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Transport Solutions and Indicators in Smart Cities. Part 2

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Summary

The subject of the article is the analysis of solutions and applications of modern information and communication technologies (ICT) in urban centers and the measurement of transport quality indicators, taking into account the requirements of the ISO 37120 standard: Sustainable social development – indicators of urban services and quality of life. The article consists of two parts. In part two, the transport indicators are described in detail along with the measurement methodology used, including the selection of source data necessary for the calculation of the indicators. For selected seven capitals of Polish provinces (Kraków, Poznań Szczecin, Białystok, Rzeszów, Olsztyn, Opole) existing smart mobility solutions were presented. The main subject of this part of the article is to present the results based on the ISO 37120 standards in the field of transport, together with a discussion and list of results. At the end, the main conclusions from the reviewed analyses and studies are presented.

Keywords: smart cities, quality of urban services, ISO 37120 standard, urban transport, quality indicators in transport

1. Introduction

The potential of smart solutions in the area of transport is eagerly used by western metropolises and foreign urban centres, which Polish cities are also trying to keep up with [1, 2]. The wide range of availability of various tools, technologies and solution possibilities means that, with public participation, cities create and adapt mobility services to specific conditions and challenges, benefiting all users, be they inhabitants, authorities, entrepreneurs, investors, tourists, etc. The investments made in urban areas in smart mobility solutions are socially welcomed and the implemented systems or improvements are positively received by the citizens.

One of the most important tasks for modern city authorities is to develop and implement effective, sustainable and safe urban mobility and public transport systems. This is because they play a very important role in the functioning of cities and will become even more significant in the future. The role of urban transport management instruments, on the other hand, is to measure sustainable mobility and the capacity of the urban transport system by means of metrics and indicators that enable an objective, measurable and comprehensive reflection of the changes taking place [3].

2. Transport quality indicators in ISO 37120 standard

With regard to transport, the ISO 37120 standard [4] contains nine indicators (Table 1). In relation to the inhabited, population, all these indicators make it possible to describe in a simple and uncomplicated way:

- the degree of "saturation" of the city with connections of different types of public transport,
- the city's transport "openness" to other parts of the country and the world (connections made by air transport),
- abundance of motorised vehicles (cars, motorised single-track vehicles),
- provision of infrastructure for bicycles in the city (cycle paths),
- degree of use of own vehicles in commuting,
- use of public transport for travel,
- safety in transport.

Sources for the measurement of the above-mentioned indicators are statistical data [5] provided by city halls, transport establishments, municipal companies, including:

- demographic data on population (Local Data Bank of Statistics Poland);

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Table 1

Transport indicators according to ISO 37120 [4]

Number and name of indicator	Indicator characteristics	Method of calculation
Core indicators		
18.1 – kilometres of high-capacity public transport system per 100,000 population	An indicator specific to large urban centres and agglomerations with infrastructure networks and efficient transport systems to meet high traffic demands. High-capacity public transport includes underground, surface rail and commuter rail systems.	Sum of the length of the high-capacity public transport network operating within the city (numerator) divided by one 100,000th of the city's total population (denominator).
18.2 – kilometres of light passenger public transport system per 100,000 population	The indicator measures, among other things, urban public transport resources, congestion, flexibility of the transport system. Light passenger transport includes trams, buses, trolleybuses.	Sum of the length of the light passenger transport network operating within the city (numerator) divided by one 100,000th of the city's total population (denominator).
18.3 – annual number of public transport trips per capita	The indicator shows the use of public transport in the context of modes of travel in the city, including transport policy. Trips include transport using underground, commuter rail, light rail and trams, light trams, buses, trolleybuses and other public transport modes.	The number of public transport trips in the city in a given year (numerator), divided by the total population of the city (denominator).
18.4 – number of personal automobiles per capita	The indicator measures traffic behaviour, the affluence of the population, but also negative impacts in the form of congestion risk, traffic accidents, health or environmental risks (stress, traffic noise, emissions). The total number of registered passenger cars includes cars used for personal use by commercial enterprises and excludes cars, trucks and vans used for the delivery of goods and services by commercial enterprises.	The total number of registered passenger cars in the city (numerator) divided by the total population of the city (denominator).
Supporting indicators		
18.5 – percentage of commuters using a travel mode to work other than a personal vehicle	The mode of transport used for commuting is a key indicator of transport policy. It includes commuters in a given city by public and private transport (bicycles, scooters, walking, carsharing trips) regardless of where they live.	The number of urban commuters who use modes of transport other than the private car as their main means of commuting to work (numerator), divided by the number of total commutes, regardless of the mode of travel to work (denominator) and then multiplied by 100.
18.6 – number of two-wheel motorized vehicles per capita	The indicator highlights the share of different modes of transport in the modal split, which influences the sustainability of urban mobility. The figure refers to motorbikes, mopeds and scooters. Bicycles and electric scooters are not included.	The total number of two-wheelers in the city (numerator), divided by the total population of the city (denominator).
18.7 –kilometres of bicycle paths and lanes per 100,000 population	This indicator shows the diversification of the city's transport system towards environmentally friendly forms of travel. A transport system which is favourable for cycling shows many benefits in the form of reduction of traffic congestion and improvement in the quality of life through beneficial effects on health and improvement of the environment. Cycle paths also require less infrastructure investment than other types of transport infrastructure.	Sum of the length of cycle paths and lanes (numerator), divided by one 100,000th of the city's total population (denominator).
18.8 –transportation fatalities per 100,000 population	Road accident indicators and, in particular, fatality rates are used to measure the overall safety of the road network and traffic, including the condition of roads and vehicles, congestion, knowledge of and compliance with traffic regulations. Any death directly related to a road and traffic accident that occurred within the city limits is included, even if the death did not occur on the spot but is directly related to the accident.	The number of fatalities associated with all types of transport within the city limits (numerator), divided by one 100,000th of the city's total population (denominator).
18.9 – commercial air connectivity (number of non-stop commercial air destinations)	Cities with high number of flights tend to have more stable economies and are able to provide a higher level of services to residents. The city's airports include all airports reachable within a two-hour travel time from the city centre.	The sum of all commercial (i.e. scheduled) aircrafts departing from all airports in a city.

- data on the length of transport networks and length of cycle paths obtained from infrastructure managers;
- demand and supply data on the offer of transport and the use of connections in the various modes of transport, from transport companies, e.g. on the ticket sales system, and from surveys on transport behaviour;
- data on the number of registered vehicles from the transport offices;
- data on accidents and fatalities provided by the police.

This information is also given in strategies and local transport plans.

3. Research on transport quality in Polish cities

Cities, diverse in terms of their existing resources and potentials (including, among other things, population and surface area data) and in terms of the conditions for the operation of transport systems and urban mobility in their areas, have been selected for transport quality analyses and indicator studies according to ISO 37120. The first criterion for selecting Polish cities for the research on transport quality was their status as capitals of provinces. The available pool of cities (Table 2) was ranked by size in terms of resident population[2]:

- 100,000–200,000 residents (group I: 7 cities),
- 200,000–500,000 residents (group II: 6 cities),
- 500,000–100,000,000 residents (group III: 4 cities),
- more than 1 million residents (1 city).

However, cities that have ever been awarded a smart city certificate (Warsaw, Gdańsk, Lublin, Kielce), i.e. those that have been subject to indicator testing according to ISO 37120 in the past, were excluded from further analyses, cf. [1, 2].

Finally, a total of 7 capitals of provinces were analysed and studied for indicators, as: 3 examples of cities from group I (Opole, Olsztyn, Rzeszów) and 2 examples each from groups II (Białystok, Szczecin) and III (Poznań, Kraków). For each city, the solutions adopted and implemented in terms of smart mobility are discussed. Based on the collected statistical data, transport indicators were calculated according to ISO 37120, as illustrated in the figures. Comparison of the calculated indicator values made it possible to create a ranking according to objective criteria.

Table 2

Population in capital cities of provinces [5]

Urban area	Population
Warsaw	1,795,569
Kraków	782,137
Łódź	664,071
Wrocław	642,687
Poznań	529,410
Gdańsk	470,621
Szczecin	395,513
Bydgoszcz	339,053
Lublin	336,339
Białystok	295,683
Katowice	286,960
Rzeszów	198,609
Toruń	196,935
Kielce	191,448
Olsztyn	169,793
Zielona Góra	140,403
Opole	127,077
Gorzów Wlkp.	120,087

3.1. Smart mobility analysis

3.1.1. Kraków

In Kraków, many innovative solutions have been introduced to improve mobility in terms of traffic management and public transport [6, 7, 8]. Among others, the city has successfully implemented and uses Intelligent Transportation Systems (ITS), including a traffic control and management system giving priority to public transport at intersections.

One of these is the Tram Traffic Control System (*TTCS*) for monitoring the operation of public transport, making detours in the event of obstructions and breakdowns and keeping passengers informed using electronic passenger information boards. Such boards have also appeared in areas of high pedestrian traffic, at junctions, in order to collectively inform about the operation of transport in the immediate area. The TTCS system also assists bus drivers with the implementation

[2] According to Local Data Bank of Statistics Poland, population in cities with powiat (district) rights; as of 31 December 2021.

of the timetable, enables the monitoring and analysis of historical data, as well as the identification of locations requiring improvements to timetables, changes to traffic organisation or the operation of traffic lights.

The second system is the Urban Traffic Control System (*UTCS*), which is mainly used to regulate car and pedestrian traffic, including measuring and analysing the number of vehicles and their speed. Depending on the situation, the system assigns a green light, detects pedestrians and cyclists and trams that need to be given priority. Since the introduction of dynamic signalling, capacity on the city's main arteries has increased by 25%. In addition, in Kraków, the smart mobility criterion is being implemented with modern, environmentally friendly fleet – in July 2020, the city ordered a further 50 electric buses.

Another solution implemented is the SUN-BUS photovoltaic technology system, which converts sunlight directly into electricity. The system is used to support the power supply of the bus's on-board system (24 V), which provides energy for, among other things, ticket vending machines, cash registers, electronic boards, lighting and air conditioning. It is powered by flexible solar panels mounted on the roof of the vehicle. The SUN-BUS system operates fully automatically, switching on when the vehicle needs energy and switching off when the batteries are fully charged. All materials used in the construction of the appliance meet the relevant requirements for non-combustibility, safety of use and ecology. The advanced technical solutions used ensure that the system functions without any noise and has a high resistance to overloading. Solar-powered vehicles run on Kraków bus lines 129 and 503.

An integrated and safe transport system, as envisaged by the Smart City, is intended to create a huge network with high speed and high efficiency allowing tangible benefits: fuel savings, reduction of CO_2 emissions, production of energy). Combined with the Kraków Resident Card (Karta Mieszkańca), which offers significant discounts for those registered or paying taxes in the city, it has the potential to encourage residents to travel using public transport.

3.1.2. Poznań

Poznań's smart city model, is characterised by high quality, economy (of time, space, money, energy and the environment) and pragmatism. The city aims to develop modern, environmentally friendly and integrated transport, enabling efficient movement both within the city and the agglomeration [9]. The objectives for the mobility area are:

- dynamically developing public transport integrating multiple modes of transport,
- data generated by units should have a real impact on the quality of transport and information services provided,
- modern and intelligent transport, permanently embedded in the city's structures and in the consciousness of its residents.

The driving force behind Poznań's smart city model is an efficient, comfortable, modern, integrated and constantly developing transport network. For years, the city has been continuously developing public transport through the construction of new routes and the renovation of existing ones, as well as through fleet investments. Quiet, green, segregated tracks, bus lanes, cycle paths and stations, two-way trams, hybrid buses, car-sharing, cycle sharing schemes - all of this is becoming an urban reality. These developments reduce journey times and increase comfort, encouraging as many residents as possible to choose public transport.

Mobile applications have been implemented, offering the possibility to purchase tickets, check travel times, bypass traffic jams, rent a bicycle or pay for parking. The city has provided an open data platform with timetable information, data on buffer and Park&Ride parking spaces, as well as data on the actual location of public transport vehicles.

Since the implementation of the PEKA system (Poznańska Elektroniczna Karta Aglomeracyjna – Poznań Electronic Agglomeration Card), Poznań has become a trendsetter for smart city cities. The PEKA system card is an extensive and technologically advanced sales and service system, enabling the unification of the fare payment system provided by various independent carriers operating on the territory of Poznań and Poznań district, which facilitates the use of public transport and increases its accessibility. The PEKA system also offers the possibility of purchasing several transport tickets at the same time, which allows passengers using multiple carriers to have their season tickets and tPortmonetka on one card. The tPortmonetka enables a passenger to pay for a journey on a chosen route. With tPortmonetka on the PEKA card, the so-called stop ticket, you pay for the number of stops you have made, irrespective of the time of your journey. A degressive tariff applies.

Another solution is the Park&Ride parking system, which allows an efficient and convenient transfer from one's own car to public transport. With proof of entry, drivers do not pay for public transport, while drivers with a season ticket leave their cars in the car park for free. The parking system is integrated into the PEKA card.

A system of passenger information boards (TIP) was also developed in Poznań. In addition to paper timetables, a dynamic passenger information system based on QR codes and Near Field Communication (NFC) tags from a smartphone application placed at each bus stop has been implemented in bus shelters. Planned smart solutions include:

- introduction of e-ink technology for timetable display,

- development of an electromobility strategy,
- construction of 3 integrated interchange stations combining rail, bus, tram, car, motorbike, bicycle and pedestrian transport.

3.1.3. Szczecin

The capital of Western Pomerania has for several years been implementing projects that are in line with the Smart City concept. In addition, these projects are included in the strategic programmes of the Strategy of Development of the City of Szczecin until 2025 [10] and Floating Garden 2050 [11], guaranteeing the long-term character of the initiated activities, which is extremely important in the Smart City concept. In terms of transport, the city has implemented the following technologies [12]:

- Intelligent Traffic Management System – the system enables an increase in traffic flow in the city and the improvement of transport systems in the Szczecin Metropolitan Area. The system improves traffic flow in the city, reduces the number of accidents and collisions. The system also provides drivers with information on road conditions.
- The Central Urban Transport Management System (Centralny System Zarządzania Komunikacją Miejską) is a single central system integrating many aspects of public transport. Its implementation included, among others: the Public Transport Fleet Management System with optimisation module, the Dynamic Passenger Information System, the Transport on Demand system, the Electronic Ticketing system, the on-board Video Monitoring System.

3.1.4. Białystok

Białystok is one of several Polish cities recognised in the European Smart Cities 2014 ranking prepared by the Vienna University of Technology. In recent years, the city has allocated PLN 2.5 billion to smart city projects, most of which came from EU funds. In addition to tasks in the area of transport infrastructure concerning the construction of the city's western ring road or the paving of many streets, city investments have included public transport. Between 2007 and 2014, 180 of the 254 buses were replaced. The new vehicles comply with the Euro 5 and Euro 6 standards. Future fleet purchases will already include electric buses.

Since 2015, the city has implemented a Traffic Management System. Elements of this system include traffic signal control, priority for public transport buses, signs informing about traffic obstructions, detours, accidents. The system constantly analyses volume of traffic and adjusts the operation of the traffic lights in real time. As a result, travel times are reduced for both public transport passengers and other drivers, thanks to the ability to react more quickly to obstructions. Information from the system is available to the public on the website (www.szr.bialystok.pl), allowing residents and visitors to Białystok to check the traffic situation and volume of traffic in real time and plan their journeys accordingly. The system covers the entire city, with numerous vehicle detectors and automatic plate recognition cameras deployed in the system area. The solution assumes priority for public transport. Buses are given priority at intersections covered by the system. The project also included the creation of a Traffic Management Centre, which integrates the entire database and allows remote operation of the system.

A functional innovation introduced in Białystok, which has only become more popular over time, was the possibility to make parking payments using a mobile phone. One of the more recent ideas of the city's IT specialists is the introduction of a system for registering free spaces in the paid parking zone.

3.1.5. Rzeszów

In 2015, a system integrating public transport of the city of Rzeszów and its surroundings was launched. The entire system consists of: control of traffic lights to determine priority for public transport vehicles including the provision of ”online” vehicle tracking, a passenger information system (electronic boards at bus stops and on city streets), the introduction of electronic tickets and stationary ticket vending machines. As part of the scheme, the transport system of the road infrastructure was rebuilt (including the provision of bus lanes and weight stations on the roads leading out of the city). Eighty new buses meeting the EEV emission standard were also purchased. All buses are compatible with e-Info as well as electronic ticket systems. This investment is part of a project to build a system integrating public transport in the city of Rzeszów.

In 2018, with the support of EU funds, the city purchased 50 modern buses, while another major purchase took place in 2019, this time it was 60 vehicles powered by natural gas (CNG). There are also 10 electric buses in operation, and the fleet of these vehicles is set to expand in the near future with the construction of charging facilities.

On the initiative of the Rzeszów University of Technology, a series of meetings presenting transport solutions for the city were organised in 2019 [13]. The aim was to create a platform for the exchange of information and ideas that can be used by the authorities of the city of Rzeszów to improve infrastructure and improve transport and transport systems. Among the solutions examined and presented were:

- dynamic bus lane,
- creation of advanced stop lines located at junctions in order to freely change lanes before a cyclist enters the junction,

- functioning composite overpass – separate crossings for cyclists through overpasses,
- creation of interchange stations – Park&Ride car parks, at the main inlet streets of the city,
- processing of available data, for decision making on shaping the transport system in the city.

3.1.6. Olsztyn

Since 2015, the city has implemented an intelligent traffic control system (ITS) covering 85 intersections. Under the new system, public transport vehicles are given priority at intersections with traffic lights.

The main objective of implementing an ITS system in Olsztyn [14] is to improve the technical and operational standards of the city's transport network, including the quality of operation and use of public transport and the improvement of individual traffic. The Integrated Traffic Management System in Olsztyn consists of more than a dozen integrated subsystems that mainly improve safety – both for people travelling by public and individual transport and for pedestrians, as well as the quality of transport and the comfort of travellers. The ITS system, includes:

- area traffic control subsystem, including priority for public transport vehicles, based on the renowned SCATS system implemented in many agglomerations around the world,
- video monitoring subsystem at intersections covered by the traffic control system,
- traffic monitoring subsystem,
- subsystem for recording red-light crossings,
- subsystem for recording vehicle instantaneous speed,
- traffic control subsystem for public transport vehicles on bus and tram lines,
- passenger information subsystem on the Internet and at stops and in vehicles,
- electronic tickets (city card) with charging system and on-board equipment on trams and buses,
- meteorological information subsystem,
- traffic flow control subsystem in the traffic system.

One of the important considerations in implementing the system is to improve security. The entire system is managed and supervised from two centres: The Street Traffic Management Centre and the Public Transport Management Centre. In addition, the city's monitoring system is extended to include a vehicle traffic monitoring system and a bus stop monitoring system, as well as an internal monitoring system installed in buses and trams. Safety on Olsztyn's streets is also improved by the red-light crossing and instantaneous speed recording systems installed in the city at a dozen major intersections, which monitors drivers who pose a danger and break traffic regulations. Since 2016, the Olsztyn City Card (Olsztyńska Karta Miejska) [15] has been used for public transport trips in addition to regular tickets.

3.1.7. Opole

The authorities of Opole and representatives of Sprint signed a contract for the construction of an Intelligent Transportation System (ITS) on 10 January 2020. The system will be operational from September 2022 [16].

The basis of the ITS system is devices that monitor volume of traffic at the 49 busiest intersections of the city. Based on the measurements, the system will be able to determine where traffic jams form and control the traffic lights at other intersections in such a way as to relieve congestion and improve traffic flow.

Among other things, the investment also included a parking information system showing drivers and guiding them to available parking spaces, which will be supported by a specially created mobile app. In strategic locations, electronic variable message signs have been installed to provide information on optimal travel routes, weather stations to measure noise and pollution levels, and cameras to monitor the passage of cars. The monitoring footage can be accessed by city agencies (police and local police).

3.2. Measurement of urban transport indicators

3.2.1. Input data

The data sources for calculating the indicators were mainly public data from Local Data Bank of Statistics Poland [5]. For information on the length of the public transport network and urban transport, the transport management units of the individual cities were contacted directly.

The most recent data covering the most recent completed year, i.e. 2021, and also the previous year, 2020, were obtained. Where no data were available for a particular period, the indicator value was calculated for the year for which all component data were available. Indicator 18.9 for all cities was examined for the year 2022.

Some of the data (such as information on modes of travel to the workplace) includes information that is difficult to obtain or that, in many cases, has not yet been researched, or is unofficial or covered by trade secrets of the entity concerned[3]. Due to the lack of reliable sources of information, or lack of access to

[3] According to the definition of the indicator, a car trip is considered to be a trip in which only 1 person travels by car. Car sharing is qualified as another mode of travel.

them, some indicators could not be calculated (due to the difficulty in obtaining reliable data, indicator 18.5 was not measured).

3.2.2. Comparative analysis of the results obtained

All the cities analysed have rail transport infrastructure for passenger transport, without distinguishing urban transport. According to the criterion of the length of the railway network for the provision of passenger transport in relation to the number of residents (Fig. 1), Opole has the longest network, with a result of just under 26 km/100,000 residents. The remaining cities achieve similar results, within the range of 5–10 km/100,000 residents.

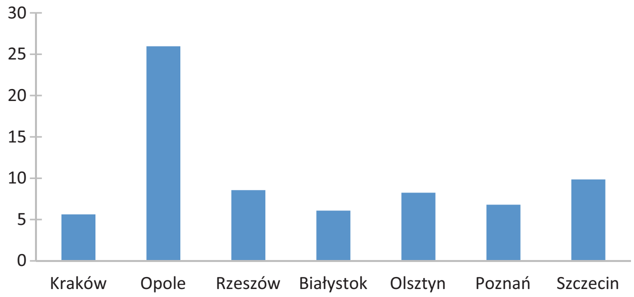

Fig. 1. Indicator 18.1: kilometres of high-capacity public transport system per 100,000 population [own elaboration]

All cities under analysis have urban transport by bus or bus and tram. Kraków and Rzeszów achieved the highest values of the indicator of the length of the public transport network in relation to the number of residents, on average approx. 370 km/100,000 residents. This indicator was the lowest in Olsztyn – less than 130 km/100,000 residents (Fig. 2).

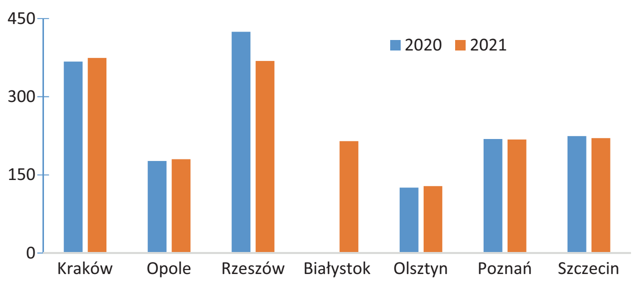

Fig. 2. Indicator 18.2: kilometres of light passenger public transport system per 100,000 population [own elaboration]

The high number of trips using urban transport is indicative of the good quality of public transport, the popularity of the choice of travel mode in the city and, as a result, the greater efficiency of urban public services. Poznań and Kraków had the most trips per resident, reaching values of respectively: 340 and 328 (Figure 3). In Opole and Rzeszów, the popularity of using public transport among residents is much lower. Here, the value of the indicator was 3 times lower, with 105 and 107 trips respectively.

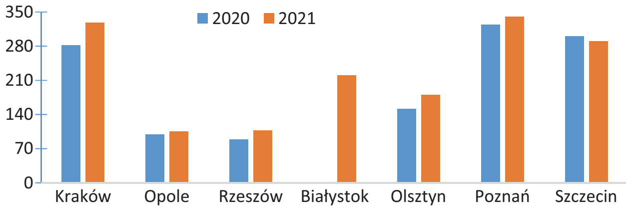

Fig. 3. Indicator 18.3: annual number of public transport trips per capita [own elaboration]

Poznań and Opole turned out to be the cities with the highest indicator of people owning a car (Figure 4), and reached 0.8 and 0.79 motor vehicles per statistical resident respectively, with the increase in the value of the indicator in relation to 2020 being the highest in Opole at 0.03. Białystok had the lowest number of passenger cars per resident, with a value of 0.51 for the last year.

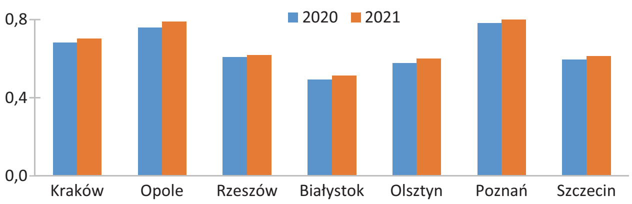

Fig. 4. Indicator 18.4: number of personal automobiles per capita [own elaboration]

According to the criterion of ownership of single-track vehicles (motorbikes and mopeds), the highest indicator in 2021 was reached by Rzeszów: 0.054 and Poznań: 0.051 (Figure 5). In contrast, the lowest indicators were achieved by: Szczecin – 0.036 and Olsztyn – 0.039. Rzeszów also had the largest increase in the indicator compared to 2020 (by 0.004), the other cities recorded an increase in the indicator half as large (by 0.002).

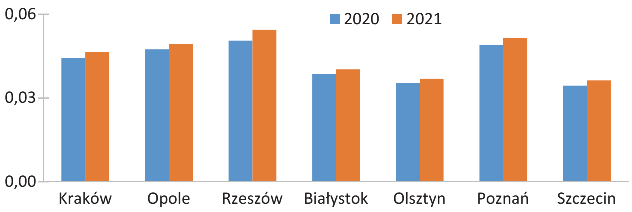

Fig. 5. Indicator 18.6: number of two-wheel motorized vehicles per capita [own elaboration]

In terms of the length of road infrastructure in relation to population (Fig. 6), Opole and Rzeszów occupy leading positions in the ranking of the analysed cities, achieving results in 2021, respectively: 85.6 and 84.6 km/100,000 residents. Kraków achieved the lowest values of the indicator (in 2020 – 32.4, in

2021 – 33.0 km/100,000 residents), despite a relatively developed network of roads and cycle paths – over 250 km. In absolute numbers, Poznań has the longest network of cycling infrastructure in 2021 – over 300 km. In relation to 2020, the capital city of Greater Poland saw the highest increase in the indicator (by 5.1 km/100,000 residents).

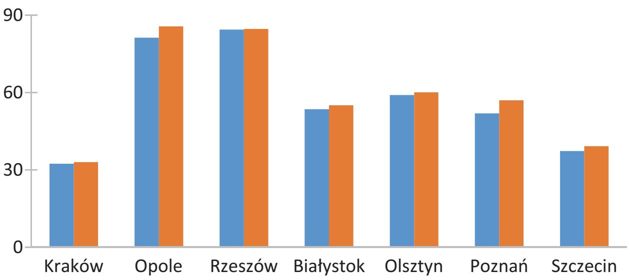

Fig. 6. Indicator 18.7: kilometres of bicycle paths and lanes per 100,000 population [own elaboration]

Białystok is a city with a low indicator of people killed in traffic accidents. In a way, this is related to the low rate of people owning a car in the Podlaskie Province capital. The highest values of the indicator of the number of people killed in traffic accidents were reached in 2021: Opole (3.1) and Rzeszów (3.0), while in 2020: Poznań (3.0), followed by Rzeszów and Szczecin (2.5 each).

In absolute numbers, the highest number of people killed in traffic accidents (Figure 7) were in Poznań and Kraków – several people each in both 2020 and 2021. This correlates with the high accident rates in these two cities. It should be noted, however, that there was a positive trend towards a decrease in the number of traffic accidents in Rzeszów, Olsztyn and Poznań, while in terms of fatalities a positive trend towards a decrease occurred in Kraków, Poznań and Szczecin.

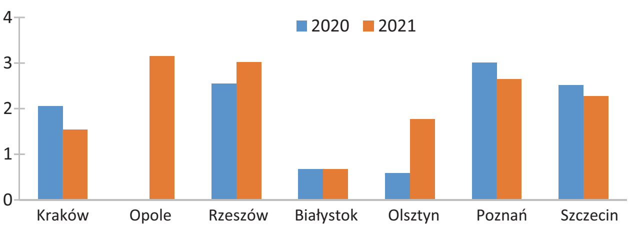

Fig. 7. Indicator 18.8: transportation fatalities per 100,000 population [own elaboration]

Indicator 18.9 was estimated for 2022 according to the summer flight schedule. In the case of Opole, flights from Katowice and Wrocław airports were taken into account. Białystok does not have an airport that can be reached within 2 hours, so no flights were shown (Figure 8).

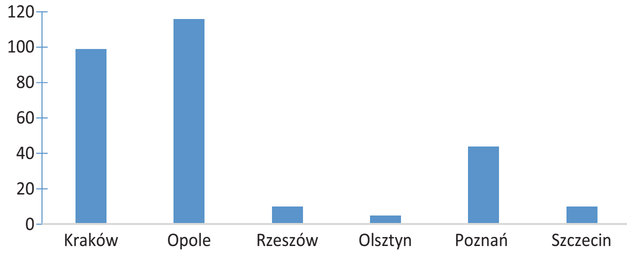

Fig. 8. Indicator 18.9: commercial air connectivity (number of non-stop commercial air destinations) [own elaboration]

The airline industry has recently been hit hard by the COVID-19 pandemic and the associated restrictions on international and domestic transport, which have drastically reduced passenger operations. The situation in the Polish market is now slowly recovering, although traffic levels are still half what they were in 2019. Among those analysed, the trend in the number of passengers at airports between 2020 and 2021 was increasing in Katowice (+60.8%), Poznań (+60.2%), Wrocław (+40.5%), Kraków (+18.4%) and Rzeszów (+8.0%) [17].

In order to obtain an collective result for the cities, individual indicator values were assigned a weight, depending on the level of the indicator values per city analysed and the assessment of the impact on the transport system.

Analytically, of all the cities analysed, Kraków and Poznań scored highest in terms of smart mobility indicators, while Olsztyn scored lowest (Figure 9). Kraków has a well-developed public transport system, which residents are keen to use, as well as the availability of an airport and growing demand for air services. Transport safety in the capital of Lesser Poland is also positive. Poznań also shows a high use of public transport for mobility and access to air transport. Szczecin has a high quality urban public transport. In the case of Bialystok, the highest scores were given to transport safety and the indicator of people owning a car, a low level of which contributes to a lower risk of traffic congestion in the city and a reduction in environmental costs (noise, pollution, accidents). In Rzeszów, despite the high indicator of public transport, there are also new developments concerning cycling infrastructure and single-track traffic. Olsztyn scored highest in terms of indicator of people owning a car and transport safety. The declining demand for air services in the capital of Warmia has negatively impacted the collective assessment. Opole has a high potential for rail transport and has additionally relied on the development of cycle path infrastructure.

Fig. 9. Cities subjected to a collective smart mobility assessment [own elaboration]

4. Conclusions

The cities analysed apply different solutions and modern technologies in the aspect of smart mobility. Intelligent Transportation Systems (ITS) for public transport are the benchmark for improving the quality of public transport and increasing the demand of residents for its services. The construction of car parks or interchange stations further encourages the use of public transport vehicles in cities. The development of cycle sharing schemes and the expansion of the infrastructure of roads and cycle paths serve the development of shared mobility and additionally play a role in the improvement of safety and the preservation of conditions which ensure the good health of residents.

ISO 37120 [4] makes it possible, in a holistic and integrated way, to measure urban services and quality of life with standardised indicators that can be successfully used in sustainable development policies and performance management of urbanised areas. Furthermore, planning regarding future needs should take into account the current use and efficiency of urban service resources.

The transport indicators, calculated in accordance with the requirements of ISO 37120, should serve cities not so much as a means of comparing and ranking themselves against other units, but as a valuable guide to evaluation and monitoring of progress and effects on investments made or changes and improvements introduced. Meeting the real needs and expectations of service users and end users (residents) by local authorities is more important than breaking any records of indicator values. Regardless of what criteria would be adopted to assess cities in specific rankings, the transport solutions implemented contribute to sustainable urban development and serve to improve the mobility of its residents.

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