

INTERMODAL GIS ANALYSIS MODEL FOR ASSESSING THE TRAVEL COST TO TOURIST RESORTS IN ROMANIA

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Abstract

Tourists, like any other users of transport systems, seek to travel safely from origin to destination, choosing the appropriate route in relation to the speed, comfort, and cost of trip. Therefore, the goal is, from a tourism transport planning perspective, to minimize connections and, wherever necessary, make them as efficient as possible. Multimodal solutions allow passengers to adopt less polluting modes of transport whenever possible, encouraging a more sustainable journey. Digital solutions and integrated planning services offer the potential for sustainable, easy-to-use and efficient multimodal travel. The purpose of this article is to present a novel GIS-type IT solution for assessing the cost of multimodal transport to tourist resorts in Romania. The IT platform considers the movement of tourists to tourist resorts through two networks in the intermodal system, railways and national roads, connected through nodes represented by the railway stations.

Keywords: accessibility, web application, multimodal transport, Romania

JEL Classification: R41, Z30, C23

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1. Introduction

Currently, at European level, travellers and tourists do not have access to digital solutions that can allow them to plan, book, and pay for their multimodal trips. Providing accessible digital ticketing and information services for multi-modal travel should, however, promote the mobility of travellers and tourists in Europe. Access to relevant data provided by travel and tourism operators and the promotion of open data policies are necessary conditions for facilitating the implementation of digital ticketing and buying services for multimodal travel. Due to this fact, the intermodal transport allows combining, advantageously on a given route, the specific advantages of each mode of transportation, such as the flexibility of road transport, the high capacity of rail transport, the low costs of shipping and the greater speed of air transport. In Romania, at the national level, the 2020 Intermodal Transport Strategy emphasizes the need to implement an intermodal system in the field of tourism. Tourism is a possible area for essential growth of the national economy, which can generate 10% of national GDP in the future.

For this reason, the aim of the study is to provide digital information services on multimodal trips, directing the tourist interest to the national resorts in Romania. From a technical point of view, the project proposes a simulation of the accessibility indicator (an indicator that expresses the combined effect of the alternative modes of transport) "Travel cost " (time) in laboratory conditions using the "cost" of moving through each cell of the represented raster by the national territory of Romania and the database on the hourly schedule of road, rail, air and naval means of transport for the main tourist resorts.

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Intermodal transport is characterized by a high degree of complexity and, consequently, a high degree of complexity of the solutions on decision support systems and their multiplication. Therefore, state-of-the-art models are complex and require a great deal of research effort. It is crucial to optimize the transfer nodes between different modes of transport in order to make them functional and enjoyable. There is also no interest in creating an efficient transport system if passengers do not know how to use it. Thus, another important aspect is the provision of high-quality information. These two aspects, which minimize waiting time and provide real-time information to effectively guide passengers, are key points for designing an intermodal transport system (Ezzedine et al., 2008). Developing an advanced algorithmic approach can help handling real-time data during the execution of transportation and react adequately to unexpected events detected. In this way, the reliability of intermodal transport can be increased, which might increase its usage and minimize the negative externalities of passenger transportation (Hrušovský, 2021).

Inter-modality is both a technical term for a specific type of travel, which includes several modes of transport, and a policy principle. However, the development of intermodal transport solutions is a key area of action for urban and regional transport policies, and the role of intermodal transport systems has become increasingly important. Such a system should support efficiency, safety, mobility, economic growth, and protection of the natural environment. Anyone departing from any of the available modes of transport (train, bus, plane, subway) must receive information through the intermodal system of additional services to reach the final destination. The models of intermodal transport described in scientific publications are diverse in terms of scope, objectives, and types of users. Some models are designed as decision-making tools, and others are research tools to study the impact of different factors on the efficiency of intermodal transport.

Digital platforms play a significant role in bringing together end consumers and transport providers, using the power of digitalization to enable new user experiences and create networked mobility. This also provides the chance for transport providers to access new customers, not just digital natives and young people used to doing everything with their smart phone, but all travelers, including occasional users of public transport, and tourists. For instance, this has led to the emergence of a range of online and app-based tools enabling users to identify the quickest and/or most environmentally friendly intermodal transport options (OECD/ITF, 2016).

The goal of operations research is to construct mathematical models of intermodal transportation systems. Operations research is a “professional discipline that deals with the application of scientific methods of decision making, especially the allocation of resources” (Rajgopal, 2004). A mathematical model of a system describes system behavior using only equations and logical relationships. Types of mathematical models include probabilistic models, mathematical programming models, and simulation models (Graham et al., 2000). An intermodal network is defined as an integrated transportation system consisting of two or more unimodal networks. Each network is composed of a set of points, called nodes, and a set of point connectors, called segments. Intermodal networks cannot fully function without the integration of key nodes within the transportation network (Asuncion et al., 2012).

Geographic Information Systems (GIS) are used as scientific and methodological tools for measuring accessibility, monitoring resulting indicators, identifying spatial disparities, and finally finding solutions to support local and regional accessibility. One of the main advantages of GIS is its capability to create a variety of network models by using arcs and nodes. The capability of visualizing of transportation networks differentiate GIS models from the mathematical models (Gohari et al., 2018). Several researchers have utilized the capabilities of GIS to construct intermodal freight networks (Boile, 2000; Southworth and Peterson, 2000). The interdisciplinary team from Rochester Institute of Technology developed the Geospatial Intermodal Freight Network (GIFT) using ArcGIS 9.3 to create an intermodal network model connecting highway, rail, and shipping networks through ports, railyards, and other transfer facilities in the United States and Canada (Winebrake et al., 2008). The main difference from the GIFT and other GIS-based models is the inclusion of energy and environmental attributes on each segment of intermodal network. The GIFT model was developed in ArcGIS 9.3 and uses the ArcGIS Network Analyst tool to conduct its optimal route solving.

In recent years, data on general transit feed specifications (GTFS) have gained popularity for estimating travel time between stations, due to its interoperability in spatiotemporal analyses. Many software packages, such as ArcGIS, have developed toolboxes to allow for the estimation of travel time with the GTFS data format (Fayyaz et al., 2017). The geospatial foundations of transport systems must be adequately taken into account in transport models. The required intelligent transport systems (ITS) are based on accurate data and high-performance communication, management, and analysis components, each with a distinct spatial notion (Miller and Shaw, 2015). For example, the VINTRA application (Jakimavičius et al., 2019) uses the GIS tools and the GTFS format for exchanging public transport programs and geographical information with two web portals that can be used by all citizens categories: an external one (plan and view public transport trips using the Geospatial Web 2.0 platform) and an internal one (with a digital map function to plan and design public transport routes using the Network Analyst analysis extension of ArcGIS). The VINTRA computer system shows how the route viewing on a digital map has been resolved when a planned route requires transfers, or the start / end point of the route is a particular place or address (not a stop on public transport) and how in which the walking routes can be viewed in a real trajectory, avoiding a visualization of the route on a straight line. This system has the ability to create and edit public transport routes and edit and compute timetables based on the distance between stations. VINTRA uses a specialized search engine (Dijkstra, 1959) to find an optimal means of travel between two or more given locations, by using several modes of transport on different criteria.

This study is aimed at developing an IT solution based on the ArcGIS Network module of the ARCGIS PRO 2.9 software and on the GTFS format of the Romanian Train Performance data. For this purpose we created a network data set using a geo-database, including all layers (transport modes) used in the analysis, and generated a network dataset specifying all rules that must be generated, repeating these procedures whenever the attributes were modified. The advantages of the proposed methodology are that it covers a very large area (approximately 238000 km²) compared to other multimodal applications and is precisely aimed to tourism, provided that most young and elder people use intermodal transport to reach desired tourist destinations.

2. Methodology

In order to create the dataset of the proposed IT solution, we started by setting up a geo-database in ArcGIS PRO. We preferred the use of a geodatabase for layer integration, due to the much easier setting of the rules, to the detriment of the inclusion of means of transport in a single layer, which leads to the saving of computing resources. The geodatabase contains the following shapefile themes: the national road network by type of road, the national rail network by type of railway, railway stations and tourist resorts of local and national interest in Romania. To create a network dataset, we used the New Network Dataset module in ArcCatalog. The main steps for finding the digital railway network at national level in Network Analyst, presented in Fig. 1 and 2, are summarized in the following.

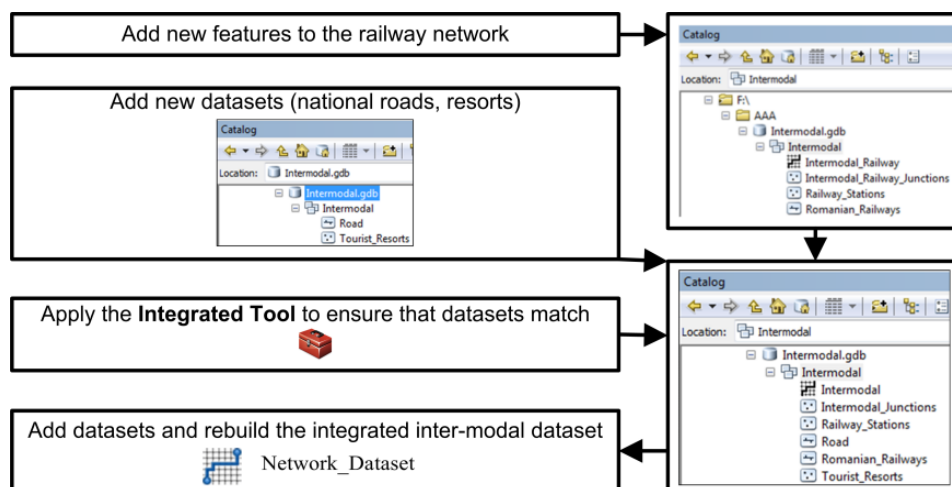


Fig. no. 1. Methodological workflow: overview

Source: The Authors

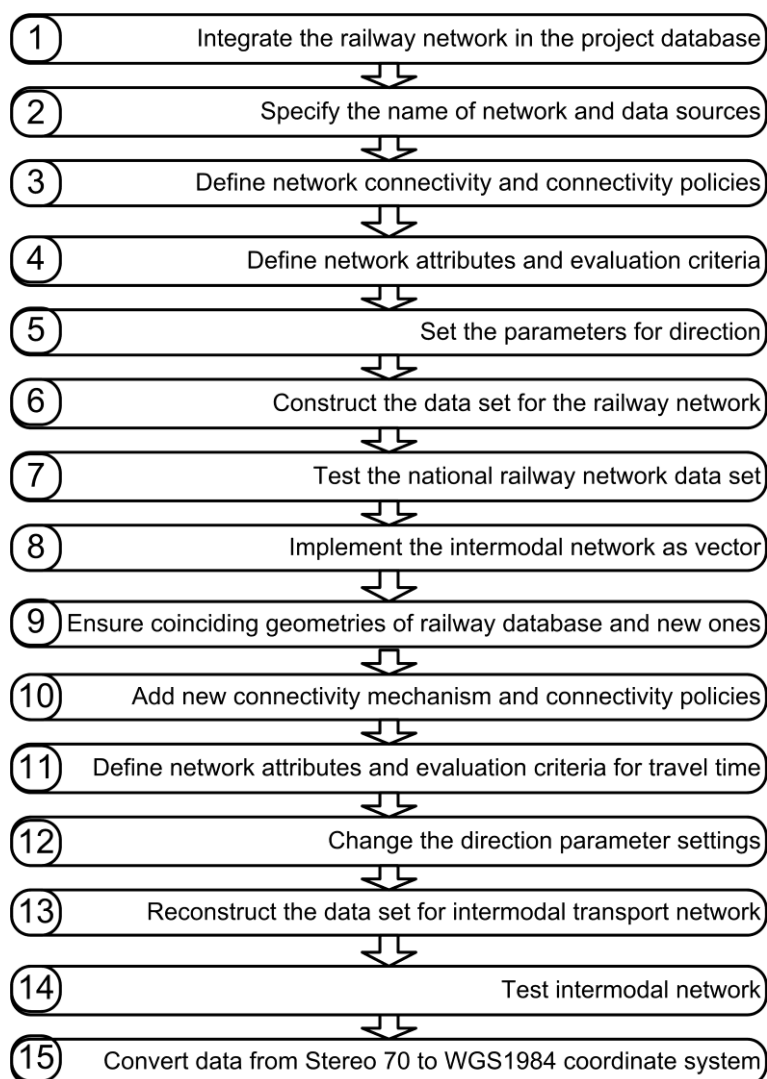


Fig. no. 2. Methodological workflow: details

Source: The Authors

1. Integration of the railway network in the project database;
2. Specification of the the name of network and data sources participating in the creation of the railway network;
3. Defining network connectivity and connectivity policies. Network connectivity defines how the characteristics of lines and points connect to each other in the network. There are two options for creating connectivity: using connectivity policies and setting elevation. We defined network connectivity for network source features and set connectivity policies.
4. Defining network attributes and evaluation criteria. In this step, we defined several network attributes for the network dataset. Network attributes are properties associated with network elements (nodes, junctions, and return points) and can be used to help control network browsing. We noticed that two network attributes have already been automatically defined by the software. We have also created a network attribute related to the travel hierarchy on the railways, i.e., main railways and secondary railways. The network travel policy represents the computation of travel time on main networks and the involvement of travel computation on secondary networks where it is not possible otherwise. To do this, we examined the network attributes and identified in the database of the Romanian railway network the fields that express the type of network (primary or secondary), network length (computed automatically by software), and travel time in minutes by the ratio between length travel section and travel speed. The travel speed can be found automatically by implementing the annual train schedule in GTFS format.

5. Setting the parameters for the direction. In this step, we have set some parameters controlling how the directions are displayed in the ArcGIS system (ArcGIS PRO). Directions can be generated for the results of route definition and nearest facilities. For this purpose, we have identified what kind of information is provided by the network data set. To define the final route, we chose the length of supplied route to be the field in the database named Length, computed automatically by the ARCGIS program, and used Kilometer as a unit of measurement. We used the DriveTime field to compute the travel time, and time in minutes as a unit of measurement. To set the route to be computed automatically by the ArcGIS Network Analyst module, we set the route to be on the main rail lines and the secondary rail to be accessed only for sections that require travel time to be as short as possible. In this regard, we have set in Network Source, the CLASS field which indicates the main railways as first route, and secondary railways as support route for automatically computed route.
6. Construction of the data set for the railway network. Before building the data set for the railway network, the Network Analyst module summarizes the indicated settings for the proposed network and implicitly checks that some important aspects are not omitted for the construction of network. After verifying the summary of proposed settings, more precisely the correctness of settings and constructed attributes, the data set regarding the Romanian railway network was finalized.
7. Testing the national railway network data set. The data set was tested using the New Route tool from the Network Analyst module. Testing was done by randomly choosing one railway station as starting point and another railway station as destination.
8. The steps for implementing the intermodal network as vector included: (1) modifying the tolerance parameters so that elements from the dataset of intermodal network can be selected and integrated; (2) importing datasets on national roads and resorts into the geo-database using the work scheme in Fig. 1; and (3) applying the **Integrated Tool** to ensure that datasets match.
9. Network connectivity in network data sets is based on coincident geometry, in particular on coincident vertices and / or endpoints between segments and points of all component layers. Therefore, it is necessary to ensure that there is a coincident geometry between the railway database and the new imported databases, representing the national roads and resorts of tourist interest in Romania. It is very important that there is a coincidence between the points representing the railway stations and the national roads, because the points representing the railway stations represent the essential nodes of the designed intermodal network. In conclusion, we can say that only the nodes that represent the railway stations are the connection points between the layer of railway lines and the layer of lines that represent the national road network. Another important element of the intermodal network is the coincidence between the points representing the resorts of tourist interest and the layers of lines representing the railways and the national road network. Applying the **Integrated Tool** checks these mentioned matches, and if there are any matching errors, the tool highlights these errors in a table.
10. Adding a new connectivity mechanism and setting up new connectivity policies. The connectivity mechanism was the main purpose of this IT solution. Specifically, the computation of distance between a location chosen as starting point and a destination tourist resort must follow two rules: most distance must be traveled on railway network and only if there is no railway station in the resort travel; and the journey must be made in national roads on the last section. To implement this mechanism, we set the trip on two networks (intermodal system) in which the first was the railways layer and the second the national roads layer, and the connection between the two data sets was made through nodes representing railway stations.
11. Defining network attributes and evaluation criteria for travel time. Setting the network attributes involved creating in the database a field for computing the travel time for sections of the national road network. For a correct approximation of travel time, we calculated the average speeds of regular passenger transport routes on different routes, including the resorts of tourist interest. For example, we computed the travel speed on the sections of the route between Bucharest and Cluj Napoca, including the cities Pitești, Râmnicu Vâlcea, and Sibiu. Also, in order to compute the

average speed of travel by passenger transport vehicles, we chose the Iași-Timișoara route in which we used the cities Roman, Piatra Neamț, Gheorgheni, Sighișoara, Mediaș, Alba Iulia, Sebeș, Deva, Lugoj, and Timișoara as landmarks. The travel time computation formula was the following: $\text{Travel time} = \text{Length} / (\text{Average speed} * 1000/60)$ [minutes]

12. Changing the direction parameter settings. In order to have precise traffic rules according to the mechanism specified in the data network properties, we introduced a field representing the type of roads that constitute the national road network (highways, European roads, national roads, county roads and communal roads). The logic of travel is the logic of speed restrictions, with priority given to roads with the highest speed - highways (110 km/h), European roads (90 km/h), national roads (70 km/h), county and local roads (50 km/h).
13. Reconstruction of the data set for the intermodal transport network
14. Intermodal network testing. The testing was done as for the railway network by choosing a starting point (railway stations, but also points on national roads) and a destination point that can be a resort of national or local tourist interest. However, given that the aim was to evaluate intermodal transport, especially by rail, the starting point was a railway station.
15. Conversion of all data in from the Stereo 70 coordinate system to the WGS1984 Web-Mercator-Auxiliary Sphere coordinate system, required for publishing in the ArcGIS ONLINE system and to a network analysis service.

The methodology also involved changing ArcMap module to ArcCatalog and then reloading the information in ArcMap (Moreno-Navarro et al., 2015), identifying the locations of transfer points in every lane before creating links (Vasiliauskas, 2002).

3. Results

Several databases and maps were generated. In order for the input data to be complete, we created the point shape for the tourist resorts of local and national interest (Fig. 3).

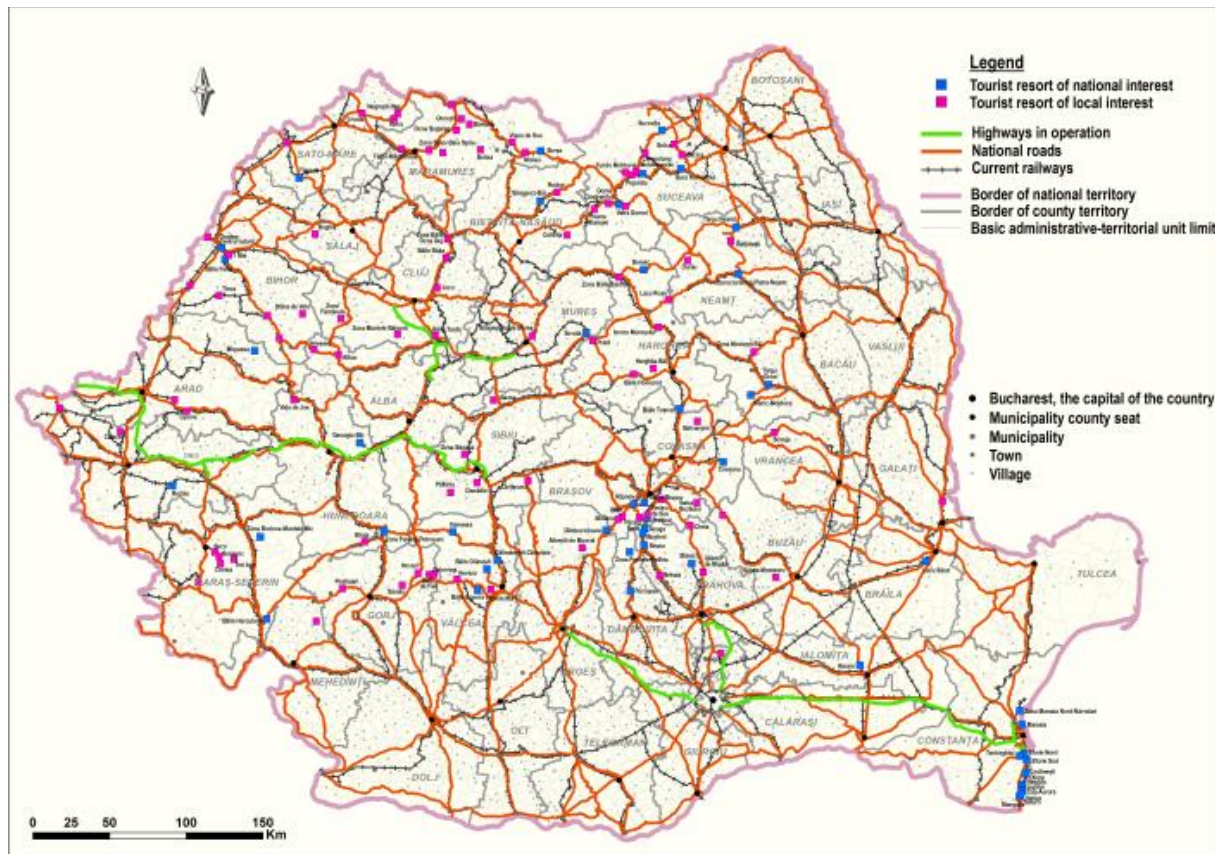


Fig. no. 3. Map of Romania with certified tourist resorts

Source: The Authors

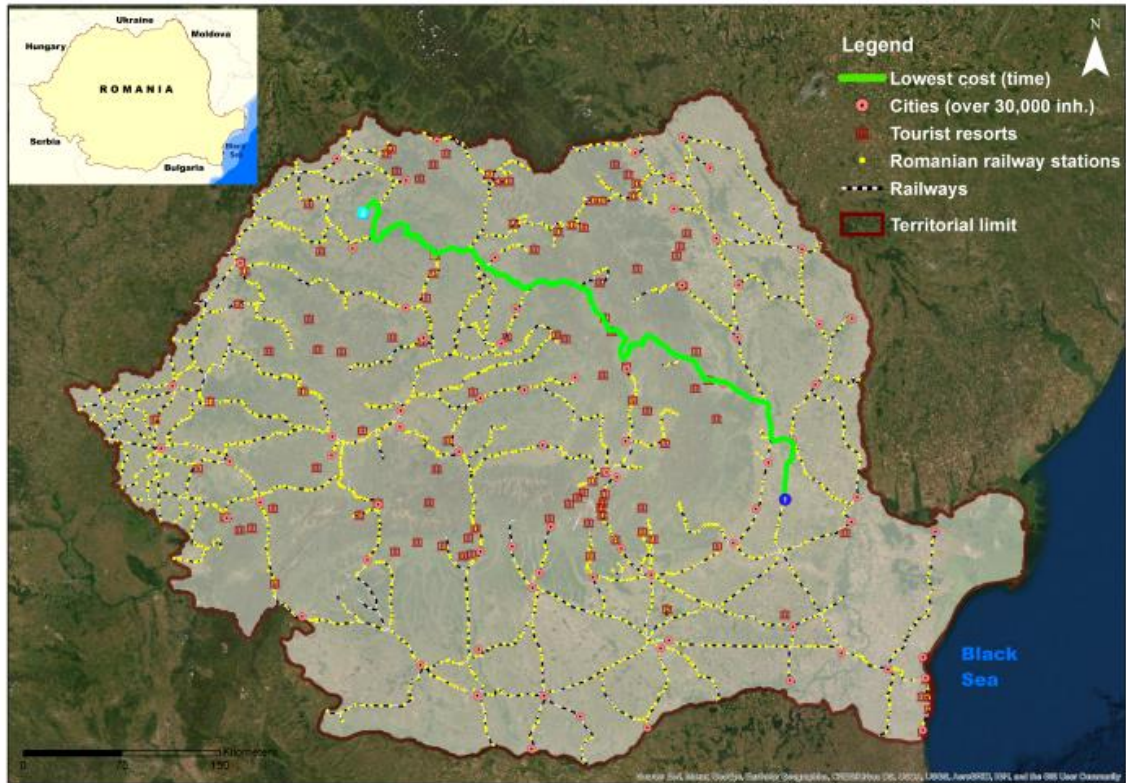


Fig. no. 4. Testing the rail transport network in the Network Analyst system

Source: The Authors



Fig. no. 5. Intermodal map testing

Source: The Authors

The first step in the development of the IT solution was the implementation of the railway transport network in Network Analyst. In the settings analysis table (Fig. 4), we selected the shortest travel time between the two randomly selected railway stations.

The layers of national roads and tourist resorts were introduced in the geo-database and the coincidence of the data sets was tested. The basic rule for setting up the intermodal network was to compute the cost of travel (travel time) to any station of tourist interest on the railway lines such that the travel on national roads was made only in the case of connections between railway stations or in the last section, where there is no railway connection with the tourist resort. The testing of the intermodal network was performed by evaluating the cost of travel between a railway station (Titu Gară) and a tourist station without railroad (Moineasa) (Fig. 5).

The map of the intermodal network was published on ArcGIS WEB in two variants. The first option was the publication of the intermodal map in ArcGIS Online and the integration of the resorts in Romania in the spatial database (Fig. 6).

The second version of the digital map was implemented in the WEB GIS system as a map image layer, and with the help of the Web AppBuilder application for ArcGIS we developed the intermodal WEB application that allows the use of specific Network Analyst tools (Fig. 7).

Using the Web AppBuilder application for ArcGIS, we developed the intermodal WEB application that allows for using specific Network Analyst tools. Because Web AppBuilder for ArcGIS is built on an ArcGIS API platform for JavaScript and HTML5, the new WEB Intermodal application can run on any Web browser on any device. Also, a digital map of the tourist resorts in Romania was made in the ArcGIS ONLINE system, integrating all tourist resort files containing images suggestive for the resort, geographical coordinates and type of relief, accessibility to the transport network, and practicable types of tourism.

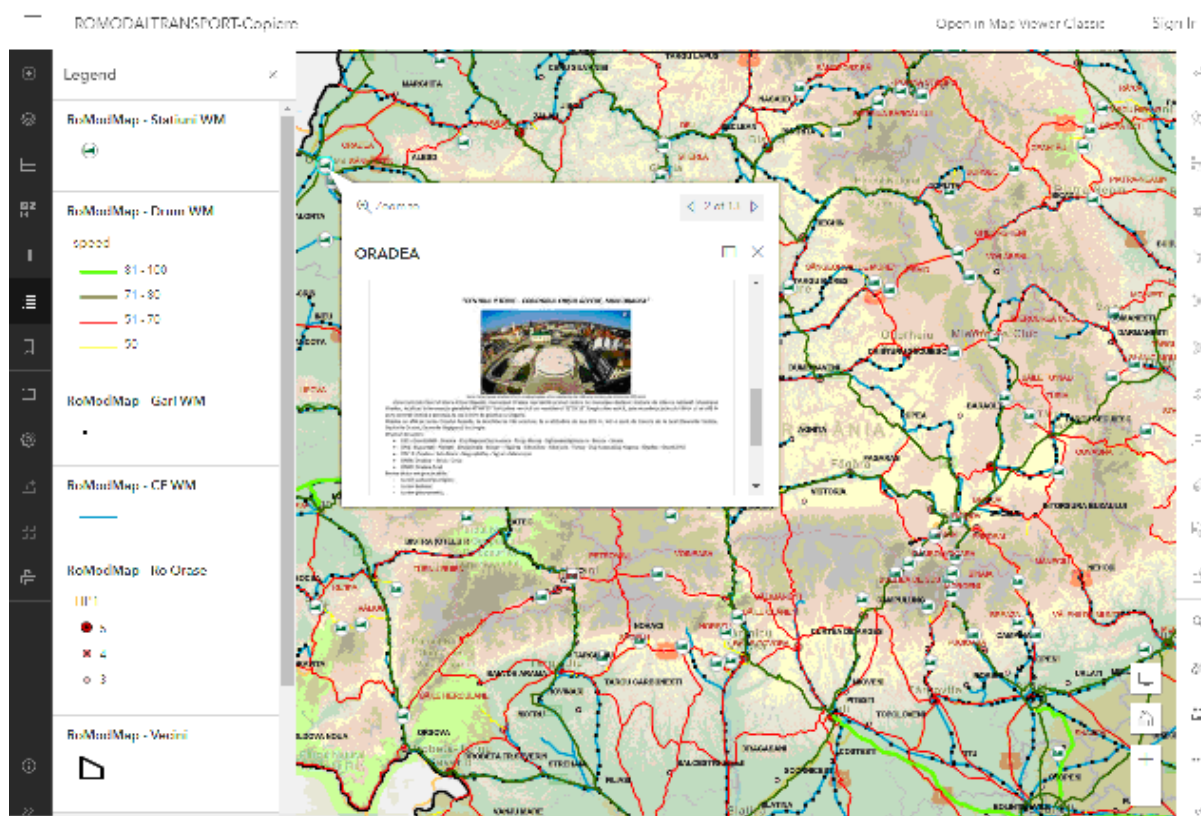


Fig. no. 6. Map of tourist resorts in Romania in ARCGIS Online system

Source: The Authors

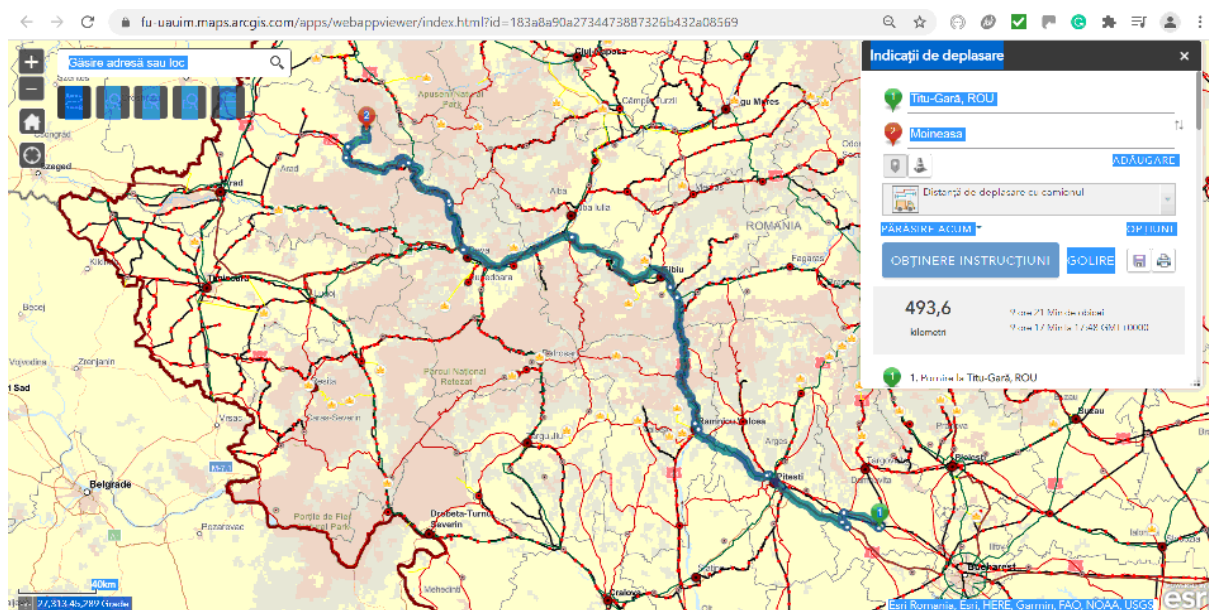


Fig. no. 7. Intermodal network map using the AppBuilder WEB application

Source: The Authors

In developing the multimodal solution, we started from the idea that a mathematical model aims to minimize transport costs and risk factors for each mode of transport (Tache et al., 2021). In addition, creating a mathematical model of an intermodal transport system requires minimal effort on the part of uninformed users to use it. Another important aspect is the provision of high-quality information. Minimizing waiting time and obtaining real-time information for users are priority elements in designing a mathematical model of the intermodal transport system.

If in Romania railways data exist in XML format, roads data for buses are very widespread. There are many data sources in different digital formats. The final solution was to combine the GTFS data for railway network with GTFS data for public bus and minibus network, so that we could compute in ArcGIS the shortest route or time between an initial destination and a final destination (tourist resort of local and national interest) using the Network Analyst network and data on the Romanian road and railway network. Unfortunately, data on transit times for tourists at bus stops for all national roads were not available. The time used in the computation was for an ideal connection between intermodal networks. For this reason, the solution of the intermodal network using the WEB AppBuilder application was not developed to be easily accessed by any tourist or traveler without a previous training in IT.

4. Discussions

4.1. Importance of research

Assessing the accessibility of transit in spatiotemporal dimensions requires the computation of travel time in all pairs of transit stations at any given time of the day. The ARCGIS Network module used in this study has the ability to build an intermodal network using GTFS and shapefile data. Using a Python script allows for detailed specification of network attributes and considerations, with the ability to view GTFS data on the map, create and edit GTFS data, and analyze the frequency of transit services. ARCGIS PRO versions 2.8 offer the possibility to store network and associated input-output layers in memory, which leads to accelerating the network analysis and increasing the network size in terms of connection nodes and final destinations. For this reason, the GIS application developed in this study, compared to other applications developed worldwide, covers a larger area with multiple arcs and nodes, which would otherwise require additional hardware and software resources.

4.2. Limitations and future research directions

One of the challenges to the development of a GIS based intermodal network model was the combination of transit and road network layers into a geodatabase, as well as the introduction of intermodal transfer points, or stations. The first step in producing an application according to the

vector methodology was the correct definition of a national road and rail network. In this context, it was necessary to consult the digital map made by the Center for Road Technical Studies and Informatics on the route of highways, the digital map of road quality in Romania made by the Pro Infrastructure Association and the type of roads in Romania, according to Google Maps. In order for computer modeling to approach real conditions, impedance had to be defined; this is a group of factors that prevent the ideal journey on the road network. Travel speed, which is one of the basic indicators of impedance, was entered in the database depending on the type of road and its characteristics. The number of settlements crossed, volume of traffic, weather conditions, and speed limits were not taken into account. The updating of the road layer database required the restoration of the topology and the completion of the database with the names and characteristics of newly introduced or reclassified roads.

A particular challenge for the IT solution was including GTFS data on passenger transport by rail in Romania in ArcGIS PRO. The process was, however, facilitated by the existence of an iOS application for Romanian Railways that contains all train stations and departures in Romania, which can be used offline without the need for a mobile connection. We also used a utility to convert this data to GTFS. GTFS data was made compatible on the ArcGIS PRO via the Transit Feed (GTFS) toolkit in the Conversion Tools toolbox. These tools were used to view stations and transport lines on the map and edit and update the GTFS stops file. Limitations in developing future applications relate to the capabilities of the single-threaded ARCGIS Network, which limits ARCGISPRO's performance in a large-scale analysis workflow. In order for the desktop map to be somewhat commercial and to transferable to the WEB system, it should be completed with themes representing Romanian cities and municipalities (point shapes), a raster theme representing the Romanian Digital Terrain Model, a polygon theme representing the Black Sea, and a polygon theme showing Romania's neighboring countries. ArcGIS Online and Portal for ArcGIS include Web AppBuilder for ArcGIS, which allows for creating custom web mapping applications in an intuitive environment. The resulting digital desktop map can be published in the WEB system as a map image layer.

5. Conclusions

A mathematical spatial programming model of the intermodal transport system aims to minimize transport costs and risk factors for each mode of transport and is based on key issues: minimizes the waiting time, and provides real-time high-quality information to guide travelers effectively. An efficient mathematical modeling of the transport system should not be created if the users (passengers) do not know how to use it. The application presented in this study will be useful for all passengers using combined transport (railway - road network) after being redesigned, as it is beneficial for traveling from any point in Romania to any tourist resort of national or local interest.

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