GIS APPLICATION FOR EVALUATING THE COST OF MULTIMODAL TRANSPORT TO TOURIST RESORTS IN ROMANIA

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Abstract
Access to relevant data provided by digital services and the promotion of open data policies are necessary conditions for multimodal travel planning. Inter-modal transport makes it possible to combine, advantageously over a given route, the specific advantages of each mode of transport, such as the flexibility of road transport, the high capacity of rail transport, the low costs of shipping and the higher speed of air transport. For this reason, the topic of the article is the provision of digital information services on multimodal travel to resorts of national tourist interest in Romania. The result is a software application in OPENGIS system, which uses ARCGIS software (NETWORK ANALYST module), ARCGIS Server and Python programming language, the design of the software being modular with a menu-based graphical interface so that it is easily accessible to uninitiated users.

Key words: Multimodal transport, Tourism, GIS, Network dataset, GTFS data, Travel cost

Introduction:
Transport is a key factor in the development of tourism, as it plays a vital role in moving tourists from their place of residence to their final destination and to various attractions. The global tourism industry is completely dependent on the safety, speed and services offered by the transport sector. Transport and travel can operate separately and independently of tourism, while tourism cannot exist without travel. Transport connects markets in tourism-generating regions to various destinations and facilitates the internal movement of visitors between the components of tourist destinations (Tache, 2019).
Building access to transport and the infrastructure of our tourist destinations, as well as the transport links between them, is crucial for the development of tourism.

The modern world transport system requires inter-modal passenger services and key aspects of their performance. Inter-modal passenger transport involves the use of two or more modes of transport in a journey and provides access to rapid transit and meets the growing needs of high-quality public transport services. The aim of the concept of inter-modal passenger transport is to make these exchanges as fast and smooth as possible in the inter-modal nodes, through access to comprehensive information, the provision of smart tickets and the safe and convenient use of inter-modal hubs. The implementation of inter-modal services in tourism will contribute to the increase of travel options, as well as to the provision of comfortable services, while increasing the efficiency of the transport system as a whole (Nikolova, 2008).

Multimodal transport combines the advantages of each mode in a single journey, such as the flexibility of road transport, the relatively high capacity of the railways and the lower costs of river and maritime transport in the best possible way (Zaheer, 2008).

There are a number of barriers to the implementation of inter-modal passenger transport (institutional, system integration, interoperability requirements) (Land and Foreman, 2001). However, the development of inter-modal transport solutions is a key area of action for urban and regional transport policies, and the role of inter-modal transport systems has become increasingly important. The inter-modal approach involves analyzing how individual modes of transport can be connected and managed as a transparent and sustainable transport system (Tache and Petrişor, 2017; Tache et al., 2020). That is, the fundamental goal of inter-modality is to integrate all modes of transport into an optimal, sustainable and ethical system. Such a system should support efficiency, safety, mobility, growth, protection of the natural environment.

The comfort and attractiveness of passenger transport systems depend to a large extent on the quality of transfers to exchanges between public transport modes. A crucial element of a successful inter-modal transport system is the coordination of hours, the synchronization of arrival and departure times as much as possible between modes of transport in order to minimize passenger travel and waiting time.

The need for inter-modal transport is also highlighted by the reduction of CO2 emissions worldwide, so the European Commission proposes several measures aimed at developing a European transport system capable of changing the balance between modes of transport and encouraging the use of multimodal transport (EC, 2011).

Inter-modal transport is characterized by a high degree of process complexity and, consequently, a high degree of complexity of IT solutions on decision support systems and their multiplication (Jakimavičius et al., 2019). Therefore, state-of-the-art models are complex and require a great deal of research effort. As a result, their practical use is very limited.

One of the most used applications in the field of GIS-T is route planning. GIS makes it possible to plan trips and find the best road, rail, air, bicycle and public or private transport route (Claramunt et al., 2000; Fletcher et al., 1995). They even allow the planning of routes
that combine different means of transport or that make optimal use of different criteria, such as the duration of the trip, the financial cost and the cultural or ecological value of the route, etc. Even in countries with poorly defined road networks and cities with complex urban structures, optimal route models are proposed at different regional and urban scales (Siangsuebchart and Winyoopradist, 2000).

A simulation model is built to evaluate solutions in terms of direct road and inter-modal costs, transit times and environmental effects. A model is implemented in a GIS application as an easy-to-use interface for decision makers (Tache et al., 2020). The complexity increases due to the incorporation of several modes of transport. ICT innovations increase data flow, improve the timeliness and quality of information, and provide the ability to control and coordinate operations in real time (Crainic and Kim, 2007).

A route optimization exercise in an inter-modal network must take into account not only the different speeds of each of the means of transport, but also the trans-shipment operating time and the waiting time. Thus, in an inter-modal network mode we can consider all the segments of a framework in which each has specific attributes and rules (Caris et al., 2008), depending on the mode of transport it represents. These segments must also add links for inter-modality, which also have attributes and rules.

The network is a system of interconnected elements, such as lines and nodes that represent a possible path from one location to another (Zhan and Noon, 1998). An important feature of the virtual network is that it allows the allocation of flows on networks between several modes of transport, allowing the representation of routes for inter-modal transport. Another feature is that each terminal is treated as a complex node, which is associated with a graph (Raicu, 2007). The graph associated with the complex node allows the description of the processes performed within it, by introducing additional arcs, to which costs, durations or other variables are attributed.

In order to determine the inter-modal transport routes and, subsequently, to analyze the options for consolidating the transport flows in the terminals, it is necessary to define a network that allows the modeling of the transfer from one mode of transport to another.

One of the main advantages of GIS is its ability to create a variety of network models through the use of arches and nodes - Analysis of route / mode choice and assessment of compromises of the inter-modal transport network (Tache and Popescu, 2014). The components of the network can be all those geographical elements that are involved in its function, such as stations, stopping places, roads, etc. These elements keep their geometry in accordance with the represented reality and will be considered arcs and nodes.

In recent years, data on general transit specifications (GTFS) have gained popularity for estimating travel time between stations, due to its interoperability in spatiotemporal analyzes. Many software packages, such as ArcGIS, have developed the toolbox to allow travel time estimation with the GTFS data format (Fayyaz et al., 2017). The capability of GTFS data is that it can power different types of transit and multimodal software applications, including multimodal trip planning, schedule creation, mobile applications, visualization, accessibility, planning analysis tools, real-time information (Antrim and Barbeau, 2013).
Starting from this theoretical context, the present study aims to design a software application in WEBGIS system that provides digital information services on multimodal travel from any locality to resorts of national tourist interest in Romania.

**Materials and Methodology:**

The necessary intelligent transport systems (ITS) are based on precise data and high-performance communication, management and analysis components, each with a distinct spatial notion (Miller and Shaw, 2015). Passengers are looking for the optimal public transport route, and their decisions are influenced by personal attributes, responses to information provided and situational factors such as time of day, mode of transport selected, purpose of journey, traffic conditions, maximum distance and maximum number of transfers (Szuucs, 2009).

The main purpose of the analysis of the designed network using public transport data is the analysis, not the travel planning. As a result, some features that would be valuable for passenger-oriented applications are not available, such as real-time transit data.

When building the virtual network, coding rules are used for real arches and for virtual arches in the transport nodes to allow the subsequent assignment of cost functions (Costescu, 2012). By transposing the transport network into a graph, the complexity of the system can be reduced, without losing the relevant information. In the case of the application, the components of the network are based on the geographical elements consisting of national roads, railways, localities and tourist resorts in Romania.

The preparation of the data, more precisely the ensuring of the coincident geometry between roads, railways, localities and tourist resorts was done within a Geodatabase feature classes. The content of the transport data set representing the source data for the network data set was classified according to the type of national roads (motorway, European road, national road, county road, communal road) and the type of railway used (road main railway, secondary railway).

Setting the network properties involves checking the coincident geometry between roads, railways, localities and tourist resorts; modeling spatial relationships for all network components and entering attribute fields for the two linear themes; thus, for the road theme as well as for the railway theme, fields containing restrictions, travel speed, road section length calculated automatically by the GIS system, time required to travel on a road or path railway section from the initial node to the final node, measured in minutes, are required.

Network connectivity defines how line and point characteristics connect to each other within the network. In this regard, we have defined different network connectivity policies for road network source subtypes and subtypes for railway network source. Connectivity policy has focused on long-distance rail transport and short-distance road transport. A great advantage in the analysis of the virtual network as close as possible to the real situation in the field was the use of GTFS data on complete data from "The train's time list document" in Romania which were added to the network data set on rail travel in ARCGIS PRO system (software that developed the toolbox to allow the estimation of travel time with GTFS data), using the Network Analyst tool.
Unfortunately, GTFS data for bus travel schedules in Romania are not available, which made it very difficult to assess the travel time from a locality to a resort of tourist interest. The solution of this impediment was made individually for each station involving inter-modal transport, and the so-called constraints representing a set of properties that are defined in the network by setting parameters on waiting times were defined based on data obtained from tourism local agencies.

ARCGISPRO software has the ability to modify the attributes of segments or impedance data for an analysis of the inter-modal network as close as possible to the reality in the field. This software capability allows us to change scenarios, evaluate results over time, and propose changes to transportation infrastructure.

After testing the desktop application, we developed a routing service for publishing a map service in ArcGIS Pro with network analysis capability enabled using the Network Analyst extension.

In the near future, this IT application will be developed as a Smartphone application both in the field of tourism and in the field of transport and spatial planning.

In this sense, the methodology used in this topic was based on the implementation of GTFS data on the running of trains in Romania in the ARCGIS PRO spatial data network and the performance of analyzes using the Network Analyst tools.

**Results and discussion:**

From a technical point of view, the computer application aims to simulate the accessibility indicator "Travel cost" (indicator that expresses the combined effect of alternative modes of transport in units of time, using the "cost" of travel on national roads and railways to Romanian territory), using the databases on the timetable of road and rail transport for the main tourist resorts.

The methods used are specific to GIS applications, more precisely the ARCGIS Network Analyst module that allows the calculation of the shortest inter-modal route or the calculation of the fastest travel cost in terms of time. In order to implement the technical solution, it is necessary to design the combined network of roads and railways to the tourist resorts of national and local interest.

The design of the road network required the updating of the spatial database with the new sections of motorways put into use and with the modification of the road classes, depending on the national rehabilitation program of the national roads. For the railway layer, the spatial database was updated with the train running schedule in the period 2021-2022. Also, GTFS data on train schedules in Romania were processed and made compatible with the GIS spatial database for railways.

In the case of localities and tourist resorts of national and local interest, the geographical positions were checked in relation to the themes of combined transport - national roads and railways, so as not to exceed the maximum allowable positioning errors.
For the topics of national roads and railways, the topology was restored, their integration was performed for the realization of the network with the help of the Network Analyst tool and the fields necessary for setting the network properties were completed. Coincident geometry was also ensured for all the topics proposed in the application, and all these themes were integrated in a Geodatabase feature classes. The theme map of the proposed application is shown in Fig. 1.

![Map of the combined network of roads and railways to the tourist resorts in Romania.](image)

**Fig. 1.** Map of the combined network of roads and railways to the tourist resorts in Romania.

As mentioned, the connectivity policy in making the network for the data used prioritized long-distance rail transport, and road transport participated in the analysis only over short distances, where tourist resorts do not have access to the rail transport system. Such an example is shown in Fig. 2.

For this evaluation, they set the waiting time parameters in node 2 at about 40 minutes, taking into account that the tourist leaves by train in the morning at 9.37 and arrives at node 2 at 17.23. The journey time is 9 hours and 5 minutes, while the bus journey time is 35 minutes. For the variant in which the tourist leaves by train in the afternoon, the waiting time in node 2 (CF Sebiş station) is 1 hour and 20 minutes.

From a technical point of view, the application is innovative, because the efficiency of the network does not fade as the size of the network increases, and the modeling of spatial relationships for all network components defined rail transport as a priority, and the theme of national roads as an auxiliary railroad component. Also, the integration of GTFS data into the spatial railway database is a rather difficult operation that requires a lot of rigor. However, the application would be much more accurate, if there were the possibility of collecting data on the timetable of transport buses to tourist resorts in Romania in GTFS format. Also, in order
for the computer application to be developed as a Smartphone application, a different option is needed that works with network analysis services such as ARCGIS Runtime SDK.

Fig. 2. Evaluation of travel time on the inter-modal network from a locality to a tourist resort.

In the future, technical challenges are related to obtaining and processing data on updating the national road network and updating the database on the timetable of means of transport (especially road and rail) to resorts of tourist interest. The scientific challenges are highlighted by the quality and quantity of information, the accessibility indicators to be evaluated, as well as by the form of their presentation - qualitative maps, dynamic maps.

Conclusions:

Real-time route planning is a computer application that has been introduced by public and commercial transport companies to minimize costs and maximize the services provided to citizens. However, most applications focused on the analysis of road transport and less on the combined analysis of transport types. The essence of inter-modal transport is the integration of different modes of transport, so as to maximize their positive characteristics, while reducing the negative effects.

Current IT solutions use specialized search engines to find an optimal way to travel between two or more given locations, sometimes using multiple modes of transportation. Searches can be optimized based on different criteria - for example, the fastest, shortest, or cheapest route or route with the fewest changes. In the case of the application “Time” was the main attribute considered and was calculated based on the speed of each means of transport and the length of each network segment. The integration of GTFS data in a complex GIS format that allows the definition of 2-level connectivity relationships between the elements of inter-modal networks is a successful solution for trip planning, schedule creation, visualization, obtaining information in real time. The application presented in this article, even if it is in the first design phase (laboratory phase), is useful for all passengers using
combined transport (railway - road network), because it benefits from time points for traveling from any point in Romania to any tourist resort of national or local interest.

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