Title

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ABSTRACT

This paper presents an analysis of the perceptions held by for-hire and private trucking company logistics and operations managers about the impacts of congestion on their operations and the feasibility and effectiveness of actual and potential congestion mitigation policies. Responses to an extensive survey of nearly 1200 California-based or large national carriers are examined using confirmatory factor analysis. The method applied facilitates both the grouping of congestion relief policies into classes and the identification of characteristics of companies which lead them to favor one set of policies over others. This research comes at a time when California government leaders and transportation policy analysts are struggling with key resource allocation issues that will impact the short and long term future of goods movement in the state. To the greatest extent possible, insights of CVO users of the transportation network should be included in the policy analysis process.

Key words: Freight Mobility, Commercial Vehicle Operations, Policy Analysis, Private and For-Hire Trucking, Goods Movement, Attitude Scales, Factor Analysis

INTRODUCTION

In many urban areas the impact of traffic congestion on commercial vehicle operations is increasingly problematic. This paper presents an analysis of the perceptions held by for-hire and private trucking company logistics and operations managers about the impacts of congestion on their operations and the feasibility and effectiveness of actual and potential congestion mitigation policies. Responses to an extensive survey of nearly 1200 California-based or large national carriers are examined using confirmatory factor analysis. This analysis facilitates both the grouping of congestion relief policies into classes and the identification of characteristics of companies which lead them to favor one set of policies over others. Both the raw information regarding carrier perceptions of the effectiveness of congestion relief policies and an analysis which matches sets of company characteristics with classes of policies are presented. These should be of interest to policy makers, transportation engineers and possibly, technology providers. Because of their considerable experience and continued investment of time and economic resources into traveling on urban, suburban and inter-urban transportation networks truckers would appear to be uniquely qualified to comment on the state of the transportation system. In addition, the considerable differences between trucking operations and commuter and other passenger transportation and the critical nature of the movement of freight should be taken in to account by policy analysts and transportation engineers.

This study comes at an opportune time. The California Department of Transportation is currently completing the 1998 California Transportation Plan which includes a lengthy section on goods movement strategy (California Department of Transportation, 1998). The first goal of the goods movement strategy is to "enhance California's economic vitality by improving multi-modal access and mobility for goods". Objectives under this goal are: 1. Reduce nonrecurrent delay due to accidents and other incidents; 2) Reduce recurrent delay on the transportation system; 3) Reduce the number of transportation system miles requiring immediate rehabilitation; Reduce delays at California state and international borders; Improve intermodal access and connections between airports, seaports, border crossings and rail, truck and intermodal terminals; and, to reduce physical, operating and regulatory impediments. Insights gained from this and related analyses of survey responses may be used to inform and guide the development of an implementable and successful goods movement plan -- one that takes the opinions of the users of the freight transportation network into account.

Related Studies

Several other surveys of the industry have been conducted recently. Holguin-Veras and Walton (1996) and Holguin-Veras (1999) investigated the use of information technologies in port operations through interviews with port operators and a small survey of carriers. The costs and benefits of Intelligent Transportation Systems (ITS) technologies in commercial vehicle operations (CVO) was recently investigated by the American Trucking Associations (ATA) Foundation through a survey of 700 U.S. motor carriers and 180 technology vendors. Scapinakis and Garrison (1993) conducted a small survey in 1991 regarding carriers' perceptions of a use of communications and positioning systems. Kavalaris and Sinha (1994) also surveyed trucking companies with a focus on their awareness of and attitudes towards ITS technologies. Ng *et al.* (1996) reported on responses from two nationwide surveys of 325 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 *et al.* (1995) surveyed 300 companies to determine carriers' propensity to use new technologies, particularly two-way communication and automatic vehicle location/identification technologies. Several specific studies of EDI use in the Motor Carrier Industry have also been conducted (e.g., Crum *et al.,* 1998). Hall and Intihar (1997) studied technology 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. Finally, Hensher, *et al.* (1996) and Hensher and Golob (1998) analyzed the freight industry preferences regarding alternative transportation planning policies in New South Wales, Australia. The

Hensher and Golob survey of 150 organizations was stratified by freight-industry sector: manufacturing, utilities, services, retailing, warehousing and distribution, as well as contract distribution, freight hauling, and freight forwarding.

This study extends the survey-based analyses of information technology use in the industry (e.g. Holguin-Veras and Walton, ATA, Scapinakis and Garrison, Kavalaris and Sinha, Hall and Intihar, Regan *et al.* and Crum *et al.*) and combines this the policy analysis addressed in the Hensher and Golob study. In addition, this study investigates carrier perceptions of the impact of congestion on their operations.

THE SURVEY

Protocol and Sample

During the Spring of 1998, a survey of California based (corporately located) for-hire trucking companies, California based private trucking fleets and national carriers was carried out by a private survey research company for the Institute of Transportation Studies at the University of California, Irvine. Potential respondents were drawn from a set of 5258 freight operators, from three strata: (1) 804 California based for-hire trucking companies, with annual revenues of over $1 million, (2) 2129 California based private fleets of at least 10 vehicles (power units) and (3) 2325 for-hire large national carriers not based in California with annual revenues of over $6 million. The list of companies and individual contact information was drawn from a database of over 21,000 for-hire carrier and 25,000 private fleets maintained Transportation Technical Services Inc

Questions were posed to the logistics or operations manager in charge of operations in California. The survey was conducted as a computer-aided telephone interview (CATI), with an average interview time of just over 18 minutes. The managers were asked if they were willing to participate in a survey and then the survey began, often at a later time suggested by the manager. The content of the survey was not described before the survey began. An overall response rate of 22.4% was obtained, with many of the national carriers excluded on the basis of insufficient operations in the state of California. After eliminating the contacts with no operations in California and invalid telephone numbers, the effective response rate was approximately 35%.

Respondents included a wide variety of private and for-hire companies providing both general and specialized services, interstate, statewide (California) and local operations and companies operating fleets of 1 to 6000 vehicles at a time in the state of California. Figure 1 displays the breakdown of respondents by primary type of service (truckload or less than truckload (LTL)) and type of operation, while Table 1 shows distributions of fleet sizes by three main types of fleet services in the survey sample.

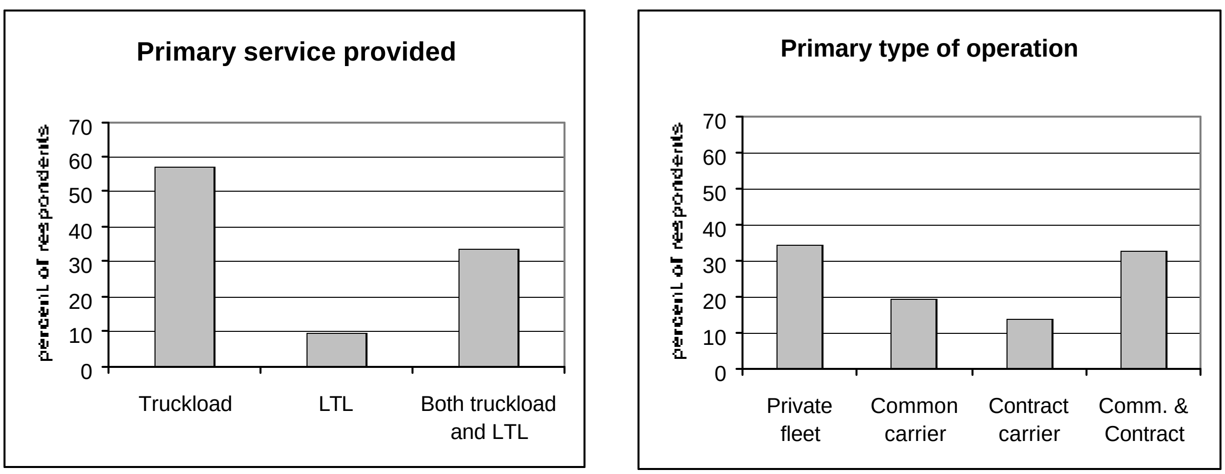

Figure 1. Primary service and type of operation

Table 1: Distribution of (California) Fleet Sizes of Respondents

Distribution of Fleet Sizes of Survey Respondents				
Power units typically operating at any one time in California	Private Fleets	For-Hire not Based in CA	For-Hire Based in CA	All Respondents
0-25	58.8%	43.2%	65.7%	58.1%
26-50	18.0%	27.7%	15.3%	19.1%
51-100	12.2%	17.0%	7.3%	11.2%
101-150	6.3%	8.1%	4.8%	6.1%
201-500	3.2%	3.0%	3.6%	3.3%
Greater than 500	0.2%	0.7%	1.2%	0.8%

Non-response analyses were conducted for each of the three strata from which the sample was drawn. Aside from contact information, for for-hire fleets based in California and for large national for-hire fleets we knew the previous years' annual revenue, the year the companies' operations began, and the average number of power units in the total fleet. For the private fleets we had an estimate of the number of power units in operation and the standard industrial classification code (SIC) of the company. Results for the California for-hire stratum are listed in Table 2. There are no statistically significant differences between respondents and non-respondents on any of the three criteria. Similarly, there were no significant differences between respondents and non-respondents on any of the criteria for the national for-hire stratum (Table 3). In terms of mean revenue and fleet size, larger national carriers responded more than their smaller counterparts, but the substantial variations and comparisons of means and medians shows that the means are influenced by a few very large companies. Most of these very large national carriers will have sufficient operations in California to respond to the survey.

Table 2: Fleet Characteristics of Survey Respondents and Non-respondents for the California For-Hire Sample Stratum

		Revenue ($millions)	Years in business	Power units
Respondents	Mean	7.62	28.0	83.1
	Median	3.00	23	25
	Std. deviation	28.78	17.9	597.8
	N	271	258	271
Non-respondents	Mean	6.19	25.9	52.4
	Median	2.75	21	25
	Std. deviation	12.99	17.1	118.4
	N	533	491	533
F-statistic		0.94	2.38	1.30
Probability		0.332	0.123	0.254

Table 3: Fleet Characteristics of Survey Respondents and Non-respondents for the Large National For-Hire Sample Stratum

		Revenue ($millions)	Years in business	Power units
Respondents	Mean	61.8	27.6	364
	Median	14.1	23	113
	Std. deviation	428	18.1	1589
	N	496	460	496
Non-respondents	Mean	38.3	30.5	249
	Median	11.0	23	94
	Std. deviation	294	51.7	1380
	N	1833	1696	1834
F-statistic		2.02	1.37	2.55
Probability		0.155	0.242	0.111

Results for the private fleet stratum are given in Tables 4 and 5. There were no significant response bias in terms of fleet size (Table 4). However, the relationship between response and business type is significant at the $p = .038$ level (Table 5). This is mainly due to a higher response rate for the wholesale trade sector and lower response rates for the agriculture and construction sectors. Because this bias is not significant at the p = .01 level, it is not deemed too serious of a concern.

Table 4: Fleet Characteristics of Survey Respondents and Non-respondents for the California Private Fleet Sample Stratum

		Power units
Respondents	Mean	58.6
	Median	28
	Std. Deviation	131
	N	410
Non-respondents	Mean	70.4
	Median	29
	Std. deviation	263
	N	1722
F-statistic		0.79
Probability		0.375

Table 5: Standard Industrial Classifications of Survey Respondents and Non-respondents for the California For-Hire Sample Stratum

	Respondents		Non-respondents	
Agriculture, forestry, fisheries	32	(16.5%)	162	(83.5%)
Construction industries	103	(16.5%)	520	(83.5%)
Manufacturing	76	(21.5%)	277	(78.5%)
Transportation, communication, utilities	19	(18.4%)	84	(81.6%)
Wholesale trade	95	(25.1%)	284	(74.9%)
Retail trade	49	(18.7%)	213	(81.3%)
Service industries	34	(18.4%)	151	(81.6%)
Total	408		1691	
Chi-square		13.37		
Degree of freedom		6		
Probability		0.038		

Survey Content

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. Each of these four sections of the survey is briefly described below.

1. Traffic congestion

This section included questions about carriers' perceptions about the impact of traffic congestion on their operations, followed by questions about the effectiveness of potential means of reducing congestion.

2. Use of Technologies

Questions were asked to elicit information on carriers' use of technologies including mobile communication devices, EDI, AVL, an electronic clearance system (PrePass$_{TM}$), as well as publicly available traffic information updates. Some questions asked the respondents to rate the usefulness of various technologies and information sources.

3. Use of and satisfaction with intermodal facilities in California

Carriers' use of maritime, rail and air intermodal facilities was investigated. Questions were asked about typical delays and the predictability of the time required for pickup and delivery of loads to these facilities. Respondents were also invited to describe the types of problems they face in operating at intermodal facilities.

4. Operational characteristics

The remaining questions asked about the operational characteristics of the companies. Of interest are the types of services offered, the average length of haul, time sensitivity of the operations, the locations of the main terminals and the fleet size. We were careful in this section not to ask questions that involved company proprietary information. The broad goal of this study was to obtain information on all of the subjects listed above from a large enough sample of the California trucking companies so that no industry segments would be left out. A follow-up study, in which a much smaller number of companies will be contacted will ask more cost and revenue related questions that we feared would have significantly increased the non-response rate.

This analysis is concerned with the first set of questions and with the operational characteristics of companies. Some summary statistics regarding the overall impact of congestion on truckers' operations are presented in the next section, while detailed analyses are presented in Regan and Golob (1998), which provides a descriptive analysis of the whole of the survey. In related analyses, Golob and Regan (1998) present a model of commercial carrier demand for information technologies.

IMPACTS OF CONGESTION

When asked how serious a problem congestion is for their business, only 18% of the respondents said that congestion was not a serious problem while 64% and 18% respectively, feel that congestion is a somewhat serious or critically serious problem (Figure 2). While many different problems may be attributable to congestion, missed schedules is one that affects both carriers and their customers -- sometimes with significant associated costs. Nearly 27 percent of the companies surveyed suffered missed schedules often or very often due to congestion while only 11 percent of company spokespersons specified that schedules were never missed due to congestion (Figure 3).

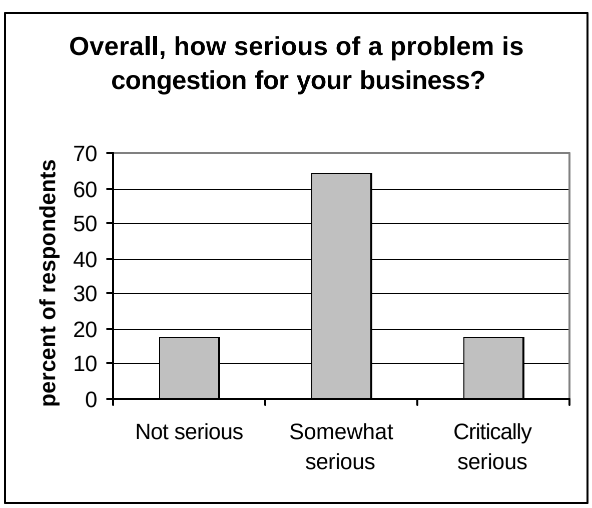

Figure 2: Impact of congestion on operations

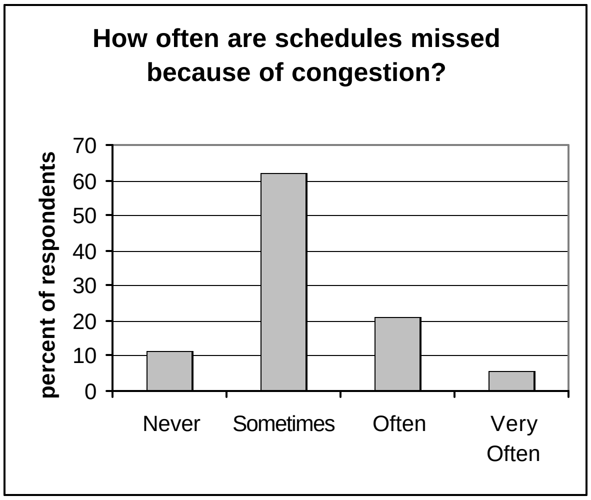

Figure 3. Regularity with which schedules are missed due to congestion

When asked what they thought congestion on freeways and surface streets would be like in the next five years, freight operators are not optimistic about the future. As shown in Figure 4, over 85% of the respondents believe that congestion will get worse in the next five years, while 10% said it would be about the same and less than 3% said it would get better.

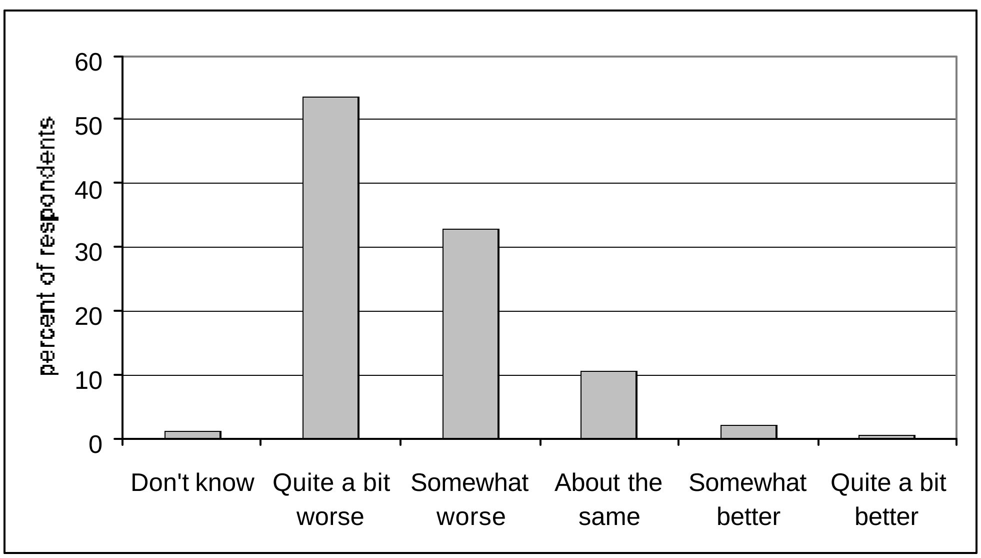

Figure 4. Freight operators' projections about future congestion

THE DATA FOR THE MODEL

Our objective in the research reported here is to determine how segments of the trucking industry in California perceive and support policies aimed at reducing the effect of congestion on freight operations. Twelve hypothetical congestion-relief policies, gleaned from discussions with transportation planners and researchers and from public policy documents (e.g., Caltrans, 1998) were presented to the nearly 1,200 survey respondents representing for-hire and private carriers operating in California. In the next two sections we describe the attitudinal data and the data used to capture differences among types of freight operations. Then we describe the methodology used to analyze these data.

The Hypothetical Congestion-Relief Policies

Respondents were asked to rate each of the twelve congestion-relief policies, couched as "ideas for relieving congestion," on a five-point scale, with anchors "1. Not at all effective" and "5. Very Effective." The policies, listed in Table 3, were rotated from questionnaire to questionnaire in a random fashion to eliminate order bias. The potential costs of the hypothetical policies were purposely withheld from the respondents for several reasons: First, 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. Second, we did not want to lead the respondents into reacting with cost as a determinant of value. And third, it was infeasible to go into detail without substantially lengthening the telephone interview and subsequently increasing non-response.

The scales on which the responses were recorded are ordinal in nature. In comparing a respondent's ratings of two policies on the five-point scale from "1. Not at all effective" to "5. Very Effective," if one policy is given a higher value than the other, we can conclude that the respondent judges the policy with the higher value to be more effective. However, the difference between a rating of 5 and a rating of 4 will not necessarily be the same as the difference between any other two adjacent scale values. Moreover, the interpretation of the anchor words and the general use of the scales will vary across respondents. For all of these reasons, we avoid using parametric statistics (i.e., statistics based on means and standard deviations that are based on arithmetic operations on the raw scale data) in analyzing these data (Siegel, 1956). Instead, we use methods specifically designed for ordinal scale variables.

Table 6: Congestion relief policies presented to respondents.

Statement Presented	Variable Label
Adding more freeway lanes wherever possible	More freeway lanes
Complete installation of electronic clearance stations (like PrePass©)	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 load info. 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

Response frequencies for the first four congestion-relief policies are graphed in Figure 5A. While adding more freeway lanes wherever possible received strong support, spokespersons' reactions to the other three policies were more mixed. In particular, less than 40% of the respondents felt that completing installation of electronic clearance stations would be "very effective." It is highly likely that support for such a policy is contingent upon the characteristics of each company's freight operations. For example, the spokespersons for companies who reported an average loaded movement of greater than 500 miles were much more likely to view the installation of electronic clearance stations as effective. Similarly, those representing companies reporting an average loaded movement of less than 25 miles tended to respond more negatively to this policy.

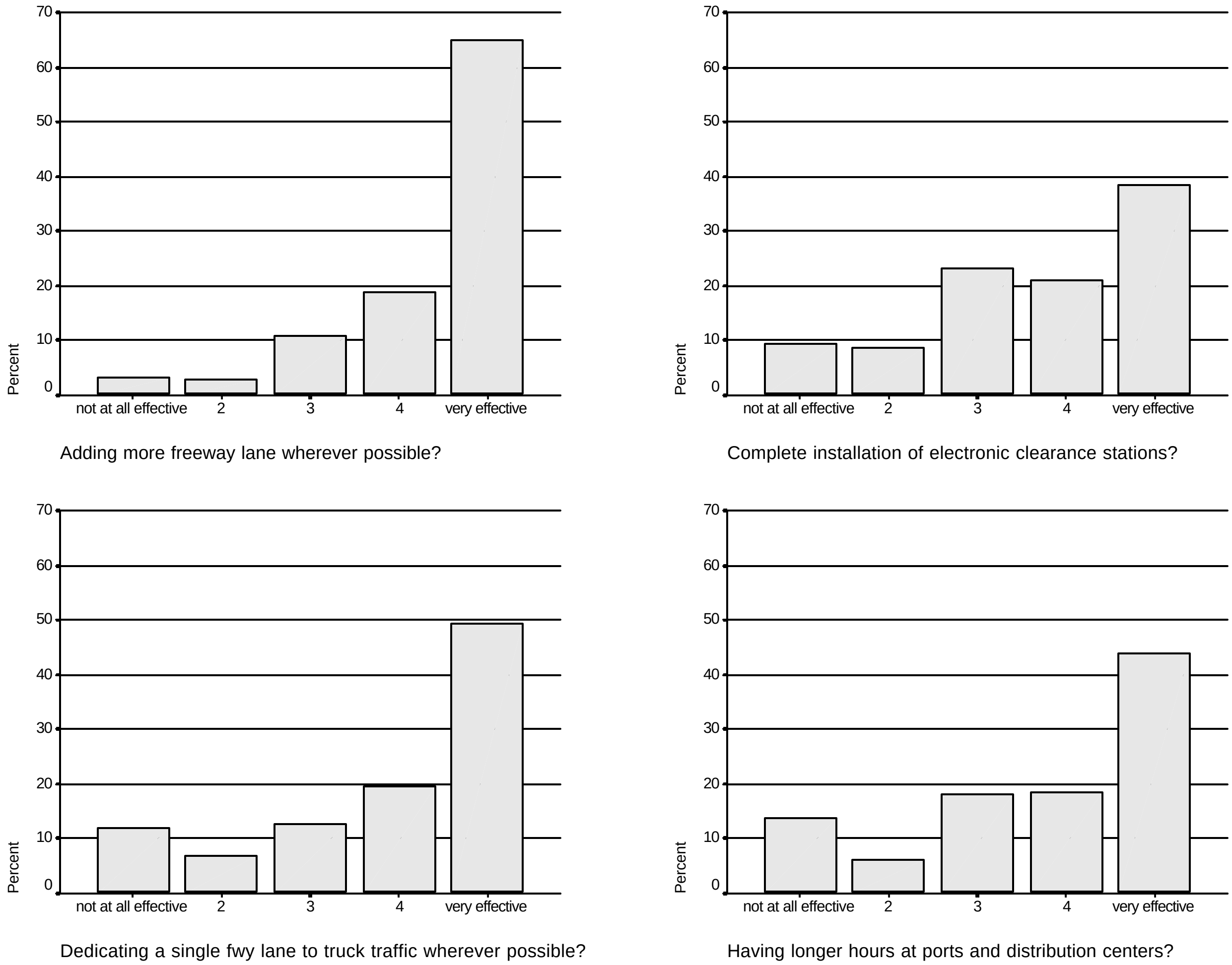

Figure 5A: Aggregate effectiveness ratings of congestion-relief policies, part 1

Both contract and common carriers responded favorably to the policy related to longer hours at distribution centers, while private carriers (who presumably have more control over the hours at the distribution centers they serve) displayed rather neutral responses. Representatives of carriers with long average loaded movements responded even more favorably to this alternative than general common or contract carriers. Understandably, carriers representing companies that provided service to intermodal terminals were much more likely than the average respondent to favor longer hours at distribution centers and terminals. However, it was not readily apparent how company characteristics were related to responses with regard to dedicating freeway lanes to truck traffic.

The frequencies for attitudes towards the next four congestion-relief policies are graphed in Figure 5B. Imposing a (congestion pricing) toll on all vehicles travelling during the rush hours was judged to be “not at all effective” by almost 60% of the respondents. However, a substantial minority of respondents, approximately 30%, rated the policy neutral or on the effective side of neutral. While there was no single characteristic that strongly predisposed respondents to congestion pricing, companies with less than five vehicles and those with short loaded movements (average loaded move < 25 miles) were more in favor of imposing a toll than others.

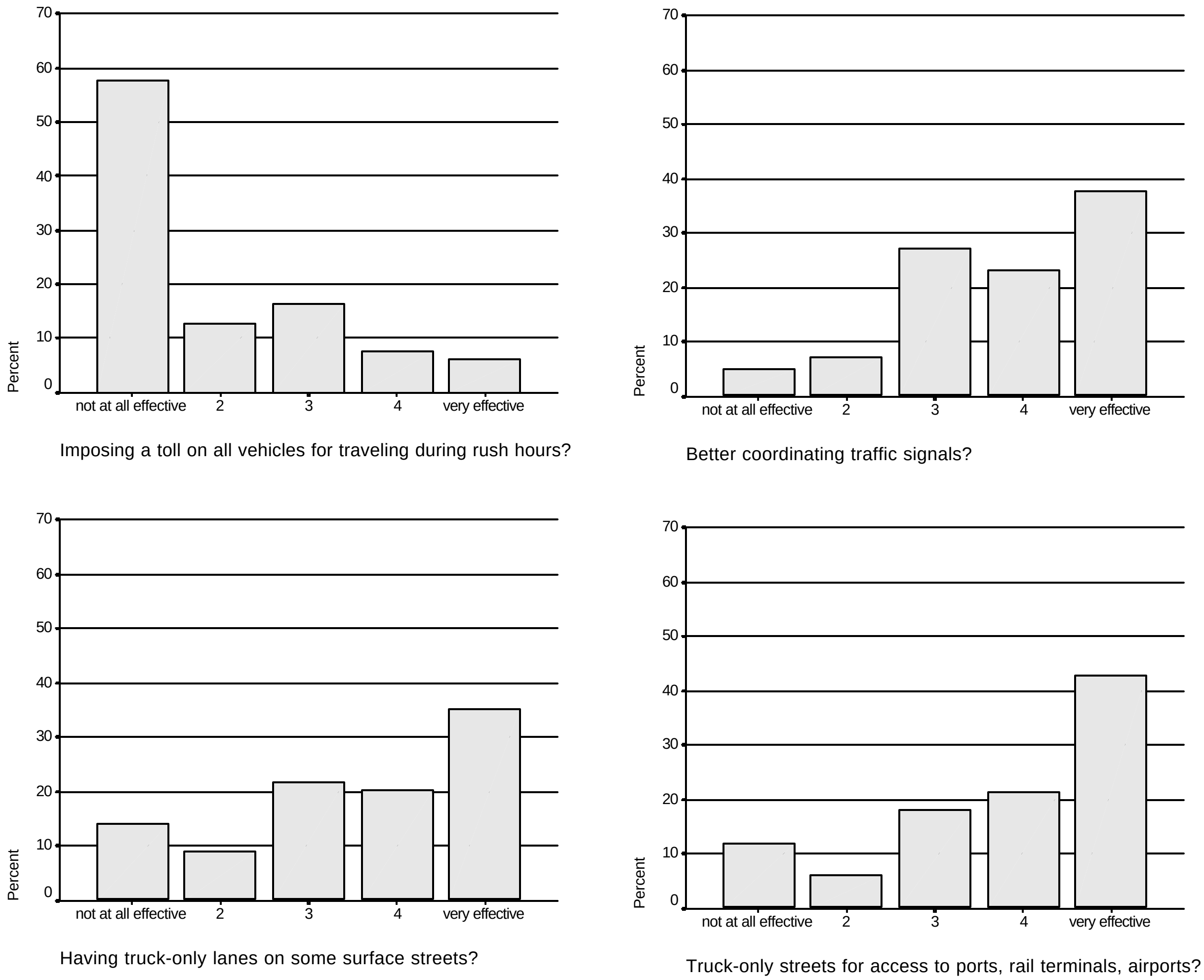

Figure 5B: Aggregate effectiveness ratings of congestion-relief policies, part 2

The aggregate ratings for the final set of policies are shown in Figure 5C. Again, company characteristics were in some instances strongly correlated to responses on some of these congestion mitigation alternatives. Carriers with short loaded movements tended to favor having a real-time database of information about hazardous materials movements. Companies with long average loaded moves tended to favor truck traffic signal preemption, a surprise, since these operators spend much of their time on major freeways.

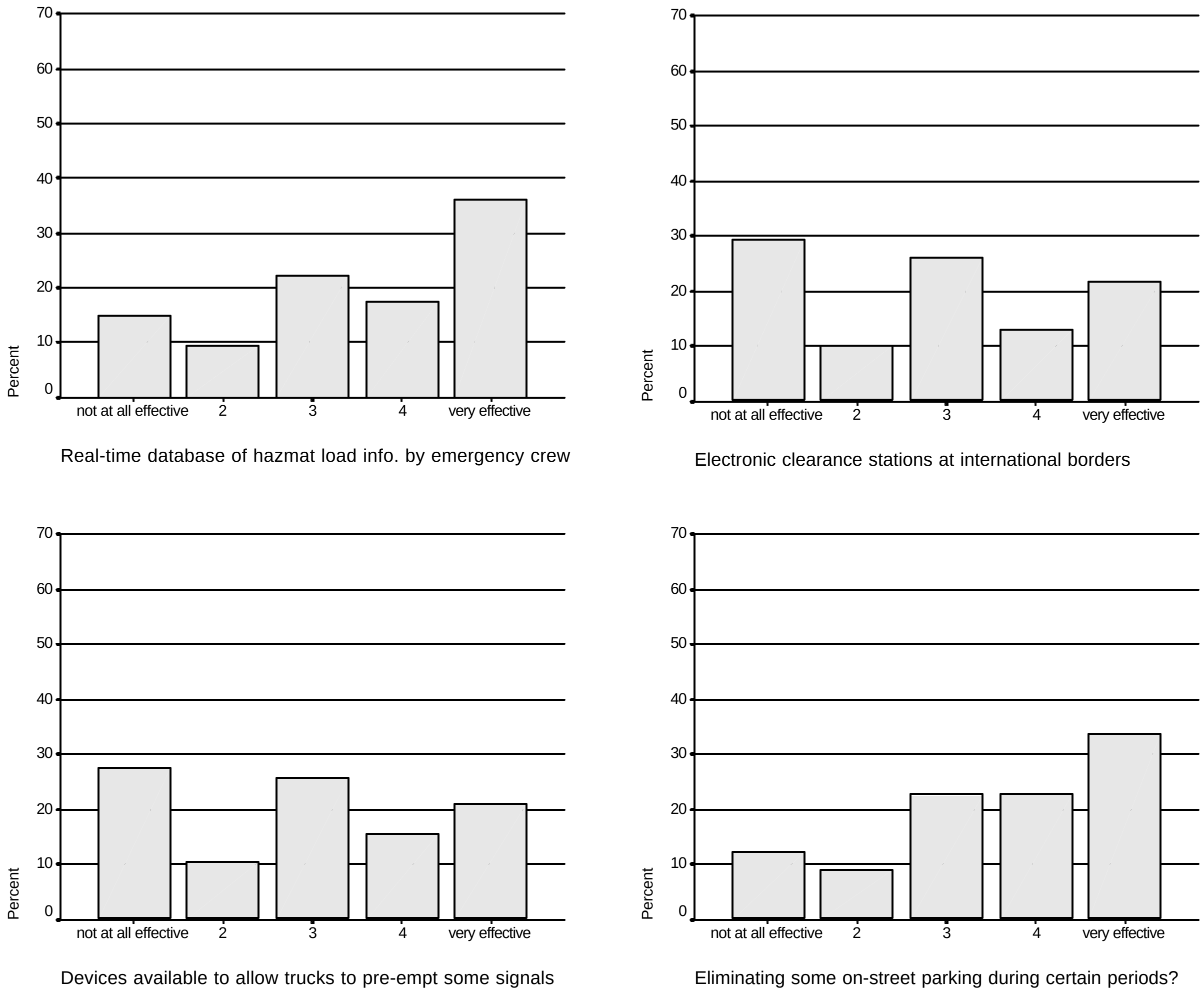

Figure 5C: Aggregate effectiveness ratings of congestion-relief policies, part 3

The aggregate frequencies for each of the policy evaluations, presented in Figure 5, will not present an accurate picture of carrier attitudes if there exist differences in attitudes across respondents that are related to carrier characteristics and if the survey sample does not represent all types of carriers in proportion to their incidence in the population. It can be expected that attitudes towards classes of these policies will be explained by characteristics of their carrier's operations, because different operations face different problems. Secondly, there are no accurate population statistics available on which to weight the sample. Thus, our analysis of similarities and differences among attitudes towards the separate policies will need to be conditional upon variables defining carrier operations, which are described next.

Characteristics of Freight Operations

Many variables can be defined to characterize the freight operations of each respondent's company. However, we found only fifteen exogenous variables defining freight operations to be effective in explaining differences in attitudes towards the twelve congestion relief policies. These exogenous variables are listed in Table 7.

Table 7: The exogenous variables

Variable	Variable Label
Engages in less than truckload operations	LTL operator
Private fleet	Private fleet
Engages in common carrier operations	Common carrier
Engages in contract operations	Contract carrier
Engages in general truckload operations	Truckload
Primary service = household goods movement	Mover
Primary service = tank trucks	Tanker
Number of power units typically operated in CA < 10	Small operator
Logarithm of number of power units typically operated in CA	Ln(size)
Picks up at or delivers to rail terminals in CA	Inter-modal rail
Picks up at or delivers to airports in CA	Inter-modal air
Picks up at or delivers to maritime ports in CA	Inter-modal port
Average loaded movements less than 25 miles	Short hauls
Average loaded movements 500 miles or more	Long hauls
100% of loads known less than four hours before pick-up	Just in time

METHODOLOGY

Freight industry spokespersons are likely to judge some of the congestion-relief policies presented to them similarly, either because they feel that certain ideas have comparable merit, or because they perceive two or more ideas to be components of a larger, more comprehensive policy. Each spokespersons attitudes should also be a function of the industry sector of their company, because each sector in general faces different problems. Thus, we expect significant rank-order correlations between many pairs of presented policies, but we expect these correlations to be conditional upon variables defining the freight industry sector.

Using a simultaneous equations system 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 approach is known as confirmatory factor analysis with regressor variables. The resulting model system can be estimated using a method that preserves the ordinal nature of the attitudinal variables.

Confirmatory factor analysis (Jöreskog, 1969; Bollen, 1982) is similar to conventional exploratory factor analysis methods, such as principal components analysis, in that latent variables (called factors, in this analysis representing policy classes) are defined as linear combinations of observed variables in an attempt to reduce the dimensionality of the data in a manner that preserves as much of the variation in the original variables as possible. With principal components analysis, the solution involves extracting the latent roots and vectors (eigenvalues and eigenvectors) of the correlation or variance-covariance matrix of the observed variables. The resulting latent factors are defined as linear combinations of all of the observed variables. The solution space can be rotated so that the coefficients of the linear functions defining the latent variables (the factor loadings) are easier to interpret, but the factors are always functions of all of the observed variables. In confirmatory factor analysis, the analyst specifies *a priori* which observed variables go into the makeup of each factor, and each factor loading has a standard error so its significance can be assessed. The factor loadings of all observed variables that are not indicators of that factor are structurally zero. Exploratory factor analysis is typically used to guide specification of initial structures. Readers not interested in the details of the model estimation are invited to skip ahead to the section entitled Congestion Mitigation Policies as Perceived by Freight Operators

Methodological Details

Confirmatory factor analysis with ordinal-scaled observed variables was pioneered by Muthén and Kaplan (1985) and Rigdon and Ferguson (1991). It was used by Golob and Hensher (1998) to model commuters attitudes concerning greenhouse gas reduction policies. However, with ordinal observed variables, in the method used to estimate the parameters of the structural equations system, the standard errors of the parameters and the overall goodness of fit of the system must respect the non-normal distributional properties of the error terms of the dependent variables correctly in order to minimize biases in hypothesis tests. Structural equations models with latent variables, estimated using asymptotically distribution free weighted least squares (ADF-WLS) is the appropriate method to deal with this problem (Muthèn, 1984).

Any structural equations model system with latent variables is defined by at least one measurement submodel and a structural submodel. The measurement submodel explains the observed dependent variables, denoted by the (p by 1) column vector y, in terms of m < p latent factors, denoted by the (m by 1) column vector η. The non-zero parameters in the (p by m) Λ matrix are equivalent to factor loadings in conventional principal components analysis.

$$y = \Lambda \eta + \varepsilon . \qquad (1)$$

The unexplained components of the observed dependent variables (measurement errors) are defined by the (p by 1) "error" vector ε, which has a (p by p, symmetric) variance-covariance matrix given by

$$\Theta = E\left[\varepsilon \varepsilon'\right]. \qquad (2)$$

The structural submodel, which captures the regressions of the latent variables on the exogenous variables, is defined by

$$h = G\mathbf{x} + x, \tag{3}$$

in which the m factors are regressed on the q exogenous variables (denoted by the column vector x). The m ξ error terms, capturing the unexplained portions of the latent variables (the errors in equations), have a variance-covariance matrix given by

$$Y = \mathbf{E}(xx'). \tag{4}$$

The parameters to be estimated are those elements of the Λ and Γ structural matrices and the Θ and Ψ error term variance-covariance matrices defined to be non-zero according to our hypotheses. Estimation and hypothesis testing of the system defined by matrix equations (1) through (4) is accomplished using the ADF-WLS method that is described in the transportation research literature by Golob and Hensher (1997) and Golob and McNally (1995). The method proceeds in three distinct steps. First, ordered-response probit models (Aitchison and Silvey, 1957, and Ashford,1959) are applied to the ordinal attitude scale variables. The second step is to obtain estimates of the polychoric correlations (Olsson, 1979) between each pair of ordinal variables and the polyserial correlations (Olsson, *et al*., 1982) between each ordinal variable and each continuous exogenous variables. Of course, the matrix of ordinary Pearson product-moment correlations among the exogenous variables, denoted by Φ, is taken as given.

The final step in the ADF WLS method is to estimate the parameters in the Λ, Γ, Θ and Ψ matrices of system (1) using the method of moments. It can be easily shown that the partitioned variance-covariance matrix of a combined set of observed dependent and exogenous variables (with the p dependent variables ordered first) implied by system (1) - (4) is

$$\sum(q) = \left[\begin{array}{c|c} L_{\mathbf{y}}\left[(I-\mathbf{B})^{-1}(G\,F\,G' + Y)(I-\mathbf{B})^{-1'}\right]L_{\mathbf{y}}' & \mathbf{A}' \\ \hline F\,G'(I-\mathbf{B})^{-1'}L_{\mathbf{y}}' = A & F \end{array}\right]. \tag{5}$$

The free parameters in the Λ, Γ, Θ and Ψ matrices are determined by making the model-implied covariance matrix Σ as close as possible to the sample covariance matrix, S, where S is composed of polychoric and polyserial correlation coefficients determined in the previous step of the estimation. The fitting function for WLS is

$$F_{WLS} = [s - s(q)]' W^{-1} [s - s(q)]. \tag{6}$$

where **s** is a vector of product-moment, polychoric, and polyserial correlation coefficients for all pairs of variables, $s(q)$ is a vector of model-implicated correlations for the same variable pairs. W is a positive-definite weight matrix that is a consistent estimator of the asymptotic covariance matrix of **s**:

$$W = ACOV(s_{ij}, s_{gh}) = 1/n\,(\sigma_{ijgh}, - \sigma_{ij}\sigma_{gh}), \tag{7}$$

where σ_{ijgh} denotes the fourth-order moments of the variables around their means, and σ_{ij} and σ_{gh} denote covariances.. Minimizing F_{WLS} implies that the parameter estimates are those that minimize the weighted sum of squared deviations of s from $\sigma(\theta)$. This is analogous to weighted least squares regression, but here the observed and predicted values are variances and covariances rather than raw observations.

Browne (1982, 1984) demonstrated that F_{WLS} with such a weight matrix will yield consistent estimates which are asymptotically efficient with asymptotically correct covariances (leading to correct parameter z-statistics), and the model fit will produce correct chi-square test values. We cannot use normal-theory maximum likelihood estimation, which is usually used in structural equation modeling, because the assumptions underlying this method do not hold for ordinal and dichotomous variables. Normal-theory maximum likelihood estimation in our case will yield consistent estimates but incorrect standard errors and C^2 statistics.

We used the LISREL/PRELIS (versions 8/2) software package to implement this ADF-WLS estimation (Jöreskog and Sörbom, 1993). Other software packages are available.

RESULTS

Model Fit

The chi-square value for the model estimated using the ADF-WLS method is 202.25 with 190 degrees of freedom. This corresponds to a probability value of *p* = .0258, which means that the fitted model cannot be rejected at the *p* = .05 level (Bollen, 1989). The model has 68 free parameters, including 21 free factor loadings in the L matrix of structural equation (1), 11 errors-in-measurement variances in the Θ matrix of equation (2), 30 regression parameters in the G matrix of structural equation (3), and 6 errors-in-equation variances in the Y matrix of equation of equation (4). Almost all structural parameters are significant at the *p* = .05 level. A few parameters were significant at a lower confidence level, but these were needed for model identification purposes

Measurement Submodel

Based on results from an exploratory principal components analysis, we chose a measurement submodel with six latent variables. The measurement submodel factor structure is thus defined in terms of the non-zero parameters of a (12 by 6) lambda (factor loadings) matrix in equation (1). The lambda matrix was found to have 27 non-zero parameters by which the six factors explain the twelve observed variables as indicators of the latent attitudinal variables. A flow diagram of this structural submodel is shown in Figure 6.

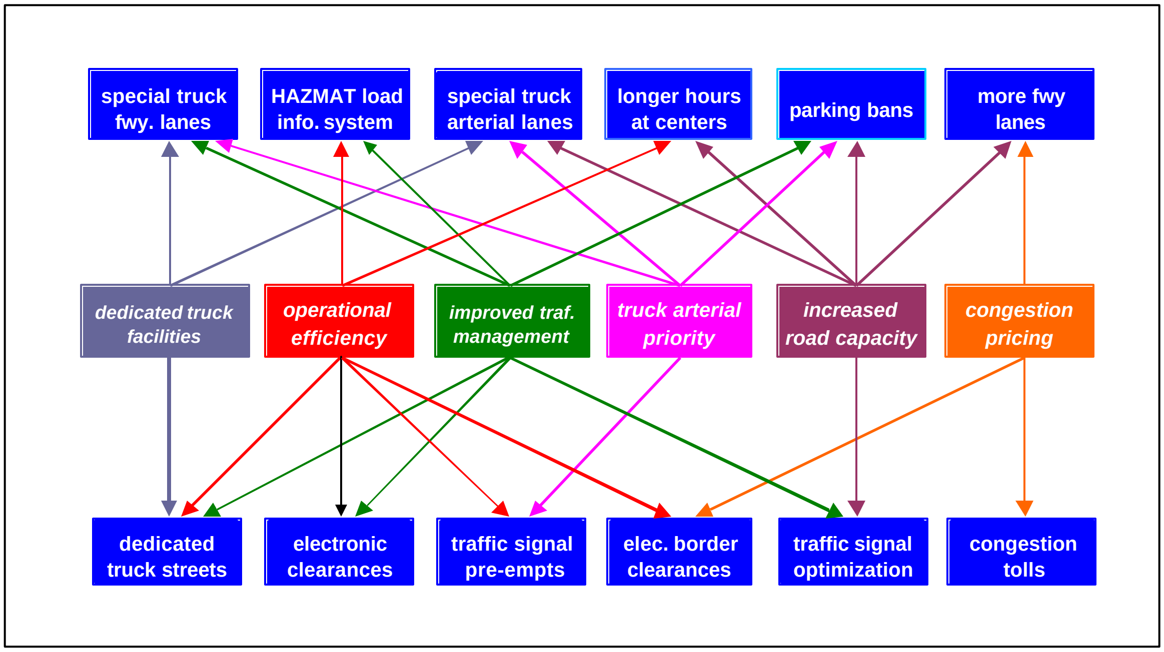

Figure 6: Flow diagram of measurement submodel
(variables in top and bottom ranks are observed variables, those in the middle rank are that latent variables – factors - that explain the observed variables)

The diagonal elements in the Θ variance-covariance matrix in equation (2) are free parameters in the estimation, and these in turn provide estimates of the overall explanation of each of the twelve observed dependent variables in terms of the six factors. The resulting R^2 values are listed in Table 8. The R^2 value for one of the observed variables, congestion tools, is not identified, because the variable is loaded on only one factor and is thus indistinguishable from that factor. For the other observed variables, the R^2 values range from a low of 0.09 for hazmat load information system to a high of 0.87 for special truck arterial lanes.

The lambda matrix parameters and their asymptotic *z*-statistics are listed in Table 9. For each latent variable, one factor loading must be set equal to unity in order to set the scale of the factor. Thus, while there are 27 links in Figure 6, there are 21 (= 27 – 6) estimated free parameters and six fixed parameters in Table 9. We refer to these factors as congestion mitigation policy *classes* because they are used to group congestion relief policies into classes.

Table 8: Percent variance of each observed variable accounted for by the factors

Observed dependent variable	R^2
More freeway lanes	0.74
Electronic clearances	0.33
Special truck fwy. Lanes	0.49
Longer hours at centers	0.38
Congestion tolls	--
Traffic signal optimization	0.49
Special truck arterial lanes	0.87
Dedicated truck streets	0.56
HAZMAT load info. System	0.09
Electronic border clearance	0.34
Traffic signal pre-empts	0.18
Parking bans	0.22

Congestion Mitigation Policies as Perceived by Freight Operators

Six distinct classes, or natural groupings of congestion mitigation policies were identified as factors. We discuss each of the classes in terms of their composite individual policies identified by the factor loadings of Table 9.

Table 9: Measurement submodel explaining the observed variables in terms of the factors (z-statistics in parentheses)

	Policy class factor					
Observed variable	h_1	h_2	h_3	h_4	h_5	h_6
More freeway lanes					1.000	**-.138 (-4.15)**
Electronic clearances		0.893 (9.06)	0.428 (4.88)			
Special truck fwy. Lanes	0.700 (9.74)		**-.404 (-3.69)**	**-.633 (-2.14)**		
Longer hours at centers		1.000			0.255 (2.47)	
Congestion tolls						1.000
Traffic signal optimization			1.000		0.225 (2.51)	
Special truck arterial lanes	1.000			0.831 (2.86)	0.124 (1.83)	
Dedicated truck streets	0.658 (9.21)	0.668 (7.64)	0.356 (4.34)			
HAZMAT load info. system		0.326 (3.63)	0.366 (4.24)			
Electronic border clearance		0.981 (9.23)				0.080 (2.01)
Traffic signal pre-empts		0.366 (3.94)		1.02 (3.40)		
Parking bans			0.409 (3.72)	1.000	0.183 (2.18)	

Class One: Dedicated Truck Facilities

The first natural grouping of congestion mitigation policies is referred as the dedicated truck facility class. This class has three positive factor loadings on policies that can all be interpreted as dealing with dedicated truck facilities: 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. All three of the observed variables are strong indicators of this class (factor), which is scaled in terms of the special truck arterial lanes variable. In terms of policy costs, dedicated lanes on arterial streets is likely to be considerably more feasible than dedicated freeway lanes and completely dedicated streets.

Class Two: Improvements in Operational Efficiency

The second class of policies is comprised of six policies, four of which have high factor loadings and two of which have relatively lower, but significant, loadings. The stronger loadings are for longer hours at ports and distribution facilities (the standardization scale for the factor), two intelligent transportation system (ITS) implementations involving advanced vehicle clearance systems at weigh stations and international border crossings, and truck-only streets for access to ports, rail terminals and airports. The weaker loadings are also for systems that fall under the broad heading of ITS: devices to allow trucks to pre-empt some traffic signals and for a real-time database of HAZMAT load information for use by emergency crews in clearing accidents. Thus, efficiency in terms of longer hours of operation is highly related in the minds of freight industry spokespersons to efficiency that can be gained from ITS.

Class Three: Improvements in Traffic Management

The third class of policy groupings (factors) is strongly indicated by one policy and weakly indicated by five policies, one of which is negative. The single strong factor loading is for traffic signal optimization. The weak positive loadings are for other policies that are somewhat related to other ways to improve traffic management:

installation of electronic clearance stations, for dedicated truck streets (for access to ports, rail terminals and airports), and for a real-time database of HAZMAT load information (for use by emergency crews in clearing accidents). Special truck freeway lanes is negatively loaded on this factor, indicating that policies in this class are those that favor improved traffic management over dedicating freeway capacity to truck traffic.

Class Four: Truck Urban Arterial Priority

The policies that are heavily loaded for this class are devices to allow trucks to pre-empt some traffic signals, parking bans on some streets during certain periods, and truck-only lanes on some surface streets. Special truck freeway lanes is negatively loaded for this class of policies, which favors improvements to the urban rather than inter-urban transportation network.

Class Five: Increased Road capacity

The class we interpret as 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.

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. This factor 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.

Preferences for Congestion Mitigation Policies: Who? and Why?

The direct effects from the exogenous variables are listed in Table 10. (These are the coefficients of the gamma matrix in equation (3) of the simultaneous equations system.) These regression effects identify preferences of segments of freight operators for specific classes of policies. The reasons given for these preferences are the authors' conjectures.

Class One: Dedicated truck facilities

The class of congestion mitigation policies capturing a variety of dedicated truck facilities, is favored by users of intermodal rail and maritime facilities, common carriers, and operators engaged in just-in-time deliveries. In general, there is a negative nonlinear (logarithmic) relationship between size of fleet and dedicated truck facilities as a congestion mitigation policy. One hypothesis for this is that because larger companies tend to make more long distance moves and because they work in small and large urban areas, so that the average amount of time that their drivers spend in heavily congested areas is less than smaller carriers who are more likely to have local operations in heavily congested areas.

Class Two: Improvements in Operational Efficiency

Positive support for class two, related to institutional as well as technical issues of operational efficiency, is found among users of all three types of intermodal facilities, rail, air, and maritime, from those engaged in long haul operations, and from truckload carriers. Private fleets, on the other hand, do not judge such policies to be effective solutions to the congestion problem.

Class Three: Improvements in Traffic Management

Strategies included in this congestion mitigation policy class are favored by small operators and, to a lesser extent, LTL operators. Contract and truckload carriers do not perceive these strategies as especially beneficial. This could be due to the fact that contract carriers tend to work established, familiar routes, relying on experience and familiarity to negotiate traffic congestion, and truckload carriers tend to spend most of their time on relatively less congested highways.

Table 10: Effects of the exogenous variables on the factors (z-statistics in parentheses)

Exogenous variable	Policy class (dependent latent variable)					
	Dedicated truck facilities	Efficiency of operations	Improved traffic management	Truck urban arterial priorities	Increased road capacity	Congestion tolls
LTL operator			0.083 (2.45)		0.067 (2.06)	
Private fleet		**-.152 (-5.56)**			**-.068 (-2.52)**	**-.091 (-2.81)**
Common carrier	0.083 (2.45)			0.054 (2.56)		
Contract carrier			**-.114 (-4.54)**			
Truckload		0.044 (1.80)	**-.064 (-2.37)**		**-.061 (-2.20)**	
Mover				0.059 (3.33)	0.048 (2.80)	0.083 (2.57)
Tanker			0.027 (1.56)		**-.059 (-2.34)**	
Small operator			0.087 (3.41)			
Ln(size)	**-.118 (-3.83)**					
Inter-modal rail	0.115 (3.88)	0.055 (2.72)				
Inter-modal air		0.052 (2.37)				
Inter-modal port	0.068 (2.10)	0.126 (5.01)				
Short hauls					0.114 (6.25)	0.120 (3.72)
Long hauls		0.111 (4.31)		0.041 (2.12)	**-.085 (-2.49)**	
Just in time	0.083 (3.11)					0.075 (2.78)

Class Four: Truck Urban Arterial Priority

The class of policies related to truck arterial priority is favored by household movers and common carriers. This class is not negatively correlated with any of the exogenous variables. Household movers, who regularly negotiate unfamiliar residential neighborhoods and for whom parking maybe extremely difficult at times stand to gain from policies to reduce urban congestion and to reduce the competition for parking spots at certain times of the day.

Class Five: Increased Road capacity

Operators with short hauls are strongly in favor of strategies to increase road capacity, while long haulers are not. LTL operators and household movers are somewhat in favor of such strategies while private fleet, truckload and tank operators are not. Short haulers tend to spend much of their time on congested facilities near urban areas or between maritime ports and railheads. In California and indeed in most states, the areas around major port facilities area seriously congested. The ports of Los Angeles/Long Beach, and the ports of San Francisco and Oakland are examples of these. Long haulers should tend to have much higher average speeds as much of their time is spend on the (relatively) open road.

Class Six: Congestion Tolls

Congestion pricing, in the form of peak-hour tolls, has some support from carriers who provide just-in-time pickups, those with short average loaded moves and household goods movers. Private fleets are not in favor of congestion pricing schemes.

CONCLUSIONS

Policy makers are increasing concerned with the needs of commercial vehicle users of the transportation network. The strength of each region's industrial base depends on the ability of freight transport companies to provide swift and reliable goods movement. In addition, traffic congestion has significant negative externalities including contribution to pollution, lost productivity, accident costs, and stress. The analysis presented in this paper identified six classes of congestion mitigation policies: (1) new dedicated truck facilities, (2) improved operational efficiency, (3) improved traffic management, (4) enhanced truck urban arterial priority, (5) increased road capacity and (6) congestion tolls and matched support for these to trucking company characteristics. From a transportation planning perspective, implementation of the policies included in classes three and four, improved traffic management and truck urban arterial priority, appear to be the most cost-effective. Moreover, industry spokespersons who are in favor of either of these two classes of policies tend not to favor the policy of dedicating a single freeway lane to truck traffic, a policy that would be controversial, have potentially severe consequences for other road users, and lead to increased taxation of trucking operations. The addition of a third class, improved operational efficiency, would effectively guarantee a set of policies that appeal in some way to all industry segments. The other advantage of these three sets of policies is that they each encompass a set of policies that can be implemented in small pieces and targeted to severely congested regions.

Possible policies that fall under freight industry perceptions of improved traffic management include, 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. The most positive attitudes toward this class of traffic management policies are held by LTL operators and small operators in general. The most negative attitudes towards this class of policies are held by contract carriers and truckload operators. We conclude that the strongest support for relieving congestion through the use of such traffic management policies would come from organizations representing small operators and those representing LTL carriers.

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. 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.

Finally, improvements in operating efficiency, attractive to intermodal operators, long haul carriers and truckload carriers include longer hours at ports and distribution centers, advanced vehicle clearance systems (AVCS) at weigh stations and border crossings, and truck only street for access to ports and rail terminals. The extent to which policy makers can affect hours and ports and distribution centers may be limited. The last three policies are already being implemented. Weigh stations and border crossings are moving towards AVCS technology our survey shows that the companies are supportive of this move. Truck only streets for access to ports and rail terminals might have sounded unlikely a few years ago. The Alameda corridor project at the Ports of Los Angeles and Long Beach is an example of a large private sector/public sector cooperative project to improve the efficiency of freight movements in the region. Such investment naturally has the support of the users of the system and may be an attractive option for severely congested freight hubs.

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