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CFIRE Research Report

Collaborating Toward the IT Highway: Linking Public and Private Investments in Intelligent Transportation Systems to Freight Flows and Supply Chain Performance

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Notes:
At least one institution listed above must be a CFIRE consortium partner.
This research document is for the purpose of the research selection process. It will be shared with CFIRE's Executive Commitee, staff, and other peers for review and evaluation.

Table of Contents

1. Project Summary iv
2. Problem Statement 1
3. Literature Rview / Methodology / Data / Discussion 2
4. Qualifications, Accomplishments, and Commitments of Research Team 2
5. Equipment and/or Facilities 12
6. Schedule 15
7. Budget 16
8. Cooperative Features and/or Partnerships 18

1. Project Summary

Project Title: Collaborating Toward the IT Highway: Linking Public and Private Investments in Intelligent Transportation Systems to Freight Flows and Supply Chain Performance

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Project Abstract: This project examines the relationship between public and private investments in intelligent transportation system (ITS) technology and the effects on transportation performance through the highway system. ITS technology is described as a special infrastructure to promote integrated information sharing that can be used to improve system performance. ITS combine better infrastructure with information and control technologies to (i) reduce traffic congestion by maintaining traffic flow, (ii) reduce transportation-generated pollution, (iii) improve transport efficiency, and (iv) produce economic benefits (1, 2).

Three hypothesized relationships were tested using a statistical analysis of partial least squares structural equation modeling. Primary data was collected from U.S. based commercial vehicle transportation service providers. Respondents were parceled using a geographic information system analysis of secondary data from the U.S. Department of Transportation's (USDOT) National ITS Deployment Tracking Survey. Based on the level of regional ITS experience, primary data respondents were matched to regions and split between regions with low ITS experience and high ITS experience as a proxy for regional public investments in ITS. Performance measures were based on efficiency, reliability, responsiveness, quality, carbon emissions reduction and equipment utilization for commercial vehicle operators.

Results indicate that private investments in ITS significantly positively effect the responsiveness performance measure for commercial vehicle operators in regions with high public ITS investments. The same relationship is not significant in regions with low public ITS investments, thus indicating at least some transportation performance improvements for regions with higher investments in ITS. Implications for research and practice are discussed.

Duration; Dates:	12 months; (8/01/2014 – 7/31/2015)
Budget:	$89,502
Matching Funds & %:	$89,506; 50% of Total Budget
Student Involvement:	1 Master's Student; 1 Ph.D. Student for dissertation work
Modal Orientation:	Highway based, some intermodal

2. Problem Statement

Intelligent transportation system (ITS) technology is known as a special infrastructure to promote integrated information sharing. Governments, organizations, and individuals can benefit from ITS. Governments can use ITS for tracking and maintaining infrastructure and truck movements for regulation purposes. Organizations can use ITS to maintain fleets and their movements in order to comply with regulations more efficiently. ITS can help inform individual drivers of current conditions for congestion delays and improved safety. While furthermore, ITS promote smooth even flows through friction points (e.g. toll booths and weigh stations) and also provides a platform for information sharing that can be used to enhance the continuous flow of freight movements. In this way, ITS combines better infrastructure with information and control technologies to reduce traffic congestion by maintaining traffic flow, to improve transport efficiency, and also to produce economic benefits (1, 2). ITS is gaining in popularity although the extent of system availability varies considerably among regions. Variance among regions can be attributed to the level of investment decision-makers put into ITS resources.

The purpose of this research is to examine how public and private investments in ITS technology effect system freight flows and transportation performance on the highway system. In this context, findings indicate that public and private investments in ITS work together to improve freight flows that lead to enhanced transportation performance. It is suggested that the successful implementation of ITS for commercial freight vehicles requires cooperation between both government and private industry (4, 5) thus driving the need for collaboration and building public private partnerships (PPP) to promote this infrastructure.

Previous work suggests the development of PPPs to overcome the barriers of implementing ITS (6). However, previous research does not report quantifiable benefits of investments in ITS in order to promote further development of ITS across transportation system infrastructure. Business-to-government (B2G) information exchange can promote both reductions in cost and improvements to efficiency (7). Because infrastructure belongs to the public domain yet businesses use the system as an extension of their private enterprises (3) in order to ensure the timely and efficient delivery of goods to market, this paper investigates the collaboration of investments between businesses and governments to further develop ITS to improve both freight flow movements and transportation performance.

When examining ITS investments, it is pertinent to note that some ITS systems have only public investments (*i.e.,* photo enforcement and vehicle compliance checking), while other systems require a marriage of investments between public and private sectors (*i.e.,* electronic credentialing and electronic tolling). Sometimes investments from private industry sources benefit both the private enterprise and society in general. For example, when companies purchase transponders for their fleet to work in conjunction with electronic tolling systems, not only does the fleet move faster for goods to be delivered in a timelier, more efficient manner, but also surrounding vehicles benefit by the reduced congestion at toll sites.

The remainder of this report is structured as follows. The next section discusses the literature review of the constructs, including support for the research model and hypotheses development. Data and methodology for analysis are discussed. The paper closes with discussion of results and conclusions then suggests implications for future directions in research and practice.

3. Literature Review / Methodology / Data / Discussion

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Early research on ITS began in the mid 1990s and focused on feasibility issues and future prospects of the enabling technologies. One study surveyed motor carriers for the feasibility of implementing and using early ITS technology (8), another discussed the feasibility of implementing a particular technology for use at individual freight terminals (9). Benekohal (10) conducted a pilot study of delays at weigh stations to investigate potential benefits of using automatic vehicle identification (AVI) and weigh in motion (WIM) technologies to reduce delays for commercial vehicle operators (CVO). Klinginberg (11) discusses other future possibilities of ITS for CVO users. Another early study developed a framework for a cost benefit analysis of ITS (2). Two studies examine potential applications of ITS in other countries (12, 13). However, discussions about the future of ITS remain open (6).

One theme is apparent among previous streams of ITS research, it has been geared toward feasibility issues and potential future outcomes. Few studies have developed a framework for examining performance indicators of ITS post implementation with quantifiable metrics for either the public or private sectors. However, there is a lack of empirical research linking ITS to quantified performance outcomes in logistics and transportation (14). Barriers to adopting certain technologies are inhibiting their widespread use (15, 14). In particular, a lack of knowledge assessing both the availability and benefits of ITS have led to a lack of adoption in transportation and logistics (15, 14).

Ultimately, the research performed in this article seeks to help fill this gap by providing an empirical study that examines how public and private investments in ITS technology enhance system performance. The main contribution of this paper is development of a conceptual framework and empirical testing of the relationships between public and private investments in ITS and transportation performance measured by efficiency, reliability, responsiveness, quality, carbon emissions reduction and equipment utilization.

Public and Private Investments in Intelligent Transportation Systems (ITS)

ITS is defined as the application of new developments in information processing, communications, sensing, and computer control technologies used to solve surface transportation problems (4, 16). Some of these technologies include the use of photo enforcement, electronic tolling, vehicle-mile taxing, weigh-in-motion, connected vehicle technologies, fleet management, computer-aided dispatch (CAD), automatic vehicle location (AVL), automatic cargo tracking, electronic pre-clearance, vehicle compliance checking, and driver monitoring (17, 18).

Specifically, ITS for freight movements are associated with CVOs and are defined as the ‘‘advanced systems aimed at simplifying and automating freight and fleet management operations at the institutional level” (19, p. 544). ITS is a commonly used terminology in research, although Wolfe et al. (15) refer to ITS for freight movements as intelligent freight technologies (IFT) and succinctly categorize them into five main areas as defined below (p. 4):

- ***Asset tracking*** *uses mobile communications, radio frequency identification (RFID), and other tools to monitor the location and status of tractors, trailers, chassis, containers and, in some cases, cargo.*
- ***On-board status monitoring*** *uses sensors to monitor vehicle operating parameters, cargo condition, and attempts to tamper with the load.*
- ***Gateway facilitation*** *uses RFID, smart cards, weigh-in-motion, and nonintrusive inspection technologies to simplify and speed operations at terminal gates, highway inspection stations, and border crossings.*
- ***Freight status information*** *uses web-based technologies and standards to facilitate the exchange of information related to freight flows.*
- ***Network status information*** *uses services to integrate data from cameras and road sensors and uses display technologies to monitor congestion, weather conditions, and incidents.*

ITS for freight movements is a promising area for investments, however previous research in this area is mainly conceptual in nature, hence there is a call for more studies with quantifiable metrics (14). Thus far in practice, industry use of ITS have primarily been hardware driven and lack the full exploitation of available data. Consequently, the transportation literature calls for operations management research to develop software components, models, and decision-support tools to analyze and make the optimal use of data components from ITS (19). Currently, detailed data gathered from these systems are often acted on by human operators without the use of decision-support tools (19; 20).

Most freight movements are controlled by private industry; therefore a key challenge is to develop cooperative efforts between businesses, government and researchers for the successful implementation of ITS (4, 5) in order to balance the necessity of moving goods into urban areas while limiting affects of environmental, social and logistic costs (5, 31, 32, 33). Peak hour congestion times are of particular concern in urban areas where traffic and congestion are higher. The basic objectives of ITS are apparent; to improve safety, and to reduce congestion and pollution in order to provide economic and environmental benefits (1, 2).

Because the underlying structures of ITS are part of the public domain, investments in integrated ITS technologies can be broken into both public and private realms to evaluate. It stands to reason then that a public private partnership based on a publicly developed platform that could be “plugged into” by businesses and individuals that could result in improvements to efficiency for all users. Therefore:

- Hypothesis 1: Public investments in ITS will have a positive impact on private investments in ITS.

ITS and Transportation Performance

In the freight sector, improvements to truck fuel-efficiencies have helped reduce transportation costs, and in turn a higher importance was placed on transport as an input to production (e.g. substitution of on-site warehousing for JIT deliveries) (24). Authorities and organizations alike have recently turned their attention toward IT applications, such as ITS, in order to improve both efficiency and environmental affects of freight transportation (25). ITS technology components help improve reliability in travel times, safety, and reduce environmental impacts (26).

Button et al. (27) conducted one of the few empirical freight ITS studies on a limited scale for a diversified transportation company, the Nova Group, Ltd. Their results document an average driver productivity improvement of 24% after implementation of the company's proprietary ITS technology called Dispatch Tools. Increases in driver productivity were likely due to improved dispatch efficiencies. Improved efficiencies in the transportation industry stemming from a wider use of ITS can reduce total vehicle miles traveled resulting in lower fuel consumption and also reduced carbon emissions. Additionally, an unanticipated effect was a decrease in stress on the dispatchers and improved communications between dispatchers and office personnel (27).

Furthermore, the U.S. Department of Transportation (US DOT) has identified a number of ITS user benefits, specifically for the private sector, based on a series of field operational tests (15). Various tests have identified ITS user improvements in efficiency, reliability, responsiveness, quality, and carbon reduction. Two examples are based on efficiency improvements for freight carriers. For instance, their Cargo*Mate evaluation (testing chassis tracking and e-seals) estimated an annual carrier benefit of $210.35 per container chassis (15). Additionally, evaluations of ITS tracking systems for Hazardous Materials Safety and Security identified $7k to $15k of cost savings per tractor per year in addition to environmental benefits (15). Reliability and service quality improvements have also been identified due to better schedule adherence, speed and other flexibility of operations that have in turn led to both inventory management and customer service benefits (15).

Results from these government based operational field tests are a promising start toward empirical evidence, however these technologies are not mature "across the board and many benefit scenarios are incomplete," (15, p. 31). Empirical results for ITS are lacking (14).

TABLE 1 Transportation Performance Outcomes, Definitions, and Literature Sources

Efficiency	The extent to which materials are handled and delivered in a cost effective manner.	Skinner (1969) Schmenner and Swink (1989) Fisher (1997) Lee (2002)
Reliability	The extent to which goods are delivered consistently within a specified time window	Skinner (1969) Schmenner and Swink (1989) Fisher (1997) Lee (2002)
Responsiveness	The extent to which the firm and its drivers are able to act quickly when faced with changing environments for pick-up/delivery circumstances.	Skinner (1969) Schmenner and Swink (1989) Fisher (1997) Lee (2002)
Quality	The extent to which the firm and its drivers are able to securely deliver damage free materials and products.	Skinner (1969) Schmenner and Swink (1989)
Carbon Emissions Reduction	The extent to which the firm is able to reduce carbon levels in the supply chain.	Lieb and Leib (2010) Cooke (2008) Murphy (2008) Diabat and Simchi-Levi (2009) Catulli and Fryer (2012) McAvoy (2014)
Equipment Utilization	The extent to which the firm is able to make use of available equipment.	Safizadeh and Ritzman (1997) Dahal (2003)

Table 1 lists each performance outcome, its definition, and literature sources. Based on the literature review above for ITS and transportation performance outcomes, the following hypotheses are presented:

- Hypothesis 2: Public investments in ITS will positively influence transportation performance outcomes for (a) efficiency, (b) reliability, (c) responsiveness, (d) quality, (e) carbon emissions reduction and (f) equipment utilization.
- Hypothesis 3: Private investments in ITS will positively influence transportation performance outcomes for (a) efficiency, (b) reliability, (c) responsiveness, (d) quality, (e) carbon emissions reduction and (f) equipment utilization.

METHODOLOGY AND DATA

Three hypothesized relationships were tested using a statistical analysis with partial least squares structural equation modeling. Primary data was collected using an online survey instrument from 260 U.S. based commercial vehicle transportation service providers. The instrument was validated using SPSS AMOS, a component based structural equation modeling package.

Secondary data was used to determine the level of public ITS investments. This came from the 2013 National ITS Deployment Tracking Survey carried out by the U.S. Department of Transportation's (USDOT) ITS Program. In that survey, freeway management (FM) agencies (operating at the state or metropolitan level) were asked to report on their general investment plans for the next three years (2013 – 2016). Agencies were also asked to rate the benefits of ten ITS technologies on freeways based on agency experience. The question covered the following ITS technologies: traffic sensors, vehicle probes, toll tags, cameras, ramp control, lane management, traveler information, automated enforcement, archived data, and environmental sensor stations.

A total of 106 FM agencies completed the survey, from these, 47 agencies were sampled based on the location of freight companies in the primary survey data collected. All sampled agencies had plans to either expand current coverage of existing ITS technologies or deploy new types of technologies (or both). In order to construct an indicator for the level of ITS deployment in each region, a dummy d_{ij} was created for each sampled regional agency i (i = 1,...,47) and each technology j (j = 1,...,10). The dummy d_{ij} was given a value of 1 if the agency had reported experience with the technology (regardless of benefit rating) or zero if the agency had responded "No experience". These dummies were then aggregated across all technologies for each regional agency to give an indication of the total level of ITS deployment in each region. The rationale behind this approach is that if a regional agency has experience with a technology, this serves as an indication that the technology is being used in the region and therefore was initially invested in. Thus, regions with greater experience are used as a proxy as regions with the highest ITS investments.

This information was then linked to the respondents from the primary data collected based on zip code level location. A total of 151 observations were matched between the two data sets for analysis. The core-based statistical areas (CBSA) represent the location of the sample of FM agencies responding to the 2013 National ITS Deployment Tracking Survey. See figure 1.0 for a map of the regional ITS investment levels and respondent locations. Respondents were parceled using a geographic information system (GIS) intersect analysis based on the level of regional ITS experience indicated in the USDOT data, primary data respondents were matched to regions and split between regions with low ITS experience (no experience to experience with six different technologies) and high ITS experience (experience with seven to ten different technologies) as a proxy for regional public investments in ITS. Performance measures were based on efficiency, reliability, responsiveness, quality, carbon emissions reduction and equipment utilization for commercial vehicle operators.

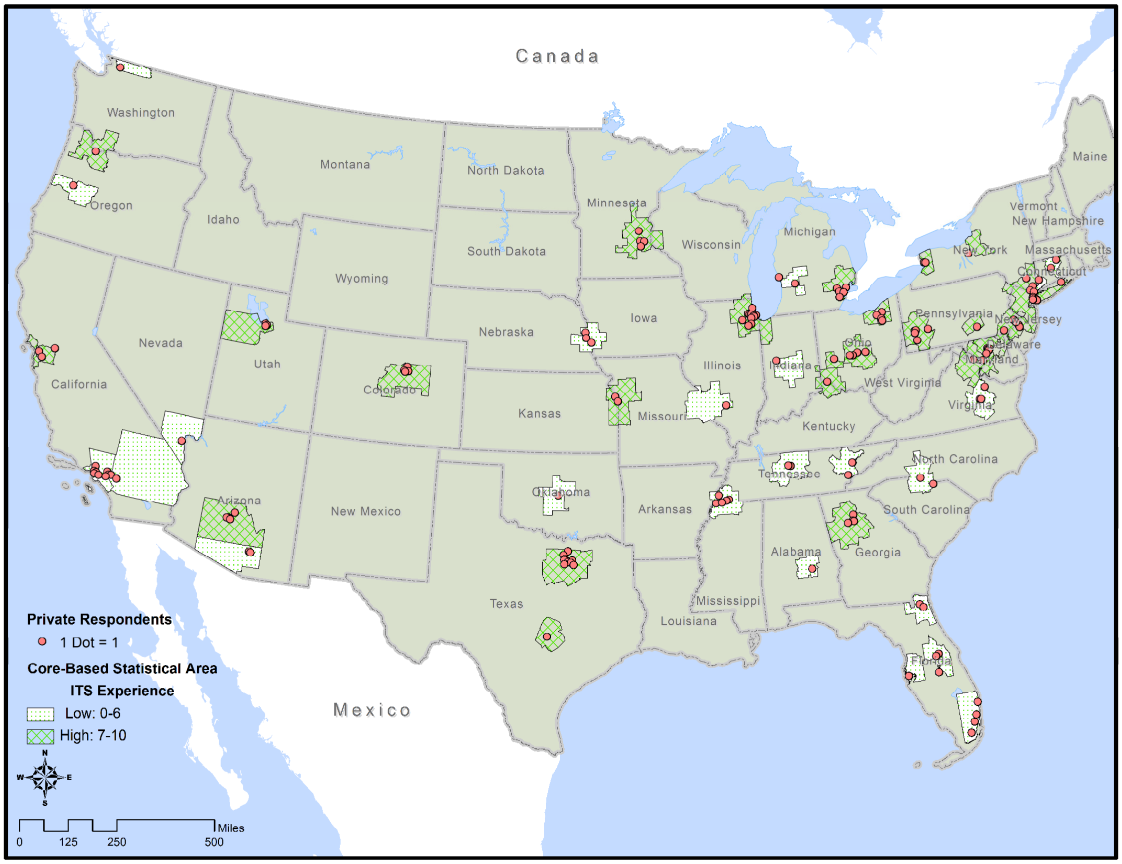

FIGURE 1 Visualization of Regional ITS Investments and Respondent Locations

DISCUSSION OF RESULTS

Results indicate that private investments in ITS significantly positively affect the responsiveness performance measure for commercial vehicle operators in regions with high public ITS investments. The same relationship is not significant in regions with low public ITS investments, thus indicating at least some transportation performance improvements can be gained through private investments in ITS for regions with higher public investments in ITS. These results suggest that public and private investments in ITS technology work as complements in enhancing the performance of freight movements. As such, the performance of a region's freight industry could benefit from increased public-private partnerships in ITS investments.

Results displayed in tables 2 and 3 show hypothesis 1, public investments in ITS have a positive impact on private investments in ITS, which is supported for both low investment and high investment regions. Thus indicating that any level of public ITS investment influences private ITS investment to some degree. For hypotheses 2 (a-f) regarding whether public investments in ITS will positively influence transportation performance outcomes, part (a) (efficiency) is supported for both groups while part (e) (carbon emissions reduction) is weakly significant for the low investment group. This could indicate that in general these are areas with slightly higher congestion where less idle time for additional emissions would be noticed and even small investments in ITS make a significant difference. For instance, Los Angeles is an area with very high levels of congestion yet the core-based statistical area it is located within is a low ITS investment region. These are important findings because some of the goals of ITS are to improve transport efficiency, reduce traffic congestion by maintaining traffic flow and to reduce transportation-generated pollution, (1); this research provides support for the importance of investments in ITS backed by quantified performance measures.

None of the other parts are significant for hypotheses 2. It is not entirely surprising that public investments on ITS are not significant for the responsiveness and quality measures, as these would be controlled at the firm level and not likely to be affected by public infrastructure as measured. Quality measured drivers' ability to deliver damage free goods and responsiveness measured the extent drivers and firms are able to adapt to changes. However, there are some interesting findings in regards to responsiveness discussed next for hypothesis 3.

Furthermore, hypotheses 3 (a-f) which considers the influence of private ITS investments on transportation performance outcomes, have some interesting results. Regions with both levels of investments in ITS indicate a significant relationship between private ITS investment to both carbon emissions reduction and equipment utilization. This could indicate that all firms are utilizing some type of ITS to improve fuel efficiencies and equipment utilization. Furthermore, that investments in ITS technologies contributes to better fuel efficiency and equipment utilization within freight companies. Most significant however, is the relationship between private ITS investment and responsiveness. Private investments made by firms in regions with higher public investments in ITS shows a positive, significant effect on responsiveness, while private investments in low public ITS investment regions do not have a significant effect on responsiveness. This indicates that public and private ITS investments works as complements in increasing firms' responsiveness to changes in pick-up/delivery circumstances. The remaining relationships are not supported.

It is surprising that efficiency and reliability are not supported, the relationship is positively indicated though not significant. This warrants some additional research. It is not as surprising that quality is not significant, as it could be related to the focus of the measure. The measure as focused could have been interpreted more on care in handling to result in damage free goods which would unlikely benefit from information technology (IT) applications. Had the measure examined lost packages/goods or another indicator that would have benefited from the use of IT, it is quite possible the results would be different. This should be further examined under another measurement lens.

TABLE 2 Hypotheses Testing Results for Firms with Low ITS Investments

Path Results for Firms in Regions with Low ITS Investments	Standardized Beta Coefficient [a]	T Statistic	P Values	Supported
H1: Public ITS Investment -> Private ITS Investment	0.631***	8.017	0.000	Yes
H2a: Public ITS Investment -> Efficiency	0.460**	3.429	0.001	Yes
H2b: Public ITS Investment -> Reliability	0.203[ns]	1.022	0.307	No
H2c: Public ITS Investment -> Responsiveness	0.260[ns]	1.35	0.178	No
H2d: Public ITS Investment -> Quality	0.242[ns]	1.399	0.162	No
H2e: Public ITS Investment -> Carbon Emissions Reduction	0.275*	1.709	0.088	Yes
H2f: Public ITS Investment -> Equipment Utilization	0.228[ns]	1.239	0.216	No
H3a: Private ITS Investment -> Efficiency	0.056[ns]	0.341	0.733	No
H3b: Private ITS Investment -> Reliability	0.197[ns]	0.972	0.332	No
H3c: Private ITS Investment -> Responsiveness	0.163ns	1.006	0.315	No
H3d: Private ITS Investment -> Quality	0.194ns	0.947	0.344	No
H3e: Private ITS Investment -> Carbon Emissions Reduction	0.436***	3.147	0.002	Yes
H3f: Private ITS Investment -> Equipment Utilization	0.374***	2.549	0.011	Yes

[a] *** significant at $p < .001$, ** significant at $p < .05$, * significant at $p < .10$, [ns] not significant.

TABLE 3 Hypotheses Testing Results for Firms with High ITS Investments

Path Results for Firms in Regions with High ITS Investments	Standardized Beta Coefficient [a]	T Statistic	P Values	Supported
H1: Public ITS Investment -> Private ITS Investment	0.532***	5.554	0.000	Yes
H2a: Public ITS Investment -> Efficiency	0.228*	1.761	0.079	Yes
H2b: Public ITS Investment -> Reliability	0.021[ns]	0.14	0.889	No
H2c: Public ITS Investment -> Responsiveness	0.027[ns]	0.2	0.842	No
H2d: Public ITS Investment -> Quality	-0.012[ns]	0.069	0.945	No
H2e: Public ITS Investment -> Carbon Emissions Reduction	0.136[ns]	1.236	0.217	No
H2f: Public ITS Investment -> Equipment Utilization	0.029[ns]	0.237	0.813	No
H3a: Private ITS Investment -> Efficiency	0.138[ns]	1.011	0.313	No
H3b: Private ITS Investment -> Reliability	0.145[ns]	0.92	0.358	No
H3c: Private ITS Investment -> Responsiveness	0.277**	2.092	0.037	Yes
H3d: Private ITS Investment -> Quality	0.131ns	0.759	0.448	No
H3e: Private ITS Investment -> Carbon Emissions Reduction	0.469***	4.701	0.000	Yes
H3f: Private ITS Investment -> Equipment Utilization	0.382***	3.586	0.000	Yes

[a] *** significant at $p < .001$, ** significant at $p < .05$, * significant at $p < .10$, [ns] not significant.

CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

ITS technology is noted as a special infrastructure to promote integrated information sharing that can be used to improve transportation system performance. ITS combine better infrastructure with information and control technologies to: (i) reduce traffic congestion by maintaining traffic flow, (ii) reduce transportation-generated pollution, (iii) improve transport efficiency, and (iv) produce economic benefits (1, 2). This paper demonstrates that a collaboration of investments between businesses and governments to further develop ITS will improve transportation performance for motor carriers. The main contributions of this paper are the development of a theoretical framework, the construction and validation of the survey instrument and the empirical analysis used to test the relationships of both public and private investments in ITS.

It is anticipated that this work will be useful for governments, organizations and researchers. This work contributes to organizations by providing a framework for value propositions of investments in ITS technology by recognizing quantified system benefits. Both business and government organizations are more likely to make investment decisions when metrics can be observed and reported to stakeholders. It is often difficult to quantify “green” system improvements though this research helps to fill this gap in terms of ITS applications.

Although this research was conducted with utmost rigor, there are some limitations to mention. First, the sample is large enough to draw valid conclusions, however a larger sample size is preferred. Second, the measure for quality could be revised to focus on an aspect related to an IT application, such as package or load tracking for lost items/materials rather than damage alone. Third, the study only examines ITS applications on the highway system, a more comprehensive study would include rail and water systems. This is further discussed for future research.

Some findings from the study indicate additional research is warranted. For instance, positive results for public ITS investment on carbon emissions reduction is significant in low investment regions, though not significant in high investment regions. This is an interesting result, it is possible that higher populated regions with greater levels of congestion benefit from even small investments in ITS and regions with lower congestion happened to have higher levels of ITS investments. Further examination is necessary. Additionally, unexpected results for private investments in ITS on efficiency and reliability performance are not supported, the relationship is positively indicated though not significant. This merits some additional research as well. It is not as surprising that quality is not significant, it is possible this is due to the measure focus as discussed previously.

In a broader sense, future research should consider using the proposed framework to test ITS technologies as a driver of not only freight movement performance, but also supply chain performance improvements. Additionally, future research should examine individual technologies and how they integrate between the public and private domain to gain a comprehensive view of individual system enablers. It is hoped that future research will support ITS investments that reduce variability between availability of ITS resources across regions. Finally, another venue for future research is to assess the value of ITS for intermodal operations including rail and inland waterway systems.

Finally, results of this work were submitted to TRB for publication in the TRR. At the time of this report, the review committee has recommended the paper for publication.

4. Qualifications, Accomplishments, and Commitments of Research Team

Richard S. Martinko, P.E. became the Director of the University of Toledo’s Intermodal Transportation Institute and the University Transportation Center in July 2007, which has also been designated as a Center of Excellence in Transportation and Logistics by the Ohio Board of Regents. Prior to coming to the University of Toledo, Mr. Martinko was the Assistant Director of Highway Operations for the Ohio Department of Transportation, one of the largest and most significant transportation systems nationally. Mr. Martinko served as a District Traffic Engineer, District Operations Engineer, District Highway Management Administrator, and District Deputy Director. Mr. Martinko had overall project management responsibility for the largest single construction project in Ohio history, the $320 million dollar Veterans Glass City Skyway in Toledo, Ohio. Mr. Martinko also has held key leadership positions in private industry. His accomplishments include major international automotive and military installation projects involving robotics and spray finishing systems. He has led major installations of manufacturing assembly line and bulk materials handling systems. Mr. Martinko is a member of the National and Ohio Society of Professional Engineers, and a trustee for the Toledo Society of Professional Engineers. His level of experience in the field provides the project team with ample contacts to leverage for the data collection effort in this work.

Sarah Schafer, **Ph.D.** is an Assistant Professor of Supply Chain Management at the University of Wisconsin Oshkosh. She graduated in 2015 from the Manufacturing and Technology Management program in the Information, Operations, and Technology Management Department in the College of Business and Innovation at the University of Toledo. She is also an experienced Research Project Manager for transportation and GIS related directed research projects. She has worked on a variety of transportation, freight and commodity flow projects for CFIRE, the U.S. Army Corps of Engineers, Parsons Brinckerhoff and other entities. Through this work experience she has established numerous contacts in both the public and private sectors to carry out this research. Her dissertation work focuses on the integration of public and private investments in intelligent transportation system technology and the connection to supply chain performance.

Peter S. Lindquist, Ph.D. is an Associate Professor of Geography and Planning at the University of Toledo. He is the Director of the Spatially Integrated Social Science Ph.D. Program and the Director for the Center for Geographic Information Science and Applied Geographics at U.T. He currently serves as principal investigator on several directed research projects for CFIRE, the U.S. Army Corps of Engineers, Parsons Brinckerhoff, and CPCS Transcom providing both data support and GIS analysis for a variety of regional and national intermodal freight studies. He has a proven track record of successfully completed directed research projects in the transportation field.

P. Sundararaghavan, Ph.D. is a Professor of Information, Operations and Technology Management at the University of Toledo with over 30 years of academic and consulting experience. He has considerable experience with supply chain related issues and data analysis. He is the founder of the UTAPICS chapter and is on the ISAC advisory board.

5. Equipment and/or Facilities

This section should demonstrate the adequacy of your facilities in the performance of this research.

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The Center for Geographic Information Sciences and Applied Geographics (GISAG) is housed in the Department of Geography and Planning at the University of Toledo. It serves as the focal point for GIS-based contract research on campus and in the wider regional community. Since its founding in 2003, The faculty and staff of the GISAG Center have participated in sponsored research and outreach projects approaching $16 Million in funding. In the area of transportation, the GISAG Center played a pivotal role in data acquisition and management for a number of freight projects. The center and its faculty have been affiliated with the National Center for Freight Infrastructure Research and Education (CFIRE) and the Great Lakes Maritime Research Institute (GLMRI). The center is the home of a comprehensive freight data repository and provides information outlets through the ***Great Lakes Maritime Information Clearinghouse*** (http://maritime.utoledo.edu) and the ***Midwest FreightView*** online GIS. An abridged list of data currently residing in the repository includes:

- Geographic Data: Counties, Census Tracts, Block Groups, ZIP Code Areas, Congressional Districts, MSAs, Urban Areas, BEA Regions, Canadian Municipalities
- Economic Data: Establishments, employment by NAICS classificaton among counties and MSAs (Sources: BEA, BLS, County Business Patterns, Minnesota IMPLAN Group, Inc., Demographics Plus, Dun and Bradstreet/Harris InfoSearch, Census of Agriculture, NASS)
- Networks: Air, Water, Rail, Highway, Terminals
- Updated, Enhanced US Highway Network—Speed / Estimated Travel Times
- Updated ORNL National Class I Rail Network (including Double Stack Lines)
- FAF2, FAF3
- Import/Export Flows (GTIS) 1999+ By State, Customs Gateway
- Domestic Cargo Flows: Water, Highway, Air, Rail

GISAG Center faculty, staff and students have worked with a number of Midwest state departments of transportation and MPOs, the U.S. Army Corps of Engineers (USACE), Great Lakes port authorities, and private firms in freight transportation projects over the past six years. A sample of freight transportation projects recently undertaken in the GISAG headed by Dr. Peter Lindquist are listed as follows:

- A Regional Freight Database for the Upper Midwest Freight Coalition (2004-Present) *Sponsors:* MRUTC, CFIRE, GLMRI, Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Kentucky DOTs.
- The Great Lakes Maritime Information Delivery System (2006-Present) *Sponsor:* CFIRE, GLMRI.
- Federal Initiative for Navigation Data Enhancement (FINDE) (2010) *Sponsor:* USACE.
- Development of a New Process for Collecting Information on Piers, Wharves, Docks and Terminal facilities in the Great Lakes Region: Phases I-II (2008-2009) *Sponsor:* USACE.
- Upper Midwest Freight Corridor Study (2003-2005) *Sponsors:* MRUTC, Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Kentucky DOTs.
- NCFRP-35 : Multimodal Freight Transportation Within the Great Lakes-Saint Lawrence Basin (2010-2011) *Sponsor:* Transportation Research Board.
- Development of Methodology for Generating Distance and Commodity Flow Tables into and through the Great Lakes Basin, U.S. Army Corps of Engineers (Buffalo District), $120,000. 2012-2013.
- Mining Automatic Identification Systems (AIS) Data for Improved Vessel Trip Analysis Capabilities, Joint project between the University of Toledo, Vanderbilt University, and the University of Wisconsin-Superior, National Center for Freight Infrastructure Research and Education through US DOT UT Portion: $80,000. 2012-2013.
- Making Freight-Centric Communities more Livable, Joint project between the University of Toledo, University of Memphis, and the University of Wisconsin-Madison, National Center for Freight Infrastructure Research and Education through US DOT UT Portion: $60,000. 2012-2013.
- Ohio Statewide Freight Plan, (Contract in partnership with UT ITI & Parsons-Brinckerhoff Consultants), Ohio Department of Transportation UT Portion: $26,000. 2011-2012.

Computing resources and staff in the GISAG Center are outlined in the list provided below:

SERVERS

- Dell Data 2003 Server: 10TB Data Repository Capacity
- 3.75 TB Noroco Server: Parity RAID (Raid 5) for backup of utilities and critical data.
- Windows 2000 Server: Storage Array (RAID 5) attached; serves as FTP server
- Windows Server 2003 #1: Citrix Server for 15 Seats

- Windows Server 2003 #2: Citrix Server for 50 Seats
- Windows Server 2003 #3: New GIS server to host our research websites on ArcGIS server
- Windows XP SP2: Backup "Storage array" backup to main Windows 2000 and 2003 Servers
- Linux 32MB: NAS server for mass Storage
- MAC 10.3.9: File server for multiple projects; External mirrored Firewire drives
- Sun Solaris Sun Fire X4140 Server with ORACLE 10g
- Three XP Software License Servers
- Two ArcIMS / FTP Servers
- Windows XP Print Server

INDIVIDUAL COMPUTERS
- 28 Dell Workstations
- 6 Laptop Research Computers

PERIPHERAL DEVICES
- HP DesignJet 800ps Large Format Printer
- Summagraphics 60" Micorgrid Digitzing Table
- Calcomp Model 34600 Digitzing Table
- Epson 1640XL Large Format Scanner

SOFTWARE AND UTILITIES
- ESRI ArcGIS and extensions ArcGIS 10 and previous versions (in archive)
- ESRI ArcView GIS and extensions
- SAS 9.3 Statistical Software
- SPSS 10 Statistical Software
- Idrisi 32 GIS
- TransCAD Transportation GIS
- ESRI ArcIMS
- ESRI MapObjects
- ESRI ArcObjects
- ESRI ArcSDE
- ESRI ArcGIS Server
- MS Visual Studio 2010
- MS Visual Web Developer
- MySQL and other open source software tools
- Oracle 10G
- Surfer 8

STAFF
- Laboratory Support Staff: 1 Half-Time Laboratory / Network Manager
- Transportation Projects Support Staff: 1 Full-Time Research Technician
- Transportation Projects Support Staff: 1 3/4-Time Project Manager
- Transportation Projects Support Staff: 4 Ph.D. Graduate Assistants
- Support Staff: 2 M.A. Graduate Assistants

6. Schedule

Provide a Gantt Chart, or similar schedule, by research task. The schedule should account for all activities including research tasks and review/ revisions to the final report and other deliverables.

Task 1: Validate previously identified ITS technology components with key experts in both industry and the public sector through initial interviews.
Task 2: Survey instrument development and validation.
Task 3: Distribution of the final survey online.
Task 4: Data collection and processing.
Task 5: Calculation of data analysis and interpretation of results.
Task 6: Complete quarterly reporting requirements and a final report.

The timetable for completion of each task is provided below:

Task/Month	1	2	3	4	5	6	7	8	9	10	11	12	13
1	X	X											
2			X	X									
3					X	X							
4						X	X	X	X	X			
5										X	X	X	
6				X			X			X			X

The project was completed on time and within budget as expected.

7. Budget

(Please use the table on the next page or a similar budget that addresses the same line items)

Budget Description: *Provide a summary tabulation indicating staffing plans and estimated person-hours specific to each operational phase. Budget estimates should include salaries, overhead and indirect costs, travel, computer time, equipment (purchase and/or rental), expendable materials and supplies, report printing (for 14 bound copies), special services (as applicable) and other related budgetary expenses.*

Capital expenditures can not exceed $5,000 without prior written approval from the USDOT's Research and Innovative Technology Administration (RITA). Foreign travel is also not permitted with these funds without prior written approval from RITA.

Matching Funding: *Budget estimates should also include identification of all matching fund sources. CFIRE encourages researchers to partner with their state transportation agencies, other public sector agencies, and/or private sector interests.*

A Ph.D. student/project manager will commit 30 hours per week toward the completion of tasks 1-6. Interviews, data collection and analysis will be conducted as part of this work time, involving both computer time and travel. It is expected that a fair amount of travel will be required to conduct the essential interviews for this work. A master's student will assist primarily for the completion of tasks 1-4. Effort provided by the PI and Co-Is will be instrumental in developing a platform for discussion with industry and government stakeholders.

CATEGORIES	UTC Budgeted Amount	Match Amount	Explanatory Notes
Center Director Salary			
Faculty Salaries		19,979	Salary match for faculty effort
Administrative Staff Salaries		21,000	ITI Director Project PI Salary match
Other Staff Salaries	38,579		PhD student/staff salary 1 yr
Student Salaries	5,250		Master's student stipend 1 semester
Staff and Student Benefits	13,768	12,416	Match includes PI/Co-I benefits
Total Salaries and Benefits	57,597	53,395	
Scholarships/Tuition		8,779	Tuition match
Permanent Equipment			
Expendable Property, Supplies, and Services	300		Printing and supplies
Domestic Travel	3,616		Travel to conduct interviews
Foreign Travel			
Other Direct Costs (Specify)			
Total Direct Costs	61,514	62,174	
F&A (Indirect) Costs	27,988	27,332	
TOTAL COSTS	89,502	89,506	

8. Cooperative Features and/or Partnerships

The work conducted here sought the collaboration of both private industry and public agencies involved in the decision-making for ITS technology investments. A number of interviews were conducted to gain insight on how public and private investments in ITS work together to support the system.

References

1. Zhou, F. and J. Shen. 2010. Deploying an intelligent transportation system in Chongming County, Shanghai. *Journal of Urban Technology*, 17(3): 39-51.
2. Brand, D. Applying benefit/cost analysis to identify and measure the benefits of intelligent transportation systems. In *Transportation Research Record 1651*, TRB, National Research Council, Washington, D.C., 1998, pp. 23-29.
3. Hsu, C. and W. Wallace. 2007. An industrial network flow information integration model for supply chain management and intelligent transportation. *Enterprise Information Systems*, 1(3): 327–351.
4. Barfield, W. and T. Dingus (Eds.). 1998. Human factors in intelligent transportation systems. Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.
5. Crainic, T., N. Ricciardi and G. Storchi. 2004. Advanced freight transportation systems for congested urban areas. *Transportation Research Part C*. 12: 119-137.
6. Shaheen, S., M. Camel, and K. Lee. Exploring the future of integrated transportation systems in the United States from 2030 to 2050: Application of a scenario planning tool. As presented at the TRB Annual Meeting, National Research Council, Washington, D.C., 2013.
7. Bharosa, N., M. Janssen, R. van Wijk, N. de Winn, H. van der Voort, J. Hulstijn and Y. Tan. 2013. Tapping into existing information flows: The transformation to compliance by design in business-to-government information exchange. Government Information Quarterly, 30: S9-S18.
8. McCord, M. and D. Hidalgo. Ohio motor-carrier preferences for intelligent transportation systems/commercial vehicle operations innovations. In *Transportation Research Record 1522*, TRB, National Research Council, Washington, D.C., 1996, pp. 69-76.
9. Hopkins, J. Feasibility of advanced vehicle control systems for freight terminals. In *Transportation Research Record 1602*, TRB, National Research Council, Washington, D.C., 1997, pp. 65-70.
10. Benekohal et al. Truck delay and traffic conflicts around weigh stations. In *Transportation Research Record 1652*, TRB, National Research Council, Washington, D.C., 1999, pp. 52-60.
11. Klinginberg, B. Opportunities for progressive deployment of intelligent transportation systems/automated highway system technologies in support of commercial vehicle operations. In *Transportation Research Record 1651*, TRB, National Research Council, Washington, D.C., 1998, pp. 107-110.
12. Mendoza, A. and A. Garcia. Potential applications of intelligent transportation systems to road freight transport in Mexico. In *Transportation Research Record 1707*, TRB, National Research Council, Washington, D.C., 2000, pp. 81-85.
13. Giannopoulos, G. Integrating freight transportation with intelligent transportation systems: Some European issues and priorities. In *Transportation Research Record 1790*, TRB, National Research Council, Washington, D.C., 2002, pp. 29-35.

14. Perego, A., Perotti, S., Mangiaracina, R., 2011. ICT for logistics and freight transportation: A literature review and research agenda. *Logistics and Freight Transportation*, 41(5), 457-483.
15. Wolfe, M., Troup, K., 2005. The freight technology story: Intelligent freight Technologies and their benefits. *FHWA Freight Management and Operations*, 1-30. Accessed at: http://ops.fhwa.dot.gov/freight/intermodal/freight_tech_story/freight_tech_story.htm#exec on March 14, 2014.
16. Vandezande, N., Janssen, K., 2012. The ITS directive: More than a timeframe with privacy concerns and a means for access to public data for digital road maps? *Computer Law & Security Review*, 28, 416-428.
17. Fries, R., M. Gahrooei, M. Chowdhury, and A. Conway. 2012. Meeting privacy challenges while advancing intelligent transportation systems. *Transportation Research Part C*, 25: 34-45.
18. Jarasuniene, A. 2007. Research into intelligent transportation systems (ITS) technologies and efficiency. *Transport*, 22(2): 61-67.
19. Crainic, T. G., Gendreau, M., Potvin, J.Y., 2009. Intelligent freight-transportation systems: Assessment and the contribution of operations research. *Transportation Research Part C: Emerging Technologies*, 17(6), 541–557.
20. Paetz, D., 2014. Personal interview. Chief Operating Officer, Tri-State Expedite Services. February 13, Walbridge, OH.
21. Figliozzi, M. 2011. The impacts of congestion on time-definitive urban freight distribution networks CO2 emission levels: Results from a case study in Portland, Oregon. *Transportation Research Part C*, 19: 766-778.
22. Schulz, J. 2003. Going the last mile. *Traffic World*, January: 25-26.
23. Anderson, S., J. Allen and M. Browne. 2004. Urban logistics—how can it meet policy makers- sustainability objectives? *Journal of Transport Geography*, 13: 71-81.
24. Goldman, T., Gorham, R., 2006. Sustainable urban transport: Four innovative directions. *Technology in Society*, 28, 261-273.
25. Sternberg, H., Andersson, M., 2014. Decentralized intelligence in freight transport-A critical review. *Computers in Industry*, 65, 306-313.
26. Chowdhury, M., and Sadek, A., 2003. Fundamentals of intelligent transportation Systems Planning, Artech House, Norwood, MA.
27. Button, K., Doyle, E., Stough, R., 2001. Intelligent transport systems in commercial Fleet management: A study of short term economic benefits. *Transportation Planning and Technology*, 24, 155-70.
28. Skinner, W., 1969. Manufacturing-missing link in corporate strategy. *Harvard Business Review*, 47(3), 136–145.
29. Schmenner, R. W., Swink, M. L., 1998. On theory in operations management. *Journal of Operations Management*, 17(1), 97–113.
30. Fisher, M. L., 1997. What is the right supply chain for your product? *Harvard Business Review*, 75(2), 105-116.
31. Lee, H. L., 2002. Aligning supply chain strategies with product uncertainties. *California Management Review*, 44(3), 105-119.
32. Lieb, K. J., Lieb, R. C., 2010. Environmental sustainability in the third-party logistics (3PL) industry. *International Journal of Physical Distribution & Logistics Management*, 40(7), 524–533.

33. Cooke, J.A., 2008. The greening of Whirlpool's supply chain. *CSCMP's Supply Chain Quarterly*, Quarter 2, 46-9.
34. Murphy, J.V., 2008. Supply chains reduce carbon footprints and save you money. *Global Logistics and Supply Chain Strategies*, 12(3), 30-42.
35. Diabat, A., Simchi-Levi, D., 2010. A carbon-capped supply chain network problem. *IEEE International Conference on Industrial Engineering and Engineering Management*, 2009 (Piscataway, N.J.: IEEE): 523-527.
36. Catulli, M., Fryer, E., 2012. Information and communication technology-enabled low carbon technologies. *Journal of Industrial Ecology*, 16(3), 296–301.
37. McAvoy, S., 2014. Personal interview. Solutions Development Manager, UPS. February 26, Gulfport, MS.
38. Safizadeh, M.H., Ritzman, L.P. 1997. Linking performance drivers in production planning and inventory control to process choice. *Journal of Operations Management,* 15(4), 389-403.
39. Dahal, K., Galloway, S., Burt, G., McDonald, J., Hopkins, I., 2003. A port system simulation facility with an optimization capability. *International Journal of Computational Intelligence and Applications*, 3(4)395-410.