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Leszek BYLINKO[1]

INTEGRATION OF AN URBAN TRANSPORTATION SYSTEM AS AN ELEMENT OF MOBILITY PLANS

Summary. In today's urban mobility scene, the increasing number of private cars trying to travel through the city centers is one of the most onerous problems facing urban transport. Knowing about the impact that different transport demand management models can have on the efficiency of the urban transport system may be of key importance for developing solutions in this area. This knowledge is the main goal of the considerations undertaken. The observations presented in this article took place during the formation of a Sustainable Urban Mobility Plan (SUMP) for the Bielsko-Biała agglomeration. The author of the article is a member of the working group that prepared the SUMP project for the city. The study examined the effectiveness of mobility planning activities. The scope of these activities included collecting the data necessary to create a mobility plan, analyzing this data, building scenarios in the area of transport demand management, and designing the assessment of the adopted solutions. The article shows the procedure for creating a model of a SUMP for urban areas, which may be a prerequisite for municipal governments for effective applications for funding projects related to transport. The most important part of the analysis is the evaluation using integration indicators of selected key elements of the urban transport system of the Bielsko-Biała agglomeration in the area of transfer accessibility. Such research allows us to answer the question of whether the locations of new railway stops proposed under the agglomeration SUMP contribute to increasing the integration of the urban transport system. The current research implements one of the dimensions of mobility management projects. Related goals are, among other things, to achieve more effective integration of the urban transport system. The analyses were carried out by measuring selected properties of the transport network and a survey questionnaire.

1. INTRODUCTION

Urbanized areas are considered to be particularly at risk of pathologies of transport processes. By their nature, urban spaces, which concentrate on social and economic life, as well as due to limited resources, require a special approach. It is about systematic actions that will allow us to limit and shape the causes of the growing demand for transport, not the effects of this demand. Such activities create the instrumentation of transport demand management. The practice of managing urban transport systems shows that, apart from the necessary political actions and the shaping of transport behavior (i.e., the choices that city travelers make or are forced to make), the basic problem is the effective financing of transport projects. Therefore, the importance of planning and management conditions is growing, which, in a difficult financial situation, will enable the systemic modeling of communication behavior and shaping urban mobility.

For this purpose, Sustainable Urban Mobility Plans (SUMPs) are settled in defined areas, which are tools that integrate the subject of a strategic approach to transport planning, including spatial planning, environmental protection, and health. These are strategic and operational documents designed to meet

[1] University of Bielsko-Biala; Willowa 2, 43-309 Bielsko-Biała, Poland; e-mail: lbylinko@ubb.edu.pl; orcid.org/0000-0001-8047-801X

the social and economic mobility requirements in the city and its surroundings while ensuring better conditions for work and living. These documents build on existing planning practices and take into account issues of integration, public participation, and assessment principles.

2. THE GENESIS OF URBAN TRANSPORT DEMAND MANAGEMENT PLANS

Transport demand management is defined in the literature in many different ways, and the definition has changed over time. From the perspective of time and the evolution of the approach to the subject, it can be said that transport demand management operates at the level of spatial mobility and, thus, enables targeted traffic design before it occurs. In addition to infrastructure planning and traffic management, transport demand management is the third dimension of modern traffic planning in the context of urban transport.

The concept of managing the demand for urban transport is, in a sense, most effective in conditions of limited resources and, to some extent, is a response to the decreasing financing base related to the provision of new elements. At the same time, the urban community begins to feel the environmental consequences resulting from the high dependence on private transport at different strengths. In this context, attempts to limit the use of private cars have become part of policy at various levels of government [6, p. 576]. A transport demand management policy strategy should be developed and integrated into the overall transport policy of the city. The strategy should explain the overall intentions and plans for promoting sustainable transport and managing the demand for car use by changing the attitudes and behaviors of travelers. The transport demand management policy document should be accepted by politicians and a wider audience [16, p. 38-40]. A combination of transport demand management (non-investment measures) and "hard" measures such as infrastructure measures, pricing, and regulations are more likely to have a better outcome in terms of modal shift [17, p. 46].

The transport demand management policy should constitute an institutional framework for the implementation of a set of actions in the area of adopted strategies. Such a program should define goals, tasks, budget, implementers, and clear relations with stakeholders. Standard tasks of the policy of transport demand management programs include [15, p. 38–41]:

- coordinating, planning, implementing, evaluating, and collecting data on transport demand management;
- implementing promotional and marketing programs;
- responding to issues and complaints about actions taken;
- providing passenger information services and public transport services;
- promoting pedestrian and cyclist traffic and transport management during special events;
- providing parking management and parking pricing as well as coordinating public parking arrangements;
- supporting the implementation of pedestrian and cycling facilities, material transport management, and safety improvements that encourage the use of alternative modes of transport;
- coordinating interactions with non-urban organizations such as transport management associations, organizations implementing travel reduction programs and institutional reforms;
- supporting integrated transport and land use planning to improve accessibility and reduce vehicle traffic (access management, smart development, and efficient site planning).

Transport demand management programs are designed to ensure that identified strategies are complementary and coordinated for maximum effectiveness. As a general rule, transport demand management policies should strike a balance between better travel choices and incentives to reduce car travel [14].

The current design of transport demand management systems seems to be limited due to the fact that individual actors in this process are assigned to solve strictly defined problems related to their individual and defined duties. For example, reducing traffic congestion is the responsibility of road authorities, while reducing pollution is the responsibility of environmental agencies. This can lead to situations where individual organizations choose to solve problems within their mandate, which may exacerbate other problems that the transport system has to deal with [5, 4].

Road authorities may carry out works to increase road capacity, which may reduce congestion. However, one should remember the so-called induced demand, which causes additional movement of vehicles and, in turn, increases other transport problems (Table 1). The full value of transport demand management can only be appreciated by considering a number of criteria and constraints [13].

Table 1

Criteria for change in transport demand management and other urban transport management strategies

Planning criterium	Increasing road capacity	Raising fuel efficiency standards	Transport demand management
Improved traffic safety	-	-	+
Efficient land use	-	-	+
Congestion reduction	+	-	+
Reduction of driving costs	-	-	+
Reduction of parking costs	-	-	+
Consumer spending savings	-	+/-	+
Transport diversification	-	-	+
Energy savings	-	+	+
Pollution reduction	-	+	+
Improved community fitness and health	-	-	+
"+" means that the strategy supports the achievement of the goal; "-" contradicts this goal. The extension of roads and increased fuel efficiency of vehicles help to achieve certain goals, but they stimulate vehicle travel and thus highlight other transport problems.			

3. SUSTAINABLE URBAN MOBILITY PLAN – SUMP

Planning is a crucial stage in the management process. Effective planning allows one to take into account the needs and preferences of the people to whom the plans apply in the decisions made. Planning can support transport demand management in various ways. It provides the basis for more integrated services, charging, user information, infrastructure provision and management, transport and land use planning, and other public policies in areas such as roads, parking, and fuel prices [10].

Mobility plans are usually necessary to apply for co-financing of planned activities from structural funds. The application selection criteria determine the necessity for local government units to have a planning document containing references to the issue of transport demand management and sustainable transport systems. The function of such a document is a mobility plan.

Mobility plans also work well in relation to incidental events, such as fairs, concerts, and sporting events, the organization of which has a significant impact on the urban transport system and often causes communication paralysis in a city. Mobility plans for these types of events allow one to limit the negative effects of their organization. They respond to specific communication problems in facilities and areas by implementing instruments related to improving transport accessibility, reducing the demand for parking spaces, or reducing traffic congestion [9, p. 31-32].

Mobility plans are strategic documents created for specific entities. They differ in the scope of coverage, taking into account a given area (e.g., commune, agglomeration, city, district) or object (e.g., an institution, enterprise, or school). The implementation process lasts from several to several months, and the duration of the plan is permanent (Table 2). The exceptions are plans prepared for temporary one-off events (e.g., fairs) [4, p. 57].

Table 2

Mobility plan characteristics

Mobility plan duration	Mobility plan scope	Mobility plan examples
Permanent	Area	Region, commune, agglomeration, city, district
	Object	Shopping malls, institutions, schools, enterprises, cultural institutions
Temporary	One-off event	Public, cultural, or sporting events, fairs

Workplaces are the most typical areas for the implementation of mobility plans. Employees travel at specific time intervals in the morning and afternoon, have the same destination (workplace), and can be informed and motivated using business communication channels. Mobility plans for workplaces help to reduce specific transport problems of plants, mainly as a result of implementing multiple measures to improve transport accessibility and reduce parking needs. Thus, they reduce traffic congestion in the nearby area. The appropriate selection of instruments depends on the characteristics of the target group, as well as the size and specificity of the institution or enterprise. The implementation of instruments must be accompanied by activities in the field of education and the promotion of sustainable mobility [8, p. 19-25]. Mobility plans for jobs are well-known and practiced and, in some countries, require mobility management instruments. For example, many US states have laws requiring employers with 100 or more employees to reduce the number of workplace-related car trips by implementing mobility plans [6, p. 575–579].

In Italy, the requirement to create a position of mobility consultant in sufficiently large enterprises is in force; in Great Britain, France, and Belgium, the private sector is supported in encouraging employees to change their communication behavior by providing information on the implementation of plans, organization of training, introducing legal regulations, subsidies for the employer, etc. [22].

One of the basic documents for managing the demand for urban transport shaping the principles of mobility management policy is the Sustainable Urban Mobility Plan. The importance of this document is influenced by the fact that it is intended to set local directions for managing urban mobility in accordance with the policy of sustainable urban transport, combining instruments for managing demand for transport. Therefore, this is an invaluable role that justifies the need to analyze certain universal stages of creating such documents [11, p. 218-219].

SUMP is a tool to facilitate planning, taking into account the wider context of the functioning of a city. It is a strategic set of interrelated actions, the implementation of which is to meet the mobility needs of residents and other "users" of the city now and in the future. SUMP is a strategic document that should be designed to meet the mobility needs of residents, the business sector, and other stakeholders relevant to the city and its surroundings, taking into account the improvement of the quality of life. The plan should build on existing planning practices and take into account the principles of integration, participation, and evaluation [7, p. 1083-1086].

4. SUSTAINABLE URBAN MOBILITY PLAN FOR THE BESKID AGGLOMERATION – BASIC ASSUMPTIONS OF THE PLAN

The Sustainable Mobility Plan for the Beskid Agglomeration (hereinafter referred to as the SUMP of the Beskid Agglomeration) covers all aspects of mobility in the area of institutionally integrated municipalities through the Association of Municipalities and Poviats of the Southern Subregion of the Silesian Voivodeship Beskid Agglomeration. The author of this article was a member of the working group that prepared this project.

A characteristic of the area of the Beskid Agglomeration is the combination of important sources of transport demand. The city of Bielsko-Biała and the city of Czechowice-Dziedzice form an urban

functional area of the regional center of the Bielsko Agglomeration (which is the center of the southern subregion of the Silesian Voivodeship) and local development centers - the cities of Cieszyn and Żywiec with direct and communes where tourism is strong. This requires an approach based on local knowledge.

The starting point for the development of the Sustainable Mobility Plan for the Beskid Agglomeration was the diagnosis of the current mobility situation of the analyzed area, prepared in the first stage of the work. During the work, primary data (collected during public consultations, individual and group interviews, and surveys) and secondary data (e.g., obtained from publicly available statistical databases from operators and organizers of public transport) were used. Good practices in Poland and Europe were also used to describe proven mobility solutions.

Regarding the vision and goals in the developed Plan, attention was drawn to the need to improve mobility through integration and increasing accessibility to public collective transport. The lines of action presented in the Plan balance mobility, not through restrictions but through competitiveness. The basic element of the vision is public collective transport, which, through effective functioning, high availability, and high comfort of travel, will ensure an increased share of passengers and reduce the current congestion [12].

The process of developing the SUMP for the Beskid Agglomeration was based on a cycle of twelve steps of sustainable urban mobility planning. The implementation of specific steps and actions was carried out in four stages:

- Stage I: good preparation;
- Stage II: rational and clear definition of goals;
- Stage III: definition of the action plan;
- Stage IV: implementation of the plan.

The starting point for the development of the plan was the desire to improve not only mobility but also the quality of life of the inhabitants of the Beskid Agglomeration. During the implementation of the document, the most important aspects of sustainable mobility planning were taken into account, including involving residents and stakeholders at each stage or integration of policies between all sectors, especially transport, spatial planning, environmental protection, economy, social policy, health, and safety.

The next step was to develop a mobility concept (i.e., to prepare development scenarios and a rational vision of the development of the entire area) and then to define priorities and measurable goals that set the direction of activities for the coming years until 2040.

Development of the plan began in 2022, and its adoption will take place by the end of 2023, according to the current forecast. During the work on the document, both strategic planning—defining strategic goals and directions of activities in the long term—and operational planning—covering a shorter period, consisting of identifying specific tasks to be implemented—were taken into account. The effective implementation of the action packages described in the plan requires defining a time horizon, which has been set as follows:

- by 2030: operationalized goals and a comprehensive and optimal set of actions combining infrastructural, organizational, and legal issues;
- by 2040: a 17-year perspective for strategic, long-term goals that are also part of the objectives of the EU and national sustainable mobility policy, climate policy, urban policy, horizontal policies, and other policies.

The developed plan also includes a system for monitoring result indicators with an indication of initial, target, and fixed values from a time perspective. The evaluation of activities should take place on an annual basis. This is the ideal time to review the results so far and possibly update the plan.

The plan, in accordance with the principles of universal design, takes into account all groups of recipients, including people with various types of disabilities. Social participation is extremely important, as it enables the involvement of various people.

The Beskid Agglomeration is located in the southern part of Poland. The agglomeration covers the southern part of the Silesian Voivodeship and completely covers the area of the Bielsko, Cieszyn, and Żywiec poviats and the city with the rights of the Bielsko-Biała poviat. Figure 1 shows the proposed functional division of the area for the Beskid Agglomeration.

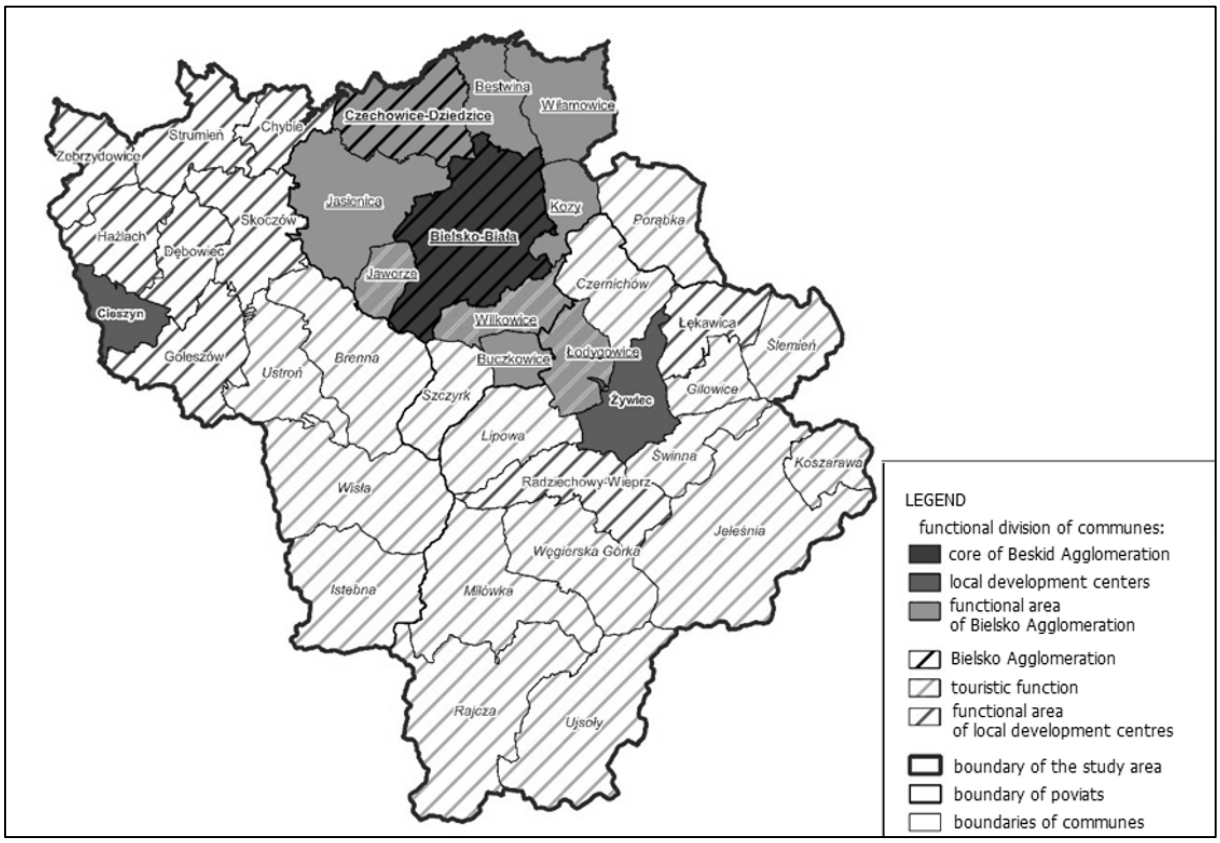

Fig. 1. Functional division of the research area

5. TRANSPORT SYSTEM INTEGRATION IN THE SUMP FRAMEWORK

One of the fundamental challenges in mobility management is the integration of the transportation system. Many cities struggle with the lack of coherence among various transportation systems, which hinders travel and leads to inefficient resource utilization. In many areas, innovative solutions to enhance mobility management, such as data-driven intelligent transportation systems or the development of eco-friendly modes of transportation, are lacking.

Urban transportation system integration pertains to creating a cohesive and efficient urban transport system that connects various modes of transportation to facilitate travel for residents and city visitors. There are several key dimensions to consider in the process of urban transportation system integration [18, 26]:

1. Modal diversity: this refers to the different modes of transportation available within a given area. Integration necessitates considering various modalities, such as public transport (buses, trains), bicycles, pedestrian travel, car-sharing, taxis, and more. The system should allow for seamless transitions between these modalities.
2. Integrated fare systems: simplifying payment methods is important for users. The ability to use a single card or application to pay for different modes of transportation within a system makes travel easier and encourages the use of public transport.
3. Integrated schedules and timetables: this involves aligning the schedules of various modes of transportation so that passengers can easily transfer between them. Schedules should be coordinated to minimize waiting times.
4. Passenger information: integration should include providing passengers with real-time information on the availability and schedules of various modes of transportation. This can include information boards at stops, mobile apps, voice announcements, and other sources of information.

5. Interchange infrastructure: adequate interchange infrastructure, such as integrated stops and terminals, facilitates passengers' transfers between different modes of transportation. This may include shelters, waiting areas, bicycle parking, and more.
6. Promoting sustainable mobility: integration should encourage the use of more sustainable transportation modes, such as bicycles, pedestrian travel, and public transport. This may involve dedicated bike lanes and sidewalks.
7. Traffic management: integration requires traffic coordination and management to ensure smooth traffic flow and minimize congestion.
8. Pricing and ticketing policy: the pricing and ticketing system should be transparent and fair. Various pricing options, such as single tickets and subscriptions, should be available.
9. Biodiversity: transportation integration should take into account environmental impact and aim to minimize negative effects on nature.
10. Social participation: another key dimension is considering the opinions and needs of local communities and involving residents in the planning and development of the transportation system.

6. RESEARCH ON SELECTED ASPECTS OF PUBLIC TRANSPORT SYSTEM INTEGRATION AND DISCUSSION OF RESEARCH RESULTS

Research on the integration of an urban public transportation system is essential for improving the accessibility and efficiency of transportation services in cities, a key condition for an effective SUMP project. There are many methods and research techniques that can be used to assess the degree of integration in the transportation system. In this study, three of them were employed:

1. Geospatial data analysis, such as mapping public transport routes and transportation infrastructure.
2. Interoperability assessment, which involves analyzing whether different modes of transportation (buses and trains) are integrated and allow for easy transfers between them. This includes examining the accessibility of stops.
3. Schedule coordination evaluation, which involves assessing the coordination between different carriers and public transport operators.
4. Field surveys, including conducting passenger surveys to understand their experiences and needs related to using the transportation system.

The survey conducted as part of the research addressed issues that allowed us to determine transportation mode preferences. City travelers typically use a single mode of transportation (77.7% of respondents). Most commonly, they travel by city bus (25.6%) or private car (67.1%). Only every 50th respondent admits to walking in the city. Intercity buses and trains are rarely used for urban transportation, and when they are, it is usually for one of two or three legs of a journey. Trains account for only about 1.5% of such trips. There is a lack of necessary coordination between intercity bus and train connections and urban bus transportation. Research results regarding the number (a and b) and type (c) of transportation modes used for commuting to work and educational institutions (most common purposes of urban trips) are presented in Fig. 2.

In light of the research results presented above, a concern arises that 31% of individuals using public transportation within the city change buses at least once during their journeys. This may indicate a lack of alignment between the route plans and the current needs of residents. The bus route layout in Bielsko-Biała has a configuration that, in several cases, has not been modified for years despite urban development changes in the city. As a result, a significant percentage (approximately 31%) of commuters traveling for work or education purposes end up using two or more buses.

A characteristic and highly unfavorable phenomenon for car travel in Bielsko-Biała, and in the vast majority of cities, is that in about 80% of cases, only one person travels in a car. Currently, in Polish cities, the average occupancy rate of a passenger car is about 1.2 persons/vehicle. In other European countries and the United States, which have a developed carpooling system, this rate is approximately 2.8 persons/vehicle.

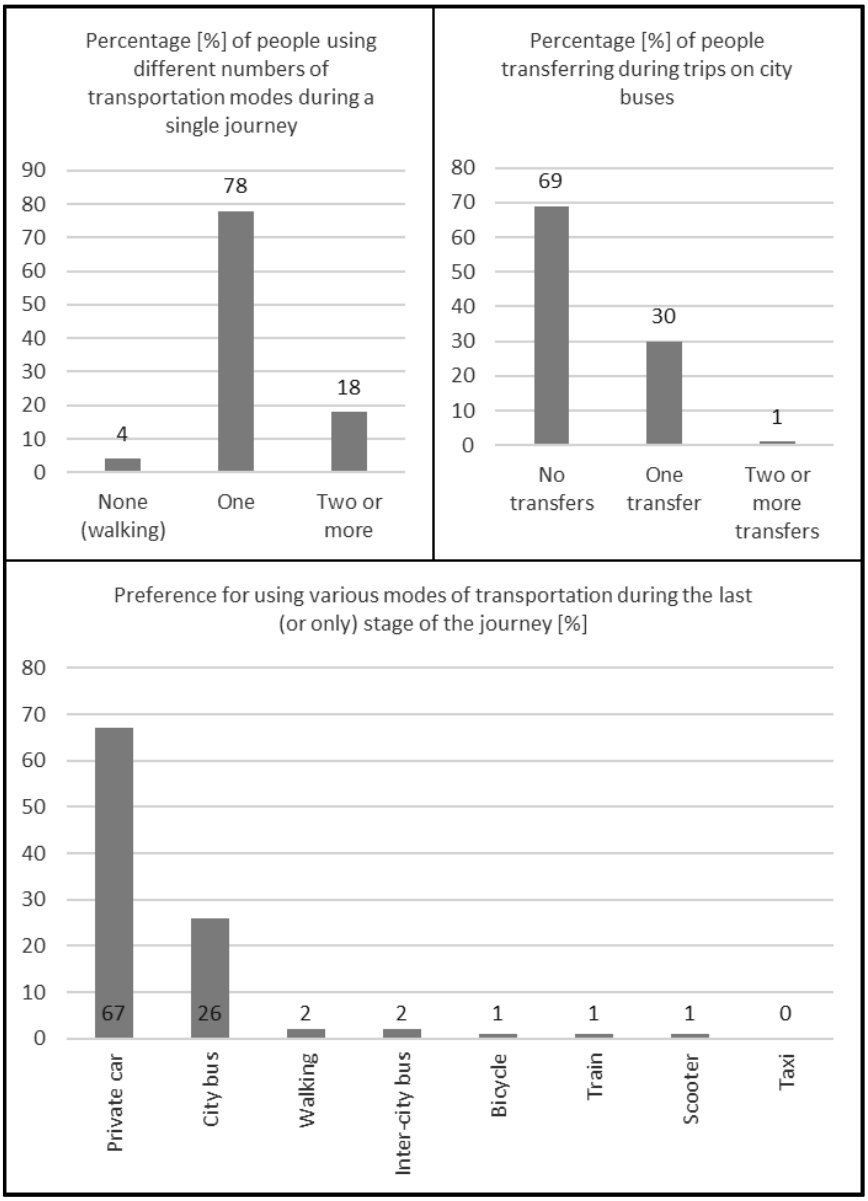

Fig. 2. The number and types of transportation modes used for commuting to workplaces and educational institutions in the Bielsko-Biała agglomeration

The analysis of geospatial data, including public transportation maps and transportation infrastructure, as well as the assessment of the interoperability of urban transportation hubs, has allowed for pinpointing locations in the transportation system of Bielsko-Biała that, in the context of survey results, could contribute to an increased share of rail transportation in regional commuting. Table 3 provides the dimensions of the integration of the transportation network in Bielsko-Biała.

Fig. 3 illustrates the so-called "transfer accessibility." This indicator measures whether railway stations and stations of different modes of transportation are close to each other. In Fig. 3, the nodes represent railway stations, and the shade of color indicates the number of bus stops near a given railway station. The maximum acceptable transfer distance, as derived from the survey conducted as part of the research related to the article's topic and mobility plans, is set at 750 meters between the station and the bus stop.

The analysis of geospatial data in the context of the plans outlined in the SUMP for the Bielsko agglomeration shows that the proposed locations significantly enhance the integration of the urban

transportation system. The average number of available bus stops is 36% higher than for stops that will be eliminated and 67% higher than for stations that will continue to operate.

Table 3

Numbers indicating the level of integration of railway stations with the transport system in Bielsko-Biała

Station status	**Railway station**	**Number of bus stops within 750 meters of the railway station**	**Number of POIs within 750 meters of the railway station**
Existing stations	Bielsko-Biała Komorowice	5	2
	Bielsko-Biała Północ	7	5
	Bielsko-Biała Główna	8	32
	Bielsko-Biała Lipnik	6	34
	Bielsko-Biała Leszczyny	7	17
	Bielsko-Biała Mikuszowice	4	5
	Bielsko-Biała Wschód	6	6
	Krzemionki	1	1
Stations on a suspended line	Bielsko-Biała Zachód	8	11
	Bielsko-Biała Górne	9	13
	Bielsko-Biała Aleksandrowice	6	10
	Bielsko-Biała Wapienica	4	11
Planned stops and stations in the SUMP	Bielsko-Biała Teatr	12	42
	Bielsko-Biała Gemini Park	7	23
	Bielsko-Biała Listopadowa	11	22
	Bielsko-Biała os. Polskich Skrzydeł	7	12
	Bielsko-Biała Stare Bielsko	8	14
	Bielsko-Biała Zachód (new location)	10	16

Based on the present research, it can also be noted that the proposed infrastructure of stops and railway stations is better integrated with points of public interest (POIs). In Polish legislation, buildings of public utility have a statutory definition. According to the Regulation of the Minister of Infrastructure of April 12, 2002, on the technical conditions that buildings and their location should meet, a POI is understood as a building intended for the following purposes [21]:

1. Public administration
2. Justice
3. Culture
4. Religious worship
5. Education, higher education, science, and upbringing
6. Healthcare, social care, or social services
7. Banking services
8. Trade
9. Catering
10. Services, including postal or telecommunications services
11. Tourism and sports

Fig. 4 shows that the planned railway stations enable a more efficient transfer to the so-called Points of Public Interest. In the case of newly designed stations, this difference is as much as 72%, meaning that the number of POIs accessible from the newly designed stations is 72% higher than from traditional stations.

The stations identified in the SUMP for elimination or relocation serve, on average, about 50% fewer POIs than the planned stations and approximately 10% fewer than traditional stations. It is evident that the selected locations presented in the mobility plan for the Bielsko-Biala metropolitan area confirm

the hypothesis that the SUMP project for the city promotes the integration of the city's transportation system.

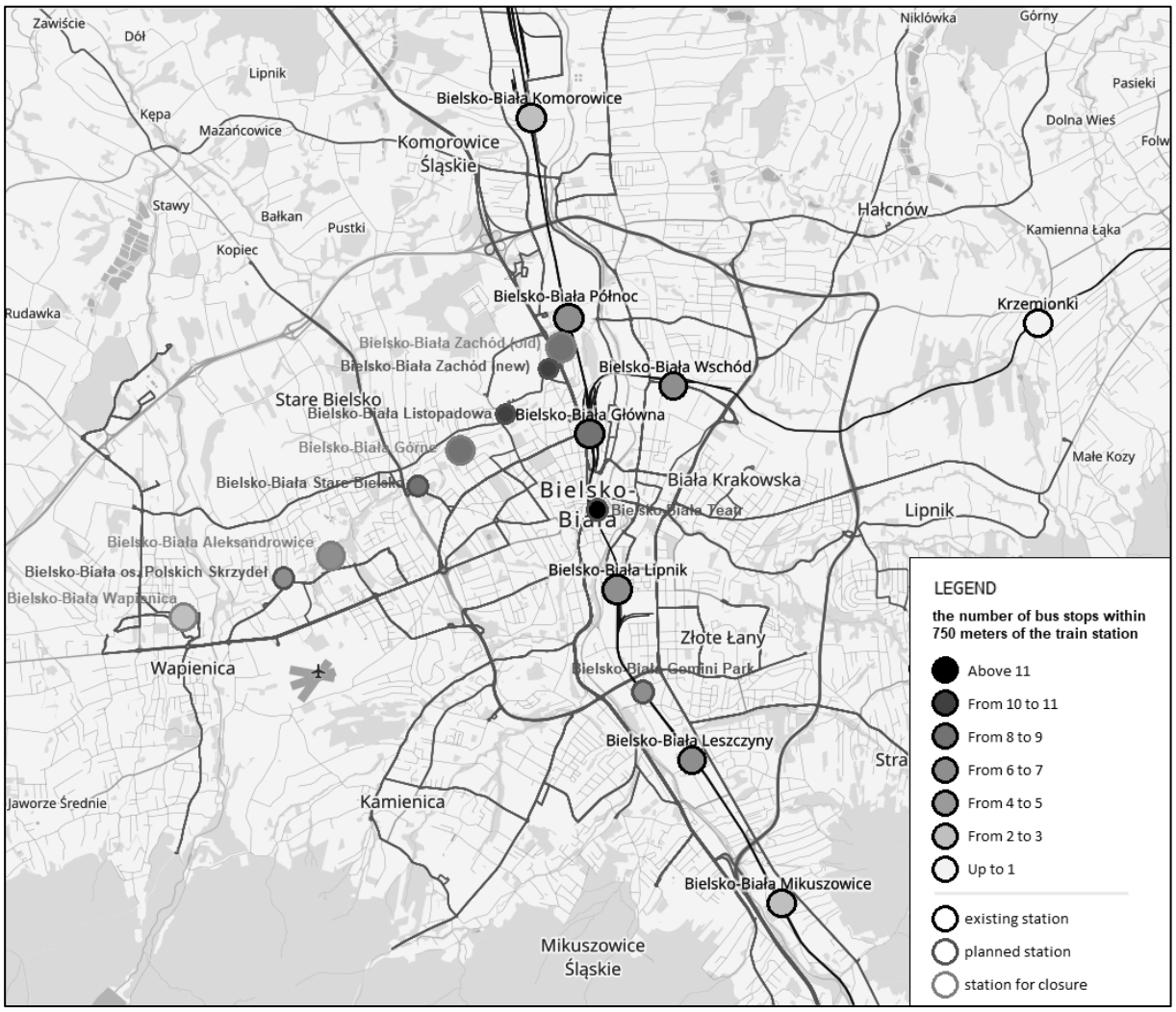

Fig. 3. Number of bus stops within 750 meters of a railway station

7. CONCLUSIONS

Research related to transport demand management has been ongoing for over 30 years. Nevertheless, transport practitioners and theoreticians have failed to establish a single and clear scientific standard for the definition and practical application of mobility management. This is an important issue, as a uniform characterization of the underlying concepts plays an important role in the quantification and evaluation of mobility management measures and in providing transport demand management policies and planning with the necessary scientific basis for systematic application.

Within this context, trends of strong economic orientation in the operational applications of mobility management can be observed. It seems that in the near future, it will be crucial for transport demand management research to develop a common internal and external understanding of mobility management. Only in this way can the social-added value of Mobility Management in relation to specific interests be guaranteed.

Urban transport systems are very diverse. Regardless of the differences, however, they are the basis for economic development and the social participation that accompanies it. Transport policymakers are

increasingly pushing the limits of what can be changed in transport systems due to a limited set of instruments. More and more often, the transport policy tools are decisions limiting car traffic and traffic calming measures. In addition, the financing of infrastructure is at risk, as it is not able to guarantee the maintenance of the appropriate quality of transport, and many roads have long exceeded their planned capacities.

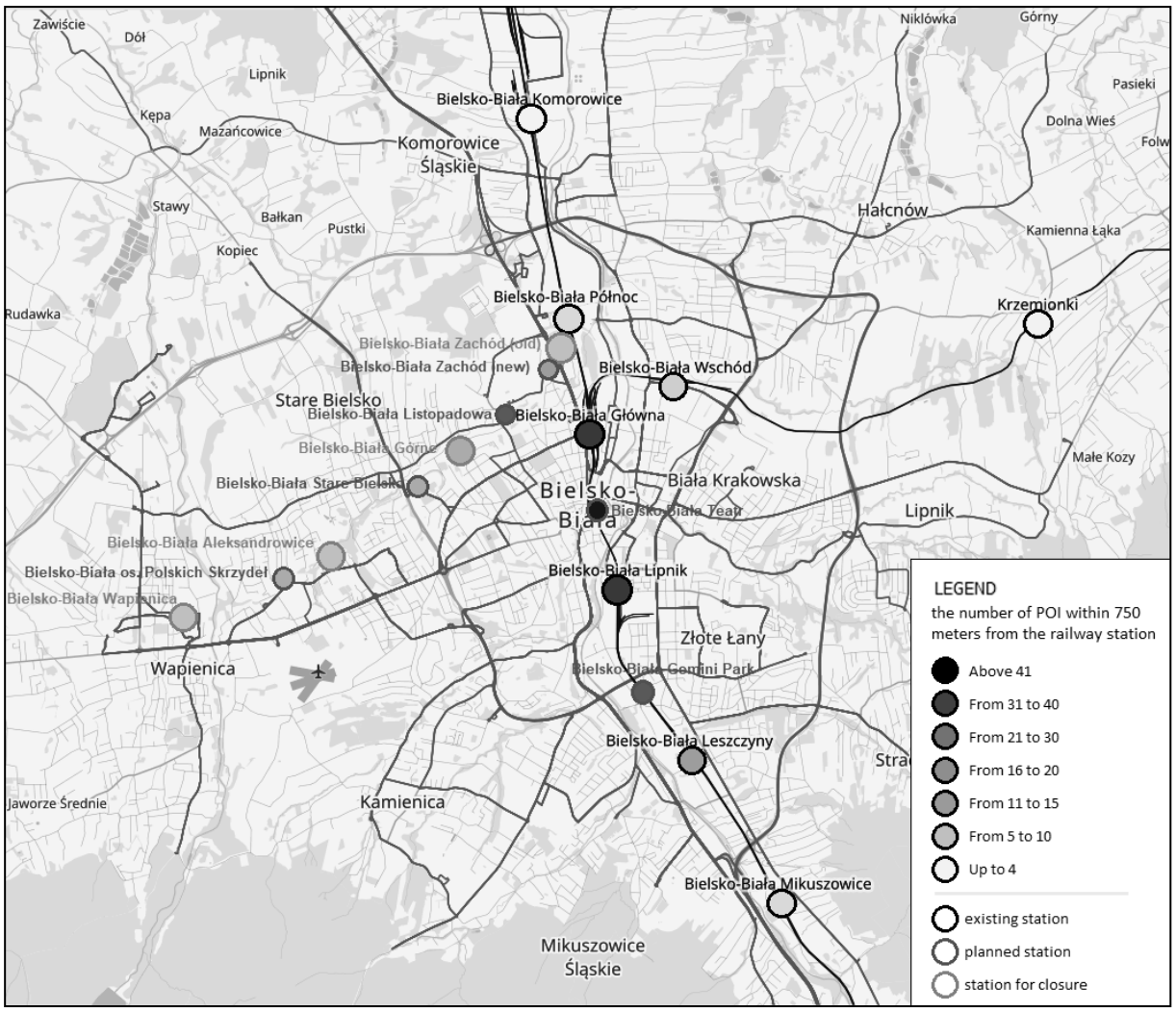

Fig. 4. Number of POIs within 750 meters of a railway station

So far, there has been no coherent overall concept that would cover all the problems and difficulties mentioned. Many cities are on the threshold of a decision to introduce motor vehicle bans, especially in central parts. In order to maintain the foundations of urban development and its quality in the future and to guarantee the participation of all city entities in social life, it seems necessary to introduce innovations related to transport demand management. It is about understanding the causes of traffic development, not controlling the physical flows.

The results presented in this article demonstrate that the policy integration assumptions adopted within the SUMP for the Beskid Agglomeration should contribute to improving the intermodal efficiency of transportation and enhancing the accessibility of travel destinations, including points of public utility.

This work can be further enhanced in the future in a couple of ways. Firstly, an analysis can be conducted concerning the integration of the public transportation system in relation to the needs of

individuals with disabilities or older adults. Secondly, there is room to analyze schedule synchronization and payment system integration.

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