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16. Abstract

The primary purpose of this research was to assess the needs and logistics associated with the development of a multi-source, multi-use travel speed database. Data were, consequently, collected and/or analyzed for ultimate use in the TransGuide Advanced Transportation Management system (ATMS) area-wide database. The travel speed data used to populate the database fall into the categories of: 1) ATMS loop detector data; 2) Automatic Vehicle Identification (AVI) data; 3) Global Positioning System (GPS) data via travel time runs; and 4) theoretical data.

The theoretical data were the product of a statistical analysis of travel speed data and respective roadway geometric and operating characteristics associated with over 2,000 GPS-based travel time runs conducted on arterial roadways in the San Antonio urban area. A predictive algorithm was successfully developed using a tree-based regression methodology to formulate the theoretical data. These data generally apply to low-speed, low-volume arterials which experience limited recurrent congestion. Adjustment factors for incidents and varying operating conditions (e.g., rain vs. no rain, peak vs. off-peak operations, etc.) were also examined. It was, however, determined that these additional factors could not be adequately analyzed due to sample size limitations.

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ASSESSMENT OF TRAVEL CHARACTERISTICS REQUIRED FOR THE DEVELOPMENT OF AN IN-VEHICLE ADVANCED TRAVELER INFORMATION SYSTEM

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Sponsored by the
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IMPLEMENTATION RECOMMENDATIONS

The primary goal of this study was to examine data needs associated with the development of a multi-purpose database to be used for the Advanced Traveler Information System (ATIS) component of a traffic management center. The TransGuide System in San Antonio was used as the case study for development and analysis purposes.

The specific approach utilized in the TransGuide System development and analysis consisted of incorporating travel speed data from several sources into one common database. The sources of speed data specifically consisted of: 1) loop detectors from the TransGuide Advanced Traffic Management System (ATMS); 2) Automatic Vehicle Identification (AVI)-based voluntary vehicle probes; and 3) Global Positioning System (GPS)-equipped vehicle probes. The development of an integrated, multi-source and multi-use database was successfully accomplished. The specific procedures and results documented herein should be valuable to other urban areas around the state and nation which are in varying stages of planning and/or implementation of ATMSs.

Specific implementation recommendations are as follows:

1. For a multi-source and/or multi-interface system, a distributed system with a centralized repository (see Figure 2) is recommended; and

2. A theoretical database developed to supplement real-time data sources in an area is feasible. A significant amount of sample data will, however, be required to establish a statistically-reliable database. Urban areas that will lack significant amounts of real-time data for the foreseeable future should consider this approach. Application of this approach at the collector-distributor roadway level and below is **not** recommended.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation, nor is it meant for construction, bidding, or permit purposes. This report was prepared by Jennifer Ogle, Shawn Turner (Texas certification 82781), Joseph Baumgartner, and Russell Henk (Texas certification number 74460).

EXECUTIVE SUMMARY

Background

In October of 1996, San Antonio, Texas was selected as one of four metropolitan areas to participate in the Federal Highway Administration's Model Deployment Initiative (MDI) program. This selection was due in part to TransGuide--San Antonio's extensive Advanced Traffic Management System (ATMS), an Intelligent Transportation System (ITS) that has been in operation since July 1995.

At the time that San Antonio was selected as a model deployment city, the TransGuide ATMS collected travel speed information on approximately 42 center-line kilometers (26 center-line miles) of San Antonio freeways and was being expanded to cover 44 additional kilometers (27 miles) (Figure 1). Through the MDI program, TransGuide is adding an Automated Vehicle Identification (AVI) system and a database of historical travel speed data, which is based on measurements taken with Global Positioning System (GPS) receivers. These additions will expand the coverage to approximately 966 kilometers (600 center-line miles).

In addition to these new travel speed data collection systems, several Advanced Traveler Information Systems (ATIS) are being added as well. These include traveler information kiosks, in-vehicle navigation units, a real-time operations map, and an enhanced World Wide Web page and low-power television system.

In order to accommodate these additional data sources and computer systems in the TransGuide environment, the Texas Transportation Institute (TTI), in partnership with Southwest Research Institute, developed a comprehensive information system to collect, maintain, and distribute a variety of traffic and travel-related data. This effort resulted in the development of a data repository, the San Antonio Travel Speed Areawide Database, and a software application, the MDI DataServer, which provide a centralized information system for the collection and distribution of data within the TransGuide environment.

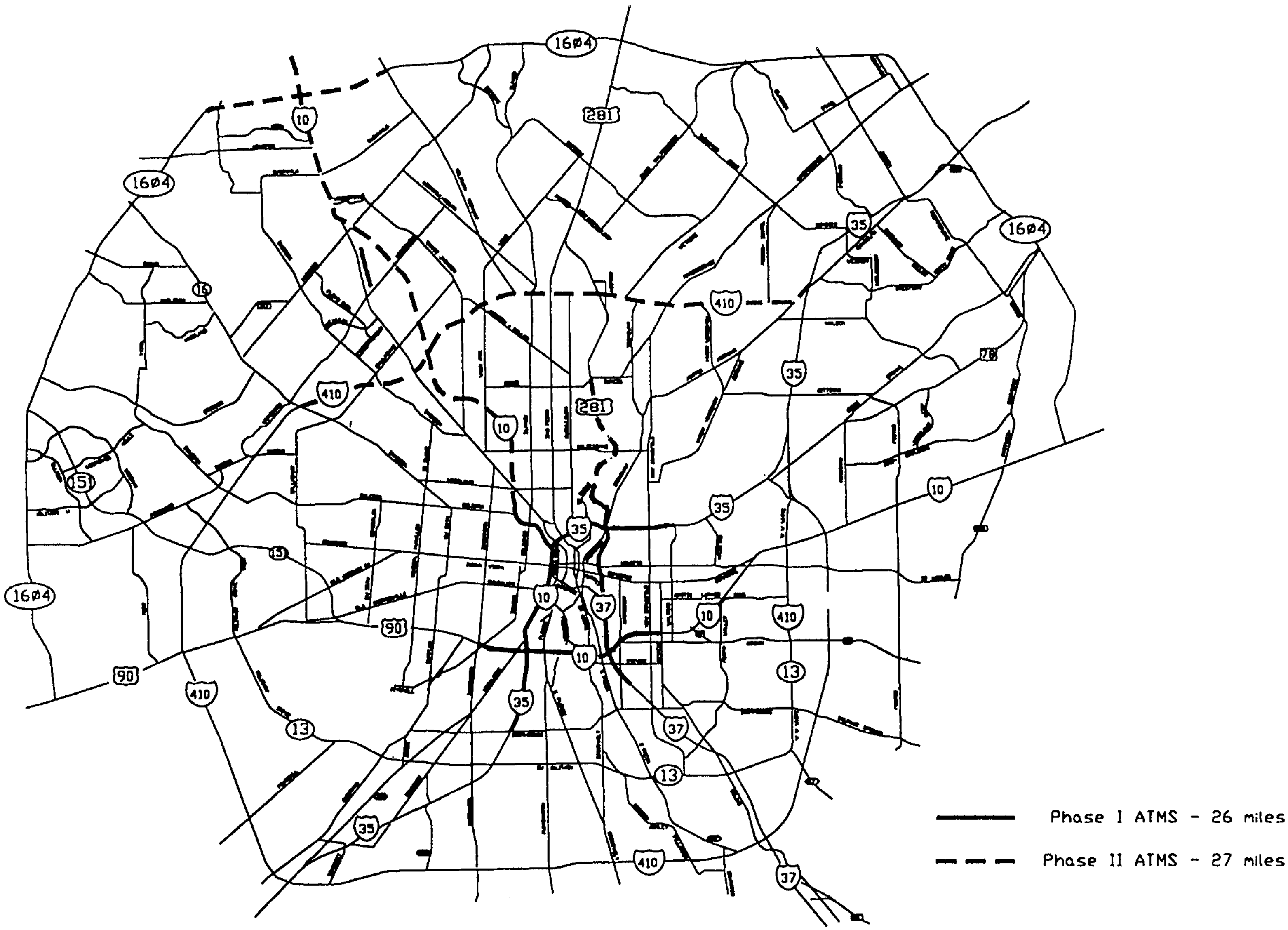

Figure 1. ATMS Coverage

The San Antonio Areawide Travel Speed Database is the central repository for the travel speed data within the data server. A large part of the effort in the development of the database revolved around the issues of collecting, maintaining, and distributing large quantities of rapidly changing travel speed data.

This Areawide Travel Speed Database was developed in order to optimize the effectiveness of the various ATIS systems. Unlike the majority of commercially available navigational databases which use static estimates of speed, the San Antonio Areawide Travel Speed Database contains up-to-the-minute speed information obtained from approximately 1600 loop detectors and 53 AVI receiver/transmitter stations located around San Antonio. This effort creates the foundation for the ATIS by allowing the utilization of real-time data to provide accurate route guidance, and more importantly, aiding the motoring public in selecting the most time-efficient route for their desired trip.

This report summarizes the alternatives that researchers considered in developing a system to collect and disseminate real-time and historical travel speed data from a variety of sources. Data descriptions, data storage requirements, and data transmission issues are also discussed, and the benefits of this approach are considered.

System Architecture

The design of the system architecture within the TransGuide environment was an important consideration for two reasons. First, through the MDI program, several new systems had to be integrated without disturbing the existing ATMS system. Second, with the rapid changes in ITS technology, provisions had to be made to accommodate the addition of new systems in the future.

The architecture chosen for the TransGuide information system, is a distributed system with a centralized data repository. This system is depicted in Figure 2. The centralized repository reduces the total number of interfaces by providing a single interface for each subsystem. Another benefit is that future subsystems can be added by making a modification to the central repository. Other subsystems do not have to be modified.

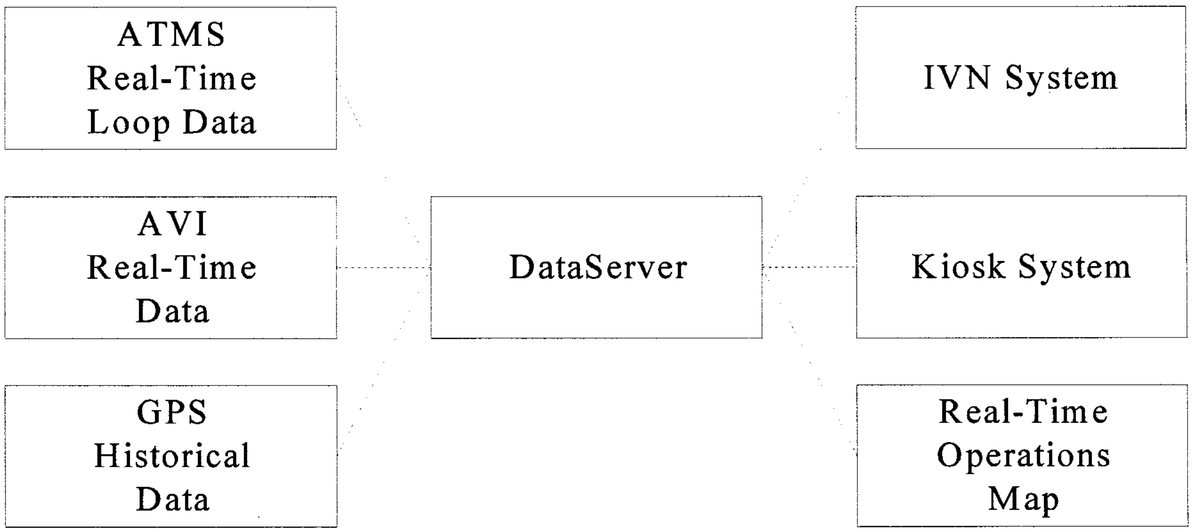

Figure 2. Distributed System with Centralized Repository

Data Server

The information system presented in this report follows the architecture depicted in Figure 3. The TransGuide Data Server, which is the central server, collects the information from the data generators, stores the data in the San Antonio Areawide Database, and supplies the data to data consumers.

The DataServer must interface with a variety of systems. These are depicted in Figure 3, which shows a graphical representation of the DataServer environment with the data generators and data consumers of the TransGuide system. The data generators include the TransGuide ATMS and the MDI AVI system which can be accessed to obtain real-time travel speed data, and the GPS and Theoretical travel speed database systems which generate travel speed data by time of day. Data generators that are not related to the areawide travel speed database are also shown and include: bus information, airport information, police reports, and the road closure database. The figure also shows several data consumers including the traveler information kiosk, in-vehicle navigation, and World Wide Web server (WWW), which all use travel speed data in different ways. These systems are discussed in more detail in the following sections.

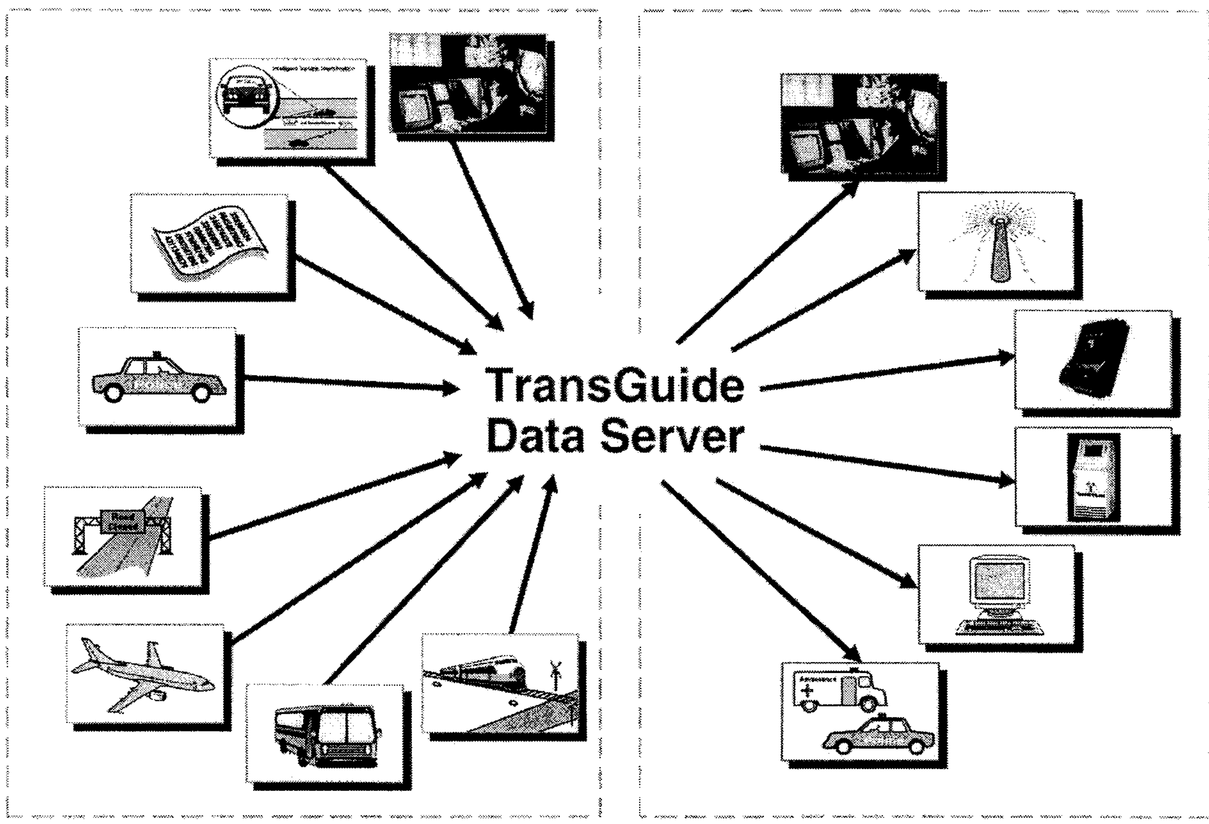

Figure 3. Data Generators and Data Consumers

Travel Speed Data Generators

Although the San Antonio Areawide Database must store a variety of travel-related data, one of the most important functions of the database is to store real-time travel speed data. These data come from a variety of sources including:

- TransGuide ATMS—real-time travel speed data collected from loop detectors;
- AVI System—real-time travel speed data collected by sensors that detect tagged vehicles acting as probes;
- GPS Data System—a historical database of travel speeds compiled by making travel time trips in differential GPS-equipped vehicles at scheduled intervals; and
- Theoretical Data System—a historical database extrapolated from the GPS data through a decision matrix based on common roadway characteristics.

Together, these data sources make up a network of over 969 kilometers (602 miles) of travel speed data. These data are continuously written to the San Antonio Travel Speed Database and distributed to the data consumers for use in ATIS applications. Each of these data sources possesses its own unique characteristics which were considered in developing the central repository. These characteristics are discussed in more detail in the following sections.

The differing sources of speed information required different segmentation methodologies and ultimately produced varying length vs. link ratios. The following table shows the data source type, and the number and length of directional links in the current TransGuide system.

Table 1. Coverage Type vs. Number of Links

Coverage Type	Length, kilometers(miles)	# of Directional Links
TransGuide ATMS (real-time)	96 (60)	240
AVI (real-time)	158 (98)	103
GPS (historical)	238 (148)	465
Theoretical (historical)	477 (296)	618
TOTAL	969 (602)	1,426

GPS Data Collection

One of the most time-consuming and costly portions of the project was the GPS travel-time data collection. The GPS system encompasses 480 directional kilometers (300 directional miles) of arterials and collector-distributorroadways, and is composed of over 30 routes of approximately 11 to 19 kilometers (7 to 12 miles) in length. Over 2,000 trip files have been recorded and included in a summarized travel speed database. In an effort to provide a macroscopic overview of the total database development, only a high level of detail will be given on the major points of the GPS data collection process in the main body of this report.

Eight differentially corrected geographic positioning system data collection units were purchased and assembled by the Texas TransportationInstitute. The units consisted of: a Trimble Navigation Placer 400 GPS receiver and antenna and a Differential Corrections Inc. RDS 3000 differential corrections receiver and antenna. Four Hewlett Packard HP1000CX palmtop computers with 2M of ram for data storage were purchased to provide field data logging capability while maintaining maximum portability. The other four units were wired to connect to external laptops in the field. The base units were placed in portable carrying cases, so the drivers could easily transport them between the office and the field.

The travel time trip files were stored on the palmtops for a period of several days, until they could be downloadedto a hard-driveand backup files. The average file for a 15 minute data collection trip uses only 15Kb of memory. The costs and time involved in GPS data collection are moderate, and it is important that no information be lost. In order to conserve computer storage space, the raw GPS data were checked for quality, and extraneous data (i.e., points collected outside the study areas) were removed from the files.

The GPS data conversion was simplified by the use of an existing Navtech GIS map and ArcView software. GPS data points representing the location of the vehicle were overlaid onto the base GIS map. The raw GPS files included the following information: latitude and longitude, time stamp, day of week, direction, heading, and speed. Information for GPS links were merged with the location and speed point data by associating each point with the nearest link. The GPS links had related attribute data for speed limit data, number of lanes, classification, roadway name, signal location, etc.

After the merging process was completed, the point data were associated with the appropriate GPS links. A travel time was calculated by determining the earliest time stamp associated with a particular link for a given trip and subtracting it from the latest time stamp associated with the link. This process produced well over 10,000 segment travel time records from the 2,000 plus trips that were made over the 32 corridors. A quality control check was done on the travel time record database, and approximately 5 percent of the records were cut due to questionable data characteristics (i.e., unattainable speeds, missing data points, etc.). The remaining records were averaged by link and by time of day to develop the typical travel speed database for the 32 routes.

Theoretical Data

The other type of travel speed data that resides in the area-wide Travel Speed Database and was a major focal point of this research is the theoretical data. This portion consists of theoretical values developed for arterial and collector streets using data collected for the GPS travel speed database. A hierarchal tree-based regression technique was used to determine an appropriate regression equation for predicting the travel speeds.

Coverage

Approximately 480 kilometers (300 miles) of the remaining major/minor arterials and collectors were placed in the theoretical data evaluation group (see Figure 4). These roadway sections typically consisted of lower volume, and lower speed roadways that were not characterized by recurrent congestion. Generally, the roadway selection process was organized to have the most accurate real-time information being collected on the most seriously congested roadways, and the historically-based information on the less congested roadways. Again, as the system matures and grows, the information will be replaced by more intelligent information sources in these latter coverage areas.

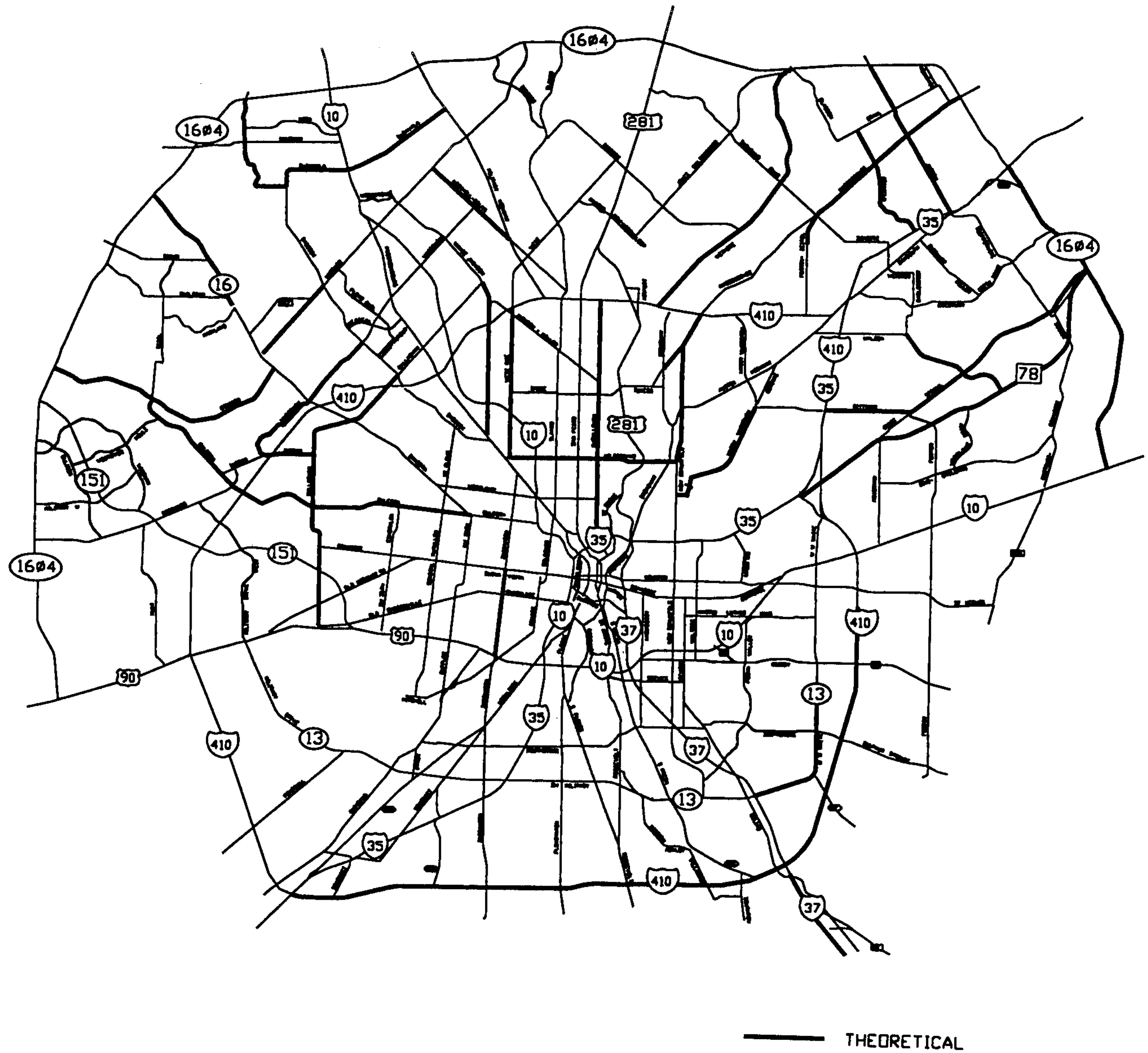

Figure 4. Theoretical Coverage

Link Segmentation Methodology

As with the GPS links, the theoretical links were primarily determined by the characteristics of the roadway sections. These characteristics included signal density, posted speed limit, volume per lane, and the location of major intersections. The links were defined to encompass sections with homogeneous characteristics and were typically in the range of 1 to 4 kilometers (0.5 to 2.5 miles) in length. Because this is the least robust of the speed data types, the segments need not be segmented to such detail. This also helped maintain a smaller amount of links to transmit via FM STIC. The theoretical links were also defined at the first discontinuity in roadway characteristic.

Theoretical Algorithm Development

From the 10,000 records contained in the aggregated GPS speed database, a statistical analysis was performed to develop a speed prediction algorithm. The analysis was based on the characteristics of each link segment that were collected from the field. The characteristics of concern were signal density, posted speed limit, and volume per lane roadway type (freeway vs. arterial). Separate analyses were performed for freeways vs. arterials since the key parameters for the two facility types are very different. The analyses was performed using an hierarchal tree-based regression (HTBR) software package called CART, (Salford Systems, San Diego, California, 1991-1995).

HTBR can be thought of as a forward stepwise variable selection method, akin to forward stepwise regression. The methods used to estimate regression trees have been around since the early 1960s and are sometimes referred to as classification and regression trees, or CARTs. The method proceeds by interactively asking (and answering) the following two questions: (a) which variable of all of the variables offered in the model should be selected to produce the maximum reduction in variability of the responses? and (b) which value of the selected variable (discrete or continuous) results in the maximum reduction in variability of the response? The method continually asks and answers these questions (through numerical search procedures) until a desirable end-condition is met, at which time the tree model is estimated. Tree terminology is similar to that of a real tree; here are branches, branch splits or internal nodes, and leaves or terminal nodes[1].

A sample of 3,000 arterial records were selected from the 10,000 record database variables included in this analysis:

- signal density (mean = 3.673, Std. Dev. = 2.574)
- speed limit (mean = 39.432, Std. Dev. = 4.302)
- lanevol (mean = 4830, Std. Dev. = 2170)
- school (mean = 1.119, Std. Dev. = 0.323)
- peak (mean = 1.883, Std. Dev. = 0.865)
- speed (mean = 32.485, Std. Dev. = 11.359)

The dependent variable was speed. The school and peak variables were factors from the GPS file. School = 1 meant school was in session (September 1st through May 31st, except for holidays), and school = 2 represented school holidays. Peak = 1 (AM peak - 07:00—09:00), Peak 2 (midday or off-peak - 09:00—16:00 minus lunch period), and Peak = 3 represented the PM peak period between 16:00—18:00 hours.

The output tree shown in Figure 5 was produced from running the CART software. To use the tree, start at the first level [speed limit < = 35]. If this is correct for the case that you are trying to predict, you will follow the branch to the left. If it is not correct, you will proceed to the right. True always goes left, and false always goes right. Each branch is conditional upon the earlier responses, so the tree decision points are determinates. The terminal nodes show the average speed in mph for each specific case. Once the tree has been produced, it is a matter of applying the step algorithm to the characteristics found for each link in the Theoretical Link List.

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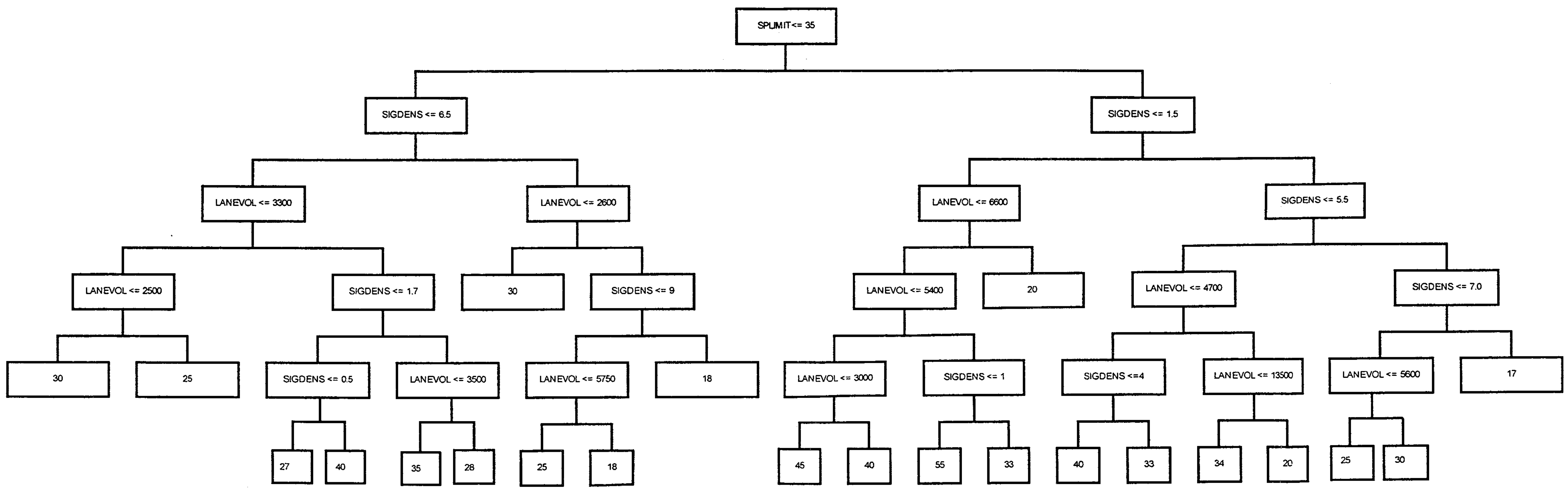
[1] Washington S., and Wolf, J. Hierarchal Tree-Based versus Ordinary Least Squares Linear Regression Models: Theory and Example Applied to Trip Generation, TRR 1581, TRB, National Research Council, 1997.



Figures 5. Arterial Speed Algorithm Tree

Further investigation of the tree structure shows no sign of the variables peak and school in any of the decision blocks. CART determined that these variables carried little to no statistical importance in the analysis. The relative importance of each variable is as follows:

Variable	Relative Importance
Signal Density	100.000
Volume Per Lane	65.566
Speed Limit	34.059
School	0.543
Peak	0.285

A validation was performed on the full GPS Speed Database to determine if the sample was representative of the full dataset. Figure 6 shows three numbers in each terminal node. The first number is the average speed that was produced from the CART model. The second number gives the number of records for the specific set of criteria in the full database; the last number is the average of speeds for the records in this case. In general, the CART model sample was quite representative of the full dataset. Differences in average speed data were typically less than 2 to 3 kph (1 to 2 mph).

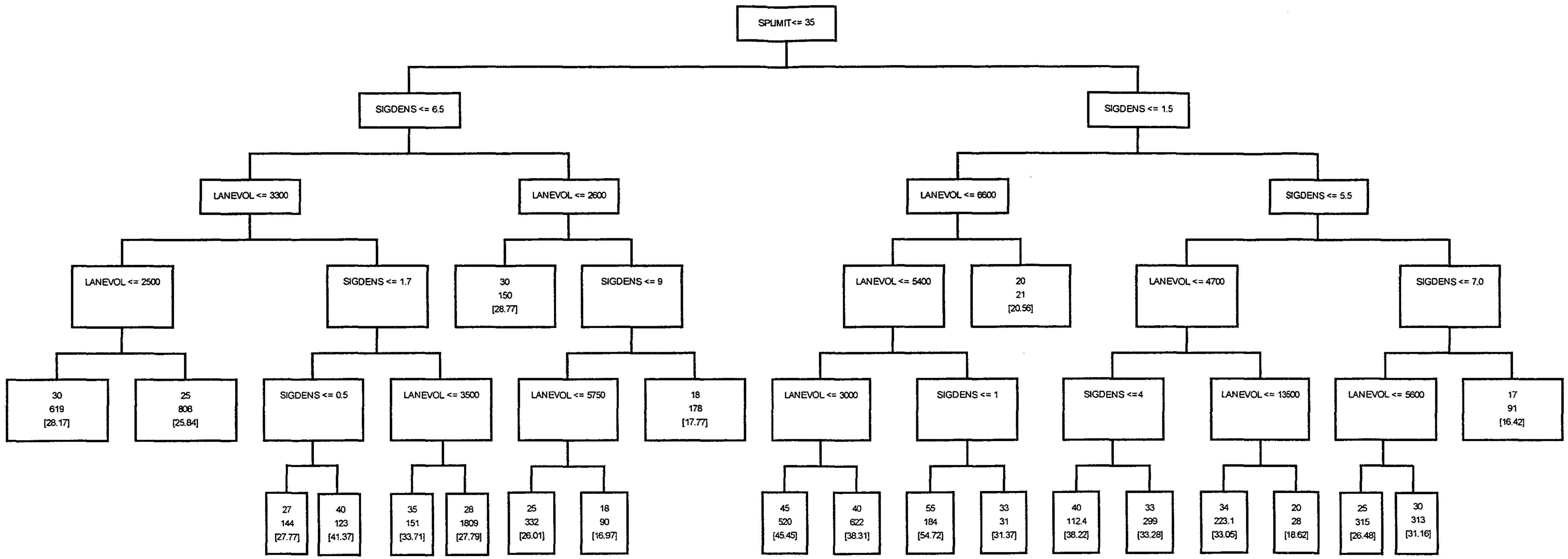
A sample of 693 freeway travel speed records were analyzed to develop a freeway tree as well—variables included:

- speed limit (mean = 57.208, std.dev. = 5.318)
- lane volume (mean = 6, 078.716, std.dev. = 1,707.724)
- peak (mean = 2.036, std.dev. = 0.862)
- school (mean = 1.189, std.dev. = 0.392)
- speed (mean = 47.841, std.dev. = 13.798)

The dependent variable was again speed.

The results of the (CART) analysis are shown in the output tree illustrated in Figure 7. This analysis showed that the variables of speed limit, volume per lane, and peak were the most important.

Variable	Relative Importance
Speed Limt	100.000
Volume Per Lane	85.729
Peak	5.165



Figures 6. Arterial Speed Algorithm Tree Validation

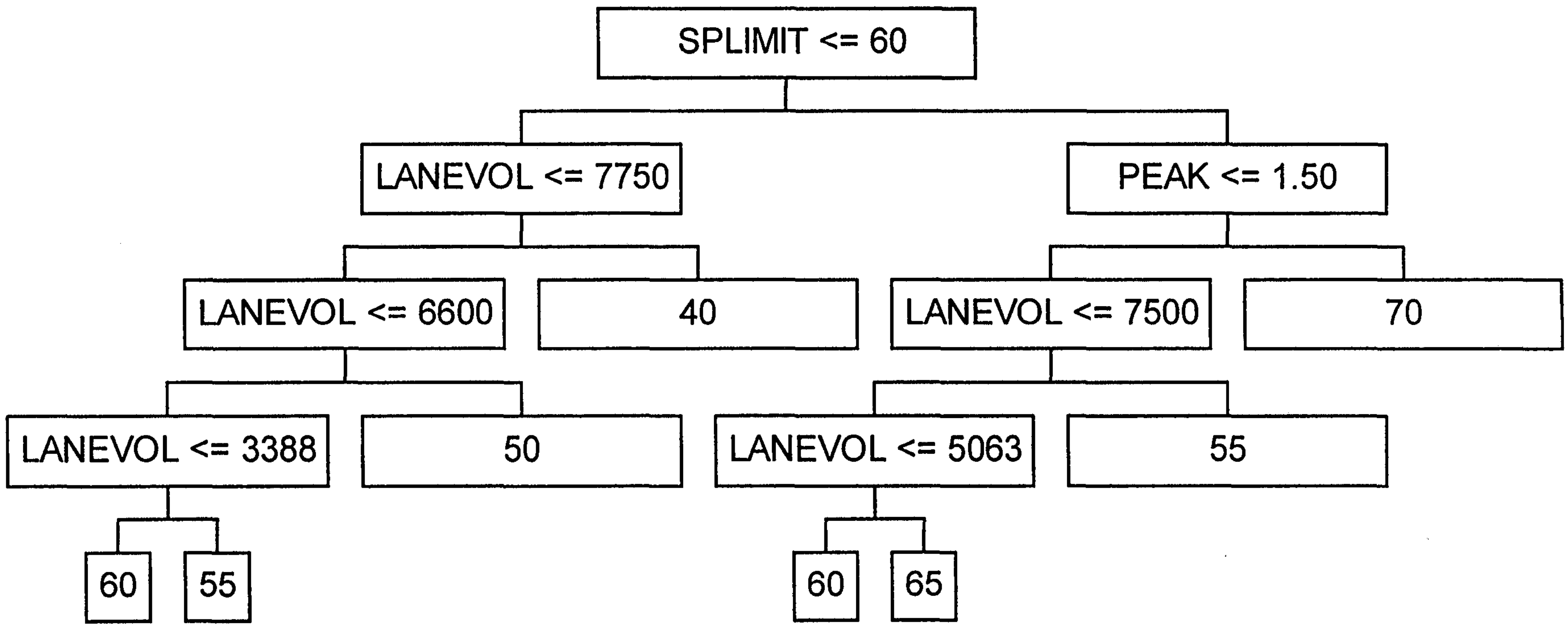


Figure 7. Freeway Speed Algorithm Tree

Incident/Delay Factors

Weather

Specific research activities were directed at assessing the effects of rainfall intensity on average travel speeds in San Antonio. Regional hourly rainfall intensity data were correlated with average spot speeds (from ATMS Phase I loop detector data) on select freeways near downtown San Antonio.

The motivation for exploring the effects of rainfall on average travel speeds was based on the need to provide accurate en-route driver information to selected motorists using route navigation devices (as part of San Antonio's Model Deployment Initiative). Based upon anecdotal data, system designers hypothesized that rainfall and several other events may increase route travel times beyond those expected for typical roadway and weather conditions.

Study Design As mentioned previously, the research team assembled two basic data elements for this study: rainfall intensity and average freeway travel speeds. Average freeway travel speed data were readily available for 42 km (26 mi) of freeway near downtown San Antonio. The average travel speed data are collected every 20 seconds from inductance loop detectors placed at nominal spacings of 0.8 km (0.5 mi). These loop detectors are monitored and report data through the TransGuide transportation management center, which is where the data were obtained. Because of the large volume of readily-accessible speed data near downtown, the researchers attempted to get rainfall intensity data at comparable locations near downtown with little success. Most of the rainfall data available had been reported on a daily basis, which would not have been sufficient detail to perform the required analyses. Hourly rainfall intensity data were obtained for a weather monitoring station (SAT WBAN # 12921) at the San Antonio Airport, approximately 13 km (8 mi) north of downtown where the travel speeds were collected. The rainfall data were obtained through the Office of the Texas State Climatologist, which is actually located in Texas A&M University's Department of Meteorology.

The research team obtained hourly rainfall intensity from August 1996 through September 1997. Because of its voluminous size, select days of average travel speed data were aggregated from 20-second averages to hourly averages. The following 55 days in 1997 were selected based on the occurrence of rainfall within some hour during the day:

- January 1, 2, 6, 7, 12, 20, 21, 28
- February 12, 14, 19, 25
- March 2, 10, 11, 12, 15, 17, 18
- May 21, 22, 23, 24, 27, 31
- June 1, 14, 15, 21, 22, 23, 25
- July 5, 7, 11, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 28, 31
- August 5, 6, 19
- September 1, 7, 21

The hourly average travel speed data were obtained for 195 inductance loop detectors (one of two computer servers in the TransGuide system) for the 55 days, resulting in nearly 75,000 average travel speed observations. Data pertaining to rain conditions on arterials were also extracted from the data collected via the GPS units. As can be noted in reviewing these data, the results are fairly inconclusive with no consistent impact of rain on arterial travel speeds being apparent.

Data Analysis and Findings The research team examined linear regression models to predict relationships between rainfall intensity and average hourly freeway travel speeds. Because average travel speed and rainfall intensity were available for each hour of the 55 days, time-of-day was also included in the analysis. The researchers hypothesized that rainfall intensity affects average travel speeds more strongly during peak traffic hours than during off-peak traffic hours with light traffic flows.

After several iterations and analyses involving different time periods, three statistically significant models were developed for different time periods during the day:

- Morning Peak Hour (7 to 8 a.m.): 3,082 observations average hourly travel speed, kph (mph) = 58 - 93 x (hourly rainfall intensity, cm [in.])
- Evening Peak Hour (5 to 6 p.m.): 3,137 observations average hourly travel speed, kph (mph) = 58 - 41 x (hourly rainfall intensity, cm [in.])
- Off-Peak Period (6 p.m. to 7 a.m., 8 a.m. to 5 p.m.): 68,534 observations average hourly travel speed, kph (mph) = 58 - 12 x (hourly rainfall intensity, cm [in.])

The evening peak hour and off-peak period models produced intuitively reasonable results, whereas the morning peak hour model appears drastically different. It should be noted that for both morning and evening peak hour models, there were not a large number of high intensity rainfall events. For example, the rainfall intensity did not exceed 0.2 centimeters (0.08 inches) per hour for either peak hour model, whereas the off-peak model had a significant number of rainfall events over 0.25 centimeters (0.1 inches) per hour, ranging as high as 1.8 centimeters (0.7 inches) per hour. The morning and evening peak hour models also had less than five hours each where the rainfall intensity exceeded 0.8 centimeters (0.03 inches) per hour. This result stems from the fact that it simply did not rain frequently or severely during the morning or evening peak hour during the time period in 1997 that was analyzed.

In summary, researchers developed three statistically significant regression models for predicting reductions in average hourly freeway travel speeds based upon rainfall intensity. The morning peak hour model estimates exaggerated reductions in average travel speed because of a limited number of rainfall events used to develop the model.

These regression models were developed based upon average freeway travel speeds. The actual models, therefore, apply to reductions in average travel speeds along freeways. There were, however, no possible direct comparisons which could be made between rain intensity and travel speeds for the same physical location on the freeway.

In addition, the application of these regression models to predict average travel speeds in real-time is potentially muted by the ability to obtain real-time rainfall intensity data over different geographic areas of San Antonio. As a result, it is recommended that these regression models not be incorporated into the travel time prediction and route navigation database.

Three alternatives have been identified for the possible inclusion of rainfall intensity reduction models in real-time speed prediction algorithms in the future:

- Have the National Weather Service, which provides information for the kiosks, send files indicating which quadrants of the city are experiencing rain. Rain delay factors could then be applied to all of the links in this quadrant.

- Overlay a grid onto the weather radar sent to TransGuide by the weather service. Write a software program that will go through the radar graphics file and determine which grid squares are mostly covered by colors indicating rain. Grid squares with 50+ percent (actual percentage unknown) coverage would have the rain delay factors applied.

- Query the AVI travel speeds from different quadrants of the city, and compare them to a historical AVI database. If the travel speeds throughout the quadrant are low compared with the average for that day and time, it could be due to a weather condition that is covering the entire quadrant. Weather data (specifically rain intensity) could be cross-referenced for these dates and/or time periods and be analyzed. This alternative relies on the availability of a historical AVI database.

INCIDENTS/ACCIDENTS

An additional adjustment factor which was considered in this analysis was one to account for incidents and/or accidents. The concept considered was to apply an incident adjustment factor to the "typical recurrent" travel speeds within the database which represented travel conditions on any part of the roadway network not instrumented with ATMS or AVI technologies.

Freeways The approach considered for assessing this potential application consisted of cross-referencing data obtained from the loop detectors of the ATMS (Phase I) and incident logs (as well as accident data from police reports), as these were the only thorough data available. Several fundamentals flaws, however, exist with this approach given potential needs and applications of such adjustment factors.

Assuming appropriate adjustment factors could satisfactorily be developed, the only portions of the freeway system to which they could be applied would be limited sections of Loop 410 South (as this is the only freeway for which no real-time data are available in some form or fashion). In addition, the only thorough data upon which to (currently) base the development of an adjustment factor is that associated with the freeway ring circling the central business district (CBD) of San Antonio. This portion of the freeway system is characterized by an inordinate amount of weaving and interchanging traffic operations as well as lower normal speeds. These operating characteristics would influence the impact incidents would have on traffic operations in relation to the remainder (and much larger portion) of the San Antonio freeway system. In short, this approach would lead to drawing conclusions from a very small portion of the freeway system with unique traffic operating characteristics and applying these conclusion to the majority of the system (which would be expected to operate in a significantly different fashion). It was, therefore, determined that at this point in time, it would be unwise to develop real-time incident adjustment factors given the limitations and characteristics of the available data from which such factors could be developed.

Arterials It was initially anticipated that arterial incident adjustment factors might be developed by review and analysis of the data (2,000$^+$ travel time runs) collected via the GPS units. Upon review of these data (and field loop kept by data collectors), only two incidents that were not associated with inclimate weather conditions were found. Based on this very small sample of "incident" data for arterials, it was impossible to draw statistically significant conclusions and develop an arterial incident adjustment factor. As it relates to the future development of incident adjustment factors for both freeways and arterials in San Antonio, recent and near-term future changes in readily-available data will soon make this a realistic endeavor. The expansion of the TransGuide System—specifically the implementation of Phase II which is scheduled for the Fall of 1998—as well as the growing amounts of data available via the ABI system should provide adequate data by early 1999 to develop relatively accurate and reliable incident adjustment factors.

School/Non-School As discussed in more detail previously, there was no statistically significant difference found between arterial travel speeds when school was in session as compared to when school was not in session. While a small difference can be noted in visually reviewing the data, this difference was not significant relative to the entire arterial travel speed data set which was assembled for this study. As noted for the incident adjustment factor, AVI data available for strategic arterials in San Antonio may soon be of adequate size to perform a more thorough assessment.

Peak/Off-Peak Similar to the assessment of the impact of school on arterial street operations, no statistically significant difference was found between peak period versus off-peak travel speeds on arterials. As is the case for all of the potential adjustment factors, the peak versus off-peak analysis would benefit greatly from the significant increase in available data which will take place over the next several months.

Travel Speed Data Consumers

The data consumers of the TransGuide environment that use travel speed data are the Traveler Information kiosk system, the IVN system, and the TransGuide World Wide Web (WWW) server.

In-Vehicle Navigation System

The IVN system was installed as part of the TransGuide MDI program and involves 590 navigation units that provide real-time travel speed data and route guidance to drivers in their vehicles. Data are broadcast to the navigation units every 30 seconds using the FM Subcarrier technology which was previously described in detail.

Travel Information Kiosk System

The Traveler Information kiosk system was installed as part of the TransGuide MDI program and includes 40 kiosks placed in key locations around the city of San Antonio. The kiosks provide real-time travel speed data on a graphical touch-screen map, as well as route planning, bus route information, and weather information. Data are broadcast using the same FM Subcarrier technology that is used for the IVN system.

TransGuide WWW

The TransGuide WWW server provides real-time traffic information to WWW users via a graphical map. Detailed information about each link is also available. The WWW server receives this data directly from the Data Server.

Other Potential Users

Many uses for the real-time database have been discussed by both transportation operations and planning groups. The planning group is extremely excited at the prospect of having such a comprehensive travel time database on hand. Planners will be able to access the original historical database for microscopic travel time data analysis or use a macroscopic version that has been aggregated for network analysis.

The operations group has already planned to archive all of the AVI data coming in to the Areawide Travel Time Database for use in the development of an extended historical database based on time of day analysis. This same information is also of interest to the planning groups for purposes of research and project programming decision-making/prioritization, specifically to see if this type of data can be used in origin-destination studies.

Conclusion

We have presented the considerations that were taken into account in the development of a travel speed database for the city of San Antonio. Our approach was to make the best use of available resources by targeting the placement of sensors and the definition of roadway links to the areas where they could provide the most benefit. While considerable effort went into the initial design and development of the system, the underlying data structures and concepts can be used as a foundation to easily expand the existing travel speed systems, or add new features in the future.

Additional research and developmental work is suggested to improve the statistical validity and enhanced application of the database and the "theoretical data" in particular. New components of the TransGuide System are now beginning to provide a wealth of valuable data which could be used for this enhancement.