Interactive Statewide Transportation Planning Modeling Process

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The Wyoming Multimodal Statewide Transportation Planning (WMSTP) model study was initiated to develop a user-friendly and data-efficient planning process to fulfill Wyoming's statewide planning needs. Described is a cooperative process developed by the University of Wyoming and the Wyoming Department of Transportation. Traditional four-step urban transportation planning models have been used extensively in statewide transportation planning (STP) processes. The Wyoming STP modeling process considers the unique nature of STP processes and travel characteristics in Wyoming. Trip purposes were redefined to fit STP needs. The WMSTP model is a planner-computer interactive process. The process uses traffic count and socioeconomic data as the primary inputs, in addition to the knowledge of the planner. Windows-based computer software packages including Excel, Visual Basic 3.0, and QRS II were used in developing the interactive planning model. To date, the model framework has been established, and the model building and sensitivity analysis have been undertaken.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires each state to develop a multimodal statewide transportation plan. The University of Wyoming and the Wyoming Department of Transportation (WYDOT) began the development of the Wyoming Multimodal Statewide Transportation Planning (WMSTP) model in December 1992. This cooperative effort focused on developing a user-friendly, data-efficient state transportation planning (STP) modeling process.

This paper begins with a discussion of the project team organization, and is followed by a brief outline of the model framework. The focus of this paper is the planner-computer interactive process. Travel segmentation by trip purpose using traffic count data and the origin-destination matrix estimation model with traffic counts and their applications are discussed.

STUDY PROCESS AND PROJECT ORGANIZATION

The ultimate goal of this research is to develop a modeling process that will fit Wyoming's statewide planning needs and be a useful tool for statewide planners. A two-phase study approach was used. Phase 1 focused on a national STP modeling method survey and Wyoming's planning needs investigations. Phase 2 focused on model development using a five-county test area in the southeast corner of Wyoming. The researchers from the university and the planners in WYDOT worked closely through the study process. A planning focus group including personnel from the university, FHWA, and WYDOT provided input into the modeling process and its evaluation.

By the end of October 1994, the framework for a computerized interactive demand model had been established; the travel segmentation by trip purpose model had been completed and applied to the test area (*1,2*). An origin-destination (O-D) matrix estimation process using traffic counts had also been programmed and tested (*3*). The sensitivity analysis for the segmentation model was also conducted to verify the validity of the proposed process (*2*).

The historical review of the nationwide STP activities and methods showed that STP modeling methods have become more simplified and practical. Modeling methods varied from state to state. Applications of microcomputer software have tremendously increased planning staffs' working efficiency. ISTEA requirements and the characteristics and needs of each state were the determinant factors in current modeling approach selection. Wyoming researchers and planners agreed that the WMSTP model should use the ideas and the approaches of other states while carefully considering Wyoming's planning needs (*4–7*).

FEATURES OF THE WYOMING MODEL

The findings concerning the multimodal transportation network and travel characteristics in Wyoming indicated that the influence of through traffic and tourism-oriented traffic should be adequately reflected in the WMSTP model. Because different types of road users have different travel service needs and mode preferences, they were modeled separately. Stratifying total volumes into several major groups by travel characteristics, such as trip purpose and origin and destination, helped to identify the travel behavior and travel pattern of each group of users. In addition to the roadway travel analysis, parallel efforts considering rail, air, and public transit in a statewide context are being undertaken. After the analysis on each mode is completed, the next step is to examine the intermodal implications for Wyoming. Origins, destinations, types of travel, and product types become key intermodal parameters. For example, 92 percent of the freight transported on railroads that originates or terminates in Wyoming is coal (*7*). Other bulk chemical raw materials are most of the remaining rail goods. These types of products are not generally suited for transport by other modes.

STRUCTURE OF THE WYOMING MODEL

The Wyoming modeling system begins with a travel characteristics analysis (see Figure 1). The outputs from these models are segmented traffic counts by trip purpose and trip origin-destination matrices. Based on the knowledge obtained from these analyses, the demand changes are estimated for land use or transportation system changes. The estimated trip tables for each trip purpose are the input for mode split models and trip assignment models. The segmented traffic flows formed a solid foundation for intermodal analysis.

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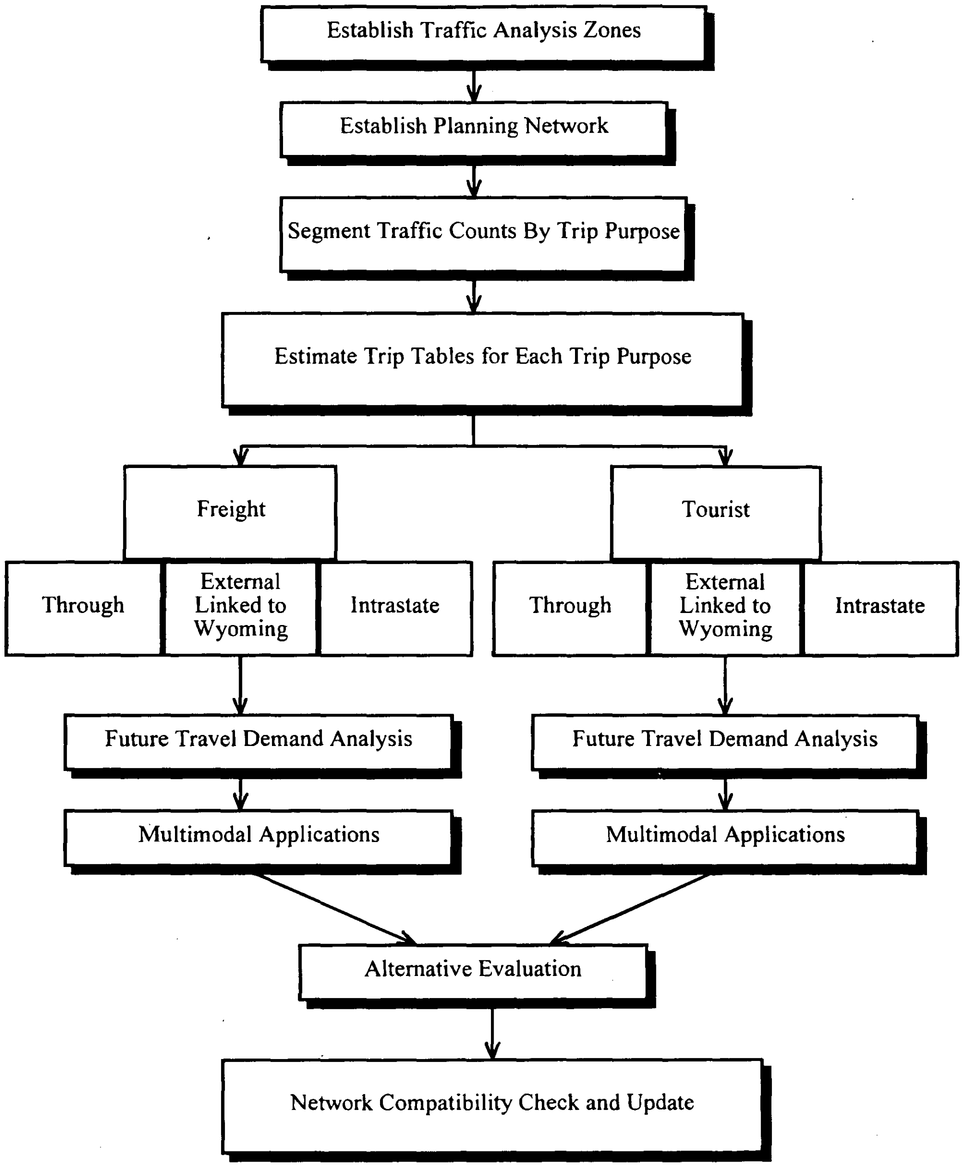

FIGURE 1 Wyoming STP model framework.

In developing the model framework, differences between urban transportation planning and STP were recognized. In urban transportation planning, a large number of trip purposes are generally used to segment the urban travel market. Proposed here is a more generalized and simpler definition, which is adaptable to Wyoming's rural travel. Trip purposes used were *goods movement*, and people movement stratified by *work (commuter)* and *tourist (noncommuter)* travel. Work trips reflect regularly scheduled commuting trips between cities. Tourist or all other people trips reflect the irregular (unscheduled) travel that occurs between cities. These trips include business trips, social and recreational trips, and shopping trips that are taken by Wyoming residents or nonresidents. As the procedure was refined, the need to segregate passenger travel into two distinct purposes was evaluated. Work commuting between cities does not constitute a high percentage of intercity traffic, except for few locations in the state due to the spatial separation between cities.

After analyzing the traffic temporal distribution patterns, it was recognized that traffic flows peak on a July weekend for most Wyoming roadway links. Tourism-oriented traffic is significant in Wyoming. Freight traffic volumes are also higher during summer months. A typical temporal traffic pattern is shown in Figure 2. The July weekend peak traffic volumes illustrated are typical for both truck and passenger travel. Since few weekend traffic volumes are commuter related, goods movements and tourism travel are the trip purposes of primary concern.

PLANNER-COMPUTER INTERACTIVE MODELING PROCESS

The user interfaces in this interactive modeling process allow the planner to influence modeling by communicating with the program. New modeling methods, such as O-D estimation with traffic counts

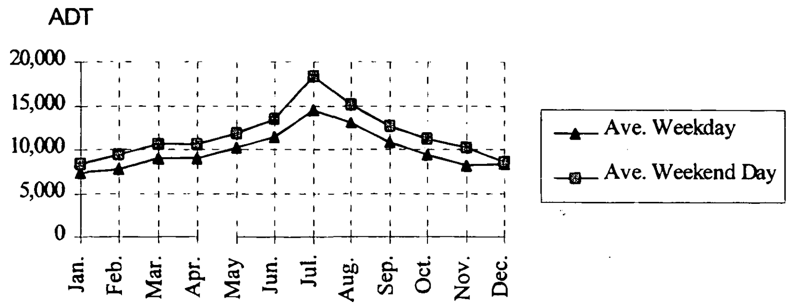

FIGURE 2 Typical monthly traffic volume trend—I-25 in 1992.

and travel segmentation with traffic counts, are used to reduce input data needs. Traffic count and socioeconomic data are the primary input sources. The judgment and the knowledge of the planner are complementary inputs.

The WMSTP modeling program uses three Windows-based computer software packages and integrates them into a menu-driven program. Visual Basic serves as the program organizer. From the main menu, built with Visual Basic, all model programs written with Excel, Visual, and QRS II can be activated. These programs include travel segmentation by trip purpose (programmed with an Excel Macro, which is written by Visual Basic for Applications), O-D estimation models (programmed with Visual Basic and QRS II), and demand analysis models (programmed with Visual Basic and QRS II).

The software was selected for programming and maintenance convenience as well as analysis capability. Visual Basic and Excel Macro are relatively easy to program and provide adequate user interface functions. The input data files to QRS II are generated from the Visual Basic program and the Excel Macro. Excel performs data processing, charting, and the interactive travel segmentation process. The interactive travel segmentation process and the O-D estimation model are discussed in the following two sections.

Interactive Travel Segmentation Process

The normal method for accomplishing traffic split by trip purpose is to conduct extensive household surveys and roadside interviews. However, both approaches are costly in terms of manpower and time required. The proposed approach uses existing traffic count data and the planner's judgment as inputs (*2*). The interactive program developed performs the following actions:

- Processes several types of raw traffic count data automatically to generate tables and traffic pattern charts;
- Checks data availability for each study location and verifies data validity;
- Obtains user's input by allowing the user to choose the data type to be used in the process, select the action taken for the next step, and provide model factors to the process; and
- Stratifies link traffic volume by trip purpose and generates output tables, charts, and data files required by the O-D estimation models and QRS II models.

The basic concept of the proposed methodology is practicality. For roadways, private vehicles are used as the major passenger transportation mode, and freight is transported by trucks. Certain classified and nonclassified traffic counts are regularly collected. Trips made by road users for different trip purposes are characterized by a specific temporal distribution pattern. Based on this knowledge, reasonable assumptions about the temporal distribution for each trip purpose are made. Combining assumptions and available traffic count data, the approximate traffic volumes by major trip purposes are estimated. Related land use data may also be collected as a complementary data source to help understand the traffic variation patterns and make assumptions. The segmentation results are verified or improved through the demand-modeling process.

The primary objective of the travel segmentation process was to obtain July weekend truck and passenger vehicle traffic flows. The process developed stratifies link traffic volumes into (a) monthly average weekday passengers cars, (b) monthly average weekday trucks, (c) monthly average weekend daily passenger cars, and (d) monthly average weekend daily trucks. Using available input traffic count data, the segmented traffic flows are tabulated and charted for the user to view and use in the later modeling process.

The flow chart of the interactive segmentation process is shown in Figure 3. Based on the examination of existing traffic counting programs, three types of traffic counts were found valuable to the segmentation process: automatic traffic record (ATR) reports, port of entry (POE) truck counts, and vehicle miles book (VMB) data. If automatic vehicle classifier (AVC) counts are available at a location, they can be used instead of ATR and POE count data. Count data availability varies by roadway link. If all three types of count data are available for the link, the standard segmentation procedure can be carried out automatically by the program. When one or more types of data are missing at a location, more user involvement in the process is required. The user interface will help the user choose the proper complementary data type. When continuous counts are unavailable at certain locations, short-term counts at the same location or substitution of same-type counts at a nearby location may be used. All regularly available traffic counts, such as traffic control counts (2-week nonclassified counts), coverage counts (24-hour nonclassified counts), and 24-hour manual classification counts can be processed and charted with the program. A traffic pattern chart (similar to Figure 2) for any nearby ATR station can be generated. After review, the user is asked to decide which data source to use as a complementary source for the missing continu-

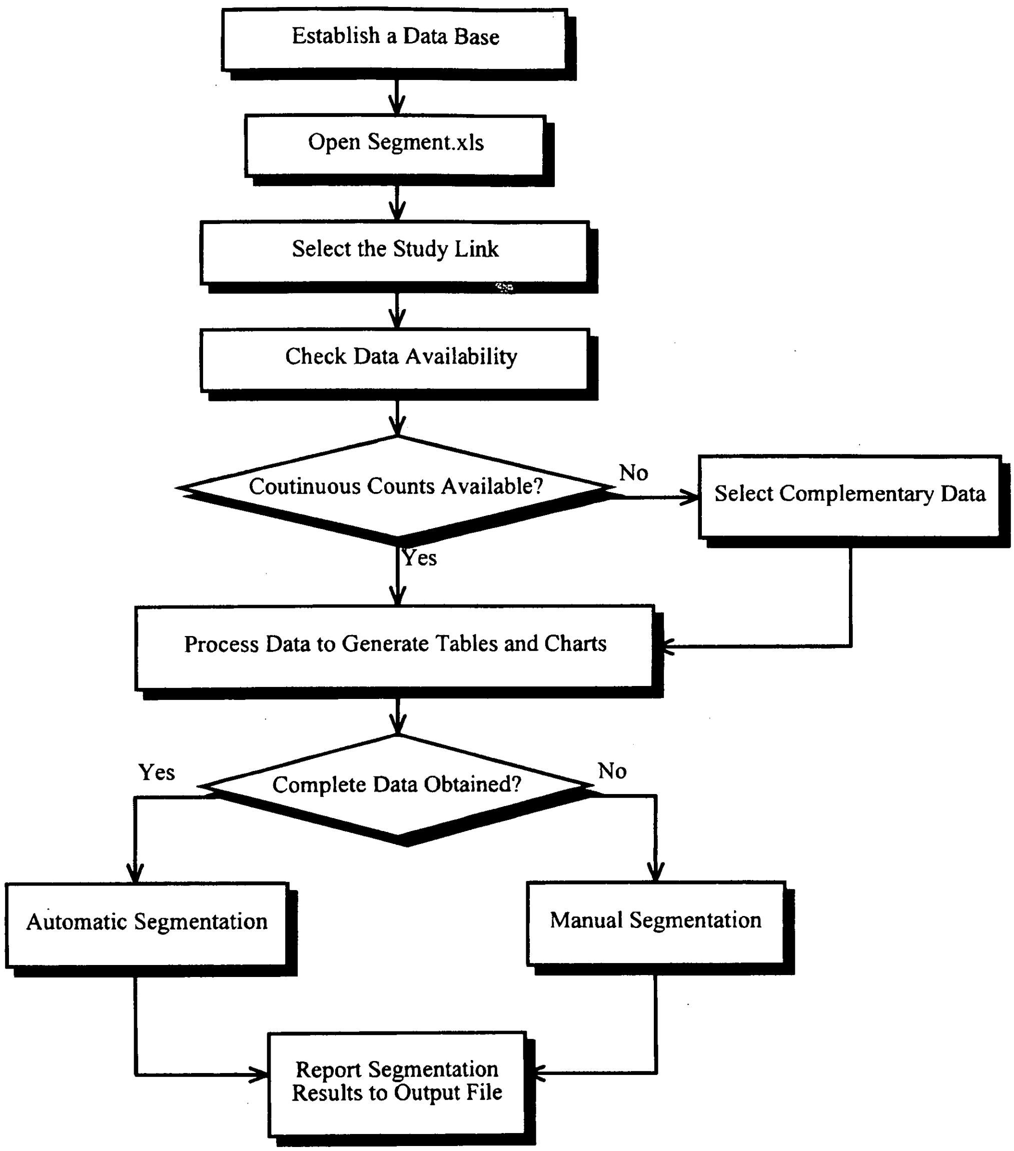

FIGURE 3 Travel segmentation process.

ous counts. Dialogue boxes and user menus are used to build user interfaces.

To assist, a data base is designed for the user to enter the link name, link location, ATR location, and file names for all available count data. An Excel spreadsheet is used. Every row is a record for a roadway link, and each column is a data field. The data base can be either edited manually using the Excel spreadsheet function or edited from the segmentation program interactively. The input data files required by the program are organized and made available through this data base. In addition to data-processing functions, the segmentation process based on entered traffic counts is automated in an Excel Macro subroutine. The segmentation results are then tabulated and charted automatically.

Sensitivity Analysis

Sensitivity analysis is used to evaluate the corresponding output error level when the input data of a modeling process deviate from their true values by a certain magnitude. For instance, in a travel segmentation process, when a 5 percent error occurs in the input ATR count data for the study link, sensitivity analysis provides the error level (i.e., 10 percent) on every resulting classified traffic volume, such as monthly average weekend daily trucks. Sensitivity analysis is critical to verify the validity of all interactive modeling processes. If this analysis detects a larger output error level than the tolerance allowed by the STP planning process (i.e., 15 percent), extra data collection efforts are recommended for the location. The sensitivity analysis for the travel segmentation process is discussed briefly in the following paragraphs as an example.

In the travel segmentation process, a set of equations was established based on the relation between each type of output and input data. The following sample equation calculates the error level on output monthly average weekend daily passenger car volumes when the input monthly average daily truck volumes increases by ΔT_{TI}:

$$\Delta T_{\mathrm{P,SS}} = -\frac{14\Delta T_{TI} R_{\mathrm{SS/M\text{-}F}}}{5 + 2R_{\mathrm{SS/M\text{-}F}}} \tag{1}$$

where $\Delta T_{P,SS}$ is the error occurred on output monthly average weekend daily traffic (car/day) and $R_{SS/M\text{-}F}$ is the ratio of weekend truck traffic to weekday truck traffic.

Sensitivity analysis was conducted for different roadway links with different data availability. These tests demonstrated that, based on the existing traffic counts in Wyoming, the segmentation process generally provides classified peak traffic volume data with adequate accuracy. Under the poorest data availability, the output error level was controlled to under 20 percent. In most cases, the error level on interstate and principal highways did not exceed 10 percent. Higher error levels usually occurred on secondary highways. Due to the significantly lower traffic volumes on secondary highways, the higher error level does not significantly affect the overall modeling accuracy.

Estimation of Origin-Destination Matrices with Expert Survey and Traffic Counts

Estimation of trip matrices for July weekend freight and tourist travel is the next step. These two trip matrices provide the trip distribution for through travel, external travel linked to Wyoming, and intrastate travel. Understanding of this distribution is significant for intermodal analysis.

Traditionally, O-D matrices are estimated by household survey and roadside interviews. Since the 1970s, new O-D estimation models using traffic counts as primary input have been developed (*8–10*). The idea of this new methodology is to obtain the O-D matrix that best replicates the counted link traffic flows. Following is a brief discussion of the procedure.

Consider a study transportation network with n traffic analysis zones. If link traffic volumes (V_a) are available, the following equation is true (*9*):

$$V_a = \sum_i \sum_j p_{ij}^a T_{ij} \tag{2}$$

where

T_{ij} = the number of trips from i to j;
P_{ij}^a = the proportion of trips from i to j that use link a; and
V_a = the traffic volume on link a.

This is the fundamental equation in the estimation of the O-D trip matrix from traffic counts. This equation describes the relationship between O-D trips and link volumes. In this equation, when link volumes are available and the path choice behavior is assumed known (p_{ij}^a can be calculated by a selected trip assignment model), the number of trips between each O-D pair (T_{ij}) is estimated by solving the equation. Different models have been developed to solve the equation. The entropy maximization (EM) model is one that is extensively used. This model is relatively easy to apply and generally results in an acceptable solution. Solving Equation 2 with the EM model, the elements in O-D trip table are estimated as (*9,10*)

$$T_{ij} = t_{ij} \prod_a X_a^{p_{ij}^a} \tag{3}$$

where t_{ij} are the trips i to j from a preliminary O-D table and X_a is the trip estimation factor for link a (iterative solution based on Equation 2).

In Equation 3, a preliminary O-D table (t_{ij}) is required. Generally, an old trip table or a table estimated with the gravity model can be used. In the Wyoming study, a small-scale expert survey was conducted to generate preliminary trip tables for both tourist and freight trips. Segmented July weekend link traffic counts were used to provide link volumes (V_a). The process was tested in the southeast area of Wyoming.

The EM modeling and survey data processing procedures were programmed with Visual Basic. QRS II was used to conduct the trip assignment. The proportional use of any link (a) by any trips between any O-D pair (p_{ij}^a) was obtained. A program was developed to read the segmented link traffic counts (V_a) from Excel and enter p_{ij}^a from the QRS II output file. The program allows the user to select the accuracy level of link volume replication and the maximum iteration number. Trip tables for the test area were estimated for the 1992 July weekend traffic. The link volume replication error level was controlled under 3 percent.

For this five-county area, based on the findings from the estimated O-D tables, through traffic is dominant. This is true for both weekend tourist travel and freight movements, but especially for freight. Internal-internal travel was the least frequent travel type. For goods movement, approximately 50 percent of total trips were through the area; 45 percent were internal-external and external-internal trips; and only 5 percent were internal-internal trips (*3*). As the study area is extended to the entire state, the percentage of through traffic will decrease, but the same trend should hold. The bridge state characteristics of Wyoming are a significant factor in planning for Wyoming's future transportation system.

SUMMARY AND CONCLUSIONS

The features of STP modeling in Wyoming have been discussed. Central to the process was to consider travel in Wyoming for a peak weekend in July. This resulted in a two-purpose model for highway travel (goods movements and tourism travel). Since the spatial separation of Wyoming cities is such that work-related travel does not increase weekday summer flows over weekend volumes, this peak weekend approach was used.

Multimodal issues are important only for movements that originate or terminate in Wyoming. Wyoming is considered a bridge state due to the high percentage of travel external to the state. The need, however, is to be able to determine potential shifts as well as analyze future transportation demand for all modes. The major future internal economic growth hinges primarily on tourism and resources development. To plan for statewide transportation, it is important to isolate types of passenger travel and goods movement, and major origins and destinations. Scenarios associated with different land use or transportation alternatives may then be evaluated by isolating the potential changes in demand.

Emanating from this study are the following conclusions:

- A cooperative modeling approach helped ensure that the modeling process will fulfill Wyoming's planning needs.
- The Wyoming STP model uses an interactive modeling process that is data efficient and user friendly. It combines the power of the computer, the use of existing data, and the knowledge and judgment of the planner.
- Classifying existing traffic flows on network links by trip purpose and origin-destination yields a better understanding of Wyoming's travel characteristics. This understanding provides a solid foundation for an intermodal analysis.

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REFERENCES

1. Wilson, E. M., and J. Y. Wang. *Wyoming Multimodal Statewide Transportation Planning Model, Phase I Report.* University of Wyoming and Wyoming Department of Transportation, Cheyenne, 1993.
2. Wilson, E. M., and J. Y. Wang. *An Interactive Process for Rural Highway Travel Analysis—Classifying Link Traffic by Trip Purpose.* Research Report. University of Wyoming and Wyoming Department of Transportation, Cheyenne, 1994.
3. Wilson, E. M., and J. Y. Wang. *Estimation of Origin-Destination Matrices by Expert Survey and Traffic Counts.* Research Report. University of Wyoming and Wyoming Department of Transportation, Cheyenne, 1994.
4. *Special Report 146: Issues in Statewide Transportation Planning.* TRB, National Research Council, Washington, D.C., 1974.
5. National Cooperative Highway Research Program. Synthesis of Highway Practice 95. *Statewide Transportation Planning.* TRB, National Research Council, Washington, D.C., November 1982.
6. Future of Statewide Transportation Planning. In *Transportation Research Record 1243*, TRB, National Research Council, Washington, D.C., 1989.
7. *Statewide Long Range Plan.* Wyoming Department of Transportation, Cheyenne, 1994, pp. 5–18.
8. Lam, W. H. K., and H. P. Lo. Estimation of Origin-Destination Matrix From Traffic Counts: A Comparison of Entropy Maximizing and Information Minimizing Models. *Transportation Planning and Technology*, Vol. 16, 1991, pp. 85–104.
9. Van Zuylen, H. J., and L. G. Willumsen. The Most Likely Trip Matrix Estimated From Traffic Count. *Transportation Research*, Vol. B 14, 1980, pp. 281–293.
10. Bell, M. G. H. The Estimation of Origin-Destination Matrices by Constrained Generalized Least Squares. *Transportation Research*, Vol. B 25, 1989, pp. 13–22.

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