Final Report for MBTC Project 2023:

Impact of Wireless Data Systems on the Transportation Systems of the Future

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Executive Summary

The explosion in both the capability of and the number of applications for wireless data systems has allowed both personal and business consumers to become better connected to the world around them. The entire transportation industry is starting to benefit from the resulting improved connectivity, as trucking carriers are now able to communicate with their drivers more effectively. Improved fleet connectivity may result in other potential benefits to the transportation infrastructure as well as to the industry's carriers and shippers. We present an overview of wireless logistics systems, followed by the results of a transportation marketplace survey to assess current applications of wireless data systems. Further, we discuss future applications of wireless data systems from the viewpoint of both end users (consumers and shippers) and carriers.

1 Introduction

Supply chains are constantly being formed, modified, and broken in response to the dynamic nature of the consumer marketplace. In fact, the total number of origin locations and final delivery destinations that any one trucking carrier has is constantly changing. As a result, shippers who wish to stay competitive are forced to constantly develop transportation logistics networks with low cost, efficient operations and minimum delivery times. Shortening product life cycles, combined with fickle, highly variable consumer demand patterns, has forced companies to create lean, agile enterprises capable of rapidly, and effectively responding to the dynamic conditions of the marketplace.

The explosion in the capability of and the number of applications for wireless data systems in the past decade has allowed both personal and business consumers to become better

connected to the world around them. The transportation industry as a whole is starting to benefit from this improved connectivity, as trucking carriers are now able to communicate with their drivers more effectively. Further, a large number of regulatory forms and permits typically required of the drivers are becoming available in an electronic format. In addition to the benefit of reducing the time required to complete such documentation, improved fleet connectivity may result in other potential benefits to the transportation infrastructure as well as to the industry's carriers and shippers.

As information processing is a crucial component for the effective operation of any company, transportation service providers are now exploring the advantages of using wireless data systems (WDS) to manage their transportation data systems as a part of their supply chain initiatives. According to Symbol Technologies (2001), most organizations have focused on warehousing/distribution and store operations as primary areas for cost control and improved efficiencies. Therefore, the transportation operations form a cost frontier where new systems utilized by carriers can provide tremendous savings which are then passed to the shippers who are trying to reduce costs by improving operational control.

Currently, wireless data systems are being used effectively to locate trailers in the fleet and for simple messaging between carriers and their drivers, such as "Where are you?" "When will you be at the delivery point?" and "Call as soon as you are empty, as there is a rush load nearby." Several carriers have deployed WDS to view the location and status of the trailer fleet assets, thereby providing greater supply chain visibility and improving overall productivity and performance. In more advanced applications, WDS are helping shippers to improve their delivery performance by reducing lead-time variation for both inbound and outbound shipments.

In this report, we explore the current impact of WDS on transportation systems and how transportation and logistics service providers can further benefit from future applications of WDS. The remaining sections of this paper are organized as follows. Section 2 contains an overview of logistics support systems, specifically describing the various types of data that are required during normal transportation operations. Section 3 discusses current wireless system applications, describing both the benefits and the potential issues associated with wireless data systems. Future applications of wireless data systems are detailed in Section 4, which includes an assessment of wireless system impacts in two different arenas: safety/security and repair/ maintenance. Finally, Section 5 contains some research conclusions and directions for future work.

2 An Overview of Wireless Logistics Support Systems

A typical wireless logistics support system at a transportation service provider receives orders from its customer's host system, through either Electronic Data Interchange (EDI) or another type of standard file transfer protocol. This can occur either at the beginning of the day or at scheduled intervals throughout a shift. Next, an order management module preprocesses the downloaded orders and sends them to a transportation optimization package. The software package usually makes recommendations for creating multi-stop truckload shipments, planning truck routes, etc., while taking into account acceptable delivery service at the least possible cost. This is accomplished by selecting the best transportation mode, considering opportunities to consolidate orders, and/or picking load profiles for trucks to minimize their empty miles, etc. given the delivery constraints of each consignee.

Typically, the generic carrier plan suggested by the optimization package is sent to a transportation management system that validates the plan and makes the actual load/resource (usually trucks) selection based on equipment availability. In almost every step of this process, timely availability of accurate information about the loads and resources, including trucks and drivers, is critical. Wireless logistics support systems improve the overall transportation system efficiency by enhancing the availability and accuracy of information, even if the underlying decision-making process outlined above is not changed.

As a widely used transportation mode in most companies, trucks have a daily schedule of carrying merchandise from the company or factory to their distribution centers or warehouses, and from the distribution centers to the customers (end users) or retailers around the country. The use of WDS can improve the quality and accuracy of the work, which will in turn, be reflected in the shipper profits.

Before we can investigate the benefits that can potentially be gained from WDS, the types of data input to and reported by wireless systems must first be evaluated. We categorize this requisite data into three main categories:

1. Startup Data—the data required at the beginning of each workday or each trip.
2. Ongoing Data—the data needed during the trip while the truck is in route to the destination point.
3. Destination Data—the data required at the end destination or delivery point.

The following subsections describe each of the three data types in detail.

2.1 Startup Data

At the beginning of each workday or each new trip, truck drivers require some initial data prior to driving. This data includes the type of load being hauled, the route assignment (e.g., primary and alternate roads), and the current delivery timetable. Two signatures are usually required before a driver can begin to haul his load to its destination. First, the truck inspector must sign off on the condition of the truck and its cargo. Then, the driver must sign to confirm his knowledge of the truck's condition, as well as his understanding of the route assignment, delivery schedule, type of load being hauled, and any pertinent safety precautions that should be taken.

Today, leading carriers execute these signatures and others using truck-mounted computers (TMCs). Truck-mounted computers are typically linked via wireless connections to various devices and sensors inside a truck and trailer, including the driver's wireless device. Figure 1 displays one example of a truck-based wireless data system. A TMC receives data from various devices and sensors, potentially pre-processes, and then sends the information via again a wireless transmitter to various company networks including an information center usually located at the headquarters of the company without any driver intervention or attention. The company's information center can then process the data in near real-time, sending back appropriate information and/or responses via a wireless transmitter. Under this wireless system paradigm, the corporate information system can transmit up-to-date data to a specific truck or can broadcast to all trucks in the fleet. Consequently, the driver only needs a few minutes to check the latest data using the truck's computer prior to executing his signature and starting his trip.

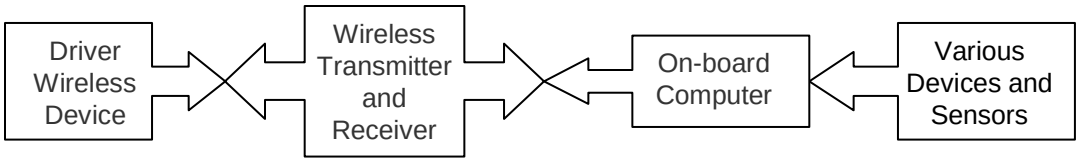

Figure 1. An Example Truck-Based Wireless Data System

Drivers typically access the information transmitted by the company's computer information center in one of two ways: according to a special schedule as dictated by the company or at any time they choose. Warning lights and/or sound alarms can also notify the driver of arrival of important information such as a change in the schedule or the failure of an onboard sensing device. Warned by the signals, the driver can access this information with the simple click of a button. When the driver is outside the cab, he can use his handheld, personal digital assistant (PDA) or another portable wireless device to access the information directly.

2.2 Ongoing Data

During the trip, WDS can provide the driver with up-to-date information on the scheduled destination, delivery time, and the truck's current location. In addition, WDS notifies the driver of changes in his destination and/or delivery schedule due to weather conditions, heavy traffic, and/or blocked roads. The WDS could also transmit information on alternative roads or changes in the delivery schedule due to inventory needs, such as when lower than expected inventory levels appear due to unforeseen demand increases. In such a case, the nearest truck could be routed to supply a portion or its entire load to meet the inventory need.

Other important information that WDS can transmit include such items as current distance from destination, current distance from origin, average speed, expected delivery day and time, and location of the nearest warehouse. Also, when and wherever necessary, the driver can

stop at a safe location to use the truck-mounted computer to send a message. This may be done by typing in full text or by clicking on certain keys that have pre-defined special messages.

2.3 Destination Data

At the delivery point or destination, the wireless data system transmits the time of arrival and the time of the unloading of merchandise by store personnel. Official signatures and forms needed at the destination can be handled electronically through the WDS. After unloading, the driver can find the next origin to pick up a load and its destination, as well as the type of load to be hauled, the suggested travel route, proposed time schedule, and information on weather conditions over his planned trip.

The enhanced availability of data provided by WDS allows carriers to reschedule their trucks' routes more frequently by updating the load schedule or by rerunning the optimization software with the up-to-date data. More frequent route scheduling using the most recent data potentially promotes better use of transportation resources including drivers and trucks plus it may lead lower inventory levels at warehouses and stores. Further, the extreme result of WDS implementation is the creation of mobile, trailer-based "warehouses on wheels." The connectivity provided by successful WDS implementations can help to reduce inventory levels at the adopting carriers' DC or warehouse by storing it in typically moving trailers.

2.4 Other Data of Interest

In addition to providing shippers with the ability to track each load and each truck on the road, WDS can provide a direct connection and a quick response between different entities in the company in case of an emergency. Examples include dispatching a maintenance team at a

breakdown or contacting an emergency response team during an accident. Wireless data systems can improve truck and trailer security through monitoring devices such as open door sensors, connected trailer sensors, engine and speed sensors, and global positioning systems (GPS) that utilize satellites to pinpoint specific geographical locations throughout the world.

The availability of low cost GPSs will allow these systems to become as basic as a telephone, allowing everyone to "know exactly where they are, all the time" (Hurn, 1989). Additionally, GPS applications will allow delivery vehicles to pinpoint their final destination, emergency vehicles to arrive more quickly where they are needed the most, and automobile drivers to quickly obtain driving directions to any destination.

Hurn (1993) describes the use of *differential* global positioning systems and their benefits that can be gained by both transportation and fleet management. "GPS is the perfect technology for this era 'just-in-time' delivery. With it, a dispatcher can monitor every vehicle in his fleet whether they're across town or across the country. The result is a tighter schedule adherence and better accountability."

Geographic analysis can yield valuable information that can be used to improve truck routing and scheduling, optimize fleet and supply chain operations, and increase asset utilization. Geographical information system (GIS) technology serves three distinct transportation management needs: infrastructure management, fleet and logistics management, and transit management (ESRI, 2002). Transportation professionals can use GIS to integrate mapping analysis into decision support systems for network planning and analysis, vehicle tracking and routing, asset management, and inventory tracking. Furthermore, geographical databases can enhance transportation, facility locations, and inventory decisions. Using geographic coding data simplifies the determinations of traveled distance, traveled times, and estimated transportation

rates between two points, which can benefit facility location analysis and approximate transportation costs (Ballou, 1999).

The additional benefit of using GIS is the ability to answer several questions, such as what is the shortest route? How many fatal accidents occurred at a specific place last year? How many houses are located in a particular area? (Brunswick Department of Transportation, 2002). When companies attempt to justify the need for logistics network upgrades, Borras (2001) asserts they need a value chain that includes companies that provide services such as mapping, least distance routing, content providers (e.g., traffic information, geospatial data, points of interest, etc.), dynamic route navigation, and location technology developers. "Companies such as SmartTrust, SignalSoft and XYPoint were found to provide computer platforms to be able to extract location information from operators networks and enable location-based commercial services and applications" (Borras, 2001).

3 Current Wireless System Applications

Recently, the need for integrated wireless data systems has surfaced due to intense competition both among transportation service providers and between shippers that use this service. Customers increasingly expect customized products and services usually with a quick response time from their suppliers. This often results in highly variable demand in terms of both place and time, and accelerated product life cycles. For example, the life cycle of electronic devices, such as computers and telecommunication, is measured in months. Since there are usually new products every so often and no historical data available concerning past customer demand for these new products, retailers have to order limited quantities to overcome the reduction in products' value during their life cycle (Mottley, 1998). Shippers typically try to

reduce their product distribution and delivery times to reduce costs. One way to respond to these challenges is to support the existing logistics systems with integrated wireless data systems.

Figure 2 depicts an example implementation of WDS in truck transportation. Figure 2 consists of three main parts or connections. First, all pertinent information is sent to the company information center (CIC) either by the driver (who sends the information using the truck-mounted computer) or by one or more truck mounted sensors. Carriers currently use this data to direct the truck on the road. This data transfer is limited, as carriers typically only contact the driver whenever there is an incident. The primary difficulty is that there is no connection between the driver and the truck when the driver is outside of the cab. Additionally, load, weight, and/or engine data is automatically sent to the company through a wireless network by onboard sensors. Another problem when carriers must contact their driver in an unusual event is the potential increase in costs by creating a need for additional personnel at the CIC.

The next part of the WDS implementation indicates the driver is responsible for informing the carrier of an accident, emergency, or other incident (via a wireless device). If the driver is unable to contact the carrier, the police or fire department on the scene informs the company. When a mechanical failure or other maintenance issue arises, the driver can use his wireless device to send information to the carrier's maintenance department to initiate (and potentially expedite) the repair process.

The third part of a typical WDS implementation pertains to the company's Internet web page providing prices, products, and shipping procedures to prospective customers. In order to gain market share and improve customer satisfaction in the highly competitive transportation marketplace, a carrier can use WDS to provide additional information such as real-time shipment

data and tracking information, and the truck's current location and expected arrival time at its destination.

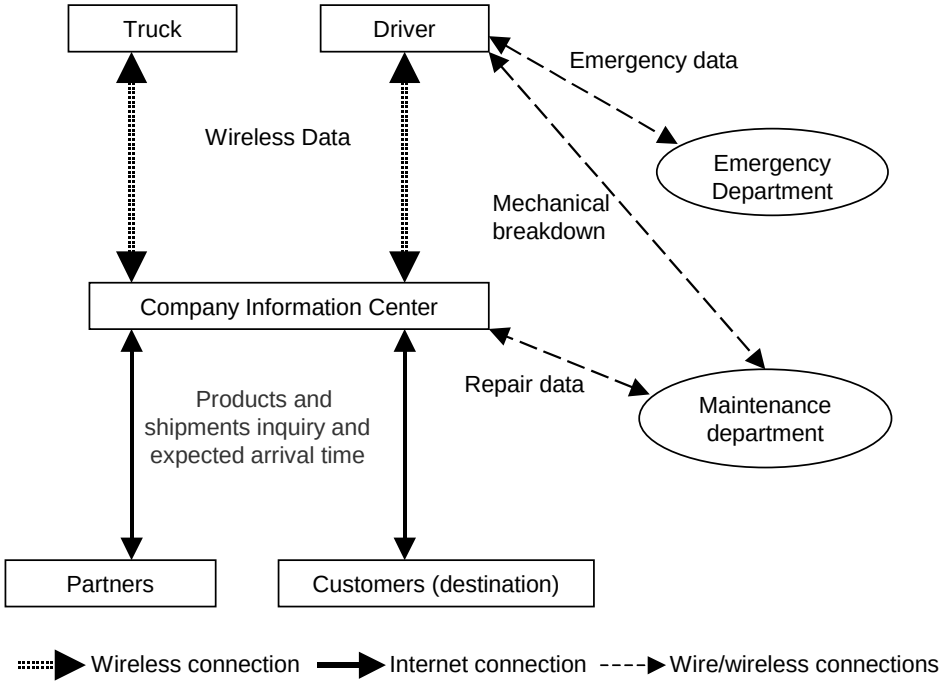

Figure 2. An Example WDS Implementation for Truck Transportation

3.1 Benefits of WDS

The overall idea behind many WDS implementations is that it might be possible to improve the use of resources (trucks, trailers, and drivers) by improving the data systems and operation practices. This includes all transportation types in a supply chain from raw material shipping up to the final products reaching the customer, as well as "after product sale" services. Wireless data systems can help logistics and supply chain professionals develop new competitive strategies by improving the following activities (with most recent data): private fleet routing and

utilization, supplier freight terms, distribution design and selection, optimization, benchmarking, cross-docking, and routing guide development.

Many companies have started to benefit from the tremendous development of WDS to improve their performance and operation. In 2000, FedEx started to use a digital dispatch and tracking system in Europe based on a popular wireless messaging service. They used the mobile network Short Message Services (SMS) channel for the dispatch and package information network. They began in Germany and planned to deploy it throughout Europe, calling their system the "mobile package-tracking system." When a FedEx driver scans a package's bar code into his handheld computer, he transmits the information via an infrared port to the courier communications terminal in his truck. The terminal then transmits the data through the European cell phone network into the company's long haul network and then into the FedEx mainframe, where they also use SMS for simple messaging (Brewin and Hamblen, 2001).

Another WDS currently available in the marketplace is provided by Symbol Technologies (2001). Their fleet technology equipment consists of a portable computer with electronic signature-capture capability, wireless LAN communications via 2.4 GHz, on-board computer (OBC) for trip recording, global positioning system, printers, and wide area wireless communications. According to Symbol, businesses benefit from their systems' fleet visibility, driver-dispatcher productivity, store communications, and management reporting. The applications for this system include activities at the start of the day that usually involve a significant amount of paperwork, labor, and time such as route assignment, pre-trip tractor inspection, trailer assignment, and trailer inspection. The application has been proven to save time by eliminating the bottlenecks in daily operations and by making drivers more efficient as the receiving store personnel are on alert as soon as he arrives (Symbol Technologies, 2001).

When the truck returns to a DC at the end of the day, it automatically senses that it is within range of the on-site system and uploads trip record information from the OBC seamlessly into the database.

The use of wireless technology on the transportation information system will result in more visibility due to the availability of real-time data; therefore, corrective action can be taken more quickly, resulting in a reduction in the distribution time and total cost of transportation. The Chrysler Corporation reduced its order processing and shipping times from seven days to three and one-half days after installing wireless networks in their four national parts centers. Their shipping and ordering is now directly entered into Chrysler's wireless networks. In addition to increasing efficiency in order and shipping processes, Chrysler's wireless communications resulted in a higher worker satisfaction (Simchi-Levi *et al*., 2000).

J. B. Hunt Transport recently equipped its fleet with Terion's FleetView trailer monitoring system. According to George Brooks of J. B. Hunt, "…wireless is a competitive necessity. A lot of shippers won't do business with you if you don't have it" (Haag *et al.*, 2000). J. B. Hunt's wireless, on-board computers helped to save almost 10% in road miles driven per day, reduced driver phone usage from two hours to 15 minutes, reduced the cost to transmit a phone call from $1 to $0.20 cents per call, and increased Hunt's fleet managers' productivity by 20 percent (Haag *et al.*, 2000).

Abraham Technical Co. reduced shipment errors by 75% and saved $11,250 in the process after implementing a WDS (Hamblen, 2000). ODC Integrated Logistics' Indianapolis warehouse passes on its labor costs to its customers. After its customers requested ODC implement a WDS, ODC and its customers enjoyed a 10% reduction in labor costs. Since then, additional customers have requested the use of ODC's WDS for their inventory (Brewin, 2000).

A number of companies have estimated a 5% savings in net shipping costs when using WDS (Brewin, 2000), while other companies have experienced a 10% increase in revenue due to WDS implementations (Sayeg, 2001).

Yen and Chou (2000) discuss the efficiencies gained by wireless technologies in business processes by Lehman Brothers. Order processing times were reduced from 90 seconds to five seconds, thereby resulting in doubled daily customer transactions. The efficiency gained was achieved primarily due to the establishment of direct communications links between remote workers and the information source.

In addition, WDS can help measure driver performance. According to Kay Palmer, an executive vice president of application services at J. B. Hunt, "in the future the system will use real-time data from each truck's engine to see who's driving efficiently and which drivers are slamming their brakes most frequently. Over time, better-trained drivers may reduce the need to call up driver safety queries, thereby making the highway safer" (Deck, 1998).

Both carriers and their customers agree on the importance of obtaining accurate, real-time shipment tracking information. Several types of devices can help describe a shipment on the road. For example, sensors can be used to record the temperature and/or pressure inside the trailer, the arrangement or layout of the merchandise in the trailer, and the total weight of the shipment, to name just a few. Further, the knowledge of the trailer's current load at all times can help increase the truck's and driver's utilization through the reduction of empty miles.

Some carriers have started to use these descriptive devices to improve operational efficiency and utilization. For example, one of the nation's largest truck transportation providers, in response to supplier, customer, and employee requests, is deploying satellite-integrated, on-board-computers for near real-time tractor visibility, satellite-integrated trailer

tracking for optimal asset management, and Internet-based trailer content visibility (i.e., loaded or empty).

3.2 Benefits of WDS in Truck Transportation

Table 1 lists various types of data that can directly benefit from the implementation of WDS in truck transportation. For each data type, the primary expected benefit is given in the second column, along with other potential benefits that may result from WDS implementation in column three.

Basically, using WDS reduces many different types of process times. By making data available anywhere, anytime, the delay in response time is diminished, as personnel at the origin, in the truck (i.e., the driver), and at the destination location are alerted of any pertinent changes in near real time. In turn, the ability to dynamically reschedule trucks and reconfigure trip plans that comes with a WDS implementation drives timelier, cost effective trucking operations.

Assume an example WDS implementation saves a carrier an average of 15 minutes per truck per trip. Conservatively, if the average truck's speed is 50 miles per hour, then the carrier can save 15 minutes of driver time, 15 minutes of truck time, and 12.5 miles of gas consumption per trip. Further, time can be saved at many points during a truck's routing, such as at the beginning of the trip, at the destination location, and during the trip. Calculating potential savings for a medium size trucking carrier that owns and operates 100 trucks, each of which goes on multiple trips per day makes real dollar savings evident.

Table 1. Potential Benefits of WDS Use in the Future

Data	Primary Expected Benefits	Other Potential Benefits
Accidents Crash Fire	The accident rates may be reduced due to the use of safety devices that allow early alerting of potential danger.	Reduced process time, improved customer service, reduced costs as a result of reduced cost per accident and time savings
Incidents Thefts Hijackers	The rate of these incidents will be reduced due to the reduction in the reaction time of the company.	Reduced as rate of incidents reduced due to the on time knowledge.
Mechanical breakdown	Repair times may be reduced due to the fast, correct diagnosis of problems.	Reduced time requirements for labor, equipment, driver, and truck, improved customer service due to the reduction in cost/hr for trucks, maintenance team, equipment use.
Destination change	Rapid route, time, and destination rescheduling will result in lower inventory levels.	Time savings, improve customer service.
Lost drivers	Lost driver time will be reduced due to quick redirection (guidance) of the truck.	Improved on-time delivery and customer satisfaction.
Traffic conditions Blocked roads Weather conditions	Driver idle time will be reduced due to quick, accurate reporting, rerouting/rescheduling.	Reduced driver costs due redirecting the truck to a new route rather than incurring idle time.
Beginning and Destination Process Times	Time required at the beginning of each trip, each day, and at the final destination will be reduced due to improved connectivity.	Automation of routine, tedious processes, reduced time requirements.
Empty miles	Driver empty miles will be reduced through more efficient utilization of trailer space.	Improved customer service, reduced driver cost and gas consumption.

The quoted lead time for materials can be reduced using WDS, as destination points receive advance shipment notices that contain information on the product(s) en route and potentially an expected arrival time. With this information, companies can prepare to receive the shipment ahead of time, thereby reducing overall order receiving and processing time. WDS

also promotes increased, effective communications between all parties in a company or across companies. By utilizing electronic signatures, drivers, customers, and other shipper teams can reduce the amount of time required to complete pre-trip inspections and eliminate many of the historically paper-based processes performed by the driver. As much of the pertinent information is captured electronically by the WDS, both the time and human errors associated with data transcription are significantly reduced. WDS benefits can be expanded to include the elimination of last minute "surprises" and hotshot shipments. Through the combination of continuous remote monitoring of critical processes and efficient, quick consumer response, the need for emergency transportation of goods can be mitigated, leading to reduced operating costs.

3.3 Potential WDS Implementation Issues

Various problems and/or restrictions accompany the implementation of WDS, such as the availability of wireless networks and satellites, sometimes high initial purchase and installation price, requirements for systems training and maintenance, and the potential for drivers to resist these new systems that they feel reduces their authority over their load. Further, when implementing any WDS on moving trucks, carriers must be aware of imposing any driver interventions or requirements that could lead to increased accident rates. This is especially true, considering that the fast growth in wireless communications over the past decade has been accompanied by the growth of potential hazards associated with drivers using wireless communication devices from moving vehicles (National Highway Traffic Safety Administration, 1997).

3.4 WDS Penetration—An Industrial Survey

Many of the problems in wireless transportation systems are quite new. These problems include, but are not limited to, the high cost of the wireless devices, the high cost of implementation, the availability of the wireless networks (either local area networks or world wide area networks), environmental effects, and driver dissatisfaction with or resistance to use the new technology that could ultimately result in a reduction in their authority. For example, some of the wireless devices may be easily mounted while others may need structural changes or may need new truck models, both of which make their implementation expensive.

To analyze the current wireless data systems used in the truck transportation industry, a survey was designed and distributed to a number of large trucking carriers. A copy of this survey is given in the Appendix of this report. The survey was structured to examine the impact of WDS on truck transportation. The potential exists for this impact to be scalable to other modes of transportation. Trucks are considered one of the most likely modes of transportation to benefit from the development of the WDS, mainly due to the high competition among trucking carriers as compared to other modes of transportation, such as barges.

The main objective of the survey was to analyze the current wireless devices used by truck carriers to assess current applications of wireless data systems and potential future directions of wireless data systems implementation. The survey consisted of seven major parts, each of which concerned one aspect of transportation logistics and WDS. These parts included truck and driver information, customer and destination information, route information, current wireless devices used, achieved/perceived WDS benefits, information about the carriers' fleet remote control system, and potential WDS applications in the future. The survey did not solicit responses about system costs or other quantitative measures, as each company's WDS may or

may not be used by another trucking carrier. This makes any comparison more difficult, as some carriers' WDS are quite simple. Therefore, it would be impossible to set a common standard. Further, cost information was not solicited due to the fact that most carriers consider their costs and benefit files proprietary information.

Analysis of each survey respondent's answers suggests that carriers are still using some type of paper-based or printout form for their Startup data in addition to WDS. One carrier transmits information to their drivers about weather conditions and blocked roads obtained from both "official" sources and their own fleet's drivers using WDS. In a more advanced implementation of WDS, another carrier uses wireless technology to describe each shipment's characteristics, delivery time, and required unloading information, as well as information on accidents and blocked roads. Yet another carrier automatically notifies their drivers of new product/merchandise pickups via WDS. On average, survey responses indicate that it takes drivers 15 to 30 minutes each morning to perform their Startup tasks.

However, we found that drivers, origin personnel, destination personnel, and maintenance personnel currently execute their signatures on paper, rather than electronically. When all signatures are verified electronically, some paperwork can be eliminated, which in turn reduces both processing time and the chance of the driver forgetting to sign the customers' papers. Therefore, this reduces the chance for error and eventually will increase customer satisfaction. Furthermore, using WDS, carriers can transmit information to hundreds of drivers simultaneously, thereby avoiding long waiting queues.

All carriers responding to the survey currently provide drivers some type of wireless device to provide specific information back to their carriers. In terms of Ongoing data, some carriers have their drivers report back their position via phone or truck-mounted computer, while

more advanced WDS users can establish each truck's position using a GPS. All carriers use an Internet web page to provide customers with real-time order tracking. In addition, some carriers provide customers the expected delivery time of their load. While some carriers use wireless devices exclusively to control the trucks in their fleet, they still depend greatly on driver feedback. One obvious outcome of WDS implementations is to reduce or eliminate the information requested of the driver, as WDS can update this information automatically without any intervention from the driver.

Our survey also asked about the benefits experienced by carriers using WDS in truck transportation. Responses included increased operational efficiency, improved utilization, reduced transportation and total cost, enhanced customer service, reduced empty miles, improved driver and customer satisfaction, reduced accidents, improved safety, reduced time delays, reduced inventory, reduced delivery costs, and reduced fuel consumption. These benefits are important, as they clearly show the positive impacts that WDS have on transportation and logistics systems.

Survey respondents also indicated that wireless devices are not likely to confuse their carrier's drivers. This contradicts the findings of the National Highway and Transportation Safety Administration (National Highway Traffic Safety Administration, 1997), who concluded that accidents are likely to increase, given the increasing numbers of cellular telephones used by truck drivers. To enhance the safety of everyone on the road, future WDS development should focus on reducing the manual handling of wireless devices by drivers.

Many issues exist in developing transportation data systems. What advanced WDS can be used that both reduce cost and improve customer satisfaction? What performance measures should be used to make WDS successful? How can the cost savings potentially resulting from

WDS implementation be transferred to the end user (customer)? According to Zieger (2001), "web architecture is evolving in new directions now that wireless devices have become a part of the Internet's information infrastructure." The way(s) in which WDS are connected to the Internet and/or the CIC can promote more accurate statistical analyses, seamless data reporting using multiple formats (e.g., hard copy, e-mail, and web-page based), and an increased number of available WDS configurations.

4 Future Applications of Wireless Systems

When discussing the information technology of future transportation logistics and supply chain management, a number of important developments must be considered:

- The incredible increase in the use and speed of the Internet and wireless communications system-based satellites. "The wave of technological advantages that brought us the Internet, mobile phones, and personal digital assistance is not likely to slow down. The future will bring a next generation Internet with higher speed, multimedia capability, and intelligent agent technology" (Golob and Regan, 2001).
- The availability of advanced and highly accurate tools such as a GPS and geographical information system. "Satellite-based communication and positioning systems are used to provide real-time communication, location, status updates and monitor vehicle conditions remotely. Hand held or home office wireless communication devices can be used to track and trace packages and shipments from any location" (Golob and Regan, 2001).
- The emergence of advanced information technologies that have increased the visibility of trucks on the road, in the fleet, and on the trailer yard.

- The availability of information on the Internet, such as road and weather conditions. This information should lead to increased driver safety, security, and customer satisfaction.
- The customer's accessibility to the Internet information and the increase in the use of wireless devices from the customer's side.

  > "…Looking for the next few years, we believe the most exciting development will be wireless Internet. Individuals carrying small hand held devices would be able to access an enormous array of information targeted to the mobile user. Through a portable traffic and flexible platform, drivers will not only be able to interface with their carriers routing system, but also access traffic and weather information, exchange messages with customers, update inventory records and request assistance when needed" (Partyka and Hall, 2000).

- The customer's behavior is based on selectivity and attractiveness of new technologies. Customers usually prefer and trust the use of high technology.
- The recent emergence of concern for the safety and security of the trucks, drivers, and shipment; safety and security measures are required by both government and private organizations.
- The high fluctuations in demand and shorter life cycles of products.

4.1 An Example Wireless System of the Future

Figure 3 depicts an example wireless transportation system of the future that provides real-time information to the truck driver on the road, the originating company, its partners, the end destination point or customers, and other different agencies. The system consists of four

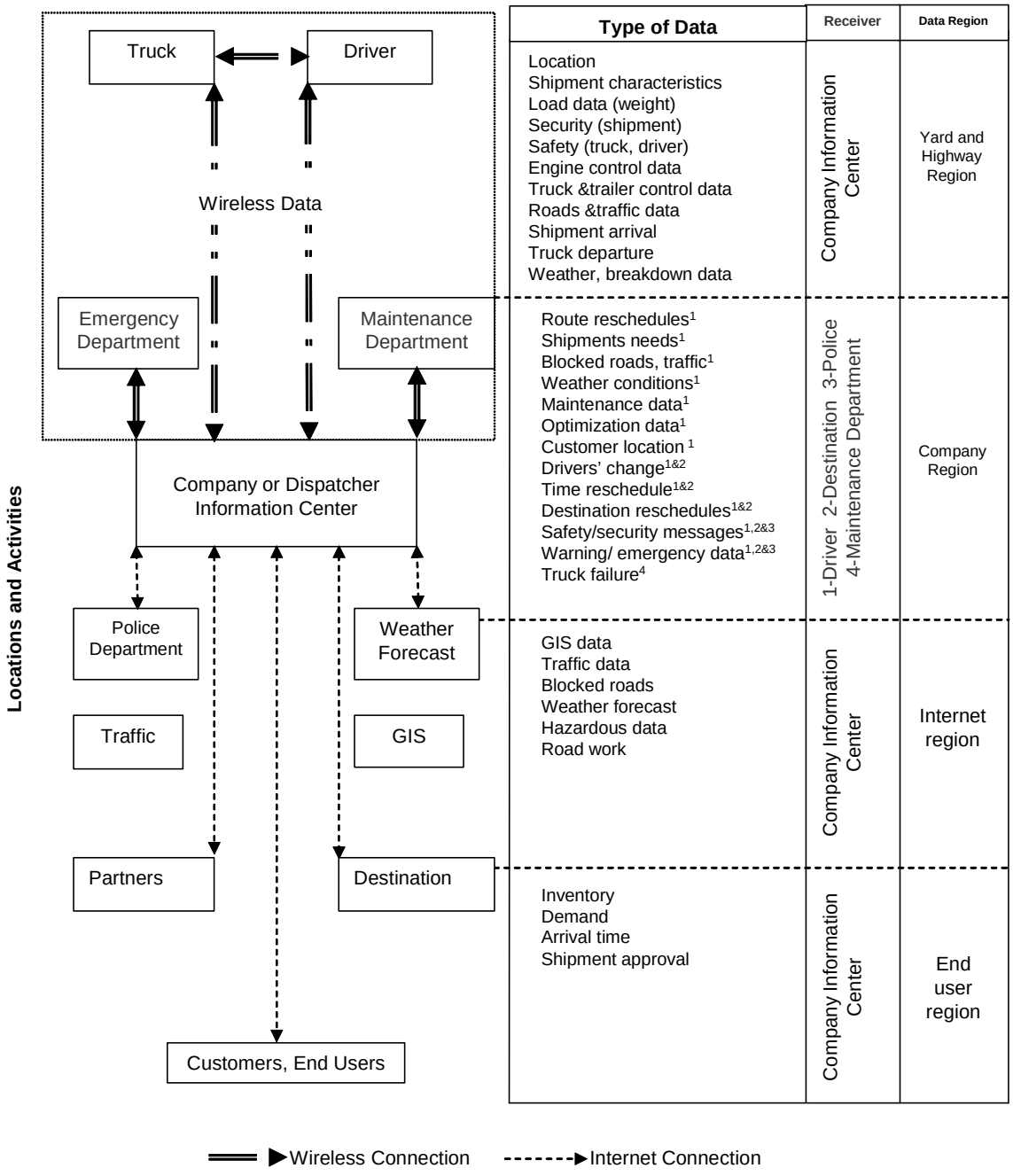

Figure 3. An Example Wireless Transportation System of the Future

components, each of which is divided into four regions according to its use. The four components are locations and activities, the type of data being handled, the intended receiver of

data, and the data region. The data regions are the yard and highway region, the company region, the Internet region, and the end user (i.e., customer) region. Figure 3 also contains two types of connections: wireless connections (represented by double dotted arrows) and Internet connections (represented by single dotted arrows), which could be either wired or wireless. The following subsections describe in detail the characteristics of the four data regions presented in Figure 3.

4.1.1 Yard and Highway Region

The yard and highway (Y&H) region contains the building blocks for transportation WDS that can lead to improved total supply chain performance and assist shippers in increasing the effectiveness of their operations. As shown in Figure 3, activities in the Y&H region include various communications between the truck and/or driver and the CIC, while the primary locations are either the driver or the truck.

The Y&H Region is connected to the dispatcher or CIC by means of a wireless network. In the future, trucks on the road will be equipped with the wireless devices necessary for achieving an integrated WDS. This system will make the truck totally visible to the originating location, destination or dispatcher. This visibility will not only include the location of the truck, but all data requisite for shippers-wide supply chain and transportation logistics system improvements. The pertinent information associated with a given truck on the load will include, but is not limited to, the location of the truck and trailer, statistics pertaining to the speed and operation of the truck, the shipment characteristics or description, including the load or weight of the shipment, any requisite safety and security concerns.

We choose to separate the driver from the truck, as the driver may leave the truck to eat, sleep, or to do some work outside of the vehicle. A truck driver is often asked to perform some task or action. While this type of request is regularly accommodated during normal driving, a new degree of communication difficulty is introduced when the driver is outside of the cab. Even though some wireless devices are truly portable (i.e., handheld devices), other devices are hard-mounted to the truck, such as TMCs, wireless transmitters and receivers, and global positioning systems.

To allow complete visibility of the transportation fleet in the future, drivers will be equipped with a wireless device such as a PDA that can be readily available for communication, regardless of the driver's location. This device will stay with the driver at all times to alert him if something has happened to the truck or trailer, especially when the shipment contains hazardous or otherwise dangerous materials. This connectivity will also prove helpful if there is a new action required of the driver or a change to the route, schedule, or destination of the truck. Using this approach, the driver will be connected to the truck at all times, ensuring the carriers can reach the driver whenever necessary.

Haag *et al*. (2000) discuss Robert Express Europe's (REE) two-way satellite communication system for maintaining communications with truck and driver. REE's system collects information about the locations of the trucks, storing this data in a central database and displaying it in real-time graphic images of shipment (truck) location on a map of Western Europe. The REE system has a set of 25 frequently used messages so the driver can select the number of the appropriate message for his response. For example, if he selects number 12, the following message is sent to the company: "I am delayed in traffic and will be 15 to 30 minutes late."

WDS in the Y&H region should be easy to use, as well as easy to maintain. The WDS should reduce the amount of required driver intervention while also improving safety. In addition to being affordable, WDS devices should be small, lightweight, and in compliance with environment and government restrictions. In the end, a WDS should provide all data necessary to help the deploying shipper to improve their performance measures of interest, not the least of which is typically to reduce costs.

4.1.2 Company Region

In addition to the ability to track the load on the road, WDS can provide a direct connection between the truck on the road and different response teams in the carrier, such as maintenance and/or emergency teams. This connection to the "Company Region" will reduce the time of response from the team(s) to the driver. This region consists of the CIC, emergency department, and maintenance department. The CIC is the heart of the automated wireless system. Data is received from various regions and processed using various optimization and heuristic approaches, and then quickly sent back to one or more of the following recipients: the driver, destination point personnel, police, and other carrier departments such as maintenance. The extensive list of information associated with the Company Region is given in Figure 3.

Information Sent From Truck to Company Information Center

Figure 4 displays the information flow to and from a typical CIC. Trucks on the road typically send their CIC four types of information:

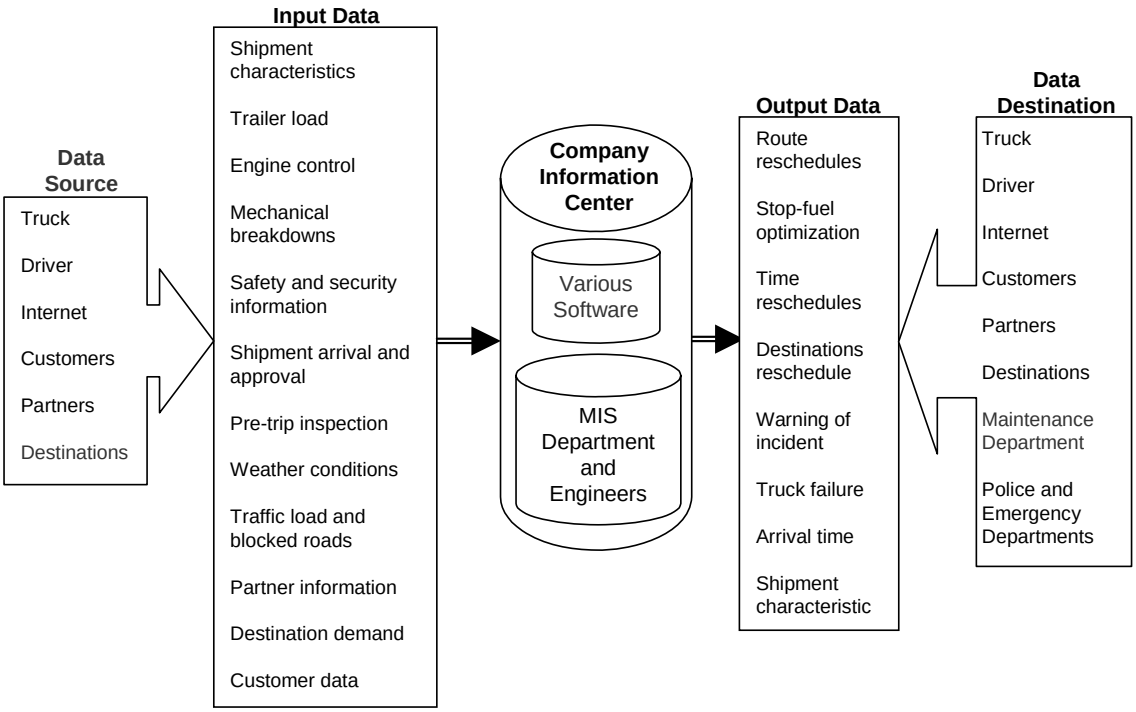

Figure 4. Information Flow around the Company Information Center

1. Pre-trip inspection signature(s) and/or driver signature when performed using the truck's WDS.
2. General data that may help improve customer satisfaction and loyalty such as shipment, location, and time to destination, shipment characteristics, and safety. This information is typically available to customers via an Internet web page.
3. Information that could be used to increase operational efficiency, such as current fuel level, load weight, or other associated maintenance information.
4. Customer approval/acceptance signatures sent using either the truck's WDS or the driver's handheld device.

Information Shared Between CIC and Destination

By using a WDS to transmit information between the CIC and the destination point, inventory levels can be more appropriately set while simultaneously improving customer service. For example, unusually high demand may drive the need for a new replenishment, while low demand may alleviate the need for replenishment altogether. All of this data can be analyzed at the CIC in the hopes of optimizing and potentially rescheduling truck routing plans in near real time.

Information from CIC to Truck

By taking advantage of its connectivity to the systems and environment around it, the CIC analyzes numerous different factors and variables. These inputs are the fuel for various optimization and decision support algorithms that produce meaningful, important information for a carrier's truck drivers. Example data that can be reported back to drivers include, but is not limited to, optimized fuel stop location(s), rescheduled routes and/or delivery times, upcoming weather conditions, and blocked road/traffic information. Information sent by the CIC can help to redirect a lost driver. CIC systems can also monitor and inform the driver of any change in the shipment's characteristics, such as an unwanted increase in trailer pressure and/or temperature, as well as assist with incident management, traffic control, and emission testing (Deck, 1998).

4.1.3 Internet Region

The combination of Internet networking and WDS can provide real-time, global access to information. Internet-based services, which are readily accessible throughout much of the world, enable freight exchange and tracking and provide continuous move matching between shipper

and trucks. "The internet is becoming an effective tool for merging systems and raising the visibility of routing information" (Partyka and Hall, 2000). Utilizing the Internet, the cost in time and manpower to provide data entry is eliminated. Moreover, the availability of fresh data allows immediate, accurate decisions about transportation processes. The personal computer, EDI, scanning and storage technology, wireless technologies, and the Internet are now standard ways of doing business. The increasing variety of wireless devices offering Internet Protocol connectivity, such as digital cellular phones and PDAs, is changing our perceptions of Internet access and use (Perkins, 1998). The next generation of mobile communications will be integrated into the Internet (Wu, 1999).

The Internet region contains the real-time, company-external data that can be used to improve the operational efficiency of the company's transportation system. Examples of the data associated with this region are given in Figure 3. As this data is not typically housed within the CIC, it is typically obtained from various governmental or private organizations such as police departments, weather bureaus, traffic centers, and GIS sources. Internet sites such as accuweather.com provide both weather and road conditions. In addition, the information can be very detailed, including air temperature, dew point, relative humidity, average and maximum wind speed and direction, precipitation, and pavement temperatures at specific locations. Traffic information may pertain to blocked roads, location(s) of heavy traffic, while police departments may furnish accident information. By using the Internet, the dynamic behavior of the real world can be tracked in near real time.

4.1.4 Customer Region

The Customer region contains three main locations (destination points): distribution centers, factories, and retailers. Customers may be a company, a factory, or even a single consumer. One of the important advantages resulting from the use of WDS is improved customer satisfaction. Customers who can access the Internet now can place their order, following the processing of their order, and track the goods while they are in transit to the customer. The demand to conduct these activities from multiple access points is constantly increasing—wireless carriers have been successful in gaining considerable revenue from customers (Andreas and Gunnar, 2001).

Simchi-Levi *et al*. (2000) discuss the Internet's capabilities that allow users to access their accounts and perform transactions from any location at any time. The availability of the real time information to the customer is now not only a "nice to have," but a "need to have," as the "…openings of the information boundaries between the customers and company is part of the new customer value equation, where the information is part of the products" (Simchi-Levi *et al*., 2000).

WDS afford shippers reduced lead times during the processing of the order, which in turn improves customer service. For example, Southern Connecticut Gas Company measured improved customer service after replacing its old paper tracking system and two-way radios with a WDS to dispatch its fleet vehicles for routine service calls and emergencies (Hamblen, 2000). When describing the competitive advantages gained in transportation and logistics by using WDS, XSILOGY points out that the real time data eliminates last minute surprises (Xsilogy Customer Brief, 2001). Further, real-time data can significantly mitigate the costs associated with a process that is out of control. For many industrial processes, real time information can be

directly translated into pricing power and competitive advantages (National Highway Traffic Safety Administration, 1997).

4.2 Impact of Wireless Data Systems on Transportation Systems of the Future

WDS will impact the performance of future transportation systems in three main areas. First, WDS will reduce delivery cycle times by expediting pre-arrival preparations, delivery approval processes, and driver interchange process times. Second, customer satisfaction will increase due to reduced delivery times, minimized delay times, and reduced human errors and incidents. Finally, WDS implementations will help reduce accidents, increase safety and security, improve operational efficiency, reduce inventory levels, and decrease both fuel consumption and empty miles.

In order to experience the most benefits possible from a WDS implementation, decision support software must be able to use the information available via WDS and consider many different factors when determining the "best" delivery routing and time schedule. Various new input factors must be considered, such as geographical information, vehicle location information, traffic congestion, blocked roads, and weather conditions, along with traditionally considered factors such as customer locations and types of loads available.

Further, the support software may potentially be able to retrieve various types of safety and security information from the truck via the WDS, creating a warning signal or message in the event of an emergency or incident. This signal could be sent to the driver, CIC, the police department, and/or the fire department to notify the appropriate parties of the truck's exact location, speed, shipment characteristics, and any other information that would be useful for saving personnel and property losses.

Another important impact of WDS on the transportation systems of the future pertains to both customer and driver satisfaction. The apparent value of near real-time packing tracking currently available will only increase in the future as more and more sophisticated wireless technologies become available for tracking goods with even greater resolution. The potential also exists for drivers to be informed of their current progress via the WDS so they may react to being ahead of or behind the promised scheduled delivery date. "Rapid advances in information technology present new opportunities and challenges to business process reengineering…today, individual packages can be tracked through transportation system in near real-time from the moment of acquisition to the moment of delivery" (McGinnis, 1999).

4.2.1 Safety and Security Applications

Carriers continue to improve the safety and security of their customers' deliveries through the reduction of accidents, theft, hijacking, and fires. Many wireless devices can be used to improve safety. For example, speed and fuel sensors can be used for monitoring and controlling truck engines. Fuel sensors can also be used for determining the optimal refueling policy and subsequent location of upcoming refueling stops. The use of these types of devices leads to a reduction in unauthorized use, providing carriers with information that can help save time and reduce errors. Many of the wireless devices that accompany a GPS system can improve security:

- Open door sensors for the trailer door can help to prevent unauthorized opening/access of the trailer's contents.
- Shock sensors can generate a massege at the company (origin) information center about any accident(s) that happen to the truck.

- Door detectors on the driver's door aid in detecting any action of theft or unauthorized use by any person other than the driver.
- Trailer connection sensors assist with determining the location of the trailer and also ensure the integrity of the truck to trailer connection is not tampered with or violated.
- Alarms, such as warning lights or bells, notify the driver of any unusual operation in the truck itself and also keep the driver informed of any new on-the-road construction, accidents, or other obstacles via carrier messages.

Hoevenaars (2001) believes that software output analysis can provide traffic managers with valuable data and insights. For example, video analysis presents an attractive opportunity for extracting valuable traffic management data. Basic vehicle recognition capability is used for signaling when an emergency is detected or when a vehicle is traveling the wrong way on the street. A suggestion could be to equip trucks with a digital video camera that transmits real-time images to the CIC. Assume a carrier has 400 trucks on the road at any one-time (i.e., a "medium" sized operation). The number of security personnel required to observe and monitor these vehicles is quite prohibitive for carriers to staff, especially when you consider these vehicles all must be tracked simultaneously in real time. Therefore, the following types of detectors and sensors are typically used to monitor trailer conditions and signal appropriately when a problem arises:

- Weight sensors under the driver seat
- Electronic signature that is performed by the driver prior to any truck movement. This can also be equipped with a modified password in case of emergency.
- Thumb stamp on the steering wheel

- Hidden button that the driver has to push frequently

These signals notify the carrier of a security or safety problem on a specific truck in a specific place at an exact time. With this information, the proper information can be sent to the right carrier department immediately so that corrective action can be taken quickly.

The public safety goals addressed by intelligent transportation systems strive to reduce the frequency of accidents, reducing the severity of accidents, reducing congestion due to incidents, and enhancing travelers' security. These goals can be met by performing many safety related functions such as improving the monitoring of onboard systems and transportation facilities, improving response to hazardous materials incidents, improving incident management, improving incident information to drivers, improving the availability of communications devices, and reducing vehicle theft.

Borras (2001) discusses personal safety, remarking that often emergency services may not be able to locate accident victims on the open road. However, if the person is carrying a mobile phone, it is quite likely that the mobile phone can be located quite accurately. One particular J. B. Hunt driver's life was saved primarily because of the existence of his wireless on-board computer: "The driver was able to notify the home office of his condition. Within minutes, the home office faxed a map of the driver's location to the Royal Canadian Mounted Police, who were able to save the man's life" (Haag *et al*., 2000).

4.2.2 Repair and Maintenance Applications

Leveraging wireless technology's ability to reduce the effect of time and geographic constraints, maintenance departments can reduce the repair process time by using WDS. When a

truck stops due to a mechanical problem, a small onboard computer can provide crucial information to the maintenance department via wireless connection. The maintenance department can retrieve pertinent information directly from the truck and analyze the malfunction using special analysis software. Once the problem has been identified, the maintenance department can proactively print out the repair process instructions and provide a detailed itemization of the tools, equipment, and spare parts requisite for the repair. By taking advantage of the WDS, the maintenance team does not have to go to the truck to assess the situation, thereby saving time and money.

5 Conclusions and Future Research

In this research project, we uncovered the potential for wireless data systems to promote more efficient operations, generate increased profits, and demonstrate improved connectivity throughout the fleet. Further, our investigations demonstrated the link between wireless data systems and improved customer service levels and reduced operating costs. Once a company's WDS is in place, the wireless system can replace paperwork and reduce repetitive, routine human tasks while providing up-to-date data for the carrier drivers and customers. An effective WDS should be flexible, capable of rescheduling routes, times, and destinations while the truck is on the road. Further, effective WDS can track any load on the road, both in terms of its location and expected time of delivery.

The inventory present in any logistics network is constantly changing due to customer demand. By using WDS, a company's information center match up requesting stores and proximal trucks, directing the truck to the nearest location that contains the requested item(s). When poor weather conditions, bad traffic, or blocked roads exist that can potentially affect a

truck's schedule, the truck may either be rerouted to the original destination via an alternate routing or simply rescheduled to another destination point. WDS assist in this process by making the "smartest" decision with respect to shipper business rules. These decisions are enabled through the exchange of wireless data to and from the truck with continuous updates from the GPS system to determine vehicle location. The potential exists for this level of connectivity to lead to a reduction in the number of DCs, as well as their corresponding inventory levels. Further, tractor trailers could become "mobile warehouses" that would further reduce inventory levels throughout the supply chain.

While our investigations into the viability of WDS are complete, future research must study the relationship between WDS implementation cost and the achievable benefits. These benefits should be quantified through a static cost model or other suitable analysis methodology. Regardless of the methodology employed, the WDS case with its associated benefits and costs should be compared to the base, no wireless system case. Further, researchers should partner with industry collaborators to validate their analysis methodology with real-world model inputs. Once the methodology has been validated, the transportation industry segments that will experience both the strongest positive and potentially negative impacts due to the emergence of wireless data systems should be identified.

Future research will also be conducted to study the impact of asset visibility anytime, anywhere within the transportation logistics network. We hope to draw additional, insightful conclusions about the effect of implementing WDS on both customer service and total cost.

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Appendix: Wireless Data Systems Survey

THE IMPACT OF WIRELESS DATA SYSTEMS ON TRANSPORTATION

Your Job Title: _____

Driver-related Data

No	Data	**Information given to drivers (Circle number if given)**	**How do drivers receive the info? (Circle the number(s))**
1	At the beginning of the day	1. Route assignment 2. Time schedule (milestones for his trip) 3. Destination schedule. (Delivery points) 4. Maintenance report (pre-trip truck inspection) 5. Weather conditions 6. Other: …… …… …… ……	1. Paper based 2. Printout 3. Electronically 4. Other …… …… …… ……..
2	During the trip (while truck is on the road)	1. Traffic (in his route) 2. Blocked roads 3. Weather conditions (On the route &destination point) 4. New pickups 5. Other. …… …… …… ……	1. Paper based 2. Printout 3. Electronically 4. Other …… …… …… ……..
3	At the delivery point	1. Time of delivery? 2. Unload information 3. Next destination 4. New pickups 5. Special delivery requirements 6. Other information …… ……	1. Paper based 2. Printout 3. Electronically 4. Other …… …… …… ……..

5. How long does it take a driver to perform his first task of the day and actually leave the company (distribution center)?	1. < 10 minutes. 2. 10-20 minutes. 3. 20-30 minutes. 4. > 30 minutes.
6. What information does the driver give back?	1. Time of delivery 2. Unload information 3. Positioning 4. Accidents 5. Blocked roads 6. Shipment characteristics 7. Other …… …… ……
7. Do you have any means of controlling or affecting either the truck and/or driver while the truck is on the road?	Please write the device(s) used. 1. 2.

B. Wireless Devices

Are any of the following wireless devices being used in your trucks or may they be used in the near future? Please circle YES or NO.

Device	Circle Yes or No	If YES, what type(s) of data are being processed using these devices? (Circle the number(s))
1. Cellular	**Yes No**	1. Time to the delivery point 2. Time to the company (distribution center) 3. Positioning 4. Traffic 5. Unload information 6. Truck malfunctioning information 7. Accidents 8. Safety information 9. Reschedule the route 10. Change the destinations (customers) 11. Report weather conditions 12. Change the drivers 13. Send massages (from/to drivers) 14. Contact Other (like driver family) 15. Determine the truckload 16. Distance to destination or from origin 17. Shipment characteristics 18. Other:…… …… …… ……
2. GPS (global poisoning system)	**Yes No**	
3. Pager	**Yes No**	
4. Computers:	**Yes No**	
Truck-mounted computer	**Yes No**	
Laptop	**Yes No**	
Mobile computer	**Yes No**	
Notebook	**Yes No**	
Sub notebook	**Yes No**	
Any other hand held computers	**Yes No**	
5. PDA (personal digital assistance):	**Yes No**	
Wireless e-mail	**Yes No**	
Fax	**Yes No**	
Hand writing recognition	**Yes No**	
6. Other: ……. ……	**Yes No**	

C. Customer or Destination Information

	Check √
1.Do you have a Web page that customers can use to enter their orders?	☐ **Yes** ☐ **No**
2. Can a customer track his load using the Web? If not, can they track it through other means? …….	☐ **Yes** ☐ **No**
3. Do you give customers special information about the trucks such as truck type, color, distance, time to destination, and driver name?	☐ **Yes** ☐ **No**
4. What type of information the customer share with company using the Web (circle number)?	1. Prices 2. Order tracking 3. Load tracking 4. Delivery time 5. Other …… …… ……

D. Routing information

Route assignment (check √)

1. Do you use software to optimally develop truck routings and re-routings when changes arise? ☐ **Yes** ☐ **No** Do you use software to position and/or locate your trucks? ☐ **Yes** ☐ **No**	6. What do drivers do when replacing another driver? Sign paper ☐ **Yes** ☐ **No** Make a phone call ☐ **Yes** ☐ **No** Other…… ……
2. Can you change the schedule easily and effectively (due to weather, traffic, accidents, higher demand) while the truck is on the road for Route? ☐ **Yes** ☐ **No** Time? ☐ **Yes** ☐ **No** Destination? ☐ **Yes** ☐ **No**	7. How do you get informed that a truck has reached the destination and/or is unloading the goods? Electronically ☐ **Yes** ☐ **No** Phone ☐ **Yes** ☐ **No** Other:…… What devices are used, if any: ……..…… ……..
3. How can drivers, destination personnel, maintenance personnel, and the origination personnel perform their signature? Paper ☐ **Yes** ☐ **No** Electronically ☐ **Yes** ☐ **No** Printout ☐ **Yes** ☐ **No** Other: …….	8. How do drivers send any messages? By phone ☐ **Yes** ☐ **No** Internet ☐ **Yes** ☐ **No** Other: ☐ **Yes** ☐ **No** Other:……
4. What type of documents or data do drivers carry in the truck? 1……. 2……. 3……. 4……. …….. How? On paper ☐ **Yes** ☐ **No** On computer ☐ **Yes** ☐ **No** Other……	9. How do you learn if a truck has had an accident? Police ☐ **Yes** ☐ **No** Phone ☐ **Yes** ☐ **No** Other:…… ……..
5. How do drivers get their schedule to go to another destination from the current destination point? ☐ Paper ☐ Electronically ☐ Printout ☐ Other:…….	

E. Benefits of wireless data systems

Which of the following effects are being realized in your company due to the application of wireless data systems?

	Circle Yes or No	**Comments**
1. Increased operation efficiency	**Yes** **No**	
2. Improved utilization	**Yes** **No**	
3. Reduced transportation or total cost	**Yes** **No**	
4. Enhanced customer service	**Yes** **No**	
5. Reduced empty miles	**Yes** **No**	
6. Improved driver satisfaction	**Yes** **No**	
7. Reduced accidents	**Yes** **No**	
8. Improved safety	**Yes** **No**	
9. Reduced delay time	**Yes** **No**	
10. Reduced inventory	**Yes** **No**	
11. Reduced cost of delivery	**Yes** **No**	
12. Reduced fuel consumption by the trucks	**Yes** **No**	
13. Increased customers satisfaction	**Yes** **No**	

F. General

	Circle Yes or No	**If Yes please write down description about it.**
1. Do you have any other types of remote control devices on your trucks?	**Yes No**	
2. Does your system analyze real-time data and present recommendation(s) for actions to be taken?	**Yes No**	
3. Are drivers confused or do they complain about reduced concentration while using wireless devices?	**Yes No**	
4. Is the required data entry at an origin or destination automatic?	**Yes No**	
5. Can the mobile maintenance and emergency groups contact drivers while they are on the road?	**Yes No**	

G. Wireless system in your company

	Circle Yes or No	**Comments**
1.Do the existing devices perform their required work correctly?	**Yes No**	
2. Is the wireless system fully automated?	**Yes No**	
3. Is there any information you need to send to or receive from the driver while the truck is on the road that you currently cannot do with the existing system?	**Yes No**	
4. Are the wireless devices connected to the internet or a local system at your company? If yes, how: satellite, local area wireless system, other?	**Yes No**	
5. Are wireless devices hard mounted in the truck?	**Yes No**	
6. Are there any security features in your trucks? □ Against thieves □ Against accidents □ Against driver violence and unauthorized use.	**Yes No**	

H. Expert opinion

What type of wireless devices do you think will be best suited for your company needs in the future (Check √) □ Truck mounted computer □ Laptop □ Mobile computer □ Notebook □ Sub notebook □ Any other hand held computers □ Other: ……..	