Modeling Washington State Truck Freight Flows Using GIS-T: Data Collection and Design

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As part of their planning process, state departments of transportation and metropolitan planning organizations are required to include detailed information on freight and goods movements. However, obtaining comprehensive information on freight truck movements is often difficult. The Washington State Department of Transportation initiated a statewide freight truck origin and destination study in April 1993, completed in March 1994, to meet this challenge. An overview of the research procedures used to conduct the study is presented. Specific emphasis is given to arranging the data to complement the role of GIS-T, which is used as a tool for organizing, analyzing, and presenting information for use by transportation planners, program administrators, and policy makers. A case study of southbound trucks on SR-395 from Canada to Spokane, Washington, illustrates how GIS-T can be used to document and analyze the characteristics of freight truck movements.

The efficient intermodal movement of freight and goods, a primary responsibility of state departments of transportation, metropolitan planning organizations (MPOs), and many local governments, has received increased emphasis because of the federal Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). ISTEA requires states and MPOs to include a specific focus on freight and goods mobility as one element of their updated plans.

Planning for the efficient movement of freight and goods by trucks is hindered by a lack of information concerning the source and characteristics of freight movements on state and regional highways. Freight movement by rail and water can be tracked adequately through Interstate Commerce Commission waybill samples, the U.S. Army Corps of Engineers Waterborne Commerce data, and other published sources. However, comprehensive information on truck freight movements is much more difficult to obtain because of the large number of carriers and the numerous potential origins and destinations.

To address this information gap, the Washington State Department of Transportation (WSDOT) initiated a statewide freight truck origin and destination study in April 1993. A regionwide freight truck origin and destination study was first proposed in Washington as an element of the Eastern Washington Intermodal Transportation Study (EWITS). EWITS is a 6 year ISTEA planning study to define the multimodal network necessary for the efficient movement of freight and people throughout the section of Washington located on the east side of the Cascade Mountains. Supplemental funding provided by WSDOT enabled the EWITS freight truck origin and destination study to be expanded to include the entire state. Washington State University and the Gillis Group, a private consulting firm, were asked to conduct the study.

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The freight origin and destination study will help the state of Washington comply with ISTEA planning requirements, and it will contribute to the Washington State Transportation Policy Plan and Statewide Transportation System Plan. MPOs and regional transportation planning organizations will use information from the study to evaluate freight and goods mobility needs for their updated plans. Examples of specific contributions that will result from the study include:

- Documented information on freight movements that will target limited resources and pave the way for infrastructure improvements important to Washington's economy.
- A better understanding of the industries most reliant on Washington's highways. This information will be important for predicting future infrastructure demands associated with growing and declining industries.
- Improved pavement management systems arising from more accurate information on the specific routes used by freight carriers and the weights of commodities hauled over those routes.
- Essential routes serving deep-water ports, international airports, and Canadian shippers that will enhance Washington's international competitiveness.
- Improved efficiency of Washington's intermodal infrastructure systems resulting from the delineation of essential highways linked to Washington's rail, air, and barge intermodal centers.
- Information to better define needs on Washington's national highway system.

A discussion of the research procedures used to conduct the Washington State Freight Truck Origin and Destination Study is presented, with specific emphasis given to designing the data to complement the role of GIS-T. GIS-T is a data base that organizes, analyzes, and presents information for use by transportation planners, program administrators, and policy makers.

FIELD DATA COLLECTION PROCESS

An extensive process of collecting information directly from the drivers of freight trucks is a unique feature of the Washington State Freight Truck Origin and Destination Study. Truck drivers are interviewed at 30 locations throughout Washington, including 21 Wash-

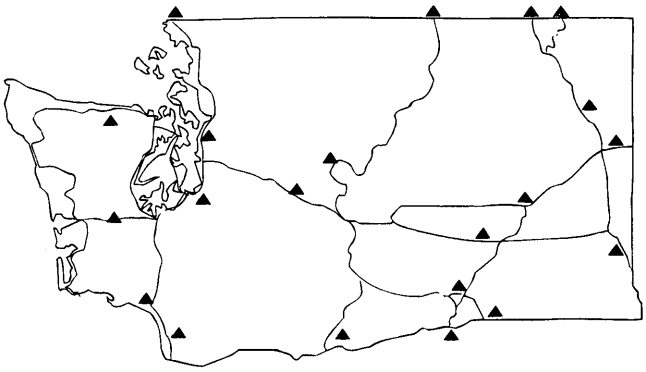


FIGURE 1 Truck interview locations.

ington State Patrol weigh stations, three Canadian border locations, and the Oregon Port of Entry at Umatilla (see Figure 1). The interviews are carried out four times over a 1-year period to reflect seasonal differences in freight movements. The summer, fall, and winter interview rounds are already complete. Interviews at most locations are conducted over a continuous 24-hr period to provide a complete 1-day freight truck movement profile for each season. To obtain median traffic patterns, truck driver interviews are conducted on Wednesdays instead of on Mondays or Fridays, when traffic flows are exceptionally heavy.

Cooperation from the Washington State Patrol Commercial Vehicle Enforcement Office and customs offices from both the United States and Canada is essential to the success of this research effort. Officers at designated locations along the highway flag down trucks and conduct routine enforcement activities. After they are stopped, truck drivers are asked to participate in a brief 2-min interview. Each driver is asked to provide information about the trucking company, vehicle weight, type of commodity carried, and the origin and destination of the vehicle.

To obtain an accurate seasonal profile of truck movements throughout the Washington, it is necessary to conduct interviews simultaneously at more than six sites across the state. Because at least 15 people are needed to cover a 24-hr interview session at each of the sites, a very large, short-term labor force was required to successfully complete the freight truck origin and destination study. To obtain the necessary manpower, members of community service clubs from across the state were hired and trained to conduct the interviews. The constant refinement of interview personnel management systems has helped improve the accuracy and effectiveness of data collection efforts. Overall, the service clubs have provided quality data in a highly professional manner.

Cooperation and participation by truck drivers also has been excellent. Statewide, more than 96 percent of the truck drivers who were asked to participate agreed. A statistical sampling procedure is used to ensure accurate representation of statewide truck freight flows. Approximately 7,000 truck drivers are interviewed during each survey round, providing a data base of approximately 30,000 interviews for the year-long study.

DATA MANAGEMENT, ANALYSIS, AND MODELING PROCEDURES

The framework for data management, analysis, and modeling of Washington state freight truck movements is depicted in Figure 2. Key data management, analysis, and modeling procedures for the study are discussed in this section.

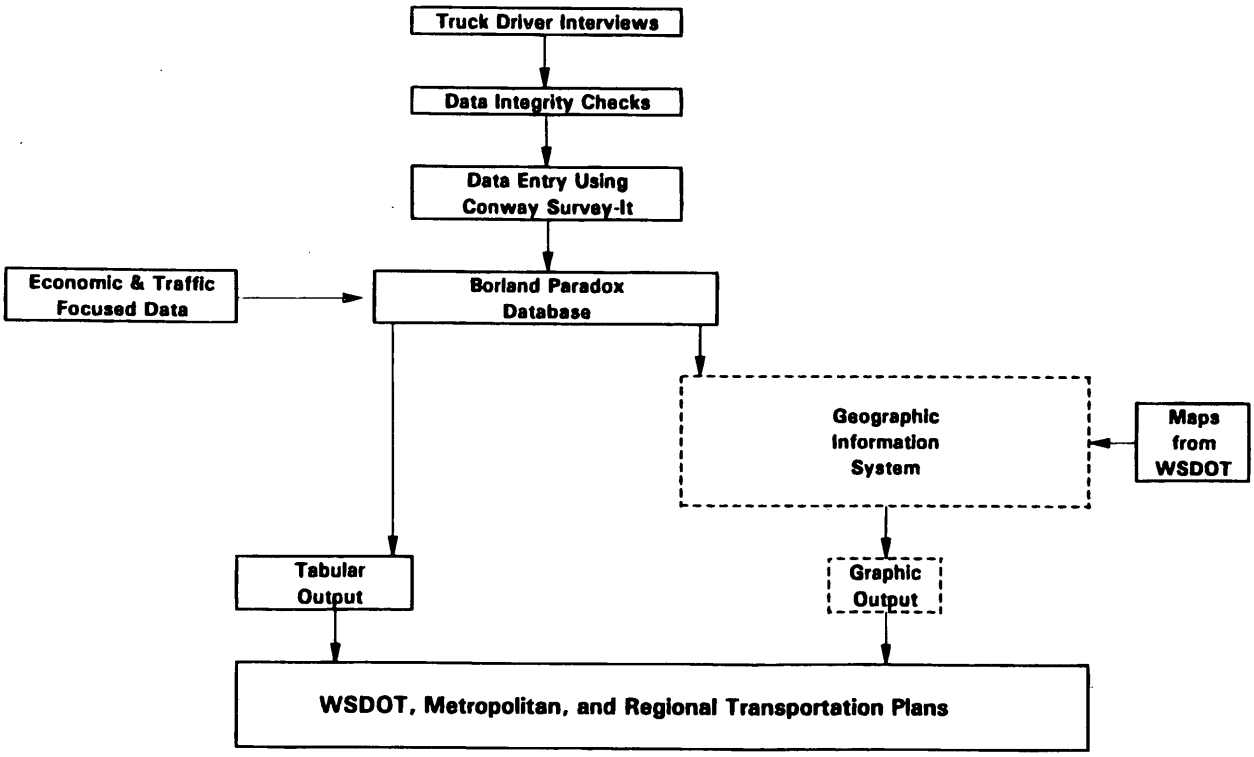


FIGURE 2 Framework for data management, analysis, and modeling.

Data Management

To accurately represent statewide and regional freight truck movements, data base management procedures must be carefully designed and implemented. Effective data management systems help reduce errors made during field data collection and data entry.

At least three potential sources of error are associated with field interviews of truck drivers. They include

1. Systematic problems caused by inappropriately worded questions, interview procedures, and site selection,
2. Inaccurate responses to questions, and
3. Interviewers who may incorrectly record vehicle data or drivers' responses.

Potential systematic errors caused by flaws in the survey methodology were minimized through constant evaluation of and adjustments to the interview questionnaire and site survey procedures. Improving the clarity of interview questions helped reduce errors related to inaccurate responses from drivers. A program of training and supervision for the community service club teams helped reduce the number of incorrectly recorded responses. Despite these safeguards, field data collection errors cannot be eliminated completely.

A data integrity review for each completed questionnaire was implemented before entering the information into the data base. Each questionnaire was reviewed to ensure that the answers were logically presented and consistent. Among the most frequent errors were questionnaires in which the total combined payload and empty vehicle weight given was well above the legal limit for a particular axle configuration. In these cases, the driver was usually providing the interviewer with the gross weight instead of the requested cargo weight. Another common error was the reporting of a truck carrying cargo when it was actually empty. The data integrity review process included the development of specific decision rules to revise incorrect data using other information on the questionnaire. For example, truck drivers who reported a combined cargo and empty vehicle weight in excess 110 percent of the legal limit were assumed to have provided gross weights. Revised payload weights were estimated as gross weight minus the reported empty vehicle weight. Empty vehicle weights were generally reported accurately.

Using these techniques, data recorded incorrectly on the field interview questionnaires were identified and corrected before data entry. The research team used the Conway Survey-It software package for data entry. Survey-It provides a user-friendly, menu-driven data entry screen, but only limited data base capabilities. Data entered into Survey-It were then exported into Borland Paradox. Paradox is used as the primary data base software for the project. Additional data integrity checks were implemented using the cross-tab, edit, and search functions of Paradox.

Data Analysis and Modeling

Data collected through statewide interviews with freight truck drivers provides valuable information for a variety of transportation planning applications. A number of specific examples of potential applications are listed in Figure 3.

Corridor Planning

- Identify highway corridors most critical to key industries
- Pinpoint major freight truck generators for specific corridors
- Document routes most widely utilized for national and international trade
- Provide base data to project freight truck traffic growth and decline for specific corridors
- Provide base data to estimate the economic value of specific commodities shipped on specific corridors

Intermodal Systems Planning

- Delineate essential highways linked to rail, air, deep water and river ports
- Evaluate intermodal systems most critical to key industries and international competitiveness
- Geographic proximity of intermodal facilities relative to origins and destinations of trucks utilizing those facilities
- Provide base data to project changes in highway usage that would result from rail-line abandonment or closing of key river ports

Pavement Management

- Document highway segments with the highest average freight cargo volumes and weights
- Provide base data to project future changes in freight cargo volumes and weights on specific highway segments

Congestion Management and Safety

- Document origins, destinations and routes used by freight trucks traveling through congested urban areas
- Provide base data to evaluate opportunities to reduce freight truck traffic through urban areas during peak commute periods

FIGURE 3 Potential applications for freight truck origin and destination data.

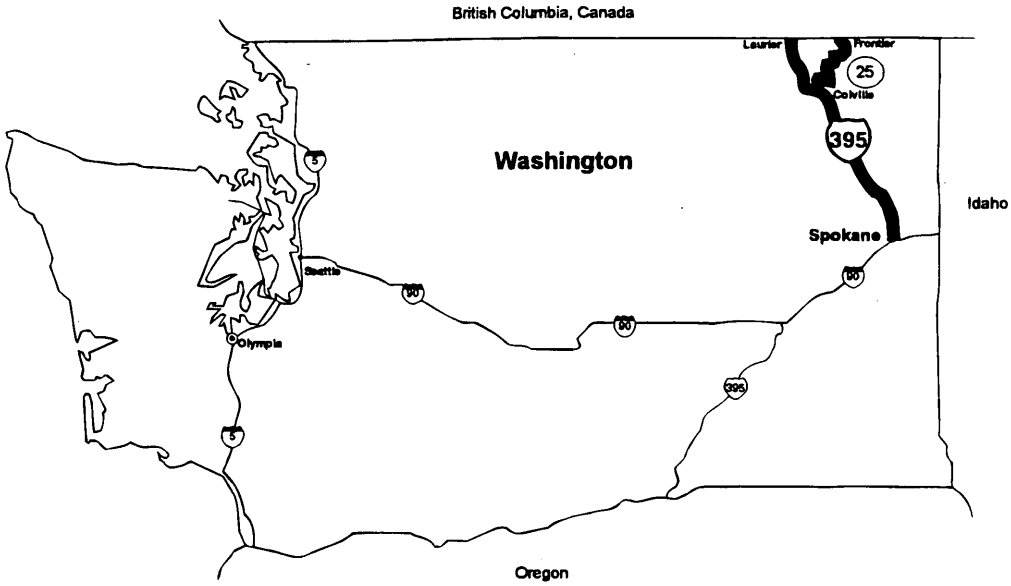


FIGURE 4 Geographic location of case study highway corridor.

The Paradox data base is organized to be as flexible as possible for specific transportation planning applications. Sample data collected from interviews with 30,000 Washington truck drivers will be weighted by the total number of freight trucks passing through each interview location over a 24-hr period. Additional weights based on vehicle route information are applied to eliminate double counting of trucks traveling on a specific highway segment. Using the weighted sample data, statewide truck movements can be accurately profiled and compared for different geographic locations within the state of Washington. After completing all four rounds of data collection, the weighted data will be used to compare differences in 24-hr freight truck movements for each of the four seasons.

For many planning applications it will be necessary to link results from the freight driver interviews with other data bases. GIS's structure provides that dynamic interlink of data. Industry data bases (such as the U.S. Census of Manufacturing and the U.S. Department of Commerce County Business Patterns) and state-level industrial growth projections are particularly useful. Each

TABLE 1 Profile of Cargo Carried by Southbound Trucks on SR-395 from Canada to Spokane and Destinations Beyond

Type of Cargo (by origin)	Number of Trucks	Percent of Total Trucks With Cargo	Percent of All Trucks
	(16 hour traffic sample, July 1993)		
Canadian Origin			
Wood Chips	31	18%	14%
Lumber Products	20	12%	9%
Fertilizer	19	11%	9%
Other Freight	5	3%	2%
Empty	8	NA	4%
Subtotal	**83**	**44%**	**38%**
Northeast Washington Origin			
Wood Chips	14	8%	6%
Lumber Products	24	14%	11%
Logs	8	5%	4%
Agricultural Products	7	4%	3%
Other Freight	42	25%	19%
Empty	43	NA	20%
Subtotal	**138**	**56%**	**62%**

Note: NA indicates not applicable

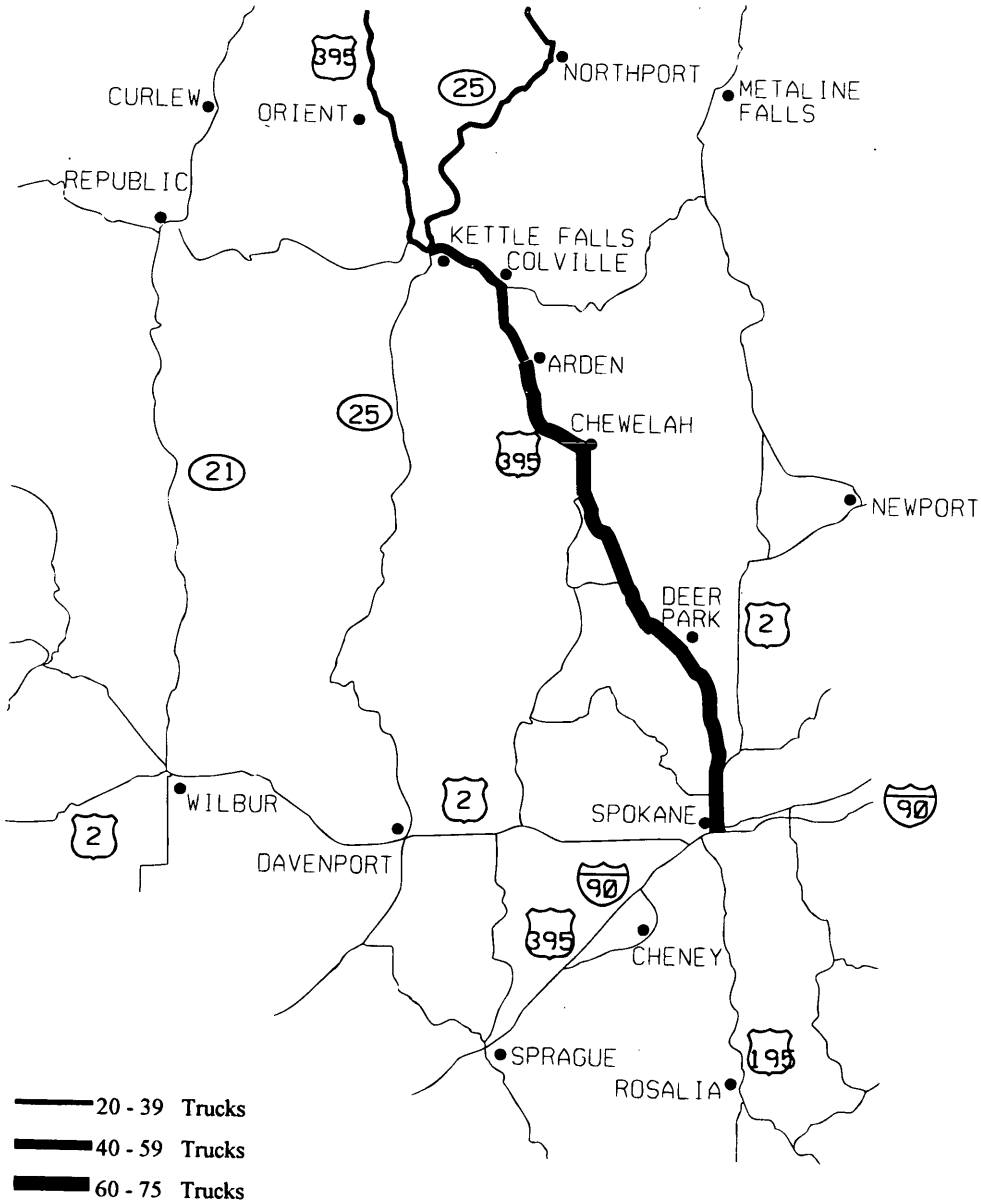
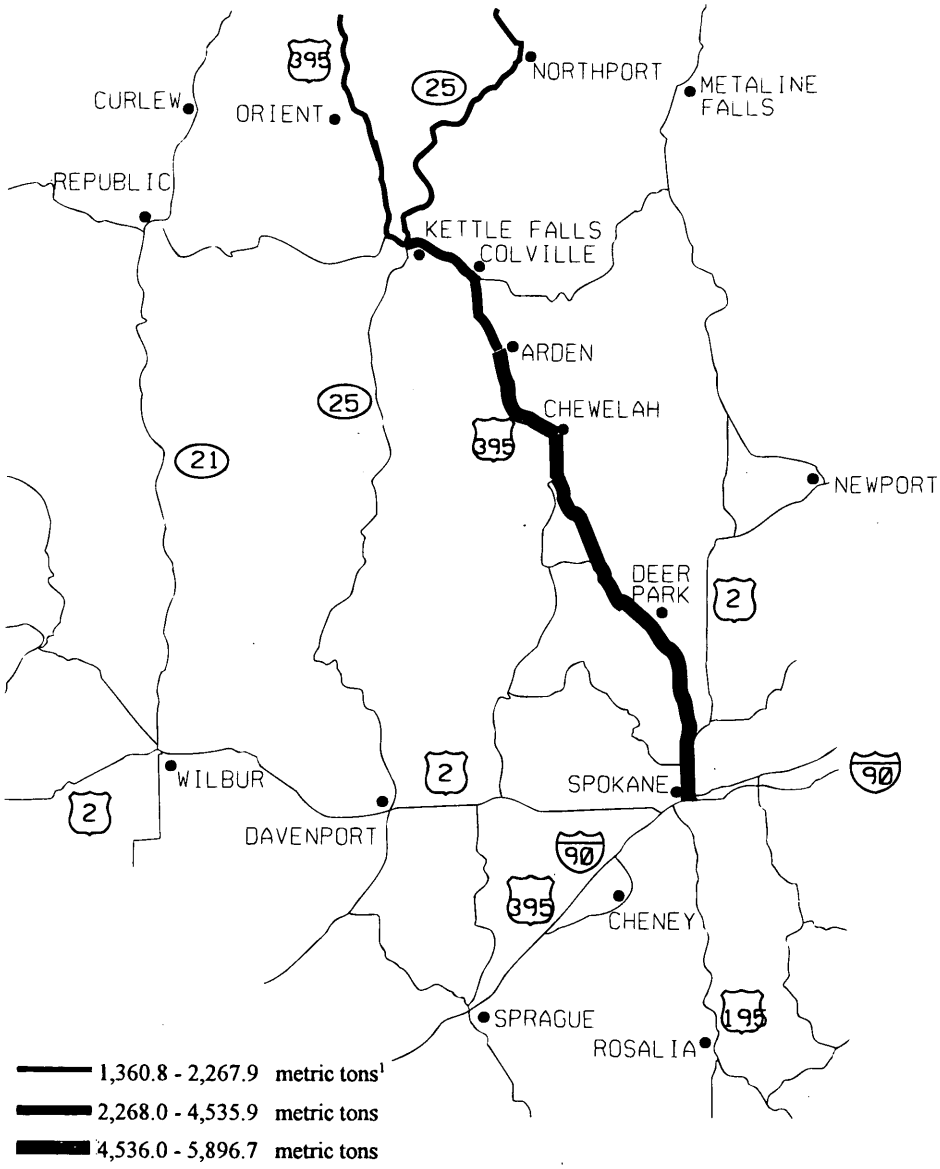


FIGURE 5 Total number of trucks carrying wood-related cargo (daily truck volumes).

truck driver interview record is assigned a specific Standard Industrial Classification (SIC) code consistent with the commodity being transported. Using the SIC code to link driver interview records with available industrial data bases will provide valuable information on both current and expected future freight truck movements on Washington highways. For example, highway corridors heavily traveled by trucks carrying commodities that are projected to grow rapidly as a component of the state's economy can expect future truck traffic increases, while corridors dominated by the shipment of commodities projected to decline should expect decreases in future truck traffic.

Tables generated from the Paradox data base will provide much of the detailed output describing key freight truck movements within the state of Washington. However, GIS-T is also used to provide graphical output highlighting characteristics of freight truck movements associated with specific segments of Washington's state highway network. Intergraph's PC-based MGE/MicroStation was selected as the GIS software for this study. Intergraph software is also being used by the WSDOT Geographic Services Division and WSDOT Planning Department. The digitized highway network, as well as substantial technical support, was provided to the research team by the WSDOT Geographic Services Division. The use of consistent software and digitized base maps will ensure the ability to easily interface with other WSDOT data bases for planning applications.

To interface with the Intergraph software, the truck driver interview data base from Paradox must be imported into Oracle. Freight truck characteristic data in Oracle is then interfaced with the tar-



[1] 1 metric ton = 2,204.6 pounds

FIGURE 6 Gross weight of total daily truck traffic.

geted digitized highway segments in MicroStation through MGE. The possible queries then become numerous.

REASONS FOR USING GIS-T

The bottom line purpose of the Washington State Freight Truck Origin and Destination Study is to provide information useful to the development of WSDOT, MPOs, and other regional transportation plans within the state of Washington. With this end purpose in mind, the use of geographic information systems provides two major advantages. First, a graphical presentation using GIS-T illustrates research findings in a form often more easily understood than the alternative of tabular output. Second, GIS-T enables a direct graphical interface with complementary planning data. For example, highway segments supporting the highest average daily cargo tonnage can be identified and directly compared with data bases documenting pavement conditions for those segments. This allows analytical questions to be posed and answered.

Graphical output complements but does not replace tabular output as a way to communicate and analyze freight truck origin and destination study results. Graphical presentation is most appropriate for geographical comparison of aggregate characteristics, such as total daily cargo tonnage on defined highway segments or key routes used by trucks traveling to a specific destination. However, tabular data is more appropriate for disaggregated information, such as detailed distribution of commodities carried by trucks traveling on I-90 to Puget Sound region ocean ports. Consequently, a combi-

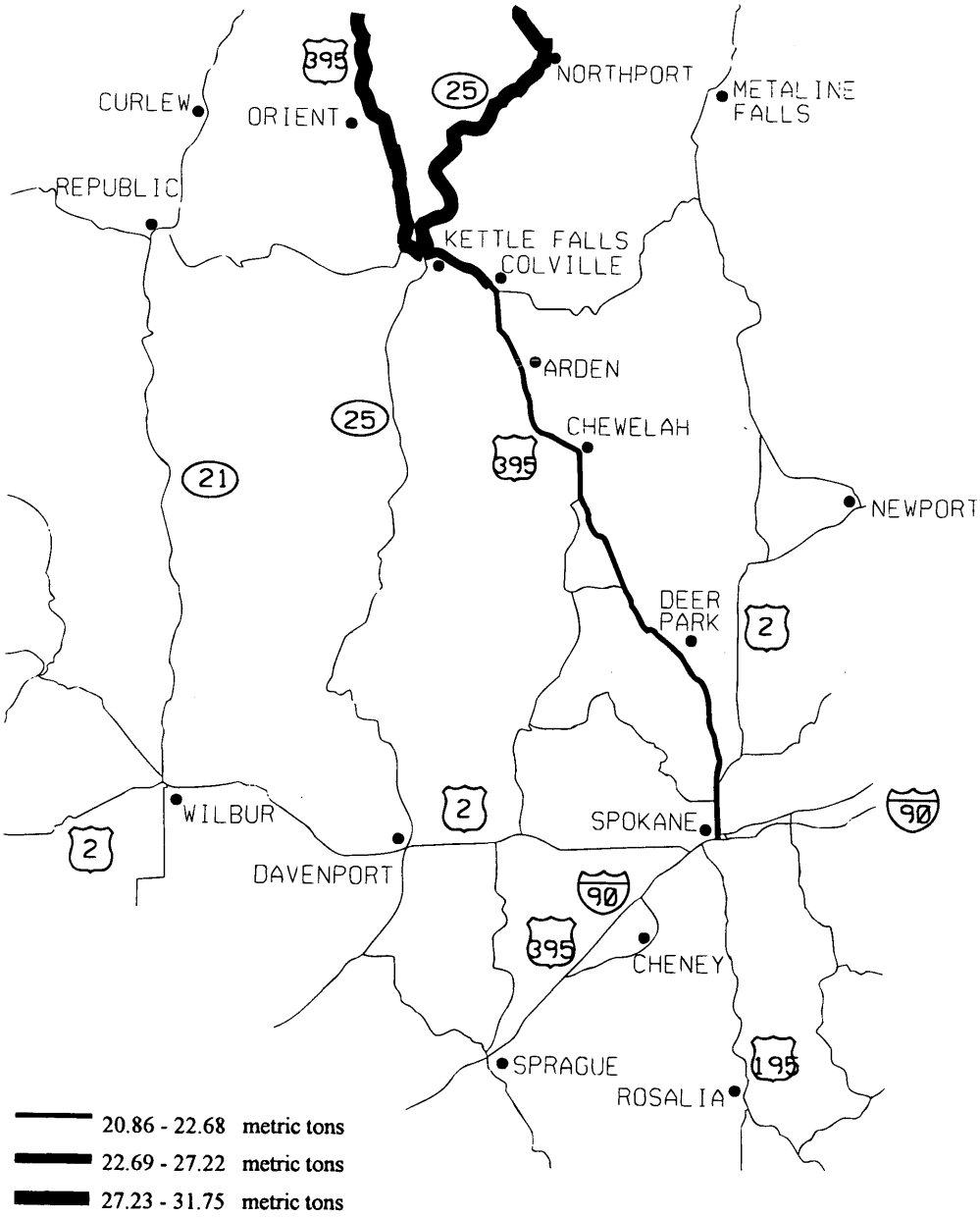


FIGURE 7 Median weight of freight truck traffic.

nation of graphical output and data tables is needed to effectively communicate findings from the freight truck origin and destination study.

CASE STUDY: SR-395 FROM CANADA TO SPOKANE

SR-395 from Canada to Spokane, Washington, is a critical transportation link, that support's the northeastern Washington economy and international trade with Canada (Figure 4). Because of the economic significance of this corridor, the WSDOT is undertaking a study of freight and goods movements on SR-395 from Canada to Spokane. GIS-T enables policy makers and WSDOT program administrators to analyze and compare key characteristics of truck movements along specific segments of this high-priority corridor. Several examples illustrate how GIS-T is being used to model freight and goods movements in the state of Washington.

Freight trucks from Canada account for 44 percent of the vehicles carrying cargo within the SR-395 study area (see Table 1). Wood chips, lumber products, and fertilizer are the primary products shipped from Canadian origins to markets in the United States. Wood-related products also are among the primary commodities transported by Washington state trucks traveling southbound on this

highway segment. Sawmills in Kettle Falls, Colville, and Arden are the primary generators of wood-related traffic from northeastern Washington.

GIS-T provides a way to compare the total volume of trucks carrying wood-related products on specific segments of SR-395 from Canada to Spokane (see Figure 5). Approximately 30 southbound trucks carrying wood products were recorded crossing the border at each of northeastern Washington's two major U.S. border crossings on SR-395 and SR-25. Approximately half the wood products trucks originating in Canada were chip trucks with loads terminating at a wood co-generation power plant located about 30 miles south in Kettle Falls. Most of the remaining Canadian-origin trucks carrying wood cargo continued on SR-395 to Spokane and destinations beyond. Additional SR-395 wood products traffic originated from sawmills in Kettle Falls, Colville, and Arden. Most of these trucks reported destinations in Spokane and points beyond. Consequently, the total volume of wood-related truck traffic was greatest on highway segments located on the southern end of the study area.

The aggregate daily gross weight of freight trucks traveling the SR-395 study area also was greatest on the southernmost portions of the corridor (see Figure 6). The pattern of increasing aggregate gross weight reflects the fact that most of the major generators of freight truck traffic in the SR-395 study area are located north of Chewelah. Total truck counts and aggregate gross weight are smallest on the highway segments between the Canadian border and Kettle Falls. Truck counts and aggregate gross weight increase steadily on highway segments located between Kettle Falls and Arden. Among highway segments in the study area, total truck counts and aggregate gross weight are highest between Arden and Spokane.

Within the study area, the road segments with the lowest daily truck traffic count support trucks with the heaviest median weight. The two highway segments connecting the Canadian border with Kettle Falls each carry trucks with a median weight over 27.2 metric tons (60,000 lbs). This reflects a high concentration of wood chip trucks that typically are loaded near the maximum legal limit for an eight-axle vehicle in the state of Washington. The relatively low truck count segment between Kettle Falls and Colville also carries a high proportion of heavier trucks, most of which originate in Canada. For road segments south of Colville, the median truck weight falls in the range of 20.9 and 21.8 metric tons (46,000 and 48,000 lbs., respectively) (See Figure 7).

CONCLUSION

Statewide, metropolitan, and regional transportation planning increasingly requires systems that can manage and analyze large volumes of data pertaining to freight and goods movements. GIS-T can play an important role in this process. A graphical presentation using GIS-T illustrates research findings in a form that is often more easily understood and communicated than the alternative of tabular data. GIS-T enables a direct graphical interface with information from other planning data bases, thus providing an environment for analytical investigations.

The statewide freight truck origin and destination study initiated by the WSDOT in April 1993 will provide substantial benefits for future transportation planning. The study will help the state of Washington comply with ISTEA planning requirements, and it will contribute to the Washington State Transportation Policy Plan and Statewide Transportation System Plan. The study also will be used by MPOs and regional transportation planning organizations to evaluate freight and goods mobility needs for their updated plans.

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