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Transportation data model implementation for Iranian roads network

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Abstract:

Geographic Information Systems (GIS) have long been recognized as a valuable tool for the representation and analysis of transportation networks and related activities. GIS have proven to be an integral tool in addressing the needs of transportation managers. Through the well-established vector data structure, GIS has provided an efficient means for organizing basic transportation related data in order to facilitate the input, analysis, and display of transport networks.

The goal of this paper is to present a data model to design an Object-Relational geodatabase for Iranian roads network. This Transportation Data Model is designed as an “essential” data model that provides a context within a GIS that can quickly and easily accept the input that from a wide range of users need in order to accomplish their transportation management goals. This model is specified in an industry-standard modeling notation called the Unified Modeling Language (UML), and is intended as a starting point for structuring transportation data. It is expected that the result of this endeavor facilitates the integration of several data models used in Iranian roads industry. Through a pilot project the establishment of such a context has been evaluated. The results of the pilot project are also presented in this paper.

Key words: transportation, Geodatabase, data model, GIS, DBMS, UML.

1. Introduction

Geographic Information Systems (GIS) have long been recognized as a valuable tool for the representation and analysis of transportation networks and related activities. GIS have proven to be an integral tool in addressing the needs of transportation managers. Through the well-established vector data structure, GIS has provided an efficient means for organizing basic transportation related data in order to facilitate the input, analysis, and display of transport networks. While these basic objects are necessary for virtually all transportation applications, they are not sufficient for any comprehensive management or planning process. It has become increasingly obvious that a much wider range of transportation related objects are essential for advanced transportation planning and management tasks.

GIS for Transportation (GIS-T) is a broad expression that encompasses all of the activities that involve the use of Geographic Information Systems for some aspect of Transportation planning, management, or science. GIS-T applications can be used to monitor traffic accidents that have occurred in the past, or they can plan for changes in the transportation network design for the future. The breadth of the field of GIS-T provides ample opportunities for the development of new and innovative applications, and at the same time presents challenges to those who will try to integrate such diverse activities.[1]

The goal of this paper is to present a data model to design an Object-Relational geodatabase for Iranian roads network. This Transportation Data Model is designed as an “essential” data model that provides a context within a GIS that can quickly and easily accept the input that from a wide range of users need in order to accomplish their transportation management goals. This model is specified in an industry-standard modeling notation called the Unified Modeling Language (UML), and is intended as a starting point for structuring transportation data. It is expected that the result of this endeavor facilitates the integration of several data models used in Iranian roads industry. Through a pilot project the establishment of such a context has been evaluated. The results of the pilot project are also presented in this paper. We hope to provide a data model that will act as a practical transition between the user’s application of transportation data and the standards that have been implemented in the creation of that data. We hope to support the standards that play an integral role in defining the transportation GIS community.

In recent, the ArcGIS™ transportation data model has designed for NewYork. We aimed to develop this data model for Iranian roads network.

2. GIS_T

GIS for Transportation (GIS-T) is a broad expression that encompasses all of the activities that involve the use of Geographic Information Systems for some aspect of Transportation planning, management, or science. Government agencies, research institutions, and members of private industry are just some of the entities that routinely build GIS-T applications. These applications can involve any mode of transportation (truck, automobile, train, ship, bus, airplane, etc.), or may consider other transportation related objects such as pavement, stop signs, or construction equipment. GIS-T

applications can be used to monitor traffic accidents that have occurred in the past, or they can plan for changes in the transportation network design for the future. The breadth of the field of GIS-T provides ample opportunities for the development of new and innovative applications, and at the same time presents challenges to those who will try to integrate such diverse activities.[1]

GIS-T can be an integral part of Departments of Transportation at the State and Federal levels of government. Local, regional, and national bus operators implement GIS-T applications for routing and scheduling. Trucking and delivery companies build applications to track their shipments. Municipalities develop routes for their snow removal and sanitation services. Researchers use GIS-T to design new routing algorithms or improve on those that are currently in use.

In short, there is a large and diverse base of users for GIS-T. They have different objectives toward which they work, and they have different constraints on the transportation activities they can conduct.

3. GIS_T Data models

In order to describe the structure of a database, it is required to know the concept of data model. A data model is a collection of conceptual tools for describing data, data relationships, data semantics, and the data constraints.

In practice, several sets of GIS-T data models have evolved over time. For the purposes of the very brief review provided here we divide these models loosely into three groups: Network Models, Process Models, and Object Models.

By far the most prolific network structure for GIS-T applications has been the model accepted by the U.S. Bureau of the Census for its Topologically Integrated Geographic Encoding and Referencing (TIGER) files. The TIGER model had developed from some earlier network data models, and it was marked by its adherence to the principle of planar enforcement. Planar enforcement simply means that all lines in the network are forced into a single plane, and all intersections of lines are defined in that plane. the planar enforced TIGER model presented several difficulties. First, many transportation applications are not concerned with the polygons that may have transportation features as their boundaries. It is the transportation features themselves that are of interest. Secondly, the planar enforcement that was needed to generate polygons also had the effect of splitting transportation features into many small segments whenever two features crossed in the plane. Therefore, there were many “intersections” in the network data structure that didn’t correspond to any actual intersection in the transportation network at all![1]

Instead of focusing on any single element of a transportation procedure, process models seek to organize many elements into a model that defines a process by which some transportation planning or maintenance activity can take place. Perhaps the most widely known transportation process model is the Urban Transportation Planning System (UTPS) – also known as the 4-Step travel demand models. By building UTPS models forecasts can be made about the demand for transportation resources under different conditions. It is important to note that process models are common and that transportation elements must be able to be associated in order to satisfy the needs of application developers who must implement such process models.[1]

The last general group of transportation models considered here are termed object models. Object models are those that seek to identify or enumerate as many transportation objects as possible and to logically organize them in such a way that they can be most profitably used. A notable effort to accomplish these goals is referred to as the Geographic Data Files (GDF). GDF has been developed in Europe and seeks to describe road and road related data. GDF specifies topological relationships and has several levels of description for different representations of objects.[1]

Related to this type of object model is the idea of an “Enterprise” GIS-T data model. Enterprise models recognize that many elements must be combined to provide an effective transportation system. Thus, enterprise models integrate network models and process models with cartographic entities. The relationships among them can then be defined.

Each of these models represents a structure that has been accepted by a group of users, and each must be respected for its utility. The development process of the ArcGIS™ Transportation Data Model has benefited from each of these models and seeks to provide a structure that can integrate with any of them.

4. Introducing the ArcGIS™ Transportation Data Model

Geographic information systems (GIS) have proven to be an integral tool in addressing the needs of transportation managers. Through the well-established vector data structure, GIS has provided an efficient means for organizing basic transportation related data in order to facilitate the input, analysis, and display of transport networks. While these basic objects are necessary for virtually all transportation applications, they are not sufficient for any comprehensive management or planning process. It has become increasingly obvious that a much wider range of transportation related objects are essential for advanced transportation planning and management tasks. The ArcGIS™ Transportation Data Model endeavors to identify and organize these objects.

The ArcGIS™ Transportation Data Model is designed to help in the development of transportation applications. It does so by providing a context within which a transportation system can be described, and assisting in the development of a geodatabase. The ArcGIS™ Transportation Data Model has a primary focus on the needs of organizations that manage road transportation networks. We have worked to understand and reflect transportation GIS standards and existing projects to provide a practical, essential ArcGIS™ Data Model. A data model for transportation is necessarily complex due to the many and varied uses of transportation data. In most industries, people typically manage their infrastructure with the purpose of reducing costs and improving customer service within their organization. Transportation systems are unique in the sense that every person and organization that interacts with the transportation network needs essential information about the transportation system(s) for their own routing, planning, business operations, and other needs. As such, the needs of these users must be considered as part of the basic infrastructure model. While the breadth of the field of transportation prevents a comprehensive catalog of objects from being assembled that would meet the needs of all user groups, those elements that are common to many transportation GIS users have been identified, and are presented here.[1]

The ArcGIS™ Transportation Data Model is designed as an “essential” data model that provides a context within a GIS that can quickly and easily accept the input that a wide range of users need in order to accomplish their transportation management goals. The “essential” data model can be seen as the intersection of many other models. This model is specified in an industry-standard modeling notation called the Unified Modeling Language (UML), and is intended as a starting point for structuring transportation data. The UML model is a detailed view of the design; it provides data types, relationships, and other details. This is the view of the database design that can be used to create a geodatabase. The second element is a logical data model view that presents the basic structure of the UML model. The third element is a set of data used to demonstrate the efficacy of the ArcGIS™ Transportation Data Model. This data set is composed of public domain, transportation related data that may be freely used to support specific applications. [1]

The ArcGIS™ Transportation Data Model can help a user or an application development team to generate a geodatabase. In general, the geodatabase is a logical extension of the relational databases that have been long accepted in GIS applications. Geodatabases are indeed relational databases with special structures designed to deal with geographic information.

In summary, the ArcGIS™ Transportation Data Model is designed to generate a geodatabase within ArcGIS™ that will serve the needs of transportation management professionals. It takes advantage of the flexibility of Object Orientation to define entities and the relationships among those entities. These objects can be created and modified within the Visio 2000 software package in an informal Analysis Diagram and a more explicit UML notation. The UML can be used to transfer the transportation system design to a geodatabase within ArcGIS™.

5. The ArcGIS™ Transportation Data Model Packages

There are 10 ArcGIS™ Transportation Data Model packages containing more than 100 feature classes, object classes, domains and relationships. Each package contains a set of object and feature classes and the relationships between those classes. Each object class within a package consists of a descriptive name and a set of attributes (and optionally behaviors) that define that object.

The ArcGIS™ Transportation Data Model Packages are:

- **Reference Network Package**

The Reference Network Package provides the foundation for the ArcGIS™ Transportation Data Model. Virtually all other objects related to the Reference Network in some way. Not surprisingly the transportation network is of primary importance to transportation professionals as well. Although not every transportation related application deals directly with the transportation network, it is such a compellingly common element that it is considered to be the core of the ArcGIS™ Transportation Data Model.

- **Assets Package**

The Assets Package contains objects that represent physical features on the landscape that are not part of the network, but are related to the network. These may

be transportation navigation aids and controls such as traffic lights or stop signs, or they may be barriers delimiting the navigable network such as curbs and guardrails. Assets may also include polygonal features that must be maintained, such as medians or parking lots. There are two main groupings of Assets, one set is made up of objects, and the other set is made up of features. The objects are point and line representations that will be displayed using linear referencing.

- **Activities Package**

The Activities Package of the ArcGIS™ Transportation Data Model is similar in many respects to the Assets Package. Both are comprised of objects that are related to the underlying network, but are not elements of the network itself. Both Assets and Activities can represent features with a variety of spatial representations. However, Activities differ from Assets in that Assets generally represent physical objects at a point or along a section of the network, while Activities represent similarly referenced transient occurrences. Additionally, Activities are transient objects that represent planned actions rather than unexpected occurrences such as traffic accidents. Activities are transient objects referenced to the transportation network.

- **Incidents Package**

Occurrences such as traffic accidents, citations, or spills are examples of objects that in the ArcGIS™ Transportation Data Model are termed Incidents. Incidents are very similar to both Assets and Activities in that they are referenced to the network and can have multiple spatial representations. Incidents vary from Activities only in the nature of the occurrence.

- **Mobile Objects Package**

Mobile Objects are representations of the entities that are transported across a transportation network. Whether it is a pedestrian walking along a road, or a car traveling down a highway, a primary focus of transportation management is the act of efficiently moving goods and people. Mobile Objects are those things that are moved.

- **Street Objects and Routing Objects Packages**

Many transportation applications are concerned with road networks. Commonly segments of road in the network are identified solely by a descriptive name. Additionally, locations along road segments are determined not by absolute location but with a relative method of addressing. Street names and addresses have become integral related attributes for virtually all road networks. The ArcGIS™ Transportation Data Model groups these attribute objects together at Street Objects. The development and maintenance of Routes for transit systems that operate across networks has long been a staple of transportation management. A number of objects can assist in that process. The ArcGIS™ Transportation Data Model groups these objects together as Routing Objects.

- **Location Referencing Package**

Location Referencing is one of the most essential processes within a wide range of transportation applications. The ability to quickly and accurately determine

locations of objects in the field is of paramount importance for the safe and efficient operation of our transportation networks. The ArcGIS™ Transportation Data Model provides a template set of objects to allow for the implementation of Location Referencing systems within transportation applications. This template also exploits several built-in capabilities of ArcGIS™.

- **Relationships and Domains Packages**

Features and Objects within the ArcGIS™ Transportation Data Model do not exist by themselves, nor should they. There are many possible relationships between objects. Some relationships within Packages are forms of direct inheritance from parent objects to their children. When more complex relationships between objects exist, these can be formalized with the relationship classes. A Package exists to specify these relationship classes. Attributes of objects can be constrained to have only specified legal values. These domains can be made explicit, and the ArcGIS™ Transportation Data Model maintains a Package where they are logically grouped.

6. Need analysis

With consider to the need analysis that is done for transportation organization of Iran, the following data is needed to build a geodatabase for Iranian roads network:[2]

- Data related to roads (such as freeways, highways, main roads,etc.)
- Foundations (such as terminals, parkings, facilities, police stations,etc.)
- City centers (such as province centers,etc.)
- X,Y and speed of mobile objects.

And also the following analysis is needed:

- Overlay
- Buffering
- Network analysis
- Terrain analysis
- Statistical analysis
- Point in polygon
- Query
- Location/allocation
- Visualization

With consider to above mentioned analysis and capabilities that are needed by a transportation data model , we choose some existance GIS software package and assessed them to find best software to develop a data model for Iranian roads network.

The following table shows the result of the assesment of different GIS software packages.(See table 1)[2]

	CadCorp	ArcGIS	Laser Scan	SmallWorld	Spans	Caris	MGE
Data input	+	+	+	+	+	+	+
Data editing	+	+	+	+	+	+	+

Map projection	+	+	+	+	+	+	+
visualization	2D, 3D	2D, 3D	2D	2D, 3D	2D, 3D	2D, 3D	2D, 3D
Data management	Object oriented, relational	Object-oriented, relational	Object oriented	Object oriented	relational	relational	relational
query	+	+	+	+	+	+	+
Topology	+	+	+	+	+	+	+
Buffering	+	+	+	+	+	+	+
Overlay	+	+	+	+	+	+	+
Network analysis	+	+	+	+	+	+	+
Statistical analysis	+	+	+	+	+	+	+
Data transfer	++	+	+	+	+	+	+
Network connection	+	+	+	+	+	+	+
Operating system	Win 98, Win NT, Win 2000	Win 98, Win NT, Win 2000	Win NT, Unix	Win NT, Win 2000	Win 98, Unix	Win 98, Win 2000	Dos, Unix
Development tools	+	+	+	+	+	+/-	+
Basic data model	Vector	Vector	Vector	Vector	Raster	Vector	Vector
Conversion to Persian system	Easy	Easy	Hard	Easy	Easy	Easy	Hard
Technical support from manufacturer (Availability)	+	+	+	+	+	+	-
Prices in Iran	Average	Average	High	High	High	Average	Average

Table 1. Comparison of different GIS software package

Based on the assessment of different software packages, it concluded that some of those package such as ArcGIS, LaserScan, Cadcorp, SmallWorld are suitable for Iranian Transportation Data Model and with more consideration from the above presented comparison, the following conclusions can be made that ArcGIS software package is the best choice for this purpose.

7. Implementing the ArcGIS Transportation Data Model

The following steps describe the process of designing the ArcGIS transportation data model:

- The Analysis Diagram can be used as a template to make initial decisions about which objects to use and how to organize them into a logical structure that is appropriate for the applications being developed.

- The UML Diagrams specify the specific attributes and behaviors of the objects to be employed, and the relationships between objects and between logical groupings of objects. The UML can be used to create an empty geodatabase structure within ArcGIS™.
- Both the Analysis Diagram and the UML Diagrams representing the ArcGIS™ Transportation Data Model were generated in the Visio 2000 Software Package.
- Exporting the UML to a Microsoft Repository within Visio 2000
- Creating a new Personal Geodatabase in ArcCatalog in which the empty schema will be created.
- Once the empty geodatabase schema has been created the geodatabase must be populated with transportation related data before the ArcGIS Transportation Data Model can be implemented in an application.

Final result is a geodatabase that is used to managing the transportation network.

8. conclusion

in this paper we introduce the ArcGIS transportation data model for iranian roads network. The following conclusions can be made:

- Through the well-established vector data structure, GIS has provided an efficient means for organizing basic transportation related data in order to facilitate the input, analysis, and display of transport networks.
- The ArcGIS™ Transportation Data Model is designed to help in the development of transportation applications. It does so by providing a context within which a transportation system can be described, and assisting in the development of a geodatabase.
- Based on the assessment of different software, it concluded that some of those package such as ArcGIS, LaserScan, Cadcorp, SmallWorld are suitable for Iranian Transportation Data Model and with more consideration from the above presented comparison, the following conclusions can be made that ArcGIS software package is the best for this purpose.
- The ArcGIS™ Transportation Data Model is takes advantage of the flexibility of Object Orientation to define entities and the relationships among those entities.

9. References

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