

WebShipCost - Risk Analysis with a Geographical Information System

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Abstract

This paper presents a geographic information system (GIS) integrated, web-based application (WebShipCost-Risk) with the ability to provide cost, time, and uncertainty analysis of intermodal transportation process based on up-to-date network information. The prototype system allows shippers to define, represent and update their specific transportation network and related data within a GIS. The integration of a decision support system with a GIS provides shippers with more convenient and efficient data management methods to support the decision making in terms of route planning. To achieve the desired goals, a three layer architecture was used which was based on a commercial GIS, a database system, and internet components. The application also provides graphic, user-friendly analysis results for interpretation. The system is currently being used to facilitate the investigation of algorithms for improving intermodal transportation networks.

Keywords

Intermodal transportation, Shortest path, Uncertainty, Multi-objective, Geographic information system

1 Introduction

Intermodal transportation is the movement of goods or services by the coordinated and sequential use of two or more modes of transportation (Mahoney, 1985). In recent years, there has been a significant increase in shipping goods using more than one mode. Intermodal carriers moved 173 million tons in 2002, an increase of 47 percent from 118 million tons in 1993 (USDOT, 2004). However, route planning within an intermodal transportation network is a complex decision process since it involves complicated network structure, multiple modes, multiple objectives, and uncertainty.

Previous research (Li et al., 2003, Li et al, 2004) resulted in the development of WebShipCost-Risk, a World Wide Web (WWW)-based implementation of an intermodal transportation decision support system. It identifies and models the key stochastic and risk-based performance metrics and their relative trade-offs, develops a multi-objective optimization approach that incorporates other constraints and objectives outside of the single objective of either time or cost within an intermodal transportation network. It also explores the effect of uncertainties on intermodal route determination and how to handle this uncertain data through simulation and sensitivity analysis. WebShipCost-Risk allows online determination of the optimal path in terms of multi-objectives from an origin point to a destination point and enables shippers to understand the trade-offs associated with barge and container-on-barge transportation.

For users of industry, analysis results are only as good as the data behind it. End users depend on current, accurate data to make correct decisions. Currently this analysis is based on data from research at University of Arkansas (Trusty and Malstrom, 1998) and the software user's manual (Boardman and Malstrom, 1997). The network includes a five-state area and is predefined. However, real, living, changing, evolving network information over time needs to be considered. How to keep data continuously updated is a challenging task for the current system.

A geographic information system (GIS) is a computer software/system that links geographic information (where things are) with descriptive information (what things are). A GIS can present many layers of different types of information. All the transportation information— infrastructure information such as roadways, railroads, waterways, bridges and tunnels, transit place, and decision related information such as cost, transport speed, reliability, etc. — is stored as layers in digital format in the computer. The integration of WebShipCost-Risk with a GIS provides the end user with more convenient and efficient data management methods to support the decision making in terms of

route planning. It also provides users with an interactive map that contains rich information. GIS also allows for a more advanced output – rather than simply presenting text based information, the system can present customized maps, displaying specific decision scenarios in graphic form.

This paper presents the concept design and implementation of our GIS integrated intermodal transportation route planning application. Researchers and practitioners can use the work in this paper to better understand how to develop integrated support systems for transportation decision making. The rest of the paper is organized as follows: first we present the architecture of the application, then we discuss some implementation and functionality issues, and finally we make brief conclusions.

2 Architecture

Internet-based GIS programs have been growing rapidly for the past several years. There are internet-based mapping and GIS software packages available. Arc Internet Map Server (ArcIMS, 2006), provided by Environmental Systems Research Institute (ESRI), is one of the most comprehensive, open and scalable solutions available. Therefore, we choose ArcIMS as the GIS component in our application.

Broadly, the architecture of the application can be divided into three layers: the presentation layer, the application layer, and the data layer, as shown in Figure 1 below. The presentation layer is on the client side; the application and data layer are on the server side. The benefit of the separation is that GIS-related data processing and decision making are performed on the server side. The client side can be thin and does not need to load any GIS software.

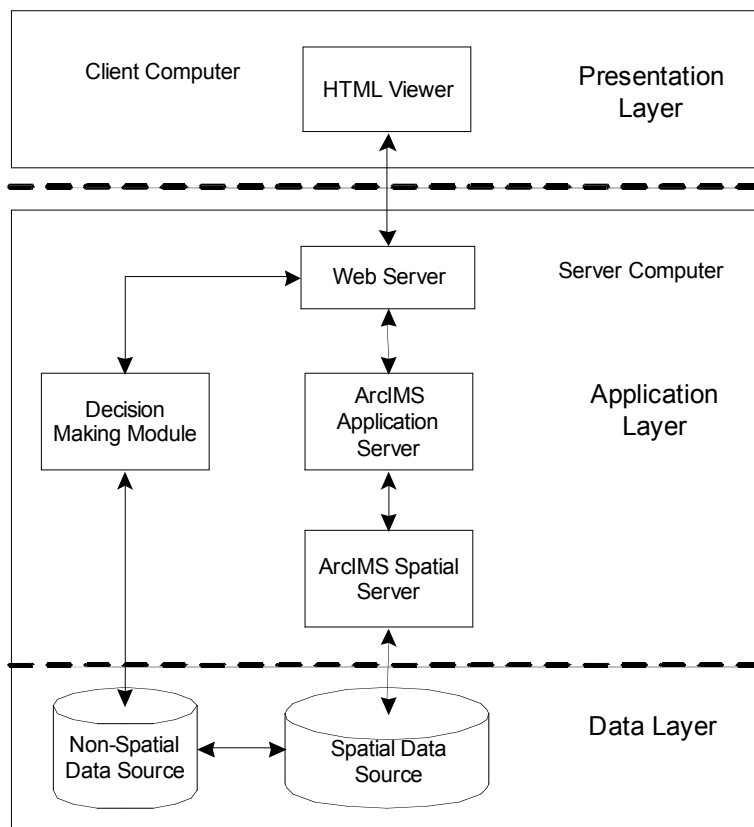


Figure 1 Three Layers of WebShipCost-Risk with GIS

Presentation Layer

Users access the system through the internet from the client side. The presentation layer consists of a HTML web browser, which is used to interact with server side programs. User requests are sent through web browser to the

server, and returned information is interpreted and displayed within it. The communication between the client and the server is coded in a XML form – ArcXML, which is specified by ArcIMS.

Application Layer

The application layer involves map analysis, processing, generating, and decision making. The Spatial Server, which is the backbone of ArcIMS, processes the requests for maps and related geo-information, e.g. creates map image files. Generally, the Web Server receives incoming requests from end users. Then the requests are passed to the Application Server. Then the requests are interpreted and processed by the Spatial Server, and generated responses are sent back to the end users. In the application layer, the decision making module encapsulates all the functionalities of WebShipCost-Risk including multi-objective decision making, path generation, and risk analysis. The preferred paths are identified based on the user inputs and this information is sent to the ArcIMS Application Server and Spatial Server for customized map generation.

Data Layer

The data layer is concerned with data storage, preprocessing, and management. It can be further divided into two data source, spatial data source and non-spatial data source. Spatial data source stores data, which can be accessed by the Spatial Server for map related processing. Some of the data are just for map displaying, while some of the data also supports decision making. ESRI defines many forms for spatial data source, e.g. Geodatabase, Shapefile, etc. On the other hand, a non-spatial database stores data to support WebShipCost-Risk decision making module. A significant improvement of current application over WebShipCost-Risk is that the decision supporting data, such as arc length, can be extracted or updated from the spatial data source, which is much easier to maintain and update.

3 System Functionality and Implementation

3.1 Data Requirements

The quality of GIS data is a key factor that affects the transportation decision making since all the decision models and result are data driven. For the WebShipCost-Risk with GIS application, we identified two sources for GIS data: 1) National Transportation Atlas Databases 2003 (NTAD2003); 2) National Atlas of the United States of America. Both of these two GIS data sources provide a comprehensive, authoritative scientific map data to support our application.

The GIS data that we imported in our application is listed in Table 1 below. All of these data are in Shapefile form. However, the geo-datum of the spatial information is not identical. In our application, we choose the World Geodetic System 1984 (WGS 1984) as the target datum and converted North American Datum of 1927 (NAD27). ArcToolbox , available within ArcGIS Desktop provides tools to perform geodetic conversions.

Table 1 GIS Data for Building Intermodal Transportation Network

Name	Type	Source	Data Description
Intermodal Facility	Point	NTAD2003	Intermodal Terminal Facilities, dataset compiled for the Bureau of Transportation Statistics, 2003.
National Populated Place	Point	NTAD2003	National Populated Places, place locations from the 2000 Census Master Area Reference File; data provided and maintained by the Bureau of the Census, 2000.
National Highway	Polyline	National Atlas	Roads of the United States Data Set, includes major roads in the U.S. The Roads map layer was compiled by the U.S. Geological Survey.
National Railway	Polyline	National Atlas	Railroads of the United States Data Set, includes railroads in the U.S. The Railroads map layer was compiled by the U.S. Geological Survey. This map layer is being revised to include more descriptive information about its linear railroad features.
National Waterway	Polyline	NTAD2003	U.S. Army Corps of Engineers Navigable Waterway Network.
U.S. States	Polygon	NTAD2003	U.S. State Boundaries, data provided and maintained by Bureau of the Census, 2000.

In order to remove unnecessary information, geoprocessing is performed on these data sets. For example, in our application, we consider three modes (truck, rail, and barge); therefore, only intermodal facilities that handle truck, rail, and barge business were extracted from the available datasets. For waterway network, non-navigable and non-freight traffic waterways were removed.

Due to the fact that ArcIMS does not come with routing capability, Network Analysis, an extension of ArcGIS Desktop, was used to identify the shortest path between each pair of cities. And the generated distance matrix was imported into the non-spatial database through a JDBC interface. In this way, the decision making module can always acquire the updated information, and the spatial data is more easily maintained through the GIS application.

3.2 Functionality

The key features of the WebShipCost-Risk with GIS are path query and map display functionality. In addition, the software provides network information updating and display customization. In this scenario, the user provides shipping related information, identifies the source and destination, and specifies decision priorities. Then the application calculates the favorable paths based on the input information and supporting data, performs risk analysis, and returns the results back to the user in text and graphic form. Figure 2 below shows the information flow and interactions among application modules to achieve this functionality.

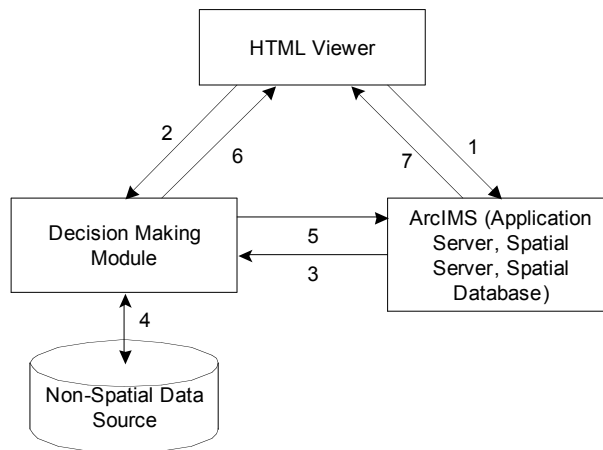


Figure 2 Information Flow Diagram of Query Functionality

The arrows in Figure 2 indicate the interaction between neighboring modules. The direction of the arrows suggests the direction of information flow. The process can be detailed as follows: First user specifies input variables such as shipping amount, holding cost rate, container capacity, etc. The source and destination city can be input either by typing, or by clicking the map. If the latter is applied, a query is sent to the ArcIMS to get the name of the most nearby city from the clicking point (1). This information plus decision priorities are then sent to the decision making module (2, 3). The decision module then performs the double-sweep algorithm to solve the k -shortest path problem and applies the Analytic Hierarchy Process (AHP) (Saaty, 1980) to generate the favorable paths. This process is supported by the data stored in the non-spatial database (4). Once the paths are generated, a request (5) is sent to the ArcIMS module for map generation. Finally, paths with text descriptions (6) and map displays (7) are returned to the shipper.

3.3 Implementation

As mentioned in the section 2, we choose ArcIMS as our GIS component. ESRI provides a set of tools to facilitate the development of an ArcIMS project. However, for our application, customization and integration is necessary. To develop a project using ArcIMS, three steps need to be followed: create map, create map service, and build the website.

Map Creation

The first step is to design and create a map. This is the map to be published and to be used interactively by the users. ArcIMS Author is the ArcIMS application we used to design a map from which a map configuration file will be created. The data source we identified were added as layers to the map. An important point to note is that the layers are on top of each other. Therefore, we need to make sure that point shapes are placed on top of the polyline and polygon shapes. Similarly, polylines should be on top of polygons. The application contains 6 shapefiles that are ordered according to desired visibility:

- Cities
- Intermodal Facilities
- Waterway Network
- Highway Network
- Railway Network
- Unites States (48)

Map Service Creation

An ArcIMS project requires a created map and an ArcIMS Map Service. In our application, an image service is created and is linked to the map created above. When the user performs map rendering operations, such as zooming in or panning, the corresponding requests are sent to the image service. It will create map pictures in JPG format and report the link of generated pictures to the web server.

Website Construction

ArcIMS provides an easy way to generate a default HTML interface. However the default interface has to be customized to fit specific applications. User inputs, decision scenarios display, results rendering are added as HTML pages. Decision modules are written into structured Servlet and EJB components and they are connected to the HTML elements.

A unique feature of the user interface is that it is built on a GIS with an interactive map interface. Users can select locations directly on the map. Some map rendering functions, such as zoom, pan, and distance measure, are also provided. Furthermore, spatial query and searching functionalities are supported. Users can obtain information about waterway, highway, railway, intermodal facility, and cities, etc. The maps use selective labeling so that, as the user zooms into the detail of the map, useful information such as name and location, will be shown on the map. This makes it easy to browse the map and identify the path and transfer facilities.

The customized website is shown in Figure 3 below. In Figure 3, an optimal path is displayed and highlighted.

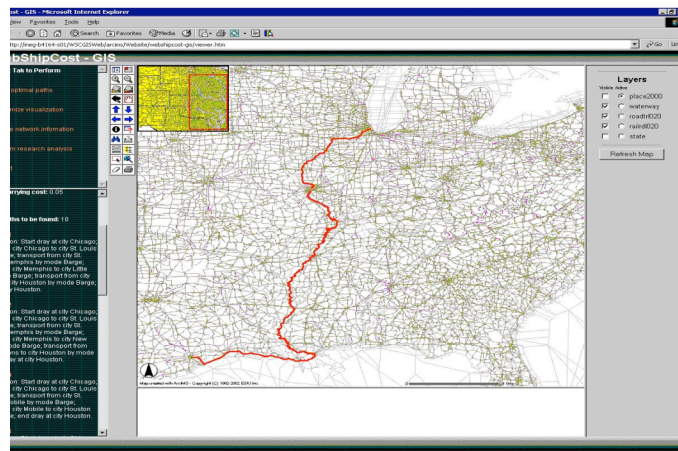


Figure 3 Website Construction and Map Display

4 Conclusions

This paper presents a geographic information system integrated, web-based application with the ability to provide cost, time, and uncertainty analysis of intermodal transportation process based on up-to-date network information. The importance of the proposed GIS integration lies in two aspects: first, GIS provides users with more convenient and efficient data management methods to support the decision making in terms of route planning. Second, GIS comes with the power of visual images to communicate technique information to industry end users. It enables the analysis results to be presented in a more user friendly way and simplifies the concepts associated with them at the same time.

5 Acknowledgment

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6 References

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