A Conceptual Model for Spatially Enabled E-Service Intelligence in State Transportation Program Development

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Abstract

Year 2000 governmental expenditures for the construction, maintenance, operation and administration of the transportation system in the United States totaled $167.5 billion. The development of the annual and multi-year transportation program is a complex process with multiple decision making activities at national, state and local governmental agency levels across diverse transportation modes. Information requirements include not only the inventory, condition and performance history of the transportation infrastructure, but also knowledge of land use, safety, freight movement, environment, commerce and strategic governmental initiatives.

To assist with the program development process, state transportation agencies are developing spatial data warehouse infrastructures using Geographic Information System technologies. Sophisticated web-enabled spatial analysis tools have the potential to effect significant improvements in program development decisions.

This paper presents a conceptual model for the development of spatially-enabled E-Service Intelligence products for transportation program development. These concepts will be illustrated with hypothetical E-Service Intelligence products for transportation safety program development**.**

Keywords: E-Service Intelligence, Geographic Information Systems, Spatial Data Warehouse, E-Government .

1. Background

Year 2000 public expenditures for the construction, maintenance, operation and administration of the transportation system in the United States totaled $167.5 billion, with approximately 30% federal funds and 70% state and local government funds. Gross government investment in the transportation infrastructure is estimated at $86.1 billion [1].

Within State Departments of Transportation (DOTs), the development of the annual and multi-year elements of the transportation program is a complex process with multiple decision making activities at national, state and local governmental agency levels across diverse modes including roadway, public transit, rail, and air.

Transportation program development decisions are dynamic, interdisciplinary, and involve considerable tradeoffs in financial, safety and political contexts. Information requirements include not only the inventory, condition and performance history of the transportation infrastructure, but also knowledge of land use, safety, freight movement, environment, commerce and strategic governmental initiatives.

Two recent events have accelerated the necessity for advanced decision support products: (1) legislatively mandated program coordination requirements and (2) the issuance of the Governmental Accounting Standards Board Section 34 criteria for government Asset Management practices.

State DOTs are responding to these requirements by pursuing the development of enterprise spatial data warehouse infrastructures using GIS technologies to integrate relevant internal and external information. Sophisticated web-enabled spatial analysis tools have the potential to effect significant improvements in program development decisions.

Internet/Intranet accessible E-Service Intelligence products are particularly relevant. The need for intelligence cuts across governmental agencies, functional departments and public stakeholders. Effective communication requires the timely identification and delivery of critical intelligence focused on decision making needs.

2. Transportation Programming Requirements and Asset Management

Within the United States, over 39,000 governmental agencies are involved with transportation program development. These include states, counties, townships and cities with a wide variety of oversight authority and capabilities (Table 1) [2]. In urban areas with a population over 50,000, the Metropolitan Planning Organization (MPO) serves as a primary participant in the planning process. There are over 300 MPOs in the United States.

Governmental Agency	Total Number
States	50
Counties	3,034
Townships	16,506
Cities	19,431

Table 1. Summary of Governmental Agencies in the United States Involved with Transportation Program Decision Making.

2.1. TEA-21

The 1998 United States Transportation Equity Act for the 21st Century (TEA-21) authorized the Federal surface transportation programs for highways, highway safety, and transit [3]. TEA-21 added additional planning requirements including the mandate that each MPO and appropriate State agency cooperatively develop estimates of funds for plan and program implementation. States must also develop the long-range transportation plan in consultation with affected officials within each non-metropolitan area [3]. Thus, all local governmental jurisdictions are participants in the programming process.

TEA-21 requirements demonstrate the complexities and tradeoffs inherent in transportation programming decisions. In addition to addressing the transportation requirements of people and freight movement, planning practitioners must also consider such factors as safety, environmental impacts, energy, and local/state/national/global commerce.

2.2. GASB 34

In June 1999, the Governmental Accounting Standards Board (GASB) issued Statement 34 that required state and local governments to begin to report on the value of their infrastructure assets, including roads and bridges. GASB 34 also required that governments have a systematic approach to mange their assets including asset inventory, condition analysis, and management planning systems [4].

Asset Management decisions often involve semistructured or unstructured problems where decision-makers view information with evolving conditions and program characteristics. The transportation program development process must balance infrastructure needs in the context of available budgets, network assessment, and alternative modes.

3. Geospatial Technologies in Transportation Agencies

To meet program development and Asset Management requirements, governmental agencies are increasingly utilizing Geographic Information System (GIS) technologies. These technologies enable the integration of information from disparate systems through a spatial data warehouse infrastructure.

Since almost all transportation information is geographically related, State DOTs have recognized that the applications of new spatial technologies can enhance and streamline transportation program activities. A recent peer exchange of state transportation agency managers on this subject identified decision support, network analysis and executive, state, district, local and public communication as key issues affecting program delivery. Other significant issues were multimodal analysis, high number/diversity of assets, data verification, and coordinated data programs [5].

In assessing future applications, the participants determined that spatial data, tools and technologies enabled the development of decision-making products. Participants specifically identified improved decision support via Internet/Intranet delivery to multiple stakeholders, direct incorporation of external spatial information, more comprehensive analysis of interrelated information, and greater ability to develop forecasting and modeling tools [5].

The Transportation Research Board (TRB) recently characterized current practices and relevant trends for GIS and Geographic Information Science (GISci) in transportation [6]. Goodchild indicated that GIS refers to the technologies for capturing, storing, processing, and communicating geospatial information. Geographic Information Science (GISci) refers to the theories, models and methods that underlie GIS [7]. The TRB study indicated that GISci is rapidly developing by incorporting time and other analysis dimensions and expanding abilities to mine multiple data sets for patterns. Table 2 summarizes these trends for GIS and GISci [6].

The study also portrayed the evolution in transportation agencies towards enterprise-wide location enabled business systems. Leading database vendors, such as Oracle and IBM, are now providing native spatial data types, indices, and operators. These trends provide a basis for the future development of spatial E-Service Intelligence products [6].

Geographic Information Systems Trends	Geographic Information Science Trends
• From Data Poor to Data Rich • Multimedia GIS • Location-Aware Technologies • Network and Mobile Computing • GIS as a Tool Kit	• Multidimensional GIS • Geographic Data Mining • Beyond Place-Based Methods • Location Based Services

Table 2. Trends in Geographic Information Systems and Geographic Information Science for Transportation Organizations [6].

4. E-Service Intelligence

Griggs et al described "E-services" as a form of middleware, much like software agents, that are used primarily for search and data mining activities on the web [8]. Lu et al describe E-service intelligence as an "integration of e-services and intelligence technologies including intelligent presentation of web content and services, personalized support, and direct user participation in organizational decision-making processes [9]."

Allen identified three qualities of intelligent agents for truly intelligent systems: autonomy, adaptivity and sociability [10]. Griggs et al suggest existing intelligent agents possess semi-autonomy, some adaptive capability and no sociability [8].

These characteristics of E-Service Intelligence products have direct applications to guide the development of complex program analysis outputs. Autonomous products provide immediate relevance to transportation program development.

5. Transportation E-Service Intelligence Model

Figure 1 displays a conceptual model for spatially enabled E-Service Intelligence in state transportation agencies. The transportation spatial data warehouse provides the information source for the application of E-Service Intelligence techniques resulting in program decision support products. Section Six applies this model to transportation safety program development.

6. E-Service Intelligence for Safety Program Development

For demonstration purposes, this section illustrates how E-Service Intelligence can be applied to the safety program development process in a state DOT. Safety is a significant issue. In 2003, the Illinois Department of Transportation identified 437,000 roadway crashes in Illinois with a total cost of $10.5 billion [11]. The effective analysis of overrepresented crash locations and the application of appropriate remediation measures in the program development process can result in significant benefits to the traveling public. Information requirements include internal legacy systems, external data sources and historical data.

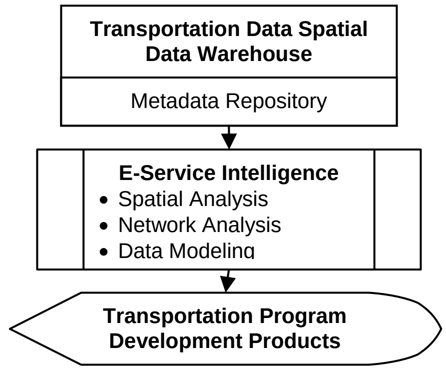

Figure 1. Conceptual Model for Spatially Enabled E-Service Intelligence for State Agency Transportation Program Development.

The concept of Autonomy for intelligent agents implies the ability to perform functions without specific instructions [8]. Surveillance Agents and Data Mining Agents have direct applications. For example, Surveillance Agents can perform continuous and repetitive background tasks such monitoring for high accident crash sites. Data Mining Agents can operate within the spatial data warehouse structure to analyze performance indicators, such as crash relationships with roadway and climatic conditions.

Smith et al investigated the implementation of GIS-based roadway safety analysis [12]. They described analytical capabilities that go beyond the simple display of crash data. These are spatial analysis, network analysis, and cell-based modeling

Spatial analysis combines data from disparate sources and spatial data sets for intelligent analysis. Example data are the history of pedestrian vehicle crashes, local demographic characteristics and the presence of school zones. Proximity analysis uses buffering techniques to promote cluster analysis [12].

Network analysis entails the searching and analysis of data along a linear feature, such as a road, rail or waterway. Examples of tools are Sliding Scale Analysis and Corridor Analysis. Sliding Scale Analysis identifies roadway segments with a high crash occurrence level based on user thresholds. Corridor Analysis links other relevant routes for evaluation. An example is the analysis of designated truck routes, including feeder routes, resulting in the identification of high truck crash segments [12].

Cell-based modeling uses grids or cells to aggregate spatial data and provides a means to identify spatial clustering patterns over large geographic areas. An example is the relationship of the crashes in a particular cell to population density, travel patterns, land use and vehicle/animal collisions [12].

Autonomous, GIS-enabled spatial E-Service Intelligence products potentially provide the rapid identification of critical safety areas to assist in program development decisions.

6.1. Spatial Data Warehouse Information Components

The following lists a representative sampling of internal and external information that has relevance in transportation safety program decision making.

Internal Information

- Current roadway crashes and characteristics
- Previous roadway crash history
- Severe Injury and Fatal accidents
- Multimodal transportation inventory asset information – roadway, rail, bicycle
- Roadway geometrics
- Traffic and freight data patterns
- Video roadway logs
- Published multi-year transportation program

External Information

- Climatic information by day/time/geography
  - Weather conditions (clear, rain, snow, sleet, wind, temperature)
  - Visibility (night, day, fog)
- Land usage (urban/rural, residential, business)
- Population demographics/density
- Household travel patterns
- Law enforcement violation data

6.2. Safety Program Development E-Service Intelligence Products

The following is a list of example E-Service Intelligence products to meet the needs of safety program development practitioners.

- Overrepresented high accident locations
- Identification of remediation measures
- Complex data verification
- Rapid accident growth locations
- Geometrics/crash characteristics
- System surveillance
- Accident forecasting models

7. Conclusions

This paper provides a conceptual model for the development of spatially enabled e-service intelligence products for transportation program development. Future research is recommended for identification of specific applications of e-service intelligence to meet decision-maker needs. A characterization of benefits would help demonstrate the value of these types of products in program development decision making.

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