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Innovative Solutions for the Development of Sustainable Transport and Improvement of the Tourist Accessibility of Peripheral Areas: The Case of the Białowieża Forest Region

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Abstract: One of the main challenges affecting development opportunities of peripheral areas, particularly the development of tourism, includes the provision of satisfactory solutions for mobility and transport accessibility. Therefore, there is a high demand for innovative and sustainable transport solutions, which would increase the competitiveness of these regions, as well as reduce the negative impact of transport on the environment. This paper includes indications of the main directions of research on sustainable transport, the analysis of innovative solutions for improving the tourist accessibility of peripheral areas, and the development of an intermodal model of tourist mobility. The developed model was verified in terms of tourists' needs for sustainable and innovative transport solutions. The region of the Białowieża Forest, exhibiting high potential for tourism development due to its natural values—unique at the European and global scale—was selected for verification. The Białowieża Forest was inscribed on the UNESCO World Heritage List as one of the few cross-border World Heritage sites. The study applied heuristic research methods, including brainstorming, the Delphi method, case studies, and a diagnostic survey (421 respondents). The developed model of tourist mobility is based on the combination of the public transport network and the availability of electric bicycle and electric car rental. The survey of tourists in the region of the Białowieża Forest showed the demand for new mobile solutions, particularly in the field of e-mobility. The results of quantitative research indicate that around 40% of respondents express high and very high demand for sustainable and innovative mobile solutions, including e-mobility.

Keywords: innovation; sustainable transport; mobility; tourist accessibility; peripheral area



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1. Introduction

Due to demographic changes, progressive problems of transport accessibility in peripheral regions constitute a significant issue in terms of management of such regions. Solutions to these problems are sought in innovative and intermodal concepts, consistent with sustainable development. They include departing from public transport in favour of individualised transport solutions. The research problem concerns innovative solutions for tourist accessibility to remote and affected areas in light of the sustainable development concept.

The main objective is to identify innovative sustainable transport solutions in order to improve the mobility and tourist accessibility of peripheral areas, develop an intermodal model of tourist mobility in the region of the Białowieża Forest, as well as to assess/identify tourists' needs for sustainable and innovative transport solutions in this region. Located in north-east Poland, the region of the Białowieża Forest is a unique natural area attractive for tourists and inscribed on the UNESCO World Heritage List as one of the few cross-border World Heritage sites. However, the region has significant problems with transport mobility and accessibility, concerning both residents and tourists. As a result, there is a need to

develop innovative solutions in the field of mobility oriented towards the sustainable development of transport, and adaptable to the conditions of other peripheral regions.

The study was conducted as part of the “MARA—Mobility and Accessibility in Rural Areas—New approaches for developing mobility concepts in remote areas” project, financed by the Interreg Baltic Sea Region Programme 2014–2020 (Priority 3 “Sustainable transport”). The concept of sustainable transport prioritizes, among others, the improvement of the accessibility of peripheral areas affected by demographic changes and located far from major urban, administrative, and economic centres.

2. Sustainable Development of Transport for the Improvement of Mobility and Tourist Accessibility of Peripheral Areas

2.1. Nature and Outline of the Sustainable Transport Concept

The efficient operation of the transport system is a prerequisite for the development of every region. Transport makes it possible to carry out many important functions and affects the quality of residents’ lives. It primarily ensures a high level of their mobility, as well as satisfying their needs related to work, education, culture and recreation. In addition, it significantly affects the development of regional tourism by influencing tourist accessibility.

In light of contemporary challenges and global problems, which primarily involve peripheral and remote areas, the development of transport should strive for sustainability. The idea of sustainable transport is derived from the concept of sustainable development, which has long been one of the main objectives of EU policy. Transport has a significant impact on sustainable development. As Rucińska [1] notes, this sector, on the one hand, constitutes the basis for the economic development of regions and their competitiveness (by providing mobility, along with constantly increasing efficiency in terms of speed, comfort, safety, and accessibility of travel) and, on the other hand, highly contributes to environmental degradation (e.g., through air, water, and soil pollution; traffic noise; and limiting the acreage of land for infrastructural investments) [2].

The literature features various approaches to the concept of sustainable transport, including narrow and broad ones. The narrow approach to sustainable transport is based on environmental aspects and refers mainly to such means of transport that minimise the emission of carbon dioxide and other pollutants [3]. In a broad sense, sustainable transport (often used as sustainable development of transport) is treated in the convention of integrated governance, which indicates that the development of transport should simultaneously involve economic, social, and environmental criteria [2,4,5]. The dimensions of sustainable transport with regard to these criteria [5] are presented in Table 1. The present work has assumed a broad definition of sustainable transport as the process of changes aimed at balancing environmental, social, as well as economic goals and criteria. In the economic dimension, it is primarily directed at improving the economic efficiency of transport; in the social dimension, it is directed at increasing mobility, accessibility, and the quality and safety of transport; while in the environmental dimension it is directed at reducing pollution (limiting gas emissions, noise, waste) and decreasing the use of non-renewable resources. As has been noticed by Litman and Burwell [6], the narrow definition of sustainable transport usually favours individual technological solutions while the broad one prefers more integrated resolutions including better options for travel, economic incentives, institutional reforms, changes in land use, as well as technological innovations.

Motowidlak [2] indicates that the concept of sustainable transport development is a planning notion, which is a long-term, integrated action plan aimed at achieving strategic sustainability goals. In the economic dimension, it focuses primarily on improving the economic efficiency of transport; in the social dimension it focuses on increasing mobility, accessibility, and the quality and safety of transport; while in the environmental dimension it focuses on reducing pollution (limiting gas emissions, noise, waste) and decreasing the use of non-renewable resources. Efficient transport is based on the integration of all its forms, while the integrating measures must involve not only the infrastructure but also the system of transport management [7].

Table 1. Dimensions of the sustainable development of transport.

Sustainability		
Social Dimension	Economic Dimension	Environmental Dimension
<ul style="list-style-type: none"> • Mobility • Accessibility • Fluidity • Safety • Social cohesion • Transport system integrity 	<ul style="list-style-type: none"> • Competitiveness • Working conditions in the sector • Infrastructure (development, modernisation, investments, transport network capacity, quantity, and quality) • Intermodality 	<ul style="list-style-type: none"> • Environmental friendliness of transport (minimising its impact on the environment) • Counteracting and eliminating the effects of transport-related environmental threats

Within subject-related literature, as has been noted by Borys [5], sustainable transport may be founded on weak sustainability standards via the realization of the weak principle of resilience recognizing the substitution of capitals (this type of sustainability allows, for example, compensating for the negative environmental effects of transport through the reduction of pollution in other fields), and hard sustainability standards via the realization of the strong principle of resilience, which puts greater emphasis on the reduction of negative effects of transport and recognizes complementarity of capitals. Present deliberations accept the aspects of strong sustainability.

The implementation of the principles of sustainable transport development requires a continuous improvement of the applied solutions and actions mainly using a wide range of economic, technological, legislative, organisational, marketing, and educational instruments [4]. According to Scuttari and Isetti [8], the transition to sustainable and integrated transport should primarily involve the management of public transport, modifications to mobility patterns (preference for pro-environmental solutions, shifting part of the demand from cars to other modes of transport), as well as the management of e-mobility. Supporting innovation and implementing new technologies will play a major role in this process. In the transport policy of the European Union, new technologies in terms of vehicles and transport management are considered key factors in reducing transport emissions [9].

An important action for the sustainable development of transport will consist of the development and promotion of pro-environmental means of transport, allowing mobility to be changed [10], the promotion of multimodality, as well as encouraging residents to limit the use of passenger cars and seek alternatives to the use of individual transport in everyday travel (e.g., through car-sharing). Optimising the use of various means of transport and creating conditions for sustainable mobility, including co-modality, constitute a significant challenge for the sustainable development of transport in European Union countries. As Kłos-Adamkiewicz [10] indicates, the combination of sustainability and mobility is a way to achieve an efficient transport system, as well as the freedom of choice in terms of means of transport for passengers, at the same time as being environmentally friendly.

In recent years, the issue of sustainable transport has been more frequently addressed in scientific research. A detailed review of the studies on sustainable transport between 2000–2019 conducted by Zhao et al. [11] made it possible to identify nine hot research topics in this area: sustainable transport indicators and performance model [12,13], sustainable transport policy [14], involvement of stakeholders [15], supply chain and logistics management, environmental impact, travel behaviour, new fuels for vehicles, transport strategic planning [16,17], and bicycles and public transport (Figure 1). The studies have also indicated the main research gaps on sustainable transport relating to its social sustainability, use of information and communication technology (ICT), sustainability benefits, and its resiliency [11].

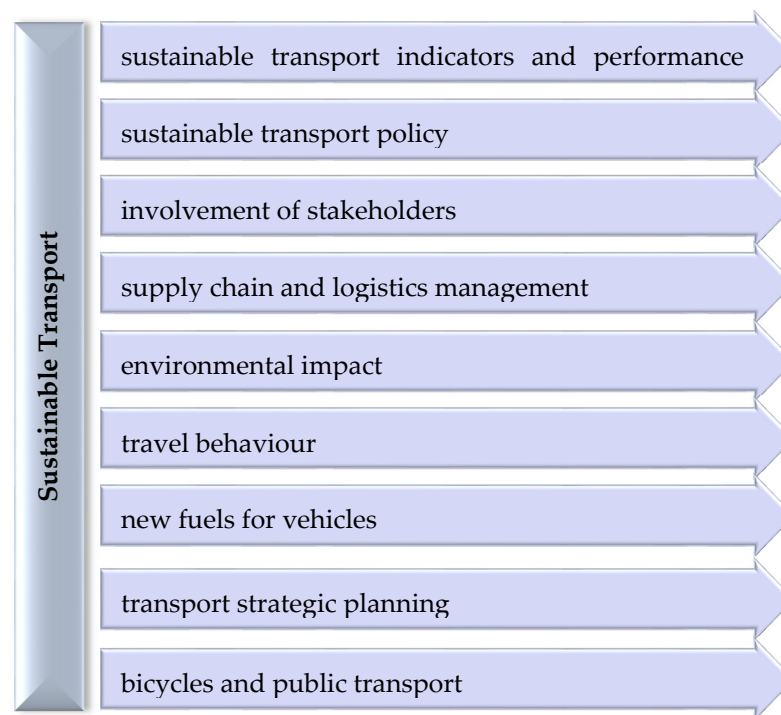


Figure 1. Directions of research on sustainable transport, according to [10].

A bibliometric analysis of studies dealing with sustainable transport infrastructure concerning economic benefits (such as rise in employment, profits, and economic growth) has been conducted by Badassa, Sun, and Qiao [18]. They have shown that studies within this sphere concern mainly sustainable public transport and new paradigms of mobility, a methodological framework for sustainable and comprehensive transport indicators (such as identification, selection, and management of sustainable transport indicators), as well as the impact of transport on climactic changes.

The literature review shows that the growing interest in the environment and sustainable development has highlighted the necessity to adopt a wide perspective when searching for transport solutions, particularly the need for broad stakeholder involvement in the process of sustainable transport planning, as well as in the support of decisions on transport initiatives [6,15,19]. A particularly significant aspect of research on sustainable transport constitutes the issue of innovation, which serves the objectives of mobility and environmental protection by increasing the efficiency and sustainability of transport. Analysing the role of innovation with reference to sustainable tourist transport, Hopkins [20] indicates several crucial and interrelated topics that set directions of research on transport and mobility: dominant mobility systems, the sustainable mobility paradigm, and mobility justice. In addition, he points to the need for new directions of research in the field of sustainable tourism and transport, capable of accelerating the transformation towards tourism and transport sustainability. It is also necessary to promote good practices and projects aimed at the implementation of sustainable development principles in transport. According to a study conducted by Sztangret [21], key dimensions of sustainable transport development include electromobility, improved urban traffic, and intelligent transportation systems (ITS), as well as transport optimisation and intermodality. A review of studies dealing with the utilisation of information and communication technologies in transport, especially intelligent transport systems for the facilitation of sustainable mobility, has been presented in the research of Janelle and Gillespie [22].

2.2. Innovations for the Development of Sustainable Transport

The development of the concept of sustainable transport initiated broad and innovative actions to support and promote sustainable transport and smart mobility. Smart mobility may be generally defined as a category of new means of personal transport, using ICT applications for safe, convenient, and economic mobility adapted to people's needs [23]. According to Santos [24], shared mobility is characterized by the sharing of a vehicle instead of ownership as well as the utilisation of technology to connect users and suppliers.

Shibayama and Emberger collected and presented an extensive overview of innovative solutions typical of sustainable transport [25]. They described several possibilities involving sharing a car and a bicycle, as well as a scooter and a motorcycle.

Sharing a vehicle refers to the renting of a car by one person for a certain period. Car rental are made via the Internet and a smart card is used as a key to open the car [26]. Since 2010, the system has been evolving and it is now also available as car-sharing: free-floating, in which cars are not required to stay at designated stations because the IT system locates available vehicles via GPI, transmits location data via mobile data networks, and displays the information on an online map. Users reserve the vehicle closest to them by using a geolocation application installed on their smartphones [27]. Another solution is the bla-bla-car carpooling system, which is based on the shared use of a car by several people at the same time throughout the journey, or the so-called slugging or casual carpooling, which is a spontaneous organisation of shared rides. In Poland, this system is popular as a form of taking regular or cyclical trips to work and is rather informal. Demand-responsive transport (DRT) is a form of sharing a trip using small or medium-sized vehicles. At the beginning, this system was present solely in cities and was used for work commutes [28]. Over time, the system began to be used by the elderly in rural areas [29]. Currently, DRT operates in both urban and rural areas and is adapted to the preferences of all passengers [30]. The system involves an operator who receives an order for a ride electronically or by phone, specifying the day and time of the trip, as well as the station/place of departure and destination. DRT services depend on the carrier and appear in the form of door-to-door services or services offered between predefined points, e.g., bus stops or road crossings [25]. The research on car-sharing indicated that such services may function as services of alternative sustainable transport [31]. They are positively correlated with increased travel activity, e.g., cycling and walking [32], and they contribute to the reduction of CO₂ emissions [33]. Car-sharing is becoming increasingly popular and is expected to initiate transport system changes [34–36].

Recently, the introduction of an electric car-sharing service has been an important solution significantly reducing the negative impact of car exhaust fumes on the environment. However, as Gawlik's research [37] indicates, the implementation of such vehicles in the city involves high costs, primarily including the price of building a single charging station, which varies from EUR 56,500 to EUR 126,500 and is largely dependent on the cost of the station terminal, as well as the length of the power cable. Additionally, Brandstätter et al. [38] analyse several problems related to the optimisation of the docking station's location, along with the vehicle charging system. They focus on the short range of electric cars (175 km) and their long charging time. Despite technological advances, the range and speed of charging electric vehicles remain somewhat limited [39]. For instance, a smart electric drive (ED) has a range of only about 145 km and takes one hour to fully charge, even with fast 22 kW charging infrastructure [38]. Similarly, the Mitsubishi iMiEV and Nissan LEAF, both with a range of about 160 km, require approximately 30 min for their batteries to charge 80% [38]. The latest solution, tested since 2016 in Paris [40] and other places, is based on self-driving (autonomous) vehicles. Self-driving vehicles use technologies from different networks, such as detection technologies, artificial intelligence, geolocation, vehicle-to-everything (V2X) communication, reliability engineering, and machine interface [41]. As indicated by Conner-Simons et al. [42], IT technologies applied in self-driving vehicles, such as technologies for monitoring vehicle environment, including

radar, lidar (detection of light and its range), computer vision, and various position and location sensors, such as accelerometers, gyroscopes, GPS, and odometers, will allow for high geolocation accuracy while advanced control systems will use the sensory information obtained from them. For navigation, geolocation-based automation will also be based on detailed 3D digital maps with exact locations of relevant objects on roads, such as lanes, curbs, and road signs. Autonomous vehicles are expected to support vehicle sharing without the need for individuals to own vehicles. However, research conducted in Germany in 2015 showed that owning a car is extremely popular among the younger generation. Among the respondents, 83% of Germans drove their own car, while 17% used a family car, and only 1% used rental or car-sharing services. In the USA, the results concerning car-sharing showed that 94% of the survey respondents drove their own car, 5% used a family car, and 1% used rental or car-sharing services. Self-driving vehicles provide an opportunity to redefine individual mobility because they create more possibilities for reciprocal car sharing (e.g., ridesharing or carpooling) [43].

The second solution to mobility problems is to share motorless vehicles such as bicycles or scooters. Station-based bicycle-sharing systems (BSSs) proved to be an alternative to individual car journeys, complementing public transport [44], and are considered a cheap and sustainable solution providing fast connections between the major transport hubs when, e.g., commuting to work or taking trips for tourism activities [45].

The modern model of sharing these means of transport is based on the use of communication and information technology (CIT) [46]. Bikes are installed at bicycle base stations and have GPS tracking devices, while users register to the system and provide payment information. The reaction to the existing problems of bicycle availability at bicycle stations at rush hours [47] was the introduction of bicycle-sharing services that were free-floating. This change was made possible by the introduction of electronic security locks and QR codes with which the lock is opened. Motorless vehicles are not the only ones that can be shared. Other vehicles of this type include electric vehicles: electric bikes, electric scooters, Segways, and motor scooters. In the case of electrically propelled vehicles, it is necessary to bring them back to the station for recharging purposes.

Changes in the mobility system took place not only in connection with new forms of transport use (forms already known in other industries) but also in connection with the use of new IT solutions based on applications. An important mobility solution was the introduction of online travel planners which contain advanced database systems and timetables that allow people to prepare a journey route using intermodal connections. The latest form of this solution is the implementation of Mobility as a Service (MaaS): a service that integrates different forms of transport services into one mobility of services available on demand. It is used to prepare a journey route using a single application and allows individuals to pay for the service via one payment system, integrating all mobile services [25]. Moreover, as part of the TEAM project (Tomorrow's Elastic, Adaptive Mobility), a system of eleven integrated mobile applications, which support various traffic types, travel problems, and scenarios, was developed. This application facilitates both cooperation among users (passengers) who drive vehicles and the management system [42,48]. The use of IT technology made it possible to implement an intermodal service system in Munich. This system provides information on the availability of bicycle-sharing and car-sharing services at major transport hubs to reduce travel time [49]. Research by Davidsson et al. has revealed a positive influence of the Internet of Things (IoT) on the development of both transport systems and intermodal ones from the traveller's point of view and in terms of their positive environmental impact [50].

The literature review shows that innovative sustainable mobility solutions are implemented in the vast majority of urban areas and are an attempt made by metropolitan authorities to combat urban smog. According to S. Porru et al. (2020) [51], only three out of the ten most important pilot initiatives of smart mobility funded by the European Union budget (MARA, RAMZES, and SMARTA) concerned solutions in peripheral areas. The separability criterion for these initiatives was a grant of more than one million euros, which

means that such projects differ from other small smart mobility initiatives. The MARA project [51] resulted in the development of the GetThere application, which integrates data from various sources, including from users. This application makes it possible to display scheduled and actual bus locations for a selected route, co-create bus locations during travelling, report traffic problems, and evaluate journey quality in real time. Besides, the partners of this project [51] explored the possibilities of combining social media with existing open data sets to obtain real-time information about passengers' needs in rural areas. Rural mobility 2.0 [52] was the subject of research as part of the RAMZES project. The result of the project was the development of an on-the-go digital platform that includes on-demand, peer-to-peer, scheduled, and non-scheduled services in rural areas. SMARTA is a project commissioned by the Directorate-General for SMARTA. It investigated the impact of existing policies on solving mobility problems in European rural areas. The result of the project was the implementation of joint mobility services in two locations using innovative digital solutions.

Other initiatives undertaken on a smaller scale in rural areas include Lopez-Iglesias et al.'s studies concerning scenario planning for the development of mobility policy in rural areas [53].

The already implemented initiatives for the introduction of smart mobility in remote and rural areas include a DRT service in north Britain known as a phone and go (travel-on-demand) service, which is used to serve disadvantaged groups such as people with mobility impairments and the elderly, also being an addition to regular bus services at weekends and at night. It is also used to support public transport in rural areas [50]. Similar initiatives are being implemented in rural regions of the north Rhine-Westphalia [54] and the Heinsberg County in Germany [55].

The key to improving transport accessibility in remote areas is the presence of three components: financial resources, cooperation with stakeholders, and flexible scheduled or on-demand transport [56].

2.3. Problems with Tourist Accessibility of Peripheral Areas on the Example of the Białowieża Forest Region

Major problems of peripheral areas include ongoing differences in the economic potential of individual regions. The nature of inter-regional differences leads to the distinction between central regions and peripheral ones in the spatial structure [57]. Peripherality means a state of underdevelopment in relation to central regions, thus peripheries are considered to "stand out", having less importance and negative associations [58]. Highly developed regions are centres of some sort that offer many business opportunities, whereas underdeveloped regions are not successful on the market and become peripheral. Therefore, the concepts of "centre" and "periphery" tell a story about the different levels of socio-economic development in particular regions [59].

In economic literature, the peripherality of regions may be of a different nature [60]:

- spatial: poor transport accessibility resulting from an unfavourable geographical location, low technical infrastructure quality, high transport costs, and remoteness from economic centres are mentioned here. In this respect, peripheral regions are associated with border regions [61];
- non-spatial: poorly developed infrastructure of information society, low qualifications of human capital, fragmented connections of the small and medium-sized enterprise sector, underdeveloped social capital, poorly developed networks of institutions, and poor connections with the global environment are mentioned here;
- economic: in the European Union's cohesion policy, the criterion of economic peripherality of regions is a low level of economic development measured by the level of GDP per capita. Regions that do not reach 75% of mean GDP per capita in the EU are classified as peripheral ones. The literature also specifies that regions with a low level of economic development are characterised by a traditional economic structure, a poor production structure [62], significant employment in the primary sectors, spe-

cialisation in raw materials with low added value, low levels of entrepreneurship, export of labour resources, import of final products, or an insufficiently developed R&D (research and development) sector [61]. The economic dependence of peripheral regions on both economic and political centres is also highlighted [63];

- socio-demographic: low level of population density, poor urbanisation, depopulation processes, and the deformation of demographic structures or quality of human and social capital are mentioned here;
- cultural: expressed by a low sense of regional identity, imitation, and adaptation of cultural patterns from outside the region;
- political and administrative: expressed by a poor political representation in the centre, lack of power elites, limited competences of regional authorities, and the low financial potential of public authorities [61].

Peripheral regions, located far from centres, cover half of the European territory and are inhabited by 20% of the population. They are characterised by undesirable demographic shifts, which mainly result from an uneven distribution of economic resources and difficult access to social services, educational and cultural facilities, or tourist attractions. These processes affect restrictions on the mobility of local people and tourists.

One of the peripheral regions in Poland, which is of international importance, is the Białowieża Forest region. It is one of the most valuable natural sites—unique in Europe and the world—included on the UNESCO List of World Heritage Sites (one of seven in the world and one of the three European cross-border World Heritage sites) [64,65]. The region of the Białowieża Forest in Poland occupies a total of 1624 km² and has a population of 44,957 inhabitants. Unique natural values of the region, especially those preserved in the form of the Białowieża National Park, are the basis for the development of the region's tourism economy. The development of tourism is determined by, among other things, transport accessibility, which is insufficient in this case. Transport accessibility difficulties are due to:

- the geopolitical location of the Białowieża Forest region (on the eastern border of the European Union), resulting in it being far from transportation routes connecting main centres of the country;
- the low percentage of local road density. The length of hardened surfaces is 39.5 km per 1 km². This is much less than the analogous indicators for the Podlaskie voivodeship (65.1 km per 1 km²) and the entirety of Poland (94.1 km per 1 km²);
- high forest cover, which accounts for 50.6% of the region;
- a low population density of 27 persons per 1 km² vs 124 persons per 1 km² in Poland [66].

The main problems with mobility and transport availability of the Białowieża Forest region include [67]:

- poor quality of road infrastructure;
- poor connection with other regions of Poland through public transport (lack of a developed offer of direct long-distance connections);
- low accessibility in terms of individual motorisation (low motorisation rate, low expenditures on road maintenance, long distances from a network of expressways and motorways);
- marginal role of rail transport (low density of railways and poor offer of passenger connections);
- poor offer of public road transport (insufficient network of bus connections, large disproportions within the frequency of buses at specific routes, insufficient numbers of direct connections);
- a lack of or insufficient integration of transport systems (connections between trains and buses), which leads to longer waiting times for transfers;

- the insufficient development of cycling infrastructure (poor number of marked bicycle routes, bicycle parking shelters, self-service bicycle repair stations, and a lack of self-service bicycle rentals, including electric bicycles);
- an unsatisfactory system of publishing timetables by road carriers on websites (lack of Internet service within a local range that ensures uniform publication of collective timetables of all carriers, and outdated or incomplete data), which restricts travel planning for tourists.

At present, four road transport companies provide transport services in the region. Two of them provide connections to the capital of the voivodeship, while the remaining two primarily provide local connections. However, there are big differences in the frequency of bus services on particular routes. Most of the bus routes are available on weekdays or only on school days. This organisation of services causes this part of the region to have no transport not only on weekends but even on school days. What is more, there are towns where there is no public transport at all. This is the biggest shortage of public road transport in this part of the country. An alternative to motorised transport is cycling using the numerous bicycle paths in the region. They connect communes and lead to places attractive to tourists. There are 14 bicycle paths in the Hajnówka County with a length of over 500 km. Four of them are loops, one (58 km long) runs through Poland and Belarus, passing through the border crossing for pedestrians and cyclists in Białowieża [68].

Local transport and the transport of tourists are, therefore, characterised by the dispersion of transportation routes and the need to ensure appropriate environmental protection. The region includes rural areas where the means of transport are not sufficiently developed, but the need to be able to travel in these specially protected areas is still considerable. Therefore, the transport network should be organised so that the environmental footprint is minimised and the demand for transport services is met [69].

3. Materials and Methods

Expert and diagnostic survey methods were used in the study. The expert method was based on a foresight diamond model developed by Popper [70]. The model includes four dimensions: creativity, expert knowledge, interaction, and facts [70], which are believed to solve a problem situation when there is insufficient information as a result of developing new solutions aimed at achieving effective innovation for economic, social, and political changes [71]. They are based on the use of codified knowledge (theoretical and empirical) of the experts participating in the survey, but also allow for the use of tacit knowledge, i.e., intuition and imagination. In this study, the following dimensions were included:

- creativity: a set of methods using thinking and creativity was applied using brainstorming;
- facts: a set of methods that allows the current state of the research area to be understood was applied using the following methods: reality structure, literature analysis, and method of key technologies;
- expert knowledge: a set of methods using the skills and knowledge of experts; this knowledge was acquired using the method of the panel of experts;
- interaction: a set of methods consisting of building new knowledge, visions of development, innovative forms of solutions was applied using the workshop method.

In the research procedure for the selection of an innovative mobility solution in the area of the Białowieża Forest, the following activities were distinguished:

- formulation of a research problem, i.e., solving mobility problems in peripheral areas and discussing them during brainstorming to identify the most probable concepts to solve the research problem;
- gathering information concerning innovative mobility solutions consistent with the concept of sustainable development using methods such as an analysis of reality structure, literature analysis, and the method of key technologies;

- presentation of four developed concepts for an innovative solution to mobility problems in peripheral areas, which is consistent with the concept of sustainable development, and selection of the best solution using the workshop method;
- evaluation of the concept of an innovative intermodal model for solving mobility problems in peripheral areas, which is consistent with the concept of sustainable development and implementation recommendation using a panel of independent experts.

A team of experts (14 researchers) was invited to develop the concept of an innovative intermodal model for solving mobility problems in peripheral areas, which is consistent with the concept of sustainable development (first three research steps). To reflect multidimensionality [72], the selection of experts was based on the principle of triangulation [73], i.e., on three differentiation criteria: generational group, scientific experience, and practical knowledge (Table 2). The study was conducted from November 2017 to March 2018. The work of the workshop group resulted in the recommendation of the most innovative and economically effective scenario for solving mobility problems.

Table 2. List of criteria differentiating experts.

No.	Differentiation Criterion	Number of Experts
1	Generational group:	
	Baby boomers (born before 1965)	5
	Generation X (born between 1965 and 1981)	5
	Generation Y or digital natives (born before 1981)	4
2	Academic title:	
	Professor/independent employee	4
	Dr	6
	MA, BA	4
3	Practical knowledge	
	1–4 years	4
	4–10 years	3
	over 10 years	7

The evaluation of both the concept and the implementation recommendation was carried out on 20 March 2018 in Berlin. A team of 12 independent international experts, including 5 representatives of science from scientific centres (Białystok University of Technology (Poland), University of Dalarna in Sweden (Sweden), University of Tartu (Estonia) and Finnish Environment Institute SYKE (Finland)) and 7 representatives of the management sector responsible for the planning, organisation, and dealing with transport issues (Ministry of Energy, Infrastructure, and Digitalization (Germany), Hajnówka County Office (Poland), Latvian Vidzeme Planning Region (Latvia), Norwegian Setesdal Regional Council (Norway), Swedish Transport Administration “Trafikverket” of Dalarna (Sweden)) were familiarised with the idea of an innovative intermodal model to solve mobility problems in peripheral areas, which is consistent with the concept of sustainable development.

The diagnostic survey method was used to verify the acceptability of the implementation of an innovative solution to solve mobility problems. The verification was conducted on a representative group of 421 tourists spending their holidays in the Białowieża Forest region. Pilot studies were conducted in August, while basic research was conducted in September and October 2019. The research tool was a questionnaire, while the research technique was a face-to-face interview. Then the interviewers entered the survey results into an electronic version of the survey. The results were analysed using Statistica.

The tourist profile of the respondents was analysed using the percentage of the responses. The assessment of mobility improvement in the region was analysed using a weighted average assessment of respondents made using a five-point scale, where 1 means no impact; 2: small impact; 3: it is hard to say; 4: high impact; and 5: very high impact. The method of linear ordering, i.e., unitization, was used to select proposals for

solutions to mobility problems with the highest index. Linear ordering is the ordering of objects in order from best to worst, and the ordering criterion is the level of a complex phenomenon [74].

In the study, the normalized values of the variables were stimulants; therefore, a higher rating was described by a higher value of the indicator. The values of the indicator ranged from 0 to 1.

The variables were normalized using the zero unitarization technique, according to Equation (1).

$$z_{ij} = \frac{x_{ij} - x_{j \min}}{x_{j \max} - x_{j \min}}, \quad (1)$$

where z_{ij} is the normalized (unitized) value of the j -th variable for the i -th object, $x_{j \min}$ is the minimum value of the acceptability level of the i -th object (a value of 1 was adopted), and $x_{j \max}$ is the maximum value of the acceptability level of the i -th object (a value of 5 was adopted).

The results were compared to the ideal model; therefore, for the variable $x_{j \min}$, i.e., the minimum value of the level of acceptability, the value of 1 was adopted, and, for the variable $x_{j \max}$, i.e., the maximum value of the level of acceptability, the value of 5 was adopted.

The interpretation of the results was made using a five-level scale of point evaluation determined by the expert method (a team of national experts) (Table 3).

Table 3. Rating scale of acceptability of innovative solutions.

Class	Class Span	The Level of Acceptability	The Level for Implementation
I	1–0.81	Very high acceptability	Recommendation for implementation
II	0.80–0.61	High acceptability	Recommendation for secondary implementation
III	0.60–0.41	Average acceptability	To be re-examined
IV	0.40–0.21	Low acceptability	To be re-examined
V	0.20–0.00	Very low acceptability	To be rejected

4. Research Results

4.1. Theoretical Result: The Concept of an Innovative and Intermodal Model of Mobility Including Electric Car and Electric Bike Sharing

The proposed innovation involves the concept of an intermodal model of traveling through peripheral and hard to reach areas. This concept consists of connecting the public transport network of a main regional centre with that of a local urban centre. The linking of connections involves the coordination of departure and arrival times of various means of public transport using the main arteries of communication: rail–rail, rail–bus, bus–bus, and bus–rail. The public transport network of the local urban communication centre will be complemented by a network of available on-demand electric cars and bicycles. E-cars and e-bikes will be used to travel within areas having limited access. Pick-up/delivery zones of electric cars and bicycles will be located at points that intersect access routes, in proximity to bus and train stations, as well as frequently used routes (arteries). They will play the role of connectors within the intermodal passenger transport network and will allow a problem-free continuation of travel. Every pick-up/delivery zone will have a charging station. To ensure failure-free communication and transport efficiency vehicle and bicycle charging infrastructure will be augmented with charging stations located along travel routes. Functionality and access to the intermodal model will be ensured through a user-friendly ICT application. With this application, a potential customer will be able to reserve tickets for connected means of transport as well as book an e-car and/or e-bike at a selected pick-up zone, date, and time. After reserving an e-bike the customer will get a

text message with an access code for the activation of the bicycle to his/her phone. When booking an e-car the customer will receive the car's registration number confirming the reservation while the activation (getting the car open) will require the use of a credit/debit card. A special box for e-car pick up will be located at the pick-up/delivery zone. Efficient infrastructure for electronic charging will make it possible for tourists to travel further into regions and explore remote areas.

The concept of the innovative model for the solution of mobility problems within peripheral areas is consistent with the concept of sustainable transport development. A diagram of that model is presented in Figure 2.

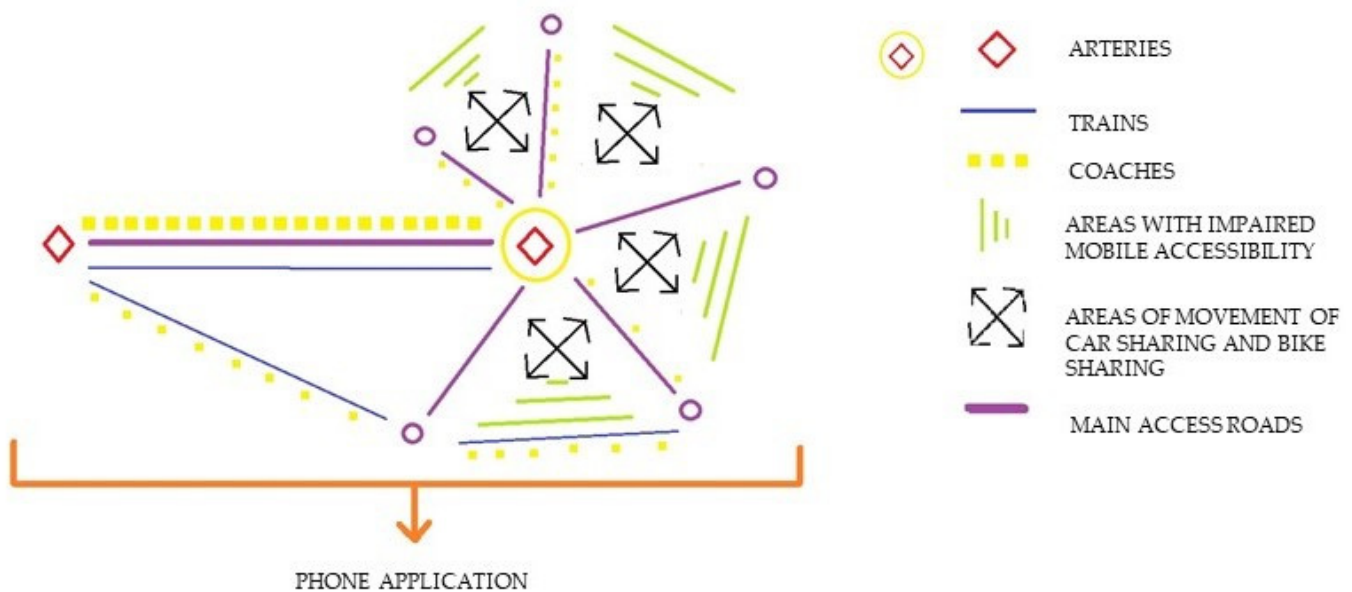


Figure 2. Concept of an innovative and intermodal mobility model including electric car and electric bike sharing. Legend: main regional centre (in Figure 2 (diamond) defined as main communication centres—arteries), local urban centre (in Figure 2 (a diamond within a circle) defined as local urban communication centres—arteries), area with limited access (in Figure 2 this is an area located between local access roads). E-car and e-bike pick-up/delivery zones will be located at points intersecting access routes (arteries), transit routes, and local access roads between a local urban centre and a village (in Figure 2 the village has been designated with a circle).

4.2. Assessment of Tourists' Needs for Innovative Solutions for the Development of Sustainable Transport (or Mobility and Tourist Accessibility Improvement). Case Study: Region of the Białowieża Forest

A representative group of tourists participated in the study. The demographic characteristics of the 421 tourists are presented in Table 4.

The vast majority of the respondents travelled to the region by private car (74.5%), while 3.6% travelled by rented car, 8.1% reached their destination by public transport, while 13.8% of tourists chose other means of transport (including bicycle, recreational vehicle, motor coach, hitch-hiking, cruise bus, on foot, motorcycle, britzka, train, plane and coach, bus tour coach) (Table 4).

Table 4. Demographic characteristics of the respondents.

	Characteristics	Frequency (%)
Gender	Male	46.1
	Female	53.9
Age	under 24	14.5
	24–34	30.6
	35–44	20.2
	45–54	13.5
	55 and above	20.9
Education	Higher	61.3
	Secondary	36.3
	Primary	1.4
	Vocational	1.0
Professional status	Employed persons	70.9
	University students	13.1
	Retirees	11.3
	Unemployed persons	2.9
	Students, persons on holiday leave, and business owners	1.8
Area of residence	City of up to 100,000 inhabitants	48.6
	Large city of over 100,000 inhabitants	25.9
	Rural area	16.4
	Town	10.7
	Sparsely populated area	0.2
Travelled to the region by	Private car	74.5
	Rented car	3.6
	Public transport	8.1
	Other means of transport (bicycle, motorcycle, bus tour)	13.8

The analysis of the manner in which tourists move around the region shows that 96% of the tourists move around the region on foot, and that 79% of them do so very often and often. Due to travel time, 57% of the tourists decide to take trips lasting more than one hour on foot; 27% of the tourists explore the region afoot from half an hour to one hour away from their stopover or place of stay, whereas 30% of them take trips on foot that last no longer than 30 min. The car is used by 81% of tourists during their stay in the region, with 52% of them using this means of transport often and very often. When it comes to travel time, the largest group of respondents (35%) go on trips that require driving for more than an hour, while almost every fourth tourist (24%) goes on trips that require a drive of 30 min to an hour. The car is also used by 33.0% of tourists for short distances of up to half an hour. The third dominant means of transport around the region is bicycle, which is used by 50% of tourists, with 35% of them using this means of transport very often and often. The survey shows that 12% of tourists use a bicycle for trips lasting up to 30 min, 14% for trips lasting from more than 30 min to one hour, and 28% of tourists travel by bicycle for trips requiring riding for more than an hour. In total, 26% of the tourists travel by local buses, with 10% of them doing so often and very often, while 14% of the tourists answered

that they travel by train, with 4% of them doing so often and very often. The results are presented in Table 5.

Table 5. Movement of tourists around the region at the leisure destination.

Mode of Transportation	Use	Very Frequent and Frequent Use	Up to Half an Hour of Travel	Between Half an Hour and One Hour of Travel	Above One Hour Travel
By walking	96%	79%	30%	27%	57%
By car	81%	52%	33%	24%	35%
By bicycle	50%	35%	12%	14%	28%
By cruise bus	26%	10%	8%	8%	9%
By train	14%	4%	5%	1%	5%
By motorcycle	3%	1%	3%	0%	1%
By scooter	1%	0%	3%	0%	0%
By taxi	10%	0%	6%	1%	1%

The assessment of tourists' expectations regarding transport accessibility improvement in the region with the use of local means of transport (Table 6, Figure 3) reveals that according to the tourists, the proposed innovative solutions do not completely solve the problems of transport accessibility (none of the solutions were considered to be highly effective). The following solutions are those that the respondents believe will have a moderate effect on the solution of the transport accessibility problems in the region.

Table 6. Assessment of tourists' acceptability of solutions to the region's mobility problems.

Description	Weighted Average of Responses	Rating	The Level of Acceptability	The Level for Implementation
Municipal/county bicycle system with a mobile application	3.74	0.68	High acceptability	Recommendation for secondary implementation
E-car system with mobile application and infrastructure (base stations, charging modules)	2.76	0.44	Average acceptability	To be re-examined
E-bike/scooter system with mobile application and infrastructure (base stations, bicycle paths)	3.59	0.65	High acceptability	Recommendation for secondary implementation
Mobile application that allows you to search for transport in a ridesharing system	3.65	0.66	High acceptability	Recommendation for secondary implementation
Mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bikes, e-scooters, e-cars, etc., with buses and trains)	3.67	0.67	High acceptability	Recommendation for secondary implementation
Mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bikes, e-cars, etc. with buses and trains) integrated with the internet payment system	3.71	0.68	High acceptability	Recommendation for secondary implementation
"Bus-on-request" service with a call centre	3.08	0.52	Average acceptability	To be re-examined
Integration of transport systems (one common ticket for all means of transport)	4.14	0.79	High acceptability	Recommendation for secondary implementation
A system of guaranteed connections between individual means of transport (e.g., the possibility of one vehicle awaiting another one being late)	3.77	0.69	High acceptability	Recommendation for secondary implementation

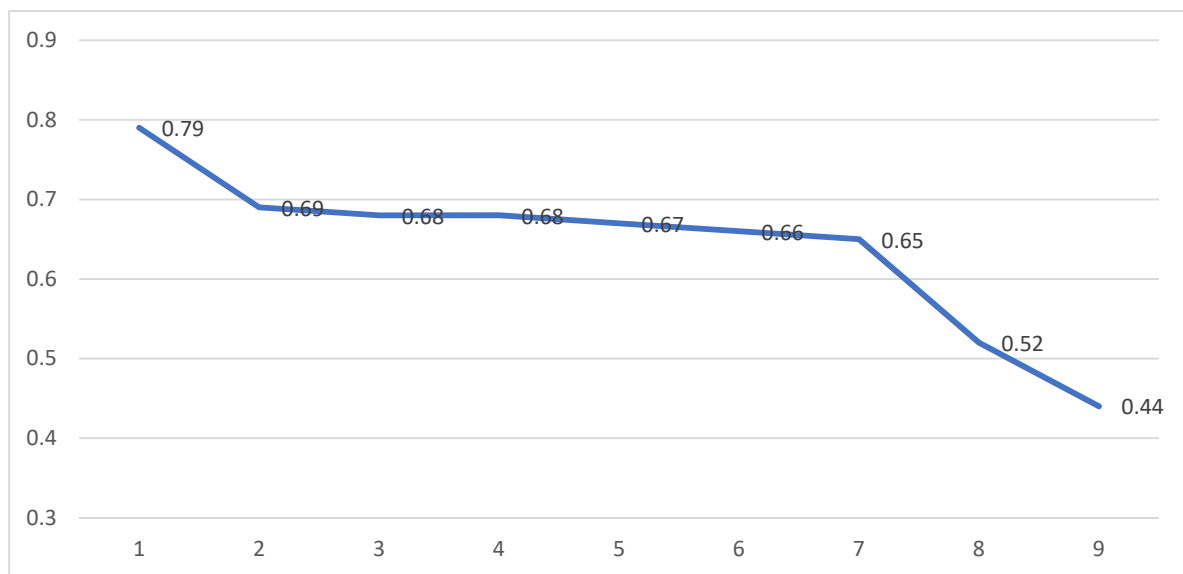


Figure 3. Ranking of the elements of solutions to the region’s mobility problems. Legend: 1: integration of transport systems (one common ticket for all means of transport); 2: a system of guaranteed connections between individual means of transport (e.g., the possibility of one vehicle awaiting another late); 3: a municipal/county bicycle system with a mobile application; 4: a mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bikes, e-cars, etc., with buses and trains) integrated with an internet payment system; 5: a mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bikes, e-scooters, e-cars, etc. with buses and trains); 6: a mobile application that allows you to search for transport in a ridesharing system; 7: e-bike/scooter system with mobile application and infrastructure (base stations, bicycle paths); 8: “bus -on-request” service with a call centre; and 9: e-car system with mobile application and infrastructure (base stations, charging modules).

According to tourists, most of the proposed solutions will improve the transport accessibility of the tourist region. They obtained a high level of acceptability and a recommendation for implementation. The respondents answered that the following solutions will have a minor effect on the transport accessibility problems in the region and should be re-examined:

- “bus-on-request” service with a call centre (3.082);
- electric car system with a mobile application and infrastructure (base stations, charging modules) (2.758).

While searching for the reason why the proposed innovation “electric car system with a mobile application and infrastructure (base stations, charging modules)” has low effectiveness, the response was compared with the means of transport used very often and often to move around the region (Table 7).

The analysis of the results shows that the highest effectiveness of this solution is reported by tourists who most frequently travel by car. On the other hand, the tourists whose dominant means of travel in the region on foot or by bicycle believe that electric cars will not solve the problem of transport accessibility or are undecided in this respect.

Due to the nominal nature of the data, the responses were evaluated in terms of their dependence on age, place of residence (broken down by inhabitants of large cities, towns, and villages), and gender.

The independence test for the responses and age showed that there are no significant correlations for most of the questions (Table 8). They were observed only for several questions, but still these correlations were rather low and resulted primarily from a higher level of indecisiveness among the elderly (over 55 years of age) compared to younger people, who more frequently answered that the suggested innovations had no impact. Nevertheless, the differences in the percentage of the answer in particular age groups are

small, while the obtained coefficients of Cramer's V dependence are low (approximately 0.2 or less).

Table 7. Evaluation of the effectiveness of the implementation of an electric car system with a mobile application and infrastructure (base stations, charging modules) by means of transport used to move around the region.

Transport Used to Move around the Region	Group Size (N)	Impact on Accessibility (in % of Responses)			
		High and Very High	Low	Hard to Say	No Impact
By car (very often and often)	209	40%	19%	21%	21%
By walking (very often and often, but rarely by car and bike)	106	35%	9%	17%	37%
By bicycle (very often and often, but rarely by car)	53	37%	9%	19%	35%
Remaining group of the tourists surveyed group	23	35%	0%	13%	52%
	414	38%	14%	19%	29%

Table 8. The results of the analysis of the relationship between the responses of tourists and residents to the question about the use of the indicated innovations in relation to gender, age, and place of residence.

Innovations	Gender		Age		Place of Residence	
	<i>p</i> -Value	V Cramera	<i>p</i> -Value	V Cramera	<i>p</i> -Value	V Cramera
Municipal/county bicycle system with a mobile application	0.297	0.108	0.377	0.133	0.143	0.115
E-car system with mobile application and infrastructure (base stations, charging modules)	0.190	0.122	0.059	0.157	0.162	0.114
E-bike/scooter system with mobile application and infrastructure (base stations, bicycle paths)	0.197	0.121	0.146	0.147	0.287	0.106
Mobile application that allows you to search for transport in ridesharing system	0.237	0.115	0.922	0.104	0.135	0.116
Mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bike system, e-scooters, e-cars, etc. with buses and trains)	0.045	0.153	0.077	0.154	0.175	0.113
Mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bike system, e-cars, etc. with buses and trains) integrated with the internet payment system	0.061	0.147	0.456	0.130	0.070	0.123
"Bus-on-request" service with a call centre	0.021	0.167	0.615	0.123	0.383	0.101
Integration of transport systems (one common ticket for all means of transport)	0.789	0.064	0.423	0.132	0.590	0.092
A system of guaranteed connections between individual means of transport (e.g., the possibility of one vehicle awaiting another being late)	0.833	0.059	0.534	0.127	0.733	0.086

A similar analysis was conducted for tourists, broken down by inhabitants of large cities, towns, and villages. Again, in general, no distinct correlations were observed. In

individual questions, only the responses of the rural areas' inhabitants were slightly more conservative (they more frequently selected the answer "it is hard to say" compared to other groups), but the differences are small.

When comparing the responses of men and women, no significant correlations were observed except for several questions. In cases when these correlations were present, they mainly concerned the fact that women chose the "it is hard to say" answer more frequently than men, whereas men more often indicated that these solutions would not affect the frequency of their travels. However, similarly to other characteristics, the correlations are insignificant.

Summarising the results of the (quantitative) surveys, it should be stated that the Białowieża Forest region is characterised by a high demand for sustainable and innovative mobile solutions, including e-mobility. The results of the research carried out among tourists indicate that the proposed concept of an innovative and intermodal mobility model including electric car and electric bicycle sharing achieves implementation recommendations.

5. Discussion

The results of the conducted research have shown that innovative transport solutions aimed at improving the mobility and communication accessibility of these areas are an important factor of sustainable transport in peripheral areas. The need and directions of these changes are confirmed by the studies of Scuttari and Isetti [8], which indicate that there is a need to change mobility patterns and that the preferential treatment of ecological solutions in the field of electromobility should be given. The concept of an innovative and intermodal mobility model including electric car and electric bicycle sharing, proposed in the article, meets these expectations and presents an integrated solution focused on economic, ecological, and social benefits. It is a consequence of adopting a broad definition of sustainable transport, which, as noted by Litman and Burwell [6], prefers more integrated solutions. The proposed concept considers the spatial aspect of sustainable development, constituting a planning study which, as Motowidlak [2] points out, requires long-term and integrated actions. The proposed solution, using ICT technologies, is part of the transport policy of the European Union [8]. The use of the transport-on-demand model (car sharing, bicycle sharing) will have a significant impact on improving the efficiency and optimization of the transport system, increasing the transport accessibility of peripheral areas and, as shown by the research by Janelle and Gillespie [22], may contribute to sustainable mobility. The use of non-motor vehicles (electric bicycles) will reduce the emission of carbon dioxide, noise, and waste [3,6], which have a destructive impact on the natural environment. In addition, the use of pro-ecological elements in the transport system will allow for a change in communication behaviour [9] and is a way to achieve an efficient transport system and a better choice of means of passenger transport, whilst simultaneously caring for the environment [9]. The developed model considers the key dimensions of sustainable transport, defined by Sztangret [21], and in particular electromobility. This model is based combining on a public transport network with the possibility of renting an electric bicycle or an electric car. It covers the application of integration of transport systems (one common ticket for all means of transport) and a system of guaranteed connections between individual means of transport (e.g., the possibility of one vehicle awaiting another one running late).

The intermodal model of tourist mobility proposed in this study has been verified in terms of the needs of tourists traveling in a remote area, such as the Białowieża Forest, entered on the UNESCO World Heritage List. Research conducted on a group of 421 tourists shows that the region is dominated by such forms of mobility as walking and cycling. The surveyed tourists positively assessed the proposed innovation of car and bicycle sharing as important, but few considered it very important. Nevertheless, the activities related to the integration of the intermodal transport system (one common ticket for all means of transport) and the compatibility of the transport system, through the

use of ICT, were rated very highly. These results are consistent with the statement of Davidson et al. [50] assuming that information technologies will force the introduction of the intelligent mobility model. It can therefore be expected that applications such as MaaS or those developed by the TEAM project will change the transport industry. In line with this mobility pattern, it is important for tourists to improve accessibility by introducing electric bicycles, as confirmed by further studies [43]. As noted by Nikitas [75], the key to the effective implementation and management of a bicycle sharing scheme is, *inter alia*, adapting the system and the development strategy to the needs of the region, synergy between the public entity (city-operator) and a trading partner, infrastructure and friendly legal regulations, better management of the transport fleet, and realistic expectations of enterprises regarding profits.

As a result of the research, the assumption that electric cars can be an alternative to traditional transport has not been confirmed [31]. In addition, support for on-demand transport (DRT) was low, which is in line with subsequent studies [30].

The proposed model is a comprehensive solution to the problems of mobility and improvement of tourism accessibility in remote areas, combining the traditional transport network with innovative solutions for the mobility of people. This solution is consistent with the needs of tourists in the field of mobility, e.g., vehicle sharing (bicycle sharing, car sharing), and at the same time consistent with the trends of changes in transport, which are described by researchers of this issue [28–30]. The effectiveness and efficiency of the model's operation is ensured by information technologies used for travel planning, the purchase of a connected ticket, and payments. Due to ICT technologies, the developed model imitates the modern model of intelligent mobility, which is in line with the research by Davidson et al. [50].

The efficient functioning of the transport system in remote areas has a significant impact on the development of the tourism function of regions. This directly contributes to increasing the tourist penetration of the area. Moreover, it influences the discovery of the tertiary and quaternary tourist attractions of the region, even far away from places of accommodation, which contributes to the return or extension of a tourist's stay. It is especially important in regions where tourism develops on the basis of natural values, and an efficiently functioning transport system is environmentally effective.

However, the developed concept of an innovative and intermodal mobility model including electric car and electric bicycle sharing has a number of implementation difficulties. These are primarily the high costs of implementing electric cars, in particular the construction of docking stations, as indicated by Gawlik [37]. Further difficulties are related to the optimal location of docking stations with a charging system, as they are located in an area with a low population density and, at the same time, with a high dispersion of residential habitats, far away from the city centre. Moreover, Brandstatter et al. [30] draw attention to the short service life of the e-car and therefore the short distances it can travel, which makes it necessary to locate additional docking stations along the travel routes. However, considering that half of the tourists visit the region by car, in the case of regions with naturally valuable areas, the decision should be made on the basis of the environmental and social cost–benefit analysis. It would be advisable to consider the results of the research by de Yong et al. [56], who showed that the key to effective improvement of accessibility in remote areas is primarily the availability of financial resources. Another difficulty related to the implementation of the proposed model, which is based on ICT solutions, is the low quality of the ICT network in peripheral areas.

The main problem with the conducted research was the lack of comparative research. It can therefore be concluded that the research gaps identified in the 2009–2020 review studies [11] also occurred on the micro-region scale, i.e., in relation to the Białowieża Forest. The gaps relate to the sustainable development of social transport and the use of information and communication technologies. One can agree with the opinion of Hopkins [20] on the need to continue research in the search for innovative approaches to sustainable transport, mobility, and tourism [76], which would allow for the identification of new

research directions and the emergence of solutions. The development and implementation of innovative solutions would contribute to the acceleration of the processes of sustainable transport and tourism development. There is no doubt that the innovations regarding the introduction of low-emission transport solutions postulated by the European Commission in the “White Book of Transport” [9] should be the subject of special attention both from local and national authorities, and from European policy, and this is the solution proposed by the authors.

6. Conclusions

The research carried out in the paper deepens the theoretical and empirical knowledge on sustainable transport and innovative transport solutions. When analysing the main directions of contemporary research on sustainable transport, it was noticed that the hot topics include research in the field of sustainable transport policy, transport strategic planning, involvement of stakeholders in solving mobility problems, environmental impact, travel behaviour, and bicycles and public transport. The policy and planning of sustainable transport both indicate a growing need to increase the innovation of the transport system. The paper identifies innovative transport solutions that improve mobility and transport accessibility and the competitiveness of peripheral areas, as well as limit the negative impact of transport on the environment. This analysis was the basis for the development of an original intermodal model of tourist mobility. In the work, not only the conceptual theoretical framework of the mobility model was developed, including various forms of transport, but also empirical testing of the possibility of its implementation in a selected peripheral area, i.e., the Białowieża Forest region, was performed. The testing was carried out on a representative research sample of 421 tourists on vacation in this area.

The results of the study conducted on tourists visiting the Białowieża Forest revealed several evident threads. First and foremost, there is a high demand for the organisation and synchronisation of solutions in the field of mobility. This primarily involves public transport and its accessibility and flexibility. Then (and only then) is there a demand for innovative solutions related to, for instance, the introduction of electric bikes. As a result, it is possible to formulate recommendations in terms of the regional policy so that the local government, which supervises public transport, addresses the needs of tourists visiting the Białowieża Forest by reorganising the public transport system. On the other hand, the development of mobility applications and the introduction of an innovation in the form of an electric bike system would significantly increase region attractiveness, simultaneously contributing to environmental protection and sustainable transport development.

The proposed intermodal model of tourist mobility based on the possibility of renting electric cars and bikes via registration in a dedicated application and with the use of a special card may be implemented in other countries of the Baltic Sea Region affected by demographic changes and located far from the main urban, administrative, and economic centres. The mobile application for the electric car and electric bike sharing system may be adapted to the needs of the partner regions.

The research results, conclusions drawn, and implementation problems identified may have significant practical and political implications. Among the various findings, the strong correlation between the tourist mobility model and the mobility needs of tourists is important for the shaping of regional policy. This relationship is based on the diagnosed need to integrate various groups of entities, such as: transport companies, ICT enterprises, and road and tourist route managers. These entities should cooperate in order to implement an intermodal mobility system based on innovative, pro-environmental solutions. This cooperation will enable the exchange of knowledge and experience in the field of implementation and will also help in overcoming difficulties related to insufficient financial resources of enterprises. In this context, a significant role should be assigned to local government and government entities. This role should be to develop policies and strategies to facilitate networking and the coordination of activities related to the implementation of the mobility model. The study showed that ICT plays a significant role

in the creation of smart mobility models, and their application is one of the main drivers of sustainable transport development. Most remote areas are characterized by inadequate and inaccessible ICT infrastructure (limited range of access to the Internet), which may significantly limit or prevent the efficient functioning of the proposed model. There is, therefore, a need for policy intervention to increase the ICT capacity of these areas as well as to support transport companies in adapting and implementing new technologies. The above-mentioned problems necessitate a political intervention in order to solve the problems of communication accessibility in remote areas.

When analyzing the contribution to the science of this article, it can be indicated that the results of the presented study, especially the development of the intermodal model of tourist mobility, contribute to social sciences, mainly in relation to the following disciplines: management and quality science (sustainable management and transport management), as well as economics and finance (theory of innovation, and sustainable development). Research contributes to the knowledge of intelligent mobility systems in remote areas. The main contribution to science is the development of a concept of an innovative and intermodal mobility model including electric car and electric bike sharing. The model is important in the absence of an established conceptual framework covering the unique features of innovative, intelligent transport models for remote areas. The proposed model framework can be used as a basis for similar empirical work and/or can be modified and extended to suit specific research objectives and other remote areas.

On the other hand, empirical research provides useful information on the role of individual elements of the intelligent transport network and the factors that shape and are necessary to create intelligent mobility solutions in remote areas, which in this case applies to the unique area of the Białowieża Forest. The research results show that not all the applied changes have the same impact on the development of intelligent mobility models. The reasons for this phenomenon should be sought in subsequent empirical studies. The identified factors of intelligent models of tourist mobility in remote areas indicate the dominance of information technology systems. As research on tourist expectations shows, advanced ICT transport systems should combine data with different scopes (local, regional, and national datasets) and come from a dataset of various types of transport (bus, rail, bicycles, and passenger cars, including electric cars). In addition, mobility systems should be compatible with payment and reservation systems. ICT is a key instrument that allows the implementation of innovative solutions aimed at: the integration of transport systems (one common ticket for all means of transport); a system of guaranteed connections between individual means of transport (e.g., the possibility of one vehicle awaiting another late transport mode); a municipal/county bicycle system with a mobile application; a mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bikes, e-cars, etc., with buses and trains) integrated with an internet payment system; a mobile application for travel planning and integrating various means of transport available in the county (e.g., e-bikes, e-scooters, e-cars, etc., with buses and trains); a mobile application that allows you to search for transport in a ridesharing system; and an e-bike/scooter system with a mobile application and infrastructure (base stations, bicycle paths).

The present study may aid the promotion of scientific discourse related to sustainable transport, innovation, and the improvement of tourist accessibility to peripheral areas. It may also be helpful to other researchers in the development of their own scientific studies (including the utilisation of its methodology) and provide material for comparative analyses.

With regard to peripheral areas, the following aspects may be the subject of further research:

- research on the demand for mobile solutions among the residents;
- verification of the possibility of making electric cars and bikes available;
- verification of the possibility of creating an intelligent charging structure in the analysed area;

- analysis of bicycle paths, as e-bike traffic should stay away from public transport routes;
- analysis of the legal regulations on the organisation of e-mobility.

The presented research results also have some limitations. The results only show the opinion of tourists. It would be desirable to present the views of other stakeholder groups, e.g., representatives of transport companies and residents. Another limitation is the lack of comparative studies from other peripheral regions.

Author Contributions: The scope of work of individual authors: E.S. prepared the concept of the paper, objectives and the research problem, the introduction, problems of peripheral areas, the discussion part, and conclusions. H.K. contributed to the concept of the paper and objectives, prepared the abstract, analysed the literature in terms of the sustainable transport concept, identified transport accessibility problems for the Białowieża Forest, and prepared part of the discussion and conclusions. E.P. analysed the literature in terms of mobility innovations and identified the problems of the Białowieża Forest region. She prepared the second part of the paper: materials and methods; and the third part: research results, the discussion part and conclusions. All authors have read and agreed to the published version of the manuscript.

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References

1. Rucińska, D. Promocja zrównoważonego rozwoju transportu—Wybrane przykłady dobrych praktyk. *Logistyka* **2014**, *2*, 85–299.
2. Motowidlak, U. Rozwój transportu a paradygmat zrównoważonego rozwoju. *Stud. Ekon.* **2017**, *337*, 138–152.
3. Miłaszewicz, D.; Ostapowicz, B. Warunki zrównoważonego rozwoju transportu w świetle dokumentów UE. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania* **2011**, *24*, 103–118. Available online: http://wneiz.pl/nauka_wneiz/sip/sip24-2011/SiP-24-8.pdf (accessed on 24 September 2020).
4. Nowak, I.; Fajczak-Kowalska, A.; Kowalska, M. Transport Policy Instruments for Sustainable Development of Transport. *Logist. Transp.* **2018**, *37*, 77–83.
5. Borys, T. Pomiar zrównoważonego rozwoju transportu. In *Ekologiczne Problemy Zrównoważonego Rozwoju*; Kiełczewski, D., Dobrzyńska, B., Eds.; Wyd. Wyższej Szkoły Ekonomicznej w Białymstoku: Białystok, Poland, 2009; pp. 166–185.
6. Litman, T.; Burwell, D. Issues in sustainable transportation. *Int. J. Global Environ. Issues* **2006**, *6*, 331–347. [[CrossRef](#)]
7. Wiktorowska-Jasik, A. Implemented sustainable public transport solutions and social expectations for the city transport system of Szczecin. *Sci. J. Marit. Univ. Szczec.* **2020**, *61*, 62–67.
8. Scuttari, A.; Isetti, G. E-mobility and Sustainable Tourism Transport in Remote Areas—Insights from the Alpine case study of South Tyrol (IT). *Z. Tourismuswiss.* **2019**, *11*, 237–256. [[CrossRef](#)]
9. European Commission. *White Paper on Transport. Roadmap to a Single European Transport Area—Towards a Competitive and Resource Efficient Transport System*; Publications Office of the European Union: Luxemburg, 2011. [[CrossRef](#)]
10. Kłos-Adamkiewicz, Z. Plany zrównoważonej mobilności miejskiej jako element polityki transportowej, 2015. *Biała Księga Mobilności*. 2015. Available online: <https://transport-publiczny.pl/BKM/BialaKsiegaMobilnosci2015.pdf> (accessed on 23 October 2020).
11. Zhao, X.; Ke, Y.; Zuo, J.; Xiong, W.; Wu, P. Evaluation of sustainable transport research in 2000–2019. *J. Clean. Prod.* **2020**, *256*, 120404. [[CrossRef](#)]
12. Jeon, C.M.; Amekudzi, A. Addressing sustainability in transportation systems: Definitions, indicators, and metrics. *J. Infrastruct. Syst.* **2005**, *11*, 31–50. [[CrossRef](#)]
13. Kjoesewski, S.; Kochov, A.; Danev, D.; Kostikj, A. Sustainable Transport Indicators in the Context of Introducing of Electric Passenger Cars. *Tech. J.* **2020**, *14*, 318–324. [[CrossRef](#)]
14. Eliasson, J.; Proost, S. Is sustainable transport policy sustainable? *Transp. Policy* **2015**, *37*, 92–100. [[CrossRef](#)]
15. Schmale, J.; von Schneidmesser, E.; Dörrie, A. An integrated assessment method for sustainable transport system planning in a middle sized German city. *Sustainability* **2015**, *7*, 1329–1354. [[CrossRef](#)]
16. Lovelace, R.; Parkin, J.; Cohen, T. Open access transport models: A leverage point in sustainable transport planning. *Transp. Policy* **2020**, *97*, 47–54. [[CrossRef](#)]
17. Pastana, S.; Pereira, G.R.B.; Nóbrega, K.C.; Campos, D.F. Innovative strategies in the planning of sustainable urban mobility. *REBRAE Curitiba* **2019**, *1*, 62–73. [[CrossRef](#)]
18. Badassa, B.B.; Sun, B.; Qiao, L. Sustainable transport infrastructure and economic returns: A bibliometric and visualization analysis. *Sustainability* **2020**, *12*, 203. [[CrossRef](#)]

19. Barfod, M.B. Supporting sustainable transport appraisals using stakeholder involvement and MCDA. *Transport* **2018**, *33*, 1052–1066. [CrossRef]
20. Hopkins, D. Sustainable mobility at the interface of transport and tourism: Introduction to the special issue on Innovative approaches to the study and practice of sustainable transport, mobility and tourism. *J. Sustain. Tour.* **2020**, *28*, 225–239. [CrossRef]
21. Sztangret, I. Systemic sustainable development in the transport service sector. *Sustainability* **2020**, *12*, 9525. [CrossRef]
22. Janelle, D.G.; Gillespie, A. Space-time constructs for linking information and communication technologies with issues in sustainable transportation. *Transp. Rev.* **2004**, *24*, 665–677. [CrossRef]
23. Wolter, S. Smart mobility—Intelligente vernetzung der verkehrsangebote in Großstädten. In *Zukunftsige Entwicklungen in der Mobilität*; Proff, H., Schönharting, J., Schramm, D., Ziegler, J., Eds.; Springer: Heidelberg, Germany, 2012; pp. 527–548.
24. Santos, G. Sustainability and shared mobility models. *Sustainability* **2018**, *10*, 3194. [CrossRef]
25. Shibayama, T.; Emberger, G. New mobility services: Taxonomy, innovation and the role of ICTs. *Transp. Policy* **2020**, *98*, 79–90. [CrossRef]
26. Rees, D. *Digitalisierung in Mobilität & Verkehr: Schiene und Öffentlicher & Verkehr*; PMC Media House GmbH: Bingen am Rhein, Germany, 2018.
27. Becker, H.; Ciari, F.; Axhausen, K.W. Comparing car-sharing schemes in Switzerland: User groups and usage patterns. *Transport. Res. Pol. Pract.* **2017**, *97*, 17–29. [CrossRef]
28. Ronald, N.; Thompson, R.; Haasz, J.; Winter, S. Determining the Viability of a Demand-Responsive Transport System under Varying Demand Scenarios. In Proceedings of the 6th ACM SIGSPATIAL International Workshop on Computational Transportation Science, Orlando, FL, USA, 5–8 November 2013.
29. Broome, K.; Worrall, L.; Fleming, J.; Boldy, D. Evaluation of flexible route bus transport for older people. *Transp. Policy* **2012**, *21*, 85–91. [CrossRef]
30. Nelson, J.D.; Wright, S.; Masson, B.; Ambrosino, G.; Naniopoulos, A. Recent developments in Flexible Transport Services. *Res. Transport. Econ.* **2010**, *29*, 243–248. [CrossRef]
31. Goldman, T.; Gorham, R. Sustainable urban transport: Four innovative directions. *Technol. Soc.* **2006**, *28*, 261–273. [CrossRef]
32. Kent, J.L. Carsharing as active transport: What are the potential health benefits? *J. Transp. Health* **2014**, *1*, 54–62. [CrossRef]
33. Firnkorn, J.; Müller, M. Free-floating electric carsharing-fleets in smart cities: The dawning of a post-private car era in urban environments? *Environ. Sci. Policy* **2015**, *45*, 30–40. [CrossRef]
34. Katzev, R. Car Sharing: A New Approach to Urban Transportation Problems. *Anal. Soc. Issues Public Policy* **2003**, *3*, 65–86. [CrossRef]
35. Prettenthaler, F.E.; Steininger, K.W. From ownership to service use lifestyle: The potential of car sharing. *Ecol. Econ.* **1999**, *28*, 443–453. [CrossRef]
36. Sprei, F. Disrupting mobility. *Energy Res. Soc. Sci.* **2018**, *37*, 238–242. [CrossRef]
37. Gawlik, W.; Litzlbauer, M.; Schuster, A.; Koller, H.; Reinthaler, M.; Norman, N.; Waldbauer, M.; Bolzer, A.; Leitner, M. ZENEM—Zukünftige Energienetze mit Elektromobilität. 2013. Available online: https://www.ea.tuwien.ac.at/fileadmin/t/ea/projekte/ZENEM/ZENEM_829953_publ_Endbericht_final_130919.pdf (accessed on 24 September 2020).
38. Brandstätter, G.; Leitner, M.; Ljubic, I. Location of Charging Stations in Electric Car Sharing Systems. *Transport. Sci.* **2020**, *54*, 1408–1438. Available online: <http://pubsonline.informs.org/journal/trsc> (accessed on 24 September 2020). [CrossRef]
39. Pelletier, S.; Jabali, O.; Laporte, G. 50th anniversary invited article—Goods distribution with electric vehicles: Review and research perspectives. *Transport. Sci.* **2016**, *50*, 3–22. [CrossRef]
40. Available online: <https://www.transport-publiczny.pl/wiadomosci/autonomiczne-autobusy> (accessed on 24 September 2020).
41. Suda, Y.; Aoki, K. Jidou-untens gijutsu-no kaihatsu-doko-to gijutsu-kadai (progresses and technical challenges of self-driving technologies). *Jouhou Kanri* **2015**, *57*, 809–817. [CrossRef]
42. Conner-Simons, A.; Gordon, R. Self-driving Cars for Country Roads. *MIT News* 2018. Available online: <http://news.mit.edu/2018/self-driving-cars-for-country-roads-mit-csail-0507>(accessed on 24 September 2020).
43. Continental corporation -mobility study 2015 continental. 2015. Available online: <http://www.continentalcorporation.com/www/download/pressportalcomen/themes/initiatives/channelmobilitystudyen/ovmobilitystudy2015en/downloadchannel/mobistud2015praesentationen.pdf> (accessed on 24 September 2020).
44. Buttner, J.; Mlasowsky, H.; Birkholz, T.; Gröper, D.; Castro Fernández, A.; Emberger, G.; Petersen, T.; Robèrt, M.; Serrano Vila, S.; Reth, P.; et al. Optimising Bike Sharing in European Cities—A Handbook. OBIS 2011. Available online: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/obis_handbook_en.pdf (accessed on 24 September 2020).
45. Ricci, M. Bike sharing: A review of evidence on impacts and processes of implementation and operation. *Res. Transport. Bus. Manag.* **2015**, *15*, 28–38. [CrossRef]
46. Parkes, S.D.; Marsden, G.; Shaheen, S.A.; Cohen, A.P. Understanding the diffusion of public bikesharing systems: Evidence from Europe and North America. *J. Transp. Geogr.* **2013**, *31*, 94–103. [CrossRef]
47. Brinkmann, J.; Ulmer, M.W.; Mattfeld, D.C. The multi-vehicle stochastic-dynamic inventory routing problem for bike sharing systems. *Bus. Res.* **2020**, *13*, 69–92. [CrossRef]
48. Bellotti, F.; Kopetzki, S.; Berta, R.; Paranthaman, P.K.; Dange, G.R.; Lytrivis, P.; Amditis, A.J.; Raffero, M.; Aittoniemi, E.; Basso, R.; et al. TEAM applications for Collaborative Road Mobility. *IEEE Trans. Ind. Inform.* **2019**, *15*, 1105–1119. [CrossRef]

49. Zeng, A.Z.; Durach, C.F.; Fang, Y. Collaboration decisions on disruption recovery service in urban public tram systems. *Transp. Res. Part E Logist. Transport. Rev.* **2012**, *48*, 578–590. [CrossRef]
50. Davidsson, P.; Hajinasab, B.; Holmgren, J.; Jevinger, Å.; Persson, J.A. 2 The Fourth Wave of Digitalization and Public Transport: Opportunities and Challenges. *Sustainability* **2016**, *8*, 1248. [CrossRef]
51. Porru, S.; Misso, F.E.; Pani, F.E.; Repetto, C. Smart mobility and public transport: Opportunities and challenges in rural and urban areas. *J. Traffic Transport. Eng.* **2020**, *7*, 88–97. [CrossRef]
52. Mobilność obszarów wiejskich w podróży 2.0. Project: RAMZES. Available online: <https://www.ruralmobility.eu/> (accessed on 24 September 2020).
53. López-Iglesias, E.; Peón, D.; Rodríguez-Álvarez, J. 2018 roku (Mobility innovations for sustainability and cohesion of rural areas: A transport model and public investment analysis for Valdeorras (Galicia, Spain)). *J. Clean. Prod.* **2018**, *172*, 3520–3534. [CrossRef]
54. Gronau, W.; Kagermeier, A. Mobility management outside metropolitan areas: Case study evidence from North Rhine-Westphalia. *J. Transp. Geogr.* **2004**, *12*, 315–322. [CrossRef]
55. Gross-Fengels, S.; Fromhold-Eisebith, M. Chapter Six—Adapting transport related innovations to rural needs: Smart Mobility and the example of the Heinsberg region, Germany. *Adv. Transp. Policy Plan.* **2018**, *2*, 125–162. [CrossRef]
56. De Jong, W.; Vogels, J.; van Wijk, K.; Cazemier, O. The key factors for providing successful public transport in low-density areas in The Netherlands. *Res. Transport. Bus. Manag.* **2011**, *2*, 65–73. [CrossRef]
57. Leszczewska, K. Aktywność ekonomiczna regionów peryferyjnych. *Nierówności Społecz. Wzrost Gospod.* **2010**, *12*, 215–225.
58. Bajerski, A. Problemy wydzielenia peryferii społeczno-gospodarczych. *Ruch Praw. Ekon. Socjol.* **2008**, *2*, 159–167. Available online: <http://hdl.handle.net/10593/5038> (accessed on 20 September 2020).
59. Idczak, P. *Wielowymiarowa Koncepcja Peryferyjności Regionalnej. Identyfikacja Regionów Peryferyjnych w Polsce*; Difin: Warsaw, Poland, 2013; pp. 84–85.
60. Proniewski, M. *Rozwój Regionów Peryferyjnych w Unii Europejskiej*; Białystok University Publishing House: Białystok, Poland, 2012; pp. 64–65.
61. Miszczuk, A. Peryferyjność regionów. In *Europejskie Wyzwania dla Polski i Jej Regionów*; Tucholska, A., Ed.; MRR: Warsaw, Poland, 2010.
62. Vaishar, A. Regional periphery: What does it mean? In *Regional Periphery in Central and Eastern Europe*; Komornicki, T., Czapiewski, Ł., Eds.; “Europa XXI” nr 15 Centrum Studiów Europejskich; IGIPZ PAN: Warsaw, Poland, 2006.
63. Grosse, T.G. *Innowacyjna Gospodarka na Peryferiach?* Instytut Spraw Publicznych: Warszawa, Poland, 2007.
64. Kiryluk, H. Forest resources as a basis to creation of an integrated tourist product of an area on the example of Białowieża forest. *Econ. Environ.* **2016**, *4*, 307–317.
65. Panfiluk, E. Wpływ środków unijnych na atrakcyjność turystyczną region. Case study Region Puszczy Białowieskiej. *Stud. Oecon. Posnan.* **2017**, *5*, 82–103. [CrossRef]
66. Główny Urząd Statystyczny, Warszawa. 2019. Available online: <https://bdl.stat.gov.pl/BDL/start> (accessed on 24 September 2020).
67. *Analiza dostępności komunikacyjnej regionu Puszczy Białowieskiej, Ekspertyza przygotowana dla Powiatu Hajnowskiego przez Zespół Doradców Gospodarczych*; TOR: Warsaw, Poland, 2014.
68. Ryciuk, U.; Szymańska, E.; Kołoszko-Chomentowska, Z.; Panfiluk, E.; Kiryluk, H.; Stepianiuk, K.; Olszewska, A. *Rozwiązania Problemów Mobilności Turystów i Mieszkańców Powiatu Hajnowskiego. Action Regional Plan, Projektu MARA*; Białystok University of Technology: Białystok, Poland, 2020.
69. Szymańska, E.; Kołoszko-Chomentowska, Z.; Panfiluk, E.; Kiryluk, H. *Potrzeby Mobilności Turystów i Mieszkańców Powiatu Hajnowskiego. Raport Projektu MARA*; Białystok University of Technology: Białystok, Poland, 2020.
70. Szpilko, D. *Forsight Jako Narzędzie Doskonalenia Zarządzania Turystyką w Regionie*; Oficyna Wydawnicza Politechniki Białostockiej: Białystok, Poland, 2016.
71. Antoszkiewicz, J.D. Metody heurystyczne w procesach przedsiębiorczych. In *Współczesne Dylematy Badań nad Przedsiębiorczością*; Kosala, M., Urbaniec, M., Żur, A., Eds.; University of Economics: Cracow, Poland, 2016; Volume 2, pp. 11–22.
72. Jonsen, K.; Jehn, K.A. Using triangulation to validate themes in qualitative studies. *Qual. Res. Organ. Manag. An. Int. J.* **2009**, *4*, 123–150. [CrossRef]
73. Kononiuk, A.; Nazarko, J. *Scenariusze w Antycypowaniu i Kształtowaniu Przyszłości*; Wolters Kluwer: Warsaw, Poland, 2014.
74. Walesiak, M. Przegląd formuł normalizacji wartości zmiennych oraz ich własności w statystycznej analizie wielowymiarowej. *Stat. Rev.* **2014**, *61*, 363–372.
75. Nikitas, A. How to save bike-sharing: An evidence-based survival toolkit for policy-makers and mobility providers. *Sustainability* **2019**, *11*, 3206. [CrossRef]
76. Szymańska, E. The influence of the Environment on the Tourism Enterprises Innovativeness. *Int. J. e Educ. e Bus. e Manag. e Learn.* **2018**, *8*, 122–129. [CrossRef]