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Abstract

Managers in charge of the California operations of nearly 1,200 trucking companies were asked their opinions regarding how useful various sources of traffic information are to their dispatchers and to their drivers. They were also asked to evaluate the usefulness of improved traveler information systems. Nonlinear canonical correlation analysis was used to link company characteristics and perceptions of the value of the sources. Results showed that evaluations of sources such as Internet traffic information, in-vehicle navigation systems, and area-wide dedicated highway advisory radio are primarily related to the location of operations, whether a trucking operation is private or for-hire, the average length of the company's load moves, and the provision of intermodal services.

Key Words: Advanced traveler information systems (ATIS), Commercial vehicle operations, Intelligent transportation systems (ITS), Intermodal operations, Trucking

1. Introduction

This paper explores the perceptions of trucking company operations and logistics managers concerning the usefulness of existing and proposed sources of traffic information. New technologies allow the delivery of traffic information in many new ways, and this information may help improve the efficiency of goods movement. Policy analysts, technology developers and information providers should be interested in the perceptions of commercial vehicle operators regarding the usefulness of different types of information systems. For instance, these perspectives can provide information useful in the design of advanced traveler information systems (ATIS). Future developments in information technologies should greatly enhance the potential for effective and user-friendly traveler information. New ATIS will be able to take advantage of Internet (Web-based) technology developed for the much larger market of business-to-business e-commerce. In the near future, drivers and dispatchers engaged in trucking operations will likely be supplied with real-time information on traffic conditions, queues at intermodal and distribution facilities, parking information, and roadway hazards. Internet systems could replace technology developed exclusively for ATIS.

Here we investigate how existing and new sources of traffic information are judged to be useful for dispatchers and drivers. The development of some sources of traffic information might benefit from direct public sector investment, while others might require public agency support of private sector initiatives and of improved information dissemination methods. It is of interest to identify which industry segments favor certain types of information sources over others. In the research presented here, we develop models that link operational characteristics with favorable and unfavorable opinions about the relative usefulness of various sources of traffic information.

Commercial vehicle operations (CVO) in general are likely to be early adopters of ATIS due to high values of commercial travel time savings and substantial potential gains in operational efficiency from the use of sophisticated dynamic routing and scheduling systems. The increase in just-in-time distribution systems that began in the 1980s continues today. “Visible” inventories, real-time communication systems and the

emergence of consumer to business and business to business e-commerce are likely to result in unprecedented numbers of time-sensitive deliveries. Accurate and detailed real-time information on roadway traffic and delays at intermodal facilities and distribution centers is valuable in optimizing time-sensitive shipments.

Some important questions about ATIS for commercial vehicle operations are unanswered at this time. What is the perceived usefulness to CVOs of current sources of traffic information? How do CVOs judge the potential of new services, based on their current experiences and expectations. How should ATIS be bundled with other information or services? What is the role of the public sector in the development and delivery of information systems which benefit the private sector? What benefits will accrue because of CVO ATIS? This paper addresses the first two of these questions in detail and addresses the third indirectly by eliciting trucking company managers' preferences about various types of information and information sources. After presenting aggregate responses, we examine which company characteristics can be linked with support for ATIS technologies. The ATIS technologies included in our survey include: (1) cheaper and better in-vehicle navigation systems, (2) computerized traffic information on the Internet, (3) traffic information for dispatchers on cable or satellite TV, (4) freeway changeable message signs, (5) kiosks at truck stops where drivers can obtain traffic information, and (6) area-wide dedicated 24-hour highway advisory radio.

This paper is organized into eight sections. In Section 2, we review previous studies. In Section 3 we discuss the content of the survey and describe the sample used in the analysis. This is followed by a discussion of methodology in Section 4. Results are then presented in three separate sections relative to information sources available to dispatchers (Section 5), drivers (Section 6) and the benefits to both drivers and dispatchers of up-to-date sources of traffic information (Section 7). This last section is likely to be most relevant to policy analysts and public agencies as developing and extending some of these information sources may require a public investment.

2. Background

The adoption of information technology (IT) by commercial vehicle operators has been studied since the early 1990s. Scapinakis and Garrison (1991) reported results from a survey of a small group of carriers regarding their perceptions of the use of communications and positioning systems, and Kavalaris and Sinha (1995) documented a survey of trucking companies that focussed on attitudes towards ITS technologies. Ng *et al.* (1995) studied acceptance of ATIS technologies, including route guidance, navigation, road and traffic information, roadside services and personal communication, based on two nationwide surveys of dispatchers and commercial vehicle operators. Regan *et al.* (1995) surveyed approximately 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) also investigated the use of IT in port operations through interviews with port operators and a small survey of carriers. Crum *et al.* (1998) studied the use of electronic data interchange (EDI) technology, while 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. Most recently, Golob and Regan (2001b) present a multivariate discrete model of the trucking industry's adoption of communication and information technologies based on the survey of carriers used in this research.

The next generation of the Internet will support intelligent (autonomous) agents (or "bots") that operate on computer-readable XML (extensible markup language), as discussed in Golob and Regan (2001a). It will be relatively straightforward to design agents and XML Websites containing real-time information on network performance levels, so that agents can interrogate the network sites and report back on the state of travel conditions. A viable extension is for the traveler's agent to recommend alternative trip routing and timing. Hand-held Internet devices (smart phones) will allow travelers to access Web pages and receive reports from smart agents at sites away from home.

3. Data

During the Spring of 1998, managers of 1177 trucking companies operating in California completed a survey conducted by Strategic Consulting and Research of Irvine, California for the Institute of Transportation Studies at the University of California, Irvine. The sample was comprised of 5258 companies, divided into three strata: (1) 804 California based for-hire trucking companies with annual revenues of over $1 million, (2) 2129 California based private carriers with at least 10 power units and (3) 2325 for-hire large national carriers based outside of California with annual revenues over $6 million. This sample was drawn from a database of over 21,000 for-hire carrier and 25,000 private carriers maintained by Transportation Technical Services Inc.

Questions were posed to the logistics or operations manager in charge of operations in California.[1] 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%.

Non-response analyses were conducted for each of the three strata from which the sample was drawn. Golob and Regan (2001c) report that there are no statistically significant differences between survey respondents and other companies 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.

The survey dealt with five main topics: (1) traffic congestion, (2) use and usefulness of information technologies, (3) use and efficiency of intermodal terminals in California, (4) usefulness of sources of traffic information, and (5) operational characteristics (e.g., types of services offered, the average length of haul, time sensitivity of the operations, the locations of the main terminals and the fleet size). The broad goal of this study was to obtain information on all of these subjects from a large enough sample of the

[1] 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.

California trucking companies so that no industry segments would be left out. An overall summary of survey results can be found in Regan and Golob (1999).

The section on traffic congestion 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] The section on information technology elicited information on carriers' use of mobile communication devices, EDI, automatic vehicle location (AVL) devices, and automatic vehicle identification (AVI) devices.[3] In the third section of the survey, data were collected on services provided at maritime, rail and air intermodal facilities. Questions were asked about typical delays and the predictability of the time required for pickup and delivery of loads to these facilities, and respondents were invited to describe the types of problems they face in operating at intermodal facilities.[4] The section of the survey dealing with the usefulness of sources of traffic information provides the data used in the research presented here.

The survey sample of 1177 trucking companies is broken down into 34% private carriers and 66% for-hire (common) carriers. Respondents were asked how many power units (tractors, tractor-trailer combinations, or trucks) they typically operated in California. The fleet size distribution, which is highly skewed, is described in Table 1. The median California fleet size was twenty power units, but the mean is 59.4 power units. The lower quartile is eight, and the upper quartile is 50. Four companies typically operated more than 1,000 power units in California.

Table 1 about here

In the analyses reported here, six different operating characteristics were found to effectively explain responses concerning the usefulness of traffic information. Fleet size was not one of these characteristics, which was an unexpected result. The functionality

[2] An analysis of carrier perceptions of the effectiveness of congestion mitigation strategies available to public agencies is provided in Golob and Regan (2000).
[3] A model of demand for information technologies is presented in Golob and Regan (2001b).
[4] Carrier perceptions of problems encountered in intermodal maritime operations are explored in Regan and Golob (2000).

of trucking operations is more important than size of operation in explaining managers' perceptions of sources of traffic information. The breakdowns of the six characteristics used as explanatory variables are shown in Figure 1.

Figure 1 about here

Load type is described in terms of truckload, less-than-truckload, and combination of the two services. Carrier type is described in terms of four categories: private carrier, common (for-hire) carrier, contract only, or a combination of common and contract. There are seven categories of primary service, with general truckload being the modal category (37%), and five categories of location of manager of California operations.[5] Finally, intermodal operations were divided into five categories, and average length of loaded movement was divided into six categories. After eliminating companies with missing data on these characteristics, the sample size for the analysis was 985.

4. Methodology

The objective of the research presented here is to produce optimal segmentations that capture how the type of trucking operation affects managers' opinions about the usefulness of different sources of traffic information. The statistical analysis is complicated by the fact that none of the variables are interval scale. The evaluations of usefulness are measured on ordinal scales, where each scale has three categories: (1) "very useful," (2) "somewhat useful" and (3) "not useful." And the characteristics of truck operations are measured according to the six nominal (categorical) variables shown in Figure 1. Each of these characteristic variables has between three and seven categories.

Relationships between a single evaluation scale and a single characteristic variable can be assessed using a contingency-table chi-square test. Alternatively, a characteristic variable with j categories can be broken up into j-1 dummy variables, and rank-order

correlations can be computed as a measure of association between the ordinal evaluation scale and each dummy variable. However, such pair-wise analyses are not effective in determining the relative contribution of different characteristics, nor do they provide concise information about how different sources of information are viewed similarly or differently.

A simultaneous analysis is needed, in which partial contributions of each characteristic can be assessed while capturing the correlations among evaluations of the different sources of traffic information. If all of the variables were interval scale, one could use a multivariate statistical analysis such as a canonical correlation analysis (CCA). In CCA, which is a simple expansion of regression analysis to more than one dependent variable, there are two sets of variables, and the objective is to find a linear combination of the variables in each set so that the correlation between the linear combinations is as high as possible. The linear combinations are defined by optimal variable weights. Depending on the number of variables in each set and their scale types, further linear combinations (canonical variates, similar to principal components in factor analysis) can be found that have maximum correlations subject to the conditions that all canonical variates are mutually orthogonal or independent. CCA can also be generalized to more than two sets of variables. With a single set of variables, CCA is essentially equivalent to principal components analysis.

Here, we have three separate nonlinear CCA problems with an explanatory variable set of six nominal variables and a dependent variable set of five ordinal variables. The linear combination on the explanatory variable side is undefined, because we have no metric to quantify the categories of each nominal variable. The linear combination of the variables on the dependent side is also undefined, because the categories of each variable can be re-scaled by any monotonic nonlinear function. Thus, we need to optimally scale or quantify the variables while simultaneously solving the traditional linear CCA problem of finding optimal weights for each explanatory variable.

[5] California operations of many large regional and national carriers are managed from outside of California.

One extensively used method for nonlinear canonical correlations analysis, NLCCA, known as alternating least squares (ALS), is described in detail in De Leeuw (1984), Van der Burg (1988) and Gifi (1990). The method simultaneously determines both (1) optimal re-scaling of the categories of all nominal and ordinal variables and (2) explanatory variable weights, such that the linear combination of the weighted re-scaled variables in one set has the maximum possible correlation with the linear combination of weighted re-scaled variables in the second set.

Hensher and Golob (1999) use a geometric perspective to describe the ALS method for NLCCA as applied in transportation research. In summary, both the variable weights and optimal category scores are determined by minimizing a meet-loss function derived from lattice theory. The meet-loss objective function is minimized by means of an algorithm that iterates between adjusting the category scores of the ordinal and nominal variables and adjusting the variable weights, subject to appropriate constraints. The ALS algorithm is similar to the power method in singular value decomposition (Gifi, 1990; Israëls, 1987), which underlies most linear multivariate methods, such as principal components analysis and discriminant analysis. ALS includes category quantifications for each variable as well as each variable's weight as parameters in the objective function. The properties of this algorithm and the general advantages and limitations of objective functions based on least squares are discussed in Gifi (1990).

NLCCA output includes several overall measures of goodness-of-fit, component loadings, and optimal category scores. The selection of the number of canonical variates is based upon comparing the decay in the goodness of fit associated with each additional dimension, similar to the selection of the number of factors in factor analysis. Component loadings, in the absence of missing data, are equivalent to product-moment correlations between the optimally scaled variables and the canonical variates (similar to factor loadings in principal components analysis). Geometrically, the sum of squared loadings (the length of the vector from the origin to the component loadings of a given variable in the orthogonal space of the canonical variates) indicates how much of the variable was explained by the canonical variates in total, and the square of the projections onto an axis reveals how much of the explanation was due to that canonical variate. For any two variables, the scalar (dot) product of the two vectors is an

approximation of the correlation between the two optimally scaled variables (Ter Braak, 1990). In our applications, the scalar product of the vectors of component loadings for two sources of traffic information indicates the degree of correlation between the optimally scaled evaluations of the two sources. The scalar product of the vector of a dependent information source variable and the vector of the quantification of a trucking attribute variable is an indicator of the correlation between the optimally scaled attribute variable and the evaluation of the information source. For each pair of a trucking industry characteristic and information source found to be strongly correlated, we then compute rank-order correlations between dummy variables defining each category of the characteristic and the evaluation rankings. This allows us to verify the statistical significance of the association between a specific type of trucking operation and evaluation of a specific source of traffic information.

5. Perceived Usefulness of Information Sources to Dispatchers

Trucking company managers were asked to rate the usefulness *to dispatchers* of five sources of traffic information on a three-point ordinal scale: very useful, somewhat useful, and not useful. For each source there was also a "don't know" category which we treat as missing data. The five sources (randomly rotated in the survey) were (1) reports from drivers on the road, (2) traffic reports on commercial radio stations, (3) traffic reports on television, (4) computer traffic maps on the World Wide Web, and (5) phones calls to Caltrans (the State of California Department of Transportation) or other information services. The aggregate response breakdowns are described in Table 2.

Table 2 about here

Overall, reports from drivers on the road are judged to be most useful, followed by traffic reports on the radio. Least useful was traffic reports on television, followed by Internet traffic maps. The relatively low rating for Internet information, and the relatively high

percentage of "don't know" responses, is probably both a function of dispatchers' Internet access and lack of availability of ATIS Internet services in 1998.[6]

A two-dimensional CCA solution exhibited a good explanation of the relationships between the set of five ratings of the usefulness of the information sources and the set of six exogenous variables representing operating characteristics. The first canonical dimension accounts for 62.1% of the variance in the optimally scaled set of five endogenous information source evaluations and 72.2% of the variance in the six optimally scaled exogenous operational characteristics. (That is, for the first canonical variate, the R^2 for the linear combination of optimally scaled endogenous variables was 0.621, and the corresponding R^2 for the linear combination of optimally scaled exogenous variables was 0.722.) The canonical correlation between the linear combinations on the exogenous and endogenous sides was 0.344. For the second canonical variate, which is independent of the first, the R^2 values were 0.533 on the endogenous variable side and 0.754 on the exogenous variable side. The second canonical correlation was 0.288.

The component loadings are listed in Table 3. On the endogenous variable side, the first canonical variate can be labeled as the "external provider" dimension, contrasting Internet and phone-in sources of traffic information with traffic reports on commercial radio stations. The second variate, which can be labeled as the "internal sources" dimension, is primarily correlated with reports from the company's own drivers on the road. In terms of variance accounted for, reports from drivers is most effectively explained, while traffic reports on television is least effectively explained. On the exogenous variable side, length of load moves is the key explanatory variable and is associated most strongly with the first variate. Base of operations, load type and

[6] Presumably this will change as dispatchers increase their use of computers with Internet connections in response to the demand for and availability of ecommerce. Networked computers will become more prevalent in commercial vehicle operations due to demand for a wide-variety of information technology applications, such as routing and scheduling, vehicle monitoring, maintenance and record keeping software, tracking and tracing technologies for containers and packages, and Internet based load matching services (Golob and Regan, 2001a). As a consequence, Internet access is likely to be available to a greater number of dispatchers, and there will be increased incentives for developing ATIS services due to their wider audience.

intermodal operations also explain the first variate. The second variate is most strongly correlated with primary service, load type and carrier type.

Four pairs of optimally scaled variables had the strongest correlations. These are as follows: (1) length of loaded movement and Internet information (correlation estimate from the scalar product of loadings = 0.32), (2) length of loaded movement and radio reports (-0.32), (3) primary service and reports from drivers (-0.24), and (4) load type and reports from drivers (0.23). Seven other pairs of exogenous and endogenous variables have correlations greater than 0.18 in magnitude, which emphasizes the need for a summary of the complex of relationships captured by the NLCCA solution. The optimal scalings of the exogenous variables reveals how industry types cluster in terms of their evaluations of sources of traffic information for dispatchers.

Table 3 about here

The optimal category scores for the exogenous variables are listed in the first data column of Table 4. The scores for each variable are centered on zero, and if two categories have similar scores on a variable, the perceptions of managers of companies in the two categories are similar. If a category exhibits a strong positive score on a variable, this indicates that the managers of the companies within this category have perceptions that are consistent with the component loadings of that variable. Companies in categories that exhibit strong negative scores on a variable tend to have managers with perceptions that are consistent with the negative of the variable's component loadings.

Table 4 about here

The optimal scaling of load type distinguishes exclusive less-than-truckload operations from the other two categories. The scaling of carrier type primarily distinguishes private carriers from contract carriers. Third, the scaling of primary service distinguishes

general LTL carriers from all other types, especially from movers; while tank carriers are most similar to general LTL.[7] Fourth, the optimal scaling of location primarily distinguishes companies with managers located in the Los Angeles Region from all other areas, especially other parts of California excluding the San Francisco Bay Region, indicating that evaluations of sources of traffic information are regionally specific. Fifth, the scaling of intermodal operations distinguishes carriers with rail and multiple intermodal services from those without intermodal services. Finally, the scaling of average length of load moves is monotonic in length category, with shorter lengths being accentuated.

The results matching specific company characteristics with perceptions of the usefulness of different information sources are summarized in Table 5. Compilation of Table 5 was guided by the calculation of the complete set of correlations between the optimally scaled endogenous and exogenous variables based upon their component loadings. The categories listed in Table 5 are further restricted to those which exhibit a statistically significant rank order correlation between the dummy variable defining the category and the three-point ordinal evaluation scale.[8]

Table 5 about here

Reports from their own drivers on the road are valued most highly by carriers with either rail or multiple intermodal operations. Conversely, this source of information is judged to be less useful by contract carriers, movers of household goods, and carriers with long average load moves. Traffic reports on commercial radio stations are useful to general LTL carriers and operations based in the Greater Los Angeles Area, which has the largest concentration of commercial radio stations. Commercial radio sources are judged to be less useful by truckload carriers, operations based outside California, and carriers with long load moves. Regarding traffic reports on commercial television stations, which have an overall low rating of usefulness (Table 2), only movers of

[7] As both the load type and primary service variables include LTL as a category, in cases where the two variables have opposite signs, they can cancel each other out for carriers whose primary service is LTL.

household goods and carriers with exclusively rail intermodal service value such sources higher than their counterparts.

The usefulness of Internet traffic information is related to the average length of load moves. Operators with long moves, regional and national carriers with operations based outside California, and carriers with exclusively rail intermodal service all tend to judge Internet information to be more useful, while carriers with short moves and private carriers place a lower value on Internet traffic information. Finally, phone calls to the California Department of Transportation (Caltrans), the California Highway Patrol (CHP) or other information sources are more useful to operations based in California, but outside of the two largest metropolitan areas. Such phone contacts are less useful to carriers based outside California and to carriers without intermodal services.

6. Perceived Usefulness of Information Sources to Drivers

Respondents were also asked to rate the usefulness of five potential sources of traffic information that drivers can use directly. The aggregate results are listed in Table 6. Freeway changeable message signs (CMS), CB radio reports from other drivers and traffic reports on the radio were deemed most useful for drivers. CMS were deemed most useful followed by CB or other radio reports from other drivers. Interestingly, these were the most high tech and low tech information sources investigated. Traffic reports on commercial radio stations were also viewed as useful as were face-to-face reports among drivers at truck stops and terminals. Dedicated highway advisory radio (HAR) was viewed least useful for drivers, possibly reflecting the incomplete availability of this source of information in 1998.

Table 6 about here

[8] Use of either Spearman's rho or Kendall's tau-b correlation coefficients at the 99% confidence limit yielded similar results. "Don't know" evaluations were treated as missing data.

A two-dimensional nonlinear CCA solution was once again found to provide an effective explanation of the relationships between the five endogenous ratings of information sources for drivers and the six exogenous operating characteristics. The first canonical component accounts for 65.7% of the variance in the optimally scaled set of five endogenous information source evaluations and 71.5% of the variance in the six optimally scaled exogenous operational characteristics. The second canonical component accounts for 55.9% of the variance in the endogenous evaluations and 70.5% of the variance in the exogenous variables. The canonical correlations were 0.372 for the first component and 0.264 for the second. These statistics indicate that the overall fit of the nonlinear CCA model explaining evaluations of sources of information for drivers is similar to the overall fit of the nonlinear CCA model explaining evaluations of sources of information for dispatchers, however the explanatory power of the model for drivers is more concentrated in the first dimension, while the model for dispatchers is a more balanced two-dimensional solution.

The component loadings of the optimally scaled variables for the NLCCA model of sources of traffic information for drivers are listed in Table 7. The information sources are aligned such that each of these two variates captures a pair of information sources, while the fifth source is explained by both canonical variates. The two sources associated with the stronger first variate are CB or other radio reports from other drivers and reports on dedicated highway advisory radio (HAR). These two sources represent information that can be intermittently tapped by drivers when they are within certain areas with heavy traffic. The two sources associated with the second variate are face-to-face reports among drivers at truck stops and terminals and traffic reports on commercial radio stations. The common attribute of these is the provision of traffic updates on a regular schedule at specific locations. The lone source loaded on both variates (but more by the first) is changeable message signs (CMS). CMS appears to be viewed as having both components of both spatial concentration and regularity. Evaluations of CB radio and face-to-face reports from other drivers are best explained by the CCA solution, while traffic reports on commercial radio stations are the least well explained, probably because managers are not well informed as to drivers' radio habits.

Table 7 about here

The relationships among the exogenous variables is given by the component loadings of the exogenous variables in Table 7 and the optimal category scores in the second data column of Table 4. These exogenous relationships are different than those for the previous NLCCA model in that the segmentation structure that best captures operational characteristics managers' evaluations of sources of traffic information that drivers use is different from the segmentation structure that captures evaluations of sources of information for dispatchers. The most important exogenous variables are base of operations (approximate R^2 = .65) length of load moves (R^2 = .55).

There is a cluster of two exogenous characteristics, length of load moves and carrier type, which are loaded primarily on the first canonical variate. (Load type is also loaded primarily on the first variate, but is not very well explained.) Considering how the variables are coded according to the category scores (Table 4), this cluster describes, on the positive side, carriers with longer average moves (peaking in the 250-499 mile range) and common (for-hire) carriers. On the negative side, it describes carriers with short loaded moves and private carriers. We can label this cluster simply as "loads." Compared to the scores for the categories representing common carriers and private carriers on the carrier type variable, the category scores for the contract carrier categories on this variable are close to zero, indicating that the contract operations characteristic has very little impact on evaluations of information sources for drivers.

A second cluster of two exogenous variables is loaded primarily on the second canonical variate: intermodal operations and primary service (negative). On the positive side this second cluster describes carriers with rail intermodal services, household movers and carriers with general LTL operations. On the negative side, the second cluster describes tank carriers and carriers engaged in either no intermodal services or multiple intermodal services. This cluster is approximately orthogonal to (independent of) the remaining characteristic, base of operations. Base of operations is the most important of all in explaining the endogenous variables, and the optimal category scores

show that it distinguishes Los Angeles and San Francisco Bay operations from those based outside the State of California.

Seven pairs of optimally scaled variables exhibited the strongest correlations, which are as follows: Length of loaded movement is correlated with radio reports from other drivers (correlation of 0.42), with CMS (0.34) and with HAR (0.32). Location of the base of operations is correlated with radio reports from other drivers (0.34) and with face-to-face reports among drivers at truck stops and terminals (-0.29). Also, carrier type is correlated with radio reports among drivers (0.31) and with CMS (0.28). In addition, five other pairs of exogenous and endogenous variables have correlations greater than 0.22 in absolute value. Compared to the previous evaluation of information sources for dispatchers, there are more pervasive differences among types of trucking operations in terms of managers' evaluations of information sources for drivers.

The results matching specific company characteristics with perceptions of the usefulness of different information sources are summarized in Table 8, in which entries are limited to those categories with statistically significant (p = .05 level) rank order correlations between the category dummy variable and the ordinal evaluation scale. These NLCCA results for drivers' information sources provide market research information for future information sources. First, improved sources of in-vehicle traffic information that can be tapped by drivers in specific congested areas with heavy truck traffic should be welcomed especially by drivers for carriers with longer moves and common carriers, and by drivers for national and regional carriers operating from outside California. Preferences for such sources of information should be less for drivers for private carriers, short-haul carriers, and carriers operating out of the Los Angeles Area. Secondly, improved sources of traffic information available to drivers at regular intervals at specific locations, such as truck stops and terminals, should be welcomed by drivers in companies serving rail intermodal terminals.

Table 8 about here

7. Future Traffic Information Sources

Ratings of potential sources of information that are in varying stages of development are presented in Table 9. Dedicated highway advisory radio was viewed as most useful to drivers and dispatchers, followed by more freeway changeable message signs and cheaper and better in-vehicle navigation systems. This result is somewhat surprising, since managers did not find current highway advisory radio systems to be as useful to drivers as any of the other information sources. This suggests that they think that improvements are on the horizon. Web-based information found in dispatch centers and at Kiosks at truck stops received mixed reviews, as did computer traffic maps on TV. The TV based maps were judged more useful than maps available on the internet, no doubt due to fact that the study pre-dated the rapid emergence of web based traffic information sources.

Table 9 about here

As in the cases of the two previous models, a two-dimensional nonlinear CCA solution was once again found to effectively explain the relationships between the five endogenous ratings of improved information sources and the six exogenous operating characteristics. In this case, the first canonical component accounts for 65.6% of the variance in the optimally scaled set of five endogenous information source evaluations and 71.2% of the variance in the six optimally scaled exogenous operational characteristics. The second canonical component accounts for 49.8% of the variance in the endogenous evaluations and 74.1% of the variance in the exogenous variables. The canonical correlations were 0.368 for the first component and 0.238 for the second, indicating that the fit was not as good as for present information sources. The component loadings for this model are shown in Table 10, and the optimal category scores are listed in the last column of Table 4.

On the endogenous variable side of the problem, all sources of information are correlated, with three sources being tightly aligned along the (negative) first canonical variate. These three sources of improved traffic information are: “area-wide dedicated 24-hour highway advisory radio” (HAR), “more use of changeable message signs” (CMS), and “cheaper and better in-vehicle navigation systems.” This is a cluster of advanced traveler information sources targeted at the commercial driver on the road. Relatively independent of this cluster of three is “computerized traffic maps for dispatchers on cable or satellite TV” (possible through the use of “set-top” Internet devices, as described by Golob and Regan, 2001a). The final source, “kiosks at truck stops where drivers can punch up traffic information” lies between the “in-vehicle” cluster and computer maps for dispatchers.

Table 10 about here

The exogenous variables fall into two pair-wise clusters and two relatively independent variables. The first pair, highly aligned with the first variate and the first cluster of information sources, is comprised of base of operations and intermodal operations. In light of the optimal category scores for these variables (Table 4), this cluster contrasts carriers based outside of California and carriers with rail, air and multiple intermodal services against carriers operated out of the San Francisco Bay Area and carriers without intermodal operations or with just maritime intermodal services. The second pair is defined in terms of primary service and load type. The load moves variable, which is correlated with the first cluster pair but orthogonal to the second, is monotonic in terms of length of loaded movement, with the shortest move category being outstanding. The carrier type variable, which is independent of the first cluster pair but correlated with the second, contrasts contract carriers and private carriers, with common carriers being scored closest to zero (indicating small effects in the model).

The strongest correlations between optimally scaled exogenous and endogenous variables involve length of load moves. Correlations between length of load moves and each of the five improved sources of information range from a high of 0.54 for kiosks at

truck stops to a low of 0.24 for more CMS. Highly correlated pairs also include location of operations and kiosks (correlation of 0.37), area wide HAR (0.29) and more CMS (0.28). Interpretations of key relationships between the exogenous and endogenous variables are summarized in Table 11.

Table 11 about here

Turning first to the first of three advanced driver-targeted ATIS, "cheaper and better in-vehicle navigation systems," the primary explanatory variables are carrier type, base of operations, intermodal services and length of load moves. Large national and regional carriers based outside California, long-haul carriers, and carriers with multiple intermodal services see such sources of information as being particularly valuable. Private carriers, short-haul carriers, those without intermodal services and those with various unspecified specialized services are less inclined to judge in-vehicle ATIS as being useful in their operations.

Evaluations of the usefulness of Internet information in the form of computer traffic maps for dispatchers are explained primarily by carrier type, location, intermodal services and length of loaded moves. The primary market for such systems will likely be large national and regional long-haul carriers. Demand for such systems is less likely to come from private carriers, operators with short loaded moves, and carriers with no intermodal services.

More use of CMS is judged to be valuable by the types of companies that favor Internet information. On the negative side, CMS is judged to be less advantageous by operators based in the San Francisco Bay Area, by short-haul carriers, by carriers with no intermodal services, and by those with various unspecified specialized services.

Preferences for ATIS kiosks at truck stops are related primarily to operators' length of load moves, and secondarily to spatial location, carrier type and extent of intermodal operations. Kiosks are judged to be useful by the same types of operators that favor

driver-targeted ATIS, namely carriers based outside of California and long-haul carriers. However, ATIS kiosks are deemed more useful by a variety of operation types: carriers operating out of either the Greater Los Angeles or San Francisco Bay Area, private carriers, short-haul carriers, carriers with no intermodal services, and by carriers with various unspecified specialized services.

Finally, dedicated 24-hour area-wide HAR finds favor among carriers which provide both truckload and LTL services. HAR is judged to be less useful by exclusive LTL carriers, short-hail carriers, and, once again, carriers with various unspecified specialized services.

These results provide market research information for future information sources. New video sources should be most welcomed by companies scoring highest on the "basic operations" dimension. For providers of traffic information on the Internet, this indicates that demand is likely to come from large regional and national carriers and all carriers with long loaded moves. Demand will be lower from short-haul carriers, private carriers, and carriers with no intermodal services. Operators scoring high on the second cluster of exogenous variables, defined by load type, area and intermodal operations, will prefer new sources that combine the attributes of the two personal-contact sources: reports from drivers on the road and phone calls to agencies. Automated phone-in information sources, or sources accessible by handheld internet devices (smart phones), are likely to received favorably by contract carriers and carriers serving rail and combinations of intermodal services.

8. Conclusions

In this paper, we have described results of nonlinear multivariate statistical models applied to attitudinal data from a large-scale survey of for-hire trucking companies and private carriers operating in California. These models help explain how perceptions of the value of specific sources of traffic information are related to the operating characteristics of the trucking companies.

Three sets of information sources were investigated: (1) those potentially used by dispatchers, (2) those used by drivers directly, and (3) future advanced traveler information systems (ATIS). The pervasive results were that evaluations of sources in each of these three categories were explained by where the trucking operation is based, whether the operation is private or for-hire, the average length of load moves, and the provision of intermodal services. In addition to the prevailing influences of these three variables, preferences of specific industry segments were identified through relationships between evaluations of information sources and whether or not a company provides specialized types of trucking services. These results indicate which segments of the trucking industry are more likely to be early adopters of ATIS technologies.

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Table 1
Distribution of California fleet sizes in terms of percentiles (N = 1177)

Percentile	1	5	10	25	50	75	90	95	99
Fleet size	1	2	3	8	20	50	110	200	500

Table 2
Aggregate ratings of the usefulness to dispatchers of five sources of traffic information (N = 985)

Information source	**Sample breakdown (%)**			
	Very useful	**Some-what useful**	**Not useful**	**Don't know**
Reports from your drivers on the road	59.7	29.3	9.4	1.5
Traffic reports on commercial radio stations	42.3	35.9	19.8	1.9
Traffic reports on television	12.6	25.1	59.9	2.4
Computer traffic maps on the world wide web	15.8	23.8	49.6	10.8
Phone calls to Caltrans or other information services	25.6	41.4	28.4	4.6

Table 3
Component loadings for evaluations of sources of traffic information for dispatchers

	Variate 1	Variate 2	Fit
Endogenous variables			
Reports from your drivers on the road	0.024	-0.476	0.23
Traffic reports on commercial radio stations	-0.344	-0.050	0.12
Traffic reports on television	0.221	0.076	0.05
Computer traffic maps on the world wide web	0.390	0.159	0.18
Phone calls to Caltrans or other information services	0.315	-0.122	0.11
Exogenous variables			
Load type	0.406	-0.473	0.39
Carrier type	0.349	0.414	0.29
Primary service	0.224	0.506	0.31
Location of operations	0.493	-0.184	0.28
Intermodal operations	0.402	-0.230	0.21
Load moves	0.693	0.323	0.58

Table 4
Optimal category scores for the exogenous variables on all three NLCCA solutions

Variable	Category	Use by Dispatchers	Use by Drivers	New sources
Load type	Exclusively truckload	.35	.19	-.59
	Exclusively less-than-truckload (LTL)	-3.25	-3.37	-2.04
	Both Truckload and less-than truckload	.39	.32	1.17
Carrier type	Private fleet	-1.17	-1.00	-1.09
	Common (for-hire) carrier	-.28	1.77	-.57
	Contract carrier	1.26	.13	1.58
	Both common and contract carrier	.96	.38	.78
Primary service	General truckload	.29	-.09	-.61
	General less-than-truckload (general LTL)	-3.06	1.47	-1.46
	Movers	1.26	1.84	.28
	Tank carrier	-1.05	-2.89	-1.67
	Refrigerated carrier	.50	-.43	.58
	Bulk carrier	-.40	-.13	.47
	Other specialized services	.65	.87	1.57
Location of operations	Greater Los Angeles metropolitan area	-1.84	-1.67	-.54
	San Francisco bay metropolitan area	-.32	-.51	-2.05
	Other parts of California	.85	.09	-.38
	Regional or national carrier outside CA	.24	.94	1.10
Intermodal operations	No intermodal services	-.87	-.41	-.79
	Air intermodal only	.79	.25	1.26
	Maritime intermodal only	.48	.34	-.10
	Rail intermodal only	2.25	4.52	1.63
	Multiple intermodal services	1.31	-.44	1.56
Load moves	Average movement less than 50 miles	-1.86	-1.85	-1.93
	Average movement 50-99 miles	-.53	-.51	-.68
	Average movement 100-249 miles	-.21	-.18	.25
	Average movement 250-499 miles	.49	1.20	.63
	Average movement more than 500 miles	.92	.64	.76

Table 5
Summary of the strongest relationships between the exogenous variables and evaluations of sources of traffic information for dispatchers

Source of traffic information	Judged to be more useful	Judged to be less useful
Reports from drivers on the road	Carriers serving rail terminals Intermodal: multiple modes	Contract carriers Movers Carriers with load moves ≥ 500 mi.
Traffic reports on commercial radio stations	General LTL carriers Operations out of Los Angeles Area	Exclusively truckload carriers Operations out of other areas of CA[a] Carriers with load moves ≥ 500 mi.
Traffic reports on television	Movers Intermodal: rail only	Carriers with short load moves
Computer traffic maps on the world wide web	Operations from outside of CA Intermodal: rail only Carriers with load moves ≥ 500 mi.	Carriers with short load moves Private carriers
Phone calls to Caltrans or other information services	Operations out of other areas of CA[a]	Operations from outside of CA Carriers with no intermodal services

[a] Any areas of California outside of the Greater Los Angeles Area and the San Francisco Bay Area

Table 6
Aggregate ratings of the usefulness of five sources of traffic information that drivers use directly (N = 985)

Information source	Sample breakdown (%)			
	Very useful	Some-what useful	Not useful	Don't know
CB radio reports from other drivers	55.6	26.4	15.1	2.8
Traffic reports on commercial radio stations	46.9	41.7	10.3	1.1
Dedicated highway advisory radio	35.0	37.1	20.9	7.0
Freeway changeable message signs	57.3	32.3	8.7	1.7
Face-to-face reports among drivers at truck stops & terminals	40.3	36.3	21.3	2.0

Table 7
Component loading for evaluations of sources of traffic information that drivers use directly

	Variate 1	Variate 2	Fit
Endogenous variables			
CB radio reports from other drivers	0.568	0.012	0.32
Traffic reports on commercial radio stations	-0.016	0.333	0.11
Dedicated highway advisory radio	0.425	0.043	0.18
Freeway changeable message signs	0.439	0.221	0.24
Face-to-face reports among drivers at truck stops & terminals	0.013	0.566	0.32
Exogenous variables			
Load type	0.287	-0.037	0.08
Carrier type	0.535	0.189	0.32
Primary service	-0.330	-0.399	0.27
Location of operations	0.604	-0.533	0.65
Intermodal operations	0.141	0.451	0.22
Load moves	0.735	0.085	0.55

Table 8
Summary of the strongest relationships between the explanatory variables and evaluations of sources of traffic information that drivers use directly

Source of traffic information	Judged to be more useful	Judged to be less useful
CB radio reports from other drivers	Exclusively truckload carriers Operations from outside of CA Carriers with long load moves	Private carriers Operations in the Los Angeles Area Operations in the S. F. Bay Area Carriers with short load moves
Traffic reports on commercial radio stations		Operations from outside California
Dedicated highway advisory radio (HAR)	Common carriers Carriers with long load moves	Private carriers Operations out of Los Angeles Area Carriers with short load moves
Freeway changeable message signs (CMS)	Common carriers Operations from outside of CA Carriers with long load moves	Private carriers Tank carriers Carriers with short load moves
Face-to-face reports among drivers at truck stops and terminals	Intermodal: rail only	

Table 9. Ratings of the usefulness of improved sources of more accurate, up-to-the-minute traffic information.

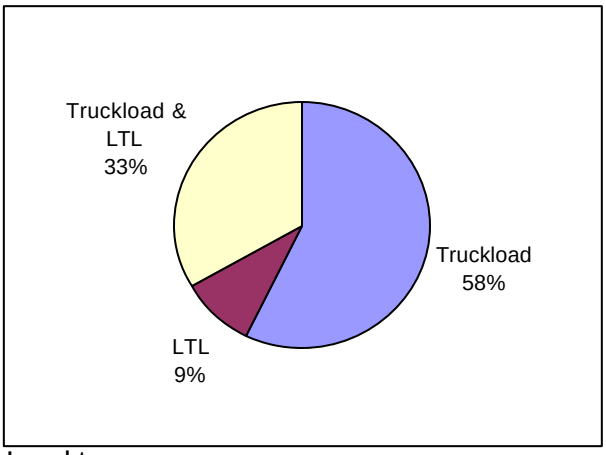
Information source	Sample breakdown (%)			
	Very useful	Some-what useful	Not useful	Don't know
Cheaper and better in-vehicle navigation systems	50.3	28.9	15.4	5.4
Computer traffic maps for dispatchers	40.1	32.1	25.3	4.3
More use of freeway changeable message signs	55.9	34.6	8.2	1.2
Kiosks at truck stops where drivers can access traffic information	43.2	33.4	21.1	2.8
Area-wide dedicated 24-hour highway advisory radio	64.7	26.1	7.4	1.8

Table 10
Component loadings for evaluations of improved sources of accurate, up-to-the-minute traffic information

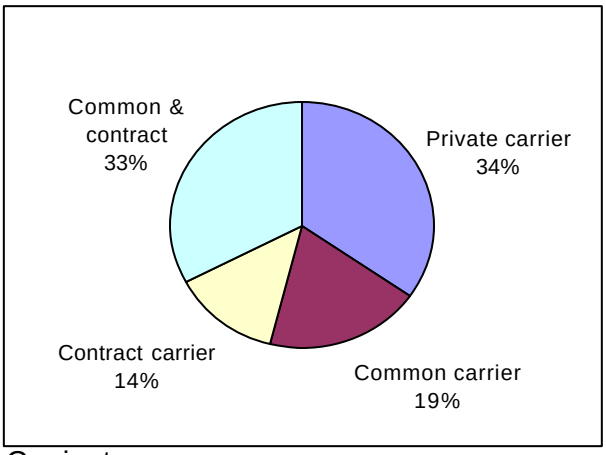
	Variate 1	Variate 2	Fit
Endogenous variables			
Cheaper and better in-vehicle navigation systems	-0.406	0.008	0.16
Computerized traffic maps for dispatchers	-0.212	-0.377	0.19
More freeway changeable message signs (CMS)	-0.404	0.189	0.19
Kiosks at truck stops for drivers to access traffic information	-0.607	-0.223	0.42
Dedicated area-wide 24-hour highway advisory radio	-0.436	0.117	0.20
Exogenous variables			
Load type	-0.105	0.254	0.08
Carrier type	-0.168	-0.552	0.33
Primary service	0.253	-0.532	0.35
Location of operations	-0.646	0.084	0.42
Intermodal operations	-0.342	0.059	0.12
Load moves	-0.751	-0.375	0.70

Table 11
Summary of relationships between the explanatory variables and evaluations of improved sources of accurate, up-to-the-minute traffic information

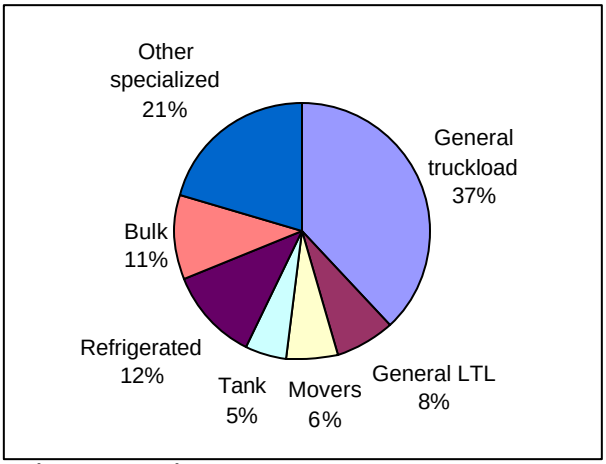
Source of traffic information	Judged to be more useful	Judged to be less useful
Cheaper and better in-vehicle navigation systems	Operations from outside California Intermodal: multiple modes Carriers with long load moves	Private carriers Intermodal: no services Carriers with short load moves Carrier with other specialized services
Computer traffic maps for dispatchers	Operations from outside California Carriers with long load moves	Private carriers Intermodal: no services Carriers with short load moves
More freeway changeable message signs (CMS)	Operations from outside California Carriers with long load moves	Carriers with specialized services Operations out of S.F. Bay Area Intermodal: no services Carriers with short load moves
Kiosks at truck stops where drivers can punch up traffic information	Carriers with long load moves Operations from outside California	Private carriers Carriers with specialized services Operations out of Los Angeles Area Operations out of S.F. Bay Area Intermodal: no services Carriers with short load moves
Dedicated area-wide 24-hour highway advisory radio stations	Carrier with both truckload & LTL	Exclusively LTL carrier Carrier with other specialized services Carriers with short load moves



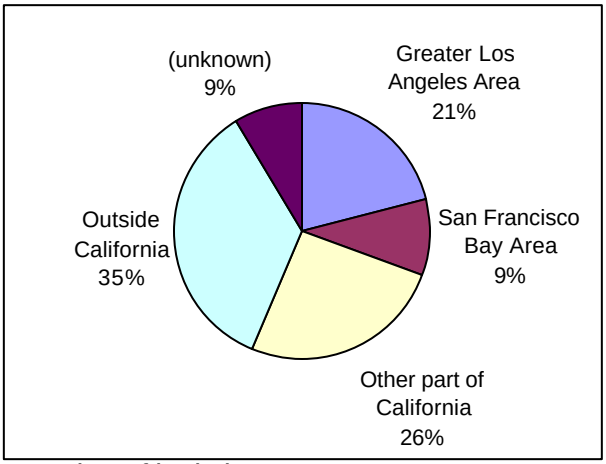
Load type



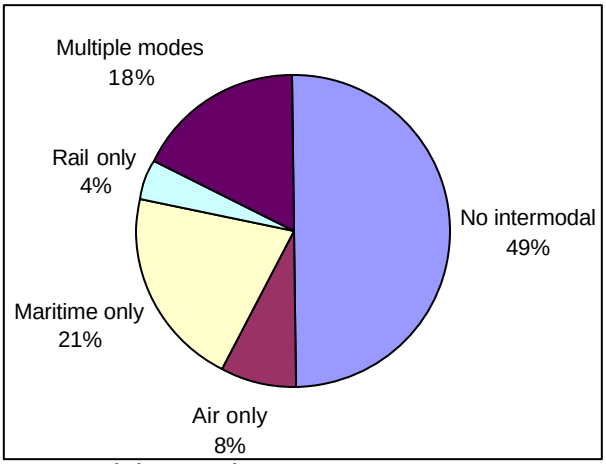
Carrier type



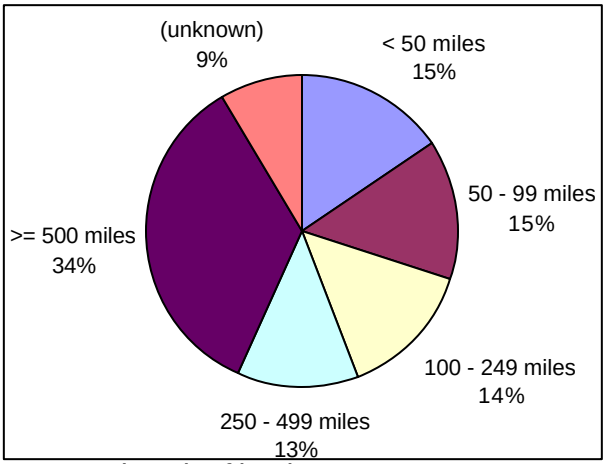
Primary service



Location of logistics manager



Intermodal operations



Average length of load moves

Figure 1
Breakdowns of the characteristic variables used in the present analyses