Photovoltaics as an Element of Intelligent Transport System Development

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Abstract Intelligent Transport System (ITS) means advanced applications aiming at providing innovative services related to different means of transport and traffic management as well as providing important information to traffic participants. Currently, ITS is applied within the areas of large cities. It is inevitable that the system should be applied in all locations where it may contribute to road safety improvement or streamlining the traffic. Application of photovoltaics as the renewable energy source for necessary devices (information signs, warning signs, variable contents signs, monitoring and lighting) is an opportunity for common application of ITS. Photovoltaics can be used practically in every location and, first of all, locations difficult to access to power grid. Based on the example of the Region of Warmia and Mazury in north-eastern Poland the current use of photovoltaics for providing power for road infrastructure was identified. Information concerning use of photovoltaic panels in marking of the national roads in the region was obtained from the General Directorate of National Roads and Motorways (GDDKiA), branch in Olsztyn. GIS tools were used for identification of the existing road signs supplied by photovoltaics. The MapInfo Professional application was applied for development of the appropriate subject map. According to the opinion of the authors the need exists for development of the pan-European GIS system containing information on the existing ITS and indicating key locations in which such a system should be implemented. Photovoltaics is the element facilitating ITS implementation in new difficult to access locations outside urban areas.

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1 Introduction

During the times of progressing socioeconomic development and general globalisation, mobility and possibility of development of modern, safe, productive and natural environment friendly transport system is the key issue. According to Koźlak [1], transport systems development must consider the need for increasing effectiveness of their operation coupled with limiting the negative consequences of transport development. According to the Strategy of Transport Development by 2020 [2], increasing territorial access and improving safety of traffic participants as well as transport sector effectiveness improvement by establishing a consistent and user friendly transport system in the national (local), European and global dimension is the main objective of the national transport policy. Implementation of the intelligent transport system is such a solution very strongly supported by the European Union.

Intelligent Transport Systems (ITS) are advanced applications which without embodying intelligence as such aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and 'smarter' use of transport networks [3]. ITS represent a combination of IT and communication solutions with transport infrastructure and vehicles aiming at safety improvement. They also increase the effectiveness of transport processes and natural environment protection.

In the ITS, defining the subjects of transport is important. As presented by Wydro [4], they include: (1) direct transport infrastructure users, (2) travellers, pedestrians and passengers, (3) means of transport, (4) roads and their direct environment, (5) institutions and organisations (including, among others, road infrastructure administration, business—infrastructure users, infrastructure construction and maintenance companies), (6) providers of complementary services (e.g. motels, restaurants, vehicle service points), (7) institutions assuring order and safety (e.g. police, border guards, emergency medical services, property protection), (8) public administration.

Overcoming geographic barriers to make integration between all subjects involved in transport possible is one of the tasks of the European Union Cohesion Policy that could be accomplished with the help of ITS. This is also the appropriate direction for a better use of the economic potential of regions.

In Poland, Intelligent Transport Systems (ITS) are usually implemented with the aid of the European Union funds of the Operational Programme Infrastructure and Environment (the subsidy is up to 85 % of the investment project value) and Operational Programme Development of Eastern Poland. Construction of new roads or modernisation of the existing ones is the best moment for implementation of such solutions.

The most frequently applied ITS solutions are: (1) traffic management systems, (2) public transport management systems, (3) freight transport and fleet of vehicles management systems, (4) road events and rescue services management systems, (5) traffic safety management and violation of regulations monitoring systems, (6) information services for travellers, (7) electronic toll collection systems, (8) advanced technologies in vehicles [1, 5].

Within the frameworks of the listed applications of ITS, photovoltaics may play the most important role in expanding the system to include further locations in particular in not urbanised areas: information signs, warning signs and, first of all, the system of variable content signs, which is primarily an invaluable impact on the safety of road users.

2 Material and Methodology of Studies

For the purpose of the paper was study and analysis of literature ITS and practical application of photovoltaic panels. Particular attention was paid to the use of road infrastructure of energy from renewable sources. For this purpose, within the framework of the paper the locations of photovoltaic panels supplying information and warning signs on national roads within the area of Warmińsko-Mazurskie voivodship in north-eastern Poland have been identified. Information concerning use of photovoltaic panels in signage on national roads in the region was obtained from the General Directorate of National Roads and Motorways, branch in Olsztyn administering those roads (data as at September 2013). GIS tools were used for identification of the existing road signs supplied by photovoltaics. The MapInfo Professional application was used for development of the appropriate subject map. For the purpose of precise location of the objects Google Maps and Street View service were used. This work is application in its character. One of the functions of MapInfo professional using to for the identification of photovoltaic panels in the road infrastructure used to geocoding. Geocoding consists in assigning the info about a given location coordinates to visualize on the map. Analysis of the use of photovoltaic panels in road infrastructure was conducted to define whether application of such solutions is justified.

3 Potential of Photovoltaics Use for Road Safety Improvement

Photovoltaics is a scientific discipline dealing with transformation of solar radiation energy into power by applying photovoltaic cells. It is one of the most promising renewable energy sources representing an alternative for traditional not renewable resources.

Solar energy may be transformed into power using photovoltaic cells (PV cells), solar cells converting light directly into power. That process is also possible by means of concentrating solar power (CSP) where parabolic solar collectors or solar towers concentrate the light for the purpose of warming up a single point generating in that way steam driving the turbine. PV cells based power stations can be connected to storage batteries or to the power grid. Heat from the CSP can be stored for energy generation in case of unavailability of solar light [6]. Solar power, i.e. photovoltaics is considered one of the most environment friendly energy sources given the wide potential for obtaining energetic benefits. Their simple construction, ease of installation compared to other energy sources and availability, i.e. the possibility of installing in difficult to access terrain are the major advantages of PV systems.

Electricity powered cars are the future of transport. According to Moćko et al. [7] the volume of total greenhouse gases emissions produced by a car is very highly dependent on the type of renewable energy in power grid. Solar energy seems to be the most rational solution. However, productivity of photovoltaic panels depends on the year season, hour, location and weather conditions. The advantage of the system is that it can be installed in places with difficult access to power, it does not pollute the air and does not generate noise. It must, however, be appropriately oriented as the highest power generation productivity is possible in case of southern exposure [8, 9].

In different parts of the world solar power is less or more popular. In Poland, so far, thermal energy obtained from solar installations enjoyed interest.

The actual spread of photovoltaics in Poland is quite limited. We observe very high disproportions compared to the other European countries. According to Forowicza [10] German photovoltaic installations offered the capacity of 17,200 MW while in Poland it was just 1.75 MW. According to Romański et al. [11], the volume of energy obtained in our climate is small and highly dependent on the year season. The authors also evaluate efficiency of the devices as very poor—ranging within 6–15 %. The examples of photovoltaics use in other countries, e.g. Germany, that are situated in the climate zone very similar to Poland can be presented as contradicting the opinions presented. In 2013, energy production from renewable sources, mainly photovoltaics, is at the record level. Worldwide, only the United States and Japan are ahead of Germany in total capacity of the installed photovoltaic systems. Photovoltaics market is developing at a surprising rate; new solar power plants are established, but Poland, unfortunately, because of the legal regulations and politics is lagging behind the majority of the European countries.

All the time new solutions for energy from renewable sources are proposed (in ventilation devices, lighting, industrial machines and motors, construction of energy efficient houses) [12].

Sharma and Harinarayana [13] propose energy production with photovoltaic installations forming a roof-type structure along the national roads and motorways. According to the authors, such solutions offer numerous benefits for road traffic participants. They draw particular attention to the effect of shade that causes decrease in energy consumption by air conditioning devices in vehicles, longer life of tyres and significantly lower damages to road surfaces [14]. The advantage of such solution is also making use of the space taken for road belts and decreasing of CO_2 emissions to the environment or creating new jobs [13].

There are also other ways and methods of using photovoltaics technology on the roads, e.g. lighting the road using the LED supplied with solar energy [15]. It is worth mentioning that lighting of roads improves the safety of traffic participants significantly.

Photovoltaic systems are economic and environment friendly solutions both at locations where connection to the existing power grid is impossible and in towns where such connections happen to be costly. Road signs supplied with solar energy provide good visibility even from long distances and during bad weather conditions. They also allow signage of every high risk location on the road [16].

Photovoltaics also has other applications in road infrastructure devices. Increasingly frequently we can see point objects supplied with solar energy i.e.: parking fee collection points, street lamps or lighting of pedestrian crossings. Photovoltaic panels' applications in Poland could be observed the most frequently along national roads and motorways, in most cases in places of roads modernisation or construction, places with particular hindrances to traffic, etc.

Location photovoltaic panels along the public roads can have a huge role in education—will get used to the new billowing RES and persuade and encourage prosumers to install photovoltaic systems in the future.

4 Photovoltaics Use on Roads Administered by GDDKiA Branch in Olsztyn

A study of transport system development and the status of development may and should use the potential of spatial information systems in the areas of both databases and analysis and modelling tools. Within both the first and the second area it is worth to take into consideration both the known base solutions and new, complementary techniques and data sources [17].

Within the area of Warmińsko-Mazurskie voivodship, General Directorate of National Roads and Motorways administers sections of express roads S7, S22 and S61 as well as sections of national roads number: 15, 16, 51, 54, 58, 59, 63 and 65. Currently there are no motorways in the area of the region. On the Governing GDDKiA in Olsztyn total is 1300, 343 km of national roads. The distribution and technical classes of national roads in the region are presented in Fig. 1 and Table 1.

During the recent time, construction works in Warmińsko-Mazurskie voivodship were carried out on 88 km of national roads of which construction of the express roads S7 (61 km) and S51 (6 km) involved 67 km. The works were carried out on two sections: Pasłęk—Miłomłyn with the length of ca. 37 and 31 km section Olsztynek—Nidzica including Olsztynek bypass on the road S51. Those projects were co-financed by the European Union within the framework of the Operational Programme Infrastructure and Environment. Funds of the same Programme are also applied for the 8.2 km section of the national road number 16 from Biskupiec to Borki Wielkie.

Fig. 1 Rough location of points on the national road No. 16 (Gietrzwałd)

Construction of 4.8 km long Ełk bypass in the course of the national roads number 16 and 65 has been completed. The bypass was constructed using the funds of the Operational Programme Development of Eastern Poland.

Another project implemented from the Operational Programme Development of Eastern Poland—Olecko bypass 7.6 km in length in the course of the national road number 65 is nearing completion. During 2012, two bridges on national roads have been commissioned for use. In Iława, a new arch bridge was constructed on the national road number 16 and in Braniewo, on the national road No. 54 the bridge over the Pasłęka river has been rehabilitated.

Based on the information obtained from GDDKiA branch in Olsztynie photovoltaic panels are applied in 95 locations. The specification for individual sections of national roads in the region is presented in Table 2.

In Warmińsko-Mazurskie voivodship, photovoltaic panels are used mainly with warning signs. They are located in areas of open spaces at locations of crossings (narrowing of road belt), pedestrian crossings and viaducts. Analysis of the use of photovoltaics in the region confirms that its application on newly constructed or modernised sections of roads (e.g. Gołdap bypass) is justified.

5 Application of GIS Tools for Identification of Road Infrastructure Elements Supplied with Solar Energy

5.1 Geographic Information Systems (GIS)

GIS is a system of software, hardware, data, personnel operating the system and methods for data development, handling, processing and analysing [18]. The main GIS functionalities include acquiring, verifying, collecting, integrating, processing and sharing of spatial data (information on the geographical space).

Table 1 List of national roads administered by GDDKiA branch in Olsztyn

Number of road	Course of the road in Warmińsko-Mazurskie voivodship	Class of road	
		Section of the class	Class
7	Border voivodship–Elbląg–Ostróda–Olsztynek–Nidzica–border voivodship	Border voivodship–Elbląg	GP
		Elbląg bypass	GP/S
		Elbląg–Kalsk	GP/S
		Kalsk–Miłomłyn	GP
		Miłomłyn bypass	S
		Miłomnyn–Ostróda–Olsztynek–Nidzica–border voivodship	GP
15	Border voivodship–Nowe Miasto Lubawskie–Lubawa–Ostróda	Border voivodship–Nowe Miasto Lubawskie–Lubawa–Ostróda	GP
16	Border voivodship–Kisielice–Iława–Ostróda–Olsztyn–Barczewo–Biskupiec–Mragowo–Mikołajki–Orzysz–Ełk–border voivodship	Border voivodship–Kisielice–Iława–Ostróda–Olsztyn–Barczewo–Biskupiec–Mragowo–Mikołajki–Orzysz–Ełk–border voivodship	GP
22	Border voivodship–Elbląg–Chruściel–Grzechotki–stateborder	Border voivodship–Elbląg	GP
		Elbląg–Chruściel–Grzechotki–state border	S
51	State border–Bezledy–Bartoszyce–Lidzbark Warmiński–Dobre Miasto–Olsztyn–Olsztynek	State border–Bezledy–Bartoszyce–Lidzbark Warmiński–Dobre Miasto–Olsztyn–Olsztynek	GP
53	Olsztyn–Pasym–Szczytno–Rozogi–border voivodship	Olsztyn–Pasym–Szczytno–Rozogi	GP
		Rozogi–border voivodship	G
54	Chruściel–Braniewo–Gronowo–state border	Chruściel–Braniewo–Gronowo–state border	GP
57	Bartoszyce–Bisztynek–Biskupiec–Dźwierzuty–Szczytno–-Wielbark–border voivodship	Bartoszyce–Bisztynek–Biskupiec–Dźwierzuty–Szczytno–Wielbark–border voivodship	G
58	Olsztynek–Zgniłocha–Jedwabno–Szczytno–Babięta–Ruciane Nida–Pisz–Biała Piska–border voivodship	Olsztynek–Zgniłocha–Jedwabno–Szczytno–Babięta–Ruciane Nida–Pisz–Biała Piska–border voivodship	G
59	Giżycko–Ryn–Mrągowo–Piecki–Nawiady–Stare Kiełbonki–Rozogi	Giżycko–Ryn–Mrągowo–Piecki–Nawiady–Stare Kiełbonki–Rozogi	G
63	State border–Węgorzewo–Giżycko–Orzysz–Pisz–border voivodship	State border–Węgorzewo–Giżycko–Orzysz–Pisz–border voivodship	GP
65	State border–Gołdap–Olecko–Ełk–border voivodship	State border–Gołdap–Olecko–Ełk–border voivodship	GP

Table 2 Use of photovoltaic panels for signage on national roads administered by GDDKiA branch in Olsztyn

Number of road	Quantity of locations	Quantity of panels	Location
7	23	27	Junction, viaduct
15	4	4	
16	31	31	Bypass Wój-towo, crossroad
22	–	–	–
51	3	6	Crossroad, crosswalk
53	4	4	Road
54	–	–	–
57	–	–	–
58	1	1	Road
59	7	8	Crossroad
63	–	–	–
65	22	22	Bypass Gołdap

GIS provides the user with the opportunity to merge descriptive data on objects with information on their spatial location, and also allows thematic mapping, performing spatial analyses, and formulating conclusions.

5.2 MapInfo Professional Software

MapInfo Professional is a product of the MapInfo Corporation company, being one of rather commonly used programs supporting geographic information systems in addition to such packages as ArcGIS, GeoMedia, or Quantum GIS. MapInfo is included in the group of programs described as "desktop GIS". It is distinguished by low system requirements, relative user-friendliness and, at the same time, high level of functionality.

Basic tasks to be accomplished using the MapInfo include: (1) creation of spatial databases, management of numerical map layers and tables of descriptive data, (2) making use of external sets of data (of various formats and locations) through ODBC import or connection, (3) searching for and transforming data using SQL, (4) vectorisation and edition of the geometry of object, imaging data input, (5) statistical calculations, measurements, calculations of the location, length and surface of objects, (6) spatial analyses, determining relationships between objects, and syntheses (e.g. regionalisation), (7) geocoding—making use of address information for the localisation of objects and network analyses, (8) editing cartographic presentations, general geographical and thematic maps (choropleth maps, diagram maps, dot map, etc.), (9) creating, publication and printing reports [19].

MapInfo Professional provides functions which allow connecting with the WMS (Web Map Services) and WFS (Web Feature Services) services. Thanks to these options of the program, it is possible to e.g. make use of the resources of Polish Geoportal, and show of the other phenomena.

5.3 Thematic Maps

The most efficient way to present a given phenomenon in space, and determine the variation of the spatial value, density, or intensity of geographical phenomena, as well as relationships between them, is through thematic maps, which provide the visualisation of specific and socio-economic issues and phenomena. Thematic maps are graphic material supporting decision-making processes of various institutions and organisations implementing socio-economic strategies and programmes. An increased interest in such maps stimulates searching for new contents which they may present [20].

Thematic maps as created in the MapInfo constitute subsequent layers in the database. These were edited on the basis of spatial objects contained in the newly-created elements of road infrastructure database. Descriptive data from multiple tables may be used through SQL queries.

For a given layer, multiple alternative presentations of the same issue may be prepared. A significant feature of thematic overlays is the dynamic refreshing thereof during the edition of attribute values. This allows maintaining the on-going relevance along with the permanent expansion of the RES database.

6 Creating the Spatial Database in MapInfo for Identification of Road Infrastructure Elements

Based on the information obtained from GDDKiA, the database concerning use of photovoltaic panels in signage on national roads administered by the branch in Olsztyn was developed.

In the data obtained from GDDKiA, location of photovoltaic panels is defined by the number of the distance marker. Given that the average distance between the distance markers obtained was 1,000 m, generally available map portals were used to increase the precision of geocoding for the purpose of identification of the location of individual photovoltaic panels. Additionally, using them allowed determination on which side of the road section the photovoltaic panel is situated as geocoding would position the point automatically on the road axis.

The precise location of the object was possible by using the Google Maps and Street View service (Fig. 2).

For the purpose of confirming the object location identification correctness, the nearest distance marker was located and the station value was read.

Data export to the tabulation format allowed automatic presentation of points in MapInfo Professional (Fig. 3).

Fig. 2 Object identification in space on the national road No. 16: point 38 Gietrzwałd (126 + 250 km)

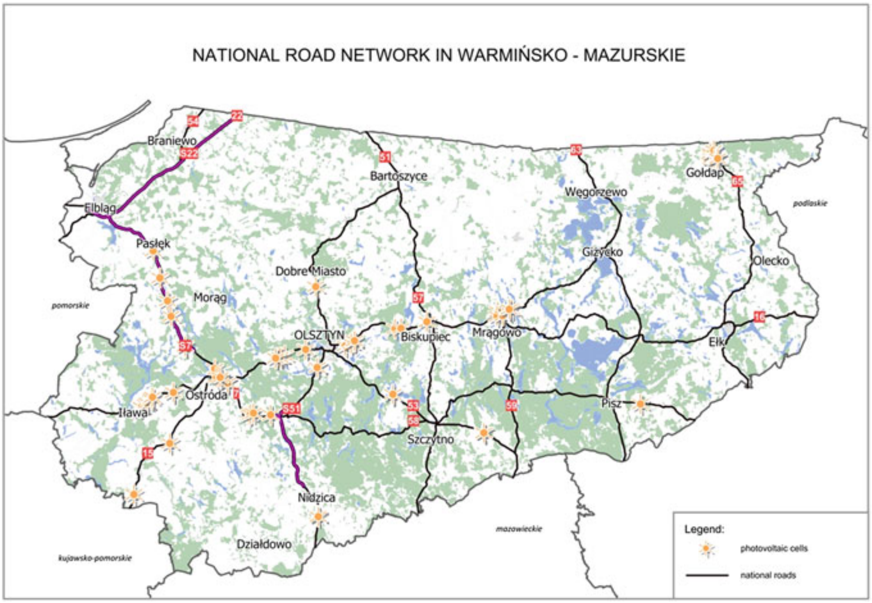

Fig. 3 Distribution of national roads in Warmińsko-Mazurskie voivodship with photovoltaic systems

Very dynamic development of the road network during the recent years and increasingly frequent use of photovoltaic cells in road infrastructure caused that for many sections of roads the presentation (Street View) allowing placement of the cells on the map has not existed yet (e.g. Olecko bypass). According to the data presented in the portal, satellite images used for locating the cells were taken in

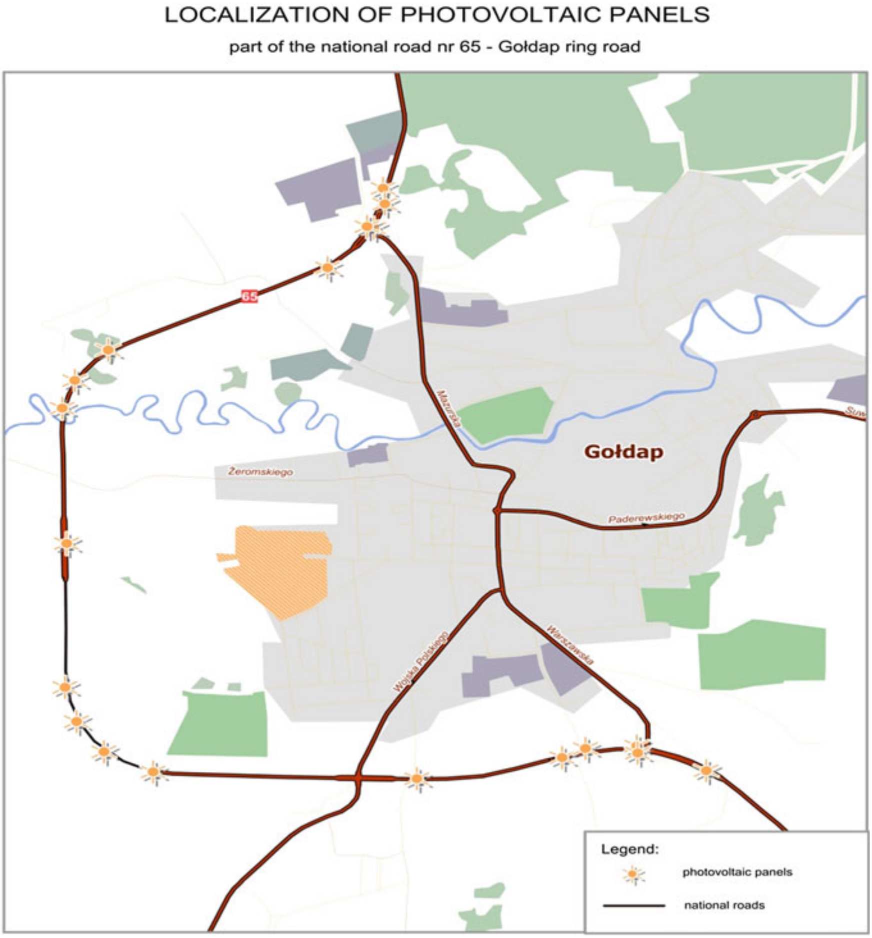

Fig. 4 Location of photovoltaic system on the Gołdap bypass

2013 while the data for Street View was obtained during the period of July–August 2012. Moreover, new photovoltaic cells are installed on the long existing sections of roads (and hence on the resulting map individual panels are missing) (Fig. 4).

7 Conclusions

Transport is one of the most important factors determining socioeconomic development of the country. Modern infrastructure and effective transport system support spreading the economic growth of strong centres over those parts of the country which, because of absence of good territorial access remain stagnant. Warmińsko-Mazurskie voivodship is an example of such a region in Poland. Poorly developed network of national roads and absence of motorways determine treatment of that region as peripherally located, i.e. a region with limited territorial access. The technical status of the roads is also unsatisfactory. Based on the conducted analyses of photovoltaics use along the roads administered by the General Directorate of National Roads and Motorways in Olsztyn up to date it can be concluded that the potential for applying solar energy is unlimited. Photovoltaic cells have been applied in 95 locations and to a limited extent only, i.e. for lighting the warning and information signs. In the analysed region, so far, photovoltaics has not been used for lighting the variable content signs.

Application of photovoltaic panels in Poland represents a new solution but, as it can be seen, an increasingly popular one. The possibilities of installation allow stating that photovoltaics is the most appropriate renewable energy source for use in road infrastructure. It works excellently in lighting road signs (information and warning). Given the plans for the ITS development, it should also find application in development of the global/mobile transport system supported by the EU. Thanks to the solar energy, the Intelligent Transport System could be implemented wide scale and outside urbanised areas. The system based on power from photovoltaics will allow presenting the current situation on the road in hard to access locations where traditional power grid is absent. General Directorate of National Roads and Motorways conducts monitoring of roads, it checks the weather conditions and provides information on road works. However, the range of services provided and information collected is of local nature while the intelligent transport system should provide at least regional and ultimately global coverage. Wider scale use of photovoltaics would contribute to ITS development. The Directive on … also draws attention to application of new solutions based on renewable energy.

For the future, development of motorisation powered by electricity is projected. It is important that the power should originate from renewable sources. Photovoltaics may play an immense role also in this case—it may be used for construction of fast loading stations in, e.g. traveller service points. Based on the solar energy cameras could be installed for traffic and safety control on roads. The need exists for creating a consistent and efficiently functioning transport system integrated with the European and global system. According to the authors, the European system of information on the current situation on the road using GIS and GSM should be implemented as fast as possible. Photovoltaics as environment friendly renewable energy source easy for installation and working under all conditions should find wider use in road infrastructure, among others in the Intelligent Transport System development.

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