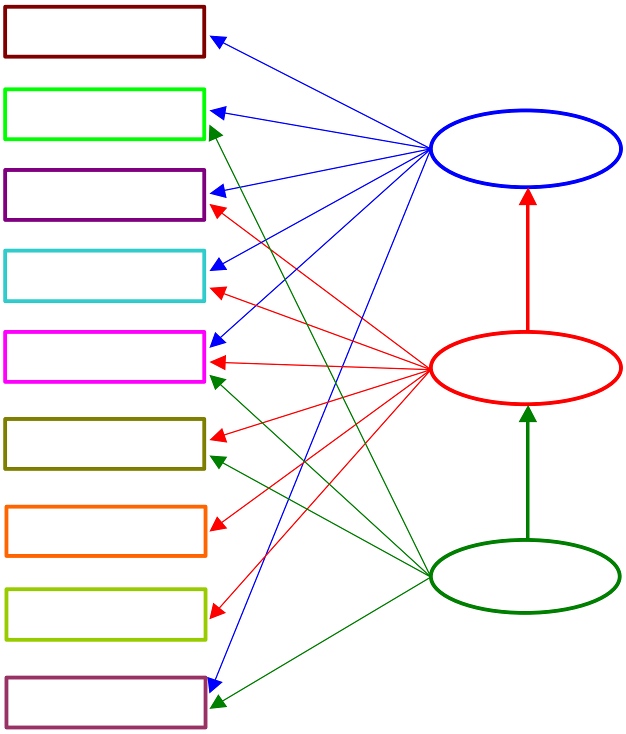

Surveying and Modelling Trucking Industry Perceptions, Preferences and Behaviour

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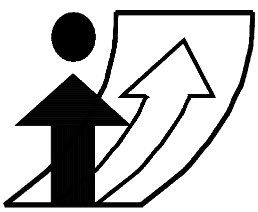
Conference paper
Session V



Moving through nets:
The physical and social dimensions of travel

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Surveying and Modeling Trucking Industry Perceptions, Preferences and Behavior

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Abstract

Methods developed to study passenger travel behaviour can be usefully applied in studying perceptions, preferences and behaviour of important actors in freight transportation. Transportation planers throughout the world can benefit by gaining improved understanding of how trucking companies are coping with changes in transportation system levels of service and how companies are likely to react to opportunities presented by information technologies and intelligent transportation systems. In this paper we present five different structural equations models (SEM) that have been estimated using large-scale survey data from the trucking industry. These models are used to examine carrier perceptions related to problems accounting for operational inefficiencies, impacts of traffic congestion on roads and at terminal facilities, transportation policy priorities, and uses of and opportunities for implementing computer and information technologies.

Keywords

Trucking, Freight, Goods movement, Commercial vehicle operations, attitude scales, preferences, surveys, International Conference on Travel Behaviour Research, IATBR

Preferred citation

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1. Objectives and Scope

Methods developed to study passenger travel behaviour can be usefully applied in studying perceptions, preferences and behaviour of important actors in freight transportation. In particular, trucking company managers are well informed about the workings and failings of the current system, and also are major political players on issues that affect their industry. Transportation planers throughout the world can benefit by gaining improved understanding of how trucking companies are coping with changes in transportation system levels of service and how companies are likely to react to opportunities presented by information technologies and intelligent transportation systems. Trucking company operations managers are a rich source of information concerning problems accounting for operational inefficiencies, impacts of traffic congestion on roads and at terminal facilities, transportation policy priorities, and uses of and opportunities for implementing computer and information technologies (CIT).

Over the past several years, the authors have conducted two separate surveys of operations managers of trucking companies. With these data, we estimated models that shed light on several transportation planning issues: (1) the perceived impacts of highway congestion on trucking operations, (2) evaluations of policies aimed at mitigating congestion, (3) adoption of computer and information technologies (4) preferences for types of information provided in advanced traveler information systems for truck drivers, and (5) demand for automated routing and scheduling systems.

In this paper we discuss lessons learned in surveying trucking company managers and analyzing the survey data. With regard to surveys, we will cover issues of sampling, and ways we found useful in reducing interview non-response and item non-response. Our experience is based on two independent surveys of managers of trucking of trucking companies operating in the Sate of California. These surveys were conducted in 1998 (more than 1,100 respondents) and 2001 (more than 700 respondents), using computer aided telephone interviews. The average interview times were 18 and 17 minutes in 1998 and 2001, respectively, and the effective response rates for both surveys were in excess of 35%. Targeted respondents were randomly drawn from lists obtained from a company that maintains extensive contact information for trucking companies in the US.

We have applied a variety of statistical methods in analyzing data from the two surveys. Here, we concentrate on the application of structural equation modeling, in forms that are appropriate for ordinal and categorical endogenous variables. The ordinal variables typically represent trucking company managers' ratings or evaluations, typically of aspects of a problem or components of a solution, and the categorical variables typically represent choices.

2. Previous Studies

There have been several recent survey based studies of the trucking industries in the US and abroad. Crum, Premcumar and Ramamurthy (1996) and Crum, Johnson and Allen (1998) detail two surveys investigating carriers use of Electronic Data Interchange (EDI) systems. Their surveys were aimed at the firms Chief Executive Officers and their sample consisted of mainly large carriers. Scapinakis and Garrison (1993) conducted a small survey regarding carriers' perceptions of use of communications and positioning systems, and Kavalaris and Sinha (1994) surveyed trucking companies with a focus on their awareness of and attitudes towards ITS technologies. Ng *et al.*(1996) reported results from two nationwide surveys of dispatchers and commercial vehicle operators to determine characteristics that would determine likely acceptance of Advanced Traveler Information Systems (ATIS) technologies, including route guidance, navigation, road and traffic information, roadside services and personal communication. Regan, Mahmassani and Jaillet (1995) surveyed 300 companies to determine carriers' propensity to use new technologies, particularly two-way communication and automatic vehicle location/identification technologies. Holguin-Veras and Walton (1996) and Holguin-Veras (2000) also investigated the use of IT in port operations through interviews with port operators and a small survey of carriers. Hall and Intihar (1997) studied IT adaptation through a series of interviews with trucking terminal managers, focus group meetings with representatives of the trucking industry, and telephone interviews with technology providers. Only one recent large-scale survey has been aimed at truck drivers themselves. That study was mainly aimed at examining the working conditions and compensation of truck drivers and is detailed in Belman, Monaco and Brooks (1999). Finally, quite a bit of research has used survey data gathered by the U.S. Census Bureau. The Truck Inventory and Use Survey (TIUS) are gathered every five years and are a comprehensive survey of the industry. Examples of research on contracting arrangements and technology adoption using those data are found in Hubbard (2001) and Hubbard (2000).

3. Surveying Trucking Company Managers

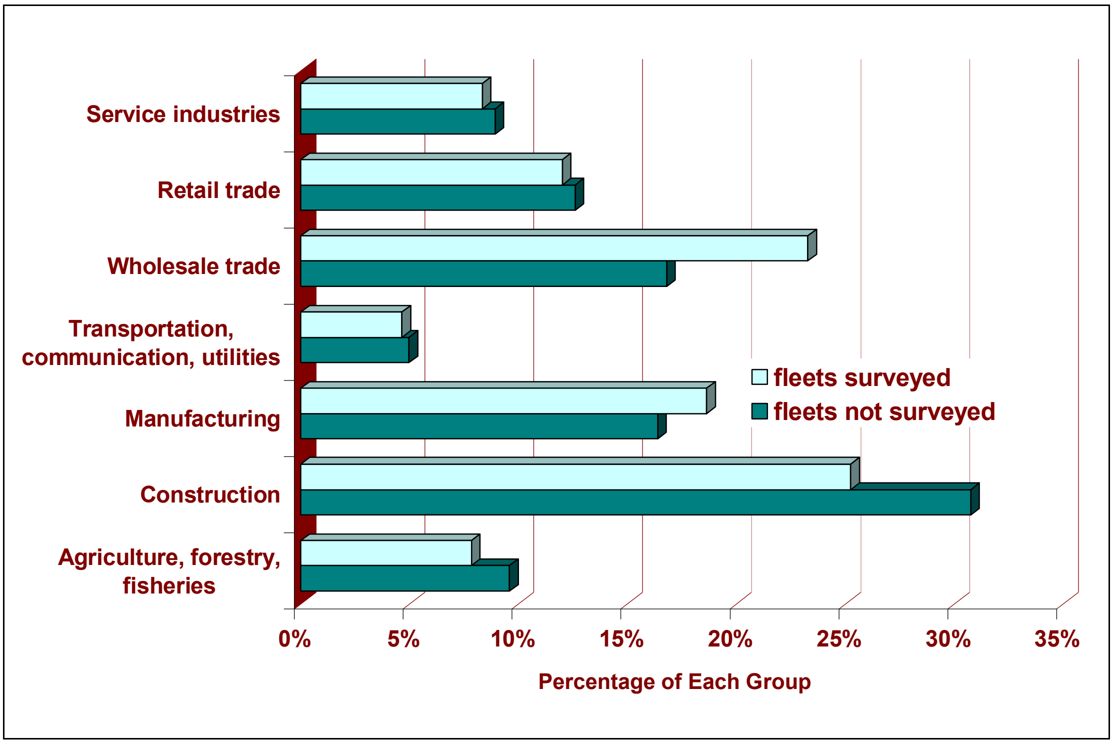
3.1. The 1998 Survey of 1177 Trucking Companies

The contact lists were obtained from a company that maintains extensive contact information for U.S. trucking companies was obtained from Transportation Technical Services Inc. Their database is well known to be an almost exhaustive contact list for trucking companies in the U.S. Most large-scale surveys of the industry rely on samples drawn from their database (for example Crum et al, 1996, 1998, Regan et al, 1996).

We chose to use a three-part sample comprised of: (1) large national carriers with operations in the state of California, (2) California based carriers of all sizes, and (3) private fleets corporately located in the state. The survey was conducted as a computer-aided telephone interview (CATI), with an average interview time of just over 18 minutes. The survey dealt with four main topics: (1) traffic congestion, (2) use and usefulness of information technologies, (3) use and efficiency of intermodal terminals in California, and (4) operational characteristics.

Non-response analyses were conducted for each of the three strata from which the sample was drawn. There are no statistically significant differences between respondents and non-respondents on any of three criteria available in the database from which the sample was drawn: revenue, overall size of fleet, and number of years in business (Golob and Regan, 2000). The median California fleet size for all for-hire companies (California-based companies and large national companies combined) was 81 for respondents and 78 for non-respondents. For private carriers, median fleet size was 28 for respondents and 29 for non-respondents. Neither of these differences is statistically significant. The 1177 companies in the 1998 sample accounted for approximately 69,000 vehicles, 52,000 in for-hire fleets and 17,000 in private fleets. The database from which the sample of private fleets was drawn also contained the standard industrial classification (SIC) codes of the companies. A comparison of the SIC code distributions for respondents and non-respondents is shown in Figure 1. The difference is significant at the *p*=0.05 level, but not at the *p*=0.01 level. Our sample over-represents trucking operations from the wholesale trade sector, and under-represents those from the construction sector. The distribution of the sample is quite close for all the other sectors.

Figure 1 Nonresponse Analysis for 1998 Survey by Industry Sector



3.2. The 2001 Survey of 712 Trucking Companies

Logistics managers of more than 700 trucking companies operating in California were surveyed in spring 2001. The target list was drawn independently of the 1998 sample. Survey response rates are tabulated in Table 1. As in the 1998 survey, trucking company logistics managers, once contacted, proved in general to be very cooperative. Managers of 3438 companies were contacted, and 86% of these qualified by having operations in California. Of the 2972 companies with California operations, 75% (2218) initially agreed to participate in the survey. For these companies, 712 interviews were completed with the person in charge of California operations. The large number of unresolved contacts reflects the difficulty of tracking down persons responsible and the need to schedule callbacks when people have available time. The 712 completed interviews represent a 49% response rate of all resolved contacts, and a 24% response rate of all qualified companies.

Table 1 Response Rates for 2001 Survey of Trucking Company Managers

Contacts attempted	5085
Bad contact information (e.g., wrong number, disconnected, fax machine)	-794
Potentially valid respondent	4263
Unable to contact (e.g., repeated busy signal, no answer)	-825
Contacted	3438
No business in California (does not qualify)	-466
Valid contact	2972
Refused	-754
Agreed to participate	2218
Unresolved (survey closed before call backs were completed)	-1506
Completed	712
Completed as % of all valid contacts	24.0%
Completed as % of all resolved contacts	48.6%

The main focus of the 2001 survey was the use and impacts of information technologies in their operations, but some of the questions were designed to clarify and expand results found in the 1998 survey. Of particular interest was the use of Advanced Traveler Information Systems (ATIS). Other parts of the survey dealt with the perceived effects of traffic congestion on trucking operations, communication between dispatchers and drivers, company use of the Internet, and relationships to third-party logistics providers (3PLs). The average time of the computer aided telephone interviews was 17 minutes.

Differences in sample selection procedures in 1998 and 2001 led to different compositions of samples. Some of the company characteristics for the two samples are listed in Table 2. These differences highlight the importance of identifying and describing differences in survey responses among different types of trucking companies. Even if only one industry segment is targeted, say for-hire general truckload carriers, survey responses will likely be a function of the makeup of the sample according to fleet size, provision of other specialized services, location of the operation, length of loaded and empty movements, and many other characteristics. Without precise specification of the sample, descriptions of aggregate response patterns can be misleading in surveys of trucking industry representatives.

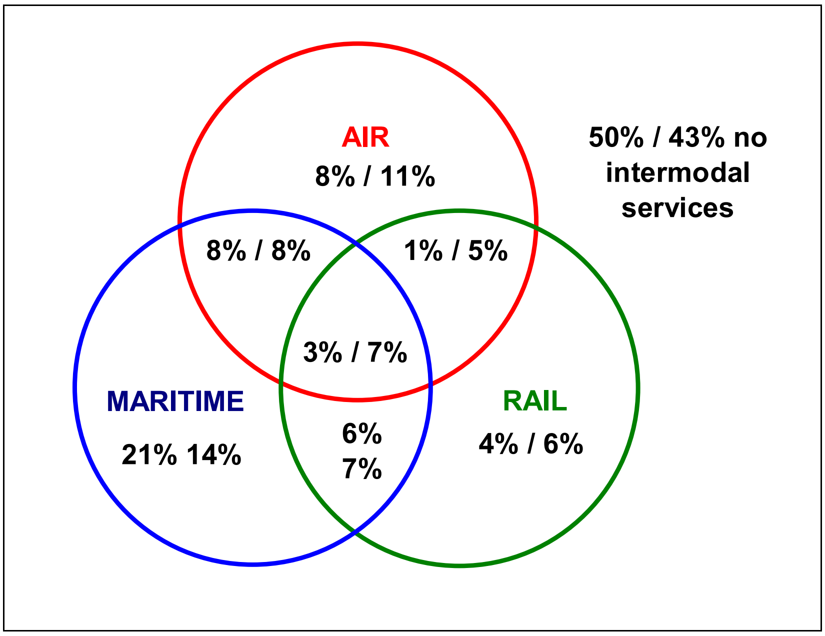
Table 2 Operating Characteristics of Companies in the 1998 and 2001 Samples

Characteristic	1998 (N=1177)	2001 (N=712)
Carrier Type		
Private fleet	34.6%	32.0%
For-hire (common) carrier	19.2%	23.9%

Contract carrier	13.5%	16.2%
Both contract and for-hire	32.7%	27.8%
Primary Type of load		
Truckload	57.3%	50.6%
Less-than-truckload (LTL)	9.3%	8.3%
Both truckload and LTL	33.5%	41.2%
Specialized services Provided		
Household goods movement	6.3%	7.1%
Tanker	9.3%	8.0%
Refrigerated	22.9%	10.1%
Bulk	19.7%	7.0%
Hazardous materials	20.0%	9.4%
High value goods	12.8%	6.4%
Size of fleet generally operated in California		
Median size of fleet	20	20
< 5 vehicles	13.8%	12.9%
> 100 vehicles	10.2%	10.0%
Length of haul		
Average loaded movements less than 25 miles	7.4%	9.3%
Median length of loaded movement	250-299 mi.	200-249 mi.
Average loaded movements 500 miles or more	37.8%	23.2%
Intermodal		
No intermodal services	49.7%	42.7%
Provides maritime intermodal service	37.8%	35.8%
Provides rail intermodal service	13.6%	24.0%
Provides air intermodal service	19.0%	30.9%
Areas of operation in California		
Statewide	53.0%	49.3%
Regional	47.0%	50.7%

Provision of intermodal services was found to be a particularly effective in explaining differences in responses among trucking company managers. As shown in Figure 2, all combinations of services are possible, and in many models it was found that interaction terms capturing the provision of multiple modes (e.g., rail and maritime) were equally significant with the main effects.

Figure 2 Intermodal Services Offered by Companies in the 1998 / 2001 Samples



4. Methodology

Attitudinal survey data can be analyzed in many ways to determine how segments of respondents – in this case types of trucking companies – differ in terms of their perceptions, opinions, preferences and choices. Commonly employed univariate statistical methods, where each model contains only one endogenous variable, include discrete choice models, other types of regressions, various tests of association between pairs of variables, and tests of differences among groups regarding central tendencies and variances. Commonly used multivariate methods include forms of simultaneous equation models, including canonical analysis and multivariate discrete choice models, log-linear model systems, multivariate analysis of variance, various types of factor analysis, cluster analyses, and types of optimal scaling. Many, but not all, of these separate analysis methods can be replaced by a single method: structural equation modeling (SEM).

SEM is designed to handle a large number of endogenous and exogenous variables, as well as latent (unobserved) variables specified as weighted averages of observed variables. Regression, simultaneous equations (with and without error-term correlations), path analysis, and variations of factor analysis and canonical correlation analysis are all special cases of SEM. It is a confirmatory, rather than exploratory method, because the modeler is required to construct a model in terms of a system of unidirectional effects of one variable on another. Each direct effect corresponds to an arrow in a path (flow) diagram. In SEM one can also separate errors in measurement from errors in equations, and one can correlate error terms within all types of errors. Readers unfamiliar with structural equation modeling (SEM) can refer to any of several comprehensive texts (e.g., Bollen, 1989; Kline, 1998; Hoyle, 1995; Mueller, 1996). An overview of SEM for application in travel behaviour research is provided in Golob (2003)

An SEM is constructed in terms of postulated direct effects between variables and optional error-term covariances of several types. Direct effects are the links between a productive variable and the variable that is the target of the effect. Each direct effect corresponds to an arrow in a path (flow) diagram. Defining which direct effects are present and which are absent specifies an SEM. Theory and good sense must guide model specification, and models must pass identification tests to enable estimation of parameters and goodness-of-fit measures. Total effects are defined to be the sum of direct effects and indirect effects, where the indirect effects represent the sum of all of the effects along the paths between the two variables that involve intervening variables. The total effects of the exogenous variables on the endogenous variables are sometimes known as the coefficients of the reduced-form equations.

Many indices are available for measuring the goodness of fit of any SEM. Several indices have established distributional properties, and many have established rules-of-thumb for acceptable values (ref. Golob, 2003). In searching for parsimonious descriptions of attitudes and behavior, criteria based on Bayesian Theory are available to for comparing the performance of models with substantially different numbers of parameters: notably, the Akaike Bayesian Information Criterion (variously abbreviated as ABIC, BIC or AIC) (Akaike, 1974, 1987), the Consistent Akaike Information Criterion, or CAIC (Bozdogen, 1987) and the Schwarz Bayesian criterion, or SBC (Schwarz, 1978).

Several methods are available to estimate parameters when a structural equations system has ordinal, discrete, or censored observed endogenous variables. One such method, asymptotically distribution-free weighted least squares (ADF-WLS), has been shown to provide estimates that have been shown to be consistent and asymptotically efficient, with asymptotically correct measures of model goodness-of-fit, for data from a broad range of distributions (Golob, 2003). ADF-WLS estimation method is described in Golob and Hensher (1998). Due to its reliance on asymptotic principles, ADF-WLS estimation requires substantial sample size. The consensus is that the minimum sample sizes for ADF-WLS estimation should be at least 1,000 (Hoogland and Boomsma, 1998).

Structural equations models with endogenous variables that are not discrete, ordinal or censored are typically estimated using the simpler normal-theory maximum likelihood (ML) method. However, ML estimation of SEM also requires a sufficient sample size, particularly when non-normal data are involved. There are several rules-of-thumb for minimum SEM sample sizes (Golob, 2003): (1) an absolute minimum sample size of 200 for any type of SEM; (2) the sample size should be at least fifteen times the number of observed variables; and (3) the sample size should be at least five times the number of free parameters in the model, including error terms; (ten times the number of free parameters with strongly kurtotic data). With a sufficient sample size, ML estimation has been shown to be fairly robust against violations of multivariate normality (Hoogland and Boomsma, 1998), and corrections have also been developed to adjust ML estimators to account for non-normality (Golob, 2003). Simulation studies have shown that corrected ML estimation can be successfully used with non-normal endogenous variables where sample sizes are insufficient for ADF-WLS estimation.

5. Impacts of Highway Congestion on Freight Operations

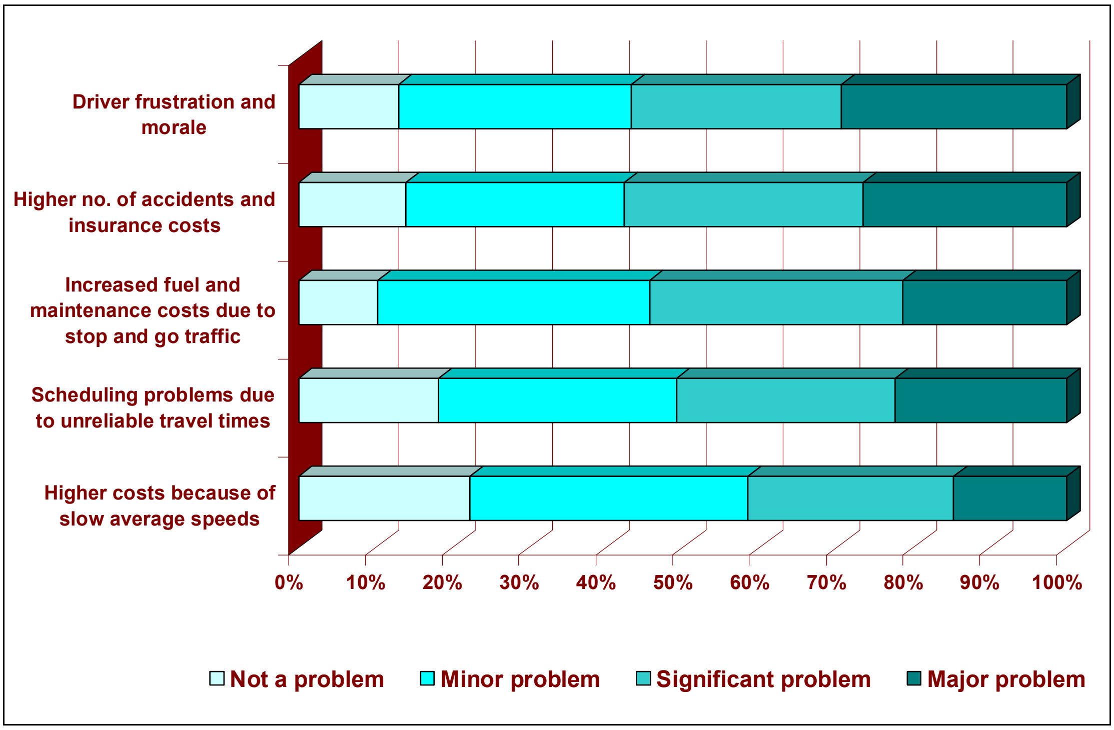
One aim of the research originally reported in Golob and Regan (2001a) was to understand to how perceptions of congestion problems differ across types of operations, such as for-hire carriers versus private carriers, truckload versus less-than-truckload (LTL) operations, various specialized services (tank, bulk, refrigerated), various lengths of loaded movements, and provision of service to inter-modal facilities (airports, seaports, and rail terminals). Another aim of this work was to determine which aspects of congestion have the greatest perceived impact on trucking operations. The aspects examined were (1) slow average speeds, (2) unreliable travel times, (3) increased driver frustration and morale, (4) higher fuel and maintenance costs, and (5) higher costs of accidents and insurance.

Managers in the 1998 Survey were asked to rate five congestion problem areas in terms of the impact of each area on the operations of their companies. Responses were collected on a four-point ordinal scale, with the categories described as "not a problem," "minor problem," "significant problem," and "major problem." Aggregate ratings of the significance of these five problem areas are shown in Figure 3. *Driver frustration and morale* and *accidents and insurance costs* stand out as major problems.

5.1. Model Specification

A multi-group structural equations model with observed variables (SEM) was used to estimate the influences of each of nine operating characteristics on each of five perceived problems, while simultaneously estimating how the five problems combine to explain a sixth endogenous variable, the perceived level of the overall problem of congestion (Golob and Regan, (2001a). Respondents rated the overall problem of congestion for their business, using a three-point scale: "not serious," "somewhat serious," and "critically serious." More than 80% of the managers of 1,177 trucking companies operating in California consider traffic congestion on freeways and surface streets to be either a "somewhat serious" or "critically serious" problem for their business. The nine operational characteristics that serve as exogenous (independent) variables are a similar to those in Table 1. By using multi-group SEM (Bollen, 1989), tests can be conducted to determine differences between responses of for-hire and private trucking companies. ADF-WLS estimation was used in which all six of the ordinal-scaled endogenous variables were treated as ordered probit submodels

Figure 3 Aggregate Ratings of Five Potential Problems Caused by Congestion



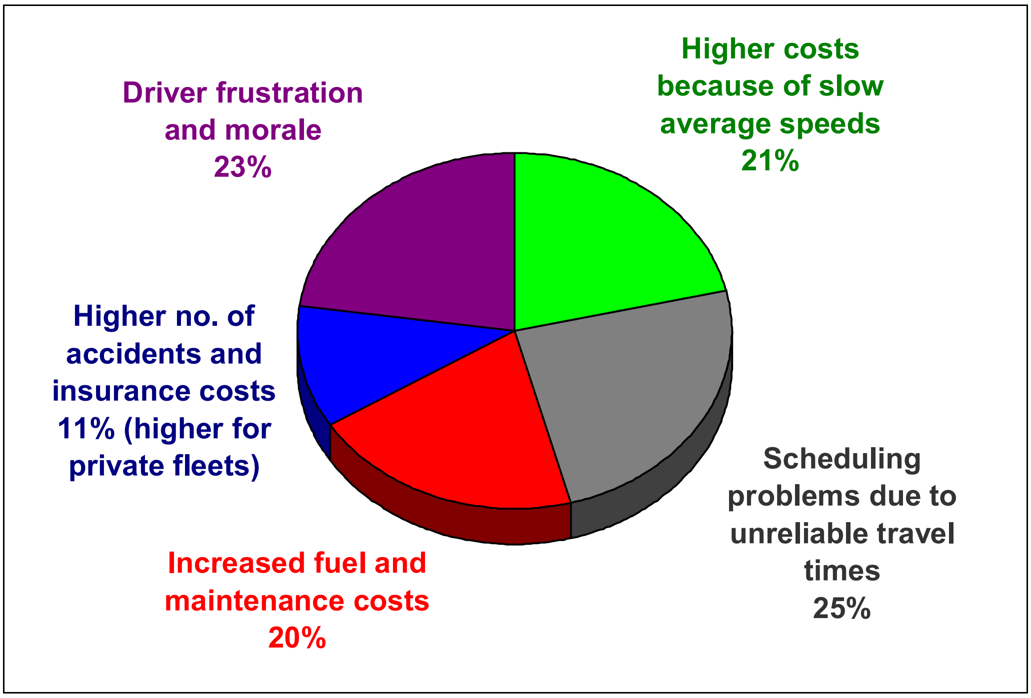
5.2. Results

The model fitted the data well and cannot be rejected at any commonly used confidence level. The 42 parameters represent six direct effects between endogenous variables, 26 regression effects for the nine exogenous effects, six error-term variances and four error-term covariances.

Results showed that road congestion is perceived to be a more serious problem by managers of trucking companies engaged in intermodal operations, particularly private and for-hire trucking companies serving airports and private companies serving rail terminals. Companies specializing in refrigerated transport also perceive congestion to be a more serious overall problem, as do private companies engaged in LTL operations.

As shown in Figure 4, the most problematic aspect of congestion is unreliable travel times. This is followed by driver frustration and morale, then by slow average speeds. Unreliable travel times are a significantly more serious problem for intermodal air operations in both the for-hire and private sectors. Unreliable travel times are less of a serious problem for bulk carriers and private carriers specializing in tanker services. Driver frustration and morale attributable to congestion is perceived to be more of a problem by managers of long-haul carriers and tanker operations, and by for-hire airport and private refrigerated operations. Slow average speeds are also more of a concern for airport and refrigerated operations, while being less of a concern for contract-only carriers and private bulk carriers.

Figure 4 Results of Structural Equations Model: Estimated Contributions to "Overall Problem of Congestion"



It is hoped that transportation planners concerned about improving the efficiency of freight operations through potential ITS and infrastructure investments can use these results to help identify sectors of the trucking industry that are most likely to benefit from and support different types of improvements.

6. Evaluations of Policies Aimed at Reducing Congestion

6.1. Model Specification

Our next model reported in Golob and Regan (2000) investigated how commercial vehicle operators view potential congestion relief policies. The policies, listed in Table 3, were presented as "ideas for relieving congestion." They were rotated from questionnaire to questionnaire in a random fashion to eliminate order bias and rated on a five-point scale, with anchors "1. Not at all effective" and "5. Very Effective." These scales are ordinal, because the inter-category difference will not necessarily be the same across categories, and the interpretation of the anchor words can vary across respondents. The potential costs of the hypothetical policies were withheld from respondents because it is not possible to accurately estimate costs without defining the extent and timing of implementation and the distribution of costs among governmental units, their constituents, and system users. Also we did not want to lead the respondents into reacting with cost as a determinant of effectiveness.

Table 3 Congestion Relief Policies Presented to Managers in the 1998 Survey

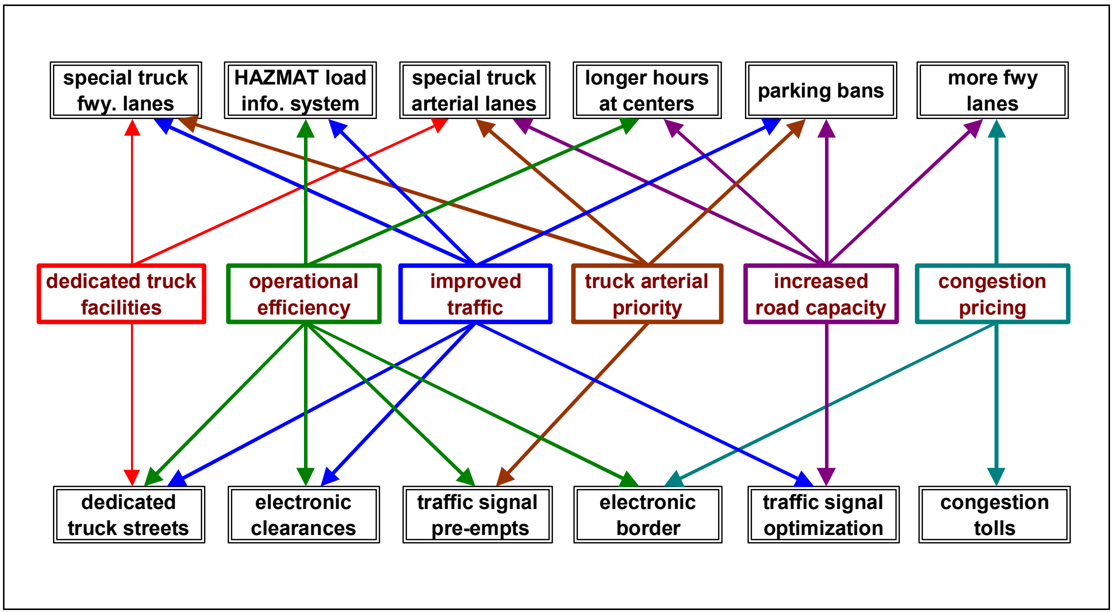
Statement Presented	Variable Label
Adding more freeway lanes wherever possible	More freeway lanes
Complete installation of electronic clearance stations	Electronic clearances
Dedicating a single freeway lane to truck traffic wherever possible	Special truck fwy. Lanes
Having longer hours at ports and distribution centers	Longer hours at centers
Imposing a toll on all vehicles travelling during rush hours	Congestion tolls
Better coordinating of traffic signals	Traffic signal optimization
Having truck-only lanes on some surface streets	Special truck arterial lanes
Having truck-only streets for access to ports, rail terminals, and airports	Dedicated truck streets
Having a real-time database of HAZMAT load information for use by emergency crews in clearing accidents	HAZMAT information system
Installing electronic clearance stations at international border crossings	Electronic border clearance
Having devices available to allow trucks to pre-empt some traffic signals	Traffic signal pre-empts
Eliminating some on-street parking during certain periods	Parking bans

Using an SEM with latent variables, we analyzed the interrelationships among the policy evaluations while simultaneously conditioning the attitudinal linkages on exogenous variables defining differences in freight operations. This is known as confirmatory factor analysis with regressor variables. Using the ADF-WLS estimation method preserves the ordinal nature of the attitudinal variables by treating the scales as ordered-response probit variables.

6.2. Results

The final model, which cannot be rejected and fits well according to goodness-of-fit rules-of-thumb, has 68 free parameters, including 21 free factor loadings, eleven errors-in-measurement variances, 30 regression parameters, and 6 errors-in-equation variances. The measurement submodel has six factors, as depicted in the flow diagram of Figure 5.

Figure 5   Flow Diagram of Measurement Submodel with Twelve Observed Congestion-mitigation Ideas (top and bottom rows) and Six Latent Policy Factors (middle row)



6.2.1. Dedicated Truck Facilities

The first of the factors was labeled as dedicated truck facilities. There are three positive factor loadings: dedicating a single freeway lane to truck traffic wherever possible, having truck-only streets for access to ports, rail terminals and airports, and having truck-only lanes on some surface streets. This set of policies is favored by smaller carriers, intermodal rail and maritime operators, and operators engaged in just-in-time deliveries.

6.2.2. Improved Operational Efficiency

The second factor is comprised of six policies: (1) longer hours at ports and distribution facilities, (2) advanced vehicle clearance systems at weigh stations and (3) international border crossings, (4) truck-only streets for access to terminals, (5) ITS devices to allow trucks to pre-empt some traffic signals, and (6) a HAZMAT load information system for in emergencies. Support for this set of Intelligent transportation system (ITS) solutions, comes from users carriers that provide any type of intermodal service, from those engaged in long haul operations, and from truckload carriers. Private fleets are less inclined to judge such policies to be effective solutions.

6.2.3. Improved Traffic Management

Improved traffic management includes, first and foremost, improved traffic signal optimization. Also included to a lesser degree are enhancements of electronic pre-clearance systems, parking bans on some streets, and a hazardous materials transportation load information data base for use in accident clearance. LTL and all small operators hold the most positive attitudes toward traffic management policies.

6.2.4. Truck Arterial Priority

Falling under industry perceptions of truck urban arterial priority schemes are policies of implementing devices for truck preemption of certain traffic signals, eliminating some on street parking during certain periods, and dedicating some arterial lanes to truck-only traffic. Special truck freeway lanes are negatively loaded on this class of policies. This class of policies is favored by common carriers, long-haul operators, and operators of household movers. Planners interested in promoting such policies should find support from these freight industry sectors.

6.2.5. Increased Road capacity

The class called "increased road capacity" is primarily indicated by the policy of adding more freeway lanes wherever possible. However, this class has four additional significant but low factor loadings, indicating that the policies of longer hours at distribution centers, traffic signal optimization, parking bans on some streets, and special truck lanes on surface streets are correlated with increased freeway capacity. Carriers with short hauls, LTL operators, and household movers are in favor of such a strategy, while long haulers private fleets, truckload and tank operators are not.

6.2.6. Class Six: Congestion Pricing

The policy of imposing a toll on all vehicles travelling during rush hours is relatively independent of all the other policies tested, but it is negatively correlated with the policy of adding more freeway lanes, and is slightly positively correlated with the policy of installing electronic clearance stations at international border crossings. Support for congestion pricing can be found among carriers who provide just-in-time pickups, short-haul carriers, and goods movers.

7. Adoption of Information Technology

Another objective of the 1998 survey was to gather information to better understand the demand for information technology among trucking companies. Information was retrieved on the extent to which each company had adopted different components of technology. The final analysis focused on seven technologies: (1) satellite or radio based communication (40.2% aggregate penetration in the 1998 sample), (2) automatic vehicle location (AVL) technologies (24.8%), (3) automatic vehicle identification (AVI) systems (16.6%), (4) electronic data interchange (EDI) (31.3%), (5) vehicle maintenance software (50.4%), (6) routing and scheduling software (51.5%), and, for a baseline comparison, (7) CB radio (14.7%).

7.1. Model Specification

Adoption of the seven technologies was modeled using SEM estimated using ADF-WLS in the form of a multivariate probit model (Golob and Regan, 2002). The exogenous influences on demand for the seven technologies from twenty trucking company characteristics are estimated simultaneously, while allowing the unexplained portions of demand (error terms) to be freely correlated. A comparison of SEM versus other means of implementing a large-scale multivariate probit model is provided in Golob and Regan (2002).

With 7 endogenous variables and 20 exogenous variables, there are 140 possible regression effects, and the error-term variance-covariance matrix has 7 variances and 21 covariances. The final model, shown to be optimal according to all of the Bayesian Information Criterion described in Section 4, has 127 parameters. Goodness-of-fit criteria indicate that the model fits the data well, and all structural parameters are significant at the $p = .05$ level.

7.2. Results

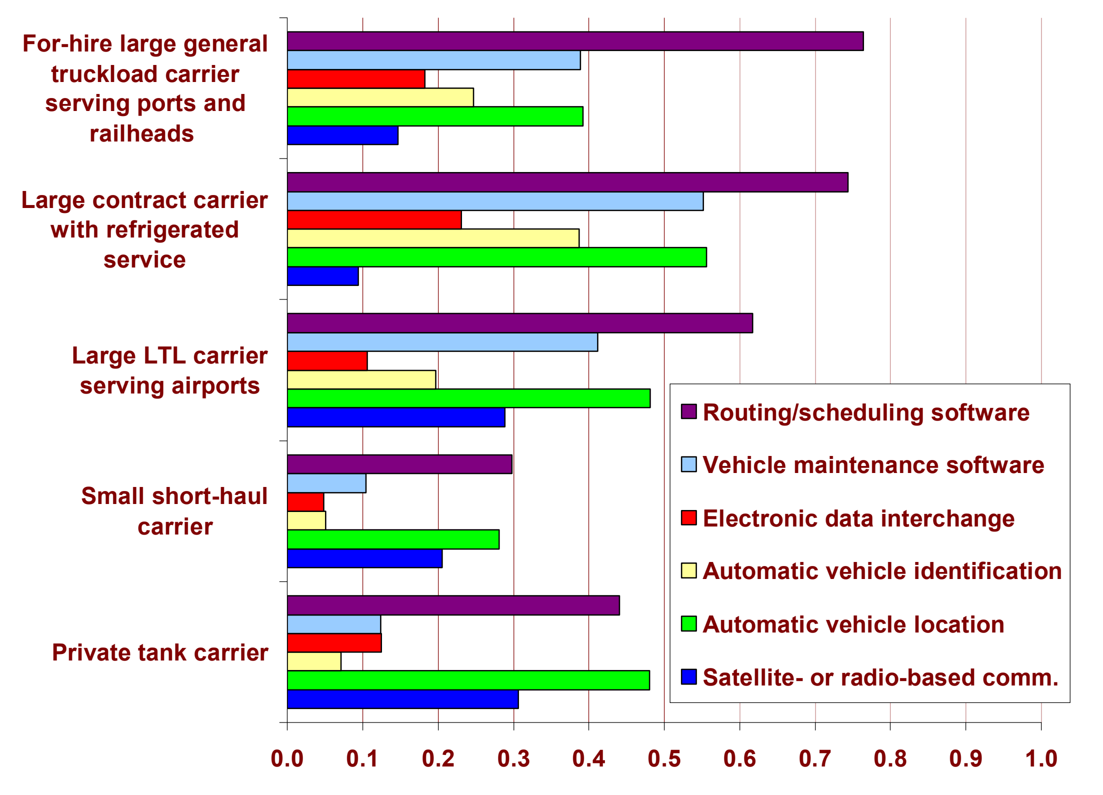
The greatest overall explanatory power resides in distinguishing private fleets. Private fleets have substantially lower levels of demand for all of the technologies with the exception of satellite and radio communication devices. The more routine operations of many private fleets negate the need for routing and scheduling technologies. Adoption of information technology is also strongly related to fleet size. Large fleets (100 or more power units typically operating in California) exhibit the greatest demand for each of the first six technology components, and small fleets (less than ten power units) exhibit the lowest demand for all technology components with the exception of EDI. For EDI, demand is lowest for mid-sized fleets.

Companies with LTL operations also exhibit consistently lower probabilities of technology adoption, unless the company is a large LTL operator with more than two terminals in California. These larger LTL carriers are more likely than smaller LTL operators to employ many of these technologies. Carriers engaged in just-in-time operations exhibit higher probabilities of adopting advanced communication devices, AVL and AVI. Short-haul carriers are less likely to adopt advanced communication devices, AVL and EDI, but are more likely to use automated routing and scheduling.

The provision of specialized services is also related to adoption of most of the technology components, particularly AVL and AVI. In particular, refrigerated services and hazardous materials services have similar effects on adoption of AVL, AVI, EDI, and routing and scheduling software. While there is some overlap of these characteristics (30% of those in our study providing reefer service also move hazardous materials while 35% of those moving hazardous materials also provide reefer service), there are also over 300 carriers in the 1998 survey that provided one type of service but not the other. Information technology is clearly important in operations that involve either of these specialized services.

The forecast probabilities that each of the five hypothetical companies are graphed in Figure 6. The model predicts the likelihood that bundles of technologies will be adopted by companies with differing characteristics.

Figure 6 Selected Forecast Demand Probabilities for Five Hypothetical Companies



8. Advanced Traveler Information Systems

An objective of the 2001 survey was to provide data for understanding the perceived benefits of different types of information that could be delivered to drivers using internet-enabled wireless devices. These types of information could be offered as part of a comprehensive advanced traveler information system (ATIS). Examples include: locations of freeway incidents and lane closures, port and rail terminal schedules and clearances, delays (queue lengths) at terminals, port facilities and international border crossings, train arrivals at grade crossings, weather, and travel times on alternative routes. Such information could be used by drivers and also by dispatchers and managers to improve efficiency through adjustments in routes and schedules. Golob and Regan (2003a) describe a model that provides policy makers and technology providers with estimates of the values placed by different types of trucking companies on different types of ATIS information.

8.1. Model Specification

Company managers were asked to evaluate the importance of nine types of information that drivers might receive or send using in-vehicle or handheld wireless devices. The question was:

"Now or in the future, drivers may receive or send information using in-vehicle or handheld Internet-enabled wireless devices. Which of the following types of information would be most important to your operation?" The interviewer elicited ratings of each of nine types of information on a four-point ordered categorical scale: "very important," "fairly important," "somewhat important," and "not important." The nine items, listed in Figure 7, were randomly rotated among surveys, and respondents were also given the opportunity to choose "don't know" as an answer for each item. Less than 2% of respondents chose "don't know."

An SEM was used to describe simultaneously how perceptions of the value of specific sources of traffic information are interrelated, and how they are related to the operating characteristics of the trucking companies. The SEM has a measurement submodel for the endogenous variables and direct effects between the latent endogenous variables. The optimal model, which cannot be rejected and fits well according to commonly used criteria, contains three latent variables (bundles of types of information), two of which are directly related. The factor structure is depicted in the flow diagram of Figure 7. The composition of each factor and its exogenous influences is discussed in the remainder of this section.

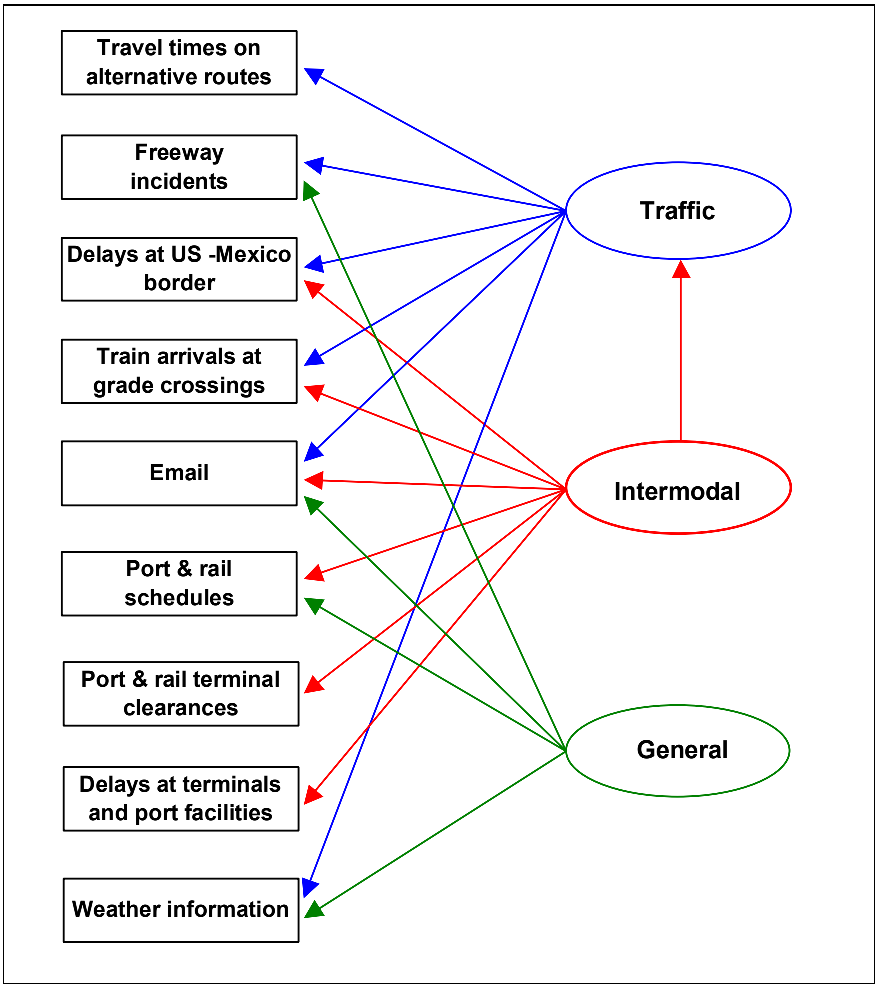
8.2. Results

8.2.1. Traffic Information

The three primary information types that make up the "traffic information bundle" are travel times on alternative routes, locations of freeway incidents and lane closures, and weather information. In addition, there is a secondary group of three: email, train arrivals at grade crossings, and delays at international border crossings.

Estimated total effects from the exogenous variables reveal that for-hire carriers place the highest value on real-time general traffic information. Provision of refrigerated, general truckload, high value, bulk, or flatbed and container services increases the value of this type of information. Conversely, private fleets LTL carriers, hazardous materials carriers, and tank carriers, all of which typically have specialized routes and schedules, exhibit lower values. As expected, companies operating in or near the three major California metropolitan areas (San Francisco, San Diego and Los Angeles) value traffic related information more than those operating exclusively outside these areas.

Figure 7 Flow Diagram of the Measurement and Endogenous Structural Components of the Structural Equation Model



8.2.2. Intermodal Information

The second bundle of services involves information important to intermodal operations: primarily port and rail terminal clearances, port and rail schedules, delays at terminals and port facilities. Also included are information about train arrivals at grade crossings, delays at border crossings, and email. The significant direct effect found from the Intermodal Factor to the Traffic Factor, means that, if intermodal information is important to a company, then so is traffic information.

Regarding intermodal information, carriers serving rail terminals are most in need of traffic information using in-vehicle or handheld wireless devices. Carriers with flatbed and container services, which are often involved in maritime operations, also place a higher value on intermodal information, as do providers of high value services which often include air cargo operations and providers of bulk cargo services, often involved in rail intermodal moves. Carriers that generally do not provide intermodal services - HAZMAT carriers, tank carriers and private fleets – naturally place lesser value on intermodal information.

8.2.3. General Information

Finally, the third bundle, labeled "general" is positively indicated by weather information and email, and negatively indicated by locations of freeway incidents and lane closures and port and rail terminal schedules. Smaller fleets place a higher value on this type of information. Many large carriers may have already invested in vehicle location and communication systems for their fleets so they have less need for the provision of such services. Finally, long-haul carriers and carriers that operate in the mountainous and desert areas between the large coastal conurbations of Southern California and the eastern border of California also value this information could be important to drivers crossing this area on long-distance runs.

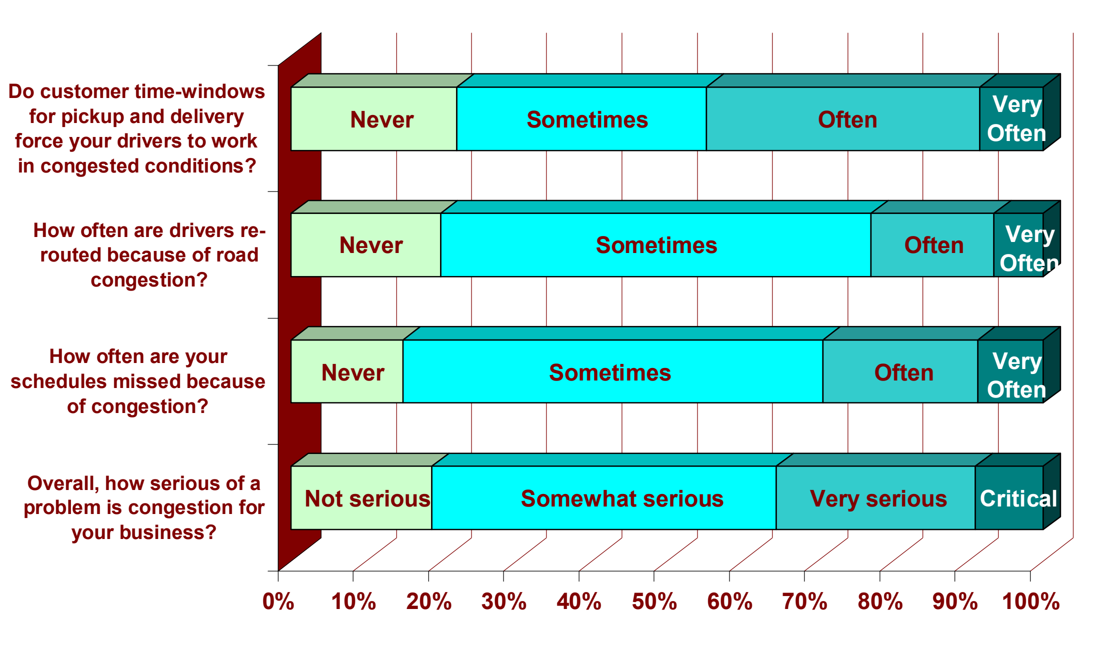
9. Demand for Automated Routing and Scheduling

Finally, in another study using data from the 2001 survey, Golob and Regan (2003b) tested relationships between managers' perceptions of the impact of traffic congestion on their operations and their companies' adoption of routing and scheduling software. One objective was to determine whether the stochastic nature of traffic congestion negates the usefulness of automated routing and scheduling, or whether automated routing and scheduling is perceived as a way of coping with problems related to congestion. A second objective was to determine how perception of the overall problem of congestion is related to the frequency of missed schedules and driver re-routing, and requirements of customers time windows.

Four of the specific survey questions that provide data for the present analysis are listed in Figure 8, which shows the aggregate response frequencies for the complete sample of 712. About 45% of managers reported that their drivers were forced, often or very often, to work in very congested traffic conditions due to customer time windows. Eighty percent said that their drivers were re-routed at least sometimes, due to congestion, and only fifteen percent reported no effects of congestion on schedules. With regard to perception of the overall problem of traffic congestion, thirty-six percent of the managers surveyed said that congestion was a serious or critically serious problem for their businesses.

The fifth variable of interest is demand for automated routing and scheduling. Just over twenty-six percent of the companies in our survey without fixed schedules use R/S software to route and re-route drivers.

Figure 8 Aggregate Responses to Questions Concerning Traffic Congestion and Routing and Scheduling



9.1. Model Specification

SEM can be used to test competing hypotheses about chains of causal effects among multiple endogenous variables. This "causal modeling" aspect of SEM reflects its roots in Path Analysis (Shipley, 2000). The series of models compared here have five observed endogenous variables and twenty exogenous variables representing trucking company operational characteristics. Each model corresponds to a different causal structure among the five endogenous variables. The fit of the models was compared using standard chi-square difference tests (in the case of nested models) and the Bayesian Information Theory criteria discussed in Section 4.

9.2. Results

9.2.1. Causal Structure

The optimal model fits the data well and implies that the degree to which customers' schedules force operators to work during congested periods causes drivers to be rerouted. These two factors combine to cause schedules to be missed. Finally, all three effects of congestion contribute to managers' feelings about the overall problem of congestion. The strongest effect is that of forced schedules on re-routing of drivers.

Regarding connections between the use of automated routing and scheduling and the four congestion-related variable, several hypotheses were tested, alone, and in combination:

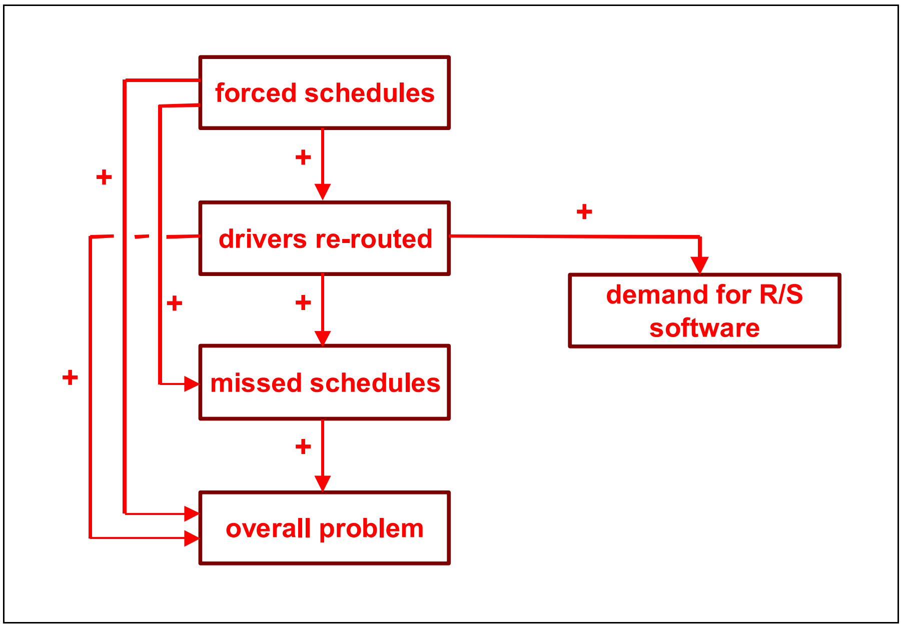
- Demand for R/S software is influenced by the necessity to operate during congested periods, because of customers' schedules.
- Demand for R/S software is influenced by the need to re-route drivers; by consequence of the structure among the first four endogenous variables, this link also implies that demand for R/S software is indirectly influenced by forced schedules.
- The re-routing of drivers is influenced by the availability of R/S software.
- Demand for R/S software is influenced by the occurrence of missed schedules, which is indirectly affected by forced schedules and the need for re-routing.
- The incidence of missed schedules is influenced by the availability of R/S software.
- Finally, managers' perception of the overall problem of congestion directly influences demand for R/S software; indirectly demand for R/S software is influenced by all of the other variables as well.

All model selection criteria unambiguously identify an optimal model in which use of automated routing and scheduling is positively influenced directly by the need to re-route drivers, and indirectly by the need, generated by customers' schedules, to operate during congested periods. The optimal model is depicted in the flow (path) diagram of Figure 9.

The result that demand for routing and scheduling software is influenced directly by the need to re-route drivers, and indirectly by the need to operate during congested periods is potentially an important finding since it reveals that uncertainty does not itself prevent companies from adopting R/S systems. The model forecasts that increased congestion will lead to increased demand for such software. This also implies that automated routing and scheduling systems can be improved by using advanced traveler information systems (ATIS) to input real-time information on traffic congestion to R/S software. ATIS are typically touted in terms of the value of direct information for drivers, but operations managers can take advantage of ATIS for dynamic R/S of multiple vehicles.

For lack of space, we leave out the discussion of the exogenous effects. Those are available in Golob and Regan (2003b).

Figure 9 Flow Diagram of the Optimal Structural Equation Model Linking Demand for Automated Routing and Scheduling with Perceptions of the Problem of Traffic Congestion



10. Conclusions

Technology developers, public agencies, research sponsors and transportation researchers alike should be well informed about the characteristics, needs and opinions of commercial vehicle operators. The trucking industry is a huge component of economies throughout the world, and the health and safety of the industry are key factor in the success of supply chains. Our research also demonstrates the usefulness of structural equations modeling for analyzing survey data over a wide variety of issues. Our research has examined issues related to technology adoption, the impacts of congestion and carrier opinions about the usefulness of ATIS efforts and investments in infrastructure.

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