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A Geographic Information System — Based Transportation Forecast Model for Use in Smaller Urban and Rural Areas

ABSTRACT

GIS has been shown to be an effective tool to be used in the transportation forecasting process and scenario analysis. Previous efforts have linked full function GIS packages with transportation forecasting models. The goal in this paper was to link a low-cost, desktop GIS package with a transportation forecasting model to better fit the technical knowledge and budget restrictions of Metropolitan Planning Organizations (MPOs) and Regional Planning Associations (RPAs) in Iowa. A desktop mapping package was integrated with an Urban Transportation Planning (UTP) model to provide an interface for network analysis. Modifications to the network are possible in the GIS environment, run through the UTP model and brought back into the GIS environment to evaluate traffic changes. Possible modifications include representing a change in land-use characteristics, alter existing link attributes, and modifying the existing network by adding new nodes and links. This linkage has been developed for Des Moines, but can be used by MPOs and RPAs to improve the transportation planning process and enhance scenario analysis.

INTRODUCTION

The use of Urban Transportation Planning (UTP) models began in the early 1950's with the advent of large-scale urban transportation studies. By then, the digital computer allowed for the storage and manipulation of large amounts of data required to perform the modeling process. Since, the transportation planning process has been expanded and is now performed in most urban areas. Today's practice has been shaped not only by technological developments, but a collection of legislative mandates. The transportation planning process was first influenced by the Highway Act of 1962. This act called for a comprehensive, coordinated and continuous transportation plan in an urban area (known as the "3C" process) to be implemented by 1965. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has reinforced continuation of the traditional "3C" planning process by calling for programs at the state and Metropolitan Planning Organization (MPO) level to manage data systems in a coordinated and efficient way (1). ISTEA legislation includes several factors MPOs are to consider when developing transportation plans and programs including evaluation of all transportation projects within the metropolitan area and preparation and periodic update of long range plans (2).

Evaluating transportation projects and developing long range plans are data intensive procedures. These procedures produce "snapshots" of the transportation network. The "snapshot's" spatial and temporal attributes have potential for applications providing improved spatial data processing capabilities. Geographic Information Systems (GIS) presents the technology to combine databases associated with UTM models with processing and mapping capabilities to provide a powerful tool for the manipulation and analysis of transportation data (3).

UTP models currently in use allow MPOs, Regional Planning Associations (RPAs), cities, and other transportation agencies to evaluate the impact of different roadway/landuse scenarios. Developing a linkage between a UTP model and a GIS provides a system to develop and evaluate the different scenarios quickly and efficiently. The linkage utilizes a GIS for the storage, retrieval, analysis, modification, and display of the data developed for the application of the UTP model. The linkage also provides a system in which analysts can manipulate network characteristics and model land-use changes in the study area. This provides analysts the ability to quickly and graphically evaluate several alternatives, be it a change in the network (additional links, increased/decreased speed on links, realignment of links) or a modification in land-use characteristics of the study area (altering the productions and attractions of centroids).

A linkage between UTP models and GISs is not novel. Development of planning tools using GIS was introduced as early as 1986 (4). Since, there have been a number of efforts examining how GIS can be integrated with and/or enhance transportation modeling including: Lewis, Niemeier, Blewett, McAdams, Replogle, Choi, and Kriger (4) (5) (6) (7) (8) (9) (10) (11). The seven county Minneapolis/St. Paul area rebuilt its regional planning model using a GIS (12), and GIS has been used in Charlotte for super-regional transportation modeling (13). Previous efforts to link models has resulted in software developed by ESRI to link TRANPLAN with Arc/INFO, a working linkage developed between TRANPLAN and Intergraph's MGE (3), and Caliper Corporation's GIS package, TransCAD, able to store, display, manage and analyze transportation data (14).

MOTIVATION

While network modifications can be made without GIS, using GIS technology improves the process by increasing efficiency and modification capabilities. One advantage of using a GIS is the ability to select nodes or links within a particular area and display or modify a database containing all the data associated with the selected records. GIS allows for queries of a database and graphically to examine changes to network characteristics. In the smaller urban and rural areas however, high power, high cost GIS packages require resources and investment beyond that generally available at planning organizations.

METHODOLOGY

This paper describes the development of a linkage between TRANPLAN (Urban Analysis Group, Danville, CA) and MAPINFO (MAPINFO Corporation, Troy, NY). TRANPLAN implements the Urban Transportation Modeling System four step planning process: trip generation, trip distribution, modal split, traffic assignment (15). TRANPLAN is currently being used at 5 of 8 MPOs within Iowa. MAPINFO GIS package represents a lower cost desktop mapping package (14). MAPINFO attaches graphical features to a database containing information about the features. MAPINFO supplies the users with the ability to perform "complex (Structured Query Language) SQL queries on multiple databases" (16). MAPINFO is currently being used or expected to be purchased by the majority of the MPOs and RPAs in the state. The platform for both TRANPLAN and MAPINFO is the personal computer.

OUTLINE

This paper describes the design of a system to interactively link the two packages and utilizes the system through a collection of tests and a case study. The paper concludes by presenting a comparison of the system with current transportation forecasting procedures.

DESIGN OF SYSTEM

The TRANPLAN files used to develop the linkage were provided by the Des Moines MPO, but the system can be applied to most other areas using TRANPLAN. Files provided contained node and link data, trip productions and attractions, turn prohibitors, friction factors, and a set of TRANPLAN control files.

Keys to developing graphics are the node and link files. In TRANPLAN, node data consists of the node number and X -Y coordinates. The link data include the A and B nodes, distance, speed, direction code, link group designation, capacity, and include an option for specifying links as either one or two way.

MAPINFO has the ability to develop point, line and polygon features. The points represent the location of nodes and lines represent the location of links. The ability to develop polygon features is not required to operate the linkage with the UTP Model. The ability to develop polygons can be used if existing features such as parks, rivers, or land-use data is desired to be combined with the transportation network.

UTP MODEL/GIS INTEGRATION

The first step in developing the linkage between TRANPLAN and MAPINFO was converting the TRANPLAN text files into MAPINFO tables. Both the node and link files have spatial components. There is no explicit spatial information related to the production and attraction information or the turn prohibitor information, but the information can be brought into MAPINFO and attached to nodes and links.

Nodes

MAPINFO requires the X-Y coordinate for each node to develop points. The production and attraction information associated with the centroids is then attached to the appropriate centroids by a FORTRAN program. Production and attraction information could be input to a separate table into MAPINFO, but combining it with the node table reduces the number of tables to be managed.

The file can then be brought into MAPINFO using MAPINFO's register table command which "allows "non-native" file to be converted into tables" (17). The nodes can then be mapped from the table using the X-Y coordinates. Once the nodes are mapped, copies of the map and table provide files which can be modified without losing any original data. Possible modifications include changing the location or placement of a new node. Modifications could also represent a change in land-use through a change in the production and attraction values associate with a centroid. Other capabilities include Structured Query Language (SQL) queries which can be applied to the table to alter node symbology to highlight centroids.

Links

MAPINFO requires the starting and ending X-Y coordinate to place a link on a map. Therefore, the X-Y coordinates associated with the A and B nodes for the links must be added to the link information (not usually stored together in a TRANPLAN). A FORTRAN program was developed which obtains the X-Y coordinates for the A-B nodes. The program examines the A and B node for each link and reads the X-Y coordinates for each from the TRANPLAN node file.

After the FORTRAN program has been run creating a links file containing the X-Y coordinate information, the file is ready to be registered into MAPINFO.

The FORTRAN program also creates a new column placed at the end of the TRANPLAN link information. This new column is a concatenation of the A and B nodes and is used as the primary key when registering in MAPINFO. The joining of information between two tables can then utilize the primary key on the condition that the primary key of one table is the same as the primary key of another.

After the links table has been registered and a map is developed displaying the links in the network, the table should be copied to allow for modifications. At this point, modifications could include changes in link attributes (e.g., capacity, speed, link group information, etc.) or the addition of new links to the network. Queries then allow the users to compare information in different "scenario" tables (e.g. to show volume changes) or to select and modify links with common attributes.

Turn Prohibitors

Turn prohibitor information can also be registered into MAPINFO as a table but there would be no graphics associated with this information. However, turn penalties in a MAPINFO table are available when viewing or modifying the network. A FORTRAN program could be written to read the turn prohibitor information and associate information with the intersection node.

REGISTERING TABLES INTO MAPINFO

The text files used in the register table command should be from an unloaded TRANPLAN network. The registered tables become the base tables. MAPINFO opens both the table and text file creating a linkage which makes the tables non-editable. The linkage slows the process of creating maps from the base tables. However, these tables are beneficial because copies can be edited to represent a new scenario without losing the original network.

A map containing the existing volumes and speeds can be made to compare the operational characteristics of scenarios to the existing conditions. This map would illustrate the effect network modification have on traffic. Once the existing information and the new scenario have been run through TRANPLAN, both the new scenario and the existing conditions can be compared to determine the effects on the network (e.g., what is the effect of a construction project closing two lanes on a freeway? Where will volume-to-capacity ratio increase?).

EXPORTING TABLES TO TRANPLAN FORMAT

After performing network modifications in MAPINFO, the tables need to be exported into TRANPLAN format. First, the node and link tables are to be exported as text files. A FORTRAN program reads the information from the exported tables and prepares new files in TRANPLAN format. As the FORTRAN program reads only the information needed by TRANPLAN, the tables may contain additional columns, but these must follow the original columns. Examples of the additional columns include the identifiers, the calculated volume, street names if available, etc.).

Note: The output file created is a TRANPLAN "Build Highway Network" control file containing node and link information. The program also prompts the user for the name of the turn prohibitors file exported from MAPINFO and includes the information in the Build Highway Network control file. The program also takes production and attraction information from the exported node table and places the information into a separate file. The program allows integration of the constructed Build Highway Network control file with existing control files to complete the planning process.

AFTER RUNNING TRANPLAN

Running TRANPLAN on the modified network produces the new link volumes and speeds. The NETCARD module in TRANPLAN converts the binary network output file into a text file. After NETCARD, another FORTRAN program is used to remove the information not updated during the TRANPLAN run (e.g., A node, B node, Link group options, etc.). The output of this program is a file which contains the new speeds and capacities which apply to the modified network. The identifier column containing the combination of the A and B nodes is again developed through this FORTRAN program, allowing for joining the information to the MAPINFO table.

The modified table does not contain the modified network information until being updated with the TRANPLAN output. For example, to test the effect of closing a lane on a freeway. The first step is copying the links table and reducing in capacity of the effected links. The nodes and links tables are exported and entered into TRANPLAN to obtain the new loadings and speeds. The links table is then updated with the new attributes and allowing queries to determine the effect the modification had on the network.

SCENARIO MANAGEMENT AND COMPARISON OF SCENARIOS

Using the base map as a starting point for new scenarios means that this map will always be available to produce a copy which can be modified. The user will have the option to build upon the last scenario modeled or return to the base map and develop a new scenario. Figure 1 represents this process of developing different scenarios from either the base map or from existing scenarios.

The number of files a user has to manage can become very large. A good file management system is therefore required avoid losing scenarios. GIS can be used to manage and store the scenarios graphically, thereby facilitating efficient data management and better quality control.

TEST OF THE SYSTEM'S SCENARIO ANALYSIS CAPABILITIES

The base map for the city of Des Moines, Iowa, was used to develop different scenarios to test the system. The initial step was the development of the base maps from the TRANPLAN text files. The base map showing links for the downtown section of the Des Moines metropolitan area is shown in Figure 2.

Copies of the base map were modified and run through TRANPLAN. Three modifications were developed to test the system. The first modification represented a change in the land-use of downtown Des Moines through an adjustment of the production and attraction information. The second modification was a change in the operational characteristics of a freeway to simulate construction activity. The final modification was the addition of new links.

Downtown, where most congestion exists in Des Moines was the focus of the changes. The existing congestion in Des Moines is shown in figure 3.

The first test demonstrated the results from a change in land-use in the downtown area. The changes represent 50% more trips attracted to downtown centroids. The centroids which are effected are shown as the diamonds and the results are shown in figure 4.

The second scenario models a reduction of capacity due to construction being performed on a segment of on Interstate 235. Proposed improvements on Interstate 235 are being considered. Capacities of the highway links are reduced by 50%. The construction area and the links with an increase in traffic volume are shown in figure 5.

The final test scenario demonstrates additional links added to the network. The additional links are intended to provide a southern by-pass around the downtown area. The addition includes four links with a capacity of 25,000 vehicles for 24 hours and a speed of 35 miles per hour. The location of the links and the decrease in traffic volume with the new links is shown in figure 6.

TEST RESULTS

As demonstrated, the system can be used to show where traffic increases or decreases are expected if there is a change in land-use represented through alteration of the productions and attractions, change in link attributes, and/or the addition of new links to the network. This information is beneficial to pin-point problem areas. The system also has improved visual capabilities to the forecasting models, provides increased speed in which to perform update and modifications, allows for queries to be made on the network, and allows for multiple evaluations to be developed and compared to each other.

CASE STUDY FOR THE CITY OF DES MOINES

To provide a practical application of the system the proposed extension of Martin Luther King Jr. Parkway to intersect with Interstate 80 was examined. The goal of this extension is to provide another north - south connection for improved access for northwest - downtown commuters. This application examines different location alternatives for the extension and compares the effects of the alternatives.

The open spaces and rivers in the city were developed by the Des Moines MPO in MAPINFO. These layers were included to determine possible locations for the extension. The area is shown in figure 7.

The development of new links and nodes involves a series of steps.

First step: determine the area which is to be developed

Second step: Remove the single interstate link

Third step: place node in interchange location

Fourth step: insert new interstate links

Fifth step: insert new nodes for roadway addition

Sixth step: insert new links for roadway addition.

These steps were performed for two different locations for the interchange to be placed in the area and two different operational characteristics for the alternatives. One of the locations places the interchange on the east side of the river and the other places the interchange on the west side of the river. (In an actual roadway design process there would be numerous other factors to examine of course.) Figure 8 shows the location of the east alternative and the west alternative.

The links which were developed were given the information required in TRANPLAN. The addition of the new links added rows to the bottom of the links table. The rows were updated with the required information (A node, B node, speed, distance, capacity, link group information, etc.). For each of the two alternatives developed, the operational characteristics for the new links on the interstate was the same as for the original link with the exception of distance. The new links for Martin Luther King Jr. Parkway (MLK) had two different operational characteristics for each alternative. The first set of characteristics models the new MLK links operating in the same fashion as the MLK links to the south and the other has an increased speed form 27.5 mph to 40 mph to model a higher speed facility.

Next, the tables for the scenarios were exported and TRANPLAN was run to determine the new loaded volumes. The new volumes were then joined with the tables used to develop the scenario maps were created to represent the new traffic levels. Figures 9 - 11 compare existing and scenario traffic volumes. (The figures were enhanced with the use of the "labeling" function of MAPINFO.)

CONCLUSIONS

The MAPINFO-TRANPLAN interactive system provides many useful features for small to medium sized planning organizations. The features include the use of a graphical interface for modifications and query analysis, enhanced presentation ability, enhanced alternative analysis, and a user-friendly, low cost, desk-top system.

The graphical interface for the modifications and query analysis allows analyst to use database capabilities linked to graphical elements. The graphical display allows analyst to better visualize the network when performing modifications through incorporating different coverages and possibly incorporating aerial photographs. The ability to perform queries allows the analyst to select certain nodes or links in the network conforming to specified constraints. The analyst can also compare multiple scenarios.

Enhanced presentation is important in the context of public displays and meetings. In these arenas, the ability to develop and display maps of the network will provide greater impact to the audience than an oral description. The systems query capabilities provide the ability to answer questions that might arise during the course of a meeting, for example if the audience is concern about a specific percent increase or decrease in traffic in a specified area.

Enhanced alternative analysis is facilitated because the system is able to test different scenarios quickly. Traffic loadings of one scenario can be compared with traffic loadings of any other stored scenario. The ability to analyze alternatives allows the analyst to perform various queries showing the changes between different scenarios and/or the existing conditions. An example would be the use of the system to query the links in the network for which loaded volumes changed between scenarios.

The final benefit of the system is that the system operates completely on a desk-top personal computer utilizing relatively low cost software which is relatively user friendly. This will provide MPOs and RPAs the ability to acquire and use the system without great expenditures into expensive hardware and software.

REFERENCES

1. Fleet, Christopher, Charles Goodman, and Ron Giguere. 1993. Travel Data Needs to Respond Effectively to Congestion Management and Air Quality Planning. *Proceedings for the 1993 GIS for Transportation Symposium.* AASHTO. Washington, D.C.: 152-169.
2. Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)
3. Hans, Zachary, N. *A Geographic Information System for Transportation Modeling, Alternatives and Policy Analysis.* A Thesis Submitted to Iowa State University, 1994.
4. Lewis, Simon and S. McNeil. October 1986. Developments in Microcomputer Network Analysis Tools Within Geographical Information Systems. *ITE Journal*: 31-35.
5. Lewis, Simon. March 1990. Use of Geographical Information Systems in Transportation Modeling. *ITE Journal*: 34-38.
6. Niemeier, Debbie A. and M. Kate Beard. 1993. GIS and Transportation Planning: A Case Study. *Computers, Environment, and Urban Systems.* Vol. 17:31-43.
7. Blewett, C. J. and M. R. Lewis. 1991. Method for Using Geographic Information Systems in Travel Demand Modeling and Other Transportation Planning Applications. *Proceedings of the Twenty-eighth Paving and Transportation Conference.*
8. McAdams, Michael A. 1992. *A Geographic Information System Application to Regional Subarea Transportation Modeling.* Center for Interdisciplinary Transportation Studies, UNC Charlotte. Charlotte, NC.
9. Replogle, Michael A. 1989. Integration of a Geographic Information System with Computer Transportation Models for Land Use and Transportation Planning. *Second Conference on Application of Transportation Planning Methods.* Orlando, Florida.

10. Choi, Keechoo. 1993. The Implementation of an Integrated Transportation Planning Model with GIS and Expert Systems for Interactive Transportation Planning. Dissertation (Ph.D.). University of Illinois at Urbana-Champaign.

11. Kriger, David, Mike Hossak, and Mike Schlosser. 1991. Integration of GIS with the Transportation Demand Model TMODEL2 at Saskatchewan Department of Highways and Transportation. *Proceedings for the 1991 GIS for Transportation Symposium.* Ed. D. David Moyer and Barry L. Larson. AASHTO. Washington, D.C.:127-138.

12. Barrett, William. 1991. Building a Regional Transportation Model with GIS Software. *Proceedings for the 1991 GIS for Transportation Symposium.* Ed. D. David Moyer and Barry L. Larson. AASHTO. Washington, D.C.:117-125.

13. Hartgen, David T, Yuanjun Li, and George Alexiou. 1992. *Super-Regional Very Long Range Transportation Modeling with a GIS.* Center for Interdisciplinary Transportation Studies, UNC Charlotte. Charlotte, NC.

14. GIS World Inc. *1995 International GIS Sourcebook.* Fort Collins, CO, 1995.

15. The Urban Analysis Group. *TRANPLAN User Manual 7.2.* The Urban Analysis Group. Danville, California, 1993.

16. MAPINFO Corporation. *MAPINFO User's Guide.* MAPINFO Corporation. Troy, New York, 1994.

17. MAPINFO Corporation. *MAPBASIC Refence.* MAPINFO Corporation. Troy, New York. 1994.

Figure 1. Description of Scenario Development.

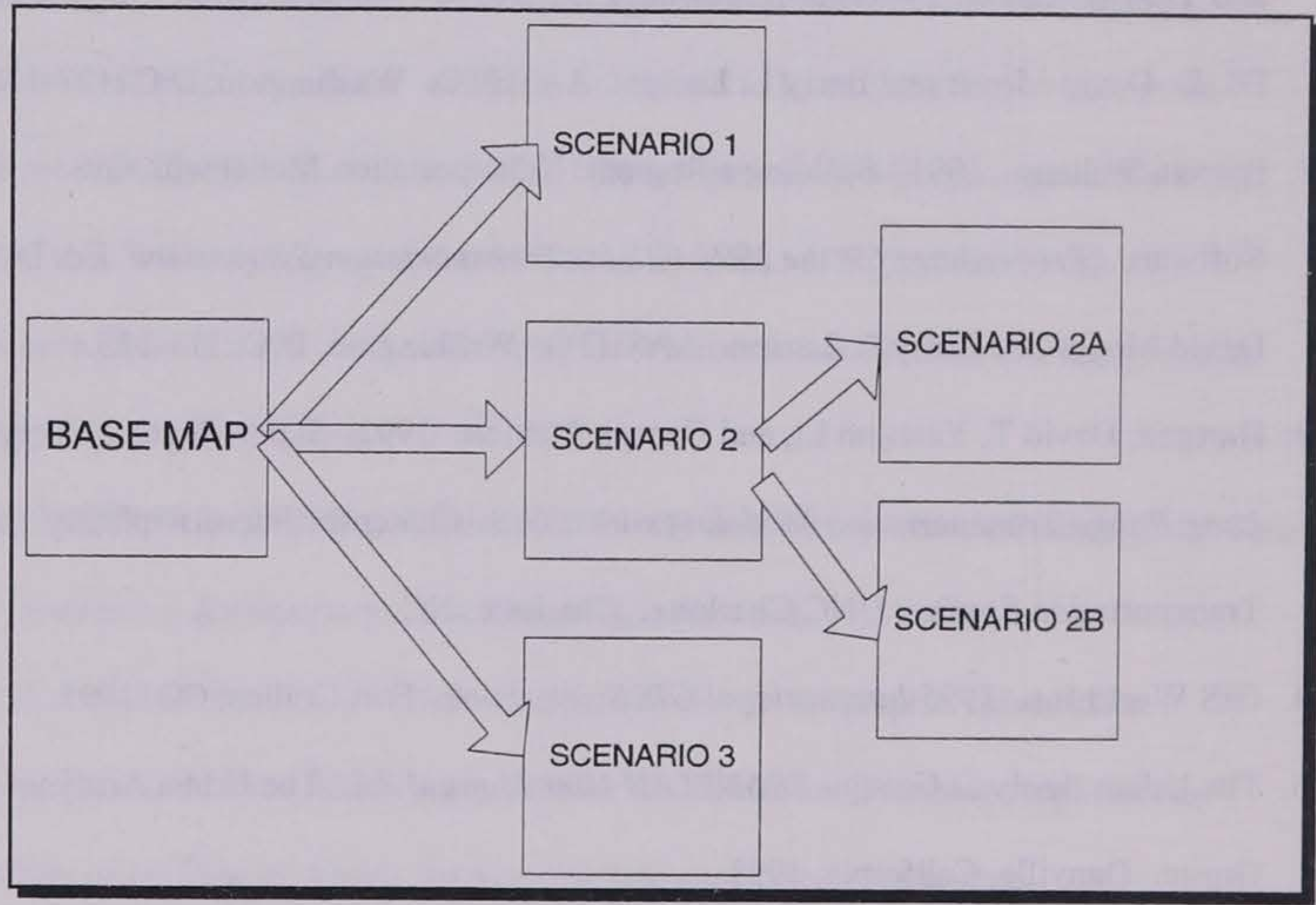


Figure 2. View of the Des Moines TRANPLAN Network

Figure 3. Existing Congestion in Downtown Des Moines.

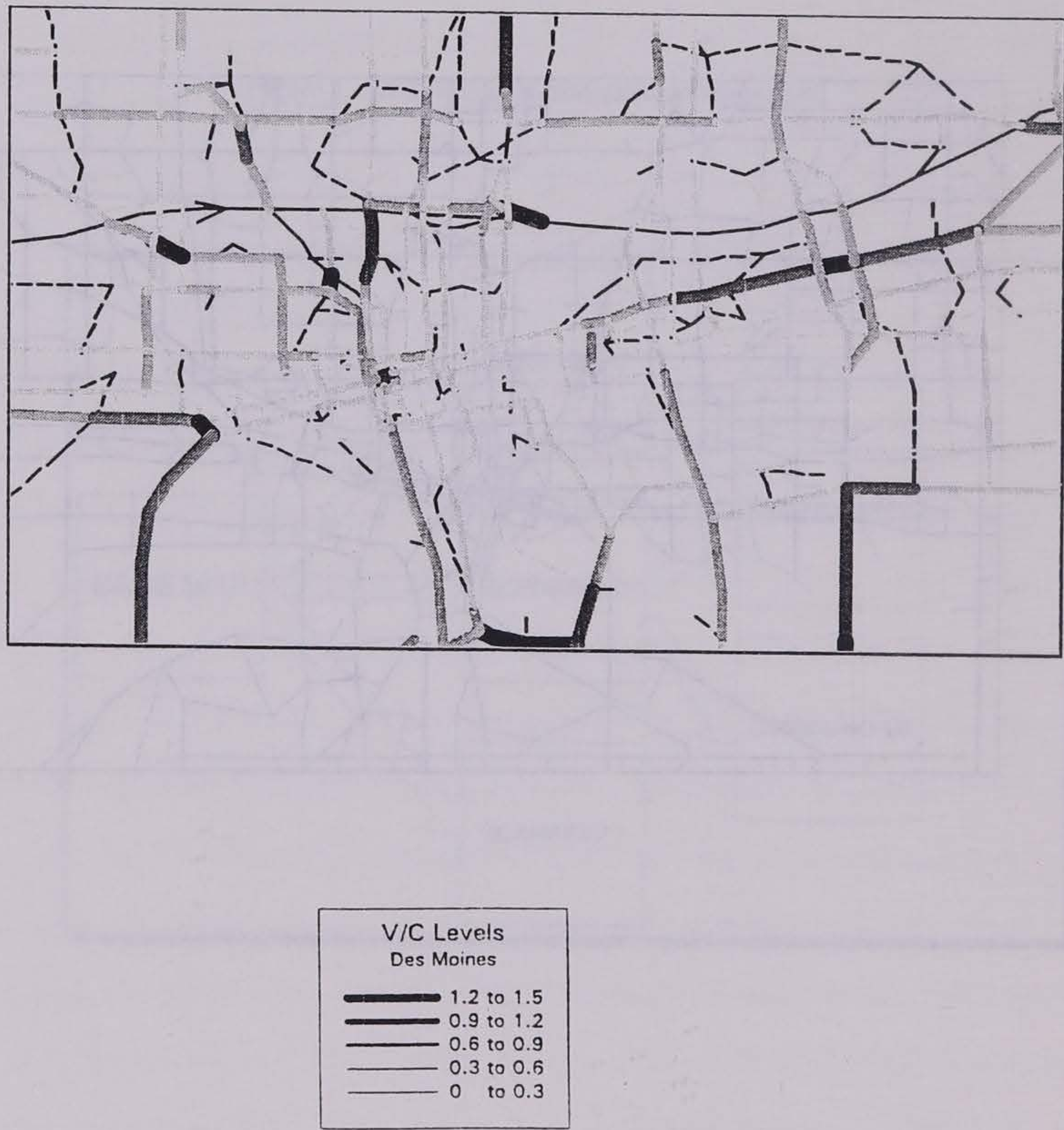
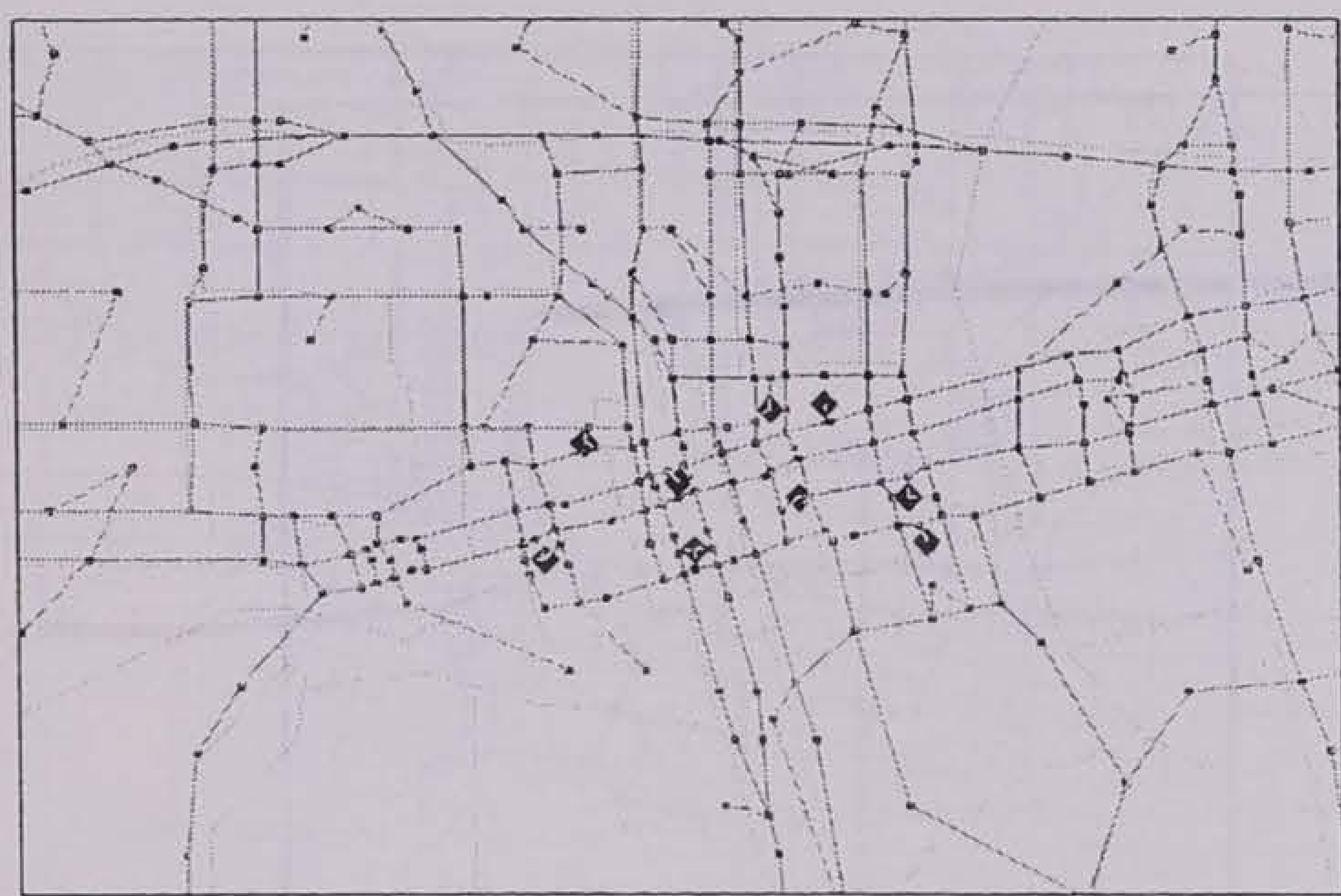


Figure 4. Test for modification of productions and attractions.

Affected Centroids



Resulting Loadings

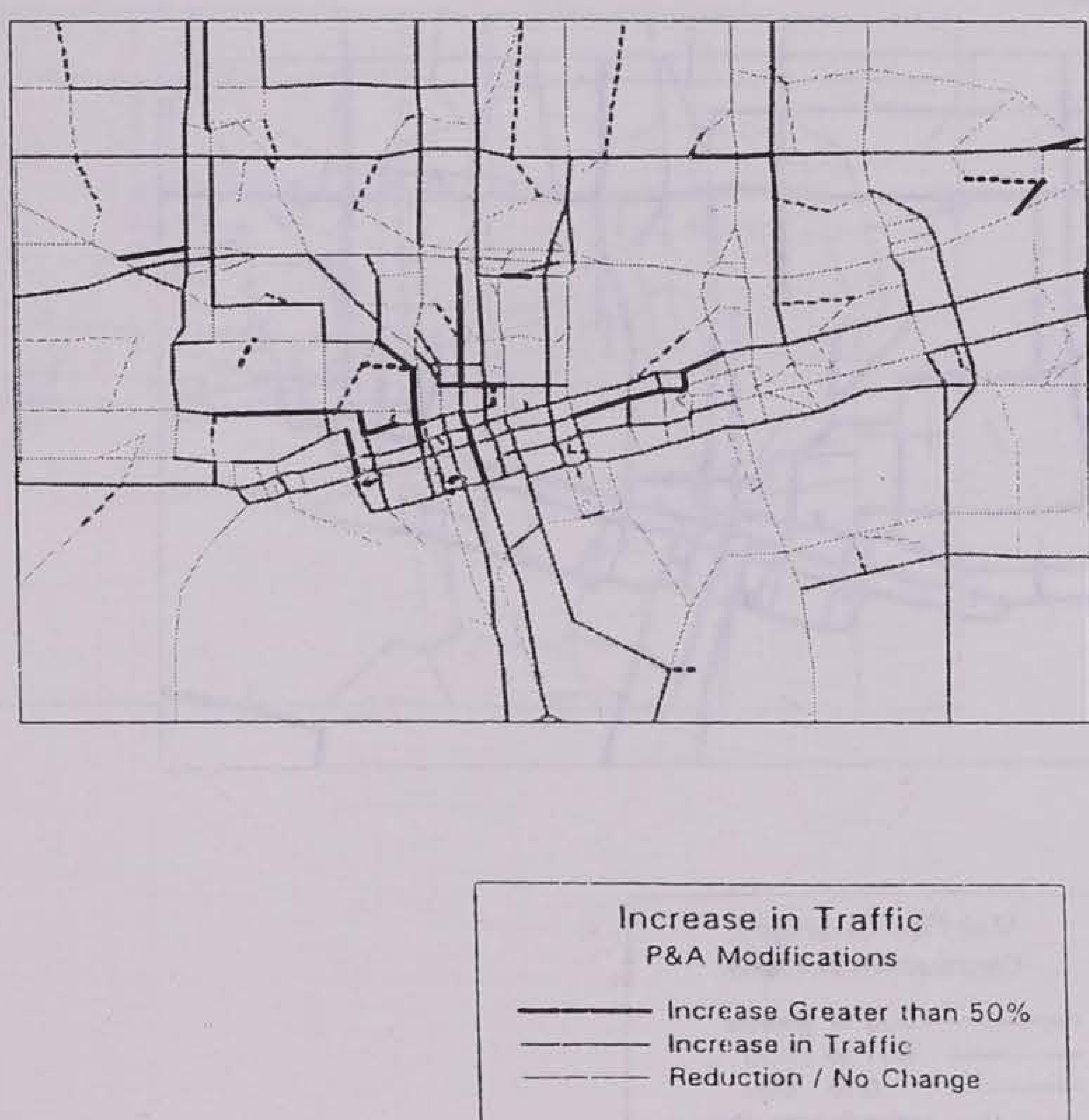
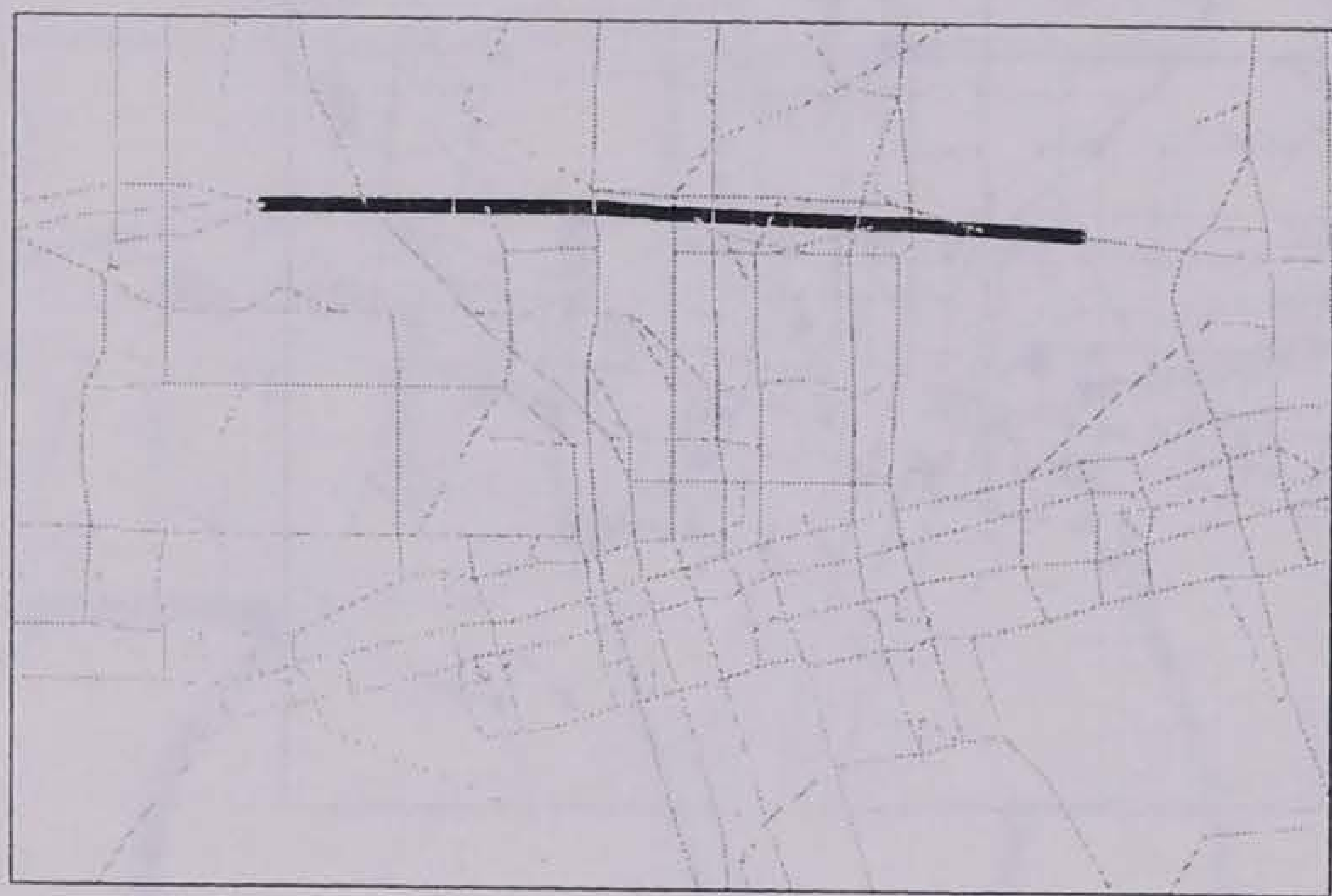


Figure 5. Test for modification of productions and attractions.

Affected links



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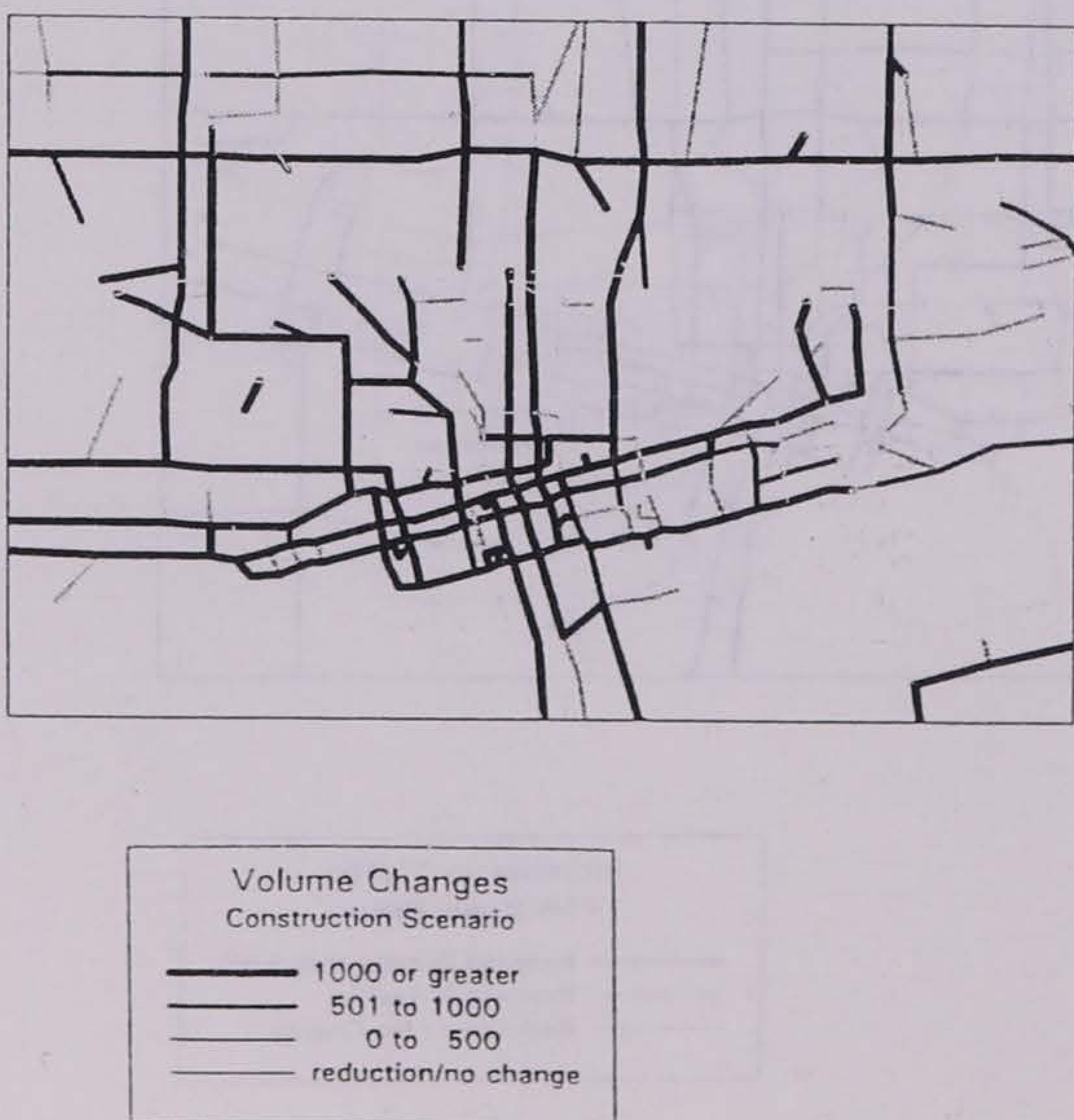


Figure 6. Test Showing the Construction of Additional Links.

Additional Links

Resulting Loadings

Figure 7. Study Area

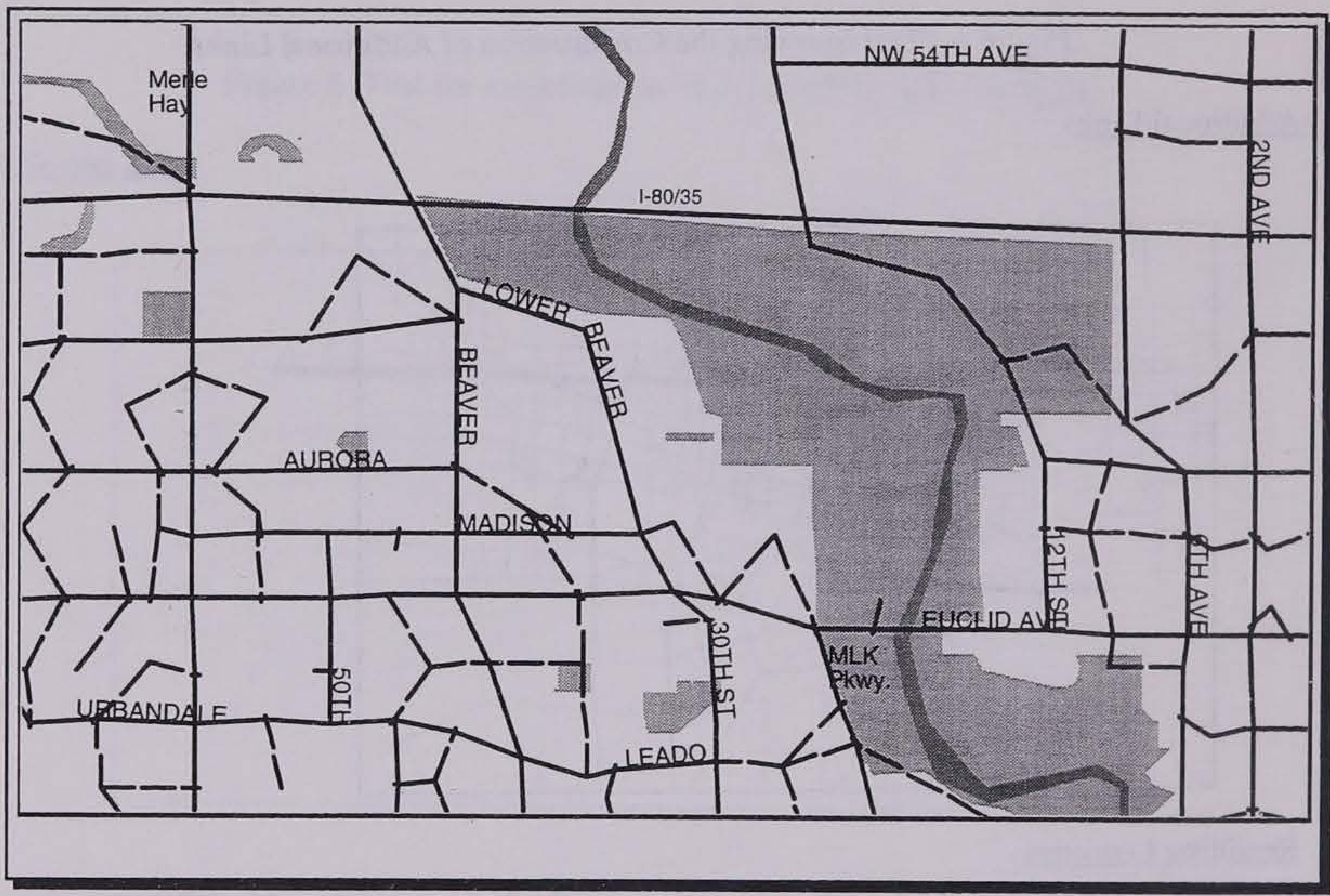
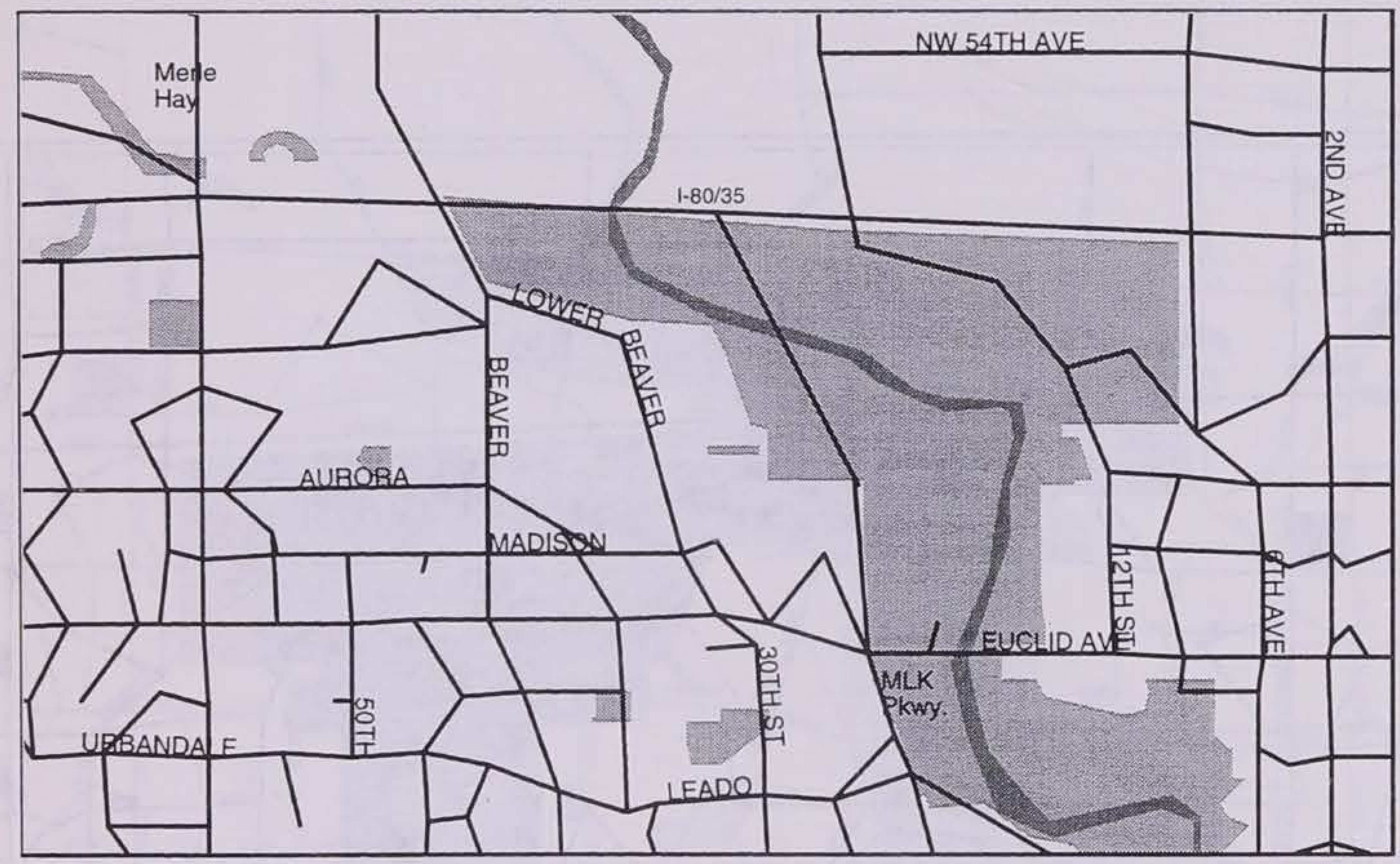


Figure 8. Alternatives for Case Study

East Alternative



West Alternative

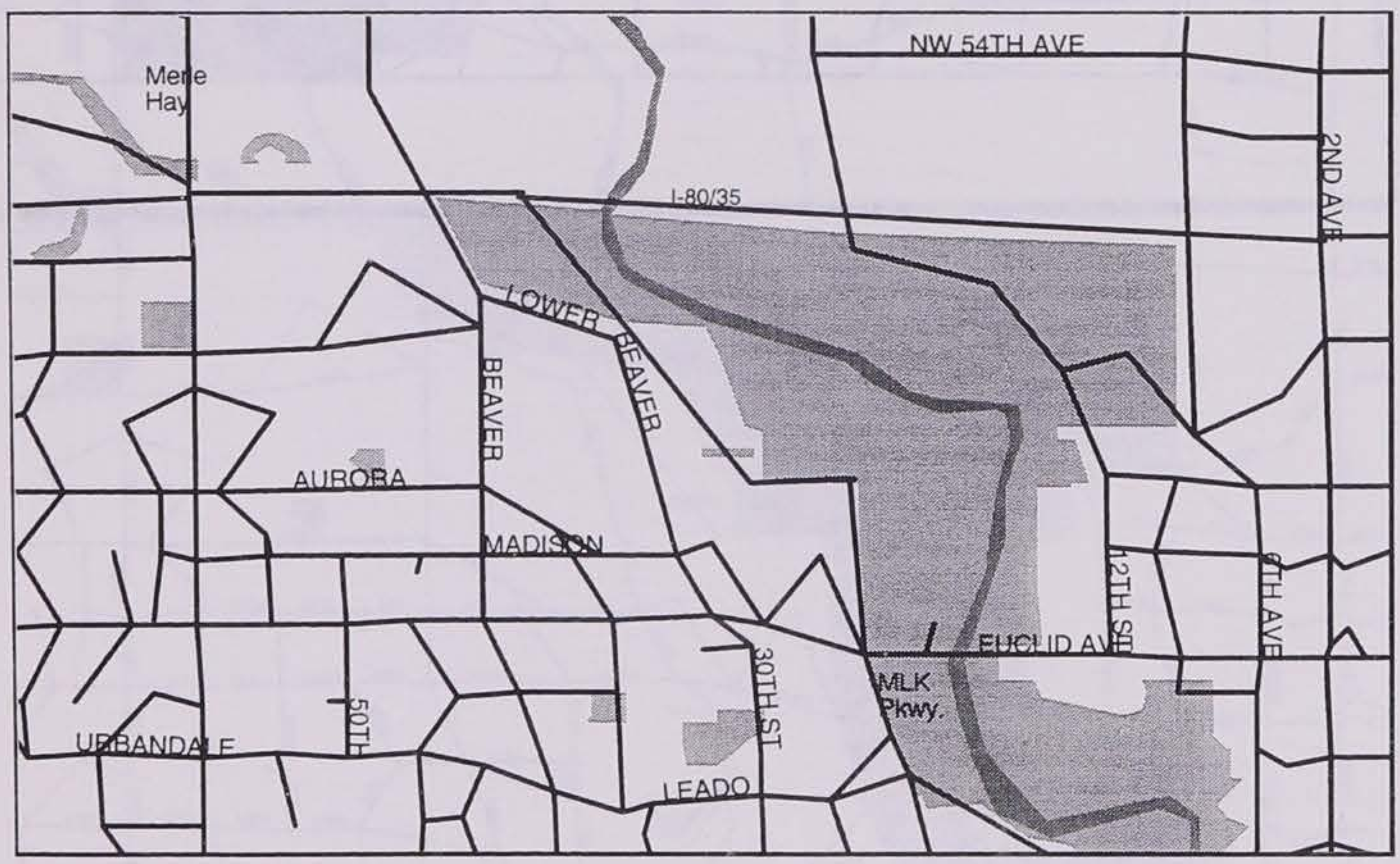


Figure 9. Existing Traffic Volumes.

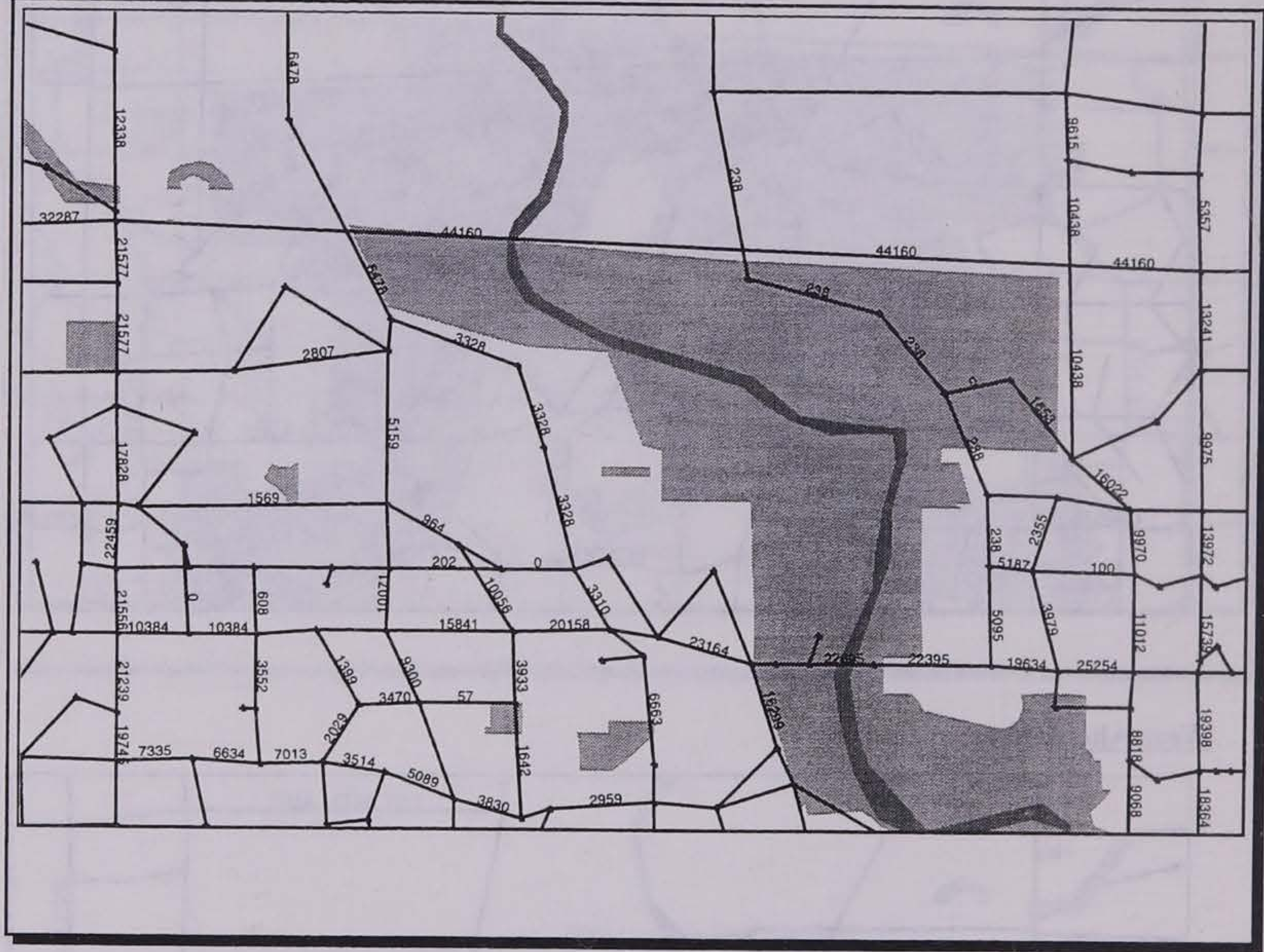
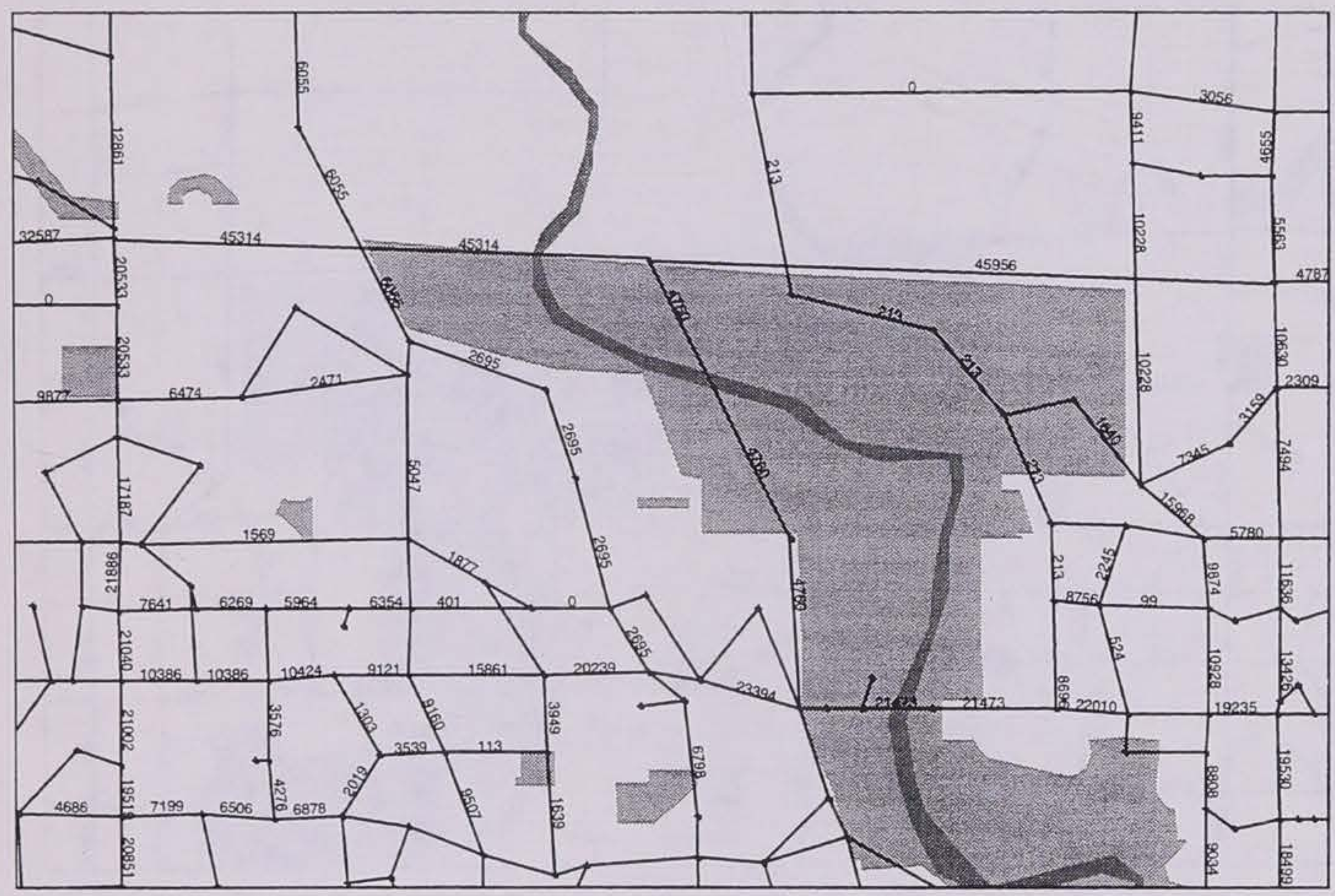


Figure 10. Traffic Volumes for Alternatives at 27.5 mph.

East Alternative



West Alternative

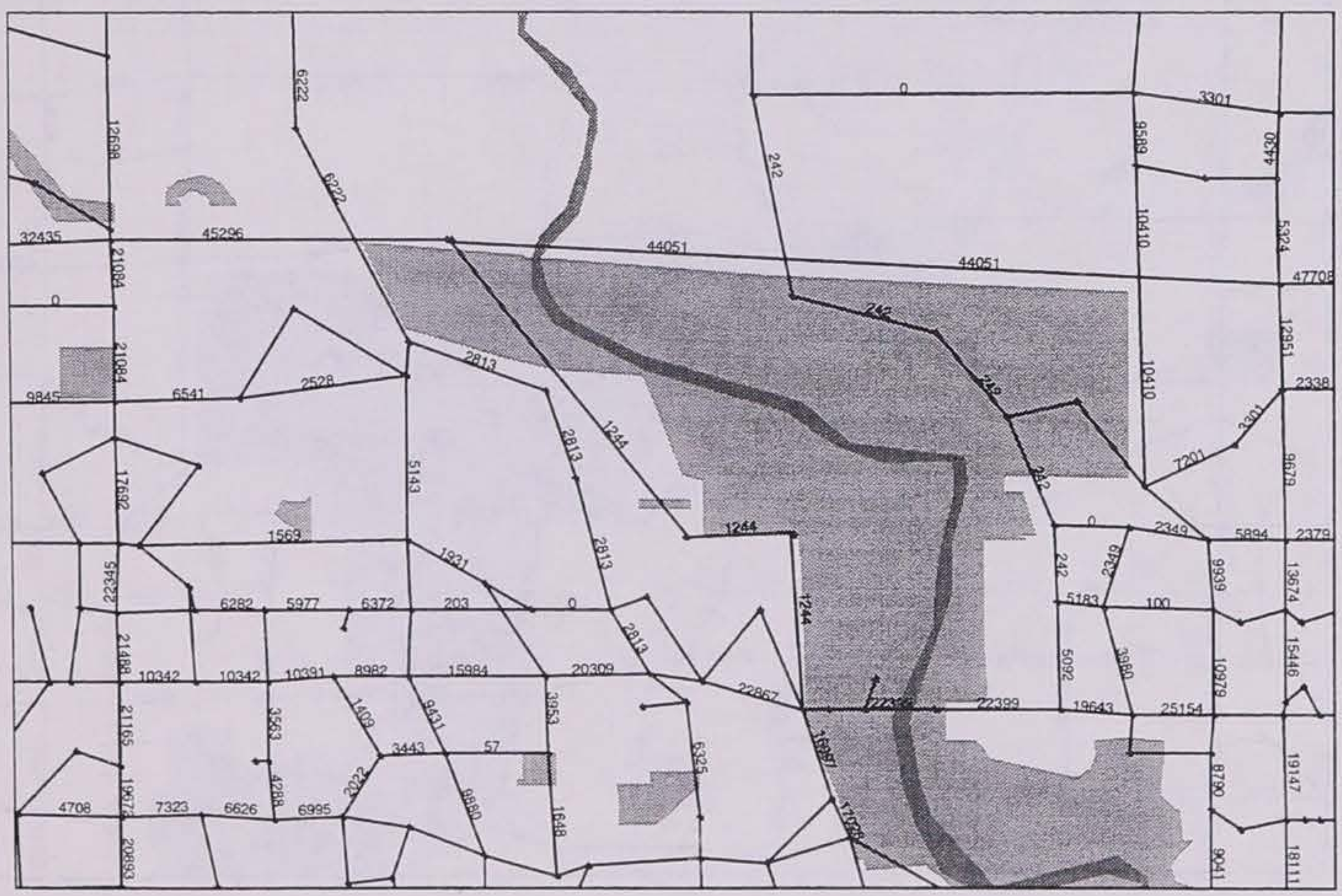
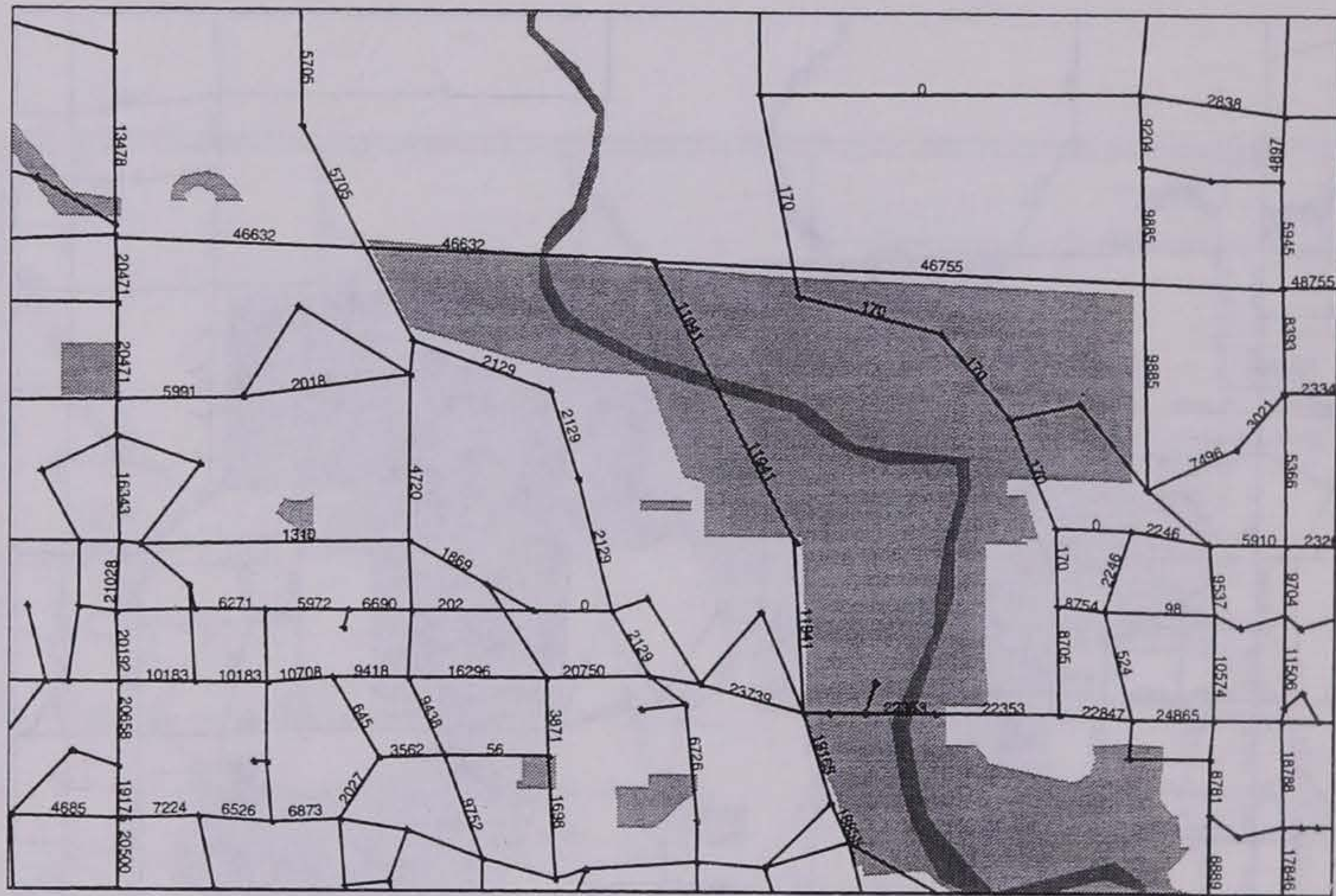
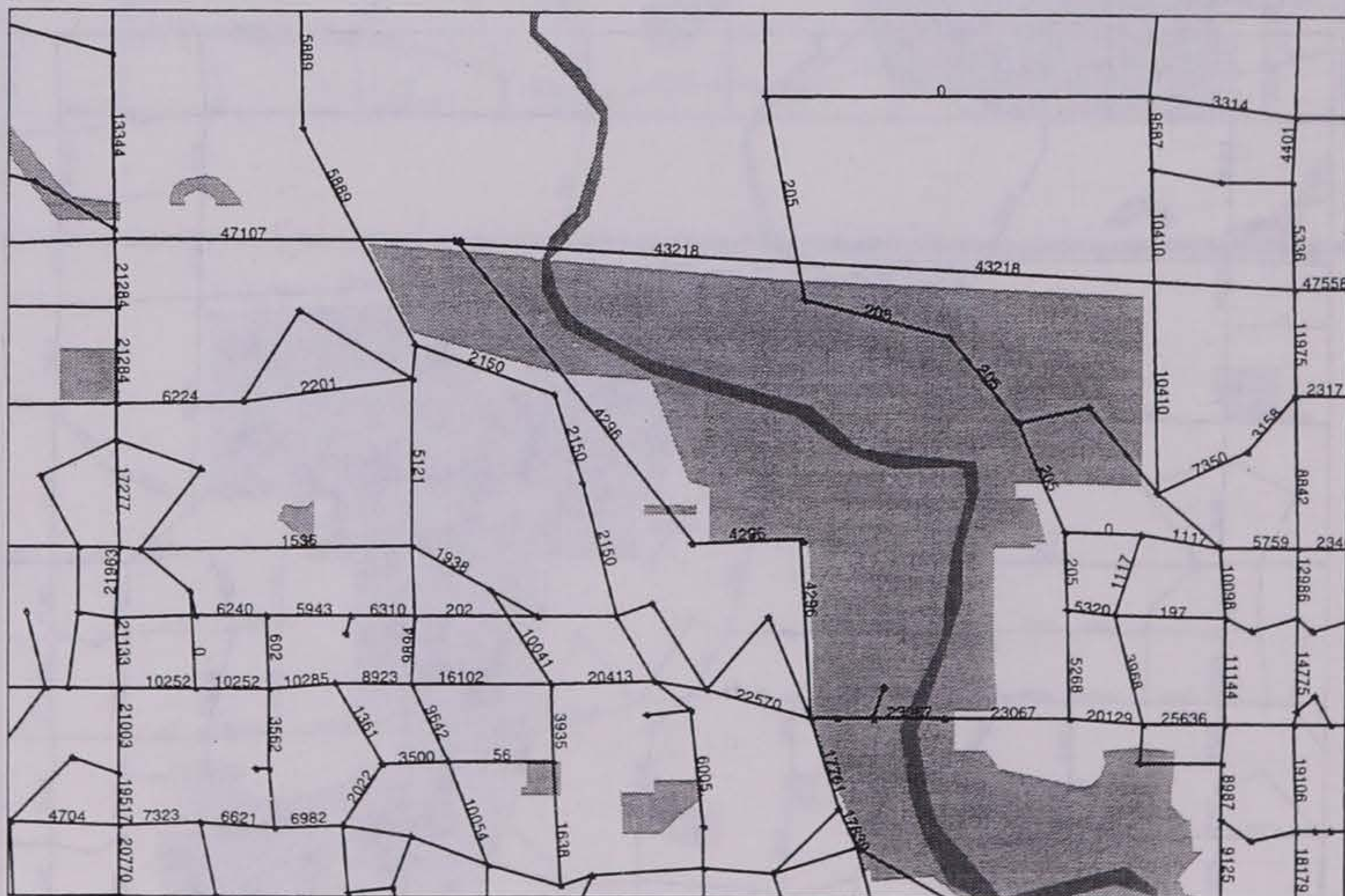


Figure 11. Traffic Volumes for Alternative at 40 mph.

East Alternative



West Alternative



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Airfare Sticker Shock: Understanding the Unpredictable Nature of U.S. Airlines and Fares in the Post-Deregulation Era

I. ABSTRACT

In the latter part of the 20th century, when the jet travel age was beginning to flourish, airline giants such as Delta and Pan Am flew a multitude of routes crossing the continent and charged seemingly reasonable rates, based on distance traveled, for those willing to pay the price for saving time. Although the high costs for air travel prevented most of the general public from flying, this was generally the period when air travel was first viewed as a common mode of transportation. The structure of airline fares and routing has changed significantly since 1978 because of the Airline Deregulation Act. This legislation was intended to reduce governmental intervention in the airline industry and help airlines become as efficient as other businesses in the private sector.

The primary objectives of this paper will be to (1) develop an understand the logic behind the current post-Deregulation route and fare structures of the major airlines, and (2) explore how start up airlines can afford to compete with major carriers by offering fares that allow passengers to fly for less than the price of gasoline to drive -- a phenomenon witnessed only within the past two decades.

II. THE END OF AN ERA

Since the Airline Deregulation Act of 1978 removed government authority over airline fares and routes that were served, the fare and routing structures of all airlines in the United States significantly changed. The first thing that airlines did after the institution of deregulation was stop serving nonstop routes that were unprofitable, and instead, tried to develop hub and spoke route networks. By doing this, many smaller towns and cities were left with greatly reduced passenger air service, and a number of marginally profitable routes were abandoned.

Prior to the Deregulation Act, commercial airlines within the United States were subsidized by the federal government. Because airlines would receive funds to offset the costs of serving routes along which they lost money, many airlines would offer frequent and direct service along routes that were not profitable. That is, airlines offered nonstop flights each day that connected many cities, and routes were chosen in a manner that neglected profitability. In doing this, airlines supplied more service than was demanded. Even though each plane would only carry a couple dozen passengers, airlines could afford to continue service on these such routes and charge fares based upon the number of miles traveled, since they did not have to compensate for lost funds.

The reason the government subsidized airlines was to shield passengers on these unprofitable flights from having to pay very high fares to compensate for revenue lost on the empty seats. The prohibitive costs of airline travel would have prevented many passengers from traveling, which would have hindered the growth of the airline industry. Because the Federal Aviation Administration wanted air travel to become widespread, it chose to subsidize routes at first, passengers would eventually increase their reliance on air travel, and that the airlines would begin to profit from these routes. The government, however, continued to lose money to the airlines. Since passenger volume had not significantly changed, the FAA decided to stop aiding the airline industry and allow airlines to serve routes and charge fares based on the economic principles of supply and demand.

III. DOWNSIZING AND REORGANIZING

Following deregulation, the airline industry stopped serving routes that were unprofitable and generated little traffic. Major carriers re-evaluated their routing systems and focused their efforts on routes and regions that performed well financially. Generally, airlines concentrated on serving the air transport needs of particular cities or regions of the country by providing non-stop flights from their home based area to a variety of destinations across the country. This helped to develop brand loyalty among passengers who live close to the airline's home base since many local passengers could rely on that particular airline for almost all of their travel needs.

When airlines began to focus on serving specific regions of the country, many smaller towns and cities were left with limited passenger air service. Airlines focused efforts on connecting primary business destinations, so flights to smaller regional airports were dropped in an effort to better serve more popular routes (5). To fill the gap in passenger air transportation left by the withdrawal of service to smaller markets, many small regional airlines started local services which linked passengers in moderately sized towns with major airlines in large cities (5).

By using smaller airplanes that better matched service demands, commuter airlines profited from their routes. These regional airlines could also provide airline service to communities which had previously been overlooked by the larger airlines (5). Having tapped into a new vein of potential passengers, regional airlines expanded their fleets of smaller aircraft and added scheduled flights to a multitude of small airstrips and small airports.

The key limitation to the popularity of these regional airlines was the limited distance their planes could cover. Although the people of Wausau, Wisconsin, for example, now had convenient airline service from a nearby airport without having to drive to Madison to reach the major airlines, the regional airlines serving Wausau could carry passengers only as far as Minneapolis or Chicago. Travel to points beyond these cities required passengers to purchase separate tickets for the regional airline flight and for the jet flight to the final destination, so regional airline service was not very cost effective for travelers who would have to switch to another airline to complete their trip.

IV. GROWTH OF HUB AND SPOKE ROUTE NETWORKS

The major airlines realized the dilemma faced by passengers who did not like buying separate tickets and transferring between airlines. They identified an opportunity to spur growth and revenue without financial drawbacks. Many major airlines drew up "codesharing" agreements with regional airlines that served airports within the major airline's area of service concentration (5). These "codesharing" agreements were intended to allow a regional airline to funnel its passengers onto the "parent" airline, contributing to the parent airline's growth (5). Reciprocally, the large airline would help to represent the smaller airline nationally by marketing the regional airline's route network as part of its own (5). These agreements gave the illusion that the major airline directly served more destinations that it actually did, and drew prospective passengers in need of transportation between a large city and a smaller town by offering through fares and streamlined connections between the major airline and its regional airline partner.

Once joining forces with a larger carrier, regional airlines usually refined their route systems. The purpose of refinement was to place more emphasis on the parent airline's hub of operations and enhance the mutual relationship between the two airlines (5). In doing so, the regional airline's route network began to imitate that of the major airline, since most of the regional airline routes were changed to become nonstop flights radiating from the hub of operations. Cooperation between the major airline and the affiliated regional carrier, both of which strove to serve passenger air travel needs for residents within the core area of operations, led to the formation of a fortress hub at the focus airport (2). "Fortress hub" generally applies when 75% or more departures from a given airport are by a certain airline (6).

Not only would the airline monopolize on overall air service to the hub city, but schedules for the major airline and its commuter carrier would be synchronized to allow passengers to make quick and easy connections between flights and simply pass through the hub enroute to their destinations (3). One example of a hub and spoke routing system can be found on Midwest Express Airlines. Midwest Express provides air service for dozens of routes in and out of its Milwaukee hub. Current routes extend from Los Angeles and San Francisco in the West to Fort Lauderdale, Philadelphia, and Boston in the East (7). Since all of these flights originate or end in Milwaukee, passengers who live in that area can take advantage of the nonstop flights that are available to all parts of the country.

V. FLIGHT BANKING TO INCREASE MARKET SHARE

In addition to providing nonstop service from the hub city to various other cities in the airline's spoke system, connections between two spoke cities via the hub became possible. The challenge that airlines faced was how to draw passengers away from competing nonstop flights onto their own connecting flights. The goal of airlines eager to draw revenue from connecting passengers who supplemented those originating or terminating in the fortress hub city provided a way to synchronize schedules, make connections quick and easy, and minimize inconvenience to connecting passengers (3).

A scheduling technique known as "banking" became widely used by airlines to achieve these goals in offering connections. Banking takes place when airline schedules are carefully planned so flights arrive into the hub airport within a short time frame (3). Planes then wait on the ground for a short maintenance check, refueling, and restocking of the galley, and unloading and loading of luggage and cargo. During the checks, connecting passengers deplane and walk through the connecting airport to the appropriate gate for their connecting flights. Passengers are then boarded onto the plane that has just arrived, and the plane takes off again shortly thereafter. This entire process usually takes approximately 30 to 60 minutes. Airline employees, including maintenance crews, must work quickly during a banking period.

This concept of flight banking can also be demonstrated using Midwest Express Airlines. Synchronization of flight schedules can allow the Milwaukee based airline to serve local passengers and allow connections between nearly all of the other cities it serves (7). Twenty-three nonstop routes from Milwaukee can yield over 450 possible connections. Not all of these connections would be feasible: travelers between San Francisco and Phoenix would not want to fly through Midwest Express's Milwaukee hub en route. The Milwaukee hub, nonetheless, can serve many of the remaining markets with connecting flights (7).

Passengers who live within the Midwest Express system would be funneled onto one of the arriving flights into Milwaukee, where they could connect onto numerous other flights which depart from Milwaukee within about an hour of their arrival (7). This allows Midwest Express to simultaneously and efficiently offer service for passengers from Denver to Washington, DC., Dallas to Detroit, and Appleton to Atlanta without flying planes on each of those routes. Skyway Airlines, the regional airline partner for Midwest Express, also plans its schedules to coincide with arriving and departing Midwest flights to make connections between jet and commuter flights quick and easy (7).

VI. COMPUTERIZED PRICING TO MAXIMIZE PROFITS

The most noticeable impact that airline deregulation has had on the traveling public is that airlines adjust fares to meet demands of their passengers while maximizing profits. Computerized reservations systems, such as Pars, Sabre, and Apollo are programmed to adjust the airfares based on the number of people traveling (3). For any given route, dozens of vastly different fares may be offered for the same coach seat. Restrictions are placed on the lowest fares to allow flexible travelers who may not otherwise fly to save on transportation expenses by modifying their travel plans (1). These restrictions also prevent many business travelers who don't have as much flexibility from taking advantage of special discounted rates. As a result, they usually pay a higher, unrestricted airfare (1). For instance, if a particular fare of $150 requires that the passenger leave on a Tuesday morning and stay over at least one Saturday night, a leisure traveler could purchase the discounted ticket and adjust his or her travel dates accordingly. If, however, a business traveler must attend a meeting on Tuesday and return no later than that Thursday, he or she would have to purchase an unrestricted coach ticket for $600. The leisure traveler may end up sitting next to and partaking in the same in-flight service as the business traveler who paid four times as much for the flight (1). Since airfares are devised with these scenarios in mind, leisure travelers' low fares are offset by the higher fares paid by business travelers. Unfortunately, this type of computerized airfare system has not helped the major airlines consistently earn profits because a number of new, small "upstart" airlines offer business travelers lower fares than the major airlines by waiving restrictions.

VII. NICHE CARRIERS AND START-UPS TAKE OFF

The most noticeable impact that deregulation of the airline industry has had on the traveling public is the proliferation of low fare start-up airlines which offer exceptionally low fares on underserved routes to attract travelers who may not otherwise afford to travel by air. The key to the success of these airlines despite the low fares they offer is that the airlines focus efforts on providing low cost transportation and has taken cost cutting measures like serving snacks instead of full hot meals on its short flights (4). Since the restructuring of the airline industry following deregulation, passengers have been able to purchase one way tickets from Kansas City to Dallas or Milwaukee on Vanguard Airlines for $9, and from Cleveland to the Washington D.C. area for $19 (7).

Low fare carriers are beginning to materialize in all parts of the country. Valu Jet originally connected a handful of southeastern cities with its Atlanta hub, but less than two years since it began operations, it has grown to include a secondary hub in Washington D.C. and flights west to Dallas, north to Montreal, and south to Florida (7). Reno Air currently provides inexpensive air service throughout California, Oregon, and Washington, but is slowly reaching eastward and now flies as far as Chicago (7).

Deregulation has allowed these new, "upstart" airlines such as Reno Air and Valu Jet to begin jet service in small areas, and to expand until major cities across the country are served by these carriers (4). Passengers usually sacrificed hot meals and the convenience of nonstop service to their destinations in exchange for lower fares and flexible tickets. People's Express even charged passengers aboard for box lunches, and assessed fees to check passenger luggage. These airlines were careful about which routes they served because they were very profit-sensitive (4). Time was taken to determine the economic feasibility of flying on certain routes by deciding where demand was sufficient, what fares the market would bear, and how frequent service should be offered (4). Because of their different concerns and objectives, Upstart airlines generally do not conform to the popular hub and spoke routing network seen in other, larger airlines. When they did decide to serve a given route, they offered lower fares than established airlines on that route. To illustrate the impact that low cost carriers have on the travel industry in general, consider the following accounts of Southwest Airlines, the largest and most powerful of all low fare airlines within the U.S.

VIII. SOUTHWEST AIRLINES

The largest low-fare airline, and the most threatening to major airlines, is Southwest Airlines, which was originally started when deregulation went into effect. As its name suggests, Southwest began service between major cities in Texas (4). Its dense routing network, in combination with its recent expansion to Washington, D.C., signifies its successful growth into a low-fare airline with service from coast to coast. A merger with Morris Air, a low fare airline with flights to many western cities from its Salt Lake City hub, gave Southwest market share to such popular Pacific Northwest markets to Portland and Seattle.

They primary pricing strategy used by Southwest Airlines is to keep its airfares low enough to remain competitive with the prices passengers would pay to drive. This pricing strategy is described by Southwest Airlines' CEO, Herb Kelleher, who said, "We're competing with the automobile, not the airlines. We're pricing ourselves against Ford, Chrysler, GM, Toyota, and Nissan." (4)

Southwest began nonstop service to the Baltimore-Washington International Airport from Chicago and Cleveland in early September of 1993. To encourage business along this new route, Southwest offered $19 unrestricted one way tickets from Washington to Cleveland, and $39 round trip tickets from Washington to Chicago. Understandably, these fares were readily taken advantage of because not only were they lower than the fares charged by other airlines in that market, but the Southwest airfares were less expensive than the prices of bus or train tickets between those cities. To remain competitive, some of the other airlines blindly lowered their fares to match the Southwest rates, while others decided to just bear the loss of business on the hope that loyal frequent travelers would continue to support them (4). Most of the major airlines matching that fare during the fare war that ensued lost much money with the sale of every ticket. Because Southwest's management is so efficient, and because extensive research was done before Southwest commenced service, it retained its status as the only large U.S. airline that has consistently shown profits since deregulation (4).

IX. CONCLUSIONS

Unfortunately, many of the well established, low cost airlines have recently merged with other airlines or have gone out of business completely, but the legacy they left has inspired the birth of other new low-cost carriers. Kiwi Airlines, a carrier founded by former employees of Eastern and Pan Am Airlines, started with flights from Newark to Chicago, Atlanta, and Florida, and now regularly provides airline service to Puerto Rico, the Virgin Islands, and Bermuda (7).

The importance of an analysis of the affects Deregulation had on the way major airlines planned and operated routes is that the changes airlines implemented following deregulation were efforts to reduce operating costs and help improve profitability. By examining the way that start-up airlines can minimize costs and afford to offer extraordinarily low airfares while turning a profit, transportation planners can develop strategies to reduce costs when developing plans. This will become an important skill because as time progresses, transportation planners will have to deal with limited budget constraints when developing plans more in the future than they do now.

X. BIBLIOGRAPHY

1. H. S. Abraison. Fear of Flying. *Traffic World*, Feb. 4. 1991, pp. 4.

2. Air Fares: The High Tech War. *The Economist*, December 26, 1992, pp.7-48.

3. A. Barnett, T. Curtis, and J. Goranson. Better than Ever: Nonstop Jet Service in an Era of Hubs and Spokes. *Sloan Management Review*, Winter 1992, pp. 49-54.

4. S. N. Chakravarty. Hit 'em Hardest With the Mostest: Superior Management at Southwest Airlines. *Forbes,* September 16, 1991, pp. 48-50.

5. C. P. Fotos. Regional Airlines Must Strengthen Ties to Major Partners in Next Decade. *Aviation Week and Space Technology*, June 17, 1991, pp. 173-174.

6. R. Kuttner. Flying in the Face of Reason: Why the Skies Need Reregulating. *Business Week,* May 3, 1993, pp. 18.

7. Information on specific routes and schedules of airlines discussed in the paper was obtained by contacting the respective airlines directly.

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Integrating Geographic Information Systems into the Pedestrian/Bikeway Planning Process

ABSTRACT

Since the introduction of mass production facilities, the use of motor vehicles swept the nation in a relatively short period of time, thus causing bicycles to lose their status as a primary mode of transportation. Consequently, transportation systems were not constructed to accommodate both modes operating together.

Bicycle trail facilities represent a significant, but often overlooked portion of the transportation system. As the use of bicycles continues to rise, there is an increasing need to plan for bicycle facilities that can coexist with other modes of transportation. Because of an increased focus on bikeway/pedestrian facilities, the need emerges for an efficient and effective way to plan and manage these facilities.

The use of a Geographic Information System (GIS) can make this possible. A GIS is a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data for solving complex planning and management problems. A GIS enables the user to incorporate a variety of data such as bikeway length, location, sign inventory, surface types and many others. These data, which are in tabular form, can then be related to particular points or line segments on a graphical display in a spatial referencing system.

As the cost of computer hardware and software continues to decline, and the computing power of computers continues to increase along with the growing sophistication of software, the use of GIS in solving transportation planning problems may become more and more common within the field of transportation planning.

INTRODUCTION

Since the introduction of mass production facilities, the use of motor vehicles swept the nation in a relatively short period of time, causing bicycles to lose their status as a primary mode of transportation. Because motor vehicles became popular so quickly, bicycles and automobiles had little opportunity to peacefully coexist. Consequently, transportation systems were not constructed to accommodate both modes operating together.

The popularity of bicycling was being reborn at the time of the post WWII urban sprawl in the early 1950's (1). Primarily due to the energy crises that took place in the 1970's, the use of bicycles as a means of transportation has become increasingly prominent (2). Many other reasons also exist for the increased usage of bicycles including health issues, environmental issues, reducing traffic congestion, and the growing popularity of recreational biking. Currently, approximately 7.2% of all travel trips at the national level are made by walking and .7% by bicycling (3).

Today, automobile traffic on the nation's roadways is increasing steadily. This increase causes additional competition for available right-of-way in which to build transportation corridors such as bikeways and roadways. Combined with increases in traffic other than automobiles, namely bicycling and walking, the transportation system becomes even more congested. Bicycle trail facilities represent an important, but often overlooked portion of the transportation system. When the bicycle started its comeback, construction of new bikeway corridors was proposed. As the use of bicycles continues to rise, there is an increasing need to plan for bicycle facilities that can coexist with other modes of transportation.

ISTEA LEGISLATION

The United States has undergone a period of change regarding the recognition of bicycling and walking as modes of transportation. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 has several provisions that directly relate to bicycle and pedestrian systems. The U.S. Appropriations Act of 1991 directed the Secretary of Transportation to conduct a National Bicycle Study. The study consists of a final report and 24 case study reports. The Clean Air Act Amendments also have positive implications for bicycling and walking. Urban areas that are not in compliance with established air quality standards must reduce emissions in order to bring air quality into compliance. Bicycling and walking improvements are approved transportation control measures (3). The commitment from the federal government for supporting bicycling and walking appears to be long term and should be an area of major interest while ISTEA is the principal transportation legislation.

Due to this commitment and the increasing use of bicycles as a mode of transportation, a need emerges to develop an efficient and cost effective way to plan for and manage bicycle/pedestrian facilities. One possible alternative is to utilize a Geographic Information System (GIS) analysis and problem solving.

INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS

A GIS is a tool which is utilized in many fields, especially urban planning, transportation planning, and engineering. A GIS is defined as a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data for solving complex planning and management problems (4). A GIS enables the user to incorporate a variety of data such as bikeway length, location, sign inventory, and surface types. These data, which are in tabular form, can then be related to particular points, line segments, or polygons on a graphical display in a spatial referencing system.

Geographic Information Systems can differ in their analytical capabilities. Topology is a branch of geometrical mathematics dealing with two types of objects- points (called nodes) and lines (called edges)- and one type of basic relation between them (called incidence). Topology is used to record and manipulate the logical relationships of map features and geographic information in a GIS (4). Topology allows questions, or queries, to be answered by the computer such as, "What Traffic Analysis Zones does a particular bikeway pass through and how many access points are on this route?" This information is then displayed graphically on a computer screen so the analyst can immediately see the spatial relationships. Most desktop GISs do not have the capability of building topology.

In the past, GIS technology has been successfully applied to areas such as resource management and mine reclamation (5). Transportation agencies have historically been among the first to identify and utilize innovative computer technology (6). State Departments of Transportation have usually taken the primary role in the implementation of statewide GIS efforts (7). However, the application of GIS to bikeway planning is relatively new.

The implementation of GISs have recently become popular at Metropolitan Planning Organizations (MPOs) and in Iowa some Regional Planning Affiliations (RPAs). Due to the expense of powerful workstations, most MPOs and RPAs utilize more affordable desktop mapping systems. Many smaller MPOs, RPAs, cities, and counties are currently in the process of conducting feasibility studies for the implementation of Geographic Information Systems while others already use GIS extensively.

A NEED FOR BICYCLE/PEDESTRIAN FACILITIES

The Bicycle Institute of America reports that approximately 3.2 million people commute to work by bicycle, 800,000 on any particular day (8). However, this is not impressive since the U.S. Census states there are approximately 110 million commuters in the U.S. and that two-thirds of them travel less than five miles. According to the *Nationwide Personal Transportation Survey, 1990,* more than 60 % of all trips nationwide are under five miles. (See Figure 1) An estimated 131 million Americans regularly bicycle or walk for exercise, sport, recreation, or just for relaxation and enjoyment of the outdoors. As modes of transportation, bicycling and walking are just beginning to realize their potential.

The U.S. Bureau of Census conducts a decennial evaluation called the "Journey to Work" survey. This study reports only on travel to and from work for people in the work force aged 16 years and older. This survey is conducted during the last week of March, so bicycling and walking trips are underreported for many parts of the country because of cold weather. The results of the 1990 survey found an estimated 4.5 million people (4% of all workers) commuted by walking, and approximately one-half million (0.4% of all workers) commuted by bicycle (3). These numbers represent national averages. Some cities had much higher percentages of people who did walk or bicycle to and from work.

NPTS SURVEY

The Nationwide Personal Transportation Survey (NPTS) is another significant study conducted concerning bicycling and walking in the United States. This survey is conducted approximately every seven years, throughout the year, and involves persons age five years and above. The 1990 survey asked respondents to provide information on all travel during a recent

24-hour period. This included mode of transportation, trip purpose, and distance traveled. Results of the (NPTS) revealed that trips to and from work amounted to approximately 20%, and the largest of 42% were for family or personal business travel. The relationship between walking and bicycling by trip purpose is shown in Figure 2. (See Figure 2) Of all trips accounted for, 7.2% were made by walking and .7% are made by bicycling (3). The NPTS survey also showed that non-motorized trips were much more prominent in the central city than the suburbs. More than 11% of all trips in central city areas were by walking or bicycling. The average length of trip recorded in the NPTS survey was 0.6 miles for walking, and 2.0 miles for bicycling.

One reason why commuting by bicycle has not become popular is because of a lack of bicycle facilities available and barriers such as weather and time. An increasing number of high technology projects have been a priority to available funding. Some examples of these projects include intelligent transportation systems (ITS), high-speed rail, and transit, while bikeway facilities have been virtually ignored. ISTEA provides specific funding for bicycle and pedestrian facilities. A Trust Fund was also established to support the National Recreational Trails Funding Program (9).

FACTORS INFLUENCING MODE CHOICE

Bicycling and walking as modes of transportation may never be seriously considered by many commuters. Factors such as weather, increased commute time, and lack of bicycling facilities may keep people away from choosing bicycling as a mode of transportation. It will be difficult for people to choose an alternative mode of transportation when they have become so dependent on the automobile. Changing the public's perspective of the "short trip to the grocery store" will be the first major step in broadening the base of bicyclists and walkers. In order to increase the awareness of bicycling and walking many communities in the U.S. have started "Bike to Work" days. These activities have appeared to be successfully observed by the public.

INITIAL CONSIDERATIONS

Many factors are present when deciding to bicycle or walk for a particular trip. (See Figure 3) Most often, distance and time are reasons for not bicycling or walking for utilitarian type trips. However, the NPTS study results show the average trip length is nine miles (3). Average work trips tend to be slightly higher, while shopping and other utilitarian trips are shorter. Most of these trips are within nine miles, while many others are within walking distance. Individual attitudes also play a major role in the decision to bicycle or walk. People may choose not to bicycle or walk because it is not the most popular thing to do, or these activities are perceived as socially inappropriate for those who can afford personal motorized transportation. On the other hand people have different perspectives, viewing bicycling and walking as beneficial to the environment, healthful, economical, and requiring less exposure to traffic.

TRIP BARRIERS

One of the most frequently stated reasons for not bicycling or walking is the fear of not being safe in traffic. Even a community planned with excellent bicycle and walking facilities can be plagued by safety problems. Given existing traffic conditions in many urban areas and city centers, narrow travel lanes, high congestion and vehicle speeds, lack of bikeway or pedestrian facilities, and pollution cause many people who would otherwise bicycle or walk to choose another mode because the safety risk is too great. Perceptions of safety as well as actual safety problems must be addressed when planning for pedestrian/bikeways. Traffic safety may be improved by utilizing educational and law enforcement activities. Bicycle rodeos which are sponsored by advocacy groups and local law enforcement offer training opportunities that cover the basics of bicycle riding that help bicyclists feel more confident and comfortable riding in traffic. Campaigns and slogans that work for transportation safety such as, "give 'em a brake" may be helpful in reminding motorists to also, "share the road".

FACILITY ACCESS

Access and connectivity can be another form of impedance to persons choosing to walk or bicycle. A well designed and engineered bikeway facility is useless to the bicyclist or pedestrian who cannot access the facility or who cannot continue from one section to another. In the same way, facilities that do not connect neighborhoods to shopping centers or central business districts may never achieve their purpose of increasing the use of non-motorized modes of transportation. Direct routes, personal safety, and security are major considerations when making a decision to walk/bicycle or drive.

DESTINATION BARRIERS

Facility needs and infrastructure do not stop when arriving at work or other destinations. Many people are discouraged from commuting by bicycle because once they arrive at their destinations they have no place to safely park their bicycles or to shower if needed (3). If shower facilities existed at the place of work, some people may incorporate a walk, run, or bike ride during their lunch hour. There is a definite need for secure parking facilities to protect bicycles from the weather and from theft or vandalism. A survey was conducted in Baltimore, Maryland, reported that 25% of the sample had experienced a bicycle theft, causing 5% of the sample to give up bicycling. In large cities where bicycling is a popular mode of transportation such as New York City, theft rates are extremely high each year. For many commuters to consider bicycling as a mode of transportation, secure facilities for parking will be needed.

Other destination barriers exist in less obvious forms such as lack of support from employers. In some cases employers do offer incentives for commuting by bicycle such as reimbursed parking expenses, a less formal dress code, and "flextime" options.

ADDITIONAL CONSTRAINTS

Many other situations exist which impose constraints on bicycling or walking, however with some planning in advance, these situations should not preclude bicycling or walking. Some examples include having heavy or bulky items to transport, dropping off children at daycare, and the need for a car at work. However, if one trip is not appropriate for bicycling or walking, there may be other trips during the week which are viable.

The weather can play a major role when making the decision to ride a bicycle to work or for recreation. Obviously most people will not choose to ride a bicycle in adverse weather, although there are some "dedicated" bicyclists who will ride year round no matter how adverse the weather. If proper facilities were available, it is possible that more people would be willing to ride to work in less than desirable weather. Facilities such as showers at the work place and bicycle parking that is protected from the weather.

It is likely that some trips made by an individual will not be viable by bicycle due to distance or other constraints. This person would then be required to use an automobile for the longer trips. If an individual had to buy a car to make the longer trips, the marginal cost of using the car for the shorter trips will be less.

All levels discussed here will need to be addressed if current levels of bicycling and walking are to be maintained or increased.

BIKEWAY/PEDESTRIAN PLANNING COMPONENTS

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires that a state level intermodal long-range transportation plan be developed (9). ISTEA also requires that states develop a long-range plan for bicycle transportation facilities and pedestrian walkways and that it be incorporated into the state intermodal long-range transportation plan. A requirement states that strategies be developed for incorporating bicycle/pedestrian facilities into projects where appropriate throughout the state. Bicycle/pedestrian facilities may be incorporated into new development projects.

The major components of a bicycle/pedestrian plan include more than a map of existing and proposed facilities. The plan might include an inventory of existing facilities, intermodal access locations, demographics of the planning area, usage data, accident data, user needs, and alternatives. A network of corridors may be established, along with existing corridors, connecting major traffic generators such as neighborhoods and shopping centers. Also included could be a description of facility corridors and their locations, phases of implementation, costs of construction, and identification of constraints.

Many cities and counties have taken a proactive role in constructing bicycle/pedestrian facilities within their local jurisdictions. Since these recreation facilities were planned and constructed independently, there is no connectivity between facilities. Facility connectivity is a major component to consider when developing an effective transportation system. Most facilities currently in place do not serve a utilitarian purpose since they do not link traffic generators together. They are constructed for recreation purposes. If people are to consider commuting by bicycle, facilities constructed for utilitarian use will be desired. The current challenge to transportation officials is to integrate existing facilities into a continuous statewide system and to include multimodal access facilities (10).

BIKEWAY/PEDESTRIAN PLANNING PROCESS

In order to produce the most versatile pedestrian and bikeway system, a combination of shared roadway and separate bikeway systems may be desired. Bicycle travel can be enhanced by improving and maintaining roads commonly used by bicyclists. Many improvements can be made to existing facilities such as signing and pavement markings. Improvements should focus on safety and creating more opportunities for people to bicycle.

In the United States, approximately 100 million people own bicycles (14). Of the 100 million people, the Bicycle Federation of America estimates that less than 5 percent qualify as experienced or highly skilled bicyclists (15). To maintain a versatile pedestrian/bikeway system, new facilities and improvements to older facilities should meet or exceed the needs of experienced riders as well as the less experienced riders. A classification system has been developed to group the various levels of cyclists.

- Group A- Advanced Bicyclists: These are comprised of the most experienced riders that can operate a bicycle under most traffic conditions.
- Group B- Basic Bicyclists: These are comprised of casual or recreational riders who are less confident of their ability to operate in traffic without special provisions for bicycles.
- Group C- Children: These are comprised of pre-teen riders who's biking activities are typically monitored by adults (15).

There exist important design features which should be addressed when developing facilities for group A bicyclists. Therefore, planners and engineers should consult the *Guide for the Development of Bicycle Facilities*, published by the American Association of State Highway and Transportation Officials (AASHTO). Group B and C bicyclists desire many of the same features as group A bicyclists, however, they also value features such as designated bicycle facilities and lower traffic volumes.

BICYCLING STRESS LEVELS

Bicyclists often choose routes that require the least amount of physical effort. They tend to choose routes which are flat and offer the least amount of stopping. Bicyclist also tend to choose routes which avoid high volumes of traffic traveling at high rates of speed. Traveling in this type of environment causes a mental stress as well as a physical one (17).

Stress levels range from 1 to 5, which bicyclists can compare to varying traffic conditions. A stress level of 1 (very low) suggests that traffic conditions are favorable for all levels of bicyclists, however, this is not applicable to children under age 10. A stress level of 2 (low) indicates that traffic conditions are favorable for the casual and experienced bicyclist and under certain conditions can be favorable for youth bicyclists. A stress level of 3 (moderate) indicates traffic conditions are favorable for experienced bicyclists and under certain conditions can be favorable for casual bicyclists. A stress level of 4 (high) indicates traffic conditions may be favorable for experienced bicyclists under certain conditions. A stress level of 5 (very high) indicates that traffic conditions are not favorable for any bicyclist under any conditions (17).

Typical conditional improvements which can make conditions favorable for lesser experienced bicyclists may consist of street widening to include wide curb lanes, paving of shoulders, separate bike lanes, and low traffic volumes.

STATEWIDE BICYCLE FACILITIES PLAN

When developing a pedestrian bikeway facility, planners and developers should also recognize there are two basic types of bicycle trips, utilitarian and recreational. The main objective of a utilitarian trip is reaching a predetermined destination such as work or the grocery store. Conversely, the recreation bicycle trip is riding for pleasure. Utilitarian and recreational bicycle trips can overlap, therefore, bicycle facilities should be planned to satisfy the needs of the various levels of bicycling. A process for developing a statewide bicycle and pedestrian facilities plan which is currently being used by the State of Iowa, is divided into three phases.

STATEWIDE BICYCLE FACILITIES PLAN: PHASE I

Phase I involves the development of the Bicycle Facilities Network Identification Handbook, which is designed to aid in the planning process. Also included in Phase I is a set of goals and objectives for the facilities plan to reach. (See Figure 4)

STATEWIDE BICYCLE FACILITIES PLAN: PHASE II

Phase II requires MPOs and RPAs to utilize the Bicycle Facilities Network Identification Handbook to identify and recommend a comprehensive bicycle and pedestrian facility network. This network should include a complete list of existing and proposed facilities and improvements within the planning area. (See Figure 5)

STATEWIDE BICYCLE FACILITIES PLAN: PHASE III

In Phase III, the networks which are recommended by the various MPOs and RPAs will be analyzed and alternative scenario networks will be developed. The next step will be the development of implementation plans for each alternative in order to determine the feasibility of each project scenario. At the same time, each MPO and RPA will develop their own implementation plans. During the development of the plans, bicycle facilities will be analyzed and a forecast of potential use will be made. Also, the need for bicycle and pedestrian support facilities eg. (bicycle parking facilities, bicycle racks on transit vehicles, bicycle lockers) will be determined. The planning process will be documented and added to the Bicycle and Pedestrian Facilities System Plan. This plan will then become the bicycle and pedestrian element of the statewide intermodal long-range transportation plan (10).

The process of analyzing large amounts of data sometimes involved with bikeway facility planning can be an arduous task. Analysis of this data can be performed more efficiently when done using a GIS. (See Figure 6)

GEOGRAPHIC INFORMATION SYSTEMS

A Geographic Information System (GIS) is defined as a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data for solving complex planning and management problems (4). In a GIS, attributes are linked to a map or graphical representation by a common identifier. For an example, a map of a transportation network may have links of the network coded by number. This number can be associated with a column in a spreadsheet or relational database which displays attributes such as number of lanes, volume, capacity, and directionality. This information can be used to perform a variety of spatial analyses.

The information in a layer-based GIS can be separated into any number of different layers which can be overlaid upon each other to perform different types of analyses. Each layer contains different map features which are of a homogenous type. For example the base layer may consist of a street centerline map with county and city boundaries represented. Today, these files are often first obtained in the format of Topological Integrated Geographic Encoding and Referencing System (TIGER) files which were created by the Census Bureau for the 1990 census (11). (See Figure 7)

TIGER files can be imported into a GIS in the form of a common file format such as a data exchange format (DXF). Then a GIS can convert a common file format such as DXF into a format it can read. In Mapinfo, a desktop mapping GIS, common file formats are converted into "browser tables" and linked to a graphic display within the GIS. TIGER files can be a valuable resource when setting up base files in a GIS. They are available to the public and cover the fifty states, the District of Columbia, Puerto Rico, the Virgin Islands of the U.S., Guam, American Samoa, and the Northern Marina Islands (4). Supplemental layers may consist of a representation of land uses, demographic data, accident locations, topographic contours, zoning, planimetric features, etc. Having all layers visible at one time could be confusing, so each layer can be made visible or non-visible. Each vector element in a vector GIS is represented as a point, line, or polygon. (See Figure 8)

An example of the usefulness of the overlay analysis capability of a GIS would be locating places where accidents have occurred along a bikeway facility in a particular jurisdiction. An analyst could show a bikeway facility map, a jurisdiction map, and an accident location map on the computer simultaneously. From this display, you can see where the accident locations are.

CAD vs. GIS

Many cities, MPOs, RPAs, and other planning agencies currently rely on Computer Aided Drafting (CAD) packages, such as Autocad, for their mapping and inventory of facilities. CAD systems which offer a variety of engineering and analysis functions are mainly used for drafting, structural plans and design of infrastructure, buildings, water and sewer systems, and roads and bridges. These systems lack the ability to perform spatial analysis and have limited attribute processing capabilities. A GIS can process graphical data as well as non-graphical data.

STRUCTURED QUERY LANGUAGE

Many GIS developers have integrated Structured Query Language (SQL) into their GIS software packages (4). SQL is a language that was developed by IBM for use with several of its mainframe database management packages. An example of the usefulness of the SQL command would be to identify the type and time of each accident on a bikeway in a particular jurisdiction. A SQL script can be written asking for this data. The GIS can search the database for each parameter set, then display the information requested in tabular format as well as a graphical one.

COMPARISONS BETWEEN GISs

At this point a distinction between the various types of GISs should be made. Some GISs have analytical capabilities that others do not, such as building topology. Topology is defined as a branch of geometrical mathematics which is concerned with order, contiguity, and relative position, rather than actual linear dimensions (12). Many GIS packages are desktop mapping software that do not have the capability of building topology. Intergraph's Modular GIS Environment (MGE) has the capability of building topology and also has the ability for creation, query, spatial analysis, and display of topological structured geographic data (12). MapInfo is another leading GIS package, however, compared to Intergraph's MGE, is somewhat limited due to the inability to build topology. Although MapInfo is somewhat limited in respect to topological functions, it remains a very powerful and affordable desktop GIS. The power of a GIS is usually directly proportional to the difficulty of learning the software. The more power a GIS has, the more complicated it is to learn.

In short, a GIS is able to identify locations of almost anything geographical, locate areas which satisfy specific or general parameters, identify the changes of a particular area over time, identify patterns, and model various scenarios.

APPLICATIONS OF GIS TO BIKEWAY PLANNING

GIS is becoming a powerful tool in the field of transportation and the requirements by the Intermodal Surface Transportation Efficiency Act, requiring that all modes of transportation be addressed equally, will increase the need for applications to the pedestrian/bikeway planning process. Whether establishing a base network or updating an existing facility, the use of a GIS can decrease the amount of time required to perform any portion of the planning process.

EXISTING INVENTORY

An existing inventory can be input and maintained in a GIS for a pedestrian/bikeway facility. Attributes such as the name of the bikeway, width, surface type, (x,y) coordinates, areas that need improvements, access points, and route length can be stored. Different attributes such as land use and the bikeway network can be placed in different layers so one may be viewed without the confusion of the other. The location of signs or access facilities can be represented by single points in a GIS. Lines on the map can represent bikeway paths, rail lines, or rivers and streams. Areas, such as parks, greenway or rail corridors, and bodies of water can be represented as multi-line polygons.

Using the database, attributes which are linked to the map features can easily be changed to represent improvements to the facility such as new surface type or corridor width. This type of data can be saved for all attributes of the bikeway facility. Using this procedure, there is no need to update hand-drawn maps which is tedious and time consuming. Maps are created or changed on the computer screen and then a hard copy can be generated by printing to a plotter or printer. These maps are valuable in terms of presenting plans and information to the public.

PLANNING

Many different types of data can be stored in a GIS which are helpful in the planning process. A layer consisting of transportation and housing data from the Bureau of the Census can be illustrated as a map, disaggregating the data into census blocks and tracts. Using this information can help professionals make analyses on different planning scenarios involving bikeways. Other types of information which can be saved in different layers consist of land use, transportation network, city or county boundaries, topographic lines, utility lines or easements, and property boundaries to name a few. All of this information can be displayed graphically and linked to a database with attributes.

Bikeway networks, obtained from surrounding jurisdictions in a digital form a GIS can read, can be used to assist in planning for a regional bikeway system that is interconnected and acts as a transportation system as well as a recreational one. A GIS can be utilized in identifying accessibility to a bikeway, also in identifying the best location for a bikeway corridor and alternatives to proposed corridor locations. Using traffic data stored in a GIS, such as speed, volume, capacity, and air quality can help you determine if a bikeway should exist in a particular traffic corridor. If so, what type of facility should it be, a shared road bikeway, separated completely from the road, or an expansion of the sidewalk.

CONCLUSION

The use of a Geographic Information System can greatly benefit transportation professionals, as well as many others, in the future. However, the full potential of GIS may not be realized for some time to come. New applications are being developed constantly that add to the usefulness of GISs. The interest in GIS by federal, state, and local organizations show that there is no shortage of opportunities to apply GIS technology to transportation planning problem solving (13). Further investigation of GIS potential should be performed in order to determine how it can be implemented to meet current and future needs.

The capabilities of a GIS specific to transportation planning are vast. Many MPOs, RPAs, cities, counties and other organizations are just beginning to discover the capabilities of GIS technology. Once GISs become more widely accepted as a planning tool and personnel become trained in GIS technology, the need will arise for the development of practical transportation planning applications. This paper has only begun to scratch the surface of identifying practical analytical applications specific to transportation planning. A GIS can enhance the output of display material such as maps and can also perform sophisticated database and spatial analysis.

As the cost of computer hardware and software continues to decline, and the power of computers continues to increase along with the growing sophistication of software, the use of GIS in solving transportation planning problems may become more and more common.

References

1. Konski, James. "Bicycle Anarchy". Transportation Engineer, Volume I, November 1973.

2. Institute of Transportation and Traffic Engineers. Bikeway Planning Criteria and Guidelines. School of Engineering and Applied Science, UCLA UCLA-Eng-7224.

3. FHWA Publication No. FHWA-PD-94-023, The National Bicycling and Walking Study-Final Report, Federal Highway Administration, 1994.

4. Antenucci, John C. and Kay Brown, Peter L. Croswell, Michael J. Kevany, with Hugh Archer. Geographic Information Systems, Van Nostrand Reinhold, 1991.

5. Stokes, Robert W. and G. Marucci. "GIS for Transportation: Current Practices, Problems and Prospects", Institute of Transportation Engineering Journal, Vol. 65 No. 3, March 1995.

6. Loukes, D.K. and J. McLaughlin, "GIS and Transportation: Canadian Perspective", Journal of Surveying Engineering 117(3), August 1991.

7. Vonderohe, A.P. and L. Travis, R.L. Smith, and V. Tsai. "Adaptation of Geographic Information Systems for Transportation". National Cooperative Highway Research Program Report 359. Washington D.C. Transportation Research Board, 1993.

8. Jones, Michael G. "Building Bikeways", Planning Magazine, Vol. 59 No. 10, October 1993.

9. FHWA Publication No. FHWA-PL-92-008, "A Summary: Intermodal Surface Transportation Efficiency Act of 1991", U.S. Department of Transportation.

10. Iowa Department of Transportation. The Bicycle Facilities Network Identification Handbook. January 1995.

11. Bicycle Institute of Ameria, Bicycling Reference Book, 1992-1993, Washington, D.C., May 1992.

12. Dodge, Karen-Jayne and Christopher Kelly, Building Better Bicycling, Federal Highway Administration, February 1994.

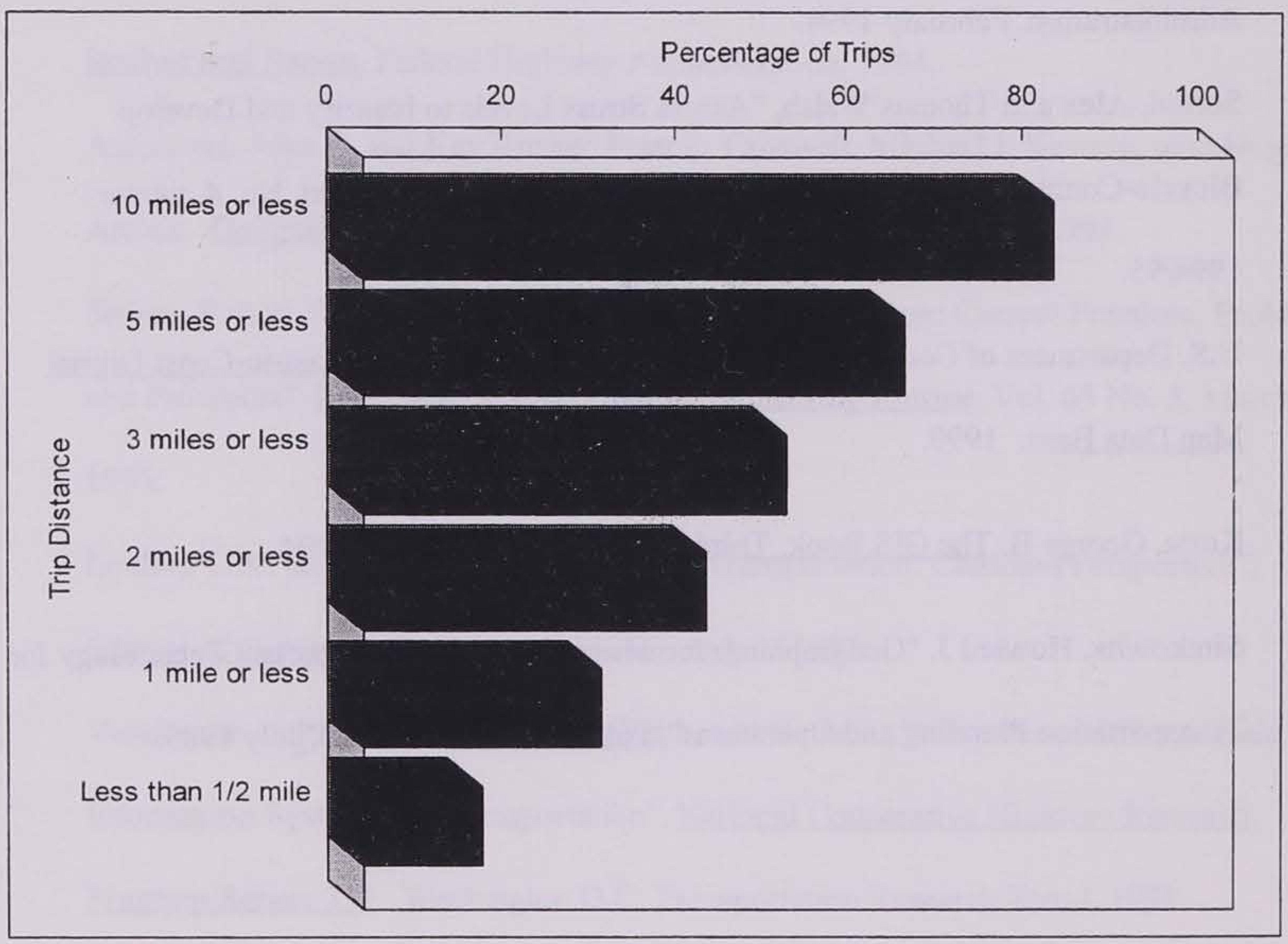
13. Sorton, Alex and Thomas Walsh, "Assess Stress Levels to Identify and Develop Bicycle-Compatible Roadways", Transportation Planning, Vol. xxi, No. 4, winter 1994/95.

14. U.S. Department of Commerce, Bureau of Census. Tiger: The Coast-to-Coast Digital Map Data Base. 1990.

15. Korte, George B. The GIS Book, Third Edition, OnWord Press 1994.

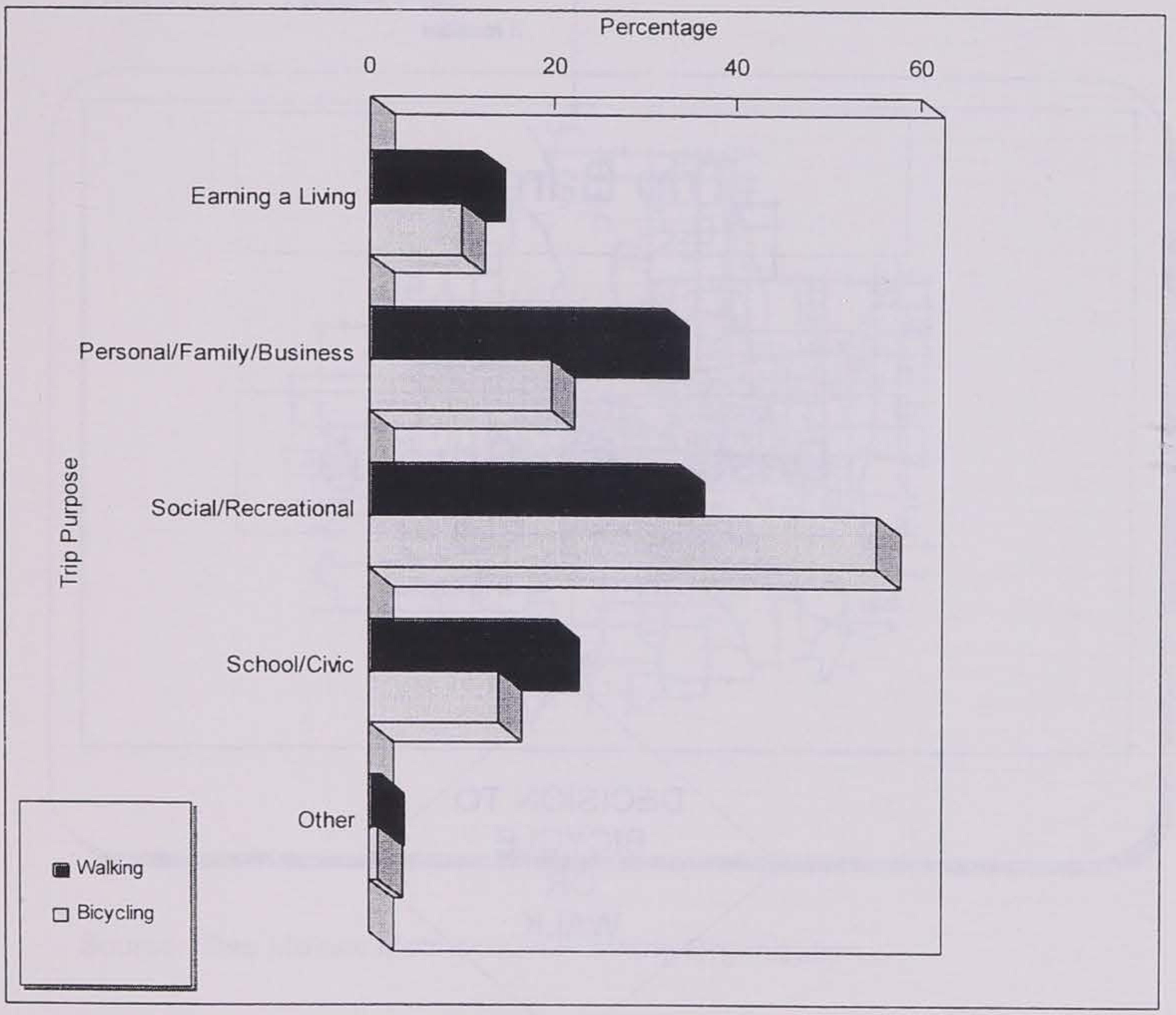
16. Simkowitz, Howard J. "Geographic Information Systems: An Important Technology for Transportation Planning and Operations", Public Works, Vol. 120, July 1989.

FIGURE 1 Daily Trip Distances



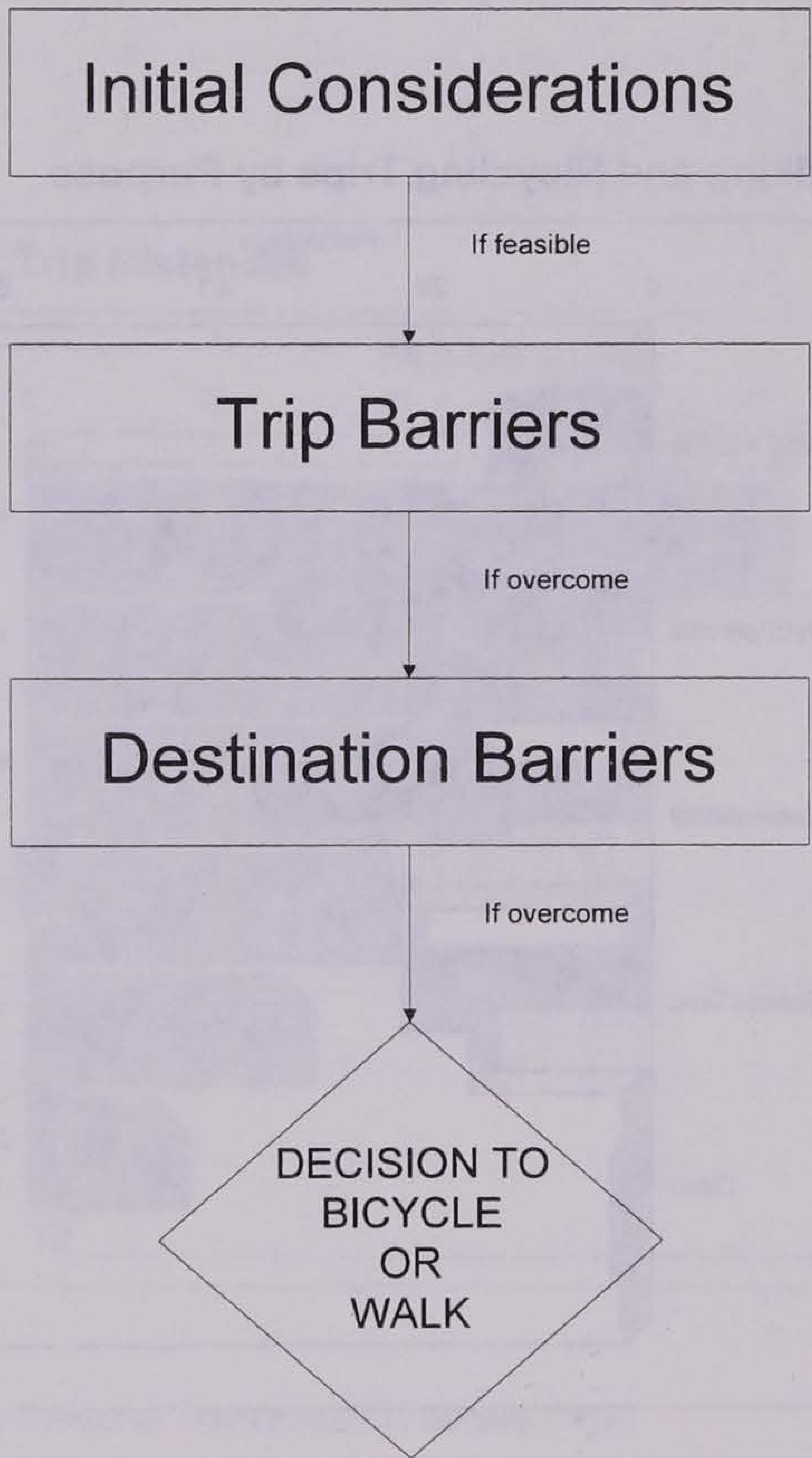
Source: Nationwide Personal Transportation Survey, 1990

FIGURE 2 Walking and Bicycling Trips by Purpose



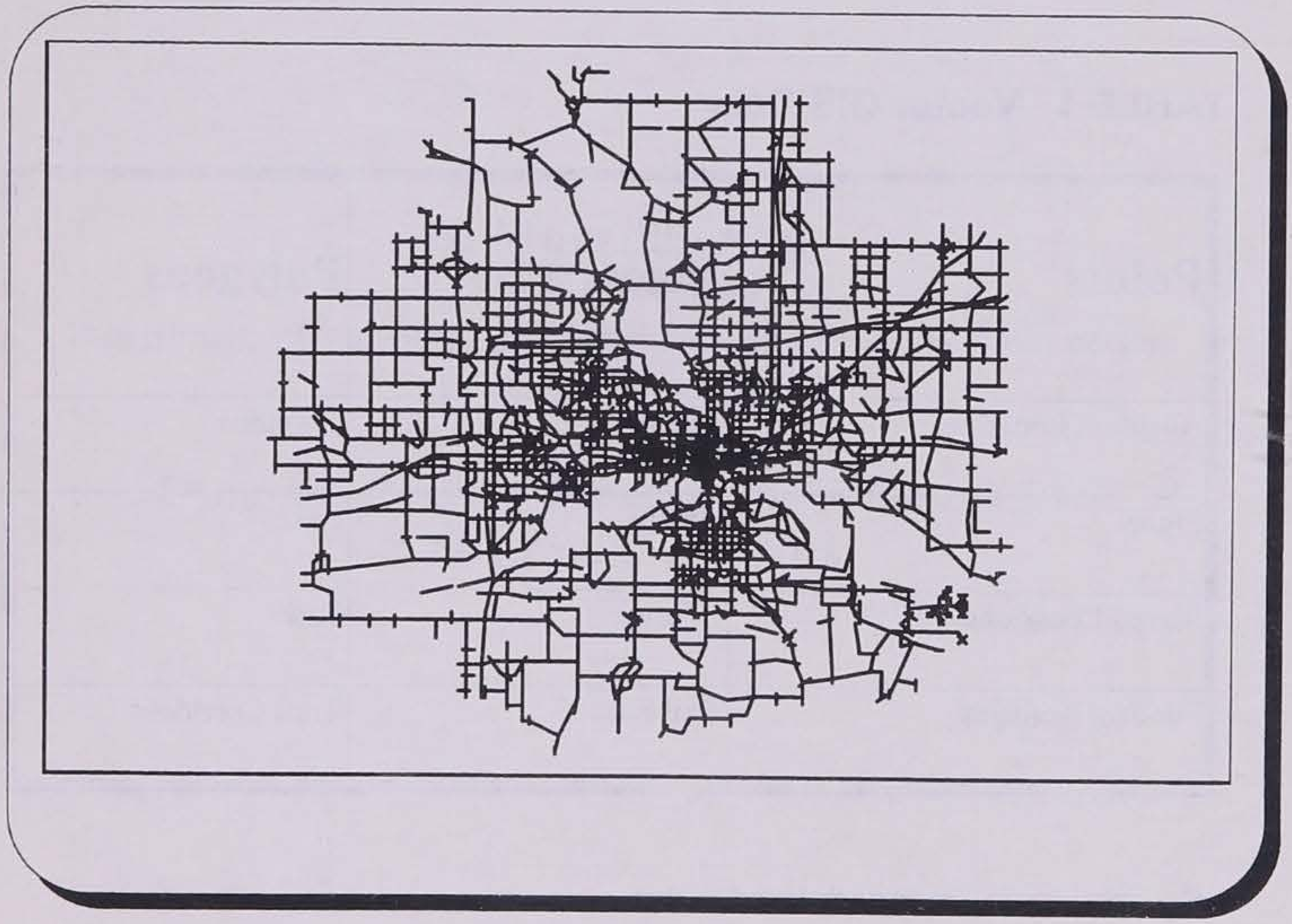
Source: National Personal Transportation Survey, 1990

FIGURE 3 Factors in the Decision to Bicycle or Walk



Source: The National Bicycling and Walking Study Final Report

FIGURE 7 TIGER File



Source: Des Moines Metropolitan Planning Organization

TABLE 1 Vector GIS Data

Points	Lines	Polygons
Accident Locations	Roads	Counties
Signs	Rivers	Lakes
Signal Locations	Bikeways	Parks
Parking facilities	Rail lines	Trail Corridors

Source: Iowa Transportation Center

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Dynamic Routing for Priority Shipment in LTL Service Network

Abstract

In this paper, the problem of routing of priority shipments in less-than-truckload(LTL) service network is considered. In current practice by the LTL carriers, the priority shipments follow the same route pattern called the load plans as the regular shipments. The proposed model exploits the stochasticity and dynamism embedded in the routing process and uses the real time information at terminals(such as loading status of trailers and driver availability) to determine the shipment routes adaptively. The proposed model is formulated as a Dynamic, Stochastic Shortest Path problem(DSSP) over a network with random arc costs and an efficient algorithm is developed that can be used in real time. The value of using an alternative routing strategy to route priority shipments is assesed using real data sets from a large LTL carrier. The numerical results show that the proposed strategy improves the level of service.

1 Introduction

A LTL carrier specializes in freight shipments that weigh between a few hundred and several thousand pounds, which usually do not fill an entire trailer. A tractor-trailer combination can pull approximately 24,000 pounds. To make economic use of the vehicle the carrier needs to consolidate many shipments. Consolidation is accomplished by using end-of-line terminals and breakbulks. End-of-line terminals maintains a fleet of small trucks and city trailers for handling pickups and deliveries in the city. The shipment at a shipper is picked up by a city trailer that will take the shipments to a end-of-line terminal. At the end-of-line terminal the shipment will be unloaded from the city trailer and loaded into a line-haul trailer that will take the shipments to a breakbulk facility. This breakbulk facility will serve as the consolidation terminal for several other end-of-line terminals in this region. Trailers always move directly between end-of-line and breakbulk terminals and normally, do not make stops at other end-of-line terminals to fill up the trailer. At the breakbulk facility the trailer is unloaded and the shipments are sorted and consolidated into trailers that will take the shipment to a breakbulk facility closer to its destination. At the breakbulk facility the trailer is unloaded and loaded into a trailer destined to an end-of-line terminal closer to the delivery point. At the end-of-line terminal the shipments in the line-haul trailer will be unloaded and loaded into the city trailer for delivery to the customers. Hence, a typical shipment route between a pair of origin and destination terminals may consist of one or two breaks. To maintain the service level standard and comply with work rules, the companies limit the number of allowable shipment routes from one terminal to another terminal and these set of fixed routes are called the load patterns. This paper considers the problem of routing of priority shipments in less-than-truckload(LTL) service network. In this paper, the value of using an alternative routing strategy to route priority shipments is assesed using real data sets from a large LTL carrier(Typically a large LTL carrier have several hundred terminals and handle hundreds of thousand shipments every day). This routing strategy utilizes real time information (such as loads available at the current terminal, driver availability) to change the routes of priority shipments dynamically.

In LTL trucking, some shipments have higher priority and hence needs to be transported faster than a regular shipment. To deliver the priority shipments faster, one needs to reduce the time spent by the shipment in some or all of the activities from its pickup to its delivery. Time spent by a shipment can be broken down as follows. The time a shipment spends in traveling is called as the enroute time T_E. When the trailer reaches its destination, it may have to wait for an empty dock which is called as time waiting to unload, T_{WU}. When a trailer finds an empty dock the shipments have to be unloaded, this time to unload is called as unloading time, T_U. When the shipments are loaded the trailer needs to wait for the driver, this waiting time is called as the time waiting to dispatch, T_{WD}. With each Origin-Destination($O - D$) pair is associated a level of service in which the shipment should be delivered from the bill's origin O to the bill's destination D. In order to meet this service level, the shipment has to leave the current terminal at a certain time and let this time be called time to make service(TTMS).

Once the trailer is opened the shipments are loaded into the trailer on a First Come First Served(FCFS) basis. Typically, when the trailer is filled to 90% of its capacity the trailer is closed thus using the trailer's capacity efficiently. The time interval between opening and closing of the trailer is called as the loading time, T_L. Waiting for 90% of the trailer's capacity to be filled may result in TTMS of some or all of the shipments to expire and hence those shipments cannot maintain the level of service. On the other hand, if the trailer is closed when the TTMS of any one of the shipment in the trailer expires, it can result in the trailers going with less than 10% filled which is not economical. Hence most LTL carriers strike a compromise, when a certain minimum economical capacity(say 75%) is filled and if the TTMS of any one of the shipments is expired then they close the trailer. Hence, longer the time to fill the minimum 75% capacity higher the number of shipments delayed. It can be realized that the loading time is dependent on the rate at which the shipments arrive and how the shipments are routed. Though all these times described above are random variables, this paper primarily focusses on random loading time, however, the methodology developed can be extended to include other sources of randomness.

The main contributions of this paper are the following. First, the proposed dynamic routing strategy is formulated as the problem of finding the expected length of dynamic stochastic shortest path (DSSP) in a network with discrete, independent random arc costs. Second, a new efficient algorithm is developed to solve DSSP in real-time. In this paper, it can be seen that the dynamism of DSSP can actually help to breakdown the combinatorial nature that appears in the static verison of stochastic shortest path problems which are NP-hard (Kamburowski, 1987). The results in this

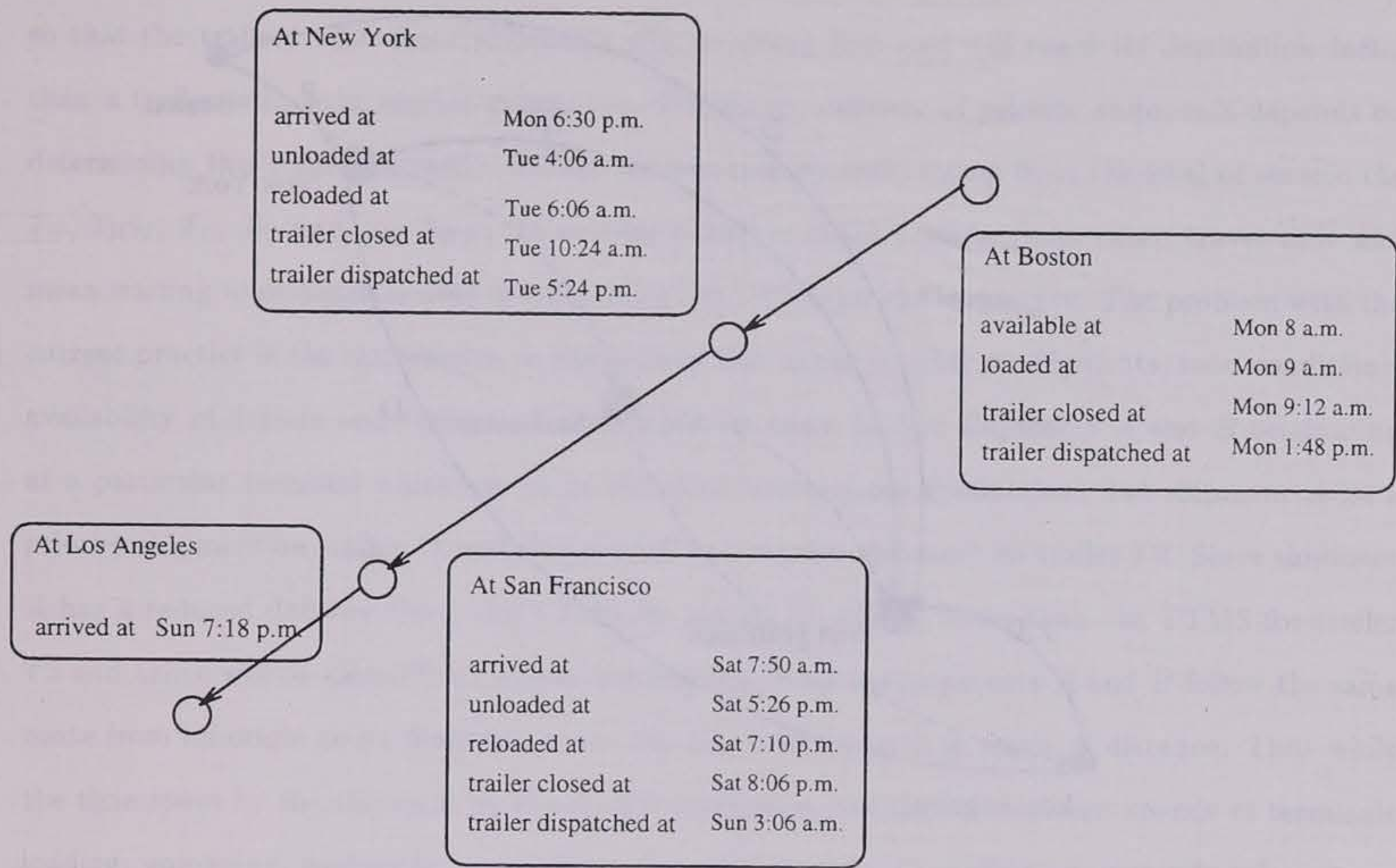


Figure 1: The itinerary of a shipment moving from Boston to Los Angeles.

paper measures the time that can be saved if the real-time information at terminals is fully used. This strategy is also evaluated by using real data to see under which conditions it works well.

Figure 1 shows that the time spent by a typical shipment going from *Boston* to *LosAngeles* through the breaks *NewYork* and *SanFrancisco*. In current practice, the shipments are routed through an LTL network in the following way. The three patterns are described using an example. Consider a shipment moving from *Boston* to *LosAngeles*. Let *Boston* and *LosAngeles* be end-of-lines terminals and the primary breakbulk of *Boston* is *Maybrook* and the primary breakbulk of *LosAngeles* is *SanFrancisco*. If there is a large number of shipments from *Boston* to *SanFrancisco*, the shipment may bypass the *Maybrook* breakbulk or if there is a large number of shipments from *Maybrook* to *LosAngeles*, the shipment may bypass the *SanFrancisco* breakbulk. If the shipment bypasses a breakbulk in the standard route then it is said to follow a direct load pattern. Thus by eliminating a breakbulk not only the need to handle(unload, sort, load) the trailer at the breakbulk terminal is eliminated but also eliminates upto a day in transit time for the shipment.

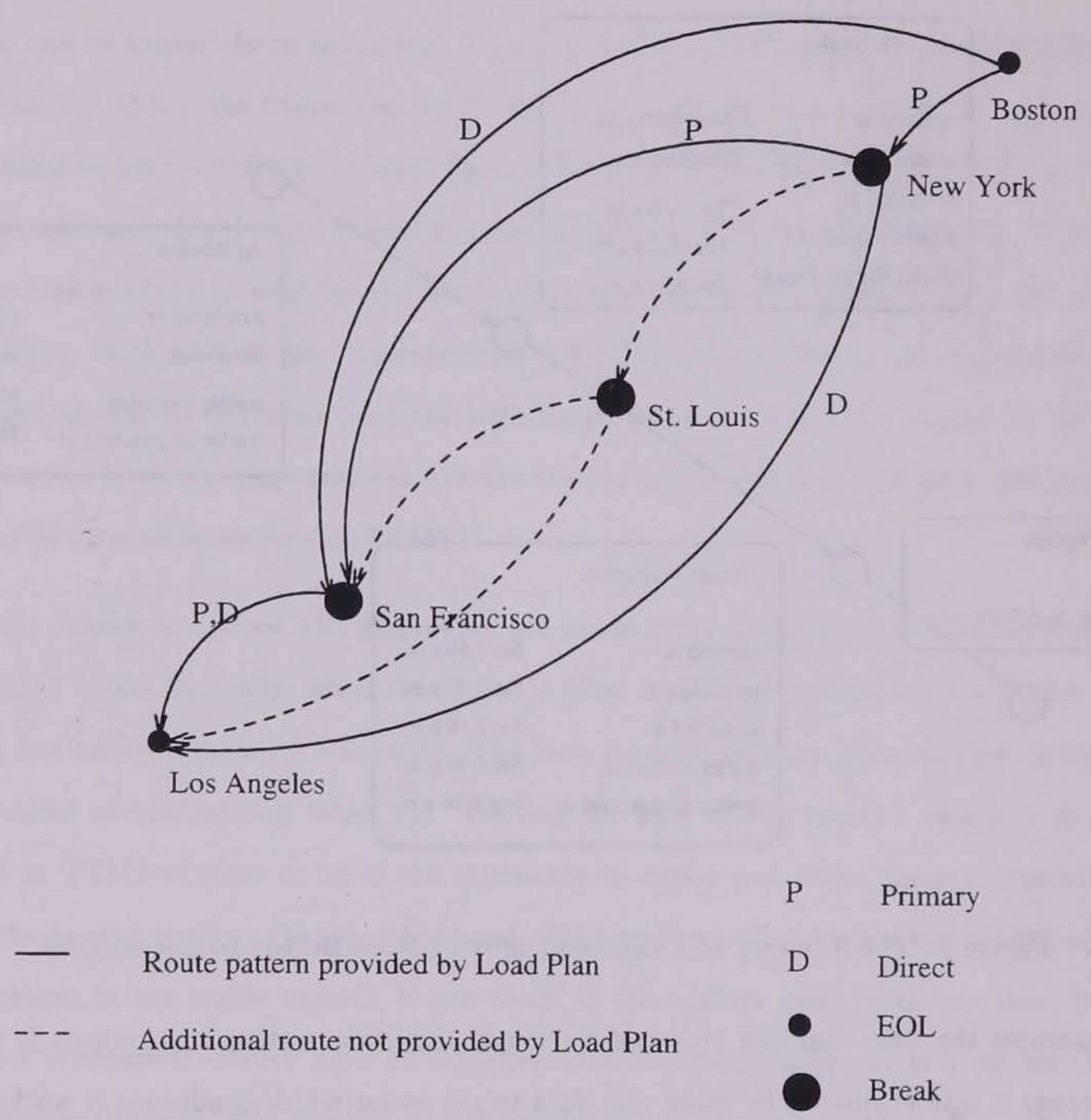


Figure 2: Example network

Initially, shipment at *Boston* is loaded on a direct trailer destined to *SanFrancisco*. But, if the trailer is not filled to the minimum economical capacity(say 75%) and the TTMS of any one of the shipment in the trailer expires, then the entire shipment is unloaded and loaded into a trailer destined to *Maybrook*. Then the shipment moves from end-of-line(*Boston*) to breakbulk(*Maybrook*) to breakbulk(*SanFrancisco*) to end-of-line(*LosAngeles*). If the shipment follows this route, then it is said to follow the primary load pattern. Sometimes if a large shipment arrives at *Boston* destined to *LosAngeles* which nearly fills the entire trailer then the shipment moves from *Boston* to *LosAngeles* directly. This type of movement is called Opportunistic direct.

In current practice, priority shipments follow the same load patterns described above as the regular shipments. But, priority shipments have reduced delivery time and hence reduced TTMS, so that the trailers with those shipments will be closed first and will reach its destination faster than a trailer with only regular shipments. The timely delivery of priority shipments depends on determining the TTMS correctly. TTMS is computed by subtracting from the level of service the T_E, T_{WU}, T_L, T_U and the T_{WD}. In current practice, mean loading time, mean travel time and mean waiting to dispatch is used in computing the TTMS for the shipments. The problem with the current practice is the randomness in these times due to the number of shipments, road conditions, availability of drivers and trailers. For example, let there be two shipments A and B originating at a particular terminal which are to be delivered to the same destination. Let shipment A be a priority shipment on trailer $T1$ and shipment B be a regular shipment on trailer $T2$. Since shipment A has a reduced delivery time, the TTMS for trailer $T1$ will be lesser than the TTMS for trailer $T2$ and hence will be closed first. In current practice, both the shipments A and B follow the same route from its origin to its destination, usually the shortest path in terms of distance. Thus while the time spent by the shipment on the road is minimized, the time a shipment spends at terminals loading, unloading, waiting to be unloaded and waiting to be dispatched are not reduced.

A typical shipment spends 40 – 50% of the total time on road and the rest at a terminal. Interestingly, the variability of travel time on a long-haul is relatively less, but the variability on the time a shipment spends at a terminal (loading time, waiting for driver availability, unloading time and waiting to unload) is large and the fact that the physical mileage between terminals is fixed indicates that the time a priority shipment spends on the road cannot be reduced by much while the time the priority shipment spends at a terminal can be reduced. This paper tries to reduce the time a shipment spends at a terminal by routing priority shipments differently instead of following the fixed load patterns described above. The ratio of number of priority shipments to regular shipments for an LTL carrier is usually less than 5%. Thus rerouting priority shipments separately will not alter the total cost a lot, but can increase the level of service.

The literature related to this paper, falls into two categories: research on LTL networks and research on DSSP. A vast majority of the research in LTL trucking is on network design, design of driver routes and routing of regular shipments. Most of these models tend to create fixed load patterns(routes). Powell and Sheffi [17] discuss how to design the LTL networks(which links should be there and which links should not be there) to reduce costs while maintaining service standard.

Farvolden and Powell[8] derive sub-gradients for introduction and cancellation of services-service network design problem in the LTL motor carrier industry. Powell [16] proposes a local improvement heuristic to determine the frequencies and flow in the LTL motor carrier network. Crainic and Roy [5] design routes for intercity drivers in a LTL network. Crainic and Rosseau [4] use a decomposition and column generation principle to determine what type and level of service to be offered on what routes and in what modes and how often. Akyilmaz [1] proposes a method to route the regular shipments so that the total empty ton-km is minimized. Hall[11] and Daganzo[7] analyze extensively routeing of freight shipments via consolidation terminals in a logistic network. The models developed by Hall[11] and Daganzo[7] route the shipments via a single terminal nearest to the origin or the destination or via the two terminals nearest to the origin and destination. Keaton[13] develops an operations planning model of LTL motor carrier to determine the number of terminals, routing of trucks between terminals to minimize cost subject to service level constraints. Finally, Barnhart and Sheffi [2] develop a primal dual heuristic approach for solving the large scale multicommodity networks and apply this technique to the problem of determining optimium vehicle routes.

Majority of research on stochastic shortest path problem have focussed on a static version where it is assumed that the arc costs are realized at once and the path is fixed once the path is chosen. Kamburowski [12] shows that such a problem is NP-Hard. Such static versions of the stochastic shortest path problems are discussed by Frieze and Grimmet[9] and Mirchandani[14]. Frieze and Grimmet[9] consider the problem of finding the shortest distance between all pairs of vertices in a complete digraph of n vertices, whose arc lengths are non-negative random variables. Mirchandani[14] on the other hand, develops an algorithm to compute the expected shortest time between nodes when the travel time on each link has a given independent discrete probability distribution.

Due to inherent randomness in number of shipments, availability of drivers, trailers, a stochastic model helps in estimating the shortest route(in terms of time) more accurately than a deterministic model. Also, since this model for routing high priority shipments makes use of the new information available(number of shipments available, number of drivers available) at each terminal and, reroutes based on the new information obtained DSSP seems to be more appropriate than the static stochastic shortest path problem(SSP). In this paper a new strategy is proposed to reroute the priority shipments through LTL service network which utilizes real time information. The underlying mathematical model for this strategy is the Dynamic and Stochastic Shortest Path(DSSP) problem. A lower end polynomial time algorithm is proposed to solve the DSSP which can be used to route priority shipments on large LTL networks in real time.

Despite extensive study on static stochastic shortest path problem, research on a dynamic version is very limited. Croucher[6] proposes an algorithm to determine a dynamic shortest route when there is a positive probability associated at each node that a particular outbound arc does not exist. Furthermore, it assumes that if an outbound arc does not exist, each of the remaining arcs has an equal probability of being traversed, regardless of their cost. Hall[10] develops a dynamic programming approach to find the expected fastest path between two nodes in a network with travel times that are both random and dependent on arrival time at a node. Psaraftis and Tsitsiklis[18] consider the shortest path in acyclic networks where the arc costs depend on certain environmental variables that evolve according to an independent Markov process. Bertsekas and Tsitsiklis[3] propose a method to find the shortest paths in networks with positive cycles in which the arc costs are Markovian.The complexity issues of both static SSP and DSSP can be found in Polychronopoulos[15]. Finally, Polychronopoulos[15] dissertation summarizes the results of static version of the shortest path problem and also describes the DSSP and proposes a simple solution approach to find the expected cost of the dynamic shortest path in a network where arc costs are discrete, independent, and finite random variables.

Differing from most research on LTL networks that focus on static planning for shipment routes, this paper addresses a dynamic aspect of shipment-route planning. This paper considers an alternative strategy for routing priority shipments, which is formulated as a DSSP problem. This model is different from those studied in the literature in that (1) the arc costs are independent, discrete, and finite random variables, and (2) the arc costs are realized dynamically and re-routing can be made whenever a node is reached. For solving the DSSP model, a low-order polynomial-time algorithm is developed. Through some numerical experiments using a real data set, the impact of the explicit considerations of stochasticity and dynamism for the shipment routing in LTL networks is also highlighted.

The primary motivation for this research is the fact that a typical shipment spends more than 50% of the time in transit at terminals and some of this time spent by the shipments in transit can be reduced using the DSSP. Also, dynamic stochastic shortest path problems have a number of applications in transportation, logistics, and communication systems. Consider the routing of an ambulance in a road network under uncertain road conditions (such as congestion). At a road intersection, the ambulance can realize the road conditions ahead and then decide which way to go. Another example is the routing of packets in data networks between two nodes. The delay in links typically depends on the congestion level, and thus the travel time is stochastic. For example, on the basis of the current congestion level, a data packet is routed to the link which will result in an expected minimum delay in the future when that packet reaches a particular node in the network. DSSP computes the exact expected shortest path costs can in seconds. Therefore, the method can be used on real-time basis in applications such as advanced driver guidance systems and data routing systems.

The rest of the paper is organized as follows. Section 2 models the dynamic routing strategy for priority shipments in LTL networks as a DSSP. Section 3 describes a new solution approach used to solve this problem. Section 4 gives the results of some computational experiments with real data. Finally, Section 5 provides some concluding remarks and comments on possible research extensions.

2 A Model

In current practice, the priority shipments use the same route as regular shipments and the routes used are fixed except that, the priority shipments will receive special attention at the breaks. Moreover in current practice, real-time information available at the terminals is not utilized. An adaptive routing strategy is proposed which utilizes the real-time information to route priority shipments through a LTL network. This routing strategy helps in delivering the priority shipments faster and thus improving the level of service. This dynamic routing strategy belongs to a class of stochastic, dynamic optimization problem. This problem is similar to the classical shortest path problem. However, this problem allows rerouting when new information is received. Interestingly, the dynamism in this problem breaks down the combinatoric structure for the static stochastic shortest problem, allowing this problem to be solved in real-time. This problem of routing priority shipments in a LTL network can be modeled as a Dynamic Stochastic Shortest Path problem(DSSP) and the DSSP can be solved efficiently in real time for large LTL networks.

Without loss of generality, let the shipment moves from node 1 to node n. Then the DSSP problem can be described mathematically as follows:

Let

$\tilde{c}_{ij}$ = the random cost of arc (i, j)

c_{ij}^k = the k^{th} realization of the cost of arc (i, j)

$\bar{V}_i$ = the expected cost of the dynamic shortest path from node i to node n

$S(i)$ = the set of successor nodes of node i (that is, the set of $\{j|(i,j) \in A\}$)

X_{ij} = $\tilde{c}_{ij} + \bar{V}_j$

r_{ij}^k = the probability that the realization of $\tilde{c}_{ij}$ (arc cost) is c_{ij}^k

Then, the DSSP can be mathematically written as

$$\min_{j \in S(1)} \{c_{1j} + \bar{V}_j\} \tag{1}$$

where $\bar{V}_j = E[\min_{k \in S(j)} \{\tilde{c}_{jk} + \bar{V}_k\}]\ \forall j = 2, ..., n-1$

The stochastic and dynamic nature of the above problem can be well understood by means of an example. Consider the network in Figure 2. A priority shipment at $NewYork$ using mean time will always be routed through the shortest path $NewYork - SanFrancisco - LosAngeles$ where $SanFrancisco$ is an intermediate breakbulk and $LosAngeles$ is the destination. Let, the shipment require 60 hours of travel to reach the destination through this path. Let, if the shipment starting at $NewYork$ goes through $NewYork - St.Louis - LosAngeles$ require 70 hours of travel to reach the destination. For simplicity, the loading time at $St.Louis$ and $SanFrancisco$ is assumed to be the same. At $NewYork$, let the trailer from $NewYork$ to $SanFrancisco$ be just closed and depending on current shipments available from $NewYork$ to $SanFrancisco$ and past data the next trailer to $SanFrancisco$ from $NewYork$ is estimated to be closed in 20 hours. But a trailer loading at

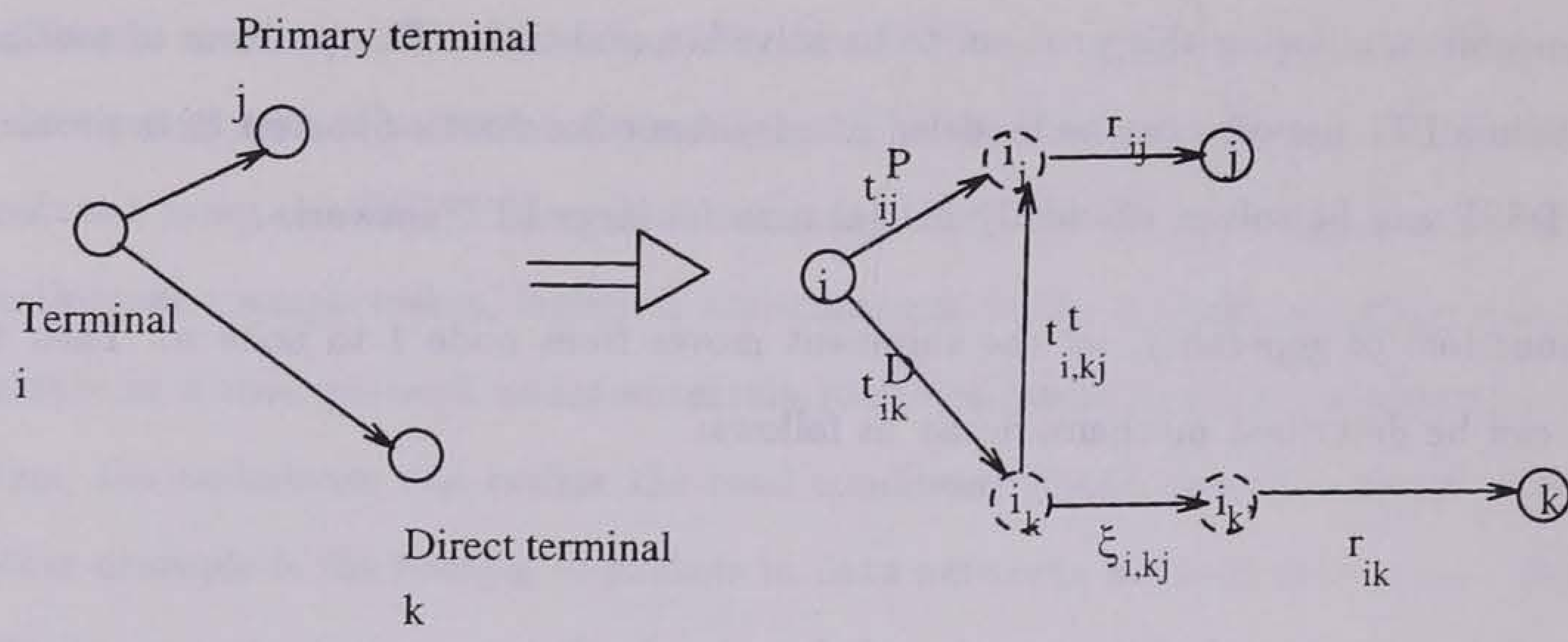


Figure 3: A network representation of the load patterns

NewYork destined to *St.Louis* will be leaving in next couple of hours, then if the priority shipment is loaded onto this trailer then it will reach *SanFrancisco* faster. The proposed solution approach is based on this idea. This strategy is modeled as a DSSP(finding the shortest path between a pair of nodes in a network with random arc costs). Whenever the costs of arcs emanating from a node are realized, based on this realization the routes can be changed.

The routing of the shipments going from terminal i (heading to terminal n) to the next terminal is modeled as a network problem as follows. In particular, arc costs are used to represent the travel times. Since there are different components of travel time, some artificial nodes needs to be generated in addition to creating nodes for the physical terminals. First, a node for each terminal is created as denoted by i, j and k in Figure 3. Second, two nodes denoted by i_j and i_k are created to represent the primary route and the direct route, respectively. Also, an additional node is generated denoted by i'_k (described later). Next, the arcs between nodes i and i_j and nodes i and i'_k with arc costs of $t^P_{i,j}$ and $t^D_{i,k}$ are created, respectively. These arcs capture the transit time at terminals if the shipments use the primary trailer and the direct trailer. Moreover, arcs from node i_j to node j with the cost of $r_{i,j}$ and from node i'_k to k with the cost of $r_{i,k}$ are created. Such arcs reflect the travel times between terminals. Then, an arc from node i_k to node i'_k is added to reflect the case where the shipments on the direct trailer may need to be unloaded and put on the primarily trailer. Thus, the arc cost, denoted by $\xi_{i,kj}$, is a bi-valued random variable with the following probability mass function: $\Pr(\xi_{i,kj} = 0) = p_{i,kj}$ and $\Pr(\xi_{i,kj} = \infty) = 1 - p_{i,kj}$. Finally, an arc from node i_k to node i_j is added with the arc cost of $t_{i,kj}$ to capture the transfer time.

The small network described above represents only the direct and primary load patterns for the given OD pair. If the use of additional shipment routes are allowed, additional nodes and arcs needs to be added in the network. For example, Figure 4 depicts the network when *St. Louis* is being considered as an alternative break for the shipments going out of *San Francisco* and heading to *Los Angeles*.

The assumptions used in developing the solution procedure are stated below

- Arc costs are independent, discrete, finite random variables.
- The network is acyclic.
- Arc costs are realized dynamically: When the trailer is at a terminal A, the actual cost of the arcs from node A can be estimated and the choice of which node the trailer is sent next is determined.

If the arc costs are assumed to be Markovian, then the state space is huge. Moreover at the breaks, the ratio of number of bills generated locally to the number of bills which are transferred from other breaks is high, which suggests that the assumption arc costs are independent is reasonable. Discrete distribution is used because planning is made at fixed time intervals at a terminal. For simplicity, the terminals in the LTL network are renamed by node numbers from 1 to n, where node 1 is the origin of a priority shipment and node n is the destination of the prirority shipment. In this case only the priority shipments originating at node 1 and terminating at node n are considered. In other words the priority shipments between same $O-D$ pair are considered. This problem can be solved for each $O-D$ pair between which there is a priority shipment and the result can be used to route the priority shipments in the entire LTL network. Without loss of generality, it is assumed that the indexes of the nodes are topologically ordered such that if $i < j$, then there is a directed path from i to j and no directed path from j to i. This assumption is reasonable because, once the shipment leaves a terminal it is not usually routed back to the same terminal again.

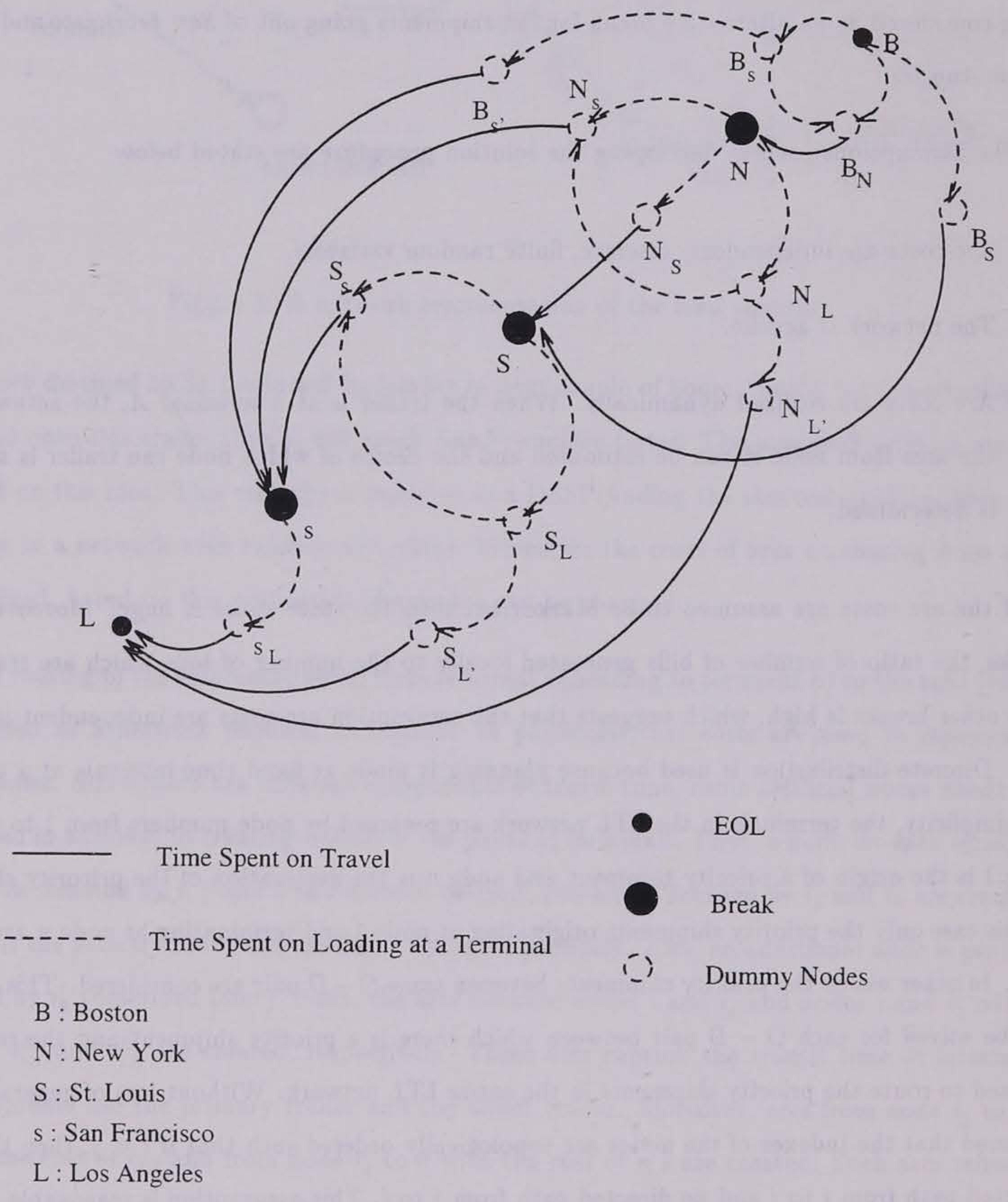


Figure 4: A network for the Boston – Los Angeles shipments with St. Louis as an alternative break.

3 Solution Approach

The solution approach, in this paper primarily focusses on random loading time, however, the methodology developed can be extended to include other sources of randomness such as unloading time, waiting to unload and waiting to dispatch. This random loading time can be estimated at a terminal, since the number of shipments currently available at this terminal is known and at what rate the shipments arrive from this terminal to any particular destination is known from the past data. In current practice, this new information available at the current terminal is not utilized and the shipments are routed through the same path once the path is chosen. In the proposed routing strategy this information is utilized to reroute the priority shipments as follows.

Procedure to Route the Priority Shipments

1. Compute the expected cost of going from each of the terminals in the network to the destination.
2. When at terminal i
    1. Let expected cost of going from each node j, $j \in S(i)$ to the destination be $\bar{V}_j$
    2. Estimate the cost c_{ij} of going from node i to node j based on current level of shipments and based on the rate estimated from past data at which the shipments arrive $\forall j \in S(i)$
    3. Find the j which minimizes $c_{ij} + \bar{V}_j$. Then load the priority shipment into the trailer destined to terminal j.

end procedure

In order to compute the expected cost of going from each terminal i to destination, the network of an LTL carrier is transformed as described in the previous section. After the transformation, the expected cost of going from each of the nodes in the transformed network to the destination n can be computed using a backward recursive technique, starting from node $n-1$ (The nodes in the network are assumed to be topologically ordered) as follows.

Procedure: DSSP

1. Initialize

$\bar{V}_i = \infty, \forall i \in N, i \neq n$

$\bar{V}_n = 0$

2. $i = n - 1$

while $i \neq 0$ do

2.1 Compute $Pr(\min_{j \in S(i)}\{X_{ij}\} = c_{ij}^k) = Pr(X_{ij} = c_{ij}^k) \prod_{j' \neq j} Pr(X_{ij'} > c_{ij}^k)$

2.2 Compute $\bar{V}_i = E[\min_{j \in S(i)}\{X_{ij}\}]$

$= \sum_{j=1}^{m} \sum_{i=1}^{k} c_{ij}^k Pr(\min_{j \in S(i)}\{X_{ij}\} = c_{ij}^k)$

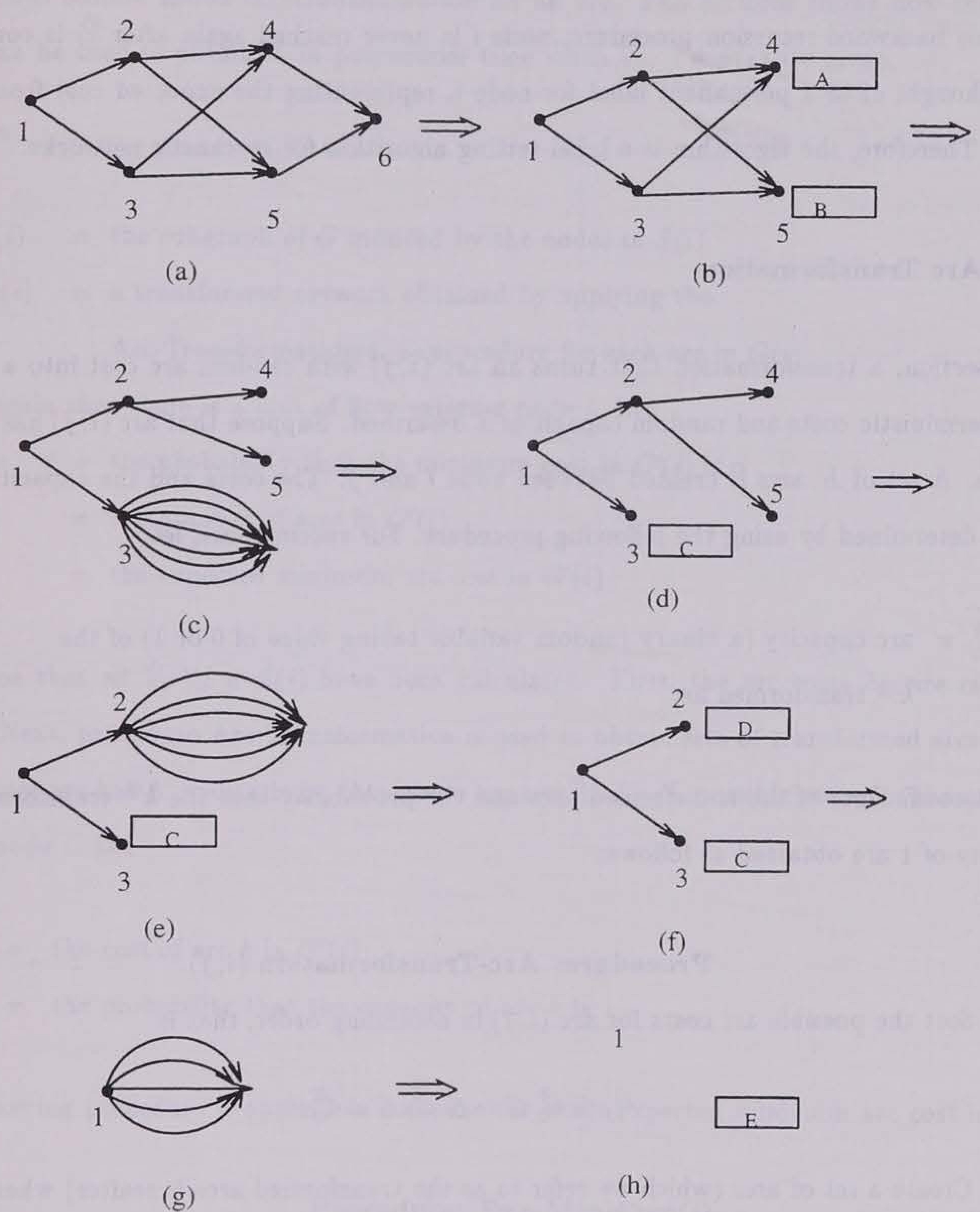
$i = i - 1$

end while loop

end procedure

Let the step 2.1 in the DSSP algorithm be called Arc- Transformation (see Section 3.0.1) step and and step 2.2 be called Exp-Min-Cost (see Section 3.0.2) step. Before the details of these procedures are explained, the DSSP procedure is illustrated using the Figure 5.

Consider the network in Figure 5a . For node 5, since there is only one outbound arc, the expected minimum cost of going from node 5 to 6 is simply the mean cost of arc (5,6). Similarly the expected minimum cost of going from node 4 to node 6 is the expected cost of arc (4,6). The results are shown in Figure 5b. Next, the arcs from node 3 are transformed into a set of arcs with random arc capacities (but with deterministic costs using the Arc-Transformation procedure described later), producing the network in Figure 5c. Then, by using the transformed arcs, the expected minimum cost of going from node 3 to node 6 is computed(using the Exp-Min-Cost procedure described later). The resulting value, is shown in Figure 5d. Again, the arcs starting from node 2 are transformed to arcs with random arc capacities (using Arc-Transformation procedure) and expected cost of going from node 2 to node 6 is computed (using the Exp-Min-Cost procedure) (see Figure 5e and 5f). Finally, the arcs starting from node 1 (see Figure 5g) are transformed



The value in the box next to a node is the expected cost from that node to node 6.

Figure 5: Illustration of the backward recursion.

(using the Arc-Transformation procedure) and the expected cost of going from node 1 to node 6 is computed (using the Exp-Min-Cost procedure).

In this backward recursion procedure, node i is never reached again after $\bar{V}_i$ is computed. $\bar{V}_i$ can be thought of as a permanent label for node i, representing the expected cost from node i to node n. Therefore, the algorithm is a label-setting algorithm for stochastic networks.

3.0.1 Arc Transformation

In this section, a transformation that turns an arc (i, j) with random arc cost into a set of arcs with deterministic costs and random capacities is described. Suppose that arc (i, j) has K possible arc costs. A set of K arcs is created between node i and j. The costs and the capacities of these arcs are determined by using the following procedure. For succinctness, let

ξ_{ij}^k = arc capacity (a binary random variable taking value of 0 or 1) of the k^{th} transformed arc.

The cost coefficients of the transformed arcs and the probability that the k^{th} transformed arc has a capacity of 1 are obtained as follows:

Procedure: Arc-Transformation (i, j)

1. Sort the possible arc costs for arc (i, j) in ascending order, that is

$$c_{ij}^1 \le c_{ij}^2 \le ... \le c_{ij}^k \le ...c_{ij}^K$$

2. Create a set of arcs (which we refer to as the transformed arcs hereafter) where arc k has a cost of c_{ij}^k

3. The probability that the arc capacity ξ_{ij}^k is 1 for $k = 1,2,...,K$ is determined recursively by:

$$P(\xi_{ij}^k = 1) = \frac{r_{ij}^k}{\prod_{m=1}^{k-1} P(\xi_{ij}^m = 0)} \quad \text{for } l = 1, 2..., K \tag{2}$$

end procedure

3.0.2 Computing the Expected Minimum Arc Cost

The previous section shows the transformation for an arc. This sections shows how the transformation can be used to obtain $\bar{V}_i$ in polynomial time when $\bar{V}_j$, $j \in S(i)$ are given.

Define

$G(i)$ = the subgraph of G induced by the nodes of $S(i)$

$G'(i)$ = a transformed network obtained by applying the Arc-Transformation(i, j) procedure for each arc in $G(i)$

Assume again that there is a unit of flow entering node i. Let

$\hat{P}_a$ = the probability that the minimum cost in $G'(i)$ is a

N_i = the number of arcs in $G'(i)$

u_i = the expected minimum arc cost in $G'(i)$

Assume that all $\bar{V}_j$ $\forall j \in S(i)$ have been calculated. First, the arc costs $\tilde{c}_{ij}$ are replaced by $\tilde{c}_{ij} + \bar{V}_j$. Next, procedure Arc-Transformation is used to obtain sets of transformed arcs. Suppose each original arc has K realizations, then there are totally $K \cdot N_i$ possible costs for the unit of flow entering node i. Let

c_i^k = the cost of arc k in $G'(i)$

τ_i^k = the probability that the capacity of arc k is 1

Then, following procedure is applied to compute the exact expected minimum arc cost in $G'(i)$.

Procedure: Exp-Min-Cost(i)

1. Sort all arcs in $G'(i)$ by costs in ascending order (there are $K \cdot N_i$ such arcs emanating from node i).
2. Compute $\hat{P}_a$ for $a = c_i^1, c_i^2, ..., c_i^{K \cdot N_i}$ by

$$\hat{P}_{c_i^k} = \tau_i^k \cdot \prod_{i=1}^{k-1}(1 - \tau_i^k) \tag{3}$$

3. Compute u_i by

$$u_i = \sum_{k=1}^{N_i} \hat{P}_{c_i^k} \cdot \hat{c}_i^k \quad (4)$$

end procedure

Step 2 of Exp-Min-Cost follows from the fact that the unit of flow going out of node i will take the least cost option. That is, it uses the k^{th} arc if and only if the first k-1 arcs have capacity 0 and the k^{th} arc has capacity 1.

The complexity of the DSSP algorithm is analyzed below. Let,

n = number of nodes in the network

r = the number of arcs from each node

k = number of possible realization of an arc

For simplicity, let all arcs have k realizations. This assumption does not affect the results. In DSSP, suppose that the $r \cdot k$ arc costs are sorted by heap sort, then $O(r \cdot k \cdot log(r \cdot k))$ steps are needed at each node i. Since there are n nodes in the network, at most $O(n \cdot r \cdot k \cdot log(r \cdot k))$ steps are needed in order to calculate the expected shortest path from node 1 to node n. With such a complexity, the proposed method can deal with real large stochastic networks of LTL carriers.

In the next section, the performance of the algorithm is evaluated using real data from a large LTL carrier.

4 Numerical Experiments

In this section, numerical experiments are performed to find out how good is the dynamic and adaptive routing strategy proposed when compared to using a single least expected cost route and how fast is the algorithm when applied to a real LTL network of a large LTL carrier.

Because of the availability of data, only the loading times (the time between a shipment is loaded onto a trailer until the trailer is closed)are considered as random variables. The ranges of loading times are typically between 1 to 48 hours or between 1 to 24 hours, depending on the type

Table 1: Comparison of solutions obtained by DSSP and by LP

O-D Pair	LP	DSSP	Time on road	Savings	Eff. Index
1	173	162	116	11	19.3
2	179	172	115	7	10.9
3	158	148	109	10	20.4
4	175	166	110	9	13.8
5	172	163	109	9	14.3
6	89	79	21	10	14.7
7	99	90	35	9	14.1
8	81	69	14	12	17.9
9	112	102	46	10	15.2
10	110	99	39	11	15.5

of terminal. The loading time is assumed to increase in 2-hour intervals. For all other times, such as travel time on road and waiting time for a closed trailer to be dispatched, the average times provided by the data set is used. Main objective of this numerical experiments is to compare the travel times for the priority shipments using the given load plan (LP) with the times using DSSP. When the routes provided by LP are used, a shipment heading from the current terminal to a destination terminal can have at most two choices of the next stop (either primary or direct). For DSSP, on the other hand some additional choices of next stops are allowed which are selected on the basis of the smallest average travel times of the paths from the current terminal to the destination via these stops. The number of additional choices is origin-destination (O-D) pair dependent. Nevertheless, this number is less than three in most cases.

In these experiment, two groups of domestic O-D pairs are considered(we exclude international shipments since they are handled differently). The first group consists of 150 O-D pairs that have the longest travel distance between the origin and the destination. The shipments between these O-D pairs generally need to pass through more breaks. The second group consists of another 150 O-D pairs that have a high percentage of total travel time spent on loading. The distance between the origin and the destination of each of these O-D pairs is relatively small while the shipments between them still need to pass through some breaks.

The experiments were conducted using an SGI Indigo2 R4000 machine. Of the 300 problems that was solved as DSSP, none requires CPU time of more than 1 second. Therefore, the algorithm is quite efficient. Table 1 shows the results for the average travel times(in hours) of priority shipments for 10 typical O-D pairs (five from each group). Column 1 gives the O-D pair numbers. Columns 2 and 3 show the times for using LP and for using DSSP respectively. Column 4 shows the time spent on road by using LP. Column 5 shows the time saved by using the dynamic routing strategy. Since it is possible that the dynamic routing can save time on loading but may increase the time spent on road, the net time-savings is expressed as a percentage of the average loading time for each O-D pair in column 6. Such percentages are called the effectiveness indexes, since in general a higher percentage means that the proposed strategy is more effective.

The average time spent on loading in group 1 is 50.5 hours whereas the average total travel time is 170 hours. The mean time-saving is 7.5 hours with the standard deviation of mean of 1.5 hours. The mean effectiveness index is 14%. Furthermore, one-third of the O-D pairs in group one have a time-saving over 10 hours. For the second group, the average times spent on loading and total travel times are 66.7 hours and 102 hours respectively. The average time-saving is 6.7 hour so that the mean effectiveness index is just over 10%. For group 2, although the loading time can be reduced, the travel distance may increase as well. Thus, the mean effectiveness index in group 2 is lower. Notice that only loading times are treated as random variables. If the probability distributions for other travel time components (such as the waiting time for a trailer to be dispatched) are allowed to be random variables, it can be expected that more time-saving can be achieved. The numerical experiment suggests that this strategy is more effective for O-D pairs that are far apart than for those that are close to each other.

5 Conclusion

An alternative shipment routing strategy for the priority shipments on an LTL line-haul network is presented. By using a network formulation, this strategy can be represented as finding a shortest path in a network in which the arc costs are stochastic and costs are realized dynamically. The lower end polynomial time label-setting algorithm presented in this paper can be used in real time and hence is practicable for large LTL networks. The numerical results indicate that this dynamic and adaptive routing strategy proposed will allow the priority shipments to reach their destination faster and hence will improve the level of service for an LTL carrier. Therefore considering the stochastic and dynamic aspects in LTL routing is worthwhile.

One interesting future research would be whether we can use DSSP to improve the routing of regular shipments as well and whether this strategy would increase the total cost by much. In fact, how to transform real-time information to a form that can be used mathematically requires further investigation. Waiting time for a closed trailer to be dispatched at a terminal is not considered as a random variable in the experiments. This waiting time depends on the availability of drivers who can handle this trailer. Further experiments needs to done if some real data is available about dispatching times, to find out whether considering this time as a random variable will save substantial time.

References

[1] M. O. Akyilmaz. An algorithmic framework for routeing ltl shipments. *Journal of Operational Research Society*, 45(5):529–538, 1994.

[2] C. Barnhart and Y. Sheffi. A Network-Based Primal-Dual Heuristic for the Solution of Multicommodity Network Flow Problem. *Transportation Science*, 27(2):102–117, 1993.

[3] D. Bertsekas and J. N. Tsitsiklis. An analysis of stochastic shortest path problems. *Math. Oper. Res.*, 16:580–595, 1991.

[4] T. G. Crainic and J. M. Rousseau. Multicommodity, multimode freight transportation: A general modeling and algorithmic framework for the service network design problem. *Transportation Research-B*, 20B(3):225–242, 1986.

[5] T. G. Crainic and J. Roy. Design of regular intercity driver routes for the ltl motor carrier industry. *Transportation Science*, 26(4):280–295, November 1992.

[6] J. Croucher. A note on stochastic shortest route problem. *Nav. Res. Logist. Quart.*, 25:729–732, 1978.

[7] C. Daganzo. The break-bulk role of terminals in many to many logistic networks. *Operations Research*, 35:543–555, 1987.

[8] J. M. Farvolden and W. B. Powell. Subgradients for service network design. *Transportation Science*, 28(3):256–272, 1994.

[9] A. Frieze and G. Grimmet. The shortest path problem for graphs with random arc lengths. *Discrete. Appl. Math.*, 10:57–77, 1985.

[10] R. W. Hall. The fastest path through a network with random time-dependent travel times. *Trans. Sci.*, 20:182–188, 1986.

[11] R. W. Hall. Comparison of strategies for routing shipments through transportation terminals. *Transportation Research A*, 21A:421–429, 1987.

[12] J. Kamburowski. An overview of the computational complexity of the PERT shortest route and maximum flow problems in stochastic networks. In G. Andreatta, F. Mason, and P. Serafini, editors, *Stochastics in Combinatorial Optimization.* World Scientific Publishing Co., Singapore, 1987.

[13] M. H. Keaton. Are there economies of traffic density in the less-than-truckload motor carrier industry? an operations planning analysis. *Transportation Research- A*, 27A(5):343–358, 1993.

[14] P. B. Mirchandani. Shortest distance and reliability of probabilistic networks. *Comput. and Oper. Res.*, 3:347–355, 1976.

[15] G. H. Polychronopoulos. Stochastic and dynamic shortest distance problems. Ph.D. Thesis, Department of Electrical Engineering and Compute Science, MIT, Cambridge, Mass., 1992.

[16] W. Powell. A local improvement heuristic for the design of less-than-truckload motor carrier networks. *Transportation Science*, 20(4):246–257, November 1986.

[17] W. Powell and Y. Sheffi. The load planning problem of motor carriers: Problem description and a proposed solution approach. *Transportaion Research-A*, 17A(6):471–480, 1983.

[18] H. N. Psaraftis and J. N. Tsitsiklis. Dynamic shortest paths in acyclic networks with Markovian arc costs. *Oper. Res.*, 41:91–101, 1993.

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Transportation Control Measures Under the Clean Air Act and ISTEA: Outlook for Success

INTRODUCTION

The automobile has exerted a tremendous influence over the development of American cities, and the quality of life in these cities, during the last half-century. While the automobile serves as the primary means of mobility, it is also the source of many urban problems, such as traffic congestion and deteriorating metropolitan air quality. Increases in traffic congestion are caused by a combination of factors, including urban sprawl and changes in travel behavior (Freilich and White, 1991). Population growth on the urban fringe increases trip lengths to places of employment. Suburban low-density shopping and residential development also contribute to traffic congestion by minimizing the density needed to make public transit feasible (Kelly, 1994). As a result, the number of vehicle miles travelled (VMT) has increased three times faster than the rate of population growth since 1950 (Netter and Wichersham, 1993).

The societal costs of the air pollution caused by traffic congestion are staggering. It is estimated that automobiles are responsible for 70% of the carbon monoxide, 45% of the nitrogen oxide and 34% of the volatile organic compounds emitted into the air nationwide (Netter and Wichersham, 1993). Excessive levels of ozone, nitrogen oxides, and carbon monoxide in urban areas are linked to a variety of health effects, including lung cancer, emphysema and other cardiopulmonary diseases. In 1989, the Office of Technology Assessment estimated that the value of the health benefits to be realized by meeting federal ozone standards could range from $1.3 billion to $9.5 billion annually (GAO, 1993).

Despite overwhelming evidence of the negative effects of motor vehicle emissions on air quality in urban areas, the automobile continues to increase its dominance over all other modes of transportation in this country. Each year, Americans own more cars and drive more miles than they did the previous year. From 1970 to 1987, the number of vehicles on the road increased by 70%, more than three times the rate of population growth during the same period. Since 1950, the number of vehicle miles travelled (VMT) has also been increasing three times faster than the rate of population growth (Netter and Wichersham, 1993).

The federal government has made efforts to curb the increasing air quality problem through legislation for over thirty years. For various reasons its efforts have been largely ineffective (*see* Mintz, 1994). Beginning in 1990, however, the federal government began taking new steps in addressing the traffic congestion/air quality problem. The 1990 Clean Air Act Amendments (The Act) place tough new requirements on metropolitan regions to reduce the negative air quality effects of automobile emissions. One approach available to metropolitan areas is the implementation of specific transportation control measures (TCM) designed to reduce automobile usage. In addition, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires states and regional governments to engage in comprehensive transportation planning that is linked to air quality goals, and further, bases funding of transportation projects on the implementation of TCMs. It is hoped that these new legislative enactments, taken together, will create a new, *effective* framework for transportation planning designed to reduce automobile usage.

This paper will look at the potential for success of this complex framework of regulation in reducing America's traffic congestion/air quality problem. Specifically, it will examine how the success of the new federal legislative framework, designed to reduce automobile emissions through a reduction in automobile *use*, depends greatly on the ability of local jurisdictions to affect a reduction in automobile *dependency*, through changes in long-established patterns of land development. It will also explain how the extensive collection of TCM strategies set forth in the Act is actually a collection of "second-best" policies that will only marginally affect the degree to which we rely on our automobiles. It is meant to be illustrative rather than definitive; it is not an extensive examination of transportation economics theory.

BACKGROUND: A BRIEF HISTORY OF THE CLEAN AIR ACT

In the fall of 1963, a killer "smog" enveloped New York City. It is estimated that from two hundred to four hundred people died when this smog, created by the reaction of nitrogen oxide and organic compounds to light and heat, was trapped at the earth's surface by a temperature inversion (Mintz, 1994). Shortly thereafter, President Johnson signed into law the Clean Air Act of 1963. This Act primarily focused on controlling pollutants from industrial sources, largely because it was believed at the time that truck and automobile emissions contributed only insignificantly to overall air pollution problems (Mintz, 1994).

In the years after 1963, however, it became increasingly evident that automobile emissions accounted for the majority of the pollutants found in the air over urban regions. Even as the Act worked to reduce industrial emissions, increasing numbers of metropolitan regions were falling out of compliance with the Act's National Ambient Air Quality Standards (NAAQS) (Freilich and White, 1991). Since the original Act of 1963, and prior to 1990, Congress made numerous revisions to the legislation, with each successive amendment directing more of the Act's focus on the control and limitation of mobile source pollution. In effect, it became clear that the nation's air pollution policy must also reflect its transportation policy.

Unfortunately, by 1990 it was obvious that the Act still remained fundamentally flawed. While Congress had finally focused the legislation on the major *source* of urban air pollution, *i.e.*, automobiles, its *methods* of controlling automobile emissions were still proving to be ineffective. Generally speaking, the air pollution generated by motor vehicles can be reduced in one of three ways: (1) lowering the level of pollutants emitted by individual vehicles, (2) reducing traffic congestion (thereby reducing the amount of time spent running at idle) by improving levels of service, or (3) lowering overall vehicle miles travelled (VMT) by reducing the number and length of vehicle trips (Netter and Wichersham, 1993). Until 1990, state and federal programs under the Act focused primarily on the first approach. Attempts were (and continue to be) made to advance technology in the areas of fuel efficiency and the use of "clean" fuels such as methane and electricity (DeLuchi, 1993). This purely technological approach, however, has not been sufficient to offset the increases in VMT experienced across the nation. Furthermore, the technology on the horizon within the foreseeable future most certainly will not be sufficiently "clean" to keep pace with the increases in VMT expected over the next twenty years (DeLuchi, 1993; Netter and Wichersham, 1993). Simply put, people are driving more cars, and driving them farther and more frequently than ever before. It has become clear that any legitimate effort to improve the air quality in the nation's urban areas must place an increased emphasis on reducing traffic congestion and VMT.

TRANSPORTATION CONTROL MEASURES UNDER THE CAAA

One mechanism employed by the 1990 Act to reduce traffic congestion and VMT is the implementation of TCMs. TCMs are measures that states can employ as part of their comprehensive efforts to reduce mobile source emissions. Section 108 of the Clean Air Act contains sixteen TCMs:

(i) programs for improved public transit;

(ii) restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high occupancy vehicles;

(iii) employer-based transportation management plans, including incentives;

(iv) trip reduction ordinances;

(v) traffic flow improvement programs that achieve emission reductions;

(vi) fringe and transportation corridor parking facilities serving multiple occupancy vehicle programs or transit service;

(vii) programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use;

(viii) programs for the provision of all forms of high-occupancy, shared-ride services;

(ix) programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicles or pedestrian use, both as to time and place;

(x) programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;

(xi) programs to control extended idling of vehicles [such as controls on drive-up windows and similar facilities];

(xii) programs to reduce extreme cold start emissions;

(xiii) employer-sponsored programs to permit flexible work schedules;

(xiv) programs and ordinances to facilitate non-automobile travel, provision and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel, as part of transportation planning and development efforts of a locality, including programs and ordinances applicable to new shopping centers, special events, and other centers of vehicle activity;

(xv) programs for new construction and major reconstruction of paths, tracks, or areas solely for the use by pedestrian or other non-motorized means of transportation when economically feasible and in the public interest.

(xvi) programs for voluntary removal of pre-1980 vehicles. [42 U.S.C.A. sect. 7408(f)(1)(A)]

As can be seen, only two of the sixteen listed TCMs (cold start emissions programs and removal of old vehicles) are focused on emissions technology. The remainder are directed primarily at reducing vehicle usage and reducing the emissions problems associated with traffic congestion.

The Act has called for the use of transportation controls since 1970. These sixteen specific TCMs have been a part of the Act since 1977. In order to understand the renewed importance of TCMs since the enactment of the 1990 Amendments, it is necessary to examine how they are weaved into the framework of the entire Act.

The Environmental Protection Agency (EPA) is the regulating body charged with the review and monitoring of the states' compliance with the provisions of the Act. The Act divides regions within states according to their compliance with NAAQ standards. These NAAQ standards are measured by the presence of six "criteria pollutants" in the atmosphere [42 U.S.C.A. sect 7408(a)(1)(a)]. Automobile emissions are the primary source of three of these criteria pollutants, lead, carbon monoxide (CO), and ozone (although ozone is not an "emission;" it is the result of the automobiles' emission of hydrocarbons that undergo chemical reactions in the atmosphere). Regions that meet the NAAQs are classified as "maintenance" or "prevention of significant deterioration" areas. If a region does not meet the NAAQs for one or more criteria pollutants, it is classified as a "nonattainment area" [42 U.S.C.A. sects. 7470-7515]. A further subclassification of nonattainment areas refers to ozone levels. Ozone nonattainment areas are classified as "marginal," "moderate," "serious," "severe," or "extreme" [42 U.S.C.A. sect. 7511a(a)(1)].

Under Title I of the Act, each state must create and periodically amend a State Implementation Plan (SIP) made up of "enforceable emissions limitations and other control measures" designed to achieve the federally-mandated NAAQs [42 U.S.C.A. sect. 7410(a)]. A state may select any mix of emissions and control measures, so long as it meets NAAQ standards [40 C.F.R. sect. 51.110]. The EPA may not reject a SIP simply because it would have chosen a different strategy of attainment [*Train v. Natural Resources Defense Council*, 421 US 60, 79 (1975)].

The 1990 Amendments have placed new emphasis on the use of TCMs in nonattainment areas. Specifically, in extreme or severe ozone nonattainment areas, the state's SIP must include one specific TCM that will:

> require that each employer of 100 or more persons in such areas increase average passenger occupancy per vehicle in commuting trips between home and the workplace during peak travel periods by not less than 25% above the average vehicle occupancy for all such trips in the area .... [42 U.S.C.A. sect. 7511a(d)(1)(B)].

In addition, these areas must adopt other TCMs to offset the increasing number of VMT in that area. In other nonattainment areas, the state must use "all reasonably available control measures" to achieve NAAQ standards by the statutory time limitations, which range from twenty years for extreme nonattainment areas to three years for marginal areas [42 U.S.C.A. sect. 7511a(a)(1)].

The biggest "sticks" in the 1990 Act are its enforcement mechanisms, the most powerful of which provide the federal government with the power to cut off federal highway funds if the state fails to comply with the mandated nonattainment area requirements [42 U.S.C.A. sect. 7509(b)(1)]. In addition, The EPA can sue directly to enforce a SIP if a state fails to act [42 U.S.C.A. sect. 7413]. The EPA may also require that substantial fees be assessed against stationary sources of volatile organic compounds (VOC) if states do not reach NAAQ standards through control of mobile source emissions [42 U.S.C.A. sect 7511(d)]. It is reasoned that these fees will act as a disincentive for industries to locate in nonattainment areas and, consequently, will create an incentive for states to reach attainment status.

ISTEA FUNDING AND TRANSPORTATION IMPROVEMENT PROGRAMS

If the Clean Air Act uses the "stick" approach to reduce automobile emissions, ISTEA provides the "carrots." Enacted in 1991, ISTEA represents a fundamental shift in federal transportation policy away from highways and automobiles to a multimodal-centered approach. According to ISTEA's policy statement, Congress set forth to:

> develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner [23 U.S.C.A. sect. 101].

ISTEA works to create an "environmentally sound" transportation system by making pollution control a central element in transportation planning efforts and infrastructure funding decisions.

Within each metropolitan area, the Metropolitan Planning Organization (MPO) formulates the transportation improvement plan (TIP), which identifies the programs and projects on which it will spend federal funds. In addition, ISTEA now requires states to do transportation planning, and to create long-range plans that combine the MPOs plans with the state's overall transportation plan (STIP) [23 U.S.C.A. sect. 135(e)]. It was the intent of Congress to force multiple jurisdictions to work together to create a consistent, systematic framework of transportation plans.

ISTEA now requires states and MPOs to "consider" ways to expand and develop transit and ways to increase ridership of such systems [23 U.S.C.A. sects. 134(f)(14), 135(c)(13)]. It also requires MPOs and states to create plans that will decrease traffic congestion, or prevent congestion from occurring in uncongested areas [23 U.S.C.A. sect. 134(f)(3), 135(c)(12)]. In Transportation Management Areas (TMAs) (areas with populations of 200,000 or more), MPOs are required to include "congestion management systems" in their transportation plans [23 U.S.C.A. sect. 134(i)(3)]. Presumably, these could include TCM strategies listed in the Act.

Perhaps the most obvious sign that a new era in transportation planning has arrived is the mandate in ISTEA that states and MPOs must now "consider" the consistency of long-term transportation plans with "all applicable short-term and long-term land use and development plans" that exist within their jurisdictions [23 U.S.C.A. sects. 135(c)(14), 134(f)(4)]. The inclusion of local officials in the planning agencies was apparently designed to help facilitate this process. Planning agencies must also consider the effect that their plans may have on land use and development patterns [23 U.S.C.A. sects. 134(f)(4), 135(c)(14)]. Federal regulations have expanded on this by requiring transportation planning agencies to examine economic, demographic, environmental protection, and land use activities [23 C.F.R. sect. 450.116(a)(4)].

The "carrots" that ISTEA provides are its funding provisions. Three percent of ISTEA funds are earmarked for planning efforts [23 U.S.C.A. sect. 104(f)(1)]. If an MPO in a TMA has not carried out its responsibility to develop congestion management strategies, the United States Department of Transportation (USDOT) has the right, or, in some cases, the obligation to cut off federal funding [23 U.S.C.A. sect 134(i)(5)]. ISTEA provides considerably greater funds than ever before for public transit, and states have more flexibility in spending funds on alternative transportation modes. ISTEA also creates a Congestion Mitigation and Air Quality Improvement Program (CMAQ) that provides funds exclusively for use in developing TCMs and on other programs designed to improve air quality [23 U.S.C.A. sect. 149].

THE CONVERGENCE OF ISTEA AND THE CLEAN AIR ACT

Individually, ISTEA and the Clean Air Act create several incentives to reduce automobile usage, thereby improving urban air quality. Provisions within each act, and many federal regulations that have since been promulgated by the Environmental Protection Agency, however, tie the Acts together in such a way as to make air quality a primary focus of all future transportation planning in the nation's cities. For example, no project or program may be included in a TIP for a nonattainment area if it conflicts with the air quality goals of an SIP, either by causing new violations of NAAQs, by worsening existing violations, or by delaying attainment of NAAQ goals [42 U.S.C.A. sect. 7506(c)(1)(A)]. Thus, transportation projects will be funded only if any emissions they cause are in "conformity" with the scheduled reduction of pollutants contained in the SIP [40 C.F.R. sect. 51.390]. Under the "conformity" requirement, MPOs must give priority funding to all TCMs contained in their TIPs [40 C.F.R. sect. 51.394]. An MPO must also use the same emissions projections in formulating its TIP that the state does in creating its SIP [42 U.S.C.A. sect. 7506(c)(2)(A)]. Further, the federal government will not fund any highway projects within a TMA classified as a nonattainment area that is likely to significantly increase single-occupancy vehicle traffic, unless it is part of a larger, overall congestion management program for a region [42 U.S.C.A. sect. 7506(c)(1)].

FEDERAL LEGISLATIVE EFFORTS: OUTLOOK FOR SUCCESS

Obviously, Congress has gone to great efforts to create the strongest air quality legislation packages seen to this point in history. With their carrot and stick system of incentives and disincentives, legislators hope to that local jurisdictions will develop transportation plans that heavily emphasize the TCMs outlined in the CAAA. The question remains, however, whether this complex framework of regulation, by itself, will reduce automobile usage to a degree that will significantly improve the air quality of our cities.

A recent study conducted by the General Accounting Office (GAO) provides an insight into what transportation planners expect from this legislative effort. In 1993, Congress requested that the GAO conduct a study to "(1) review evidence on the effectiveness of TCMs in reducing pollution, and (2) assess the prospects for implementing TCMs in areas that have not attained federal air quality standards for ozone and carbon monoxide" (GAO, 1993). To accomplish this, the GAO conducted an extensive survey of the 119 MPOs in ozone and carbon monoxide nonattainment areas to evaluate their plans for TCM implementation and their expectations for pollution emission reductions.

Fifty-six percent of the surveyed MPOs stated that TCMs would receive "strong" emphasis in their transportation programs over the next five years (1993-1998). Only 8% of the surveyed MPOs reported that TCMs had received strong emphasis in their planning programs over the previous five years (1987-1992). Of course, because of the legal mandates of the Act and ISTEA, all jurisdictions had incorporated at least some form of TCM into their transportation plans (GAO, 1993).

The survey also asked MPO officials to estimate the reduction in hydrocarbon and carbon monoxide emissions expected from TCM implementation in their regions. The results of the survey were less than optimistic. *Eighty-three percent* of the planners for ozone nonattainment MPOs expressing an opinion said that TCMs could be expected to reduce emissions by only *zero to three percent*. Ten percent expected emissions reductions of between four and ten percent. Only 6% expected reductions of over 10%. Citing a 1992 Federal Highway Administration (FHWA) report, the GAO stated that the FHWA expected that "typical TCMs would rarely yield more than a five percent reduction in emissions and in most cases would not yield more than a two percent reduction" (GAO, 1993).

Why, in light of such a massive federal legislative effort, are metropolitan transportation planners so pessimistic about the long-term impacts of this legislation on air quality? It is undoubtedly due to their recognition of the fact that this legislative effort does little to impact the two major forces driving transportation systems today: market pricing of transportation choices and land use decisions.

TCMs AS "SECOND BEST" PRICING POLICIES

It is significant to note that the respondents to the GAO survey made a clear distinction between the likely effectiveness of the traditional TCMs listed in the Clean Air act and "market-based" TCMs. Market-based TCMs were defined as those strategies that imposed direct financial disincentives on the use of automobiles. These included increases in the gasoline tax, highway congestion pricing programs, and carbon taxes or other types of emission fees. Sixty-four percent of the MPOs stated that such market-based measures would be far more effective in reducing emissions than the traditional TCMs. A study of the San Francisco Bay Area MPO's proposed implementation of gasoline taxes and congestion pricing found that such measures could be expected to yield an 8.4% decrease in hydrocarbon emissions and a 22.5% reduction in carbon monoxide emissions (GAO, 1993).

In emphasizing TCMs as a way to effect a reduction in automobile usage, policy makers are dealing with efficiency issues through policies that indirectly influence market pricing of transportation systems, rather than by directly regulating transportation system pricing. Economists refer to the types of policies reflected by the enactment of TCM strategies as "second-best" policies because, although they influence prices, none are substitutes for a system of efficient prices. The market-based TCMs (gasoline tax increases, carbon taxes and congestion pricing programs) are examples of direct pricing policies likely to have a major impact on automobile usage. Evidence to support this is the fact that the energy crises of 1973-1974 and 1979, and the resulting increases in gasoline prices, brought about reductions in VMT for the first (and only) time in history. Average miles driven per automobile fell from 10,046 in 1978 to 9,002 in 1981, then gradually recovered to 9,809 in 1984 (Heilbrun, 1987).

Historically, the increases in gasoline taxes and other direct pricing policies have not kept pace with the costs to government, and society, of automobile transportation. These costs include the planning, constructing, and maintaining roadways, not to mention a variety of other transportation-related services (e.g. police, fire, emergency medical services). These are all costs that are borne by taxpayers, not roadway users. A recent study estimated that the gasoline tax would need to be raised to approximately $1.80 per gallon to increase the the price of an average automobile trip to the cost it imposes on society (Moore, et. al., 1994)

Unfortunately, the advice of economists who argue that pricing is the most efficient way to control the effects of the market has had little impact on public policy. Because of the political upheaval that would result from attempts to propose such programs, policy-makers enact second-best programs, such as the TCM strategies outlined in the Act, and content themselves with marginal impacts. Over 80% of the MPOs surveyed by the GAO stated that implementation of pricing programs in their jurisdictions was highly unlikely (GAO, 1993). A system that simply prices automobile usage in a manner that more closely approximates the actual costs of that usage to society would go far in gaining control of the the traffic congestion/air quality problem.

TRANSPORTATION/LAND USE INTERACTION

A major traffic facility, whether it be an urban expressway or an additional transit line, exerts a tremendous influence on subsequent land development in the service area. But causality runs both ways. Generally, new transportation links are built in response to transportation demands created by private locational decisions. The relationship between land use policies and transportation policies is cyclical: a change cannot be affected in one without also changing the policies of the other. We cannot force a massive-scale reduction in automobile *usage* in this country unless and until we correspondingly reduce our society's absolute *dependency* on automobile transportation; a dependency created by our historical pattern of sprawling, low-density land use.

Many studies have been published on the the cyclical relationship between transportation facilities and land use patterns. A few generally agreed upon principles have developed from these studies that are useful for transportation and land use planners. One of these principles is that urban density directly affects transit ridership. For example, in a 1977 publication entitled *Public Transportation and Land Use Policy,* Pushkarev and Zupan examined the relationship between residential development and public rail transit. Their research led them to the following conclusions:

- At densities between one and seven dwelling units per acre, transit use is minimal;

- A density of seven dwellings per acre appears to be a threshold above which transit use increases sharply;

- At densities above sixty dwellings per acre, more than half the trips tend to be made by public transportation.

A study conducted in Australia by Newman and Kenworthy (1989) also found a direct correlation between high density and transit dependence.

This conclusion should not be surprising when considering the early development patterns of cities such as Chicago, Brooklyn and Philadelphia that initially had extensive trolley or fixed-rail lines. The original urban core development of these cities is dense and concentrated around what were then transit stations. This type of development encouraged transit ridership, and the site of transit stations promoted increased residential density. Needless to say, the pattern of suburban sprawl that has dominated the urban landscape for the past fifty years is not conducive to transit-oriented travel. The inertia of the existing pattern of land use is an important constraint on any plan for modifying current transportation habits. Once an extensive highway system has been built, the resulting decentralized, low-density land use pattern cannot be served economically by mass transit, since the latter requires concentrated origins and destinations to operate efficiently (Heilbrun, 1987). In the Portland, Oregon metropolitan area, planners are attempting to coordinate future land use development with transportation system planning by implementing land use strategies designed to locate high density, mixed use developments near transit lines that service the major regional commercial centers (Moore, et. al., 1994)

Unfortunately, the most significant inhibitor of transit use and automobile trip reduction, the sprawling, low-density residential suburb, is still the development pattern of choice in most growing urban regions. Nothing about this urban form is conducive to transit or pedestrian travel. As this urban form continues to sprawl out from our cities, our automobile dependency only increases.

The only explicit reference to land use controls in the Act states that none of the Act's provisions shall be construed as "an infringement on the existing authority of counties and cities to control land uses" [42 U.S.C.A. sect. 7431]. ISTEA does specifically mandate that transportation planners "consider" the short- and long-term land use plans of jurisdictions within the planning area when developing transportation plans [23 U.S.C.A. sect. 134(f)(4)]. No studies have been conducted, however, to determine how states and MPOs are "considering" these land use plans. Buchsbaum (1993) has suggested that this requirement, when tied to ISTEA's funding provisions, could have a significant effect on local land use planning. This assertion ignores the fact that there is still very little nexus between the transportation planning functions of MPOs and the zoning and subdivision regulatory functions of local jurisdictions. While it may affect planning patterns in corridor areas, the residential subdivisions, which are served by county and city street systems, will still not be built to a scale that favors transit or pedestrian mobility. If there is a trickle down effect, it will undoubtedly be minor.

CONCLUSION

Unfortunately, careful analysis suggests that the monumental effort that Congress made to attempt to improve the air quality in our urban areas will only have marginal effects on the nation's traffic congestion/air quality problem. In order to comprehensively attack the air quality problem policy-makers must be willing to make difficult choices, and the public must be willing to make personal sacrifices. A complete policy for dealing with the problem must include (1) a system of market pricing that makes the price of an automobile trip more reflective of its costs, and (2) a comprehensive approach to transportation planning that includes land use regulations as part of the overall equation.

REFERENCES

Buchsbaum P.A. (1993) Federal regulation of land use: Uncle Sam the permit man, *The Urban Lawyer,* Vol. **25**, 589-626.

23 C.F.R. sect. 450 et. seq.

40 C.F.R. sects. 51 & 52 et. seq.

Cervero R.C. (1991) Land use mixing and suburban mobility. *Transportation Quarterly,* Vol. **42**, 429-441.

The Clean Air Act Amendments of 1990, codified at 42 U.S.C. secs. 7401-7671.

DeLuchi M.A. (1993) Greenhouse-gas emissions from the use of new fuels for transportation and electricity. *Transportation Research,* Vol. **27A**, 187-191.

Freilich R.H. and White S.M. (1991) Transportation congestion and growth management: Comprehensive approaches to resolving America's major quality of life crisis, *Loyola of Los Angeles Law Review,* Vol. **24**, 915-950.

Giuliano G. and Hwang K. (1993) Employee trip reduction in Southern California: First year results. *Transportation Research,* Vol. **27A**, 125-137.

Heilbrun J. (1987) *Urban Economics and Public Policy,* Third Edition, 173-206.

The Intermodal Surface Transportation Efficiency Act (1991), codified at 23 U.S.C. sec. 101 et. seq.

Kelly E.D. (1994) The transportation land-use link. *Journal of Planning Literature,* Vol **9**, 128-145.

Mintz P. (1994) Transportation alternatives within the Clean Air Act: A history of Congressional failure to effectuate and recommendations for the future, *N.Y.U. Environmental Law Journal,* Vol. **3**, 156-194.

Moore T. and Maness J. (1994) The transportation/land use connection. *Planning Advisory Service Memo No. 448/449,* 47-66.

Netter E.M. and Wichersham J. (1993) Driving to extremes: Planning to minimize the air pollution impacts of cars and trucks, *Zoning and Planning Law Report,* Vol. **16**, 145-159.

Newman P. and Kenworthy J. (1989) Gasoline consumption and cities. *Journal of the American Planning Association*, Vol. **55**, 24-37.

Orski C.K. (1990) Can management of transportation demand help solve our growing traffic congestion and air pollution problems? *Transportation Quarterly*, Vol. **44**, 483-498.

Pushkarev B.M. and Zupan J.M. (1977) *Public Transportation and Land Use Policy*.

United States General Accounting Office (1993). *Urban Transportation: Reducing Vehicle Emissions with Transportation Control Measures*.

Watterson W.T. (1993) Linked simulation of land use and transportation systems: Developments and experience in the Puget Sound region, *Transportation Research*, Vol. **27A**, 193-206.