m2 (109.6 hectares). In terms of space-functional compositions holds a dominant function of housing in apartment buildings. Residential buildings are mostly built in a U shape with exterior surfaces (with centre public playgrounds and the dominant urban vegetation). Housing construction in the area is designed in the form of 8-storey and 12-storey panel blocks of flats. The vast range of amenities consists of commercial and service facilities, facilities for sports and administrative buildings.

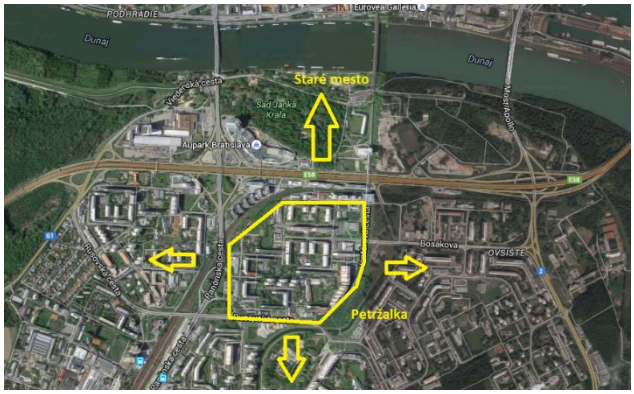


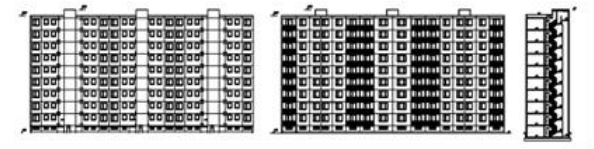
Figure 9. Defining of the solved area [27]

Solved area represents a residential zone, which is an aesthetic appearance and functionality relatively the same as the surrounding urban environment within the territory of city district of Petrzalka (Fig. 9). On this residential zone are linked monofunctional zones of sport, recreation and employment opportunities. Solved area and all the territory of Petrzalka in addition to interconnection of individual zones requires also a certain humanization of the urban environment and creation of living street space, which at many locations are missing.

Baseline emission inventory of CO2 production within the model area

Within the framework of the solved area are situated panel apartment blocks built in 1983-1987. Construction and technical solution of residential buildings is different, whether the type, size, number of stories or the number of flats (see Figure 10). Therefore, the energy consumption also varies in each apartment buildings. As the age of the buildings reaches almost 30 years, a major potential for reduction of energy consumption currently lies in the reconstruction of housing stock in this area. In the solved area is situated 37 residential buildings covered by housing association. Within the framework, the solved area was carried out renewal of the 25 apartment buildings. For another 14 apartment buildings, the renovation project has not taken place and no requests has not been submitted for realization any renewal.

Type A



Type B

Type C

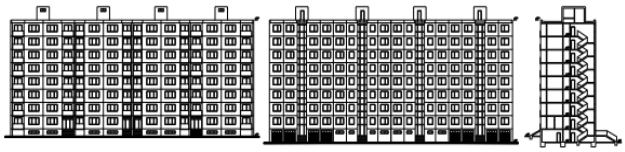


Figure 10. Views and cuts of individual types of apartment buildings in the solved area [28]

Another factor influencing the leakage of CO2 emissions into the atmosphere is the age of apartment buildings, which in this case is determined by approximating the value of the object from a technical point of view. This means to what extent is influenced the overall energy consumption through technical condition and constructional features of a residential building. From housing association were given information about the energy consumption of buildings in 2012-2014. According to the methodology of redistribution of energy consumption in households (58% for heating, 22% for heating the water, 10% for lighting and 10% of electrical appliances) was calculated individual production of CO2 emissions from housing (see Appendix B).

STRENGTHS	42	**WEAKNESSES**	49
Green areas	10	Panel technology	10
Public spaces	10	Technical condition of apartment buildings	8
Thermal insulation for over 50% of apartment buildings	7	The total energy consumption of apartment buildings	8
Monitoring of energy consumption	8	Energy consumption for public lighting	9
The quality of life of residents	7	Emissions arising from the concentration of vehicles	7
		The aesthetic appearance of the environment	7
OPPORTUNITIES	37	**THREATS**	15
Green infrastructure	9	Increase in CO2 production	8
Complex reconstruction of apartment buildings	10	Climate change	7
(energy certification)			
Smart public lighting	8	Environmental pollution	8

Table 1. SWOT analysis: Identification of positive and negative elements in the context of reduction / production of CO2 [27]

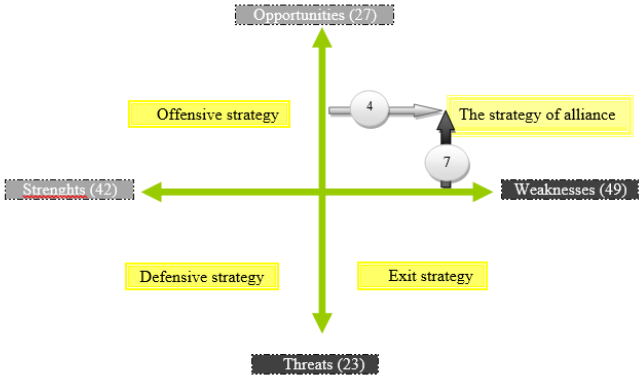


Figure 11. Weighted SWOT analysis [27]

For the classification of SWOT analysis prevails weaknesses (49) above strengths (42), while above threats (23) dominates opportunities (27). Based on the assessment, can be determined the strategy of alliance for a given area. Taking into account the weaknesses that area has, also has the potential for development in the context of decreasing production of CO2 by improving green infrastructure, comprehensive reconstruction of residential buildings and applying smart technology for public lighting. Under the final strategy of alliance we can understand cooperation of housing association with different legal entities and public authorities to improve living conditions and even all environment.

The conception of housing estate development

The philosophy of the conception of area development is based on the analysis of the current state of the territory and lies in the deepening issues in the field of energy consumption with the aim of intensifying functional relations, and reducing CO2 gas emissions. The output for design of adequate measures for the model area is a concept developed in connection with invariant solution of the final concepts (fig.). Interconnection of individual elements of concepts will contribute to a radical reduction in CO2 emissions through various technical and environmental instruments applicable to the model area.

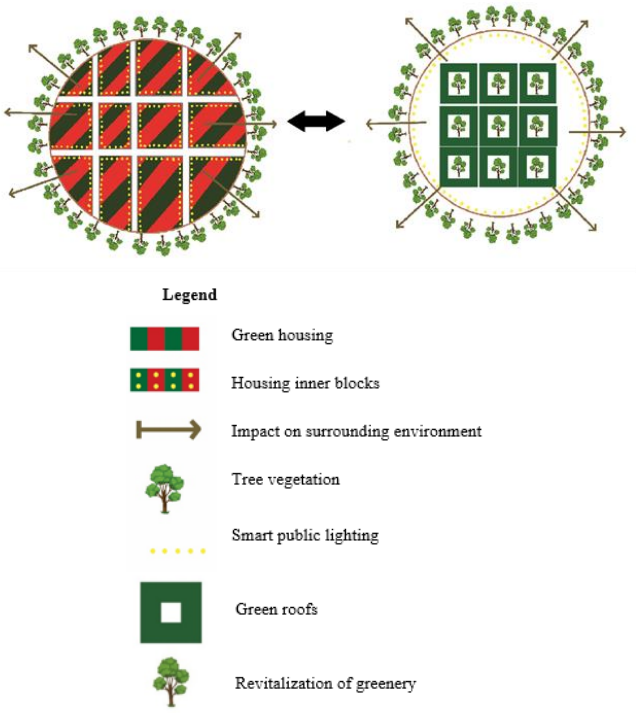


Figure 12. Final concepts of the model area development [27]

The concept on the left, naming interest area as "low-energy housing estate". Housing estate with arranged vegetation and interconnected with green gardens in combination with water features could to a certain degree ensure a reduction of emissions and also affect an environmental behaviour of residents of the solved area. Each housing inner block should have a uniform structure and continuity to the surrounding green living by using various technical and technological instruments. "Low-energy housing development" would become an economically-profitable and energy-efficient housing estate with a direct impact on the surrounding environment with the possibility of applications to locations outside of this area. The principle of the final concept is the creation of urbanistically compact unit with a lower energy consumption. It also includes the transition of this area to economic efficient and environmental friendly mode of public lighting. This would ensure a significant reduction in energy consumption and thus there would be a housing estate based on power save mode from the energy and economic point of view.

The concept on the right side, naming interest area as the "green housing estate." The philosophy of this concept is to reduce CO2 emissions through green elements. Besides the possibility of revitalization of public green spaces, which has the ability to absorb CO2 emissions it is also an appropriate solution for implementation of green roofs on residential buildings. Together with smart public lighting this model area could become greener and a more ecological environment for its residents.

Summary

Based on the calculation of the energy consumption of residential buildings in the solved area and the subsequent production of CO2 emissions, we concluded that one of the most effective tools for reducing emissions is the complex renewal of residential buildings. By using building renewal could be decreased CO2 emissions by up to a quarter. By using other technological and technical interventions such as green roofs, smart street lighting, public green revitalization, etc. the reduction of CO2 in the area could reach more than 50%.

5. Conclusion

In order to Bratislava achieve the Smart City concept it needs to develop and implement mainly a comprehensive concepts a policies in the field of residential and non-residential buildings, transport infrastructure, technical infrastructure, public spaces but also in the field of sustainable economy and governance. Of course, main condition to achieve this effective sustainable development is the implementation of the latest materials, technologies and innovative concepts in each of these areas, whether in the field of urban development, ICT and construction and architecture, etc. In this would help to Bratislava a generous funding from the European funds, the potential of which the city does not know sufficiently take full advantage. This could help the generous funding from the European funds, the potential of which the city does not know to sufficiently take full advantage. Precisely in these areas Bratislava could take inspiration from the sister city of Vienna and Amsterdam, which actual projects and its approaches to them could be considered as an exemplary direction of sustainable development of a modern European city.

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Appendix A. Smart Cities benchmarking indicators

Dimension	Working Area	Indicator	Description
	Smart Buildings	Sustainability-certified Buildings	Number of LEED or BREAM sustainability certified buildings in the city (Note: if your city uses another standard please indicate)
			% of commercial and industrial buildings with smart meters
			% of commercial buildings with a building automation system
		Smart homes	% of homes (multi-family & single-family) w/ smart meters
Environment	Resources Management	Energy	% of total energy derived from renewable sources (ISO 37120: 7.4)
			Total residential energy use per capita (in kWh/yr) (ISO 37120: 7.1)
			% of municipal grid meeting all of following requirements for smart grid (1. 2-way communication; 2.) Automated control systems for addressing system outages 3.) real-time information for customers; 4.) Permits distributed generation; 5.) Supports net metering
		Carbon Footprint	Greenhouse gas emissioned measured in tonnes per capita (ISO 37120: 8.3)
		Air quality	Fine Particular matter 2.5 concentration (µg/m3) (ISO 37120: 8.1)
		Waste Generation	% of city's solid waste that is recycled (ISO 37120: 16.2)
			Total collected municipal solid waste city per capita (in kg) (ISO 37120: 16.3)
		Water consumption	% of commercial buildings with smart water meters
			Total water consumption per capita (litres/day) (ISO 37120: 21.5)
	Sustainable Urban Planning	Climate resilience planning	Does your city have a public climate resilience strategy/plan in place? (Y/N) If yes provide link.
		Density	Population weighted density (average densities of the separate census tracts that make up a metro)
		Green Space per capita	Green areas per 100,000 (in m2) (ISO 37120: 19.1)
Mobility	Efficient Transport	Clean-energy Transport	Kilometers of bicycle paths and lanes per 100,000 (ISO 37120: 18.7)
			# of shared bicycles per capita
			# of shared vehicles per capita
			# of EV charging stations within the city
	Multi-modal Access	Public Transport	Annual # of public transport trips per capita (ISO 37120: 18.3)
			% non-motorized transport trips of total transport
			Integrated fare system for public transport
	Technology Infrastructure	Smart cards	% of total revenue from public transit obtained via unified smart card systems
		Access to real-time information	Presence of demand-based pricing (e.g. congestion pricing, variably priced toll lanes, variably priced parking spaces). Y/N
			% of traffic lights connected to real-time traffic management system
			# of public transit services that offer real time information to the public: 1 point for each transit category up to 5 total points (bus, regional train, metro, rapid transit system (e.g. BRT, tram), and sharing modes (e.g. bikesharing, carsharing)
			Availability of multi-modal transit app with at least 3 services integrated (Y/N)
Government	Online services	Online Procedures	% of government services that can be accessed by citizens via web or mobile phone
		Electronic Benefits Payments	Existence of electronic benefit payments (e.g. social security) to citizens (Y/N)
	Infrastructure	WiFi Coverage	Number of WiFi hotspots per km2
		Broadband coverage	% of commercial and residential users with internet download speeds of at least 2 Mbit/s
			% of commercial and residential users with internet download speeds of at least 1 gigabit/s
		Sensor Coverage	# of infrastructure components with installed sensors 1 point for each: traffic, public transit demand, parking, air quality, waste, H2O, public lighting
		Integrated health + safety operations	# of services integrated in a singular operations center leveraing real-time data. 1 point for each: ambulance, emergency/disaster response, fire, police, weather, transit, air quality
	Open Government	Open Data	Open data use
		Open Apps	# of mobile apps available (iPhone) based on open data
		Privacy	Existence of official citywide privacy policy to protect confidential citizen data
Economy	Entrepreneurship & Innovation	New startups	Number of new opportunity-based startups/year
		R + D	% GDP invested in R&D in private sector
		Employment levels	% of persons in full-time employment (ISO 37120: 5.4)
		Innovation	Innovation cities index
	Productivity	GRP per capita	Gross Regional Product per capita (in US$, except in EU, in Euros)
	Local and Global Conexion	Exports	% of GRP based on technology exports
		International Events Hold	Number of international congresses and fairs atendees.
People	Inclusion	Internet-connected Households	% of Internet-connected households
		Smart phone penetration	% of residents with smartphone access
		Civic engagement	# of civic engagement activities offered by the muncipality last year
			Voter participation in last municipal election (% of eligible voters) (ISO 37120: 11.1)
	Education	Secondary Education	% of students completing secondary education (ISO 37120: 6.3)
		University Graduates	Number of higher education degrees per 100,000 inhabitants (ISO 37120: 6.7)
	Creativity	Foreign-born immigrants	% of population born in a foreign country
		Urban Living Lab	# of officially registered ENOLL living labs
		Creative Industry Jobs	Percentage of labor force (LF) engaged in creative industries
Living	Culture and Well-being	Life Conditions	Percentage of inhabitants with housing deficiency in any of the following 5 aereas (potable water, sanitation, overcrowding, deficient material quality, or lacking electricity)
		Gini Index	Gini coefficient of inequality
		Quality of life ranking	Mercer ranking in most recent quality of life survey
		Investment in Culture	% of municipal budget allocated to culture
	Safety	Crime	Violent crime rate per 100,000 population (ISO 37120: 14.5)
		Smart Crime Prevention	# technologies in use to assist with crime prevention, 1 point for each of the following: livestreaming video cameras, taxi apps, predictive crime software technologies
	Health	Single health history	% of residents w/ single, unified health histories facilitating patient and health provider access to complete medical records
		Life Expectancy	Average life expectancy (ISO 37120: 12.1)

[14]

Appendix B. The total average energy consumption and CO2 production of renewed and non-renewed residential buildings

Type of apartment building	number of buildings	number of households	The total average consumption of renewed buildings [kWh] (2012-2014)	The total average consumption of non-renewed buildings [kWh] (2012-2014)	The resulting value of CO2 of renewed buildings (2012-2014) [t]	The resulting value of CO2 of non-renewed buildings (2012-2014) [t]	Average percentage of CO2 production of renewed buildings on non-renewed
A	9	768	496782,74	512181,08	100,002	103,102	15,90%
B	4	192	254500	288715,56	51,231	58,118	
C	25	1440	262656,93	391430,5	52,873	78,795	

Source: authors