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Abstract

The objective of this research is to understand how trucking companies perceive the benefits of traditional and advanced traveler information sources. There is considerable interest in identifying the appropriate public sector role for investments in real-time traveler information sources. Managers in charge of the California operations of more than 1,100 private and for-hire trucking companies were asked to evaluate the usefulness of various sources of traffic information. These evaluations were collected on ordinal scales, and nonlinear canonical correlations analysis models were computed to simultaneously link company characteristics and perceptions of the value of information sources for dispatchers and for drivers. In addition, perceptions of the benefits of a set of improved sources of accurate, up-to-the-minute traffic information were examined. The results show how segments of the trucking industry value different sources of traffic information.

Key Words: Freight, ITS, ATIS, Commercial Vehicle Operations, Trucking, Traffic Congestion, Intermodal Operations, Intelligent Transportation Systems, Fleet Management.

1. Objectives and Scope

In this paper we explore the perceptions held by trucking company operations and logistics managers about the usefulness of existing and proposed sources of traffic information. These perspectives 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, as discussed in Golob and Regan (2001a). 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 commercial vehicle operations (CVO) will likely be supplied with real-time information on traffic conditions, queues at intermodal and distribution facilities, parking information, and roadway hazards. Web-based systems could replace technology developed exclusively for ATIS.

CVOs 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 sharp increase in just-in-time distribution systems begun in the 1980's has an even steeper trajectory 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 vehicles 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 company 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 are cheaper and better in-vehicle navigation systems, computer traffic maps for dispatchers on cable or satellite TV, more use of freeway changeable message signs, kiosks at truck stops where drivers can obtain traffic information and area-wide dedicated 24-hour highway advisory radio. In 1998 these appeared to be the most important developments. The same survey conducted in 2000 would need to test additional technologies.

This paper is organized into eight sections. In the following, Section 2, we review previous studies. Next, we discuss the content of the survey and describe the sample used in the analysis. This is followed by a methodology section. Results are 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. The final section deals with conclusions.

2. Background

The adoption of Information technology 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 trucking industry 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) Internet information content, 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.

In preparation for such a “connected” future, the present research investigates how existing and near-term 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 CVO characteristics with favorable and unfavorable opinions about the relative usefulness of various sources of traffic information.

3. Data

3.1. Protocol and Sampling

During the Spring of 1998, a survey of 1177 trucking companies operating in California was carried out by Strategic Consulting and Research of Irvine, California for the Institute of Transportation Studies at the University of California, Irvine. The sample was drawn from a set 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 fleets with at least 10 power units and (3) 2325 for-hire large national carriers based outside of California with annual revenues 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%.

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.

3.2. Survey Content

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

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. An analysis of carrier perceptions of the effectiveness of congestion mitigation strategies available to public agencies is provided in Golob and Regan (2000). 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. A model of demand for information technologies is presented in Golob and Regan (2001b). In the third section of the survey, data was 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. Carrier perceptions of problems encountered in intermodal maritime operations are explored in Regan and Golob (2000d). The section of the survey dealing with the usefulness of sources of traffic information provides the data used in the research presented here.

3.3. Sample Description

The survey sample of 1177 trucking companies is broken down into 34% private fleets 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. 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

In the analyses reported here, six different operating characteristics were found to be significantly explain responses concerning the usefulness of traffic information. Fleet size was not one of these characteristics, which was an unexpected result. The functionality 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 here as explanatory variables, are shown in Figure 2.

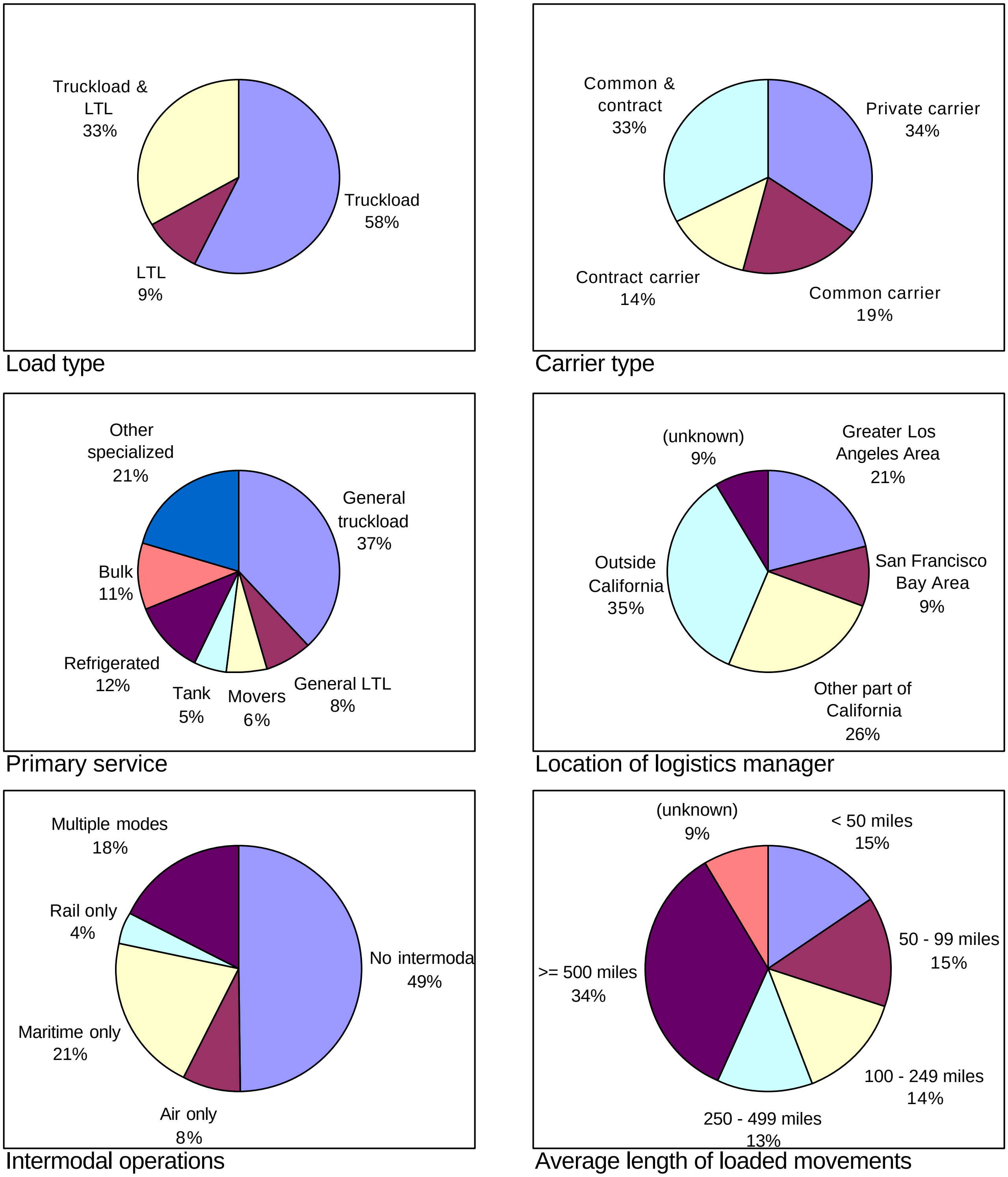

Figure 1. Breakdowns of the characteristic variables used in the present analyses

Load type is described in terms of truckload (58%), less-than-truckload (9%), and combination of the two services (33%). 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 four known categories of location of manager of California operations; California operations of many large regional and national carriers are managed from outside of California. Finally, intermodal operations were divided into five categories, and average length of loaded movement was divided into five known categories. After eliminating companies with missing data on these characteristics, the sample size for the present analyses was 985.

4. Methodology

The objective was 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. The number of canonical variates is usually limited to two or three because of practical reasons associated with interpreting the results. CCA can also be generalized to more than two sets of variables, and with only one set of variables, CCA is essentially equivalent to principal components factor analysis.

Here, we have a 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 lnear combination of the variables on the dependent side is also undefined, because the categories of each variable can be re-scaled by any nonlinear function that preserves monotonicity. 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.

Researchers at the Department of Data Theory of Leiden University in the Netherlands developed an elegant solution to such a nonlinear CCA problem. The Leiden method for nonlinear CCA, originally known as CANALS (Canonical Analysis by Alternating Least Squares), is described in detail in De Leeuw (1984), Van der Burg (1988) and Gifi (1990). CANALS has been applied in the analysis of transportation attitudes and perceptions by Hensher and Golob (1999). 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 how the alternating least squares (ALS) solution method works. 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 conventional singular value decomposition (Gifi, 1990; Israëls, 1987). Most linear multivariate methods, such as principal components analysis and discriminant analysis, are also based upon singular decomposition (eigenvalue) solutions. CANALS is just a more complicated formulation, because category quantifications for each variable, as well as the variable's weight, are parameters in optimization of 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).

Graphical representations are very important in interpreting a CANALS solution. Patterns in the combination of optimal category scores and variable coefficients in multidimensional space data can best be detected by the eye (Cailliez and Pagès, 1976; Ter Braak, 1990). Assuming we have a two-dimensional CANALS solution, interpretation begins with a two-dimensional plot of the weights of the optimally scaled variables in the orthogonal space of the canonical variates. In such a "component loadings" plot, the square of length of the vector from the origin to the coordinates of a given variable indicates how much of the variable was explained by the two 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 inner product of the two vectors is a close approximation of the correlation between the two optimally scaled variables (Ter Braak, 1990). In our application, the inner product of the vectors for two sources of traffic information on the component loadings plots indicates the degree of correlation between the evaluations of the two sources. The inner product of the vector of a dependent information source variable and the vector of the quantification of a trucking attribute variable gives the correlation between the quantification of the attribute variable and the evaluation of the information source. The optimal category score plots provide the rest of the information we need to interpret a nonlinear CCA solution in the present application. By comparing the component loadings and category scores we can determine which types of trucking operations find specific sources of traffic information to be most and least useful.

5. Perceived Usefulness of Information Sources for Dispatchers

Trucking company managers were asked to rate the usefulness *to dispatchers* of five sources of traffic information on a three-point scale: (1) very useful, (2) somewhat useful, (3) not useful, or "don't know". 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, (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. Aggregate ratings of the usefulness to dispatchers of five sources of traffic information (N = 985)

Information source	Sample breakdown (%)			
	Very useful	Somewhat 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

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. Presumably this will change as dispatchers increase their use of computers with Internet connections in response to the demand for and availability of e-commerce. 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.

A nonlinear CCA model was computed to optimally segment the ratings of the usefulness of the sources to dispatchers according to the six exogenous variables representing operating characteristics. A two-dimensional CCA solution exhibited a good explanation of the relationships between the five endogenous and six exogenous variables. 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. A two-dimensional solution was chosen as the canonical correlation for the third dimension fell off to 0.236.

The optimally scaled variables are plotted in the two-dimensional space of the orthogonal canonical components in Figure 2. As described in Section 4, the inner products of any two vectors in this space approximate the correlations between the two variables. Focussing first on the endogenous variables, Figure 2 shows that traffic reports on television stations and computer traffic maps on the World Wide Web are viewed similarly, but evaluations of traffic reports on television stations are less well explained by the CCA solution (because the vector is shorter, and the sum of squared projections on the axes indicates the proportion of variance accounted for by the two canonical variates). Also associated with these two sources of visual information is traffic reports on commercial radio stations, which is negatively correlated with the two sources of visual information because the former variable is aligned with 180-degree projections of the two former variables. The is a negative correlation between ratings of commercial radio stations and ratings of both television and Internet reports. We can define this cluster of sources as the “commercial provider” dimension. Evaluations of reports from drivers on the road and phone calls to agency sources are relatively independent of each other and of the commercial provider dimension. The two sources of information best explained by the model, as measured by the length of the vectors in the components loadings plot of Figure 2, are reports from drivers on the road and traffic reports on the World Wide Web. The source of information least well explained is traffic reports on television stations, probably because fewer operations rely on such reports.

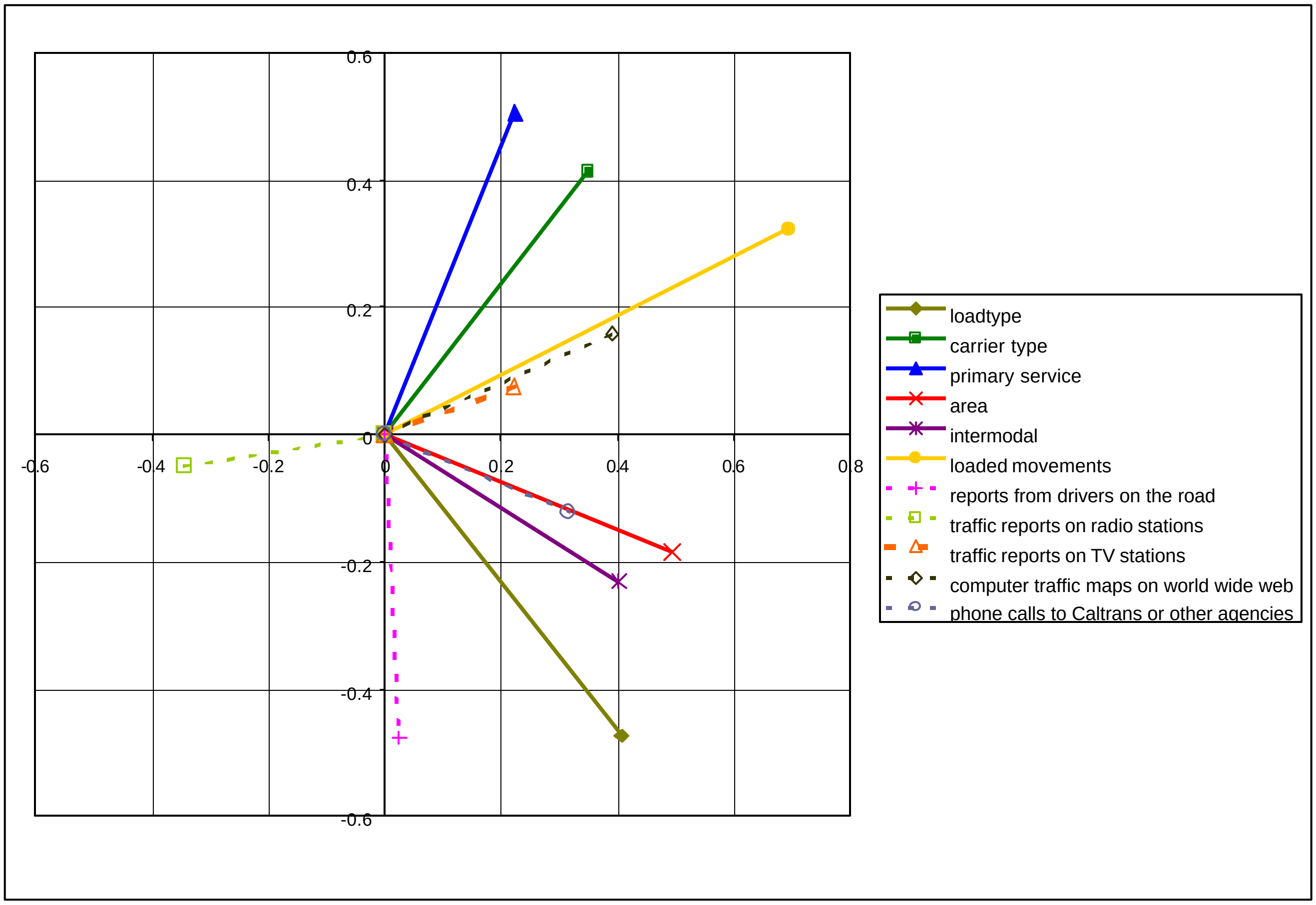

Figure 2. Component loadings for all variables: Nonlinear canonical correlation analysis of evaluations of sources of traffic information for dispatchers.

Regarding relationships among the six optimally scaled variables on the exogenous side of the problem, Figure 2 shows that two approximately orthogonal clusters of operating characteristics have similar segmentation powers. These two clusters are approximately orthogonal (independent of each other) in the component space, and the orthogonal space they define is rotated approximately 45 degrees from the x-y axes. The core of the first cluster is the pair “carrier type” and “primary service,” with “length of loaded movement” also being strongly associated. The second cluster is composed of “location” (area), “intermodal operations,” and “load type.” The category scores of each variable, listed in Table 3, are needed to interpret these exogenous clusters and their relationship to the endogenous variables. The category scores for each variable are centered on zero, and if two categories have similar scores on a variable this indicates that 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 graphed in Figure 2. Companies in categories that exhibit strong negative scores on a variable tend to have managers with perceptions that are consistent with the variable's component loadings multiplied by negative one, which is defined by a 180-degree reverse projection of the vector in Figure 2.

Table 3. Optimal category scores for the exogenous variables: Nonlinear canonical correlation analysis of evaluations of sources of traffic information for dispatchers.

Variable	Category	Quantification
Load type	Exclusively truckload	.35
	Exclusively less-than-truckload (LTL)	-3.25
	Both Truckload and less-than truckload	.39
Carrier type	Private fleet	-1.17
	Common (for-hire) carrier	-.28
	Contract carrier	1.26
	Both common and contract carrier	.96
Primary service	General truckload	.29
	General less-than-truckload (general LTL)	-3.06
	Movers	1.26
	Tank carrier	-1.05
	Refrigerated carrier	.50
	Bulk carrier	-.40
	Other specialized services	.65
Base of operations	Greater Los Angeles metropolitan area	-1.84
	San Francisco bay metropolitan area	-.32
	Other parts of California	.85
	Regional or national carrier outside CA	.24
Intermodal operations	No intermodal services	-.87
	Air intermodal only	.79
	Maritime intermodal only	.48
	Rail intermodal only	2.25
	Multiple intermodal services	1.31
Loaded movements	Average movement less than 50 miles	-1.86
	Average movement 50-99 miles	-.53
	Average movement 100-249 miles	-.21
	Average movement 250-499 miles	.49
	Average movement more than 500 miles	.92

The optimal scaling of the “carrier type” variable primarily distinguishes private fleets from contract carriers. The scaling of “primary service” generally distinguishes general LTL carriers from all other types, especially from movers; tank carriers are most similar to general LTL. For the third variable in the cluster, the scaling is monotonic in length category, with shorter lengths being accentuated. Thus, the first cluster, which can be labeled “basic operation” has on its negative side private fleets, general LTL operations and carriers with short average loaded movements. On the positive side are contract carriers, movers, and carriers with long average loaded moves.

For the second cluster of exogenous variables, 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. The scaling of intermodal operations distinguishes carriers with rail and multiple intermodal services from those without intermodal services. Finally, the scaling of load type differentiates carriers with only LTL operations from those with truckload operations. This cluster of exogenous variables captures exclusively LTL operations, operations centered in Los Angeles, and operations without rail intermodal services on the negative side. On the positive side are non-exclusively LTL operations, operations centered outside the two major conurbation in California, and rail intermodal operations.

Comparing the endogenous and exogenous variable clusters in Figure 2, the “basic operations” cluster is in close proximity to the “commercial provider” cluster of information sources. Particularly, evaluations of the usefulness of commercial video information (Internet and television) is closely related to the average length of loaded movements. Operators with long moves tend to judge video information most useful, and those with short moves tend to judge such sources less useful. Correspondingly, traffic reports on commercial radio stations are judged to be more useful by operators with shorter loaded moves, and less useful by those with longer moves.

The other exogenous variable cluster, defined by load type, area and intermodal operations, is more aligned with the two “personal” sources of traffic information: reports from drivers on the road and phone calls to Caltrans or other agencies. Reports from drivers on the road are not favored by general LTL carriers. Driver reports are favored instead by carriers serving rail terminals. Phone calls to agencies are also deemed useful by carriers engaged in rail services, but calls are deemed less useful by carriers operating primarily in the Greater Los Angeles Area.

The results matching specific company characteristics with perceptions of the usefulness of different information sources are summarized in Table 4. Compilation of Table 4 was aided by the calculation of the inner (dot) products of the vector in Figure 2, which approximate correlations between the explanatory variables and sources of information for dispatchers; these correlations are shown graphically in Figure A.1 of the Appendix.

The CCA results in Figure 2 and Tables 3 and 4 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 carriers with long loaded moves, by contract carriers and by movers. Demand will be lower from carriers with short loaded moves, general LTL carriers, and private carriers. 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.

Table 4. Summary of 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	Private fleets Tank carriers	Contract carriers Contract & common carriers Movers
Traffic reports on commercial radio stations	Carriers w short load moves Operations out of Los Angeles Area Private carriers	Contract carriers Contract & common carriers Carriers with long load moves Operations out of other areas of CA
Traffic reports on television	Carriers with long load moves	Carriers with short load moves
Computer traffic maps on the world wide web	Carriers with long load moves Contract carriers Contract & common carriers Movers	Carriers with short load moves Private carriers General LTL services Operations out of Los Angeles Area
Phone calls to Caltrans or other information services	Carriers serving rail terminals Carriers with multiple intermodal	Operations out of Los Angeles Area Carriers with no intermodal services

6. Perceived Usefulness of Information Sources for Drivers

Respondents were also asked to rate the usefulness of five potential sources of traffic information that drivers can use directly on the same three-point scale. The aggregate results are listed in Table 5. Freeway changeable message signs (CMS), CB radio reports from other drivers and traffic reports on the radio were deemed most useful for drivers. Freeway changeable message signs were deemed most useful followed by CB 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 was viewed least useful for drivers, possibly reflecting the incomplete availability of this source of information at that time.

A two-dimensional nonlinear CCA solution was once again found to provide a good 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.

Table 5. 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 and terminals	40.3	36.3	21.3	2.0

The optimally scaled variables for the nonlinear CCA model of sources of traffic information for drivers are plotted in the two-dimensional space of the orthogonal canonical variates in Figure 3. 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 citizens band (CB) 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 listening habits.

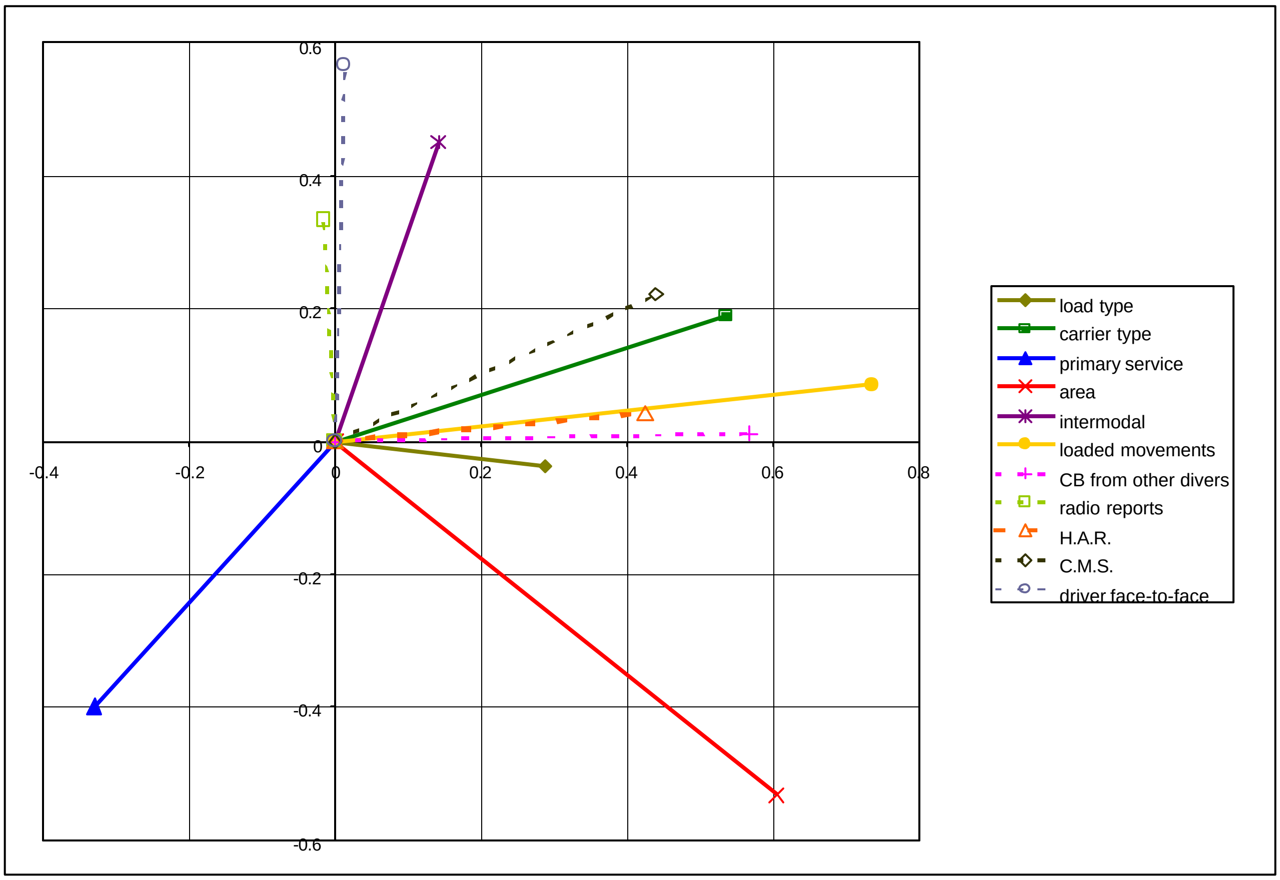

Figure 3. Component loadings for all variables: Nonlinear canonical correlation analysis of evaluations of sources of traffic information that drivers use directly.

The relationships among the exogenous variables in the present nonlinear CCA is given by the component loadings of the exogenous variables in Figure 3 and the optimal category scores in Table 6. In general these exogenous relationships are different than those for the previous CCA model (Figure 2 and Table 3), meaning 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.

Table 6. Optimal category scores for the explanatory variables: Evaluations of sources of traffic information that drivers use directly.

Variable	Category	Quantification
Load type	Exclusively truckload	.19
	Exclusively less-than-truckload (LTL)	-3.37
	Both Truckload and less-than truckload	.32
Carrier type	Private fleet	-1.00
	Common (for-hire) carrier	1.77
	Contract carrier	.13
	Both common and contract carrier	.38
Primary service	General truckload	-.09
	General less-than-truckload (general LTL)	1.47
	Movers	1.84
	Tank carrier	-2.89
	Refrigerated carrier	-.43
	Bulk carrier	-.13
	Other specialized services	.87
Base of operations	Greater Los Angeles metropolitan area	-1.67
	San Francisco bay metropolitan area	-.51
	Other parts of California	.09
	Regional or national carrier outside CA	.94
Intermodal operations	No intermodal services	-.41
	Air intermodal only	.25
	Maritime intermodal only	.34
	Rail intermodal only	4.52
	Multiple intermodal services	-.44
Loaded movements	Average movement less than 50 miles	-1.85
	Average movement 50-99 miles	-.51
	Average movement 100-249 miles	-.18
	Average movement 250-499 miles	1.20
	Average movement more than 500 miles	.64

There is a cluster of two exogenous characteristics, length of loaded movements and carrier type, loaded primarily on the first canonical variate. Load type is also aligned with the first variate, but is not well explained by the solution (indicated by the short length of the vector). Considering how the variables are coded according to the category scores (Table 6), 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 fleets. We can label this cluster simply as "loads." Compared to the scores for the categories representing common carriers and private fleets 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 (abbreviated in the Figures as "area"). This spatial variable is the most important of all in explaining the endogenous variables, and the optimal category scores show that it distinguishes Los Angeles, and then San Francisco Bay, operations from those located outside the State of California.

Comparing the endogenous and exogenous variable clusters in Figure 3, the "loads" cluster of exogenous variables is aligned with the CB radio and HAR pair of sources and with the CMS source, all of which provide drivers with traffic updates in certain areas of presumably heavy traffic. Thus, carriers with longer moves and common carriers value such sources more highly, while carriers with shorter moves and private fleets do not. The second cluster of exogenous variables, intermodal operations and primary service (negative) exhibits more power in explaining evaluations of face-to-face reports among drivers at truck stops and terminals and traffic reports on commercial radio stations, in addition to HAR Thus, the provision of traffic updates on a regular schedule at specific locations is valued more highly by carriers serving railheads and by tank carriers. Such sources are valued less highly by movers, carriers with general LTL operations, and carriers engaged in either no intermodal services or multiple intermodal services.

The results matching specific company characteristics with perceptions of the usefulness of different information sources that drivers use directly are summarized in Table 7, which was compiled with the aid of the correlation estimates generated from the dot products of the vectors in Figure 3 and shown graphically in Table A.2. One of the most pervasive exogenous variables in Table 7 is the location variable, which was included in the analysis in order to understand how local traffic conditions might influence a managers perceptions of the usefulness of different information sources. Indeed, managers in the Los Angeles Metropolitan Area, which is known for its "Sigalert"[1] traffic advisories carried by most commercial radio stations, find traffic reports on commercial radio stations most useful. The optimal category scores (Table 6) show

[1] A Sigalert is a radio announcement sent out by the California Highway Patrol to make the community aware of an incident on the freeway that will block one or more lanes for at least thirty minutes. It was named for Lloyd Sigmon, its inventor, who was co-owner of radio station KMPC in the 1950's.

that managers of operations out of the San Francisco Bay Area are most similar to managers of Los Angeles operations in their opinions of the usefulness of information sources for drivers.

Table 7. Summary of 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	Carriers with 250-499 mi. moves Common carriers Operations from outside California Carriers with moves ≥ 500 mi.	Carriers with short moves Private carriers LTL carriers
Traffic reports on commercial radio stations	Intermodal: rail only Operations out of Los Angeles Area Tanker services	Operations from outside California Movers General LTL services
Dedicated highway advisory radio (HAR)	Carriers with 250-499 mi. moves Common carriers Operations from outside California	Carriers w/ load moves < 50 mi. Private carriers LTL carriers
Freeway changeable message signs (CMS)	Common carriers Carriers with 250-499 mi. moves Intermodal: rail only Carriers w/ load moves ≥ 500 mi.	Private carriers Carriers with short moves Operations out of Los Angeles Area
Face-to-face reports among drivers at truck stops and terminals	Intermodal: rail only Operations out of Los Angeles Area Tanker services	Operations from outside California Movers General LTL services

These nonlinear CCA 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 fleets and for drivers of operations 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 for carriers operating out of the Greater Los Angeles Area (and also the san Francisco Bay Area), for tanker operators, and for carriers serving railheads. Preference should be lower for drivers for movers of household goods and carriers engaged in general LTL operations.

7. Improved Future Sources of Traffic Information

Ratings of potential sources of information that are in varying stages of development are presented in Table 8. 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 8. 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 on cable or satellite TV	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 punch up traffic info.	43.2	33.4	21.1	2.8
Area-wide dedicated 24-hour highway advisory radio	64.7	26.1	7.4	1.8

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 plot for this models is shown in Figure 4, and the optimal category scores are listed in Table 9.

On the endogenous variable side of the problem, all sources of information are positively 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" (area-wide HAR), "more use of changeable message signs" (more CMS), and "better and cheaper 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 "computer traffic maps for dispatchers on cable or satellite TV" (possible through the use "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.

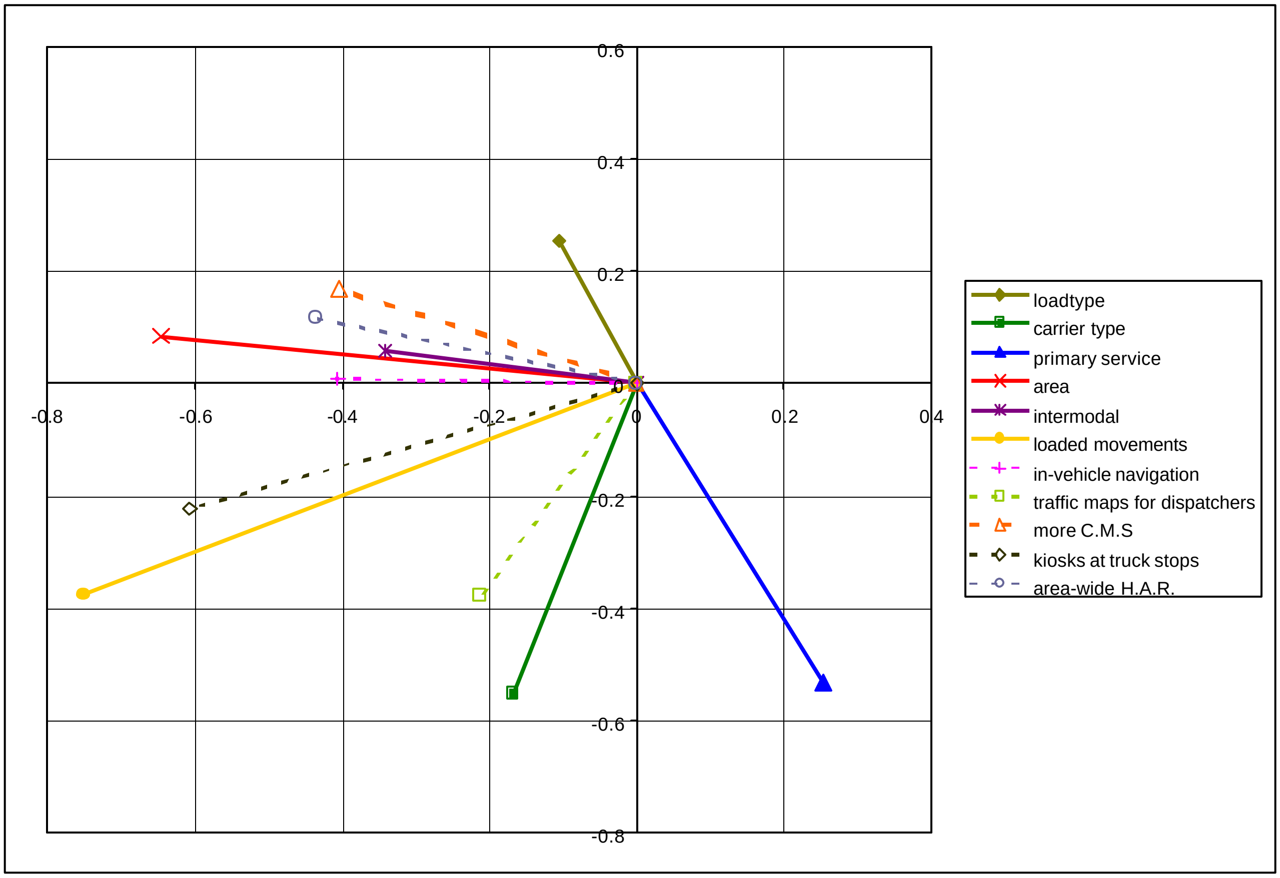

Figure 4. Component loadings for all variables: Nonlinear canonical correlation analysis of evaluations of improved sources of accurate, up-to-the-minute traffic information.

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 spatial location and intermodal operations. In light of the optimal category scores for these variables (Table 9), 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 (negative) primary service and load type. It contrasts tanker operators and operators who provide general LTL services together with truckload services against carriers that provide *exclusive* LTL operations and carriers with other specialized operations. The loaded movements 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 fleets, with common carriers being scored closest to zero (indicating small effects in the model).

Table 9. Optimal category scores for the explanatory variables: Evaluations of improved sources of accurate, up to the minute sources of traffic information.

Variable	Category	Quantification
Load type	Exclusively truckload	-.59
	Exclusively less-than-truckload (LTL)	-2.04
	Both Truckload and less-than truckload	1.17
Carrier type	Private fleet	-1.09
	Common (for-hire) carrier	-.57
	Contract carrier	1.58
	Both common and contract carrier	.78
Primary service	General truckload	-.61
	General less-than-truckload (general LTL)	-1.46
	Movers	.28
	Tank carrier	-1.67
	Refrigerated carrier	.58
	Bulk carrier	.47
	Other specialized services	1.57
Base of operations	Greater Los Angeles metropolitan area	-.54
	San Francisco bay metropolitan area	-2.05
	Other parts of California	-.38
	Regional or national carrier outside CA	1.10
Intermodal operations	No intermodal services	-.79
	Air intermodal only	1.26
	Maritime intermodal only	-.10
	Rail intermodal only	1.63
	Multiple intermodal services	1.56
Loaded movements	Average movement less than 50 miles	-1.93
	Average movement 50-99 miles	-.68
	Average movement 100-249 miles	.25
	Average movement 250-499 miles	.63
	Average movement more than 500 miles	.76

Interpretations of relationships between the exogenous and endogenous variables are guided by the results in figure 4 and Table 9 and the estimated correlations in Table A.3 of the Appendix. These interpretations are summarized in Table 10.

Table 10. 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	Carriers w/ both TL and LTL service Operations from outside California Carriers with long load moves Intermodal: rail only, air only or multiple modes	Operations out of S.F. Bay Area Carriers w/ load moves < 50 mi. Intermodal: none
Computer traffic maps for dispatchers on cable or satellite TV	Operations from outside California Contract carriers Carriers with long load moves Other specialized services	Operations out of S.F. Bay Area Carriers with load moves < 50 mi. Private carriers Tanker services General LTL services
More freeway changeable message signs (CMS)	Operations from outside California Intermodal: rail only, air only or multiple modes Carriers with long load moves	Operations out of S.F. Bay Area Carriers w/ load moves < 50 mi. Intermodal: none LTL carriers
Kiosks at truck stops where drivers can punch up traffic information	Carriers with long load moves Operations from outside California Contract carriers Intermodal: rail only, air only or multiple modes	Operations out of S.F. Bay Area Carriers with load moves < 50 mi. Intermodal: none Private carriers
Dedicated area-wide 24-hour highway advisory radio stations	Logistics manager outside CA Intermodal: rail only, air only or multiple modes Carriers with long load moves	Manager in the S.F. Bay Area Carriers w/ load moves < 50 mi. Intermodal: none

Turning first to the cluster of three advanced driver-targeted sources of traffic information, the primary explanatory variables are spatial location, intermodal services and length of load moves. Such sources, which include dedicated 24-hour area-wide HAR, more use of CMS, and better and cheaper in-vehicle navigation systems, are deemed useful especially by carriers based outside of California and carriers with rail, air and multiple intermodal services. Carriers with load moves under fifty miles are less inclined to judge driver-targeted ATIS as being useful in their operations.

Preferences for ATIS kiosks at truck stops are related primarily to operators' length of loaded movements, 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, carriers with rail, air and multiple intermodal services, and carriers with long load moves. In addition, ATIS kiosks are deemed more useful by contract carriers and less useful by private fleets.

Finally, evaluations of the usefulness of computer traffic maps for dispatchers on cable or satellite television are explained primarily by carrier type and by operators' length of loaded moves. Secondarily, evaluations of computer traffic maps are also explained by primary service and by spatial location. The primary market for such systems might be among contract carriers and carriers with long loaded moves, and from operators based remotely. Support for such systems is less likely to come from private fleets, operators with short loaded moves (specifically those with moves less than fifty miles), general LTL carriers, and tank carriers.

8. Conclusions

The trucking industry plays a critical role in the U.S. economy. The strength of each region's industrial base depends on the ability of freight-transport companies to provide swift and reliable goods movement at reasonable costs. New technologies make the delivery of traffic information possible in many new ways. Such information may help improve the efficiency of goods movement. The trucking industry is very diverse. Policy analysts, technology developers and information providers should be interested the perceptions of commercial vehicle operators regarding the usefulness of different types of information systems. In this paper, we describe results from the application of nonlinear multivariate statistical models to attitudinal data from a large-scale survey of for-hire trucking companies and private trucking fleets operating in California. These models explain how perceptions of the value of specific sources of traffic information are related to the operating characteristics of the trucking companies. The models are used to gain both performance and market research information.

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Appendix

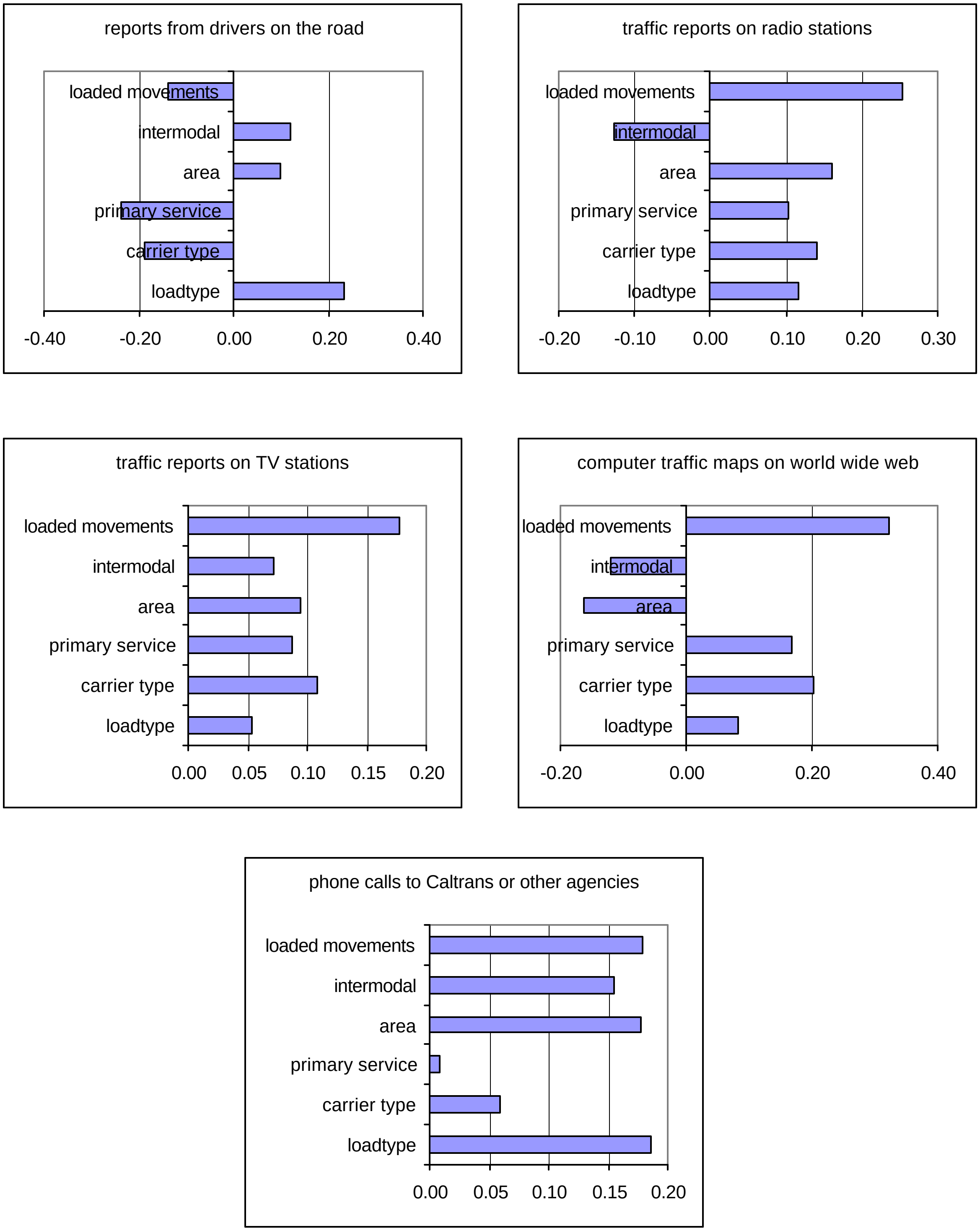

Figure A.1. Estimates of correlations between the explanatory variables and evaluations of sources of information for dispatchers in the nonlinear CCA solution

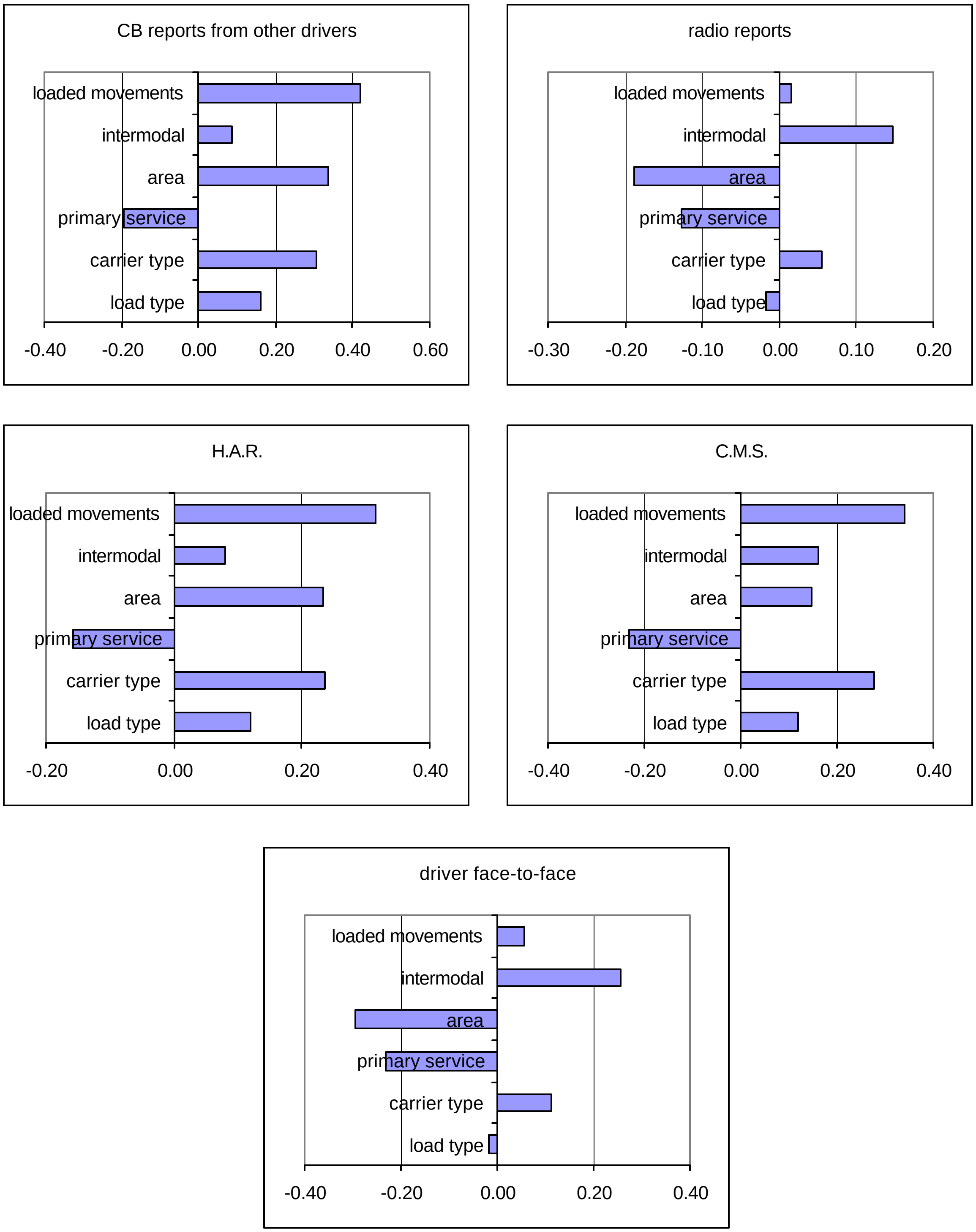

Figure A.2. Estimates of correlations between the explanatory variables and evaluations of sources of information for drivers in the nonlinear CCA solution

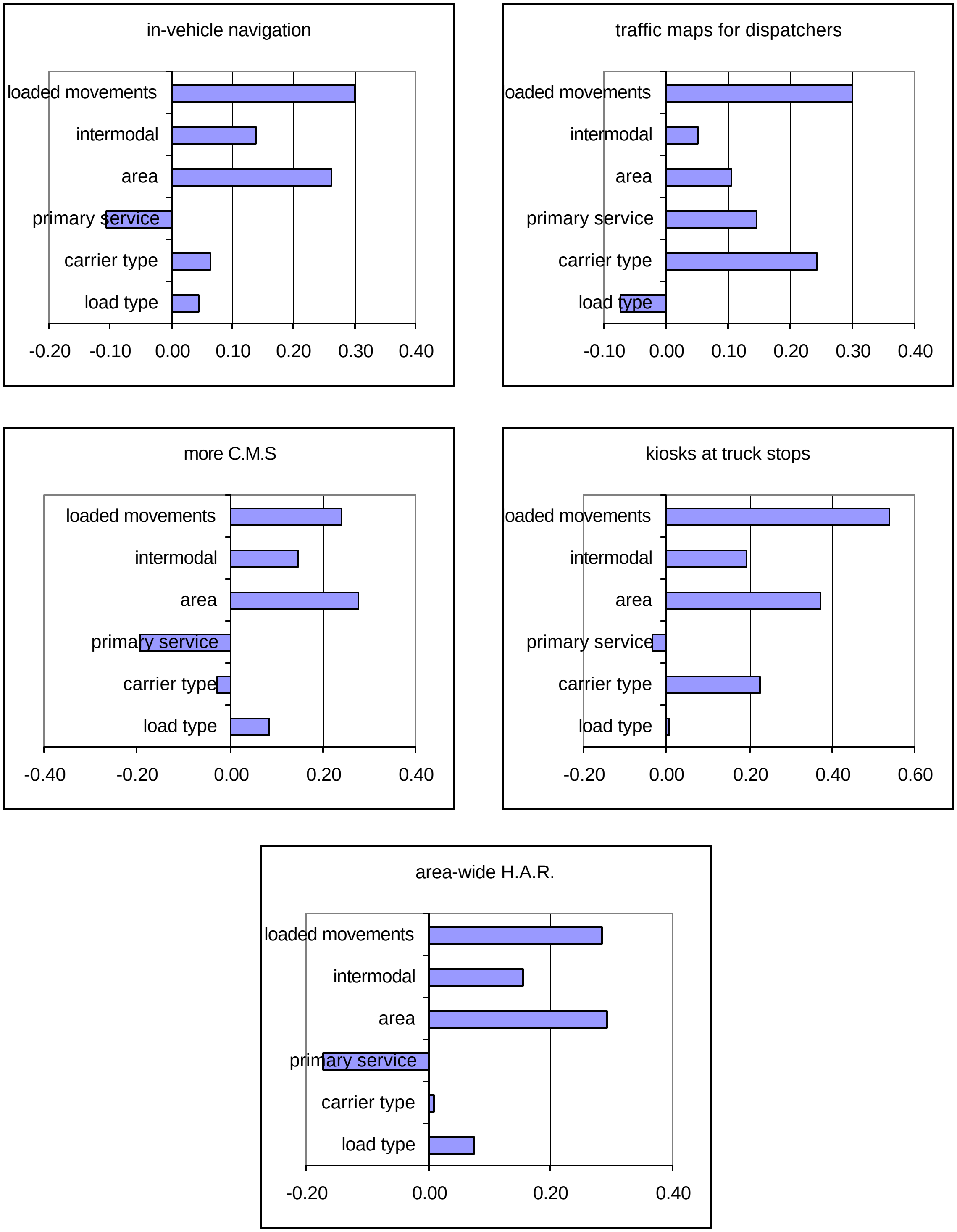

Figure A.3. Estimates of correlations between the explanatory variables and evaluations of future information sources in the nonlinear CCA solution