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THE INTEGRATION OF GIS AND TRANSPORTATION MODELING: A STATE-OF-THE-PRACTICE REVIEW

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ABSTRACT

One of the factors that continuously affect the quality of life and the desirability of metropolitan areas as a place to live and work is an effective local transportation system. As individuals, business and government search for ways to relieve congestion and reduce travel time, the role of geographic information systems (GIS) in relation to transportation planning, analyzing, evaluating and planning of transportation networks and systems becomes more critical. There is a powerful relationship between GIS and transportation modeling systems. State departments of transportation (DOT) and metropolitan planning organizations (MPO) have begun to utilize ESRI's ArcInfo, ArcView, and Intergraph's GeoMedia Suite with transportation models; however these activities have not been documented together in a single source. The purpose of this report is to document the active use of GIS-T (if any) at the 50 state departments of transportation and metropolitan planning organizations.

EXECUTIVE SUMMARY

One of the factors affecting the quality of life and the desirability of metropolitan areas as a place to live and work is an effective local transportation system. As individuals, businesses and government search for ways to relieve congestion and reduce travel time, the role of geographic information systems (GIS) and transportation planning, analyzing, evaluating, and planning of transportation networks and systems becomes more critical. A powerful relationship exists between GIS and transportation modeling systems. State departments of transportation (DOT) and metropolitan planning organizations (MPO) have begun to utilize ArcInfo and ArcView with transportation models. However, these activities have not been documented together in a single source.

Geographic information systems for transportation are:

- interconnected hardware,
- software,
- data,
- people,
- organizations
- institutional arrangements for collecting, storing, analyzing, and communicating particular types of information about the earth.

The particular types of information are transportation systems and geographic regions that affect or are affected by these systems (Fletcher, 2000). The application of GIS to transportation is commonly known as GIS-T. Currently DOTs across the nation use GIS-T to maintain comprehensive roadway databases, and to edit, display, and plot networks and related data. ArcInfo can be used to store, edit, display, and plot a simulation network, both before and after traffic assignment. In some instances the GIS is simply used to display the model results with other GIS datasets as a backdrop. In more sophisticated applications, ArcInfo is used to update and manage the network as well as display the model results. This use of ArcInfo helps the modelers to validate model output and identify inconsistencies caused by network coding errors or the wrong location of zone centroid connectors.

GIS also plays a useful part in organizing inputs at other stages in the travel demand forecasting process such as compiling data in Traffic Analysis Zones for trip generation. Inputs at other stages include formatting the zonal data into trip tables for trip distribution modeling and organizing mode choice data by geographic area as part of mode split analyses. Since incorporating the use of GIS with transportation modeling packages such as EMME2 or TRANPLAN it has become possible to extend modeling capabilities. However, there is room for improvement in the interoperability of these two systems.

In order to have optimum interoperability some limitations in the GIS would need to be addressed. GIS capability in dealing with temporal information such as traffic conditions is still limited. Agencies need to understand and consider temporal changes and their interactions with the transportation system in transportation decision-making. Another growth area under consideration is the ability of the GIS to represent three-dimensional data. In this context there is a need to detail the existing uses of GIS-T and document any innovations developed by individual users. Researchers initiated this project in response to the desire to define the basic needs of GIS-T based on current and anticipated uses and characteristics of transportation agencies. The researcher contacted selected state DOTs, and regional and municipal agencies with transportation responsibilities to assess the implementation status of GIS-T.

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CHAPTER 1

INTRODUCTION AND RESEARCH APPROACH

In the 1980s only a few hundred people used GIS. In the two decades since then that number has grown to more than half a million. By the end of this decade tens of millions of people will be using GIS to access all kinds of information through a geographic framework. Societies in general are becoming very aware of the need to manage information from a geographic perspective. This awareness has been brought about by the growing trend toward a global community and economy. There is also widening recognition that transportation is a major component of quality of life and sustainability (Wiggins et al., 2000). At the same time, the often-negative impact of advancing technology has shown the need for wise management of the earth's resources. GIS provides the tools to help meet these challenges (Antenucci, 1991). A geographic information system is a means to make many types of work more efficient and workers more effective. It enables better decisions based on better information.

1.1 Need for GIS in Transportation

The transportation industry utilizes such technology as real-time geographic positioning system (GPS) in:

- automobiles,
- public transportation,
- insurance companies, and
- enhanced 9-1-1 emergency communications.

The uses of such technology grow daily, yet no person, division, or agency is nurturing this essential technology.

A representative sample of the applications (Figure 1) in which GIS technology is being used today to improve transportation decision-making includes:

- road design,

- highway mapping,
- pavement and maintenance management,
- capital budget planning,
- analysis of accident data and traffic volumes, and
- routing and dispatching vehicles.

Many states are in the process of linking existing road log data with their mapping and drafting systems.

GIS-T applications cover much of the broad scope of transportation. Transportation analysts and decision makers use GIS tools in:

- infrastructure planning,
- design and management,
- public transit planning and operations,
- traffic analysis and control,
- transportation safety analysis,
- environmental impacts assessment,
- hazards mitigation, and
- configuring and managing complex logistics systems

Intelligent transportation systems, including services such as intelligent vehicle highway systems and automatic vehicle location systems are a particularly ambitious integration of GIS and communication technologies to a wide variety of transportation services (Souleyrette and Strauss, 1999; Waters 1999). What is the fuss about GIS-T? Part of the excitement is certainly a spillover from the meteoric rise of geographic information science and systems in general (Longley et al., 1999). This rise is only the beginning of the geographic information revolution. We continue to see vast, perhaps even accelerating, increases in the volume, scope, and spectrum of digital geographic data, capabilities for processing geographic data into geographic information, and information technology (IT) for moving these data and information to where they are needed. We will soon enter the era of the geographically enabled scientist, engineer, and citizen who can access, process, and communicate digital geographic information anywhere at anytime (Mark, 1999; Fletcher, 2000).

Many public sector transportation and metropolitan planning organizations are also evolving from engineering and design agencies to multipurpose information providers operating in a context of increasing public scrutiny (Fletcher, 2000). GIS-T can play a central role in the new environment for public land-use and transportation decision-making. By allowing a wide range of information to be integrated based on location, GIS-T fosters (but does not guarantee) a holistic perspective on complex land-use and transportation problems. GIS-T allows analytical and computational tools to be used in conjunction with detailed representations of the local geography, allowing analysis and problem solving to be tailored to the local context. GIS-T can also greatly reduce the gulf between analysis and communication, allowing greater public input into analytical decisions such as choice of data, modeling assumptions, and scenario development. This increased public input could lead to greater public “buy-in” to transportation decisions, particularly important in an era of pervasive “not-in-my-backyard” attitudes. GIS-T can also make transportation information more accessible, potentially enhancing location and transportation decision-making by the public at large and encouraging wider participation in the transportation planning process (Miller and Shaw, 2001).

Representative GIS Applications

Abandoned Mines/Wells Inventory	Land Ownership Mapping
Agricultural Crop Monitoring/Modeling	Legislative District Delineation/Redistricting
Air Pollution Emissions Inventory/Modeling	Mineral Resource Tracking/Leasing
Archeology Surveys	Municipal Solid Waste Facility Permitting
Census Data Analysis	NAFTA Policy Analysis
Client Analysis	Nonpoint Source Pollution Analysis
Coastal Fisheries Assessment	Oil and Gas Well Permitting/Tracking
Construction Project Tracking	Oil Spill Response, Deployment/Management
Contamination Source Analysis	Pavement Management
Crime Analysis	Petroleum Storage Tank Facility Permitting
Disaster Relief Assistance	Pipeline Routing, Permitting and Tracking
Disease Mapping	Population Projections
Drought Planning	Precision Agriculture
Emergency Response, including 9-1-1	Property Tax Appraisal
Endangered Species Management	Public Lands and Facilities Management
Environmental Compliance Studies	Public Water Supply Tracking
Environmental Justice Studies	State Park Planning
Environmentally Sensitive Areas Monitoring	Surface Water Modeling
Erosion Studies	Timber Tracking/Permitting
Flood Analysis/Modeling	Transportation Modeling/Analysis
Future Water Demand Modeling	Utility Facility Management
Groundwater Modeling	Utility Service Area Delineation
Groundwater Pollution Potential Analysis	Watershed Delineation/Analysis
Habitat Analysis/Planning	Wellhead Protection
Hazardous Materials Spill Response	Wetlands Resources Monitoring/Mitigation
Highway Performance Tracking/Modeling	Wildlife Tracking
Industrial/Hazardous Waste Facility Permitting	

Source: Texas Geographic Information Council, January 1999.

Figure 1. Representative Sample of the Ways GIS are Being Used.

1.2 Research Objective

GIS have been applied successfully to several different fields and the need to facilitate the application of GIS to transportation (GIS-T) and to alleviate the interoperability issues is essential.

The intention of this study is to determine if GIS have been properly integrated into the transportation planning process, and to observe what improvements need to be addressed to make the integration a success. GIS has been applied successfully to various fields and because of its far-reaching potential it will be imperative to facilitate the application of GIS to transportation. Making this process more accessible and improving the interoperability issue will be essential to the success of a useful GIS-T. To substantiate this statement, researchers will conduct a survey. The results will be analyzed and a conclusion developed on the progress of the integration of GIS into the transportation planning process. This information will then be used to push forward an understanding of how to integrate GIS into the transportation planning process to reduce interoperational issues.

1.3 Scope of the Study

The overall study will be limited to and focused on current users of GIS-T as an effective tool to improve the transportation planning process. The study will focus on the use of GIS-T by transportation planners, to assess and evaluate the state-of-the-practice for the integration of GIS into the transportation planning process. This report is intended to provide a look at the state-of-the-practice for GIS-T so that transportation organizations can assess and plan to exploit GIS technology to the fullest. The results of the study will provide a model to use for MPOs, state DOTs, other transportation planners, and other stakeholders to assist in the planning process. Recommendations from this study will be based on the results of the data collected from the survey questionnaire.

1.4 Research Approach

A survey instrument will be developed to query the views, opinions and current practices of transportation professionals and organizations that use GIS as a tool in the transportation planning process. The survey questionnaire will be used to collect data from targeted organizations and transportation professionals to determine their use of GIS-T in the transportation planning process (see appendix 1, for survey). The survey questionnaire will provide data related to the degree to which organizations use GIS. The research that the survey will establish will target users in the transportation field that desire or already use GIS and transportation modeling programs.

The questionnaire will cover 12 topic areas that were being used to assess the current status of GIS-T usage:

1. GIS systems that are being used:
 - ARC/INFO
 - ArcView 3.x
 - GeoMedia Suite
 - MGE Suite
 - TransCAD
 - MapInfo
 - ArcGIS
2. Planning Models being used:
 - EMME/2
 - TRANPLAN
 - QRS
 - TransCAD
 - VISSIM
3. If two of these systems can be combined, are there any interoperability issues that are occurring?
4. If the GIS software is used in relation to transportation planning, can it be used for Traffic Analysis Zones for trip generation or formatting the zonal data into trip tables for trip distribution?
5. Does the organization give any education of GIS and if so has using transportation planning models and GIS ever been covered?
6. What advantages and disadvantages come with GIS-T?
7. Do you transfer information in GIS-T to microscopic simulation?
8. Can the public read information retrieved by GIS-T?
9. What organizations are using GIS-T?
10. Who in the organization is using it?
11. Are these organizations creating custom applications?
12. Is any effort being made to communicate with other users?

These preliminary questions are necessary to assess the state-of-the-practice for integrating GIS and the transportation modeling in the transportation field. This information will help in identifying needed growth areas with the integration process.

CHAPTER 2

FINDINGS

Information retrieved from the survey questionnaire will be used to determine how various organizations responded to the integration of GIS into transportation. It is apparent that GIS-T is being used with transportation models but there are problems that occur. The format used to interpret the survey will allow one to distinguish various patterns of use throughout the industry of GIS in the transportation field. The data collected can be interpreted, given to organizations that will be using these programs and hopefully will prevent future users from running into occurring problems.

With this information users can address or avoid problems that occur can be addressed and should be avoided. The purpose of this survey is to address issues that occur with GIS in transportation. The survey does target this information and from this information improvements can be made. Researchers sent 50 surveys throughout the industry specifically to the departments of transportation and metropolitan planning organizations, to find out how and if they were using GIS-T. Twenty-four responses were received and a format was developed to summarize the answers (see Appendix 2).

2.1 Summary of State-of-the-Practice

The survey and data collection effort revealed success in some areas and gaps in others. In order to assess the state- of- the- practice, researchers had to retrieve and identify the pros and cons were retrieved from the survey. Survey respondents mainly showed success in areas such as GIS and the use of transportation planning models. Nearly half of the respondents were able to combine the two programs and the other half was not. GIS is mainly used for a creation of visual answers to spatial problems in relation to transportation planning. GIS is used in the travel forecasting process such as compiling data in Traffic Analysis Zones. This process is used for trip generation or formatting the zonal data into trip tables for trip distribution.

The majority of the transportation planning organizations provides GIS user education. Ironically, the majority of the respondents, who received GIS user education, did not receive

education on the topic of using transportation-planning models with GIS. GIS-T has incompatibility of results, but visual power is the most beneficial aspect of GIS-T. Multipurpose gravity models, mode choice functions, and speed feed backs are a few factors missing from GIS-T.

In certain situations a program is needed to interpret information that is retrieved and that has to be used by others. The majority of the organizations that were surveyed were not using a program to create a hot linkage between their GIS and planning model. Transferring GIS-T data to a microscopic simulation model is not that useful. GIS-T is not being used to transfer data over the Internet to other planners or to the public.

CHAPTER 3

INTERPRETATION OF FINDINGS

In order to assess the state-of-the-practice for the integration of GIS into the transportation planning process, and to help in identifying needed growth areas, a survey was used to as a tool to document this information. A total of 50 surveys were sent to target state DOT and MPO's. From these 50 surveys we received 24 responses. Out of these respondents 24, 38 percent were Transportation planners, none were from transportation engineers, 8 percent were GIS technicians and 54 percent were "other". Out of these positions held, 21 percent of them worked for a MPO, 71 percent worked for DOTs, none worked for city/regional transportation organizations, and 8 percent worked for private consultant firms. The following charts and text present a graphical and textual display of the designated questions (see Figures 2 through 7).

In the chart below, displays the percentage of GIS systems being used.

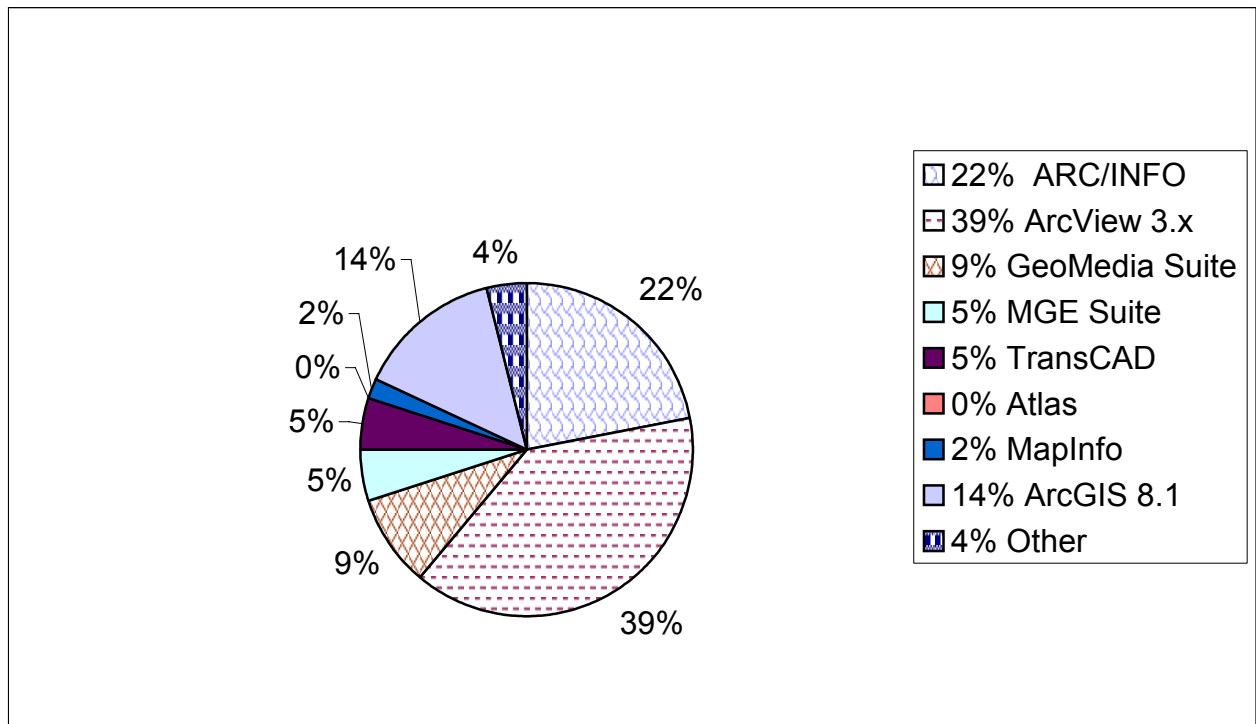


Figure 2. Question 3. What Geographic Information System Are You Currently Using?

The chart below shows the percentage of transportation models being used.

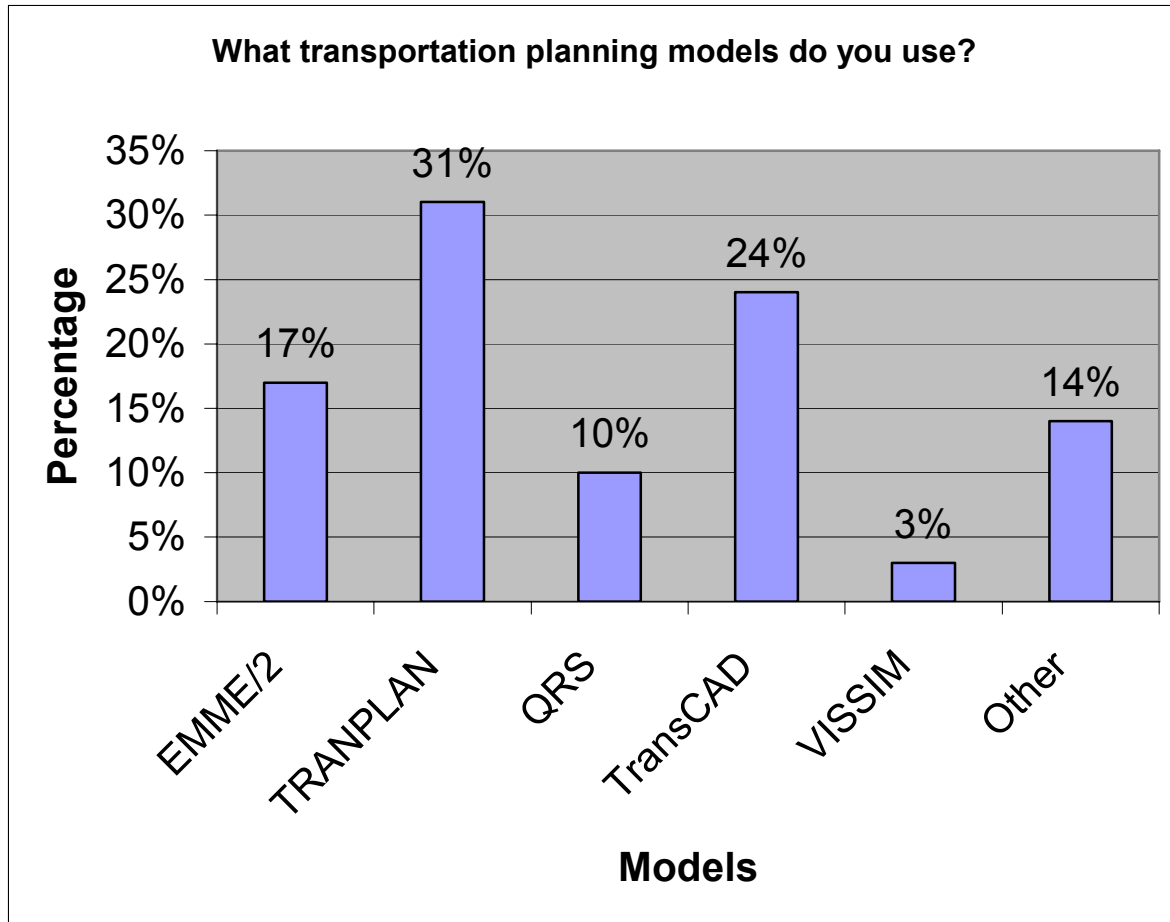
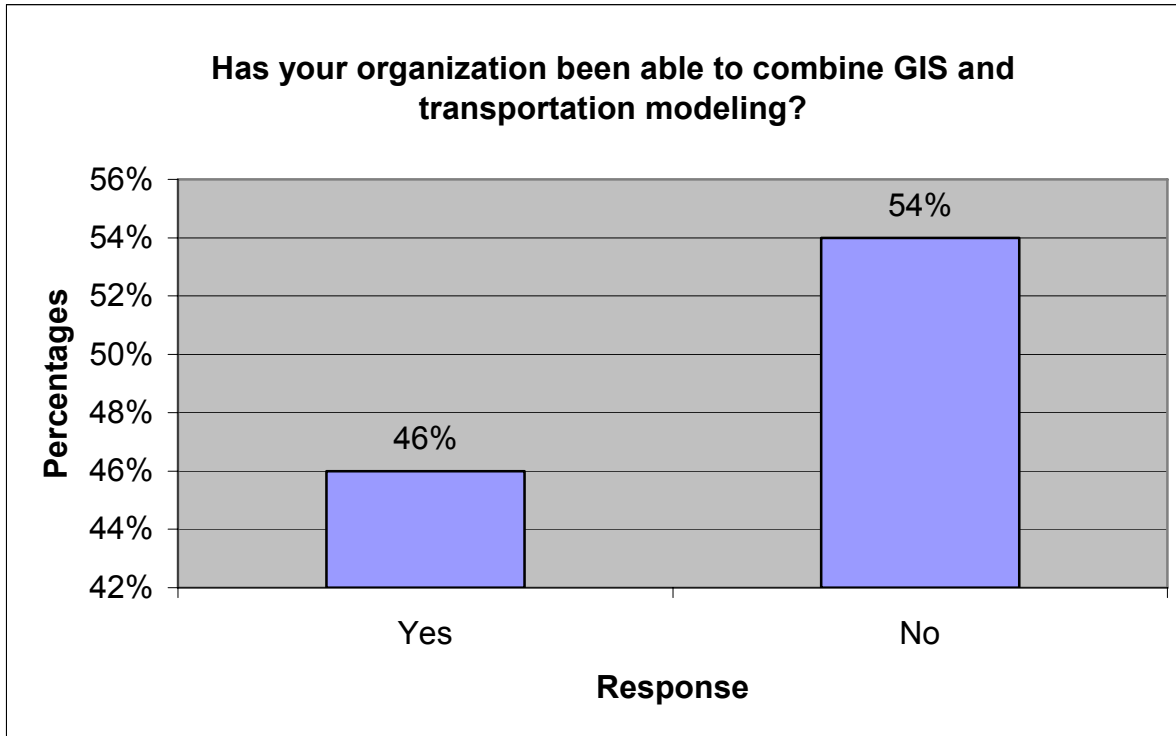


Figure 3. Question 4. What Transportation Planning Models Do You Use?

The chart below shows the percentage of users that have been able to combine GIS and transportation models.



The percentages in this chart illustrate the companies that were able to combine the two systems and that are or are not experiencing problems.

Figure 4. Question 5. Has Your Organization Been Able to combine GIS and Transportation Modeling

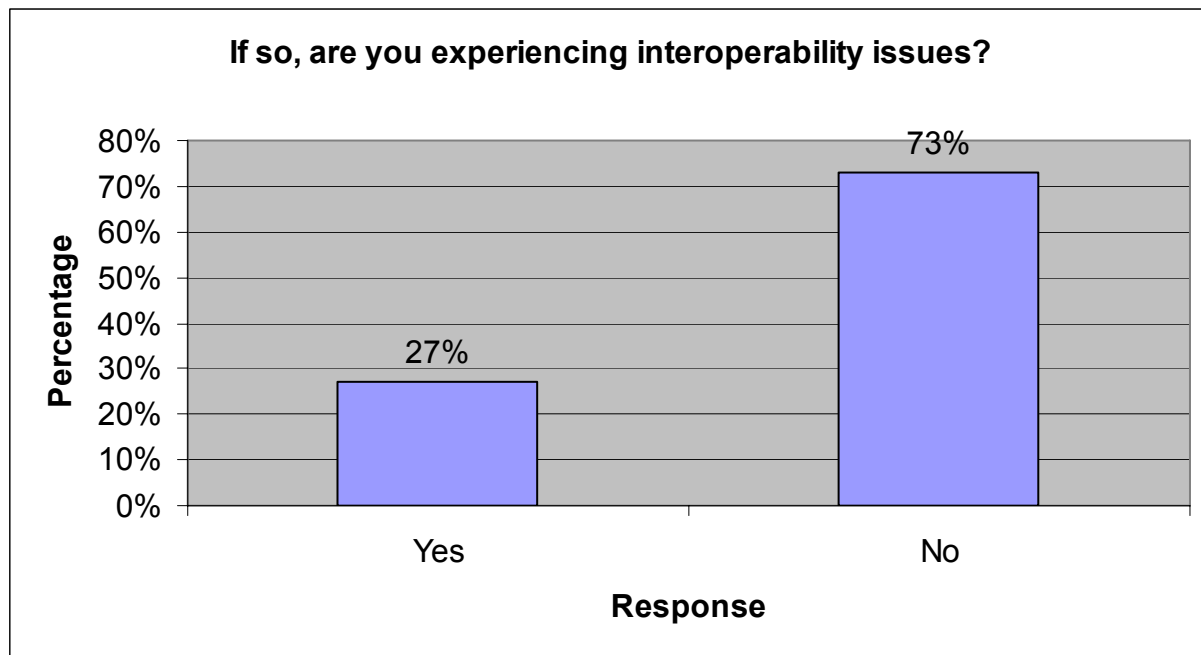


Figure 5. Question 6. If So, Are You Experiencing Interoperability Issues?

Question 7. GIS software packages can be used in relation to transportation planning in various ways. 28.5 percent of the respondents use GIS as a full analysis tool, 38 percent use it for creation of visual answers to spatial problems, and 33.5 percent use GIS for network building.

Question 8. Has GIS played a useful role in organizing inputs to other stages in the travel forecasting process such as compiling data in Traffic Analysis Zones for trip generation or formatting the zonal data into trip tables for trip distribution? Responses were: 54 percent said yes, 38 percent said no, and 8 percent said neither.

Question 9. The need to educate users about GIS is very imperative to an organization. Seventy-five percent responded that GIS user education is provided and 25 percent responded no.

Question 10. The yes respondents were asked if the topic of using transportation planning models and GIS were ever covered. Twenty-one percent responded yes and 79 percent responded no.

Question 11. The organizations were asked if they create custom application with GIS for planning problems. Fifty-four percent said yes and 46 percent said no.

There are several benefits of GIS-T; the chart below displays the percentages of benefits.

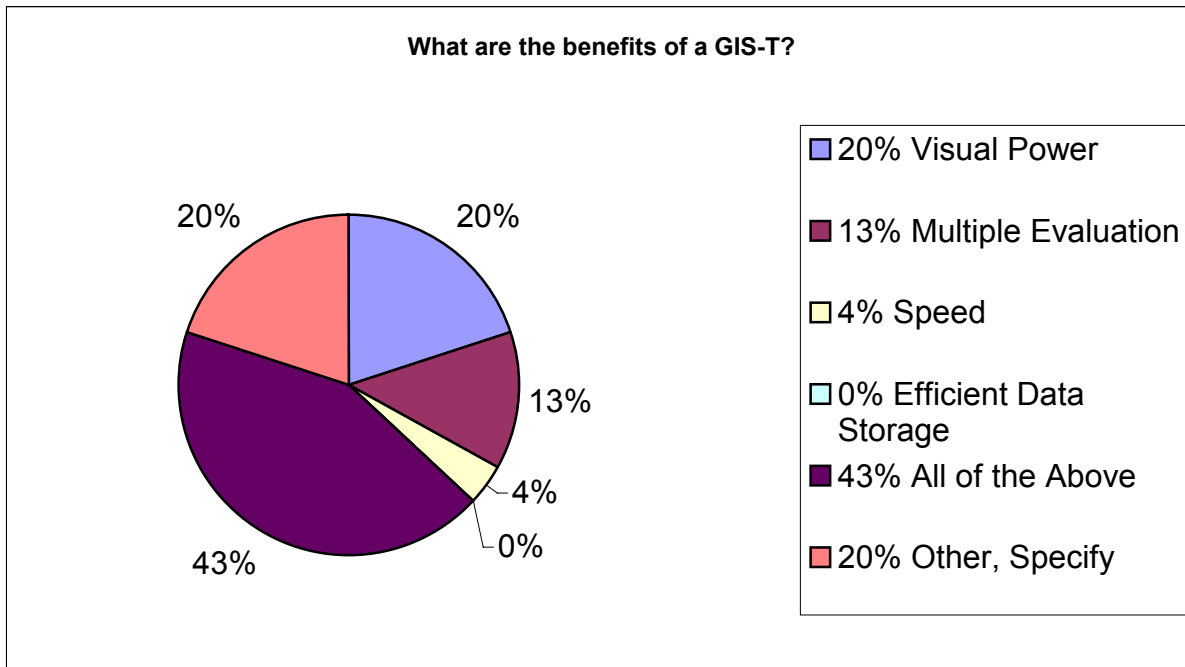


Figure 6. Question 12. What Are The Benefits of a GIS-T?

The percentage of missing factors from GIS-T is shown below.

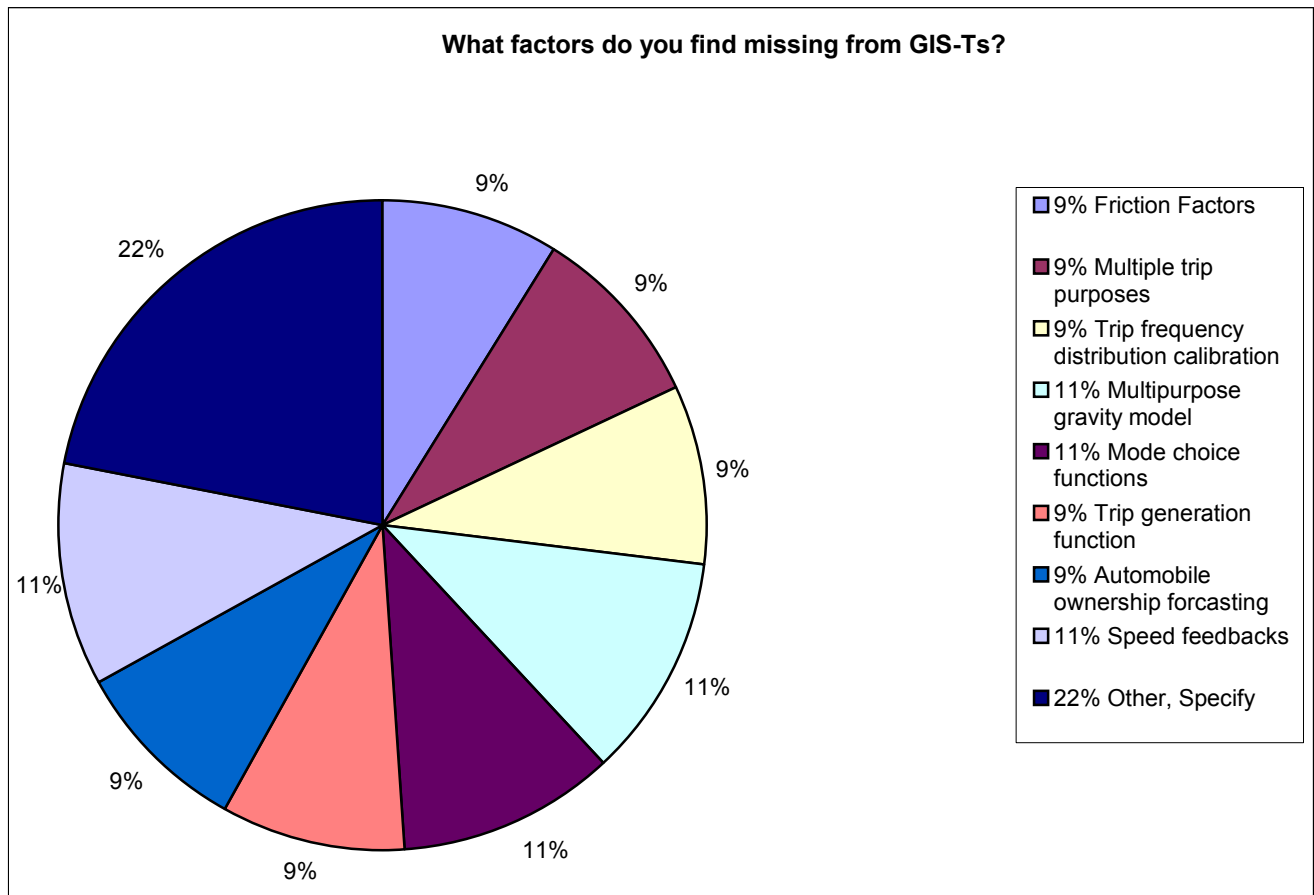


Figure 7. Question 13. What Factors do You Find Missing From GIS-Ts?

Question 14. Some disadvantages about GIS-T found in the industry through the survey were 10 percent overly simple, 18 percent lack of accuracy, 27 percent incompatibility of results, and 45 percent said other.

Question 15. Eighteen percent of respondents are using a program to create a “hot linkage” between their GIS and planning model and 82 percent were not.

Question 17. Thirty-three percent of respondents transfer GIS-T data to their microscopic simulation models and 67 percent did not.

Question 18. The 67 percent who did not were asked if they would like a transfer pipe, and 50 percent said yes and 50 percent said no.

Question 19. Respondents who transfer GIS-T data then you were asked if they provide travel model results via GIS-T as a web service to other planners or to the public. One hundred percent said no.

Question 20. Fifteen percent said there are no appropriate tools, 46 percent said they see no use for it and 39percent responded to “other”.

For the respondents who chose to answer question 21, their responses are listed below.

Question 21. Please provide additional comments relative to your experience with GIS and transportation application.

Responses to Question 21

- Creating Transportation travel and demand models is not a business requirement of the Department. Those analyses are left to the MPOs and LDDs.
- Most business requirements are running ahead of the technology and data. Business staff frequently goes to traditional IT solutions. Are dissatisfied with results, but decide it’s cheaper to live with than use GIS now that technology and data have caught up.
- Most GIS conferences are preaching to the choir. The business community needs someone other than me to tell them what GIS can do for them. Business community lacks creativity and provides little guidance to focus areas for GIS development. Results are a bunch of software companies, technical staff, and consultants drive the technology and its application.
- GIS-T has led to greater efficiencies for productivity, decision-making, and data access.

- It all depends on what level of accuracy you want. 90 percent accuracy is fairly easy to achieve. The closer you get to 100 percent the more time is needed. Accuracy at the small area geography level can also take an inordinate amount of time.
- The Nebraska Department of Roads is in a formative stage of our development of our GIS-T models. It will take time for us to fully realize the potential of the new arena for modeling traffic on our streets and highways.
- Our transportation planning work is done through contract to our University and the National Institute for Advanced Transportation Technology.
- We are working to better integrate GIS in trans planning but have concentrated on building our network model and maintaining our legacy database of attributes regarding the trans infrastructure in Idaho.
- Currently we have not incorporated our Departmental GIS effort with transportation planning models. In the future we undoubtedly will.
- The ARC/INFO and Arcview GIS software we currently use totally lacks modeling applications of most, if not all, modeling packages. We do not use ARC/INFO and Arcview for modeling applications.
- As a GIS professional, I would like to get our planners more involved with using GIS and GIS-T forecasting models. However, the majority of this work is done by hired consultants. I don't anticipate that this practice will change any time in the near future.

- Biggest problems are:
lack of a network with connectivity and topology , and lack of qualified staff with GIS/modeling experience.

- The current purpose of our GIS organization is to provide a comprehensive graphical road network to the various offices within the State Highway Administration and to provide software and tools to use the network along with tabular and other spatial data layers for solving various problems faced by the administration. Our current thrust is to integrate GIS and Mapping data into a geodatabase to better serve it to our organization.

- I don't know how you are differentiating GIS-T from GIS, but we use GIS for a variety of transportation and planning related tasks. Much of the data used in the transportation models are initially developed and analyzed using GIS. Revisions needed to geometry of model data may be done in GIS. An ArcView extension is used to move data between ArcView and EMME2. This data movement is the extent of interoperability between GIS and modeling software? GIS does not provide a method for analyzing and manipulating matrices. Microsoft Excel is often used for this task. However, free software called 'R' is being evaluated for this purpose and has been found to be very versatile.

- We currently haven't invested much effort into modeling and the GIS staff hasn't had enough time to become familiar with modeling software and how GIS could contribute to this effort. We have attempted to provide DXF files to the modeling group in only one sample city so far; otherwise, our Modeling Group has used old CADD data.

CHAPTER 4

FUTURE OUTLOOK

Due to the indivisible relationship between transportation and geography, geographic information systems (GIS) and related technologies stand unique in their potential application to these requirements. The ability to use geographic locations and relationships to manage all of the information necessary for transportation planning, engineering, and operations offers opportunities unavailable until now. The power of geographic reasoning, as incorporated into GIS, has potential to become a central, indispensable component of a transportation organization's overall information strategy.

GIS-T in the private sector is also expanding and showing few signs of abating. Dramatically improving information technologies (particularly communication technologies) are creating an increasingly hyper-competitive, global-scale economy. This hyper-competition is creating new requirements for efficiency and customer-responsiveness. Meeting these objectives requires an effective logistics system for managing the flow and storage of material, information, and services from their points of origin to their places of final consumption. Since many organizations are dispersed across geographic space, sometimes at national and global scales, the "supply chains" from origin to consumption are geographical. GIS-T is being increasingly used to configure and manage geographical supply chains for maximum efficiency and responsiveness (Miller and Shaw, 2001).

GIS-T is also diffusing to the public at large. Wireline and wireless access to the World Wide Web (WWW) and the Internet is increasing and will soon achieve penetration rates similar to telephony. Wireless GIS services will become increasingly available, both from the private sector as well as from public and quasi-public organizations. Many of the queries posed by casual users will be transportation, and travel related; (e.g., "Is there a good Mexican restaurant within ten minutes of my current location?" (Smyth, 2001). Not only will this create direct demands for GIS-T services such as intelligent transportation systems, but will also quite likely improve the geographic and transportation literacy of the citizenry at large. (As an example, consider how many more people now know about geographic referencing systems due to the increasing use of the global positioning system for recreational uses.) This new found knowledge

in the general public could create additional, indirect demands for GIS-T services, including greater sophistication in citizen scrutiny of transportation decisions in the public and private arenas (Miller and Shaw, 2001).

It is likely that transportation-related problems will be at the forefront of private sector decision-making and public sector debate as the world navigates through the 21st century. Our connected and crowded world requires efficient, responsive and environmentally friendly transportation systems. We have also come to the realization (too late in some cases) that transportation decisions have enormous impacts on land, and life.

REFERENCES

- Antenucci, John C., Kay Brown, Peter L. Croswell, Michael J. Kevany, and Hugh Archer. Geographic Information Systems, A Guide to the Technology. Van Nostrand Reinhold, New York, 1991.
- Fletcher, D. "Geographic information systems for transportation: A look forward in *Transportation in the New Millenium: State of the Art and Future Directions*", Washington, DC: Transportation Research Board, CD-ROM, 2000.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., and Rhind, D. W" (eds.) Geographical Information Systems, Volume 1: Principles and Technical Issues, 2nd ed., New York: John Wiley and Sons, 1999.
- Miller, Harvey J, and Shih-Lung Shaw. Geographic Information Systems for Transportation (GIS-T): Principles and Applications. Oxford University Press (*Spatial Information Series*), 2005.
- Mark, D. M. Geographic Information Systems: Critical Issues in an Emerging Cross-disciplinary Research Domain," Report from a workshop on Geographic Information Science and Geospatial Activities at the National Science Foundation, January 14-15, 1999. Available at <http://www.geog.buffalo.edu/>), 1999. Accessed August, 2005.
- Smyth, C. S) "Mining mobile trajectories," H. J. Miller and J. Han (eds.) Geographic Data Mining and Knowledge Discovery, London: Taylor and Francis, forthcoming, 2001.
- Wiggins, L., Deuker, K., Ferreira, J., Merry, C., Peng, Z. and Spear, B. "Application Challenges for Geographic Information Science: Implications for Research, Education and Policy for Transportation Planning and Management" URISA Journal, Vol.12 52-59, 2000.

APPENDICES

APPENDIX 1
DOT SURVEY

In order to assess the state-of-the-practice for the integration of GIS into the transportation planning process, and to help in identifying needed growth areas, there is a need to document the use of GIS in conjunction with transportation planning models and the use of the software packages currently known as GIS-Ts. Please take a few minutes to help us improve the understanding of interoperability issues so that a dialog can be started and the potential to better integrate the two systems can begin. Thank you.

1. What is your position in your organization?
 - a. Transportation Planner
 - b. Transportation Engineer
 - c. GIS Technician
 - d. Other, specify _____

2. What type of organization do you work for?
 - a. MPO
 - b. DOT (State or Federal)
 - c. City/Regional transportation organization
 - d. Private transportation consultant
 - e. Other, specify _____

3. What geographic information system are you currently using?
 - a. ARC/INFO
 - b. ArcView 3.x
 - c. GeoMedia Suite
 - d. MGE Suite
 - e. TransCAD
 - f. Atlas
 - g. MapInfo
 - h. ArcGIS 8.1
 - i. Other, specify _____

4. What transportation planning models do you use?
 - a. EMME/2
 - b. TRANPLAN
 - c. QRS
 - d. TransCAD
 - e. VISSIM
 - d. Other, specify_____

5. Has your organization been able to combine GIS and transportation modeling?
 - a. Yes
 - b. No

6. If so are you experiencing interoperability issues?
 - a. Yes
 - b. No

7. How are your GIS software packages used in relation to transportation planning?
 - a. Full analysis tool
 - b. Creation of visual answers to spatial problems
 - c. Network building

8. Has GIS played a useful role in organizing inputs to other stages in the travel forecasting process such as compiling data in Traffic Analysis Zones for trip generation or formatting the zonal data into trip tables for trip distribution?
 - a. Yes
 - b. No
 - c. Other, specify_____

9. Is there any type of GIS user education provided by your organization?
 - a. Yes
 - b. No

10. If yes, has the topic of using transportation planning models and GIS ever been covered?
 - a. Yes
 - b. No

11. Do you create custom applications with GIS for planning problems?
 - a. Yes
 - b. No

12. What are the benefits of a GIS-T?
 - a. Visual power
 - b. Multiple evaluations

- c. Speed
 - d. Efficient data storage
 - e. All of the above
 - f. Other, specify _____
13. What factors do you find missing from GIS-Ts?
- a. Friction factors
 - b. Multiple trip purposes
 - c. Trip frequency distribution calibration
 - d. Multipurpose gravity model
 - e. Mode choice functions
 - f. Trip generation function
 - g. Automobile ownership forecasting
 - h. Speed feedbacks
 - i. Other, specify _____
14. What disadvantages do you find in GIS-Ts?
- a. Overly simple
 - b. Lack of accuracy
 - c. Incompatibility of results
 - d. Other, specify _____
15. Are you using a program to create a “hot linkage” between your GIS and planning model?
- a. Yes
 - b. No, go to question 17
16. If yes, what program are you using?
Specify _____
17. Do you transfer GIS-T data to your microscopic simulation models?
- a. Yes, go to question 19
 - b. No
18. If no, would you like to have a hot transfer pipe?
- a. Yes
 - b. No
19. Do you provide travel model results via GIS-T as a web service to other planners or to the public?
- a. Yes, go to question 21
 - b. No
20. If no, why not?

- a. No appropriate tool
- b. No need for that
- c. Other, specify_____

21. Please provide additional comments relative to your experience with GIS and transportation application.

**APPENDIX 2
SUMMARY OF SURVEY
PARTICIPANTS**

Summary of Survey Participants						
Organization	Title	GIS Used	Planning Software Used	Used Together	Use of GIS	
1. DOT	GIS Section Manager	GeoMedia	None	No	Full analysis tool, Creation of visual answers to spatial problems	
2. MPO	Transportation Planner	ArcInfo, ArcView	TranPlan	Yes	Creation of visual answers to spatial problems	
3. DOT	Transportation Planner	ArcView	TP+ , TranPlan, QRS	Yes	Network Building	
4. DOT	GIS Manager	ArcView, GeoMedia, MGE Suite	TranPlan	No	Network Building	
5. DOT	GIS Coordinator	ArcInfo, ArcView, ArcGIS 8.1, MapObjects, ArcIMS	None	No	Creation of visual answers to spatial problems	
6. MPO	Transportation Planning Coordinator	ArcInfo, ArcView	EMME2	No	Full analysis tool, Creation of visual answers to spatial problems, Network Building	
7. DOT	General Professional	ArcInfo, ArcGIS, ArcView 8.1, ArcIMS	TranPlan, TransCad	No	Creation of visual answers to spatial problems	
8. DOT	GIS Technician	ArcView, ArcInfo, ArcGIS 8.1	None	No	Network Building	
9. DOT	GIS Supervisor	ArcInfo, ArcGIS, ArcView 8.1	EMME2	No	Creation of visual answers to spatial problems	
10. Consultant	Transportation Planner	ArcView	TransCad	Yes	Full analysis tool	

11. DOT	Statewide Planning Engineer	TransCad	TransCad, QRS	Yes	Full analysis tool, Creation of visual answers to spatial problems, Network Building	
12. DOT	GIS Manager	ArcInfo, ArcGIS, ArcView 8.1, ArcIMS	None	No	Full analysis tool	
13. DOT	GIS Technician	ArcInfo, ArcGIS, ArcView 8.1, ArcIMS	None	No	Network Building	
14. DOT	Transportation Planner	ArcView, GeoMedia	TranPlan	No	Network Building	
15. DOT	Associate Transportation Planner/GIS Analyst	ArcView, ArcInfo, GeoMedia	EMME2, Tranus	Yes	Full analysis tool, Creation of visual answers to spatial problems, Network Building	
16. DOT	GIS Manager & Data Collections Bureau Chief	ArcInfo, ArcView, ArcGIS 8.1	None	No	Full analysis tool, Creation of visual answers to spatial problems, Network Building	
17. MPO	Transportation Planner	TransCad, ArcView	QRS, EMME2	Yes	Full analysis tool	
18. DOT	GIS Technician	TransCad	EMME2	Yes	Full analysis tool	
19. MPO	Transportation Planner	ArcInfo, ArcGIS, ArcView 8.1, ArcIMS	TranPlan	Yes	Full analysis tool, Creation of visual answers to spatial problems, Network Building	
20. DOT	GIS Analyst	ArcInfo, ArcGIS, ArcView 8.1, ArcIMS	EMME2	Yes	Full analysis tool, Creation of visual answers to spatial problems, Network Building	
21. DOT	GIS Technician	ArcInfo, ArcGIS, ArcView 8.1, ArcIMS	TransCad	Yes	Creation of visual answers to spatial problems, Network Building	
22. DOT	Transportation Planner	ArcView, GeoMedia	TranPlan	No	Network Building	
23. MPO	GIS Analyst	ArcInfo, ArcView, Arc	TranPlan	Yes	Full analysis tool, Creation of visual answers to spatial	

