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USING SPACE SYNTAX METHOD AND GIS-BASED ANALYSIS FOR THE SPATIAL ALLOCATION OF ROADSIDE REST AREAS

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Abstract. A well-grounded system of Roadside Rest Areas (RRA) for transit travellers and local inhabitants in Latvia and Lithuania is absent. To select places for the location of RRA on Latvian–Lithuanian cross-border roads space syntax method and GIS-based analysis was used. The aim of this article is to present the developed methodology, results of the performed research and to lead discussion for the further development and applicability of the methodology. The application of space syntax method to nine transit roads in Latvian–Lithuanian border zone reveals that considering both local and regional contexts three roads or their parts could be recommended for the location of RRA. For the more precise location of RRA GIS-based method was developed. This method includes the GIS capabilities of information collection, spatial analysis and multi-criteria (eight criteria were selected) evaluation. The main proposed methodical stages are: creation of the thematic GIS database; formulation of RRA sites selection criteria, division of the analysed road into intervals, and assignment of attribute data according to the criteria to the road intervals; generation of buffer zones for the analysed road and evaluation of them according the selected criteria; assignment of values provided to the buffer zones to the road intervals attribute data and total rating of roadside area potential to equip rest areas; elaboration of road buffer zone area suitable for the location of RRA.

Keywords: road; rest area; GIS; space syntax; cross-border zone.

Introduction

We live in the global world where external flows of people, information, materials and energy for local territorial systems quite often become more important than internal ones. In such situation logistic activities, transit roads and road infrastructure become extremely important from cultural, economic, social points of view for both local and global territorial systems.

Significance of sustainable development puts additional requirements to the development of transit corridors, related to more harmonious ecological, social, economic and cultural development of the regions and the corridors itself. Questions of sustainable development of transit roads infrastructure are addressed in European Union Strategy for the Baltic Sea Region (EC 2009). Protection of available resources and multifunctionality of the spatial structures becomes relevant in the context of sustainable development in the Baltic Region because of its small size and inevitable, at least partial, integration of external and internal transit users of the road infrastructure. Well-grounded location of the subsystem of road rest areas is a significant aspect of sustainable development of transit corridors in the Baltic States. However, despite its obvious necessity, the above mentioned infrastructure practically does not exist in the Baltic States.

Solving this problem Latvian Transport Development and Education Association in cooperation with Latvian National Association of Haulers (LANA, *http://www.lana.org.lv*), Kaunas University of Technology (Lithuania, *http://ktu.edu*) and Lithuanian National Association of Forwarders and Logistics (LINEKA, *http://www.lineka.lt*) implemented the project 'Concepts of roadside infrastructure and rest areas' within Latvian–Lithuanian Cross Border Cooperation Program 2007–2013. This project is aimed to provide methodological support for planning and development of roadside infrastructure and development of safe parking and rest areas along the E-routes in Latvian–Lithuanian cross border area in order to encourage safe, quick and efficient movement of people, goods on state and transit roads of Latvia and Lithuania. The project promotes the concept of modern, comfortable, safe and secure rest areas, which are considered to be an approved tool for tackling problems of cargo safety, drivers' and passengers' safety. The main project issues cover cargoes and pas-

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sengers' security, transportation service quality, roadside environment protection and tourist support. The main target groups are state institutions, municipalities, non-government organizations, cargo carriers, local communities' population and visitors of the both countries.

Under the frame of this project there was prepared the integrated methodology for identification of Roadside Rest Areas (RRA).

Because of the small traffic flows in Latvian–Lithuanian border zone the RRA should perform a double role: they should offer necessary services for international travellers and, at the same time, act as specialized small central places or part of the central places for local inhabitants travelling inside Lithuania and/or Latvia, e.g. in some cases RRA can help to satisfy the need for local infrastructure in areas of urban sprawl. It means that RRA should be planned in the places that are the most suitable for both functions.

The best locations for RRA for international transit travellers could be modelled on the base of many criteria, but in all cases it depends on the real transit roads. Those are the following in the investigated area: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils–Rēzekne; E77 Kelmė–Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; A11–A13 Klaipėda–Liepāja; E272 Ukmergė–Vilnius; P70 Panevėžys–Kupiškis–Rokiškis–Daugavpils; P73 Subate–Nereta–Vecumnieki, P89 Pasvalys–Biržai–Ķekava (total length of 1421 km) (Fig. 1).

The best locations of RRA for local inhabitants depend on such factors as accessibility for the inhabitants, central place phenomenon, suitability of location for accidental local travellers, etc. Selection of the most suitable locations for RRA from the point of view of local users was performed in two steps. Identification of the optimal segments of the roads for RRA allocation at the regional and national levels was based on Space Syntax methodology. It allowed identifying the following road segments: the roads which are the most often chosen ones for all potential travels by both national and international travellers (fast choice values of Space Syntax); the roads that provide access to the biggest number of

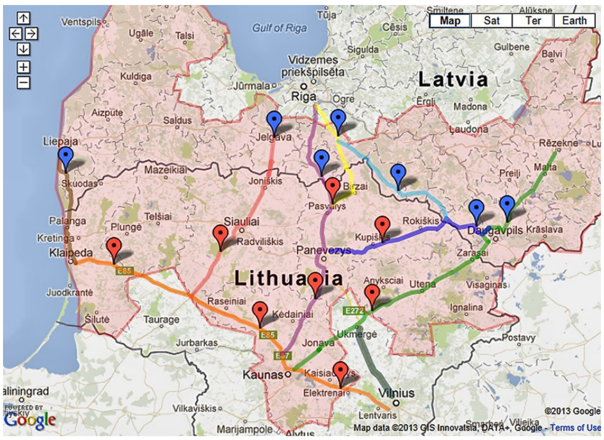


Fig. 1. Project area with the main transit roads in Latvian–Lithuanian cross border area

other roads and travel directions (control values); the road segments that are the most easily accessible within both whole investigated area and specified shorter radius; etc.

GIS databases were used for more precise allocation of RRA at the local scale. Cultural and natural heritage, landscape features, existing urban formations and roadside infrastructure, etc., were taken into consideration when the GIS-based method was applied.

The aim of this article is to present the developed methodology and results of the performed research and to lead discussion for the further development of the methodology, its applicability etc.

1. Methods

The most often space is analysed from the point of view of territorial theory, semiotics, or as an objective environment without the social content. Form of space is more often seen as an object of investigation instead of spatial universal patterns. Space syntax theory developed by Hillier (2007) focuses on spatial-social dimension of space and evaluates patterns or genotypes of spatial environment from more systematic point of view. Space syntax model is widely used for analysis and prognosis of meta-usage of urban public spaces and influence of spatial characteristics on human behaviour, e.g.: identification of the routes most often chosen for transit; identification of strategic positions for logistics inside the city; evaluation of the influence of spatial structure on crime in public spaces; etc. Space syntax analysis considers two types of city users: transit and local. Space syntax models have never been used at the regional level, but the method of logical analogy allows at least partial application of space syntax analysis at the regional or metropolitan scale at least for local transit users or people who do not use the roads as spaces of local social interaction. At the regional level, the transit users could be divided into two groups: international transit travellers and local transit travellers or inhabitants of Lithuania and Latvia travelling inside the country. Because of the selected research area the needs of the local transit travellers are modelled while using space syntax method.

These are the essential features of the systems of regional roads and city streets that allow for the analogy:

- a-locality of urban way of life and processes of metropolization;
- appearance of peripheral and edge city models, urban sprawl and loss of integral spatial composition in those models;
- relatively small size of investigated areas (Latvia and Lithuania) that, from the point of view of journey time, could be compared to some big cities in the world;
- high level of mobility of inhabitants;
- hipper-consummation and usage of countryside landscape just as 'nice places' and its commodification;
- globalization and technological evolution of society, which changed classical specialization of

urban and rural zones; new technologies such as urban agriculture;
- metropolization processes and development of integrated urban regions.

The method of space syntax if applied at the regional level allows modelling influence of spatial network on behaviour of local transit travellers and allocation of the most important meta-functions related to the roads from the point of view of social, economic, and cultural dimensions. Method is based on analysis of some graph features of the street-road network, e.g. integration, control, fast choice, depth, etc. Usage of the method is based on logical analogy between urban street structure and road structure at the regional-national level.

Identification of the most suitable zones for RRA from the point of view of local transit travellers was performed in the following steps using the method of space syntax:
- Axial maps of Latvia and Lithuania were prepared. Because of the big amount of axes in the map, more conceptual then visual perception of the big segments of roads and limited reflection of changed road line angles in the conceptual perception or mental maps (e.g. city image by Lynch (1960)) the continuity lines were modelled in the maps. It means that all changes of directions up to 35 degrees were not considered as changes of directions; as a result two segments of road/axes connected at the angle smaller than 35 degrees were modelled as one axe.
- Space syntax method was used to analyse the road network characteristics. It was done in three stages: analysis of Lithuania as an autonomous territory in social, economic, cultural terms; analysis of Latvia as an autonomous territory; analysis of both territories together to identify the potential role of border zone for the local users. While analysing the Lithuania three categories of roads were used in the model: highways, national, and regional roads. In Latvia the main roads, 1st class, 2nd class roads were used in the model. While modelling the both territories together the only two highest categories were used as the most relevant and potentially usable for international journeys of local inhabitants. Important note: only the network characteristics of the roads were modelled. The physical characteristic of the precise roads were not considered.
- The following aspects of the road networks were analysed:
  - Fast choice – the most often used roads for all possible journeys from/to all possible points of the network were identified. It represents the highest probability of the biggest number of the local traffic and accidental passers.
  - Control – the roads that allow entering the biggest number of other roads were identified. These roads are strategically important axes for logistics in the country and are the most logical point for placement of some elements of national transport infrastructure, e.g. gas stations, logistic terminals, etc.
  - Global integration – reachability of the axes was evaluated. These roads attract/cause the most intensive land use besides the road as streets do in the city. Using analogy with urbanism these axes can help to identify axes in metropolitan areas, edge or peripheral city, location of big multifunctional RRA. Axes of global integration form the urban frame of the country as an opposition to nature frame as well.
  - Local integration identifies reachability within limited distance/radius. In presented investigation radius was established as 3 conditional steps – changes of direction of movement as the basic indicator used in space syntax modelling. The result allows modelling the local urban frame.
  - Depth – the most shallow, multi-functional zone of the investigated area was identified. In urban case it demonstrates multi-functionality of the usage of public spaces itself. Because roads are not used as street spaces then, in conducted investigation, it could be seen as additional check or identification of catalyser for the axes with the highest values of integration. It could be concluded from logical sequence: in urban scale multi-functionality of spaces attract more users and more users attract more objects besides the public spaces.

Layer overlay method integrates all above mentioned results of space syntax modelling. The most overlapping zones, that coincide with the international transport transit roads as well, are considered as the most suitable for RRA from the point of view of local users and international traffic. Additional analysis for more precise selection of RRA sites on the chosen road segments could be performed on the base of the received results, e.g. the GIS databases could be used for more precise location of RRA within the given road segments.

Today, GIS is an essential tool for implementing sustainable metropolitan spatial planning, assessment of the environmental potential, and impact on the environment, to develop simulation models for spatial development and resolve conflicts in land use planning (Sheina *et al.* 2010; Zhang *et al.* 2012; Carsjens, Ligtenberg 2007; Herrmann, Osinski 1999; Dai *et al.* 2001; Lenz, Beuttler 2003). GIS can be also used for the assessment of existing land-use sustainability level, for example: using game theory, adapted to GIS urban compactness level is evaluated (Turskis *et al.* 2006).

GIS is also used for the planning of different spheres of activity and objects. Plans of city infrastructure and eco-compensational areas – green infrastructure and other special plans are prepared using GIS (Coutinho-Rodrigues *et al.* 2011; Chang *et al.* 2012; Sheina *et al.* 2010; Joerin *et al.* 2001). GIS capabilities are used for the assessment of areas recreational potential on the basis of objective indicators (Sheina *et al.* 2010) and integrating public opinion (Kienast *et al.* 2012; Bhat, Bergstrom 1997); planning the development of tourism (Bahaire, Elliott-White 1999; Boers, Cottrell 2007); planning protected areas (Brown, Weber 2011), etc.

While assessing the recreational potential of the areas and planning tourism development, GIS capabilities are used for data integration and management; inventory of recreational resources; designation of areas for various purposes (economic activities, scientific research, conservation, etc.) using layer overlay method; land use analysis and environmental impact (including visual) assessment (feasibility studies and buffer zones generation); assurance of public participation in the planning process (Kienast *et al.* 2012; Boers, Cottrell 2007; Bhat, Bergstrom 1997; Bahaire, Elliott-White 1999).

Most commonly used methods of spatial analysis are: layer overlay, buffer zones generation, optimization, measurement, and so on.

In the most described cases, capabilities of GIS and multiple criteria decision analysis are integrated (Sheina *et al.* 2010; Joerin *et al.* 2001; Zhang *et al.* 2012; Coutinho-Rodrigues *et al.* 2011; Turskis *et al.* 2006; Dai *et al.* 2001). Multi-Criteria Decision Analysis (MCDA) methods generally fall into three groups: 1) outranking models, 2) value measurement models, 3) goal, aspiration or reference level models (Belton, Stewart 2002). Methods in brief are described in the Table. Any of these methods can be applied to solve spatial planning problems. Each of them has its own advantages and disadvantages, so it often uses the combinations of MCDA methods. The most commonly used methods are: ELECTRE, SAW, TOPSIS, AHP and others.

As the purpose of the international project is to provide the technical and methodological tools for planning and development of roadside recreational infrastructure along the E-routes in Latvian–Lithuanian cross border area, GIS tools are important in terms of determining the localization of RRA sites, namely here we are dealing with a particular object localization problem. To solve this problem, it is necessary to establish the site assessment criteria, taking into account the specific characteristics of the localized object and the environmental (social, economic, ecological) sustainability indicators, to distinguish environmental factors relevant to a particular object (RRA) which have to be assessed, to assess the area according to the selected criteria and to identify optimal locations for RRA. For this purpose spatial analysis techniques of layer overlay and buffer zones generation combined with capabilities of MCDA may be used.

The main proposed methodical stages of RRA sites selection adjacent to cross-border roads using GIS are established considering theory and practice of GIS use for solving problems of particular object localization. They are the following:

- creation of the thematic GIS database;
- formulation of RRA sites selection criteria, division of the analysed road into intervals, and assignment of attribute data according to the criteria to the road intervals;
- generation of buffer zones for the analysed road and evaluation of them according to the selected criteria;
- assignment of values provided to the buffer zones to the road intervals attribute data and total rating of roadside area potential to equip rest areas;
- elaboration of road buffer zone area suitable for the location of RRA (Fig. 2).

2. Identification of the Most Suitable Zones for RRA Using the Method of Space Syntax

2.1. Establishment of the Most Suitable Road Segments in Lithuanian Context

The analysed international roads in the territory of Lithuania are: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils; E77 Kelmė–Šiauliai–Jelgava; A11–A13 Klaipėda–Liepāja; E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; P70 Panevėžys–Kupiškis–Rokiškis–Daugavpils; P89 Pasvalys–Biržai–Ķekava.

5% of the shallowest axes coincide with the following transit roads segments within Lithuania: the bigger part of the road E85 except its segment from Klaipeda to Rietavas municipality; part of E262 (Kaunas–Ukmergė); part of E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys– Ķekava (Fig. 3).

Table. The main methods of MCDA (Polatidis *et al.* 2006; Punys *et al.* 2011; Mendoza, Martins 2006)

Groups of MCDA methods	
1. Outranking models (for instance, ELECTRE, PROMETHEE, REGIME) Alternative courses of action are compared pairwise, initially in terms of each criterion in order to identify the extent to which a preference for one over the other can be asserted. In aggregating such preference information across all relevant criteria, the model seeks to establish the strength of evidence favouring selection of one alternative over another.	*2. Value measurement models* (for instance, MAUT, SMART, SAW, AHP, TOPSIS) Numerical scores are constructed in order to represent the degree to which one decision option may be preferred to another. Such scores are developed initially for each individual criterion, and are then synthesized in order to effect aggregation into higher level preference models.
3. Goal, aspiration or reference level models Desirable or satisfactory levels of achievement are established for each criterion. The process then seeks to discover options which are closest to achieving these desirable goals or aspirations.	*4. Other models* For instance, NAIADE (Approach to Imprecise Assessment and Decision Environment), FLAG, SMAA (Stochastic Multiobjective Acceptability Analysis)

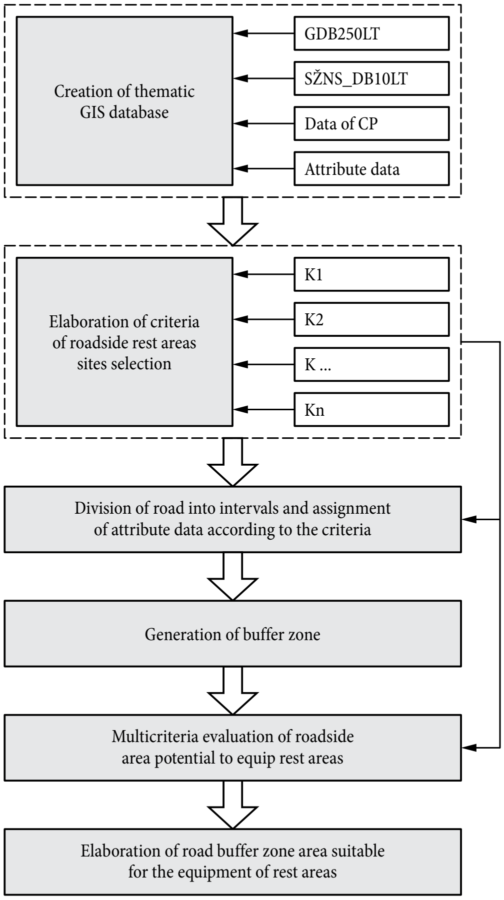


Fig. 2. Methodical stages of RRA sites selection adjacent to cross-border roads using GIS

All actual international transit roads are covered by the zone of 5% of the axes with the highest fast choice values except the road A11–A13 Klaipeda–Liepāja (Fig. 4).

The 5% zone of the highest global integration values covers the following roads: E85 Klaipeda-Vilnius (except the segment from Klaipėda to Rietavas municipality); part of E262 Kaunas–Ukmergė; E77 Kelmė–Šiauliai–Jelgava; E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys–Ķekava. The 5% zone of the highest local integration values covers practically all the analysed international transit roads except the road A11–A13 Klaipėda–Liepāja (Fig. 5).

The 5% zone of the axes with the highest control values covers practically all the analysed international transit roads except the road A11–A13 Klaipėda–Liepāja (Fig. 6).

Summarizing the research results it can be stated that in Lithuanian context the following road segments are the most suitable for the location of RRA: the bigger part of the road E85 except its segment from Klaipeda to Rietavas municipality; part of E262 (Kaunas–Ukmergė); part of E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys–Ķekava. They form the most attractive, integrating, shallow, potentially multifunctional backbone of urban frame in Lithuania.

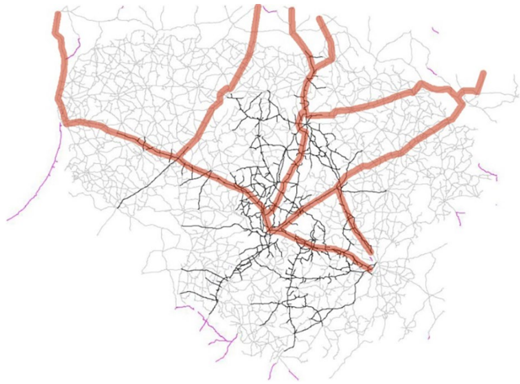


Fig. 3. Zone made by 5% of the shallowest axes and international transit roads in the border zone

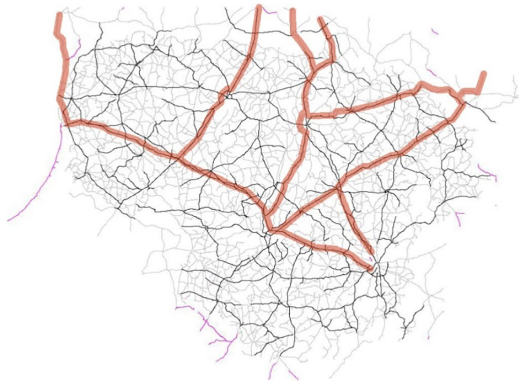


Fig. 4. 5% of the axes with the highest fast choice values

a)

b)

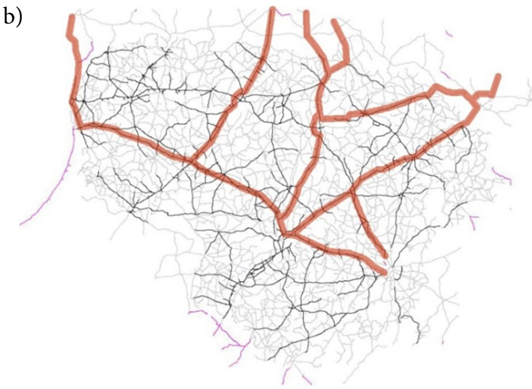


Fig. 5. 5% of the global integration axes with the highest values (a) and 5% of the local integration axes with the highest values (b)

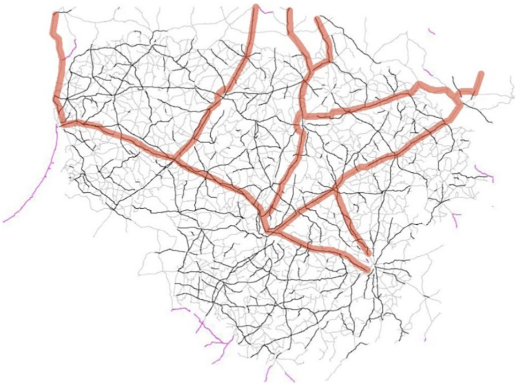


Fig. 6. 5% of the axes with the highest control values

2.2. Establishment of the Most Suitable Road Segments in Latvian Context

The analysed international roads in the territory of Latvia are: E262 Zarasai–Daugavpils–Rēzekne; E77 Šiauliai–Jelgava; A11–A13 Klaipėda–Liepāja; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; P70 Panevėžys–Kupiškis–Rokiškis–Daugavpils; P73 Subate–Nereta–Vecumnieki; P89 Pasvalys–Biržai–Ķekava.

All the analysed roads except some very small segments around Daugavpils and Biržai are within the zone of 5% of the highest control values (Fig. 7).

5% of the area of the shallowest zone contains the following roads: E77 Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava (Fig. 8).

5% zone of the axes with the highest fast choice values contains practically all the analysed transit roads except some small segment of the P73 Subate–Nereta–Vecumnieki around Nereta (Fig. 9).

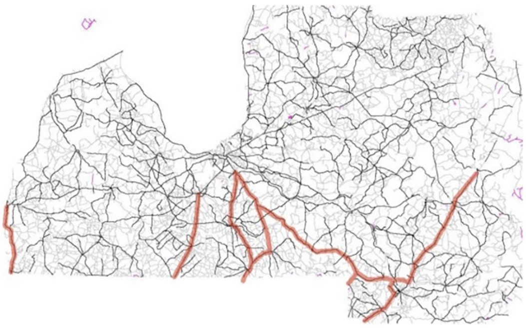


Fig. 7. 5% of the axes with the highest control values

Fig. 8. 5% of the area of the shallowest zone

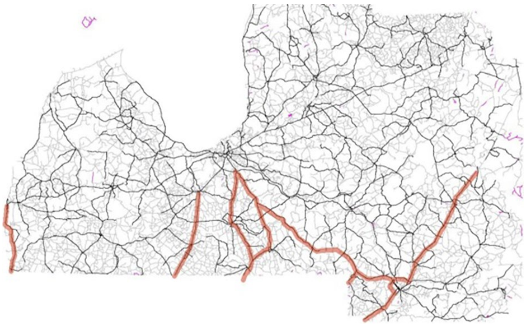


Fig. 9. 5% of the axes with the highest fast choice values

a)

b)

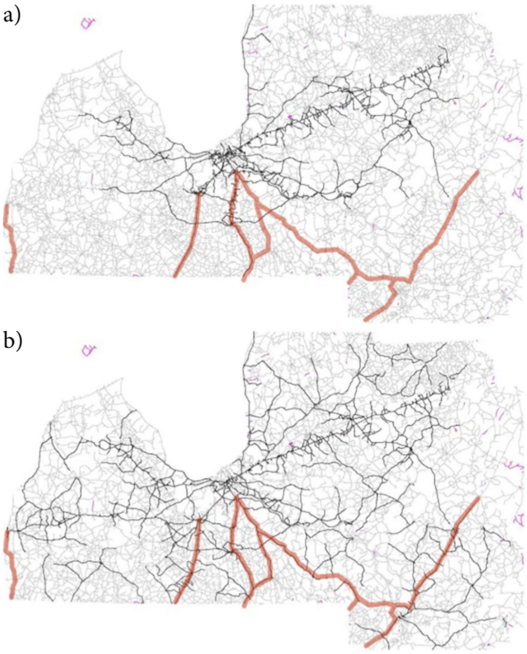


Fig. 10. 5% of the axes with the highest global integration values (a) and 5% of the axes with the highest local integration values (b)

5% of the axes with the highest global integration values coincide with the road E77 Šiauliai–Jelgava and road Ķekava–Bauska–Pasvalys. 5% of the axes with the highest values of local integration cover the following international transit roads: E262 Zarasai–Daugavpils–Rēzekne; E77 Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; segment Rīga–Stelpe–Nereta; P89 Pasvalys–Biržai–Ķekava (Fig. 10).

Summarizing the research results it can be stated that in Latvian context the following road segments are the most suitable for location of RRA: E77 Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava.

2.3. Border Zone in the Context of One Common Latvian–Lithuanian Space (Cultural, Social, Economic, etc.)

The analysed international roads in the area of Lithuania and Latvia are: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils–Rēzekne; E77 Kelmė–Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; A11–A13 Klaipėda–Liepāja; E272

Ukmergė–Vilnius; P70 Panevėžys–Kupiškis–Rokiškis–Daugavpils; P73 Subate–Nereta–Vecumnieki, P89 Pasvalys–Birzai–Ķekava.

The 5% zone with the highest control values contains the following roads: segment of E85 Babtai–Kaunas–Vilnius; part of E262 Kaunas–Ukmergė–Utena and Daugavpils–Rēzekne; part of E77 Kelmė–Šiauliai; E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys– Ķekava except some small segments; P73 Subate–Nereta–Vecumnieki (Fig. 11).

The 5% of the area of the shallowest zone does not contain the following roads: segment of road E262 Daugavpils–Rēzekne; A11–A13 Klaipėda–Liepāja; P70 Panevėžys–Kupiškis–Rokiškis–Daugavpils; P73 Subate–Nereta–Vecumnieki (Fig. 12).

5% zone of the axes with the highest fast choice values contains the following roads: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils–Rēzekne; E77 Kelmė–Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; part of the road P73 Subate–Nereta–Vecumnieki from Rīga to Nereta, road P89 from Biržai to Stelpe (Fig. 13).

Fig. 11. 5% zone with the highest control values

5% zone of the highest global integration values cover the following transit roads: E85 Klaipėda–Vilnius; segment of E262 Kaunas–Ukmerge–Utena; E77 Kelmė–Šiauliai–Jelgava; segment of E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; small segment of the road around Stelpe; P89 Pasvalys–Biržai–Ķekava. 5% zone of the highest local integration values covers the following transit roads: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils–Rēzekne; E77 Kelmė–Šiauliai–Jelgava; E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; segment of the road P70 Panevėžys–Kupiškis–Rokiškis–Daugavpils between Kupiškis and Rokiškis; P73 Subate–Nereta–Vecumnieki; P89 Pasvalys–Biržai–Ķekava (Fig. 14).

In Latvian–Lithuanian context the following transit roads and road segments could be recommended for allocation of RRA: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils–Rēzekne; E77 Kelmė–Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; the part of the road P73 Subate–Nereta–Vecumnieki from Rīga to Nereta, the road P89 from Biržai to Stelpe.

When both local (Latvia and Lithuania separately) and regional context (Latvia and Lithuania together) is considered, the following roads could be recommended for the location of RRA: the bigger part of the road E85 except its segment from Klaipeda to Rietavas municipality; the part of E262 (Kaunas–Ukmergė); the road E67 Kaunas–Panevėžys–Pasvalys–Ķekava (Fig. 15).

It is important to note, that the observations in place, made during the inventory of existing infrastructure, revealed the following: chaotic bottom up development of road infrastructure takes place in more or less the same road segments as identified during the research. It confirms the suitability of space syntax models for application at the regional level.

More precise location of RRA within recommended segments of the roads should be done while using the methodology of use of GIS databases performing cross-border roads research and preparing concepts of RRA.

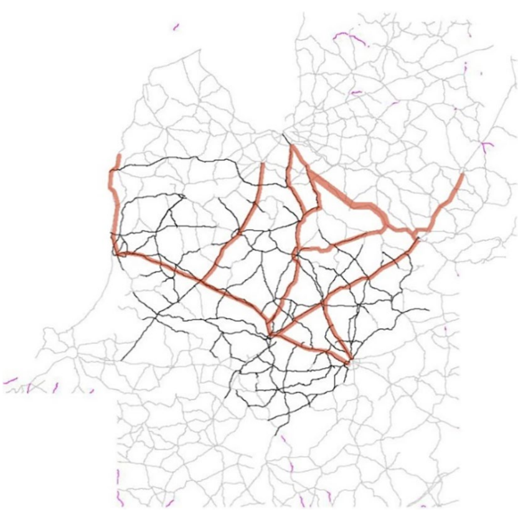


Fig. 12. 5% of the area of the shallowest zone

Fig. 13. 5% of the axes with the highest fast choice values

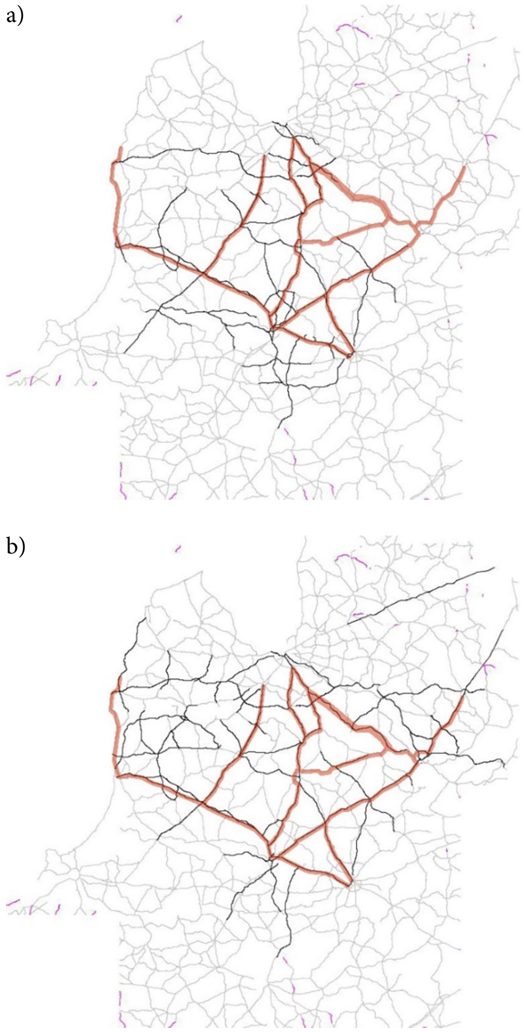


Fig. 14. 5% of the axes with the highest global integration values (a) and 5% of the axes with the highest local integration values (b)

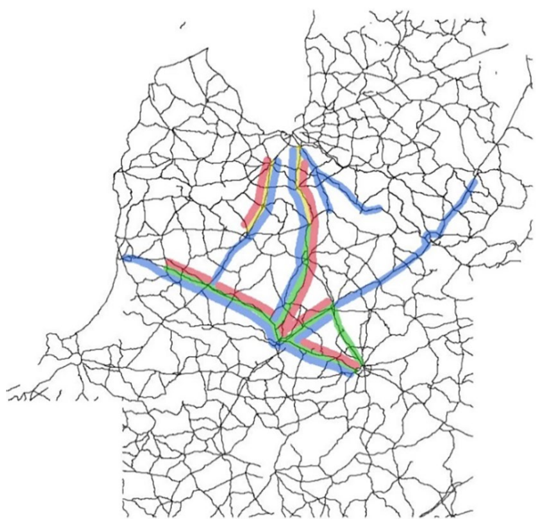


Fig. 15. The recommended road segments for location of RRA: green – Lithuanian context; yellow – Latvian context; blue – regional context; red colour means the final integrated proposal

3. Methodological Stages of use of GIS Databases Performing Cross-Border Roads Research and the Way of Their Application

3.1. Creation of the Thematic GIS Database

Arranging short rest for vehicle drivers and passengers next to the E-category roads in Latvian–Lithuanian border region, this type of recreational activity should be considered as a territorial recreation system (Kavaliauskas 1992; Bučas 2001; Gurskienė, Ivavičiūtė 2012; Boers, Cottrell 2007; Bell 2008). It consists of a territorially defined complex of vehicle drivers and passengers, recreational infrastructure and recreational resources with a common recreational stream function. Considering this systematic approach, selection criteria of GIS data necessary to determine the sites of rest areas adjacent to cross-border roads are formulated:

- detailed spatial and attribute information about physical components of environment (terrain, forests, water bodies, residential areas, roads, engineering infrastructure, etc.), which determines roadside rest area site selection;
- detailed spatial and attribute information about protected areas, objects of natural and cultural heritage;
- detailed spatial and attribute information about restrictions of land use;
- detailed spatial and attribute information about existing roadside infrastructure;
- sufficient accuracy of the spatial information for the selection of RRA sites.

A thematic database, including information on the physical environment components, protected areas, cultural and natural heritage, land use restrictions, the existing road transport infrastructure and rest areas, and etc. is created at this stage. As the basic data for the thematic database information stored in GDB250LT is used. This database does not contain information on land-use restrictions, and this information is taken from the database SŽNS_DB10LT (GIS-Centras 2012; GeoPortal 2012; NŽT 2012). To assess the prospective use and management of the areas adjacent to the roads, data of comprehensive plans of regions are also integrated into the thematic database. The results of drivers' opinion survey, traffic flow intensity measurements and results of present state analysis of the existing rest areas are integrated as attribute data too.

3.2. Formulation of RRA Sites Selection Criteria, Division of the Analysed Road into Intervals of 2 km and Assigning Attribute Data According to the Criteria to the Road Intervals

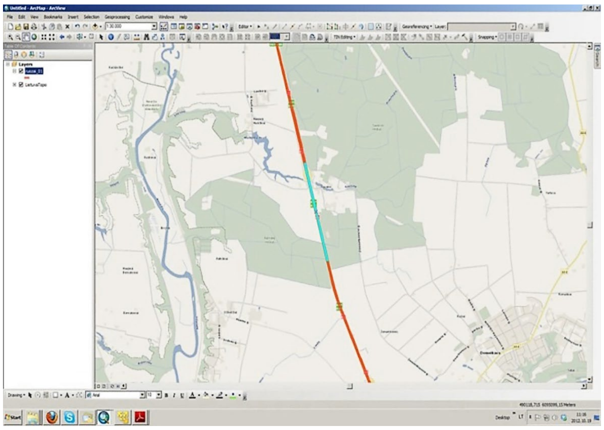
Criteria for RRA sites selection are selected on the basis of sustainable development principles, criteria and indicators (Kavaliauskas 1992; Bučas 2008, 2009; Europos urbanistikos chartija 1998; EC 2004, 2006; LRV 2009) with the purpose to identify the most attractive areas for the planned investments:

- K1 – access to residential areas (representing criteria of the socio-economic efficiency: employ-

ment and entrepreneurship development, fostering of social cohesion and inclusion, etc.);
- K2 – access to objects of natural and cultural heritage (representing criteria of heritage integrated conservation: preservation by using);
- K3 – presence of recreational infrastructure (car parking areas) and transport services (gas stations) (representing criteria of the effective use of area and other environmental resources (materials, energy);
- K4 – road safety (representing criteria of the validity of the proposed development and the optimal ratio with the real situation);
- K5 – intensity of traffic flows (representing criteria of the validity of the proposed development and the optimal ratio with the real situation);
- K6 – degree of equipment and quality of existing rest areas (representing criteria of the validity of the proposed development and the optimal ratio with the real situation);
- K7 – access to the border zone (represents ergonomic criteria);
- K8 – modal road intersection (representing socio-economic efficiency and validity criteria).

During this phase, the analysed road is divided into intervals of 2 km considering the speed of pedestrian (1.5 m/s) and in the attribute table of the analysed road as many attribute columns are created as there are selection criteria of the RRA adjacent to the cross-border roads (Fig. 16).

a)



b)

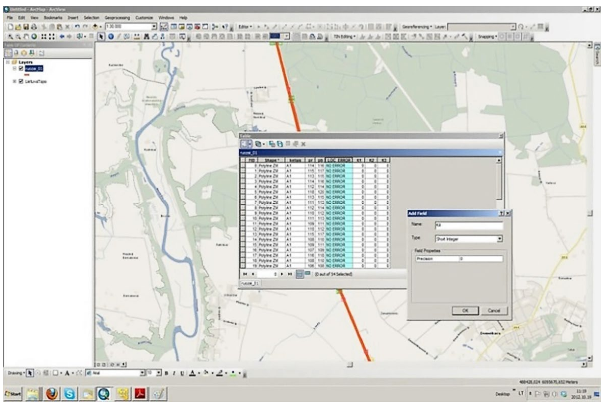


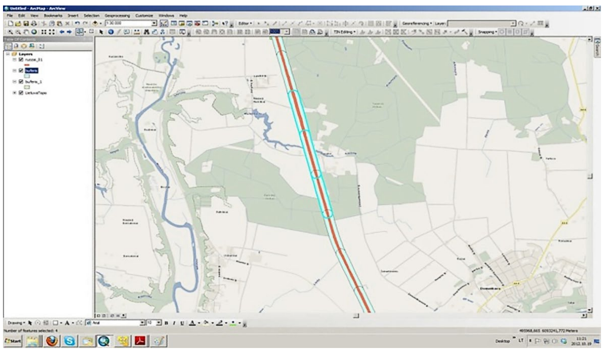
Fig. 16. Division of the analysed road into intervals of 2 km (a) and assigning attribute data according to the criteria to the road intervals (b)

3.3. Generation of the Buffer Zones for the Analysed Road and Evaluation of Them According Criteria

The following buffer zones are generated for the selected roads (Fig. 17):
- 100 m width buffer zone on both sides of the road from its axis, in which RRA can be located (the width of the buffer zone is determined by the width of road protection zone and average distance of the existing roadside infrastructure from road axial line);
- 2 km width buffer zone on both sides of the road from its axis, to identify accessibility to residential areas and natural and cultural objects (considering the speed of pedestrian);
- 20 km width buffer zone on both sides of the road from its axis, to identify accessibility to the border zone and modal road intersection (considering the car speed and possibility to reach the object within less than 30 min).

Values in scores according to the criteria are assigned to buffer zones (100 m, 2 km and 20 km) of each road interval as attribute information at this stage. Suitability of buffer zone to equip RRA is evaluated in scores according each criterion (Fig. 17).

a)



b)

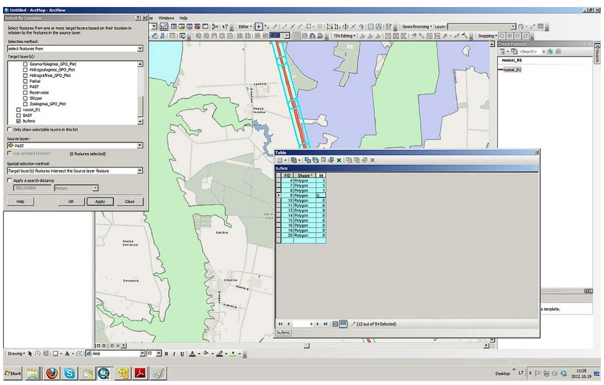
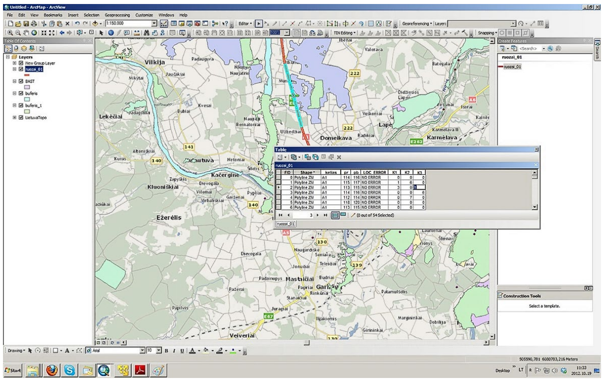


Fig. 17. Generation of the buffer zones (a) and evaluation of them according criteria (b)

3.4. Assignment of Values Provided to the Buffer Zones to the Road Intervals Attribute Data and Total Rating of Roadside Area Potential to Equip Rest Areas

At this stage, values assigned to the buffer zones of the road interval are assigned to the attribute information of the road interval and total rating of the road intervals is determined according the criteria and the total values are assigned to 100 m width buffer zone of the road interval, which can be seen as possible zone of RRA location (Fig. 18).

a)



b)

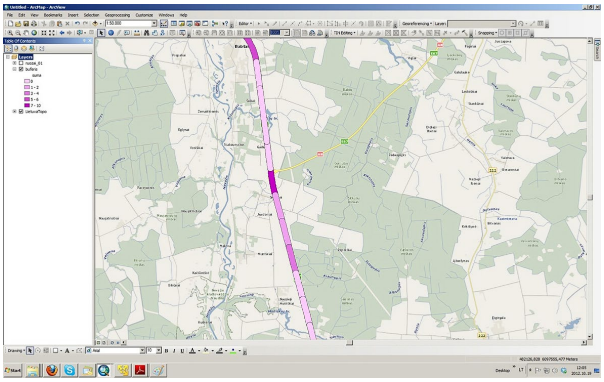


Fig. 18. Assignment of values provided to the buffer zones to the road intervals attribute data (a) and total rating of roadside area potential to equip rest areas (b)

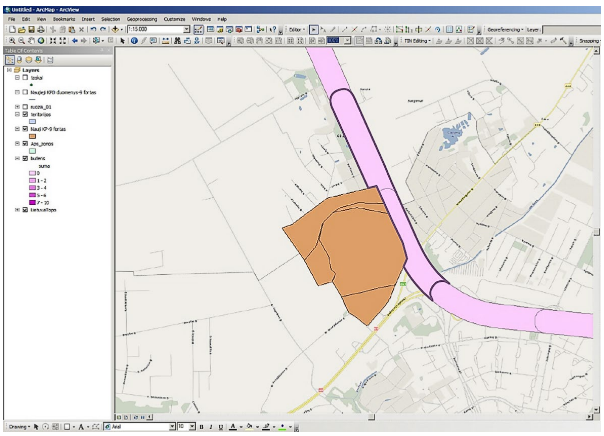


Fig. 19. Elaboration of road buffer zone area suitable for the equipment of RRA

3.5. Elaboration of Road Buffer Zone Area Suitable for the Location of RRA

At this stage, using the method of logical overlay, there are designated parts of the buffer zone falling in the forest, natural and cultural heritage sites, nature reserves, water protection belts and zones and other areas that are protected from new structures. The rest part of the buffer zone is suitable for the equipment of rest areas (Fig. 19).

Discussion and Conclusions

Space syntax model is widely used for analysis and prognosis of meta-usage of urban public spaces and influence of spatial characteristics on human behaviour. Space syntax models have never been used at the regional level, but the method of logical analogy allows at least partial application of space syntax analysis at the regional or metropolitan scale. Space syntax method can help to identify the most suitable segments of transit roads for location of RRA. It is especially applicable if we speak about RRA oriented towards both international and national users. The same methodological approach could be applied in other countries as well, especially if RRA and other complexes of road infrastructure will be used to satisfy needs of the both local and international travellers.

In Lithuanian context the most suitable for location of RRA are the following road segments: the bigger part of the road E85 except its segment from Klaipėda to Rietavas municipality; part of E262 (Kaunas–Ukmergė); part of E272 Ukmergė–Vilnius; E67 Kaunas–Panevėžys–Pasvalys–Ķekava. They form the most attractive, integrating, shallow, potentially multifunctional backbone of the urban frame in Lithuania.

In Latvian context the most suitable for location of RRA are the following road segments: E77 Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava.

In Latvian–Lithuanian context the following transit roads and road segments could be recommended for allocation of RRA: E85 Klaipėda–Vilnius; E262 Kaunas–Ukmergė–Utena–Zarasai–Daugavpils–Rēzekne; E77 Kelmė–Šiauliai–Jelgava; E67 Kaunas–Panevėžys–Pasvalys–Ķekava; part of the road P73 Subate–Nereta–Vecumnieki from Rīga to Nereta, road P89 from Biržai to Stelpe.

If both local (Latvia and Lithuania separately) and regional context (Latvia and Lithuania together) is considered, then the following roads could be recommended for location of RRA: the bigger part of the road E85 except its segment from Klaipeda to Rietavas municipality; part of E262 (Kaunas–Ukmergė); road E67 Kaunas–Panevėžys–Pasvalys–Ķekava.

More precise location of RRA within the recommended segments of the roads should be done while using other methodologies. Space syntax model could be combined with GIS analysis tools for more precise identification of the most suitable and effective location sites for RRA.

Considering necessity of sustainable spatial planning and sustainable territorial development, GIS possibilities are very high. First of all, this is unlimited amount of spatial and attribute information stored in the geo-referential databases and capabilities of its spatial analysis and modelling. Analytical methods are classified into queries, measurements, transformations (buffer zones generation, overlays, spatial interpolation), descriptive statistics, optimization, and testing of hypotheses. As for modelling, GIS enable the modelling of various activity scenarios and assess their potential impact on the environment.

In addition, capabilities of GIS spatial analysis are often integrated with multi-criteria evaluation, which is essential precondition for an optimal solution of many planning tasks. The most common multi-criteria evaluation methods used for planning purposes are methods based on similarity (preferences) assessment and benefit function (value) estimation.

Solving the particular task of geo-referential databases use for cross-border roads research (identifying potential sites of rest areas adjacent to the roads), the methodology is developed, which includes the GIS capabilities of information collection, spatial analysis and multi-criteria evaluation. Criteria of RRA adjacent to cross-border roads sites selection are formulated based on principles and indicators of urban areas sustainable development, declared at international and national political levels and theoretical works.

The main proposed methodical stages of RRA sites selection adjacent to cross-border roads are: creation of the thematic GIS database, division of the analysed road into intervals, assignment of attribute data according to the criteria to the road intervals, generation of buffer zones, evaluation of buffer zones according criteria, assignment of values provided to the buffer zones to the road intervals attribute data, total rating of roadside area potential to equip rest areas, and elaboration of road buffer zone area suitable for the equipment of rest areas using logical overlay technique.

The proposed methodology also can be used for the sites selection of other particular objects adjacent to roads when preparing special plans, for ex.: gas stations, outdoor advertisement structures, commercial centres, etc. For this purpose, the site assessment criteria, environmental factors, sizes and types of buffer zones, and other methodological aspects, relevant to a particular object, have to be established.

It also can be used in other countries. In this case, we have to consider particular legal basis and normative documents of the country, landscape characteristics, specifics of urban development processes, roads structure and way of their use, etc.

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