Motor Carrier Efficiency Study
Phase I

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

February 2009

FOREWORD

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, Public Law 109-59), Section 5503 – Motor Carrier Efficiency Study, set aside funding to examine the application of wireless technology to improve the safety and efficiency of trucking operations in the United States. The intent of this Section is to enable the U.S. Department of Transportation to partner with the motor carrier and wireless technology industries to cooperatively identify and test promising applications and devices in a real-world environment, and to promote the adoption and use of successful solutions by an array of motor carriers.

The specific objectives of the Study are to:

- Identify inefficiencies in freight transportation.
- Evaluate safety and productivity improvements made possible through wireless technologies.
- Demonstrate wireless technologies in field tests.

The Federal Motor Carrier Safety Administration (FMCSA) was assigned responsibility for administering this program via the Motor Carrier Efficiency Study (MCES). The program will be completed in two Phases. Phase I has been completed and addressed the first two objectives listed above. The actual field tests will be conducted under Phase II of the program.

The results of Phase I are summarized in this MCES Final Report. This Report constitutes one of seven reports developed under Phase I of the MCES. The others are:

- Motor Carrier Efficiency Study Final Literature Review Report: A Primer on Wireless Technologies and Freight Inefficiencies for Motor Carrier Operations, March 2007.
- Motor Carrier Efficiency Study Analysis Methodology Development Report, February 2007.
- Motor Carrier Efficiency Study Stakeholder Summary Report, May 2007.
- Motor Carrier Efficiency Study Inefficiencies Report, July 2007.
- Motor Carrier Efficiency Study Analysis of Wireless Technologies, December 2007.
- Motor Carrier Efficiency Study 2006 Annual Report, October 2007.

Electronic copies of these documents are available from FMCSA upon request.
Please call 202-385-2377.

NOTICE

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This program was administered through the Federal Motor Carrier Safety Administration (FMCSA). The FMCSA Program Manager is Mr. Jeffrey Loftus.

16. Abstract

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, Public Law 109-59), Section 5503, set aside funding to examine the application of wireless technology to improve the safety and efficiency of trucking operations in the United States. The intent of this Section is to enable the U.S. Department of Transportation to partner with the motor carrier and wireless technology industries to cooperatively identify and test promising applications and devices in a real-world environment and to promote the adoption and use of successful solutions by an array of motor carriers. The specific objectives of the program are to: Identify inefficiencies in freight transportation; evaluate safety and productivity improvements made possible through wireless technologies; and demonstrate wireless technologies in field tests. The Federal Motor Carrier Safety Administration (FMCSA) was assigned responsibility for administering this program via the Motor Carrier Efficiency Study (MCES). The program will be completed in two Phases. Phase I consists of the completion of activities pursuant to the objectives stated above. The actual field tests will be conducted under Phase II of the program.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					AREA		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	square kilometers	0.386	square miles	mi^2
		VOLUME					VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	l	l	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	cubic meters	35.71	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	cubic meters	1.307	cubic yards	yd^3
		MASS					MASS		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.202	pounds	lb
T	short tons (2,000 lbs)	0.907	megagrams	Mg	Mg	megagrams	1.103	short tons (2,000 lbs)	T
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION					ILLUMINATION		
fc	foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m2	cd/m2	cd/m2	candela/m2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

***SI is the symbol for the International System of Units. Appropriate rounding should be done to comply with Section 4 of ASTM E380.**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

ACRONYMS

Acronym	Definition
1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
ACE	Automated Commercial Environment
BCA	Benefit–Cost Analysis
BCR	Benefit–Cost Ratio
CB	Citizens Band
CBP	U.S. Customs and Border Protection
CDPD	Cellular Digital Packet Data
C-EFM	Columbus Electronic Freight Management
CHCP	Cargo Handling Cooperative Program
CMV	Commercial Motor Vehicle
C-TIP	Cross-Town Improvement Project
CVISN	Commercial Vehicle Information Systems and Networks
CVSA	Commercial Vehicle Safety Alliance
DSRC	Dedicated Short-Range Communications
ECM	Electronic Control Module
EFM	Electronic Freight Management
EOBR	Electronic On-Board Recorder
ERG	Expert Resource Group
ESCM	Electronic Supply Chain Manifest
ETA	Estimated Time of Arrival
FAST	Free and Secure Trade Program
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FSO	Free Space Optics
FTAT	Freight Technology Assessment Tool
GHz	Gigahertz
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
IEEE	Institute of Electrical and Electronics Engineers
IrDA	Infrared Data Association
IRISystem	Infrared Screening Inspection System
IRR	Internal Rate of Return
IT	Information Technology

Acronym	Definition
ITS	Intelligent Transportation System
kbps	kilobits per second
LAN	Local Area Network
LTL	Less-than-Truckload
MARR	Minimum Attractive Rate of Return
Mbps	Megabits per second
MCES	Motor Carrier Efficiency Study
NAFTA	North American Free Trade Agreement
NPTC	National Private Truck Council
NPV	Net Present Value
OOS	Out of Service
PDA	Personal Digital Assistant
RF	Radio Frequency
RFID	Radio Frequency Identification
RPM	Revolutions per Minute
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SCOR	Supply Chain Operations Reference
TL	Truckload
USDOT	U.S. Department of Transportation
UWB	Ultra-wideband
Wi-Fi	Wireless Fidelity
WIM	Weigh-in-Motion
WiMAX	Wireless (or Worldwide) Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
WTA	Washington Trucking Association

EXECUTIVE SUMMARY

PURPOSE

Phase I of the Motor Carrier Efficiency Study (MCES) focused on the application of wireless technologies to overcome common motor carrier inefficiencies. This Final Report summarizes findings in the areas of wireless technologies (in general), motor carrier inefficiencies and potential economic gains in overcoming inefficiencies, proposed wireless applications, and the estimated benefits and costs of applying the proposed technology solutions within the motor carrier industry.

PROCESS

The study was divided into several work tasks:

- Gathering and analyzing existing literature regarding freight system inefficiencies and the potential application of wireless technologies to these inefficiencies.
- Compiling pertinent background information for the analysis of the safety benefits and efficiencies that can be achieved through the use of various wireless technologies.
- Completing stakeholder outreach sessions and individual interviews to capture information regarding baseline freight performance, user needs, performance measures, and feedback regarding technology options.
- Isolating the inefficiencies recognized as most pressing by motor carriers and identifying evidence of their effects to evaluate potential solutions.
- Analyzing wireless technology solutions via feedback from industry representatives in Expert Resource Groups and conducting a benefit–cost analysis (BCA) using the Freight Technology Assessment Tool (FTAT).
- Completing task reports and this final project report.

The MCES literature review examined common motor carrier inefficiencies extracted from more than 200 individual published sources and/or offered by industry experts. Where appropriate, these inefficiencies were examined in the context of various motor carrier industry segments (i.e., truckload, less-than-truckload, intermodal, etc.). In addition, the literature review provided a primer with detailed specifications for current and emerging wireless technologies.

The Study Team, under the direction of FMCSA, completed eight stakeholder outreach sessions around the United States, and identified high-priority inefficiencies in order to narrow the list of potential challenges to which wireless technology solutions might be applied. Since an in-depth quantitative analysis of every inefficiency identified during the literature review was considered too large an undertaking for the scope of this study, the Study Team prioritized inefficiencies based on their relative importance to the motor carrier community.

The Study Team also examined the degree to which individual inefficiencies could be clearly defined, in both qualitative and quantitative terms, by members of the motor carrier community. Inefficiencies that met these basic conditions, and were cited on multiple occasions by Stakeholder Session participants as being significant issues for their operations, were examined in depth.

A viability analysis provided useful information regarding the relative opportunities and challenges associated with pursuing pilot demonstrations for nine technology applications that might mitigate the effects of the identified inefficiencies. A BCA was developed for these scenarios using FTAT, a decision support tool that evaluates potential effects of emerging technologies on the performance of the transportation supply chain from qualitative and quantitative perspectives.

STUDY FINDINGS

The MCES literature review revealed that motor carrier operations, specifically profitability and safety, are subject to a broad array of inefficiencies that result in financial losses estimated at tens of billions of dollars per year. In all, the Study Team identified 43 types of inefficiencies across seven categories:

- Equipment/asset utilization.
- Fuel economy and fuel waste.
- Loss and theft.
- Safety losses (i.e., crashes).
- Maintenance inefficiencies.
- Data and information processing.
- Business and driver management.

The Literature Review served as the basis for discussion with motor carriers during the MCES Stakeholder Sessions. Table 1 summarizes the top inefficiencies identified by stakeholder group as identified in the Stakeholder Sessions.

Table 1. Inefficiencies Identified by MCES Stakeholder Groups

Stakeholders	Priority Inefficiencies
Private Fleets	• Hours of Service (HOS) • Fuel waste due to excessive speed
Less-than-truckload (LTL) Carriers	• Waiting for unloading • Congestion delay
Truckload (TL) Carriers	• Waiting for unloading • Fuel waste due to excessive speed
Pick-up and Delivery	• Congestion delays

Stakeholders	Priority Inefficiencies
Cross-Border Carriers	• Waiting time—cross-border wait times (processing, paperwork, infrastructure/capacity limitations) • Congestion delay
Intermodal Carriers (Rail)	• Waiting for loading • Lack of backhaul
Intermodal Carriers (Port)	• Waiting for loading • Chassis roadability
Expedited Carriers	• Congestion delays
Public Sector	• Safety (Crashes, noncompliance) • Intelligent Transportation System (ITS) integration (limited applications for motor carriers)
Private-Sector Technology	• Waiting for loading/unloading • Poor routing, scheduling and out-of-route miles

The results of the detailed inefficiency analysis conducted as part of the study are shown in Table 2. The total effects of these inefficiencies are significant. Based upon high-level calculations performed by the Study Team, it is estimated that the motor carrier community incurs financial losses of tens of billions of dollars per year.

Table 2. Identified Inefficiency Effects

Inefficiency	Potential Gain to Carriers	Potential Gain to Society
Time Loading and Unloading	$3.08 billion annually	$6.59 billion annually
Waiting in Ports	$900 million annually	Unknown
Paperwork Delay at Borders	$23 million annually	$50 million annually
Time in Weigh Stations	$215 million annually	$461 million annually
Incident-Related Delay	Unknown	Unknown
Urban Routing Problems	Unknown	Unknown
Management Tools	Unknown	Unknown
Vehicle Safety	Unknown	$1.55 billion annually
Driver Safety	Unknown	$1.35 billion annually
Compliance Review Inspections	Unknown	$23.1 million annually
Processing Capacity at Borders	$211K per Owner/Operator annually	Unknown
Driver Turnover	$8,200 per driver	Unknown
Excessive Speed	$1.6 million annually for one 150-truck carrier	Unknown
Cargo Theft and Pilferage	Unknown	$15-30 billion annually

Inefficiency	Potential Gain to Carriers	Potential Gain to Society
Empty Intermodal Moves	$21 million annually in Chicago alone	Unknown
Empty Miles	$2.7 billion annually	Unknown
Vehicle Maintenance	$320 million annually	Unknown

Table 2 summarizes the potential gains for overcoming these inefficiencies both for carriers and for society, where societal gains include potential environmental, safety, and traffic congestion benefits (among many others) associated with overcoming the inefficiencies noted. Entries of "unknown" indicate that empirical evidence sufficient to calculate potential benefits was not available.

The Study Team, working from suggestions offered by motor carrier stakeholder representatives, formulated high-level concepts for nine proposed wireless technology applications:

- **Virtual Queuing**—an application to reduce waiting for loading and unloading by allowing consignees to monitor and dynamically reschedule dock operations to compensate for delays due to congestion, traffic incidents, or delays in a truck's departure from the shipment origin.
- **Driver Acuity Monitoring**—an application to permit a carrier to remotely monitor driver behavior characteristics indicative of fatigue and adjust the remaining Hours of Service (HOS) accordingly.
- **Variable Speed Limiter**—an application to allow the carrier to alter the governed maximum speed remotely, based on any combination of factors deemed appropriate by the carrier. Additionally, it could link to a database of posted speed limits, and as a truck passed from one zone to the next, the speed governor would be adjusted automatically.
- **Border Crossing Compliance Notification**—an application to provide pre-screening status information available prior to a driver's arrival at the border, which could significantly reduce delay and idling and improve safety.
- **Border Crossing Tracking Compliance**—an application that allows motor carriers to comply with emerging shipment tracking requirements from U.S. Customs and Border Protection (CBP) and provides a means for information regarding border crossing travel times to enhance border operations.
- **Truck-Specific Congestion Avoidance**—an application to link to existing traffic information and truck-specific alternate routing information.
- **Chassis Roadability Notification**—an application to give drivers access to chassis maintenance data and inspection history upon entering a storage facility or terminal.
- **Cross-Town Intermodal Interchange**—an application to reduce empty trips and congestion-related delay, and improve safety and the environment.
- **Untethered Trailer Tracking**—an application that allows asset owners and shippers to monitor the integrity and location of goods and equipment, which may mitigate theft and pilferage and enhance security.

The results of the execution of the FTAT calculations offer some interesting insights into the potential benefits of the various proposed applications. As the information in Table 3 shows, the benefit–cost ratios (BCR) and internal rates of return (IRR) for the applications span a broad range of values.

Table 3. Combined FTAT Calculation Results

Scenario	Supply Chain Segment	Inefficiency	Solution	BCR	IRR
1	International Border	Paperwork delay at border	Border Crossing Compliance Notification	.08	-48.05%
2	International Border	Processing delay at border	Border Crossing Tracking Compliance	5.2	73.78%
3	Port to Inland Destination	Waiting time in container ports	Virtual Queuing	2.64	35.85%
4	Port to Inland Destination	Vehicle safety (crashes, noncompliance)	Chassis Roadability Notification	0.21	-33.29%
5	Closed-Loop Pick-Up and Delivery	Incident-related congestion	Truck-Specific Congestion Avoidance	1.96	38.5%
6	Closed-Loop Pick-Up and Delivery	Waiting, loading and unloading	Virtual Queuing	1.62	18.98%
7	Rail Intermodal	Empty trips	Cross-Town Intermodal Interchange	8.92	216.76 %
8	Rail Intermodal	Waiting, loading, and unloading	Virtual Queuing	2.33	30.98%
9	Long-Haul Truckload	Fuel waste due to excessive speed	Variable Speed Limiter	3.86	54.26%
10	Long-Haul Truckload	Theft and pilferage	Untethered Trailer Tracking	2.47	33.22%

Several applications—notably, the Border Crossing Tracking, Virtual Queuing, Variable Speed Limiter, Cross-Town Intermodal Interchange, and Untethered Trailer Tracking Systems—offer estimated benefit–cost ratio (BCR) values in excess of 2:1. These are promising results, particularly when the lowest internal rates of return (IRR) for these applications exceeds 30 percent (it is noted that the application of Virtual Queuing to the closed-loop supply chain segment results in a lower value). The results for most of the applications improve as the level of deployment increases, and if they can be deployed by carriers already using wireless devices (e.g., cellular telephones or satellite tracking systems) for other purposes.

Caution is warranted when examining these figures. For example, the Study Team assumed that the operating environment would be conducive to the use of the application, and that maximum estimated benefits would be realized. This is unlikely in all scenarios. For instance, because making the necessary staffing changes within international border crossing compounds (namely, the reassignment or increase in number of staff by CBP to accommodate surges in demand) presents a number of operational challenges, and because a large portion of the border user population would need to be equipped with devices in order for the data to be reliable enough to warrant such measures, it is unlikely that the full benefit will be realized from the deployment of the Border Crossing Tracking Compliance application.

CONCLUSIONS

With few exceptions, the common thread running through the priority inefficiencies is delay caused at least in part by the actions (or lack thereof) of a party other than the carrier. Perhaps more evident, however, is that each inefficiency may be mitigated by improving the quality, accuracy, and timeliness of data held by one or more of public and private sector stakeholders, and the degree to which the data are exchanged and used for decision-making.

Under such circumstances, wireless technologies, which are first and foremost mechanisms to accurately capture and exchange information, appear to offer significant relief to the carrier community. Given that an enhanced level of situational awareness is vital to mitigating these inefficiencies, it is logical that wireless systems that promote that enhancement would be of some value.

In fact, enhanced situational awareness would likely have a profound positive effect on several other inefficiencies—namely, those associated with vehicle and driver safety. Better knowledge about vehicle, operator, and roadway conditions should contribute significantly to reducing driver- and vehicle-caused crashes and drivers operating at speeds in excess of those warranted by roadway conditions.

Better situational awareness can help to counter cargo theft and pilferage, and reduce empty trips, both of which represent significant costs for motor carriers. Simply knowing when and/or where a shipment has been tampered with or infiltrated would allow carriers to define and implement more effective security solutions. Likewise, knowing the locations and delivery requirements of other intermodal loads could allow dray haulers to allocate resources better to meet customer needs.

Based on the evidence, technology may provide creative solutions to real, specific needs. The role of wireless systems is unclear, but the analysis suggests it holds potential for measurable positive effects.

Near-Term Opportunities

In the near term (less than 10 years), the combination of a large existing deployed base, mature infrastructure, and high levels of user confidence make technologies such as satellite tracking, digital cellular, and radio frequency identification (RFID) attractive as bases for additional applications. The applications suggested and supported as viable by the motor carriers that participated in the study reinforce their preference for leveraging existing systems over the development and deployment of entirely new systems. For example, two currently available systems—RFID for weigh station bypass and Untethered Trailer Tracking—already yield significant net effects for users.

One primary uncertainty is the ability of these systems to accommodate future information exchange needs, both on an individual device basis and on a network-wide basis. As more users seek increasingly sophisticated capabilities, the overall demand for information will increase, leading to the need for more robust systems and networks.

Longer-Term Opportunities

Many of the wireless technologies examined in this study have barely begun to be deployed. Some offer compelling combinations of data transfer capacity, range, and potential convenience of use, but too little is known about how useful they may be in the trucking environment, where reliability, ruggedness, and low cost are of paramount importance.

Over the next 10 to 20 years, significant advances may improve the performance and affordability of wireless technologies. As cellular, RFID, and satellite-based systems have advanced dramatically over the previous 20 years, components are likely to be made smaller and more energy-efficient. Battery life, which has long been a challenge to deploying stand-alone devices for tracking and security of trailers, will be extended due to the significant investment being made in other sectors—most notably the automotive industry.

As wireless networks become ubiquitous and commercial entities add new services, information systems will become more accessible, perform at higher speeds, and deliver increasing value to users. Commercial vehicle manufacturers will likely continue to package on-board electronics that will rely on wireless communications for remote monitoring and control of vehicle systems including safety-related items (e.g., brake performance, tire pressure, and driver awareness monitoring) and efficiency-related items (e.g., fuel delivery, engine control parameters, and driver evaluation and education tools).

This new level of transparency will likely enable motor carriers to incrementally lower operating costs and improve profitability. Decisions regarding routing, driver assignment, and maintenance scheduling will be made more effectively, and component failures will be detected before trucks are placed out of service—either due to inspection violations or to the failures themselves. As new trucks are delivered and older trucks are retired, the level of deployment of wireless systems—including some that are several generations old—will expand to include a larger percentage of the trucks on the nation’s roadways.

Perhaps the most significant wireless technology advances will be new levels of connectivity between fleet owners and assets (both equipment and personnel), fleet assets and customers, between different assets, and the assets and the cargo being transported. This connectivity will allow significantly more coordinated operations and increased productivity across all segments of the motor carrier community. This level of connectivity will also permit the development of intelligent freight delivery management tools that can make full use of real-time information regarding prevailing business conditions, traffic congestion, weather, traffic incidents, and public safety conditions, and allow trucks and cars to operate safely in close proximity.

To this point, the catch phrase associated with freight efficiency has been visibility. The next generation of wireless devices will be tasked with facilitating the evolution to intelligent freight—freight that knows where it is, where it needs to go, and how best to transport itself to its destination in a safe, efficient, secure manner, including which carriers and drivers are suitable to move it. This can only occur when communication barriers are removed and unimpeded interconnectivity and interoperability is possible.

MCES Phase II Options

Based on the results of the research and analysis conducted during Phase I, a number of conclusions can be drawn regarding the potential investment of Phase II research funds. Several viable pilot project candidates emerged as promising. These are discussed below.

New Technology Applications

A review of the wireless technology-based applications endorsed by the motor carriers that participated in the study for analysis using the FTAT BCA tool reveals some important considerations in moving into Phase II. The first is that, with regard to implementing new technologies, carriers preferred incremental systems enhancement. Even when financial investment to deploy and operate a system was relatively large, the actual level of technical sophistication of the overall system would not be considered highly advanced beyond what is currently in use. The carriers preferred adding new capabilities to existing technologies, even if they do not currently use them.

Further, because their prioritization of inefficiencies reflected their beliefs that the most significant sources of inefficiency are external to their own operations (e.g., traffic congestion, border processing delay, waiting for loading and unloading), they preferred applications to overcome burdens imposed by others. It is unclear, based on the findings from this study, whether they have confidence that they have already optimized their own internal operations, or have resigned themselves to the fact that any further investment in internal improvement would be subject to the law of diminishing returns. Among the wireless applications that do focus on operations within the carriers (Variable Speed Limiter, Untethered Trailer Tracking), there continues to be a preference for applications that manage the behavior of those that use a carrier's assets.

Even within these somewhat limited boundaries, several promising alternatives exist for examination during Phase II. Seven scenarios had estimated IRRs of more than 30 percent. Based on relatively conservative estimates of potential gain, and the use of system implementation and use costs that assumed a carrier would have to purchase all of the necessary hardware (vs. leveraging current systems), each of these seven warrants further examination through a pilot demonstration. Among them, the Cross-Town Intermodal Interchange, Border Crossing Tracking Compliance, and Variable Speed Limiter posted the largest estimated investment returns. The BCRs and IRRs for each of these suggest that, even if cost and benefit estimates are modestly optimistic, motor carriers would likely find them attractive as pilot test subjects.

Existing Technology Applications

Two systems demonstrating large potential returns—RFID for weigh station bypass and Untethered Trailer Tracking—already exhibit empirical proof of value; it is not clear why such systems are not in wider use. In the case of the Untethered Trailer Tracking application, this may be due in part to a combination of a relatively high per-unit price and the historically slow technology adoption rate among most motor carriers.

As for RFID-based weigh station bypass, there appears to be sufficient financial incentive for carriers to take part in such systems. Figures published by one of the bypass program management organizations, HELP, Inc., suggest that since 1997, motor carriers enrolled in the organization's PrePass program have accrued reductions in delay of nearly 20 million hours, and savings of nearly 120 million gallons of fuel. Based on an operational cost estimated at $5 per stop, it is estimated that PrePass-enrolled carriers have saved more than $1.1 billion since 1997 (HELP, Inc. 2006).

The USDOT/Motor Carrier Partnership

Input received from motor carriers throughout the project—beginning with the industry meeting prior to the start of the Phase I study—indicated substantial interest in assisting FMCSA in characterizing systemic inefficiencies, and in participating in pilot tests of wireless technologies aimed at addressing them. Motor carrier representatives are willing to participate and suggest where research should be directed. Short of applying it as a marketing investment for a particular vendor's products, the carrier community expressed little apprehension regarding the expenditure of a modest amount of Federal funds on targeted research in this area.

One possible exception was investment in technology applications that required the release of sensitive information or the surrendering of operational control to a Government agency. For instance, in the case of the Variable Speed Limiter application, some carriers expressed concern that such an application might be looked upon as a method of speed enforcement. Excluding this and other concerns regarding data security, participating motor carriers generally welcomed the idea of public investment aimed at providing cost-effective solutions to the inefficiencies they encounter.

RECOMMENDATIONS

The Study Team recommends that, as the MCES moves forward and the Government evaluates which applications (either those contained herein or those detailed in other project documents) to pursue during Phase II, the Government take into account a number of important considerations. These considerations include practical programmatic and technical analysis-related issues revealed during the Phase I study. These considerations are discussed in the sections that follow.

Analysis Recommendations

Actual benefits could vary significantly from those reflected in this report. The assumptions related to costs and potential benefits are based on a statistically insignificant number of inputs, many of which are based on estimates provided by stakeholders. This sort of method, while very useful for estimation, is by its nature imperfect. For future instances where FTAT is to be employed, the Study Team recommends focusing on fewer scenarios, capturing more statistically significant input, and exploring a greater number of sensitivity analyses than was possible under this study.

Even in cases where systems and service costs are known, these costs often decrease as the number of units of a particular application are deployed, resulting in lower overall costs to carriers. The net result would logically be increases in BCR and other financial measures. The Study Team recommends that economies of scale be employed as one dimension of sensitivity analysis in future FTAT use. Further, as the sensitivity analysis revealed, BCR, and hence other measures such as IRR, can be greatly affected by relatively modest changes to the independent variables used in the BCA. Additionally, because wireless technology and its applications evolve so rapidly, some data points used may be replaced with more accurate numbers. This is likely to be true especially with regard to functions that might be added to existing systems. For this reason, the Study Team recommends that Phase II activities include the re-evaluation of the selected technologies using FTAT once more specific information is obtained from those proposing solutions. The FMCSA may also consider using this analysis as an initial decision point regarding following through with the proposed Phase II deployment.

MCES Phase II Program Recommendations

As the FMCSA and its U.S. Department of Transportation (USDOT) partner agencies move forward with Phase II of the MCES program, it will be important that the program's leaders recognize that although the potential solutions identified in this report do not necessarily cover the spectrum of possibilities, they do address the specific, stated concerns of the motor carrier representatives who took part. As such, they reveal a desire on the part of the members of the various industry segments to examine alternatives that will mitigate the effects of a small subset of the universe of inefficiencies explored during the Phase I study. With that in mind, the Study Team recommends that Phase II pilot demonstration projects focus on delivering capabilities that allow motor carriers to:

- Reduce the amount of time waiting to be loaded or unloaded, or to access the facilities where these activities are performed. Where possible, pilot projects addressing this should include participation from facility owners and operators, since motor carriers indicated that they represent the primary source of delays.
- Reduce empty trips, particularly when interchanging loads between intermodal facilities. Again, participation by parties outside of the motor carrier community (e.g., terminal operators, railroads) will be essential.
- Reduce delays entering the United States at international border crossings. The participation and cooperation of CBP field headquarters staff will be critical to the success of any efforts in this area, since benefit calculations are based upon the assumption that CBP, in particular, will take action to reduce delays.
- Reduce the frequency and duration of delays associated with congestion—particularly congestion associated with traffic incidents.
- Reduce fuel consumption. This need can be addressed in a wide variety of ways, including addressing the inefficiencies listed above. It can also be addressed by providing motor carriers a means to better control the speed at which their trucks are operated.

Despite the fact that some of the applications examined to address the other inefficiencies cited by motor carriers are likely to provide modest returns, there are valid reasons to seek creative solutions that address a number of other important inefficiencies:

- Reduce the risk of having a crash or being put out of service due to failures of equipment—particularly equipment owned and maintained by others.

- Reduce the risk of having a crash due to excessive speed or other driver errors.
- Reduce empty miles.

Some of the wireless solutions examined in Phase I represent a significant departure from the way that motor carrier operations are currently conducted. Further, most of them assume that technological solutions to address such issues as communications among vehicle-based systems, and between these systems and the stationary communications infrastructure, can be fashioned from existing technology (e.g., digital cellular, satellite location and communications). As such, efforts to deploy them as they are defined in this study are likely to encounter challenges that are predominantly operational or institutional in nature, rather than technical.

As such, the Study Team recommends that FMCSA consider mandating that teams proposing to deploy pilot projects under Phase II of the MCES be required, at a minimum, to include a detailed plan for engaging the organizational entities necessary for a cooperative solution to be implemented, and that the evaluations conducted during Phase II include a system sustainability analysis that explores the following:

- The level of process change that will be necessary to adopt and use the solution.
- The degree to which the organizations participating in the pilot are likely to agree to adopt practices and policies that will facilitate long-term success.
- The likely solution adoption rate, both within the targeted industry segment and within other segments.
- The risks associated with the inability to achieve a deployment level below that at which measurable benefits will accrue to the system's users.
- A time-based benefit/cost analysis profile that examines how benefits and costs may change over time.

Finally, the Study Team recommends that any pilot demonstrations pursued during Phase II be evaluated with an eye toward affordability. Despite the fact that the FTAT analysis revealed significant potential for positive returns for several of the solutions examined, it is important to remember that regardless of the BCR and IRR figures, the cost of deployment for a given solution may be higher than many carriers could afford. Therefore, it will be important that any sustainability analysis examine the effects of per unit implementation, operation, and maintenance costs, and seek to identify a cost threshold acceptable to motor carriers.

Wherever possible, opportunities to further leverage deployed systems should be pursued as a means to reduce costs and improve overall payback to the motor carriers. Adding a function to an existing system may yield better investment returns, even if the existing system costs more than the proposed system. For example, many applications described herein might be add-on features to cellular telephone services, provided the devices in use by carriers possess the necessary location referencing and information processing capabilities. Similarly, the FMCSA may also find it advantageous to "piggyback" on other efficiency enhancement projects, particularly within the USDOT.

1. INTRODUCTION

1.1 BACKGROUND

The primary mission of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce crashes, injuries, and fatalities involving large trucks and buses. In carrying out its safety mandate, FMCSA:

- Develops and enforces data-driven regulations that balance motor carrier (truck and bus companies) safety with industry efficiency.
- Harnesses safety information systems to focus on higher-risk carriers in enforcing the safety regulations.
- Targets educational messages to carriers, commercial drivers, and the public.
- Partners with stakeholders including Federal, State, and local enforcement agencies, the motor carrier industry, safety groups, and organized labor on efforts to reduce bus- and truck-related crashes.

In pursuit of its mission, FMCSA regularly engages in cooperative technology research and development with the motor carrier community. The administration routinely collaborates with industry leaders and technology vendors to define and examine innovative solutions to challenges facing the industry.

Since its formation by the Motor Carrier Safety Improvement Act of 1999, FMCSA has sought to reduce the number and severity of commercial motor vehicle (CMV) crashes and enhance the efficiency of CMV operations by:

- Conducting systematic studies directed toward fuller scientific discovery, knowledge, or understanding.
- Adopting, testing, and deploying innovative driver, carrier, vehicle, and roadside best practices and technologies.

The research and technology program helps to expand the knowledge and portfolio of deployable technology, thereby helping FMCSA to reduce crashes, injuries, and fatalities and deliver a program that contributes to a safe and secure commercial transportation system. In pursuit of these goals, the Office of Analysis, Research and Technology developed a set of strategic objectives that it relies upon to guide its work. These objectives are:

- Produce Safer Drivers: Research techniques that help to ensure that commercial drivers are physically qualified, trained to perform safely, and mentally alert.
- Improve Safety of Commercial Motor Vehicles: Improve truck and motorcoach performance through vehicle-based safety technologies.
- Produce Safer Carriers: Support efforts to improve carrier safety by applying safety management principles, compiling best management practices, communicating best practices, and supporting the Agency’s enforcement of carrier-related regulations.

- Advance Safety Through Information-Based Initiatives: Improve the safety and productivity of CMV operations through the application of information systems and technologies.
- Improve Security Through Safety Initiatives: Develop and implement safety initiatives that also have security benefits for truck and motorcoach operations.
- Enable and Motivate Internal Excellence: Improve performance to serve the customers and stakeholders of the Research and Analysis Divisions more effectively and economically.

Consistent with its stated mission, goals, and objectives, and in acknowledgement of its comprehensive knowledge of the motor carrier industry, FMCSA's Office of Research and Analysis was assigned the responsibility to administer the requirements set forth in The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), Section 5503.

1.1.1 SAFETEA-LU Section 5503

SAFETEA-LU, Section 5503, set aside funding to examine the application of wireless technology to improve the safety and efficiency of trucking operations in the United States. The intent is to enable the U.S. Department of Transportation (USDOT) to partner with the motor carrier and wireless technology industries to cooperatively identify and test promising applications and devices in a "real-world" environment and to promote the adoption and use of successful solutions by an array of motor carriers.

The specific objectives of the program are to:

- Identify inefficiencies in freight transportation.
- Evaluate safety and productivity improvements made possible through wireless technologies.
- Demonstrate wireless technologies in field tests.

The FMCSA was assigned responsibility for administering this program via the Motor Carrier Efficiency Study (MCES). The MCES program will be completed in two Phases. Phase I, which encompasses work detailed in this report, consists of the completion of activities pursuant to the first two objectives above. The actual field tests will be conducted under Phase II of the program.

The Section 5503 language specified that the MCES focus its research on the application of wireless technology to a minimum of four specific program element areas:

- Fuel monitoring and management systems.
- Radio frequency identification technology.
- Electronic manifest systems.
- Cargo theft prevention.

Consistent with its safety mission, FMCSA evaluated the set of minimum program elements defined in the law, and determined that it would be both appropriate and advantageous to include an additional element. With an ever-growing population of trucks and a relatively constant level of roadside inspection resources, this element, “Roadside Safety Inspection Systems,” focuses on new automated approaches to roadside inspections that would target unsafe motor carriers while not hindering the operations of safe and legal operators. Such an approach could allow public safety agencies and carriers to improve both safety and efficiency.

Additionally, FMCSA expanded the scope of the “Fuel Monitoring and Management Systems” program element to include fleet management practices that promote safe operations, which can also contribute to more efficient operations. The new program element, entitled “Fuel Monitoring and Operations Management,” encompasses opportunities for applying wireless technologies that leverage safety innovations to improve efficiency.

Finally, because it represents a specific type of wireless application rather than an application area, the RFID program element area was examined throughout the study as a technology. As a result, the final set of program element areas used as guidance for study activities included:

- Fuel monitoring and operations management systems.
- Electronic manifest systems.
- Cargo theft prevention systems.
- Roadside safety inspection systems.

Phase II of the program will consist of one or more pilot demonstrations wherein promising technologies will be deployed under realistic operating conditions. Also in Phase II, industry and Government partners will assess the degree to which the solutions improve safety and operations consistent with the program objectives. The goal for these pilots is to provide sufficient evidence to support investment decisions for the Government and for the technology providers and user community.

1.1.2 Application of 5503 Requirements

The FMCSA is primarily dedicated to the mission of enhancing the safety of motor carrier operations, and by extension, the overall safety of the motoring public. As such, the Administration’s core research focus is on the application of technology to further this mission. However, it is important to note that an efficient freight system that reduces delay and cuts operating costs ultimately delivers a safety benefit. Specifically, improvements in productivity can reduce the pressure on a motor carrier and its drivers to compromise safe operations in order to meet delivery requirements. Further, improved efficiency can also enable a motor carrier to meet customer demand with fewer resources, and thereby allow them to be more selective about the drivers they choose to employ. For these reasons there is a strong tie between the efficiency and safety, reinforcing the logic of assigning responsibility for the program to FMCSA.

The FMCSA is acutely aware of the challenges that face the commercial trucking community, and is a strong partner with its members in the pursuit of operational, institutional, and technical enhancements that will promote a safe, efficient freight delivery system. With that in mind, FMCSA has defined a program to address the Section 5503 language that relies upon a collaborative partnership among Government, trucking industry, and vendor community.

Using rigorous research and technical assessment tools, FMCSA seeks to work with private industry partners to mitigate the risks associated with operational research and development of wireless technology. Conversely, FMCSA recognizes that the purpose of this legislation is not to replace what is typically privately funded research and development of technologies and applications, nor to serve as a promotional platform for specific products or devices. Throughout the program, measures will be taken to ensure that all activities are transparent and open, and that every effort is made to support the identification and evaluation of vendor-independent solutions.

Consistent with these principles, the FMCSA formulated an MCES Phase I work plan that included the following elements:

- Gathering and analyzing existing literature regarding freight system inefficiencies and the potential application of wireless technologies to these inefficiencies.
- Compiling pertinent background information for the analysis of the safety benefits and efficiencies that can be achieved through the use of various wireless technologies.
- Completing stakeholder outreach designed to capture information regarding baseline freight performance, user needs, performance measures, and feedback regarding technological options.
- Isolating the inefficiencies recognized as most pressing by motor carriers and identifying evidence of their effects in order to enable the evaluation of potential solutions.
- Analyzing wireless technology solutions via feedback from industry representatives in the ERGs and conducting a benefit–cost analysis (BCA) using the Freight Technology Assessment Tool (FTAT).
- Completing task reports and this final project report.

1.1.3 Pre-Study Activities

Upon assignment of program responsibilities, FMCSA immediately began the task of planning its implementation. Because of the broad scope to evaluate the impact of wireless technologies on safety and productivity in motor carrier freight transportation, FMCSA assembled a program management team. The team includes representatives from the USDOT Office of the Secretary freight and policy office, the Federal Highway Administration (FHWA) Offices of Freight Management and Policy, and the Research and Innovative Technology Administration Bureau of Transportation Statistics. This joint program management team led by FMCSA meets regularly with the charge to monitor and guide the program.

The FMCSA also engaged external stakeholders consistent with the congressional direction to engage the trucking and wireless industries in the execution of this program.

Program planning was accomplished in phases. The FMCSA defined the fundamental structure of the program with input and consensus from the joint management team. This included the analysis of the Section 5503 language and the extrapolation of program specifics based on the FMCSA mission. During this initial planning process, it was determined that the overall program methodology would be enhanced through collaborative discussions with representatives from the motor carrier community, wireless technology industry, and the consultants with experience in evaluating technologies that service it. Collaboration with these interests was accomplished through a one-day forum hosted by FMCSA that followed a joint trucking and wireless industry conference sponsored by Eyefortransport, an industry provider of technology information and research.

During the forum, FMCSA managers and staff solicited input regarding a number of key program planning elements. An industry conference was held in Miami, Florida, in February 2006, and brought together technology experts from across the country; it also served as an invaluable tool for refining the program plan. The results of the workshop were used to refine the Phase I statement of work, and the technical feedback has been incorporated into FMCSA guidance for the program. A copy of the summary report is available on FMCSA's website, http://www.fmcsa.dot.gov/facts-research/research-technology/report/industry-capabilities-summary.htm.

1.2 STUDY APPROACH

1.2.1 Overview

The Study Team concluded that the program objectives and the guidance from the FMCSA necessitated a significant degree of interaction with the motor carrier community. This was considered essential to accurately quantify the effects of current inefficiencies, and to ensure that any proposed wireless applications would provide capabilities consistent with the operational environments encountered in motor carrier operations. With this in mind, the Study Team followed the approach illustrated in Figure 1.

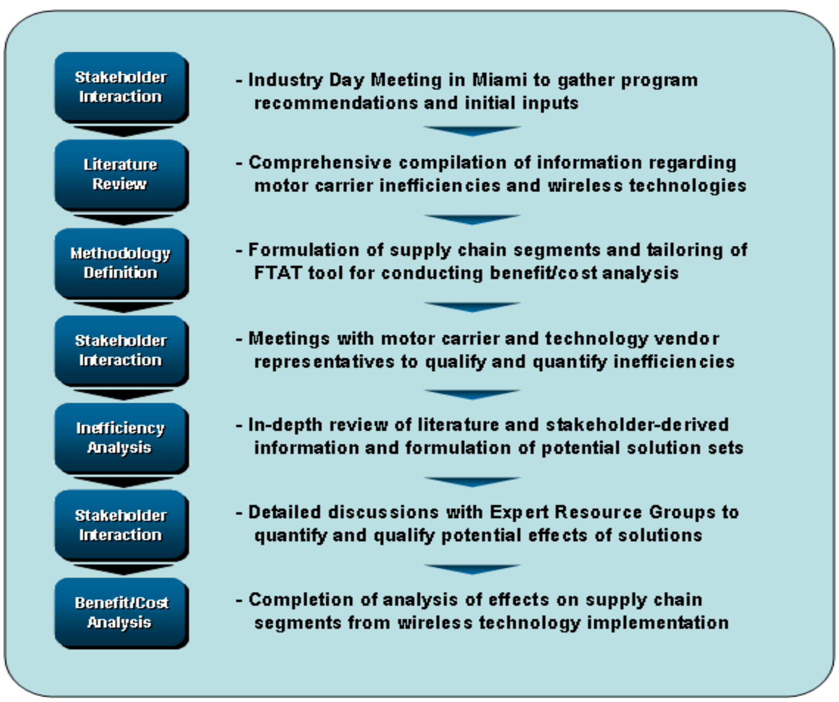


Figure 1. MCES Phase I Study Approach

As the figure shows, there were four main analytical tasks: the Literature Review (Task 1), the Methodology Definition (Task 2), the Inefficiency Analysis (Task 4), and the Benefit–Cost Analysis (Task 6). In addition to these tasks, the Study Team undertook three separate activities to engage representatives from the various segments of the motor carrier community. The information and feedback gained from these stakeholder interaction activities served to provide input for the various analyses, and validation and verification of the assumptions employed during their execution. The specific methods employed by the Study Team are discussed in greater detail in the sections that follow.

1.2.2 Task Details

1.2.2.1 Literature Review

The MCES project began with a Literature Review that sought to accomplish several objectives. The first objective was to capture as much published information as possible regarding the type, nature, and effects of inefficiencies encountered by motor carriers across all known supply chain types. This was accomplished by locating and reviewing more than 200 individual documents and online resources, including Government-sponsored technical reports, trade journal articles, privately funded research, promotional literature, and various newspapers and magazines. The Study Team then assessed and categorized the findings according to the effects they imposed on the motor carrier community.

The second objective of the Literature Review was to capture information regarding the various types of wireless technologies, both those that are currently available for use, and those that are in late-stage development. The Study Team conducted in-depth research to identify the technical capabilities and limitations of each, and the various applications they currently support.

The final objective of the Literature Review was to explore the applicability of the various technologies to motor carrier operations by identifying both current and potential future applications at a generic level. Specifically, the Study Team analyzed the degree to which each technology type might provide technical capabilities that would be valuable for motor carrier operations.

1.2.2.2 Methodology Definition

The second major task undertaken for the MCES was the development of a methodology for examining the potential benefits and costs associated with applying wireless technology to motor carrier operations. This task consisted of two major components: the development of baseline generic supply chains and the adaptation of an existing BCA tool for use later in the MCES.

The Study Team applied a combination of collective experience and information obtained during the Literature Review to define five different supply chain segments. These consisted of a "Level 1" depiction of the supply chain partners, a "Level 2" decomposition of the supply chain into major component steps, and a "Level 3" decomposition into discrete activities associated with the movement of goods. Each of the resulting supply chain representations—which were called supply chain segments because they consisted only of the components of a given supply chain that consisted of truck-based movement and the adjacent processes—was defined in such a way as to encapsulate the activities that would likely exist in a very large percentage of actual supply chains. This was done to ensure that these "generic" supply chain segments would provide a contextual analysis framework that would produce results applicable to a large portion of the motor carrier community.

The second major component of the Methodology Definition task was to adapt a pre-existing BCA tool for use in the MCES—the FTAT, a decision support tool designed to assist decision-makers in evaluating the potential effects that adoption of emerging technologies could have on the performance of their transportation supply chain from both the qualitative and the quantitative perspective. This is achieved by examining the business processes within certain portions of a supply chain before and after the implementation of these technologies, and evaluating the effects against an array of performance metrics to select the option that will yield the best safety, productivity, cost, and efficiency improvements. The primary objective of this software, developed under the leadership of the FHWA Office of Freight Management, is to provide users with an objective means for prioritizing future efforts and ensuring that project dollars are allocated to the efforts that can realize the greatest returns.

FTAT was initially designed based upon the Supply Chain Operations Reference (SCOR) model. The SCOR model is a reference model developed by the Supply Chain Council to capture, generically, the widest view of the supply chain, including supply chain processes, performance measures, and best practices. The Supply Chain Council is a global, not-for-profit trade association open to all types of organizations. It sponsors and supports educational programs including conferences, retreats, benchmarking studies, and development of the SCOR. The first SCOR model was released in 1997. The Supply Chain Council is continuously updating the SCOR model, now in its sixth version, to apply to the changing environment and advancement in the research, development, and technology associated with current and evolving supply chain practices.

The SCOR model integrates three concepts in its framework and implementation methodology. The concepts are business process reengineering, benchmarking, and best practices. This framework makes SCOR effective for a complex management process such as those that exist within a supply chain. The business process reengineering portion of SCOR captures and defines the current, or the "as is" supply chain. The term "as is" is used to signify that the process describes the current status of the supply chain and will serve as a starting point to optimize the supply chain processes and implement the "to be" supply chain, which represents the proposed future state of the supply chain. The use case diagram in Figure 2 details the intended approach to utilizing FTAT (USDOT, 2006a).

The core of the FTAT tool is the benefit cost methodology and analysis component. This component is made up of a benefit cost methodology whereby economic benefits, costs, minimum attractive rate of return (MARR), and useful life are defined as they pertain to the user of the system under examination. Below are some additional characteristics of the tool:

- The economic *costs* are defined as being any additional cash expenditures required to adopt and implement a wireless technology. The costs include the initial investment required for equipment, infrastructure, or training, the annual operating costs incurred for additional resource requirements or support, annual maintenance costs for hardware or software, and could include additional costs such as increased insurance or customs costs.

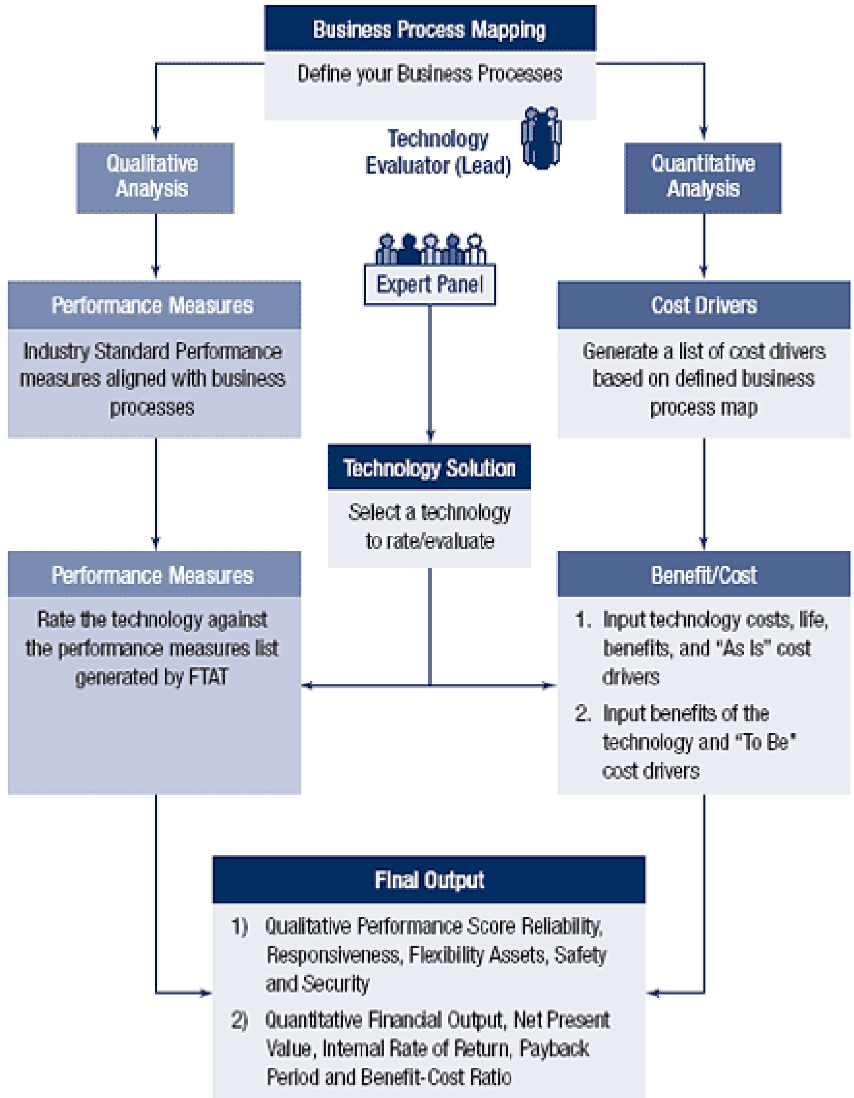


Figure 2. FTAT Use Case Diagram

- The annual *benefits* are any additional cash flows or cost savings resulting from the adoption of a wireless technology. These can include increased revenues, reduced insurance costs, reduced loss due to pilferage or damage, reduced customs handling costs, and savings resulting from process improvements. In order to accurately estimate the potential process improvement savings, *cost drivers* are identified for each of the processes defined within the supply chain. Cost drivers reflect the factors that result in changes to the cost of a process when they are altered. Data are collected to identify the "as is" value for each of these cost drivers. Once these "as is" values are identified, anticipated "to be" cost driver values are defined for each of the technologies under study. Linear mathematical algorithms are then used to calculate the anticipated process improvement savings.
- The MARR is used to discount future cash flows to determine the present value of those flows. A 7 percent MARR was utilized for each of the analyses described herein. This

MARR was selected based on the guidelines set forth by the Office of Management and Budget in Circular A-94, "Guidelines and Discount Rates for Benefit–Cost Analysis of Federal Programs" (Office of Management and Budget, 1992).

- The *useful life* represents the anticipated duration for which a wireless technology can be utilized before it becomes obsolete.

Once these items have been defined, they are used to provide several key financial measures. These measures allow users of FTAT to objectively compare the financial impacts of the technologies being studied. They are as follows:

- Net Present Value (NPV)—The total discounted benefits minus the total discounted costs. The present value of each of the cash flows is calculated (initial investment year = 0). The following formula is used to calculate the present value of each cash flow where *I* = MARR and *t* = year:

  $$PV = FV / (1+i)^t$$

  The discounted value for each of these flows is then summed to calculate the NPV. Positive numbers are considered attractive.

- Internal Rate of Return (IRR)—The rate required to provide a NPV of zero. The IRR is calculated by finding the value that satisfies the following equation where *C* = cash flow and *t* = year:

  $$0 = Initial\ Investment + \sum_{t-1}^{N} C_t / (1+IRR)^t$$

  A number greater than the MARR is considered attractive.

- Payback Period—The amount of time required to recoup the initial investment based on the anticipated net annual cash flow. The following formula is used to calculate this:

  $$Initial\ Investment / Annual\ Cash\ Flow$$

- Discounted Payback Period—The amount of time required to recoup the initial investment based on the anticipated net annual cash flow discounted using the MARR. The present value of each cash flow is added to the initial investment until the sum of these values changes from negative to positive.

- Benefit–Cost Ratio (BCR)—The ratio of the total discounted benefits to the total discounted costs. The formula used to calculate this is as follows:

  $$\sum_{t-0}^{N} PV_{pos} / \sum_{t-0}^{N} PV_{neg}$$

  where PV_{pos} = the Present Value of all positive cash flows
  PV_{neg} = the Present Value of all negative cash flows

  Greater numbers represent increasing attractiveness; values greater than 1.0 are considered attractive.

In addition to the BCA, FTAT provides a robust view of supply chain performance by evaluating the effects of technology adoption on a set of key performance measures. These measures can be either quantitative (e.g., change in compliance rates, on time delivery rates, etc.) or qualitative for items of interest where historical data may not exist, such as those that are often associated with indirect safety benefits. By using this feature of the benefit cost analysis, users of FTAT are provided with a more holistic view of the potential impacts of a given technology adoption. This has proven to be especially critical in studies for the Government, where public safety and interest benefits must be measured in addition to the economic benefits needed to achieve industry acceptance. Copies of the FTAT software are available from the FHWA Office of Freight Management and Operations, and the user guide can be found at: http://www.ops.fhwa.dot.gov/freight/intermodal/index.htm.

The primary tool adaptation activity undertaken by the Study Team was the definition of a set of performance measures to quantify and characterize the effects of current motor carrier-related transport practices, and the potential benefits and costs of implementing one or more wireless technologies.

1.2.2.3 Stakeholder Interaction

The Study Team recognized the essential value for the MCES Phase I project of focused, regular interaction with the motor carrier community. It therefore developed and executed a plan for obtaining specific, targeted data, and for vetting the assumptions and methodologies used in constructing the analytical context for the FTAT BCA. This interaction divided into three categories: Scenario Vetting; Inefficiency Identification and Prioritization; and Analysis Input Identification.

As discussed in the previous section, the use of the FTAT requires the formulation of analysis scenarios in the form of business process representations. These scenarios are defined to be generic so as to apply to a large portion of the motor carrier population, a procedure which allows for the use of general input data and for the extrapolation of results. For the analysis results to have the broadest possible application, it is essential that these scenarios accurately represent real-world motor carrier operations. To ensure that this was the case, the Study Team vetted each of the following five supply chain segments—one for each of five different supply chain types—with motor carrier representatives.

- International Border Crossing—a supply chain involving the movement of goods across a land border between the United States and Mexico or Canada.
- Port to Inland Destination—a supply chain involving the movement of goods out of a seaport to a destination in the United States.
- Rail-Truck Intermodal—a supply chain involving a movement of goods using both rail and truck modes.
- Closed-Loop Pick-Up and Delivery—a supply chain involving the execution of multiple pick-up and delivery operations, typically over a short-haul distance (less than 500 total miles).
- Long-Haul Truckload and Less-than-Truckload—a supply chain involving the movement of goods from point to point over longer distances (500 miles or greater).

The Study Team asked the stakeholders to offer verification of the accuracy of the initial representations, or to provide corrections where processes or subprocesses were incorrectly characterized. Once consensus was reached regarding the accuracy of each supply chain segment, the components for that supply chain were frozen, and the next phase of the data collection process began: the identification of specific inefficiencies, and their effects, within each supply chain segment.

Using the inefficiency information gathered during the Literature Review, the Study Team asked the stakeholders to validate those inefficiencies that pertained to their operations, to prioritize them according to their order of importance, and to provide additional contextual detail regarding their impact on day-to-day operations. Once this was completed, the Study Team then asked the stakeholders either which performance measures they employed to quantify the effects of these inefficiencies, or which ones they thought would be useful to employ. The outcomes of these discussions are detailed in Section 1 of this report.

The final component of the Stakeholder Sessions consisted of the Study Team asking stakeholders to offer specific quantifiable evidence of the effect of the inefficiencies that pertained to their operations. These figures, which consisted of figures that were in some cases specific to certain types of supply chains, and in other cases were more universally applicable, constituted a portion of the "as is" and "to be" data entered into the FTAT.

These data collection efforts were accomplished through a combination of three different activities. First, the Study Team conducted Stakeholder Sessions at locations around the United States. Some of these sessions were targeted at motor carriers that serve certain types of supply chains, while others were conducted to seek a somewhat broader representation. In each case, the Study Team facilitated discussion among the participants to gather the needed information. More detail regarding the specific methods employed during these sessions can be found in Section 2.1.1.2 of this report.

Second, where additional detail or a broader representation from motor carriers was needed for a specific data element, the Study Team contacted representatives from the motor carrier community and various industry experts to obtain the information directly (see Section 2.1.1.3). Third, the Study Team convened (via teleconference) groups of motor carrier representatives to reach consensus on specific input data. These groups, termed Expert Resource Groups (ERGs), served as critically important sources for FTAT input data and the validation of analysis assumptions.

Using data from a number of other published sources, the Study Team rounded out the data set to include generally accepted industry averages. A detailed accounting of all data sources is provided in Section 3 of this report.

1.2.2.4 Inefficiency Analysis

The MCES Inefficiency Analysis was focused on accomplishing three major objectives. The first was to examine more thoroughly the characteristics of each of the major inefficiencies identified in the Literature Review. The second was to enumerate, to the extent possible from a combination of sources including the Literature Review documents and discussions with industry experts, the effects of the various inefficiencies on motor carrier operations. The third was to begin to explore opportunities to apply wireless technology-based capabilities to address the inefficiencies. The methodology employed, the results developed, and the conclusions and recommendations associated with the evaluation of potential wireless solutions are discussed in detail in Section 1 of this report.

1.2.2.5 Benefit/Cost Analysis

The final major MCES task was to carry out the cost/benefit analysis. This consisted of applying the methodology discussed in Section 1.2.2.2 using the data derived from the combination of sources outlined above. The final result is an FTAT-generated set of comparative analyses of two different wireless technology-based solutions for each of the five different supply chain types. These results are presented in terms of quantitative financial measures such as BCR, IRR, and NPV, and in qualitative terms that reflect the opinions of members of the motor carrier ERGs regarding their relative value in addressing key performance areas. Section 4.1 of this report contains specific information regarding the methodology application and the results of the FTAT analysis.

1.2.3 Report Structure

The purpose of this report is to document the findings and results of Phase I of the MCES. Although the project work plan was divided into tasks, this report is organized differently in order to provide a more seamless presentation of the findings. Hence, the remainder of the report is presented as follows:

- **Section 2: Motor Carrier Inefficiencies.** This section contains the consolidated results of all activities associated with identifying, defining, characterizing, and quantifying the effects of the inefficiencies experienced by motor carriers. It contains a review of the methodology used to gather information, and the results of the Study Team analysis regarding the potential for wireless technologies to address the inefficiencies identified by motor carrier stakeholders as those most significant for their operations.
- **Section 3: Wireless Technologies.** This section contains a summary of the compendium of wireless technology information gathered by the Study Team, its applicability to the MCES program elements identified in the Section 5503 guidance, and the viability analysis performed on each potential wireless technology application. The section also discusses the methodology used by the Study Team for the data gathering and analysis conducted.
- **Section 4: Benefit/Cost Analysis.** This section details the final BCA for the technology concepts presented in Section 3. Data used to run the FTAT are also presented, as is the methodology for collecting data from industry experts via the ERGs. The contents of this section mirror very closely the content in the Task 6 Wireless Technology Analysis report.
- **Section 5: Wireless Opportunities.** The final section of this report provides a summary of the findings, relevant specific and general conclusions regarding the application of wireless technology to address motor carrier inefficiencies, and a series of recommendations regarding the application of the results of Phase I to the activities to be undertaken during Phase II.

2. MOTOR CARRIER INEFFICIENCIES

Inefficiencies in motor carrier operations include any practices, procedures, incidents, or events that produce waste, incur unnecessary expenses, require excess effort, do not generate revenue, and/or do not contribute to the safe, secure, and timely transportation of cargo from the point of origin to the point of destination. Points of inefficiency documented in the literature and/or experienced in practice by the Study Team and motor carrier industry stakeholders are summarized in the sections that follow.

This section describes the process the Study Team used to identify high-priority inefficiencies in motor carrier operations. Section 2.1 details the approach for summarizing and presenting common inefficiencies to motor carriers. Section 2.2 summarizes the high-level categories of inefficiencies as detailed in the Literature Review, as well as those cited by stakeholders, both in the MCES Stakeholder Sessions and in follow-up industry interviews. Section 2.2 also provides the results of the analysis of these inefficiencies and the potential value for overcoming them. Finally, this section details the finalized supply chain segments that were used for FTAT analysis.

2.1 METHODOLOGY

2.1.1 Data Gathering

2.1.1.1 Literature Review

As described in section 1.2.2, the MCES Study Team first located and reviewed more than 200 individual documents and online resources, including Government-sponsored technical reports, trade journal articles, privately funded research, promotional literature, and various newspapers and magazines. The purpose of this activity was to assemble a comprehensive compendium of information regarding motor carrier inefficiencies and wireless technologies.

2.1.1.2 Stakeholder Sessions

The Phase I work plan for the MCES included a stakeholder outreach task designed to capture motor carrier inefficiencies as wells as information regarding motor carrier freight performance. The sessions were developed based on the high-level inefficiencies documented above with a focus on extracting those that are particularly critical to day-to-day motor carrier operations.

The general approach to vetting these inefficiencies was to present them to the stakeholders in the context of supply chain segments that relate directly to participants. Supply chain segments were chosen based on the Study Team's industry knowledge, but were updated to reflect participant comments. Updates to processes and subprocesses for each supply chain segment were made. Based on stakeholder feedback gathered during the sessions and the follow-up interviews, five supply chain segments were chosen for FTAT analysis:

- International Border Crossing.
- Port to Inland Destination.
- Closed-Loop Pick-Up and Delivery.

- Rail-Truck Intermodal.
- Long-Haul Truckload.

These supply chain segments are discussed in more detail in Section 2.2.

To gather key information for the MCES from a broad range of stakeholders, the Study Team completed a total of eight Stakeholder Sessions at seven locations throughout the United States. These sessions ranged in length from two hours to a full day:

- **Session #1:** 2-hour session in coordination with the National Private Truck Council (NPTC) Fleet Management Institute, January 12, 2007, Jacksonville, FL.
- **Session #2:** 2-hour session at the Eyefortransport Conference, February 20, 2007, Miami, FL.
- **Session #3:** Full-day session coordinated through the Washington Trucking Association (WTA), March 1, 2007, Seattle, WA.
- **Session #4:** 2-hour session at the Commercial Vehicle Safety Alliance (CVSA) Annual Conference, March 27, 2007, Atlanta, GA with Industry Forum.
- **Session #5:** 2-hour session at the CVSA Annual Conference, March 29, 2007, Atlanta, GA with CVSA Intelligent Transportation System (ITS) Committee.
- **Session #6:** 2-hour intermodal session, April 3, 2007, at the Port of Long Beach, CA.
- **Session #7:** Half-day border session at the Otay Mesa border crossing, April 5, 2007, San Diego, CA.
- **Session #8:** Half-day intermodal session coordinated through the New Jersey Motor Truck Association, April 19, 2007, East Brunswick, NJ.

Table 4 shows eight Stakeholder Sessions matched with the targeted industry representatives at each. These sessions were designed to facilitate the vetting process for determining priority carrier inefficiencies (and in some cases linking them to potential wireless solutions) by allowing stakeholders to engage in a conversation that made possible a free flow of ideas and opinions. The Study Team used the principles of equity and transparency to develop an agenda and session content that would encourage participation across the spectrum of motor carrier types and sizes. The topics for the meetings included:

- Motor carrier inefficiencies and safety deficiencies (and methods to measure performance) within relevant supply chain segments.
- Current technology use and acceptance among different stakeholders from a cross-section of motor carrier industry representatives.
- Technical, operational, and institutional issues that may help to establish the "deployability" of potential wireless solutions to common motor carrier inefficiencies.

The baseline inefficiencies described in Section 2.2 were discussed in detail in all Stakeholder Sessions, were further broken down into 35 more specific areas of inefficiencies, and were provided to session participants. The Study Team asked participants to specify the three inefficiencies they consider most important to their daily operations. For each supply chain segment presented, stakeholders were asked to identify specific areas of concern. For example, if carriers identified waiting time as a critical inefficiency, the Study Team noted points where waiting occurs within that particular supply chain and collected any baseline data available to better define the extent of the inefficiency.

Table 4. MCES Targeted Stakeholders

Session Number	#1	#2	#3	#4	#5	#6	#7	#8
Stakeholders	NPTC Session	Eyefortransport Session	Washing Trucking Association Sessions	CVSA Session: Industry Group	CVSA Session: ITS Committee	Port of Long Beach Session	Otay Mesa Border Session	NJ Motor Truck Association
Private Fleets	•	•				•		•
Less-than-truckload (LTL) Carriers	•	•		•	•			•
Truckload (TL) Carriers		•		•	•			•
Pick-Up and Delivery		•						•
Cross-Border Carriers	•	•	•	•	•		•	
Intermodal Carriers			•			•	•	•
Expedited Carriers				•	•			•
Public Sector		•		•	•	•	•	
Private Sector—Technology	•	•		•	•			

2.1.1.3 Follow-Up Industry Interviews

As a follow-up to the stakeholder outreach sessions, the Study Team contacted various individuals within the trucking community to capture additional and more specific information regarding the inefficiencies identified during the Literature Review and Stakeholder Session tasks of the MCES. This allowed the Study Team to more accurately identify, characterize, and quantify the specific effects of the inefficiencies. Table 5 summarizes the contacts made to augment the study inefficiencies dataset.

In those instances where the individual's name is listed as "Anonymous," the contact requested that his/her name and affiliation not be provided. These individuals are respected leaders in the carrier community and are routinely called upon by representatives of one or more of the firms on the Study Team. The table also contains the summary content of the inefficiencies discussed and verified with the industry representatives.

Table 5. Follow-Up Inefficiency Interviews

Organization Description	Organization Name	Individual Name	Topic Discussed
TL carrier	Anonymous	Anonymous	Rates and empty ratios
Drayage firms, East and Gulf Coasts	Anonymous	Anonymous	Rates and waiting times
Regional and long-haul TL firms	Anonymous	Anonymous	Stops in weigh stations
Trucking consultant	n/a	George Edwards	TL rates, empty ratios, fuel efficiency, operating costs, and cash-flow issues
Trade association for owner-ops	Owner-Operator Independent Drivers Association	John Siebert	Stops in weigh stations and cash-flow issues
Trade association for small carriers	National Association of Small Trucking Companies	Buster Anderson	Cash-flow issues
Factor for small carriers	Orange Commercial Credit	Cathy Dasel	Cash-flow issues
Authority on trucking labor	Wayne State University	Michael Belzer	Stops in weigh stations and days worked per year
Authority on economics of freight transport	Penn State University	Peter Swan	Stops in weigh stations
Large TL carrier	Anonymous	Anonymous	Days worked per year and incident-related congestion
Large LTL carrier	Anonymous	Anonymous	Incident-related congestion and stops in weigh stations
Large TL carrier	Anonymous	Anonymous	Incident-related congestion
Trucking economics researcher	U. of Minnesota	Stephen Burks	Stops in weigh stations and days worked per year
Government agency	USDOT	Randy Rogers	Port terminal and drayage operations
Truck drivers union	International Brotherhood of Teamsters	Miguel Lopez	Port terminal and drayage operations
Cross-border dray carrier	Anonymous	Anonymous	Cross-border dray movement and changes since North American Free Trade Agreement (NAFTA)
Cross-border dray carrier	Anonymous	Anonymous	Cross-border dray movements
Port intermodal carriers	Anonymous	Anonymous	Dray moves from Port of Los Angeles/Long Beach
Expedited carrier	Anonymous	Anonymous	Quantification and validation of inefficiency effects

2.1.2 Analysis

The Study Team assessed and categorized the inefficiency findings according to the effects they imposed on the motor carrier community. The team then conducted an analysis of the technical capabilities and limitations of each identified wireless technology, and the various applications they currently support. Finally, the team combined its collected knowledge of the inefficiencies with the various supply chain segment types identified for study to identify both current and potential future wireless technology applications that might provide technical capabilities that would be valuable for motor carrier operations.

Because an in-depth quantitative analysis of every inefficiency was considered too large an undertaking for the scope of this study, the Study Team prioritized inefficiencies based on their relative importance to the carrier community as defined by the Stakeholder Sessions. In addition, the Study Team examined the degree to which individual inefficiencies could be clearly defined, in both qualitative and quantitative terms, by members of the carrier community. The inefficiencies that met these basic conditions, and were cited at least twice by Stakeholder Sessions participants as significant issues for their operations (a subjective distinction based on their perception of the inefficiencies as described using terminology contained in the literature review, are discussed in detail in the sections that follow.

In addition to these inefficiencies, the Study Team considered it important to analyze in more detail data regarding a few other inefficiencies. These supplemental inefficiencies were indicated as being potentially valuable to examine by members of the Study Team or the Government project team, or by individual carrier representatives. Because they were not offered for examination and prioritization during the Stakeholder Sessions, the degree to which these items represent serious inefficiencies is not known. However, rather than disregard them, the Study Team opted to provide whatever information and effects data were available.

2.2 FINDINGS

2.2.1 Inefficiencies

The Literature Review documented the following high-level categories of inefficiencies:

- **Equipment/asset utilization**, including wait for loading and unloading at the shipper or receiver, waiting at roadside inspection facilities, empty/non-revenue miles, bobtailing, equipment repositioning, lack of 24/7 operations, lack of optimized routing, unauthorized equipment use/misuse, and highway congestion/ travel time reliability.
- **Fuel economy and fuel waste** from aerodynamic drag, rolling resistance, drive train friction, and inertial forces during acceleration or climbing, as well as waste from excessive speed, idling, poor transmission and engine management and maintenance practices, and poor routing and scheduling.
- **Loss and theft** including pilferage, hijacking, cargo fraud, damage claims, vehicle and equipment theft, and law enforcement seizure or shutdown.
- **Safety**, including events, actions, or practices that result in truck-involved crashes.

- **Maintenance inefficiencies** resulting in breakdowns, post-inspection out-of-service, and tire failure.
- **Inefficiencies related to data and information processing** including latency of information and/or lack of information sharing between supply chain partners, integrity of cargo tracking information, and general information technology (IT) issues relate to user proficiency and support of software applications.
- **Inefficiencies related to business and driver management**, including driver turnover, lack of adequate driver training, and lack of customer service and IT resources.

The inefficiencies explored were summarized in great detail in the Literature Review as a baseline of what might be important to stakeholders. The motor carriers themselves, in most cases, determined which inefficiencies should be addressed by the proposed technology applications. The priority inefficiencies were determined by presenting the baseline inefficiencies collected to motor carriers and association representatives attending the Stakeholder Sessions. Stakeholder Session participants identified the following inefficiencies as high-priority:

- Waiting time for loading and unloading was the “high-priority” inefficiency most cited across all stakeholder groups. Carriers expressed particular frustration regarding delays waiting for their trucks to be unloaded at consignee locations, as well as at marine terminals. In addition, cross-border wait times had a significant effect on the efficiency of cross-border motor carrier operations.
- Additional equipment and asset utilization-related inefficiencies, including empty/non-revenue miles, lack of 24/7 operations, lack of optimized routing, and highway congestion/travel time reliability were also cited with relative frequency.
- Inefficiencies associated with fuel economy, including excessive speed, idling, and out-of-route miles have received considerable attention.
- Inefficiencies associated with the driver, including training, turnover, and HOS were cited as significant on a regular basis.
- Carriers were also asked to indicate which segment of the motor carrier community best described their operations. The Study Team sought this information in order to discern the extent to which a relationship exists between the rankings of the inefficiencies and the various supply chain segments. The top inefficiencies were then categorized by stakeholder group and matched with a supply chain segment.

Table 6 shows the top motor carrier inefficiencies by stakeholder group.

Table 6. Inefficiencies Identified by Stakeholder Group

Stakeholders	Priority Inefficiencies
Private Fleets	• Hours of Service (HOS) • Fuel waste due to excessive speed
LTL Carriers	• Waiting for unloading • Congestion delay
Truckload Carriers	• Waiting for unloading • Fuel waste due to excessive speed
Pick-Up and Delivery	• Congestion
Cross-Border Carriers	• Waiting time—cross-border wait times (processing, paperwork, infrastructure/capacity limitations) • Congestion delay
Interposal Carriers (Rail)	• Waiting for loading • Backhaul
Interposal Carriers (Port)	• Waiting for loading • Chassis roadability
Expedited Carriers	• Congestion
Public Sector	• Safety (crashes, noncompliance) • ITS integration (limited applications for motor carriers)
Private Sector—Technology	• Waiting for loading/unloading • Poor routing, scheduling and out-of-route miles

Stakeholders were also asked to list the methods used for realizing or measuring inefficiencies, which included travel time, cost per mile, insurance costs, driver turnover rates, and others. Participants were given a list of 39 measures of operational performance commonly used in the analysis of motor carrier operations. The Study Team then asked participants to rate all measures for their value in indicating business performance. The high-value performance measures most commonly cited were:

- Annual fuel consumption.
- Cost per mile.
- Crashes per vehicle mile.
- Damage rate per shipment.
- Driver retention rate.
- Driver utilization rate.
- Insurance costs.
- Loading and unloading times.
- Percentage of on-time arrivals.

- Roadside safety inspection compliance rate.
- Safety regulation compliance rate.
- Savings resulting from increased fuel efficiency.
- Truck dwell time.

Table 7 provides a summary of the inefficiencies analyzed by the Study Team and the potential gains associated with overcoming these inefficiencies. In those instances where the entry is listed as “Unknown,” the Study Team was not able to find sufficient empirical data to formulate potential gain figures.

Table 7. Identified Inefficiency Effects

Inefficiency	Potential Gain to Carriers	Potential Gain to Society
Time Loading and Unloading	$3.08 billion annually	$6.59 billion annually
Waiting in Ports	$900 million annually	Unknown
Paperwork Delay at Borders	$23 million annually	$50 million annually
Time in Weigh Stations	$215 million annually	$461 million annually
Incident-Related Delay	Unknown	Unknown
Urban Routing Problems	Unknown	Unknown
Management Tools	Unknown	Unknown
Vehicle Safety	Unknown	$1.55 billion annually
Driver Safety	Unknown	$1.35 billion annually
Compliance Review Inspections	Unknown	$23.1 million annually
Processing Capacity at Borders	$211K per Owner/Operator annually	Unknown
Driver Turnover	$8,200 per driver	Unknown
Excessive Speed	$1.6 million annually for one 150-truck carrier	Unknown
Cargo Theft and Pilferage	Unknown	$15-30 billion annually
Empty Intermodal Moves	$21 million annually in Chicago alone	Unknown
Empty Miles	$2.7 billion annually	Unknown
Vehicle Maintenance	$320 million annually	Unknown

2.2.2 Supply Chain Segments

As part of the Stakeholder Sessions, four initial supply chain segments were reviewed by the relevant stakeholders. The initial segments proposed were for the International Border, Port to Inland Destination, and Rail-Intermodal Supply Chains. The Closed-Loop Pick-Up and Delivery Supply Chain was added after the NPTC Session. Later, the long-haul truckload supply chain segment was added for analysis.

The finalized supply chain segments used in the FTAT analysis were:

- International Border Crossing.
- Port to Inland Destination.
- Closed-Loop Pick-Up and Delivery.
- Rail-Truck Intermodal.
- Long-Haul Truckload.

The final supply chain segments are summarized in following sections and include all revisions suggested by stakeholders. More detailed breakdowns of the supply chain segments analyzed are provided in the Methodology Report.

2.2.2.1 International Border Supply Chain Segment

The first supply chain segment represents a typical international border crossing for a commercial vehicle. The process flow begins with the pick-up of containerized goods (or a trailer) at a pick-up facility and ends with the drop-off of the container (or trailer) at a destination facility on the opposite side of an international border.

The partners in this supply chain segment are a pick-up facility, the trucking company which transports the goods, and a drop-off facility which could represent an end customer, a distribution center, or some other intermodal facility (e.g., rail terminal). The partner-level depiction of the process is shown in Figure 3.

Figure 3. International Border Level 1: Supply Chain Segment Partner View

The Level 2 processes reflect the high-level operations carried out in the execution of this supply chain segment. This level focuses on the physical movements of the commodities throughout the supply chain segment. The Level 2 process for the International Border Supply Chain segment is depicted in Figure 4.

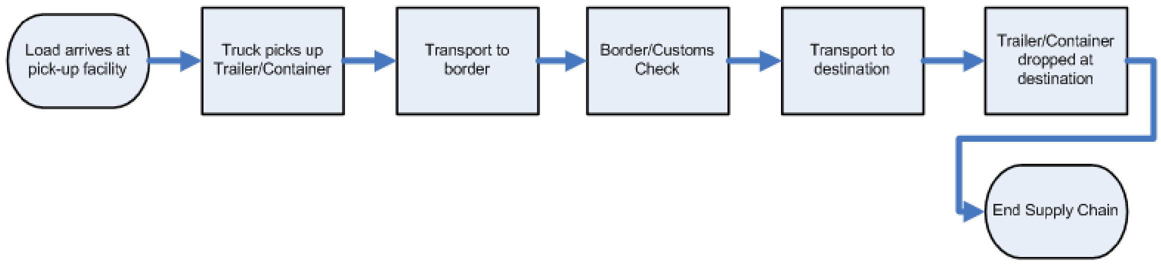


Figure 4. International Border Level 2: High-Level Process View

Each Level 2 process was further broken down to reflect specific activities where motor carrier inefficiencies occur. For the International Border Supply Chain segment, these subprocesses are shown in Table 8. The columns in the table reflect the sequential progression in the Level 2 process as they are arranged left to right. The FTAT analysis, described in more detail in Section 1.2, reflects the incorporation of detailed industry data for these subprocesses by showing the "as is" values for the current process and the "to be" values with proposed technology applications. These before and after values were collected for all Level 2 process data, as defined in tabular form for each supply chain segment that follows.

Table 8. International Border Transport—Supply Chain Segment Subprocesses

Truck Picks Up Trailer/Container	Transport to Border	Border/Customs Check	Transport to Destination	Trailer/Container Dropped at Destination
• Trucking company books pick-up time • Trucking company dispatches truck • Truck to gate transportation • Truck checks in at pick-up location • Truck retrieves trailer/container • Driver checks customs paperwork • Driver departs pick-up facility	• Truck driver updates status with dispatch • Begin transport (drive to border) • Paperwork exchange • Driver updates/ maintains records • Arrive at international border	• Truck enters commercial Customs queue • Truck enters Customs import • Import Customs documents inspection • Cargo inspection • Secondary cargo inspection • Truck exits Customs process	• Truck driver updates status with dispatch • Begin transport (driving) • Driver updates/ maintains records • Driver break • Arrive at destination facility	• Destination check-in • Drop trailer/ container • Update status with trucking dispatch • Truck departs for next pick-up • Truck driver updates, maintains records

2.2.2.2 Port to Inland Destination Supply Chain Segment

The second supply chain segment represents the processes required for a commercial truck to pick up goods from a seaport. In this example, trucks pick up containerized goods coming off of a ship at a seaport. Based on inputs from stakeholders at the Port of Long Beach session, the supply chain segment was extended to include the transport of goods to a nearby destination facility and the return on the truck carrying an empty to pick up another load at the marine terminal.

As shown in Figure 5, the partners in this supply chain segment are a shipping company that transports goods via cargo ship, a seaport where containerized goods are unloaded from ships and transferred to other modes of transport, a trucking company which transports the goods to an offsite destination and returns to drop the empty chassis and pick up another load, and a destination facility where the goods are delivered and dropped. Based on the feedback from the Port of Long Beach session, the drop-off facility was added as a partner and supply chain segment was extended to include the truck returning to the port.

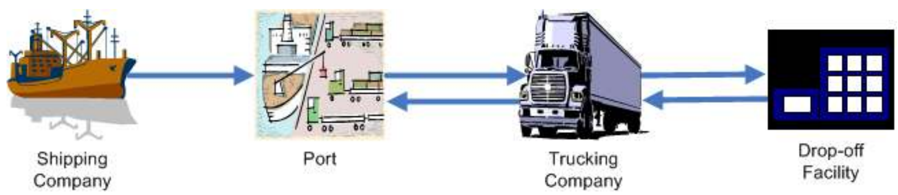


Figure 5. Port to Inland Destination Level 1: Supply Chain Segment Partner View

The Level 2 processes shown in Figure 6 reflect the high-level operations carried out in the execution of this supply chain. This level focuses on the physical movements of the goods as they arrive at the seaport and are unloaded, and possession of the goods is transferred to the trucking company, the goods are dropped at a nearby facility, and the truck returns to the marine terminal to drop the empty chassis and pick up another shipment. The Level 2 decomposition was extended to include the “transport goods to drop-off facility,” “drop off goods, and “return to port for another pick-up” processes, based on inputs from stakeholders at the Port of Long Beach session.

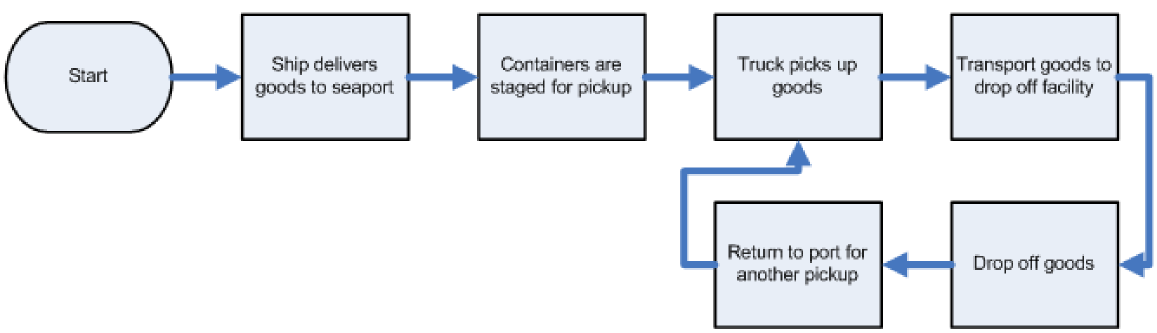


Figure 6. Port to Inland Destination Level 2: High-Level Process View

Each Level 2 process was further broken down to reflect specific activities where motor carrier inefficiencies occur as shown in Table 9.

Table 9. Port to Inland Destination—Supply Chain Segment Subprocesses

Ship Delivers Goods to Seaport	Containers are Staged for Pick-Up	Truck Picks Up Goods	Transport to Drop-Off Facility	Drop Off Goods at Destination	Return to Port for Next Pick-Up
• Shipping company dispatches ship • Ship runs to seaport • Ship lands at seaport	• Marine terminal schedules resources • Crane operator lifts off containers • Containers are stacked or loaded onto chassis • Motor carrier checks cargo availability • Yard hostler designates pick-up spot	• Notify trucking company of goods arrival • Trucking company books time/ dispatches truck • Transport to gate/gate check-in • Drop chassis/ pick up chassis • Roadability inspection (flip) • Truck retrieves load • Gate inspector conducts checkout	• Driver updates status w/ dispatch • Transport • Driver updates/ maintains records • Arrive at drop-off facility	• Notify/ check in at destination for container drop • Drop container • Truck departs for next pick-up • Update status • Driver updates/ maintains records	• Driver updates status w/ dispatch • Begin transport • Driver updates/ maintains records • Arrive at marine terminal

Closed-Loop Pick-Up and Delivery Supply Chain Segment: The third supply chain segment represents a Closed-Loop Supply Chain where a commercial trucking company picks up and drops off goods at multiple locations in a sequential process. As shown in Figure 7, the partners in this supply chain segment are the trucking company that transports goods from site to site and the various pick-up/drop-off facilities.

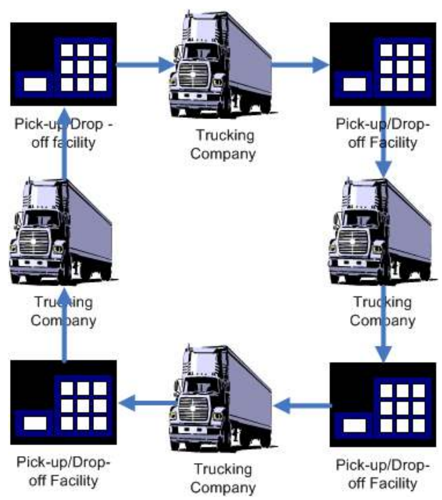


Figure 7. Closed-Loop Pick-Up and Delivery Level 1: Supply Chain Segment Partner View

The Level 2 processes shown in Figure 8 reflect the high-level operations carried out in the execution of this supply chain. This level focuses on the physical movements of goods as they are picked up, transported, and dropped off at the various pick-up/drop-off facilities within the closed-loop system.

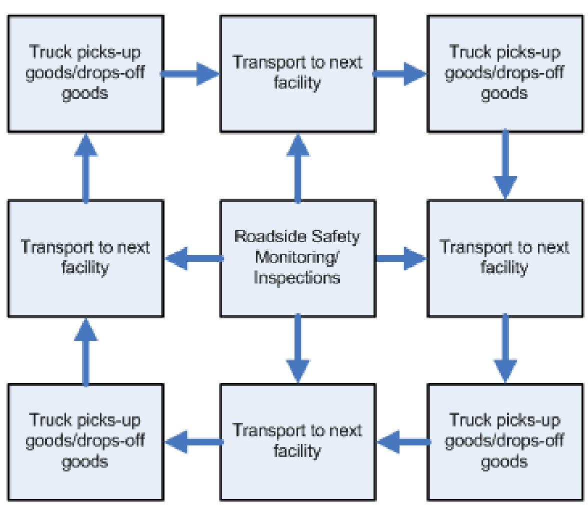


Figure 8. Closed-Loop Pick-Up and Delivery Level 2: High-Level Process View

Each Level 2 process was further broken down to reflect specific activities where motor carrier inefficiencies occur as shown in Table 10.

Table 10. Closed-Loop Pick-Up and Delivery—Supply Chain Segment Subprocesses

Truck picks up/drops off goods	Transport to next facility	Roadside safety/ monitoring inspections
• Notify/check in at facility • Drop off/pick up • Transfer documentation • Update status with dispatch • Final checkout/ truck departs for next facility	• Begin transport • Driver updates/ maintains records • End transport	• Enter roadside inspection queue • Electronic scale and visual inspection (to detailed inspection if selected) • Update status with dispatch • Exit roadside inspection

2.2.2.3 Rail-Truck Intermodal Supply Chain Segment

The fourth supply chain segment represents a common set of actions for a typical movement of containerized or trailered goods by rail, through a rail terminal, and delivered by truck. The process flow begins with the transportation of the goods via rail and ends with exit of the loaded truck from the intermodal facility. As shown in Figure 9, the partners in this supply chain segment are a railroad operator that transports goods via rail, an intermodal facility where trailers are unloaded from trains, and a trucking company which transports the goods to an offsite destination.

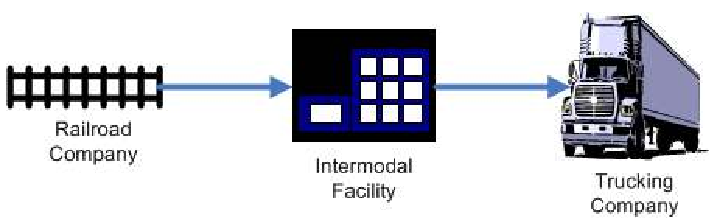


Figure 9. Rail Truck Intermodal Level 1: Supply Chain Segment Partner View

The Level 2 processes shown in Figure 10 reflect the high-level operations carried out in the execution of this supply chain segment. This level focuses on the physical movement of goods as they arrive at the intermodal facility and are unloaded, and possession of the shipment is transferred to the trucking company.

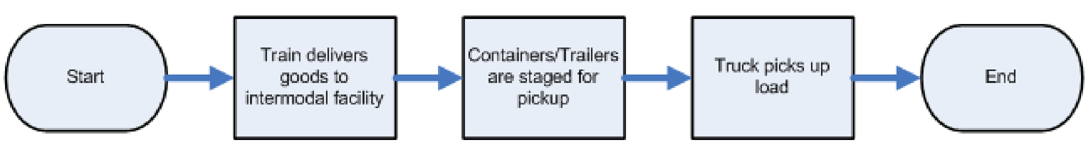


Figure 10. Rail Truck Intermodal Level 2: High-Level Process View

Each Level 2 process was further broken down to reflect specific activities where motor carrier inefficiencies occur, as shown in Table 11.

Table 11. Rail Truck Intermodal—Supply Chain Segment Subprocesses

Train Delivers Goods to Intermodal Facility	Containers/Trailers Staged for Pick-Up	Truck Picks Up Load
• Rail company routes and dispatches train • Train runs to destination • Train arrives at destination	• Intermodal facility schedules resources • Container/trailer is lifted off train • Yard hostler stages container/trailer in designated pick-up spot	• Notify trucking company of container/trailer arrival • Trucking company books pick-up time • Trucking company dispatches truck • Truck transport to gate/gate check-in • Truck retrieves load • Driver updates dispatch w/status • Gate inspector conducts check-out

2.2.2.4 Long-Haul Truckload Supply Chain Segment

The fifth and final supply chain segment represents a common set of actions for a typical movement of goods by truck, over a distance greater than 250 miles, from a pick-up facility to a drop-off facility. The process flow begins with the pick-up of the goods at a facility and ends with drop-off of these goods at another facility. This supply chain segment was added after extensive discussion during MCES Stakeholder Sessions and Study Team meetings. As shown in Figure 11, the partners in this supply chain segment are a pick-up facility, a trucking company that transports the goods, and a drop-off facility.

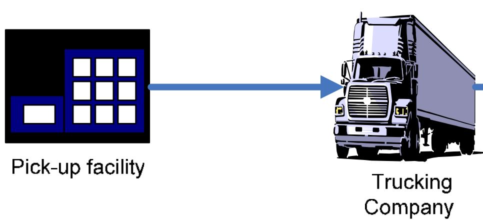


Figure 11. Long-Haul Truckload Level 1: Supply Chain Segment Partner View

The Level 2 processes shown in Figure 12 reflect the high-level operations carried out in the execution of this supply chain segment. This level focuses on the physical movement of goods as they are transported over great distances from one facility to another.

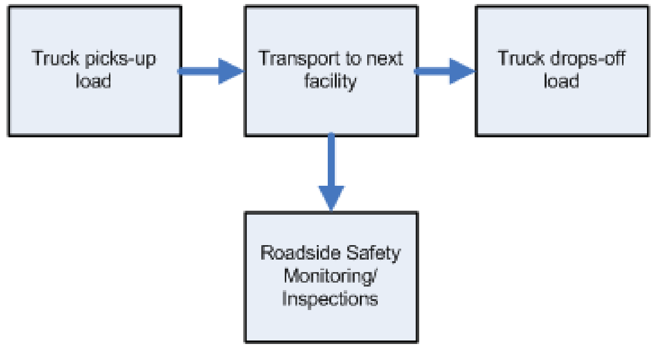


Figure 12. Long-Haul Truckload Level 2: High-Level Process View

Each Level 2 process was further broken down to reflect specific activities where motor carrier inefficiencies occur, as shown in Table 12.

Table 12. Long-Haul Truckload—Supply Chain Segment Subprocesses

Truck Picks Up Load	Transport to Next Facility	Roadside Safety Monitoring/ Inspections	Truck Drops Off Load
• Notify/check in at facility • Update dispatch with status • Pick up load • Transfer documentation • Update dispatch with status • Final checkout/truck departs for next facility	• Driver updates status • Begin transport • Driver updates/ maintains records • Driver break • Refuel • End transport	• Enter roadside inspection queue • Update status • Document inspection • Truck/cargo inspection • Update status • Enter pertinent information into system • Exit roadside inspection site	• Notify/check in at destination for drop-off • Drop load • Update status • Depart of next pick-up • Driver updates/ maintains records

3. WIRELESS TECHNOLOGIES

This section describes the wireless technologies considered—and processes utilized—to develop the proposed technology applications for the FTAT BCA. Section 3.1 details the approach to documenting current wireless technologies and developing the proposed applications. Section 3.2.1 details the wireless technologies explored with the program element applications available in the marketplace summarized in Section 3.2.2. The proposed Section 5503 applications are summarized in Section 3.2.3. These proposed technology applications—developed specifically for the MCES—are matched to analysis scenarios for benefit–cost assessment as summarized in Section 3.3: Conclusions.

3.1 STUDY METHODOLOGY

3.1.1 Data Gathering

The proposed applications for the MCES, described in Section 3.2.3, are based on the findings of a detailed review of current wireless technologies available in today's marketplace, both in the program element areas and in other areas of motor carrier inefficiencies. These technologies were identified and summarized based on:

- The knowledge of the Study Team and the FMCSA, as well as any ideas collected from the February 2006 industry meeting;
- A comprehensive Literature Review of information regarding common motor carrier inefficiencies and wireless technologies;
- Meetings and follow-up phone calls with motor carrier industry stakeholders and technology vendors;
- Analysis completed by the Study Team, including detailed documentation of the viability of the technology concepts presented.

The proposed MCES applications represent the culmination of these activities, from stakeholder interaction to the development of an understanding of applicable wireless solutions. A great deal of analysis regarding wireless technologies was completed in the Literature Review, with additional follow-up with industry representatives regarding specific wireless applications completed during Tasks 4 and 6. The data collection effort represents a way to understand the wireless technologies on the market, but the analysis conducted was designed to link these technologies to the inefficiencies of the carrier community.

3.1.2 Analysis

The core technologies for wireless systems and devices continue to evolve rapidly, resulting in continuous changes in capabilities, availability, sustainability, and practical applications. Therefore, the technologies examined in the Literature Review and summarized in Section 3.2.1 were compared to those found in literature less than five years old. The technologies detailed in the Literature Review were also presented to industry stakeholders at the Stakeholder Session to help the Study Team understand technology acceptance and comfort of use of wireless technologies across stakeholder groups.

The application of the program elements was an important component of the wireless technologies analysis. This included research and documentation by the Study Team and information-sharing during the Stakeholder Sessions. The specific language in Section 5503 of the SAFETEA-LU legislation identified four program elements: operations and management systems, radio frequency identification (RFID), electronic manifest systems, and cargo theft prevention. FMCSA modified these requirements slightly for the study. Roadside safety inspection systems were added as a program element, while the RFID element was reclassified as a technology. Each of the resulting elements represents what could be described as functional groupings of capabilities aimed at improving motor carrier efficiency. Specifically:

- **Fuel monitoring and operations management systems** offer carriers a way to achieve a higher overall level of efficiency. These systems make this possible by helping carriers to enact practices that reduce waste, increase safety, and extract a greater degree of productivity from the fuel they use. Given that fuel costs and consumption concerns are an often-cited concern in such publications as *Transport Topics*, it is logical that efforts to improve fuel efficiency would be of interest to the trucking community. Further, market forces, such as an increasingly worrisome shortage of qualified drivers, and the need to adopt more stringent security practices, place additional importance on maximizing efficiency across all operations.
- **Electronic manifest systems** not only have the potential to allow the carrier community to comply with emerging new rules from the U.S. Customs and Border Protection (CBP) for import shipments, they also offer opportunities for the freight community to continue its own progress towards reducing paperwork, and the costs and delays associated with handling it.
- **Cargo theft prevention systems**, aimed at reducing costly pilferage of shipped goods and the prevention of unauthorized access to trailers and containers by smugglers and terrorists, could have a profound effect on the overall cost of goods and transportation, and on the security of the entire freight network.
- **Roadside safety inspection systems** have the potential to expand both the safety and the efficiency gains that have come about through the use of such applications as weigh station bypass, which reward safety-conscious carriers by reducing delays, and assist enforcement personnel in focusing on higher-risk vehicles and operators.

The findings in Section 3.2.2 describe the MCES program elements and identify some of the wireless technologies and systems currently in use for these purposes. Although the research was certainly extensive, is highly unlikely that every available and/or planned technology application pertaining to these areas was identified. Nonetheless, it can be stated with confidence that the sources consulted provided the Study Team with a comprehensive set of opportunities with which to explore the application of wireless communications.

While the analysis of technologies related to the program elements was a key component of the study, the Study Team focused on gathering inefficiencies from stakeholders both within and outside the program areas. In the Stakeholder Sessions, and in subsequent follow-up interviews with selected industry representatives, discussions regarding inefficiencies were typically followed by brainstorming regarding potential solutions, both within and outside the program areas, depending on the interests of the carriers consulted. Most often, these discussions centered on the identification of capabilities that, were they available, might rectify the inefficiencies under discussion, or alleviate the effects of the inefficiencies on the motor carrier community.

In some instances, carrier representatives spontaneously identified capabilities that would meet the prescribed needs, while in others the Study Team offered generic ideas to spur discussion. In each case, the capabilities discussed were examined at a high level to discern the opportunities and challenges associated with bringing them to fruition. Inherent in the process of identifying potential solutions was the understanding that the BCA, and potential pilot deployment, of any such solution should reasonably represent valid opportunities for the Government to be involved in what otherwise might be considered strictly the domain of private industry.

Based on suggestions and feedback from the stakeholders, the Study Team was able to formulate concepts for seven different technology applications that might at least partially mitigate the effects of the identified inefficiencies. An eighth option—the expanded evaluation of an Untethered Trailer Tracking solution—constitutes a more thorough examination of existing capability and is included for completeness. These technology applications, listed below, are described in more detail in Section 3.2.3.

- **Virtual Queuing**—an application that would reduce waiting for loading and unloading by allowing consignees to monitor and dynamically reschedule dock operations to compensate for delays due to congestion, traffic incidents, or delays in a truck's departure from the shipment origin.
- **Driver Acuity Monitoring—**an application that would permit a carrier to remotely monitor driver behavior characteristics indicative of fatigue (e.g., steering inputs, unsignaled lane departures, head nodding, erratic speeds, etc.), and adjust the remaining HOS accordingly.
- **Variable Speed Limiter—**an application that would allow the carrier to employ wireless communications to alter the governed maximum speed remotely, based on any combination of factors deemed appropriate by the carrier. Additionally, it could be equipped with a geographic referencing capability that is tied to a database of posted speed limits, and as a truck passes from one zone to the next, the speed governor would be adjusted automatically.
- **Border Crossing Compliance Notification—**an application that would make information regarding pre-screening status available prior to a driver's arrival at the border, offering the potential to significantly reduce delay and queuing, which would also likely reduce idling and improve safety.
- **Truck-Specific Congestion Avoidance**—an application that would provide a wireless link to existing traffic information, which would allow drivers to receive traffic data that are applicable to their operations, and in the event that alternatives exist, would provide truck-specific alternate routing information.
- **Chassis Roadability Notification**—an application that would provide a means for drivers to wirelessly access chassis maintenance data and inspection history upon entering a storage facility or terminal.

- **Cross-Town Intermodal Interchange**—an application formulated under a separate research effort within the Federal Highway Administration that applies a combination of wireless technology and coordinated operating practices among railroads, motor carriers, and public agencies (e.g., Metropolitan Planning Organizations, State Departments of Transportation, first responders, freight economic development entities, etc.) to reduce empty trips, reduce congestion-related delay, and improve safety and the environment.
- **Untethered Trailer Tracking**—an application that allows asset owners and shippers to monitor the integrity and location of goods and equipment, and potentially offers the ability to mitigate theft and pilferage, and enhance security.

In addition to these solutions, the Study Team examined in some depth solutions that are already commercially available to gain a better understanding of the benefits that might accrue from expanded adoption levels. One particular wireless application reviewed was the use of RFID for weigh station bypass programs. These technologies are matched to the supply chain segments (described in Section 1) in Section 3.3, where each FTAT analysis "scenario" is presented.

3.2 FINDINGS

3.2.1 Wireless Technologies Summary

Wireless technologies currently available in the marketplace were explored in detail in the Literature Review. The Study Team identified 10 general classifications of wireless technologies with potential application to motor carrier inefficiencies:

- RFID
- Digital cellular
- Bluetooth®
- Wireless Local Area Networks (WLAN) / Wireless Fidelity (Wi-Fi)
- Satellite (for position/navigation and communications)
- Ultra-wideband
- Worldwide Interoperability for Microwave Access (WiMAX)
- Optical wireless technologies—Free Space Optics (FSO)
- Zigbee®
- Two-way radio

3.2.1.1 Radio Frequency Identification

RFID is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object. RFID, sometimes called dedicated short-range communication (DSRC), does not require direct contact or "line-of-sight" scanning. An RFID system consists of three components: an antenna and transceiver (often combined into one reader) and a transponder (the tag). The short-range communications capabilities of RFID technologies are suitable for supporting location-based mobile services. Location-based mobile services use triangulation of known geographic coordinates of fixed antennas to calculate the location of a mobile device (such as a transponder in a vehicle, or cell phone carried by a person) and then provide some service based on the device position.

3.2.1.2 Digital Cellular

In wireless communications, cellular refers to the structure of the wireless transmission networks, which are comprised of cells or transmission sites. The first generation of wireless telephone technology (sometimes called 1G) used analog radio signals. The new generations of wireless telephone networks are digital. Digital cellular telephone technologies currently fall into second-generation (2G), third-generation (3G), and fourth-generation (4G) service categories. The breadth and depth of the capabilities of cellular technologies are directly associated with their particular generations. Adoption of later-generation cellular network technologies in current or future communications equipment expands the number and quality of services available.

3.2.1.3 Bluetooth®

Bluetooth is a computing and telecommunications industry standard for short-range and low-speed radio frequency transmission of digital voice and data between wireless devices. The technology supports point-to-point and multipoint applications; it is designed for low power consumption and is well suited for connecting personal or handheld devices such as personal digital assistants (PDAs), cell phones, wireless headsets, and computers in short intervals. With regard to motor vehicle applications, it has been suggested that Bluetooth may serve as a vehicle-to/from-infrastructure communications channel for stationary vehicles in very close proximity to the desired communications point.

3.2.1.4 Wireless Local Area Networks Wireless Fidelity

Many businesses, homes, and public gathering places now offer wireless access to local area networks (LANs) with subsequent access to the Internet. This technology, commonly known as Wi-Fi, permits any device (such as a notebook computer, or some PDAs) to connect to the network and access any Internet-available web site or application. Many truck stops now routinely offer Wi-Fi hot spots as a courtesy to their customers, allowing them to access e-mail, Internet services, or their company's web services without attaching any cables. Wi-Fi also supports all local area networking functions for office, yard, or dock operations, including wireless download of data from any Wi-Fi-enabled devices (laptops, PDAs, smart phones, or vehicle data systems, such as Electronic On-Board Recorders [EOBR], in-cab computer systems, or other vehicle diagnostic systems).

3.2.1.5 Global Positioning System Satellites

All Global Positioning System (GPS) location services rely on Earth-orbiting satellites that apply the basic navigational principle of triangulation, which measures the time it takes for a signal from each of three satellites to be sent to and received back from a transceiver on the ground. The location of the transceiver on the ground is then calculated, based on the known location of the satellites. This system, which consists of a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations, has a distinct and dedicated function as a radio-navigation system. GPS uses U.S. Department of Defense satellites, is now well established, and has been adopted by private and commercial users. The system has been put to work for location, navigation, tracking, mapping, and timing functions. Satellite technology for positioning is often combined with, and supports, other technology applications.

3.2.1.6 Communications Satellites

The largest numbers of satellites currently in orbit are communications satellites. Satellite applications for communications include point-to-point telecommunications links, mobile phone networks, and direct broadcast. Satellite communications are complex but provide telecommunications capabilities remotely and globally in places where other wireless communications technologies do not have infrastructure. Satellites that provide telecommunications capability, while using the same principles, are separate and distinct from the U.S. Government satellite constellation currently used for GPS. Communications satellites are publicly or privately owned and provide two-way communication capabilities to a variety of communications service providers and their customers around the globe, including data and mobile telephone service. Satellite mobile phone systems have not been as successful as originally anticipated, because of the extremely rapid expansion of terrestrial-based cellular communications. Satellite-based mobile phone systems were set up to use low-Earth-orbiting satellites, with handsets that communicated directly with satellites that process and relay the signals.

3.2.1.7 Ultra-wideband

Ultra-wideband (UWB) technology refers to a radio communications technique or a wireless air interface for short-range, high-speed data transmission. UWB transmits data over a large bandwidth, which allows high-data-rate wireless short-range (e.g., personal area networks) connectivity and longer-range, lower-data-rate applications (e.g., ground-penetrating radar Because of the low power transmissions, UWB communications are best suited for short-range communications, including sensor networks, and wireless personal area networks (WPANs) and vehicle collision avoidance systems. Collision avoidance systems have been demonstrated; however, systems have not yet been deployed.

3.2.1.8 Wireless Interoperability Microwave Access

Wireless Interoperability Microwave Access (WiMax) is a wireless networking standard intended primarily for metropolitan area networks. This standard is an Institute of Electrical and Electronics Engineers (IEEE) specification of fixed broadband wireless typically used in metropolitan access networks that use point-to-multipoint architecture. The standard defines the use of bandwidth between the licensed 10-gigahertz (GHz) and 66-GHz and the 2-GHz and 11-GHz frequency ranges. The standard supports very high upload and download bit rates from a base station up to a distance of 30 miles (Eklund et al., 2002). WiMax operates over long distances, provides high bandwidth, takes advantage of a broad range of frequencies, and supports a variety of deployment architectures, including non-line-of-sight operation (a significant advance). WiMax is based on Orthogonal Frequency Division Multiplexing, a modulation technique developed to improve range and propagation quality of data signals.

3.2.1.9 Optical Wireless Technologies (Free Space Optics)

Free Space Optical Communication Technology, also called Free Space Optics (FSO), is a telecommunication technology that uses light propagating in free space to transmit data between two points. FSO uses infrared light waves that have been translated from electronic data to transmit information between devices. The light waves can originate from lasers or light-emitting diodes. A simple type of FSO communication is the Infrared Data Association (IrDA) interface, commonly used on devices such as remote controls, handheld computers, PDAs, and mobile phones within WPANs.

3.2.1.10 Zigbee®

Zigbee is an open-source radio frequency communication protocol and standard. Zigbee is most applicable for networks that can use a large number of nodes and cover a large area using any of the flexible, star, cluster tree, or mesh network topologies. Topology is the way in which nodes on a network are connected to, and therefore communicate with, one another. Zigbee is commonly used for networks where devices are scattered, such as security systems, home and industrial automation, remote metering, automotive networks, and active RFID asset tracking.

3.2.1.11 Two-Way Radio

Two-way radios include all devices that can transmit and receive radio signals. The technology discussed in this section is limited to those radios that require manual activation of the transmitter to send the signal, communicate half-duplex (meaning that a user cannot talk and listen at the same time; transmission is in one direction at a time), and use push-to-talk (meaning that a microphone must be activated by a button on the radio to transmit the signal). Two-way radio technology is intended primarily to communicate with other radios. Cellular phones are technically two-way radios that can send and receive signals at the same time; this is known as a full-duplex operation. It should also be noted that the distinction between radio telephones and two-way radio is becoming blurred as the two technologies are often packaged together.

3.2.1.12 Technologies Summary

The technologies described briefly in the previous sections are summarized in tabular form in this section. Table 13 reviews the primary attributes of the wireless technologies discussed. Each technology is briefly reviewed according to the following table columns:

- Technology—Name of the technology or family of wireless technologies reviewed.
- Description—Brief description of the basis and/or primary purpose of the wireless technology.
- Characteristics—Snapshot of the technology performance characteristics, including Data Transfer Rate [approximate documented speed (or range of speeds) within which data can be transferred to or from the subject technology], Range (approximate distance over which data can be transmitted to or from the subject technology).
- Maturity—Simple assessment of the level of maturity of the subject technology, taking into consideration the length of time that the technology standard has been in existence, and the deployment level (how widely this technology is currently deployed). High = technology standards established and accepted for 5+ years, widely deployed; Moderate

= technology standards established 2–5 years, evolving to wide deployment; Low = technology standards established for less than 2 years, evolving deployment.

- Motor Carrier Applications—Examples of typical motor carrier, or potential motor carrier, applications.
- Summary of Advantages and Disadvantages—A brief summary of the assessed advantages and disadvantages of the subject technology within the motor carrier's operating environment.

Table 13. Wireless Technologies Summary

Technology	Description	Characteristics	Maturity	Motor Carrier Applications	Summary Advantages/Disadvantages
Wireless technology type	*Brief description of technology*	*Data transfer rate and operating range*	*Level of maturity*	*Summary of motor carrier applications*	*Advantages or disadvantages of technologies within a motor carrier's operating environment*
RFID	Low-powered radio transmitters to read data stored in a transponder (tag)	**Data Transfer:** Dependent on vendor tag/reader system, environment **Range:** 1 inch to 1,000 feet (effectively, depending on type of tag: active, passive; or power level)	High	Weigh station by-pass programs, port operations, international border crossing systems, yard and gate management systems, asset management and tracking (vehicle ID, supply chain/pallet ID), security, wireless keys, cargo/container security	**Advantages:** Readable from varying distances, angles, and through certain materials. Environmentally robust. Unique object identification, authentication. Potential for real-time tracking. **Disadvantages:** Range limitations, private- or facility-based infrastructure required.
Digital Cellular	Wireless network of transmission cells providing digital data communications capabilities	**Data Transfer:** 144 kbps to 3.1 megabits per second (Mbps) **Range:** Line-of-sight cellular tower, infrastructure-dependent, mobile equipment reception, transmission, and power-dependent	High	Personal telephone communications (cell phones), on-board computer and communications systems, remote vehicle monitoring systems (security systems, vehicle location systems), remote financial transactions	**Advantages:** High-performing "always-on" data connections in newest-generation services, extensive networks, mature technologies, continued technology advancement. **Disadvantages:** Competing, non-interoperable systems, bandwidth limitations, real-time data exchange latency.
WLAN/Wi-Fi (IEEE 802.11x)	Wireless network technologies for local area network and internet access	**Data Transfer:** Rates up to 54 Mbps **Range:** 25–100 meters (depending on protocol variation)	High	Wireless local area network applications, yard/dock operations, service facility hot spots, fuel facility operations	**Advantages:** Mature technology, strong connections between devices and routers or gateways, suitable for full-scale operation, fast connections, better local base station range than Bluetooth, IrDA. **Disadvantages:** More complicated network, peripherals, and connecting devices; Not designed for long-range communications.

Technology	Description	Characteristics	Maturity	Motor Carrier Applications	Summary Advantages/Disadvantages
WiMax (IEEE 802.16)	Wireless network technology for metropolitan area networks	**Data Transfer:** Less than 54 Mbps **Range:** 0.5 mile (theoretical)	Low	Fleet management and monitoring applications in metropolitan/urban environments	**Advantages:** Operates over greater distances than Wi-Fi, more bandwidth, broader range of frequencies, non-line-of-sight operation. **Disadvantages:** Subject to multi-path signal interference, environmental factors, modest data transfer rates.
Bluetooth (IEEE 802.15.1)	Short-range radio frequency (RF) communications technology for enabled devices in close proximity	**Data Transfer:** Up to 2 Mbps **Range:** 1 to 100 meters	Moderate	Very-short-range device-to-device communications, data exchange, inter-vehicle communications	**Advantages:** Low cost, simplified discovery and setup. **Disadvantages:** Very-short-range operations dependent on power, no transmission control protocol/internet protocol support
Satellite	Global-satellite-based telecommunications network and GPS network	**Data Transfer:** 75 bit/s to 4.8 kbps **Range:** Global	High	GPS, satellite telephone systems, fleet management and monitoring systems	**Advantages:** Remote and global availability, higher data rates than older satellite technologies. **Disadvantages:** Cost of systems, equipment; latency; potential terrain interference.
Ultra-Wideband (UWB) (IEEE 802.15.3)	Short-range, high-data-rate RF communications	**Data Transfer:** 100+ Mbps in the 3.1 to 106 GHz bands **Range:**10 meters	Low	RFID tags, radar detection and imaging, precision geolocation systems, collision avoidance and collision warning sensors, high-speed WPAN	**Advantages:** High data transfer rates in multi-user networks, good for mobile wireless applications, simple components, low cost. **Disadvantages:** Limited commercial development due to Federal Communications Commission limitations, range limitations, disadvantages similar to those of other RF wireless technologies.

Technology	Description	Characteristics	Maturity	Motor Carrier Applications	Summary Advantages/Disadvantages
Free Space Optics (FSO)/Infrared (IrDA)	Wireless Infrared telecommunications technology for point-to-point data transmission, typically Infrared (IrDA)	**Data Transfer:** 2.4 to 16 Mbps **Range:** 0.3 to 1 meter (depending on power)	Moderate	Primarily hand handheld device communications, high bandwidth access to fiber optic networks, roadside beacons for low bridge or curve speed detection applications	**Advantages:** High data transfer rates, secure full-duplex (two directions at the same time) data transmission, low power, low cost. **Disadvantages:** Short range, subject to environmental, light and shadow conditions; subject to beam dispersion; limited to line-of-sight operations.
Two-Way Radio	Push to talk, half-duplex radio technologies that transmit and receive signals	**Data transfer and Range:** data transfer speeds and range of operations depend on infrastructure, handheld equipment power, environmental conditions and terrain	High	Dispatch operations, large organization (public or private) two-way communications applications (law enforcement, utility fleets, emergency responders), citizens band (CB) radio	**Advantages:** In non-trunked systems, dedicated frequencies; immediate push-to-talk voice communication capability, public services such as CB radio are low radio cost with no recurring service costs. **Disadvantages:** Subject to limitations of infrastructure, handheld equipment and terrain; not suitable for data transfer.
Zigbee (IEEE 802.15.4)	Short-range radio frequency standard for monitoring and control in mesh networks	**Data Transfer:** 20 to 250 kpbs **Range:** 1 to 75 meters	Low	Possible in-vehicle applications, convenience controls similar to home automation and consumer electronics applications Industrial automation (intelligent sensor networks); active RFID asset tracking (local inventory systems); security applications (sensor networks for intrusion detection)	**Advantages:** Reliable, low power, low manufacturing cost, simple and small; very long battery life; mesh networking allows thousands of nodes per network. **Disadvantages:** Slow data transfer rates; vehicle application behavior not known; stringent standards for reliability increase downstream costs to consumer,

3.2.2 Program Elements and Technology Applications Summary

The FMCSA is acutely aware of the challenges that face the commercial trucking community; and is a strong partner with its members in the pursuit of operational, institutional, and technical enhancements that will promote a safe, efficient freight delivery system. With that in mind, FMCSA has defined a program to address the Section 5503 language that relies upon a collaborative partnership among Government, trucking industry, and the vendor community. This program includes the review, documentation, and potential application of technologies within the four identified program elements:

- Fuel monitoring and operations management systems.
- Electronic manifest systems.
- Cargo theft prevention and security.
- Roadside safety inspection systems.

The findings in this section describe the study program elements and identify wireless technologies and systems currently in use for these purposes. At the conclusion of this section, Table 14 summarizes the detailed analysis of these program elements as provided in the Literature Review.

3.2.2.1 Fuel Monitoring and Operations Management Systems

Definition: Fuel Monitoring and Operations Management Systems monitor, record, electronically control, various vehicle systems to improve vehicle and driver safety, increase security, and improve vehicle and driver performance and efficiency.

Fuel Monitoring Systems typically consist of on-vehicle systems used to monitor fuel consumption, dispensation/replenishment, and fuel system/engine performance using various sensing, data collection and data exchange technologies. Tachographs, which record various engine operational data, are commonly used fuel monitoring and management systems.

Operations Management Systems are those types of systems that carriers use to monitor the performance of their fleet assets, which include vehicles, drivers, and facilities, and manage programs that enhance safety, security, and efficiency. EOBRs and lane departure warning systems are examples of technologies used for this purpose.

Operations management is a multi-faceted responsibility of the motor carrier that encompasses business management functions, vehicle and driver safety and security functions, and regulatory compliance functions. Wireless technologies and systems that assist the motor carrier in carrying out these functions more efficiently are currently available, or evolving, in many forms. These technologies may be used independently, but are often integrated into highly capable on-board computer and communications systems (with supporting sensors, communications devices, hardware and software).

Supporting technology components that provide communications capabilities, data, safety or security functionality include engine electronic control modules (ECM), EOBRs, wireless handheld communications devices (e.g., cell phones, PDAs), GPS components and devices, transponders, wireless networking components and devices, security systems, and driver safety systems (lane departure warning systems, collision avoidance systems). Each of these wireless technology components provides some form of automated monitoring and control, for transmission of data between the components, or from the components to the motor carrier's back office systems. The systems are often integrated to form a set of operations management capabilities that expedite the carrier's ability to communicate with and respond to the vehicle, driver, and customer in near-real-time.

Fuel monitoring by motor carriers is currently, and has been historically, a necessity for regulatory and tax compliance purposes. Given the rising cost of diesel fuel, control of fuel use is among the most important factors in maintaining profitable trucking operations. Basic data used for manual fuel recording and monitoring, and now for automated recording, include:

- Odometer/hubodometer readings (to calculate vehicle miles traveled per trip, and within each jurisdiction, and for regulatory compliance or business management purposes).
- Fuel purchase information for each refueling event, including date/time of purchase, seller information, purchaser information, vehicle identification, type of fuel purchased.
- Vehicle miles traveled (further broken down by jurisdiction, origin, destination, starting/ending date per trip, routes, direction of travel, etc.).
- Amount of fuel obtained at each refueling stop (typically in gallons of fuel pumped into the vehicle).
- Cost of fuel, retail price per unit, including all Federal, state, and local taxes charged; total sales price (data point for regulatory compliance and for small fleets or owner operators, or those without automatically reconciled bulk fuel accounts; typically in dollars per gallon) (California Sate Board of Equalization, 2006).

Refueling stops are necessary CMV service activities that are included as part of the driver's overall on-duty time in the driver's record of duty status (USDOT, 2007a). Additionally, fuel taxation regulations in various jurisdictions, generally by state in the U.S., require accurate logging of miles traveled in each jurisdiction so that tax revenue collected at the point of sale can be accurately apportioned to the appropriate jurisdiction.

For regulatory and business management purposes, the data collected manually serve their purpose, although it is subject to inaccuracy due to driver error, omission, or falsification. Fuel tax reconciliation support software, used in conjunction with various on-board vehicle computer systems and associated back-office systems, has fully automated the reconciliation activities for most carriers. This activity is also often outsourced by owner-operators and very small fleets.

Fuel consumption rates are also an indicator of vehicle engine and drive train performance, vehicle maintenance status, and driver behavior. Dependence on manually collected data introduces delays into the engine maintenance, diagnostic, and repair cycles. Additionally, less emphasis is placed on training drivers on fuel consumption improvement techniques. Although many other types of data could be extrapolated from the manual data collected, most often the only other calculated variables are vehicle miles per gallon and average speed.

Factors such as engine idling, engine speed, engine load, vehicle speed, acceleration, braking, and transmission activity cannot be calculated or considered using manual data collection. Automation of vehicle systems monitoring provides the ability to monitor all of these factors, and others, in order to optimize fuel system, driver behavior, and overall vehicle performance. Automation provides data, detail, and accuracy not possible with manual data collection.

Wireless technologies, as part of integrated automated systems, may be applied at various points in the fuel acquisition and consumption cycle to manage the dispensation at the pump, monitor and manage the vehicle's fuel system performance, and document fuel regulatory compliance data, while in the vehicle is in operation. Systems that integrate cellular or satellite mobile communications capabilities to transmit fuel-system-related data over the air are examples of integrated systems with fuel monitoring or management capabilities.

3.2.2.2 Automated Vehicle ID at Refueling Stations

At the pump, systems are currently commercially available that identify the vehicle automatically by way of a ruggedized, active RFID tag mounted on or under the vehicle. The infrastructure is equipped with readers or loop antennas that identify the vehicle and actuate the pump. This type of system eliminates the need for fleets to issue personal identification numbers, keys, or fuel cards, which are often lost or abused. A similar related application uses a small RFID tag (often a key ring attachment) that is carried by the driver. Like the vehicle tag, no action by the driver is required to actuate the fuel pump once it is in the vicinity of the reader.

3.2.2.3 On-Board Data Recorder and ECM Data Transmission

Various types of data recorders are currently on the market, and each system, depending on its cost, sophistication, and specification, will record data from sensors included in the vehicle's electronic control module (ECM) and/or aftermarket diagnostic systems. A best-practice case study, *Good Practice Case Study 342: Fuel Management for Transport Operators*, by the United Kingdom Department of Environment, Transport, and Energy Efficiency, indicates that in this case, automated management of the fuel systems (such as with engine revolutions per minute [RPM] and vehicle speed governors) provided for a 5.8 percent improvement in fuel mileage. In addition, this case study was among the first to demonstrate that the introduction of on-board data recorders improved driver performance and lowered the company's crash rates, by allowing company management to provide guidance or take corrective action in a timely manner to improve driver behavior.

With the automated collection of the data, and subsequent diagnostics and corrective action, efficiency improvements are expected. Timeliness and accuracy of data still depend on interpretation of ECM data sets, fleet management practices, and frequency of data download. Engine makers work with truck manufacturers, distributors, and other major customers to assist them in making these data useful for operations improvement. Transmission of the data from the vehicle to the motor carrier's management systems at their offices and maintenance facilities is currently and primarily performed by downloading the data to a terminal at the carrier's facility. Systems currently exist that allow the transmission of some vehicle ECM data through Wi-Fi, satellite, or digital cellular communications.

Data that can be obtained from ECMs include:

- Engine RPM.
- Time in gear.
- Idle time and percent fuel use.
- Fuel used idling.
- Load factors.
- Power take off time.
- Power take-off fuel used.
- Speed vs. RPM.
- Engine load vs. RPM.

ECMs also may record other information such as over-speed data, hard-brake incidents, last stop information, and other operational history.

3.2.2.4 Truck, Trailer, and Fleet Management Systems (Including Untethered Trailer Tracking)

Various technology manufacturers and integrators now offer comprehensive fleet management systems that provide a menu of options for trucking fleets of all types and sizes. These options allow companies to choose from a variety of technologies that assist them in monitoring their fleet's productivity, asset utilization, customer service, vehicle systems, safety, and security. The systems may include in-cab computers in conjunction with other sensing technologies and components on the vehicle that may be managed and monitored wirelessly by software applications and computers at the motor carrier's dispatch, maintenance, and management offices. The systems are intended to be used to reduce per-mile operating costs by assisting the carrier in improving productivity, reducing fuel consumption, reducing breakdowns and crashes, and lowering maintenance costs. Near-real-time monitoring may also allow the carrier to improve customer service through more accurate estimated times of arrival (ETA), to manage shipments, to respond to customer's demands more quickly, and to improve on-time performance.

The ability to monitor a truck or trailer remotely also provides information and a level of security not possible with simpler security systems. Trucks and trailers can be monitored within a virtual perimeter, or "GeoFence," and alarms can be set to notify the motor carrier when vehicles are out of a specified area or are a certain distance off a specified route. In addition, the capabilities discussed for near-real time monitoring, and depending on the options chosen by the motor carrier, the systems may also assist in streamlining regulatory compliance tasks such as fuel tax reporting, vehicle safety and maintenance reporting, driver HOS reporting, automated billing, payroll, and out-of-route miles reporting.

Trailers provide a distinct monitoring challenge for the motor carrier when they are untethered from the tractor. Without visibility to the status and location of the trailer, it is subject to under-utilization, unauthorized use or drop, theft, or loss. Wireless trailer tracking solutions, also known as Untethered Trailer Tracking systems, are emerging from a number of vendors to provide visibility and offer a variety of options for monitoring various aspects of a trailers location and security. To meet customer demand, companies often buy excess trailers so that the more expensive asset, the tractor, can be available and more effectively utilized. Excess trailers require additional effort for tracking, inventory, maintenance, security, and storage. Untethered Trailer Tracking systems provide these capabilities with significantly reduced effort and cost.

3.2.2.5 Vehicle Safety Systems

A component of operations management includes vehicle safety management for driver safety, crash prevention, and for regulatory compliance. The ECM provides information and data regarding vehicle systems condition and assists in managing the vehicle's basic safety components—engine, transmission, lights, and brakes. However, other critical safety management systems target a variety of driver behaviors and assist drivers in controlling their vehicles, negotiating the highway, avoiding roadway hazards, and avoiding collisions with other vehicles. Some applications of safety systems with wireless technology components that may be of particular interest for commercial vehicles have been identified (USDOT 2005a). These applications include:

- **Collision Warning—**These types of systems include cooperative warning systems that use information communicated to and from adjacent vehicles and position information from on-board vehicle systems to avoid forward or lateral collisions. These systems also include those that warn the driver that a vehicle occupies a blind spot or an adjacent lane.
- **Collision Avoidance Systems—**These systems are more sophisticated and assist the vehicle in steering or braking to avoid collisions. These systems are evolving and have been tested and demonstrated, but are not yet deployed.
- **Lane Departure Warning Systems—**This application warns the driver that he/she is changing lanes and/or that an intended lane change may cause a crash with a nearby vehicle. These systems are available through aftermarket providers and original equipment manufacturers.
- **Adaptive Cruise Control—**This application uses many of the same principles and system capabilities as collision avoidance systems, but applies them to automatically adapt (increase or decrease speed, detect stopped vehicles) the cruise control settings of a vehicle. These systems are evolving and have been tested and demonstrated, but are not yet deployed in commercial vehicles.
- **Curve Speed Warning—**Curve speed warning aids the driver in negotiating curves at the appropriate speed. There is some limited and military deployment of this type of system. This system may also use roadside beacons in conjunction with on-board vehicle systems to determine if the speed and acceleration of the vehicle warrant an alert for the driver.
- **Low Bridge Warning—**These systems provide low-bridge warning messages to alert commercial vehicle drivers when they are approaching a bridge too low for their vehicles. Although roadside beacons have been suggested as a technology solution, other proposed solutions include vehicular radar.

- **Visibility enhancers**—This application uses information from its own GPS and map database for visibility enhancement implementations that may range from simple (veer left or right indicators) to more sophisticated and complex (superimposed road and vehicles on the inside of the windshield).

The primary factors that influence motor carriers to purchase and use on-board safety technologies, which may include the previously discussed systems or a component of those systems, are:

- Return on investment.
- Reliability and maintainability.
- Demonstrated effectiveness to improve safety.
- Initial cost.
- Liability.
- Market image.
- In-cab technology interface integration.
- Driver acceptance.

These factors will be important in considering how wireless technologies associated with safety systems can be successfully tested, incorporated into motor carrier operations, and supported by Government programs and research.

3.2.2.6 Electronic Manifest Systems

Definition: Electronic manifest systems expedite the exchange of cargo and Customs-related data between shippers, carriers, receivers, and governing agencies using various dedicated and automated computer systems, wire line, and wireless technologies.

Most large carriers and shippers use electronic technologies to catalog and track cargo within their systems, and to transmit cargo information outside their systems to Government agencies. However, approximately 28 percent of motor carriers surveyed indicate that they use only paper documents to account for their shipments (eyefortransport, 2005).

Interestingly, carriers that have adopted electronic communications often consider it a competitive advantage and are reluctant to disclose the details of the application of technology within their systems. Further, an evaluation of electronic supply chain manifest (ESCM) benefits calculated as an update to ATA Foundation's *Phase II Report: Developing and Testing and Electronic Supply Chain Manifest*, indicates a 94 percent savings for trucking companies using automated ESCM vs. traditional manual and paper processes (USDOT, 2005b).

3.2.2.7 Supply Chain e-Manifest

Several electronic data exchange systems for transferring manifest data electronically between supply chain partners have been evaluated. An evaluation of an electronic supply chain manifest system field operational test identified these exchanges and discussed the technologies used

(USDOT, 2002). Technologies used included Smart Cards and Readers, biometric readers (for fingerprint verification), and Internet-enabled software. Some of these technologies may potentially be replaced by wireless systems with the proper security and encryption.

3.2.2.8 Electronic Freight Management

Following the Supply Chain e-Manifest project, the USDOT formulated and initiated a technology-related demonstration aimed at expanding the scope of the earlier effort. Currently underway, this program, and the Columbus Electronic Freight Management (C-EFM) project, will explore opportunities to tie together operations at all levels within the supply chain. Wireless technology is not a primary focus of this demonstration; however, the information-sharing processes necessitated by the pilot set the stage for the use of wireless technologies to exchange data between freight vehicles and the infrastructure.

3.2.2.9 Border Crossing e-Manifest

CBP has mandated the filing of e-Manifests for all cargo crossing the border via motor carrier. Under this program, an e-Manifest is filed electronically by the shipper, or by a third party that has assumed responsibility for completing the Customs filing. As a part of the CBP Automated Commercial Environment (ACE) Program, participating motor carriers are given the option of using a CBP-approved transponder that allows CBP to wirelessly retrieve e-Manifest data at the border by matching identification with pre-filed entry or in-bond requests. If a truck is not transponder-equipped, the CBP officer at the border uses the vehicle license plate and the individually assigned trip number to retrieve the manifest information.

Among the benefits reported by CBP is a processing time for trucks that is 23 percent faster, on average, than before ACE program implementation (Customs and Border Protection, 2006). Data currently required under the ACE e-Manifest program include the following:

- Crew Identification (driver, passenger).
- Description of Conveyance (vehicle, truck, cab).
- Description of Equipment (trailer, container, chassis).
- Shipment Details (detailed cargo description).

E-Manifests are filed with CBP though one of the following systems: the web-based ACE Secure Data Portal or a CBP-approved Electronic Data Interchange. E-Manifests must be received one hour prior to the truck arrival at the first U.S. port of entry. If a carrier and its supply chain partners are enrolled in the Free and Secure Trade (FAST) Program, the advance reporting requirement is reduced to 30 minutes prior to arrival.

3.2.2.10 Cargo Theft Prevention

Definition: Various systems and technologies applied to vehicles (power units, trailers, and containers) to monitor, report, and prevent the compromise of cargo security (tampering, theft, and pilferage).

3.2.2.11 Cargo Container Seals

Although some are designed to hamper entry (through the use of a steel cable or a bolt that fits through the locking mechanism on the vehicle), electronic cargo seals are intended primarily to provide an electronic indication that a closed cargo container or trailer has been opened without authorization. This is typically accomplished when a seal that has been breached passes within range of a reader. The reader interrogates the seal, which reports a status message. This information is then passed along from the reader location to authorized parties.

A July 2003 evaluation of electronic cargo security seals—often referred to as e-seals—as a part of the Cargo Handling Cooperative Program (CHCP) showed that the overall product was relatively mature, with wide variations in maturity depending on manufacturer. One common feature was the ability of the seal to communicate wirelessly with fixed readers using radio frequency technology.

All RF-based e-seals operate using the same underlying technology, but different manufacturers use different approaches to application, and offer a wide range of design features. The major areas of design in which variation occurs are:

- Frequency (signal propagation around objects, interference from other RF devices).
- Communication protocol (seal transmission frequency vs. readability vs. battery life).
- Reader infrastructure (range of the seals/readers vs. cost/number of readers for required coverage).
- Seal location (door/frame installation vs. locking mechanism installation).

The CHCP evaluation emphasized the need for standards in the area of electronic seal design and operation. Currently there is low or no interoperability between seals and readers from various manufacturers. A worldwide frequency with adequate bandwidth for future container security systems would ensure future interoperability (Science Applications International Corporation [SAIC], 2003).

Among the more significant recommendations from the CHCP test is that future systems should focus on the security of the entire container rather than just on sealing the doors. This recommendation was based on the finding that intermodal containers are compromised not only with the opening of the doors, but also by being removed from the container entirely, or by having one of the walls cut through.

In addition to e-seals—and often in tandem with them—other sensors have been evaluated to detect container and trailer intrusion. These sensors are used to detect unusual changes in light levels (optical sensors), vibration characteristics (sonic sensors), and even pressure levels within containers and trailers. Results to date indicate that such devices are technically capable of measuring conditions that may be predictive of an open door event; however, questions remain about whether these devices offer sufficient operational usefulness to be a practical part of a comprehensive security solution.

According to the combined results of the studies examined for this review, environmental factors appear to have the greatest effect on the reliability of e-seals. The primary environmental factors affecting seal performance are the line of sight from reader to the seal, the distance between the reader and the seal, and RF interference (SAIC, 2003).

One alternative to RF seals that has been evaluated is the contact memory seal. Contact memory e-seals require a worker to physically touch the seal with a reading device (typically some sort of wand) to collect data. The major advantages of contact seals are significantly lower costs for the seal and the reader, reduced fixed infrastructure, and greater reliability in reads. The tradeoff is significantly increased labor costs, since an individual must manually touch the reader to the seal. The evaluation of the device showed that in terms of data functionality and security provided, there is no difference between the contact memory and RF solutions.

3.2.2.12 Remote Vehicle Disabling Systems

Remote vehicle disabling systems offer another approach to cargo theft prevention, by preventing the unauthorized movement of the vehicle power unit. Theoretically, remote disabling allows the driver or other authorized user to prevent the vehicle's engine from starting, prevent movement of the vehicle, or stop or slow an operating vehicle. This type of system may use a variety of wireless technologies, including RFID and on-board computer technologies that incorporate GPS, satellite, or digital cellular communications.

3.2.2.13 Untethered Trailer Tracking Systems

Untethered Trailer Tracking systems provide trailer identification, location, and status updates for commercial motor vehicle carriers to track and manage their assets. Untethered Trailer Tracking systems, by virtue of their ability to monitor trailer or container location and movement, may also contribute to a cargo theft prevention program or system. Current deployments of this type of system have varying capabilities and are constrained by the battery life of the active or passive transponder or other communications device on the trailer. This type of system also uses a variety of technologies, including GPS, satellite, or digital cellular communications, and RFID.

3.2.2.14 Roadside Safety Inspection Systems

Roadside safety inspection systems provide electronic interchange and processing of vehicle and carrier status data with computer and communications systems used by law enforcement agencies responsible for commercial vehicle safety. Such systems commonly include, at some level, interactive data exchange between a motor carrier, commercial vehicle, driver, roadside safety inspection stations, and Government agency information systems.

3.2.2.15 Inspection Station Bypass Systems

Motor carrier efficiency is improved whenever the number of stops or delays is minimized from origin to destination. The Government's responsibility to ensure highway safety and regulatory compliance mandates that it stop commercial vehicles at roadside safety inspection stations. Motor carriers that consistently comply with Government safety and regulatory requirements can participate in programs that allow them to bypass roadside safety inspection stations or weigh stations and only stop periodically for random checks. Compliant motor carriers are rewarded by reducing the number of non-shipping-related stops in their route.

Wireless technology has played a central role in the implementation of these bypass programs. RFID is the primary enabling technology. A transponder is mounted inside the truck and readers are installed along the roadway upstream from the safety inspection stations. Indicator lights on the transponder signal the driver to bypass or pull into the inspection station, based on a risk assessment performed within the screening system employed by the screening authority. Such RFID-based bypass systems have been in use for a number of years and are currently deployed in 35 states (HELP, Inc., 2006).

3.2.2.16 Wireless Commercial Vehicle Operations (CVO) Safety Information Exchange Systems

Further application of wireless technology within the roadside safety inspection facility includes safety information exchange between law enforcement and safety and credentials administration agencies. While not directly correlating with a motor carrier's efficiency, an indirect relationship exists between the efficiency of the law enforcement activity at the inspection station and the amount of time a commercial vehicle is retained at the station for inspection and/or credentials verification.

The deployment of technology for this purpose is in limited use. For example, the State of Connecticut has deployed more than 70 specially equipped laptop computers, or mobile data terminals. This equipment is comparable in capability to the systems installed at the state's fixed-site weigh stations, and gives the mobile officer the same information exchange capabilities as the officer at the fixed station. All network connections to and from the mobile data terminals in the patrol vehicle and the fixed station sites use wireless cellular digital packet data (CDPD) modems for communication between their system and the Connecticut Department of Motor Vehicles Communication Server (USDOT, 2004; I-95 Corridor Coalition, 2002).

3.2.2.17 Virtual Compliance Stations

A number of efforts have been undertaken, both in the United States and beyond, to apply various forms of wireless communications technology to roadways not currently served by traditional weigh and inspection stations. Typically, these involve the use of remote monitoring schemes involving cameras and/or weigh-in-motion (WIM) scales.

One form is to use video to monitor trucks on routes that bypass fixed inspection sites. Using vehicle characteristics, identification markings, and operating parameters, authorities can make a determination as to whether enforcement personnel should be dispatched to intercept vehicles to perform manual inspections. This is currently being done in Florida and Kentucky.

In Indiana, tests have been conducted on a system that relies on a WIM equipped with a wireless transmitter and camera that send data in real time to a patrol car. If a potential violation is detected, the patrol car is dispatched to escort the vehicle in question to a pull-off location where it can be weighed using a certified scale (Rodier et al., 2005). In Saskatchewan, Canada, enforcement officials examined the use of a system that consisted of a WIM scale, a license plate reader, a side capture camera, and an RFID reader. The intent is to enable the verification of weight, dimension, and credentials compliance remotely.

3.2.2.18 Electronic On-Board Recorders

In addition to their functionality as fuel management devices, EOBRs have been in use by commercial fleets to replace paper driver logbooks. Often referred to as electronic logs because of the purpose for which they are predominantly used, these systems can be add-on modular features or integrated into the underlying wireless on-board solution a fleet chooses to use.

EOBRs typically offer a way to store data obtained from various vehicle sensors and transmit them to an off-vehicle location, such as a trucking company dispatch operation. Although much remains to be resolved regarding any Government requirements for capture and use of the data, carriers are already realizing benefits.

EOBRs have been studied for several years by the Federal Government in conjunction with HOS rule revisions. A new and separate notice of proposed rulemaking was published for EOBRs for HOS compliance. Through this notice of proposed rule making, issued in January 2007, FMCSA sought input from the motor carrier and technology communities to update its understanding of the current capabilities of on-board recording devices and EOBRs. The proposed rulemaking indicates that consideration will be given to wireless communications capabilities that are now commonly integrated into automated on-board recording devices. Impacts of EOBRs and any associated usage requirements on motor carrier safety and efficiency will be determined after implementation of the new rule (USDOT, 2007b).

3.2.2.19 Remote Vehicle System Sensors

Remote vehicle system sensors come in various types and perform a variety of functions. The common thread is the use of handheld or infrastructure-based "interrogation" devices (i.e., readers) to capture instantaneous condition information from one or more vehicle components without performing a physical inspection.

One study evaluated an Infrared Screening Inspection System (IRISystem) used to check CMVs for brake problems. The technology used infrared cameras housed in mobile vans to monitor traffic entering and passing highway weigh stations. The cameras were able to detect temperature variations in truck wheel and brake components as heat friction was generated from brake applications (USDOT, 2000).

The test took place in four states over a period of one year. The system was placed at weigh station entry ramps, and screened trucks as they passed by. Trucks that were screened with the system underwent safety inspections after screening. The results from the test indicated that approximately 59 percent of vehicles identified as problematic by the infrared IRISystem were placed out of service after a subsequent Level 1 brake inspection. Eighty percent of these vehicles had brake problems (USDOT, 2000).

One manufacturer of commercial vehicle systems has developed and is currently selling a wireless tire pressure sensor. The system provides real-time tire-pressure monitoring via RFID technology. Sensors attached to the wheels via metal bands send signals to a wireless gateway receiver. The sensors record and store the data, along with transmitting them to an in-dash display for the driver to see.

3.2.2.20 Summary of Program Element Applications

The following table summarizes the program element applications discussed in the previous sections. Each of the applications is described according to the following table columns.

- **Functional Area—**Program element functional area.
- **Description—**Briefly explains what the systems in the subject functional area are expected to do within a motor carrier's operation.
- **Systems and Applications—**Examples of current and emerging systems used within the functional area, including wireless hardware, systems, and integrated, ancillary, or supporting hardware and software.
- **Supporting Technologies—**Current and emerging supporting wireless technologies used by the systems and applications in the systems and applications column.
- **Critical Data Elements—**Critical data elements include, but are not limited to, the basic data and information exchanged by the components of the wireless system.
- **Assessment of Suitability—**Brief assessment of the degree to which this wireless system and/or supporting wireless technology can provide data for new applications.

Table 14. Summary of Program Element Applications

Functional Area	Description	Systems and Applications	Supporting Technologies	Critical Data Elements	Assessment of Suitability
Fuel Monitoring and Operations Management System	Monitor, record, report, and electronically control various vehicle systems to improve vehicle and driver safety, and improve vehicle and driver management, security, performance, and fuel efficiency.	On-board computer and communications (fleet management) systems, Electronic Tacograph, ECM (J1708, J1939) interfaces and Data Link devices, and sensors, Vehicle & Driver Safety Systems	Established: RFID, Digital Cellular, Satellite, GPS; Emerging: UWB, Zigbee®	Date, time, vehicle location, vehicle speed, engine operation and condition data, brake application data, engine idle data	Opportunities appear to exist to expand the potential benefit of fuel monitoring and operations management applications by linking them wirelessly with motor carrier office operations. Safety benefits of wireless applications that assist the driver have potential to improve operational safety. The need for continuous-position data limits technologies to those with the faster data transfer rates to support real-time requirements. For business operations, modest bandwidth and data transfer rates, and the need for only periodic (as opposed to real-time) downloads, suggest that several technologies would be capable.
Electronic Manifest Systems	Exchange cargo manifest, bill of lading, billing data electronically to improve accuracy and expedite data exchange.	Customs and Border Protection ACE System—Transponders, Reader Infrastructure, and Web Portal Software (also includes third-party providers of back-office supporting software)	Established: RFID, cellular network, Wi-Fi	Harmonized electronic freight management (EFM) data elements; supporting data elements associated with FIH programs: International Trade Data System, ACE, FAST, Commercial Vehicle Information Systems and Networks (CVISN), and other Advanced Transportation Information Systems	Opportunities appear to exist to enhance the value electronic manifest applications by linking them wirelessly with back-office operations, and to other supply chain partners. Modest bandwidth and data transfer rates, and the need for only periodic (as opposed to real-time) downloads, suggest that several technologies would be capable.

Functional Area	Description	Systems and Applications	Supporting Technologies	Critical Data Elements	Assessment of Suitability
Cargo Theft Prevention Systems	Monitor, record, report, and electronically control security of cargo in trucks, trailers, and containers.	Cargo Container Seals, Vehicle Disabling Systems, Tractor and Untethered Trailer Tracking	Established: RFID, Satellite/GPS, Cellular Network; Emerging: UWB, Zigbee®	Vehicle identification, location, seal status	The technical demands for cargo theft prevention systems will vary based upon the reporting frequency (i.e., constant monitoring vs. exception reporting) and intervention method. Data rates, total coverage, power storage, communications standards, and environmental hardening requirements will be different for different applications (e.g., domestic only vs. international, tethered vs. untethered). New technologies offer new opportunities.
Roadside Safety Inspection Systems	Provide electronic interchange of driver, vehicle, and carrier status data with roadside safety inspections systems.	Inspection Station Bypass Programs, Law Enforcement Mobile Data Terminal Systems	RFID, Digital Cellular; Emerging UWB	Required state and Federal carrier identification numbers, driver identification, vehicle identification, vehicle operating parameters and component status	RFID has served well in supporting exchange of documentation, but may not have the bandwidth or store and forward capabilities necessary to communicate vehicle component status. Other wireless technologies appear to offer the necessary capabilities, but will likely be more expensive to implement and use. Low cost will be important.

3.2.3 Proposed MCES Technology Applications

The sections that follow offer several ideas for applying wireless technologies to address the key motor carrier inefficiencies identified in Section 1 of this report. Within the description of each potential solution is the content of the discussion(s) held with industry representatives. Any characterizations regarding the ability of the solution to meet all of the needs intended, and to represent a viable commercial solution, reflect the thoughts expressed by the stakeholders. A summary technology viability analysis is provided in Section 3.2.4, with a full viability analysis detailed in Section 7 of the Task 4 Inefficiencies Report.

3.2.3.1 Virtual Queuing

The inefficiency most often cited at the MCES Stakeholder Sessions was that of drivers waiting to retrieve a load at a shipper location or to drop a load at a consignee facility. According to carriers consulted during the study, these delays are often the result of facility operators seeking to optimize their own operations. For example, consignees often schedule deliveries in such a manner that a queue of several trucks is waiting to be unloaded at any given time. This ensures that receiving personnel are working nearly continuously, thereby maximizing the productivity of their operations.

Carriers indicated that one possible solution might be to use wireless tracking technologies, in association with technology that would allow for accurate estimation of travel time for each inbound truck, to construct a “virtual queue.” Using such a system, consignees would be kept apprised of the estimated arrival time of each inbound load, and could dynamically reschedule dock operations to compensate for delays due to congestion, traffic incidents, or delays in a truck’s departure from the shipment origin. Such a system might operate in a manner similar to an air traffic control system, though with less complexity, and theoretically at a lower cost.

3.2.3.2 Driver Acuity Monitoring

The latest operator hours-of-service regulations, when coupled with the various pick-up, delivery, and travel delays experienced by drivers, present some significant challenges for certain segments of the carrier community. This travel-time uncertainty forces some carriers to shorten routes or risk having drivers run out of HOS before the completion of a trip or set of trips. Additionally, the accrual of service hours by drivers while not driving is seen by some carriers as a significant source of operational inefficiency.

One option that appeals to at least a portion of the carrier community that engaged in the Stakeholder Sessions is that of a wirelessly enabled driver-acuity monitoring capability. With such a system, a carrier could remotely monitor driver behavior characteristics indicative of fatigue (e.g., steering inputs, unsignaled lane departures, head nodding, erratic speeds, etc.), and adjust the remaining HOS accordingly. With such a system in use, drivers who are alert and operating safely would be permitted to continue to drive, perhaps beyond the pre-defined limits, and those exhibiting signs of fatigue would be instructed to stop and rest, even if they had not yet reached the statutory limit on HOS.

3.2.3.3 Variable Speed Limiter

Excessive speeds are considered enough of a source of inefficiency by carriers that many have installed vehicle speed governors on their trucks. Doing so allows carriers to enhance both safety and efficiency, and in many instances, to receive more favorable rates for insurance. Unfortunately, systems developed to date prevent the carrier from altering the maximum speed to accommodate for changing conditions without returning the truck to a maintenance facility. The result is a fixed maximum speed limit that does not take into account factors such as differences in posted speed limits on highways in different states, neither does it allow for the maximum speed to be lowered when a truck is operating on a secondary road, or in the event of inclement weather.

A Variable Speed Limiter would allow the carrier to employ wireless communications to alter the maximum speed remotely, based on any combination of factors deemed appropriate by the carrier. Additionally, it could be equipped with a geographic referencing capability tied to a database of posted speed limits, and as a truck passed from one zone to the next, the speed governor would be adjusted automatically, perhaps after warning the driver that the adjustment was about to take place. Finally, the system could be tied to weather and traffic report information, and the maximum speed could be adjusted to reduce the likelihood of a crash.

3.2.3.4 Border Crossing Compliance Notification

The frequency and severity of delays at international border crossings have been the subjects of various studies, and the impetus for the test and deployment of a number of technology-based solutions. Most of these efforts have focused on reducing the delays associated with processing through the import vehicle, cargo, and driver compliance verification process managed by the CBP. They include transponder-based pre-screening programs that allow shippers to pre-file paperwork with CBP, and to have that filing evaluated in advance of the shipment reaching the border. For shipments for which all paperwork is in order, including that for the carrier and driver, processing times can be shorter, thereby saving costs associated with shipment delays.

However, because the carrier is not the filing organization (this is typically handled by a licensed customs broker), the carrier and its drivers don't know whether the paperwork is in order before reaching the border. When it isn't in order (e.g., missing information, processing incomplete, etc.), the driver and shipment must stop at the border facility, and either wait for the processing to be completed, or interact directly with a CBP inspector to rectify any paperwork issues. The result is delay and truck queuing at the border.

Carriers consulted during the study indicated that an application that made information on pre-screening status available before a driver arrived at the border has the potential to significantly reduce delay and queuing, which would also likely reduce idling and improve safety. This capability would involve capturing processing status information from CBP and relaying it wirelessly to the driver, perhaps through the carrier's dispatch operation.

3.2.3.5 Truck-Specific Congestion Avoidance

Roadway congestion remains one of the most significant, most frequently mentioned sources of inefficiency within the carrier community. With overall traffic volumes, and freight volumes in particular, expected to continue to grow at a greater rate than the capacity of the network, it is anticipated that the amount of delay associated with congestion will also increase. The carriers consulted for this study understand that the primary issues that affect the rate of capacity growth are fiscal, rather than technical. They did indicate, however, an interest in examining the degree to which technology might reduce the negative effects of congestion related to incidents, construction, and special events.

With the increasing availability of in-vehicle navigation systems that incorporate traffic information, carriers are expressing a renewed interest in obtaining similar capabilities that cater specifically to the trucking community. Through a wireless link to existing traffic information, such an application would allow drivers to receive traffic data that are of particular applicability to their operations, and in the event that alternatives exist, to receive truck-specific alternate routing information. Such information would be useful in reducing the likelihood that a driver would take an alternate route that features insufficient clearances, bridge weight ratings that are too low, or roadway geometry that would be difficult to navigate with a tractor-trailer combination.

3.2.3.6 Chassis Roadability Notification

Carriers that provide intermodal transportation services—particularly those that retrieve containerized cargo in seaports—continue to struggle with problems associated with intermodal chassis. Specifically, the frequency with which chassis fail driver walk-around inspections and/or are put out of service by safety enforcement personnel is an ongoing source of inefficiency. This is considered important by carriers regardless of which party (carrier or chassis owner) is ultimately responsible for the payment of fines and the remediation of chassis deficiencies.

This technology opportunity would provide a means for drivers to wirelessly access chassis maintenance data and inspection history upon entering a storage facility or terminal. Using a simple interface, such as a cellular telephone, the driver would enter the chassis number into a query system to obtain information that might lead him/her either to retrieve an alternate chassis, or to focus additional attention on a certain component or subset of components that had not been recently serviced. In addition to providing this information in incoming intermodal drivers, such a system would provide useful data to terminal hostler operators and chassis maintenance personnel. Hostler operators could avoid positioning chassis of questionable maintenance history for mounting of containers, and maintenance personnel could wirelessly access maintenance records to assist in zeroing in on the identification of problems.

3.2.3.7 Cross-Town Intermodal Interchange

The exchange of freight between intermodal facilities often occurs between terminals located in and around congested urban areas. Much of this interchange activity is conducted using trucks to ferry containers, intermodal chassis, and trailers between rail heads, or between ports and rail heads. These entities support goods moved for a variety of different supply chains that may be individually well-coordinated, but in situations in which little or no coordination exists regarding the back-and-forth moves between facilities that are necessary to keep the freight moving. The result is an overabundance of one-way moves, and a measurable percentage of empty moves (e.g., bobtail trucks and empty chassis and containers). In major freight centers, such as Chicago, Long Beach, Seattle, New York/New Jersey, Jacksonville, Miami, and Kansas City, these "cross-town" moves are a significant contributor to congestion, and a significant source of inefficiency and safety effects.

One wireless-technology-based solution for this situation has been identified, and has been defined and developed to a degree by the Federal Highway Administration and industry and Government partners. Called the Cross-Town Improvement Project (C-TIP), it applies a combination of wireless technology and coordinated operating practices among railroads, motor carriers, and public agencies (e.g., planning organizations, State DOTs, first responders, freight economic development entities, etc.) to reduce empty trips, reduce congestion-related delay, and improve safety and the environment.

Initial analysis has been completed for C-TIP using the FTAT, and some of the data provided in later sections of this report come from that effort. This initiative has been under development for some time (since early 2005), and is currently seeking funding for deployment of a prototype in the Kansas City, Missouri area.

3.2.3.8 Untethered Trailer Tracking

Previous sections in this report refer to a technical viability test that FMCSA conducted on Untethered Trailer Tracking systems. The results of that analysis suggest that significant potential exists to reduce theft and pilferage using such systems. However, the referenced test stopped short of examining the operational benefits at a detailed level.

Therefore, an opportunity exists to expand the body of knowledge regarding the effects of a broad deployment of such systems. Specific, situational information regarding return on investment is critically important to decision-makers considering investment in systems in price ranges that exceed $1,000, such as the system examined during the FMCSA test. Provided with such information, fleet owners would be able to make more informed decisions regarding the deployed value of such systems.

3.2.3.9 Additional Wireless Solutions

The preceding sections contain several ideas that have been discussed at some level among various carrier stakeholders throughout the project. They do not, however, represent the universe of possibilities for applying wireless technologies to address inefficiencies. As the project progresses, and these ideas and others are more thoroughly examined, new opportunities are likely to emerge, and current ideas will probably evolve or be eliminated as too costly, too complex, or inadequate to address the needs of the carrier community.

New opportunities may emerge from several different sources. The project team (which includes the Study Team and the Government) may become aware of applications that are either in use in a different environment, or were in early research and development phases at the time this report was completed, and information was scarce or unavailable. One such example is the FHWA's Electronic Freight Management (EFM) program, and the application of its principles of standardized transmission of shipment information among supply chain partners, as is being demonstrated under the C-EFM pilot project.

3.2.4 Technology Viability Analysis

Based upon suggestions and feedback from the stakeholders, the Study Team was able to formulate concepts for seven different technology applications that might at least partially mitigate the effects of the identified inefficiencies. An eighth option—the expanded evaluation of an Untethered Trailer Tracking solution—constitutes a more thorough examination of existing capability and is included for completeness.

Though not an exhaustive list, these applications may stimulate discussion during subsequent tasks, and yield a more comprehensive set. These applications are:

- Virtual Queuing
- Driver Acuity Monitoring
- Variable Speed Limiter
- Border Crossing Compliance Notification
- Truck-Specific Congestion Avoidance
- Chassis Roadability Notification
- Cross-Town Intermodal Interchange
- Untethered Trailer Tracking

A viability analysis undertaken by the Study Team yielded useful information regarding the relative opportunities and challenges associated with pursuing pilot demonstrations for each of these concepts. At a high level, each has merit, and each has challenges. The Study Team constructed a subjective, comparative rating scale based on an initial analysis according to a number of issues:

1. Does the inefficiency being addressed represent a major inefficiency identified by the motor carrier community and documented by both the literature and the representative stakeholders?
2. Do the inefficiency and potential solution have implications for more than one stakeholder across a single supply chain?
3. Does the concept represent a reasonable means for FMCSA to be involved (i.e., standardization is involved; smaller carriers would not undertake research and development to extract value; and/or it supports underserved segments of the market) and, as a measure, does it reasonably align with FMCSA's goals and objectives?
4. Is there an evident or conceivable wireless-based solution that is NOT already commercially available (Literature Review, Government project team, and ERG, additional technology-industry expert discussions)?
5. Will the effects of solutions be quantifiable and assignable to a source (needs to be isolated so that information can be measured)?
6. Does the concept realistically align with one or more program element areas?
7. Does the potential exist for opportunities to exploit other research and development efforts?

Table 15 reveals the results of that viability analysis. The ratings in each of the columns indicate the following:

- A rating of "H" indicates that the concept rates "High" in the particular category, meaning that it fully meets the criterion.
- A rating of "M" indicates that the concept rates "Medium," which means it partially meets the specific criterion.
- A rating of "L" indicates that the concept rates "Low" with respect to the stated criterion.

Table 15. Project Concept Viability Analysis

Project Concept	Technically Viable?	Operationally Appropriate?	Institutionally Plausible?	Addresses Major Inefficiency?	Has Broad Implications?	Warrants FMCSA Involvement?	No Current Solution Exists?	Has Quantifiable Effects?	Aligns with a Program Element?	Leverages Other Research?
Virtual Queuing	M	H	M	H	H	H	M	H	H	M
Driver Acuity Monitoring	H	M	L	H	M	H	H	M	H	M
Variable Speed Limiter	H	M	M	H	H	H	M	H	H	H
Border Crossing Compliance Notification	H	H	M	H	H	M	H	H	H	M
Truck-Specific Congestion Avoidance	M	M	M	H	H	M	M	M	H	M
Chassis Roadability Notification	M	M	M	H	M	H	H	M	H	M
Cross-Town Intermodal Interchange	H	H	M	H	H	M	H	H	H	H
Untethered Trailer Tracking	H	H	M	H	H	M	L	H	H	H

The extensive interaction with motor carrier representatives indicated that there truly are a small number of very-high-priority efficiency-related concerns among carriers. Not surprisingly, the majority of these issues relate to inefficiencies that prevent carriers from extracting the greatest productivity from their on-road assets—their trucks and their drivers. Motor carriers that participated in the Study Team's data collection effort consistently considered waiting for loading and unloading, whether at a customer facility or an intermodal terminal, to be the highest-priority inefficiency. Of the other inefficiencies mentioned by motor carriers, many represented variations on the theme:

- Paperwork delay at international border crossings.
- Processing delay at international borders.
- Waiting at weigh and inspection stations.

- Congestion-related delay.
- Lost time due to routing problems.

Based on the findings of this portion of the MCES, it would appear that wireless technologies that can significantly enhance situational awareness have the potential to mitigate many of these inefficiencies. It follows that wireless systems that promote that enhancement would be of some value to motor carriers experiencing these inefficiencies.

The results of the viability analysis offer some useful considerations for pursuit of the various options. First, only two "L" ratings were assigned. One was given to the Driver Acuity Monitoring concept because a significant amount of uncertainty exists regarding the plausibility of replacing or supplementing prescribed regulatory safe operating limits with a form of performance monitoring. This would likely represent a very difficult institutional issue to resolve, particularly given the sensitive nature of the HOS topic. The technical complexity of such an undertaking is also reflected in the preponderance of "M" ratings for this application. The combined ratings for this concept indicate that it may be a good topic for continued research, but that a pilot demonstration may be some time off in the future. The second "L" was given to the Untethered Trailer Tracking concept because several commercially available solutions exist, and commercial research and development may be a preferable method to one involving the Government.

At the other end of the viability spectrum is the Variable Speed Limiter concept. It addresses specifically identified safety and efficiency needs, the basic capability of limiting speed based on designated speed limits would appear to be relatively practical to implement (adding a roadway condition monitoring element would be more difficult), and it aligns very well with FMCSA and industry goals.

The Cross-Town Intermodal Interchange concept also rates favorably. Its consistently positive ratings reflect primarily the level of development that the concept has already undergone as a project under the FHWA's Intermodal Freight Technology Working Group. It not only has been technically defined, it has broad industry and Government support.

Perhaps one of the more difficult concepts to rate is the Truck-Specific Congestion Avoidance application. While stakeholders agree that congestion is a serious challenge, research to date suggests that quantifying its specific effects and implementing a practical solution that addresses them in a significant way are objectives that are likely to remain difficult to accomplish.

The rest of the concepts, Virtual Queuing, Border Crossing Compliance Notification, and Chassis Roadability Notification, require the collaborative efforts of multiple supply chain stakeholders, some of which may be difficult to bring into a partnership necessary to implement a meaningful solution. CBP, chassis owners, and shippers and receivers have not been consistently active participants in previous research efforts to improve carrier efficiency; however, each of these concepts has the potential to offer capabilities that align well with the operations of those stakeholder groups. As a result, each offers promise for creative solutions to high-priority carrier needs.

3.3 RECOMMENDED ANALYSIS SCENARIOS

At a high level, the nature of responses captured during the Stakeholder Sessions and supplemented by discussions with carrier representatives suggests that there truly are a small number of very-high-priority efficiency-related concerns among carriers. As mentioned earlier, the majority of these issues are centered on inefficiencies that prevent carriers from extracting the greatest productivity from their on-road assets—their trucks and their drivers. Likewise, carriers feel comfortable with only a limited number of wireless technologies, noting that complex applications can actually add to operational inefficiencies.

The technology concepts analyzed were linked to the motor carrier inefficiencies summarized in Section 1 and were developed based on the wireless technologies reviewed. The Study Team concluded that:

- Applications that address waiting for loading and unloading, waiting in ports, and empty intermodal moves provide opportunities to address problems that are probably too institutionally complex for carriers to resolve without the unifying, objective assistance of Government.
- Similarly, a Border Crossing Compliance Notification application would address a significant ongoing problem and would effectively require Government intervention and assistance.
- Finally, a variable speed limiting application, though seemingly attainable without government involvement, might benefit from accelerated development and deployment if Government were to recognize the safety benefits of such a tool and implement incentives for its adoption and use.

The scope of work for this study allows for the execution of a BCA of a total of 10 different scenarios. Each scenario consists of a specific supply chain segment, a type of inefficiency, and a potential solution. These analyses are intended to address demonstrated, high-priority inefficiencies that affect a significant portion of the domestic carrier population. Hence, the final set of scenarios must offer stakeholders—both public and private sector—a sampling of the type and magnitude of improvements that might be realized through the deployment of the proposed solutions.

To accomplish this, industry stakeholders must be able to identify with the inefficiencies in the context of day-to-day operations. With this consideration in mind, the Study Team recommended that the BCA be conducted for the scenarios identified in Table 16, below:

- **Scenario 1:** Border Crossing Compliance Notification for the International Border Supply Chain Segment to address the inefficiency of paperwork delays at the border.
- **Scenario 2:** Border Crossing Tracking Compliance for the International Border Supply Chain Segment to address the inefficiency of border processing delays.
- **Scenario 3:** Virtual Queuing for the Port To Inland Destination Supply Chain Segment to address the inefficiency of waiting times in container ports.

- **Scenario 4:** Chassis Roadability Notification for the Port To Inland Destination Supply Chain Segment to address the inefficiencies of waiting times in container ports and vehicle safety.
- **Scenario 5:** Truck-Specific Congestion Avoidance for the Closed-Loop Pick-Up and Delivery Supply Chain Segment to address the inefficiencies associated with incident-related congestion.
- **Scenario 6:** Virtual Queuing for the Closed-Loop Pick-Up and Delivery Supply Chain Segment to address the inefficiencies associated with waiting for loading and unloading at consignee locations.
- **Scenario 7:** Cross-Town Intermodal Interchange to address the inefficiency of empty trips in the Rail Intermodal Supply Chain Segment.
- **Scenario 8:** Virtual Queuing to address the inefficiencies associated with waiting for loading and unloading at intermodal facilities in the Rail Intermodal Supply Chain Segment.
- **Scenario 9:** Variable Speed Limiter to address the inefficiency of excessive speed in the Long-Haul Truckload Supply Chain Segment.
- **Scenario 10:** Untethered Trailer Tracking to address inefficiencies associated with theft and pilferage in the Long-Haul Truckload Supply Chain Segment.

Table 16. Recommended Analysis Scenarios

Scenario	Supply Chain Segment	Inefficiency	Solution
1	International Border	Paperwork Delay at Border	Border Crossing Compliance Notification
2	International Border	Processing Delay at Border	Border Crossing Tracking Compliance
3	Port to Inland Destination	Waiting Time in Container Ports	Virtual Queuing
4	Port to Inland Destination	Vehicle Safety (crashes, noncompliance)	Chassis Roadability Notification
5	Closed-Loop Pick-Up and Delivery	Incident-Related Congestion	Truck-Specific Congestion Avoidance
6	Closed-Loop Pick-Up and Delivery	Waiting, Loading, and Unloading	Virtual Queuing
7	Rail Intermodal	Empty Trips	Cross-Town Intermodal Interchange
8	Rail Intermodal	Waiting, Loading, and Unloading	Virtual Queuing
9	Long-Haul Truckload	Fuel Waste due to Excessive Speed	Variable Speed Limiter
10	Long-Haul Truckload	Theft and Pilferage	Untethered Trailer Tracking

Scenarios 1, 3, 6, 7, 8, 9, and 10 follow quite logically from the analysis in the report. They address significant inefficiencies in a manner consistent with the criteria identified above. Scenarios 4 and 5 are somewhat less conclusively supported by the findings, primarily due to the challenges associated with quantifying the effects of a wireless implementation and clearly identifying specific functionality that would promote improvement. Finally, the stakeholders did not offer any potential solutions to address the inefficiencies identified for Scenario 2; however, the Study Team developed a proposed technology application based on their knowledge of cross-border tracking regulations for Mexican long-haul and other Customs-Trade Partnership Against Terrorism (C-TPAT) certified carriers.

Note that additional inefficiencies and technology concepts discussed in this report are not listed in the table. This is either because stakeholders did not identify any sorts of applications that would address those inefficiencies, or because they did not score well in the Study Team's viability assessment. It is important to recognize that, as the project moves forward, additional applications may be suggested by the Study Team, the Government project team, or the industry stakeholders that participate in the ERG.

The scenarios described above were subjected to benefit–cost assessments using FTAT, as detailed in Section 1.

4. BENEFIT-COST ANALYSIS

4.1 STUDY METHODOLOGY

Section 1.2 of this report contains a high-level summary of the methodology employed for the BCA of the wireless solutions examined in the MCES. Within that section, the report discusses the application of the numerical analysis components resident in the Freight Technology Assessment Tool (FTAT) to the data obtained from printed and expert sources. The specific sequential actions necessary to execute the BCA are explained in detail in the final Wireless Technology Assessment Report, which may be obtained by contacting the FMCSA Office of Analysis, Research and Technology. The sections that follow provide a summary of these actions is provided for ease of reference.

4.1.1 Using the Freight Technology Assessment Tool

4.1.1.1 Defining and Mapping the Supply Chain

The first step in applying FTAT to analyze the potential benefits and costs resulting from the adoption of wireless technologies is to define and map the supply chain(s) to be studied. As indicated earlier in this report, supply chain segments of five different types were defined generically with the intent to capture supply chains representative of common trucking operations. Input to the FTAT began with the formulation of a partner view for the supply chain segment under analysis. An example for the International Border Crossing Supply Chain Segment is presented in the FTAT screen shot in Figure 13. The partner view is a graphical representation of the business entities being modeled within the tool. This simple example depicts the movement of goods from a pick-up facility to a drop-off facility by a motor carrier.

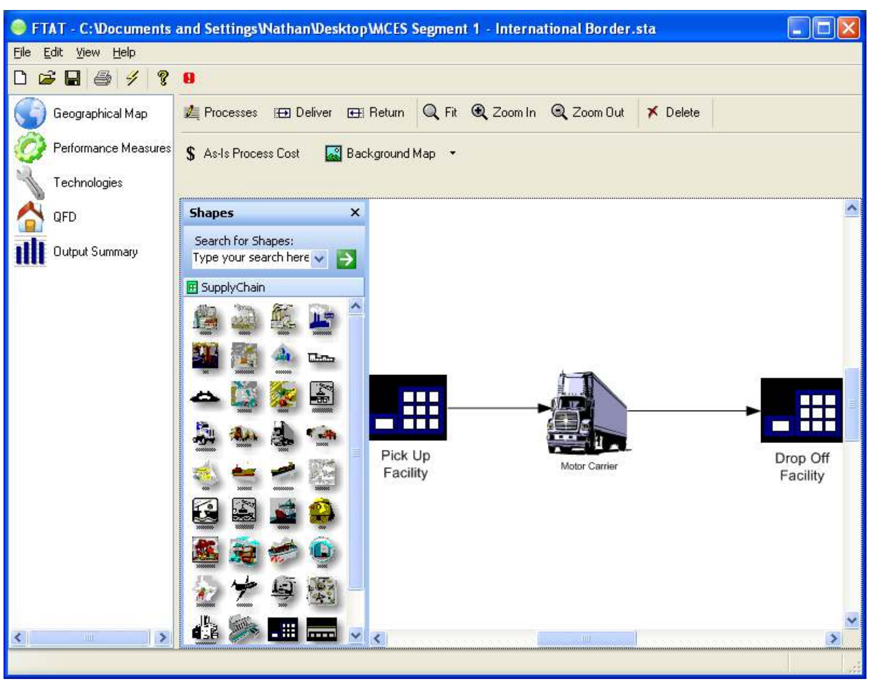


Figure 13. FTAT Screen Shot of Supply Chain Partner View

4.1.1.2 *Modeling the Process, Freight, and Information Flows*

Once the supply chain segments were defined at the partner level, the Study Team decomposed them to show increasing levels of detail. A preliminary set of business processes, freight flows, information flows, and performance measures was defined. The Study Team vetted these processes and the performance measures associated with them with the appropriate motor carrier stakeholders. Figure 14 shows an example of how the processes are modeled in FTAT.

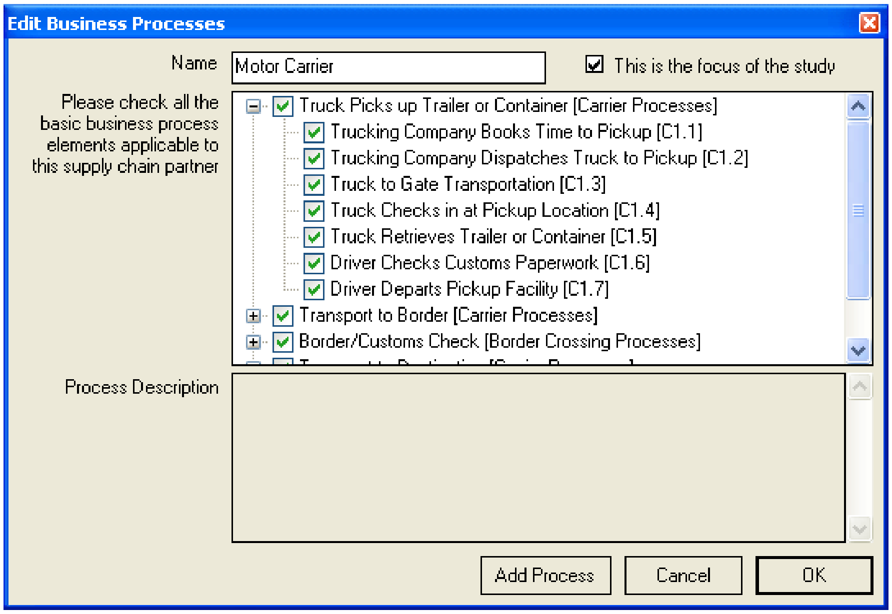


Figure 14. FTAT Screen Shot of Supply Chain Processes

4.1.1.3 *Defining the Performance Measures*

The Study Team defined performance measures using a top-down approach. At the top level the Study Team defined performance attributes. These attributes represent classes or categories to which the lower-level performance measures could be assigned. The four performance attributes defined by the MCES team are safety, security, efficiency, and cost. At the next level, under each attribute, the Study Team defined specific performance metrics. A great deal of attention was given to capturing the relevant performance measures that could potentially be affected by the adoption of the selected wireless solutions. Figure 15, Figure 16, and Figure 17 provide an example of the process of performance measure definition in FTAT.

Figure 15 shows the subset of overall potential performance measures that would be used for the specific supply chain segment analysis under review. Figure 16 shows a screen shot of how an individual performance measure would be assigned to a performance attribute.

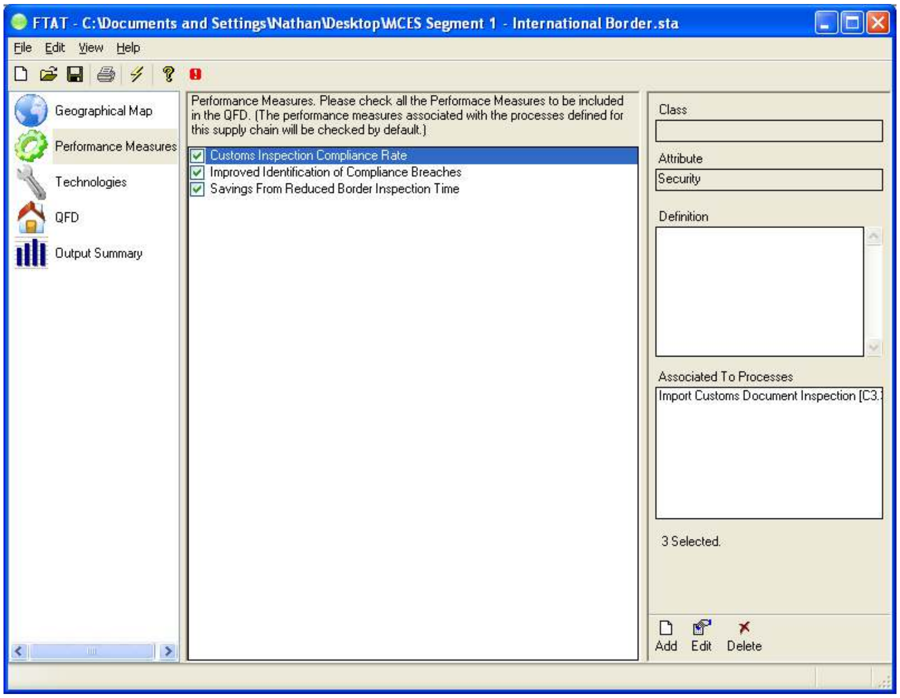


Figure 15. FTAT Screen Shot of Overall Performance Measures

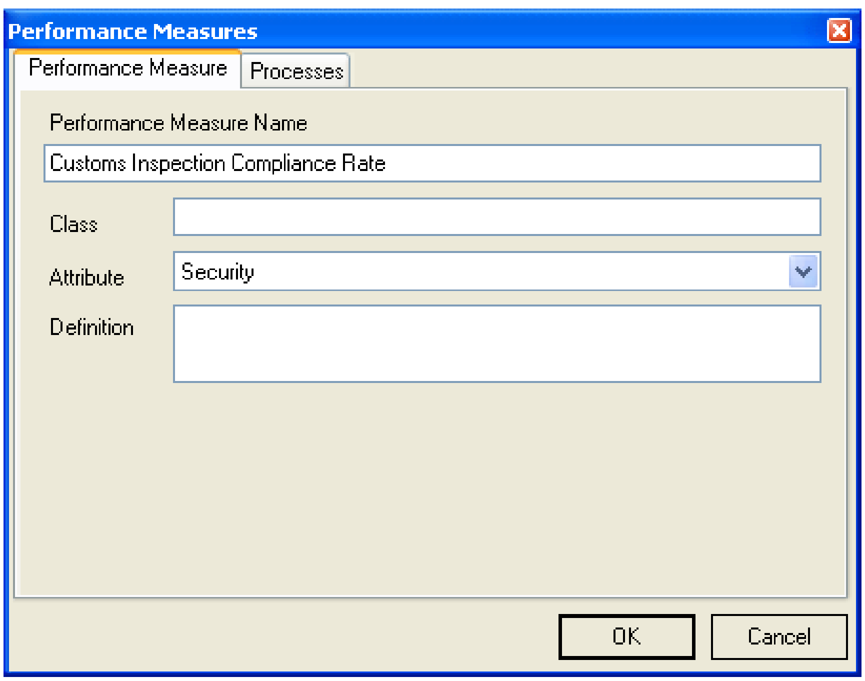


Figure 16. FTAT Screen Shot of Performance Measure Assignment to Attribute

Figure 17 shows a screenshot showing how individual subprocesses are associated with an individual performance measure. In effect, the user selects subprocesses for which the identified performance measure is likely to represent a useful means for evaluating changes to that subprocess.

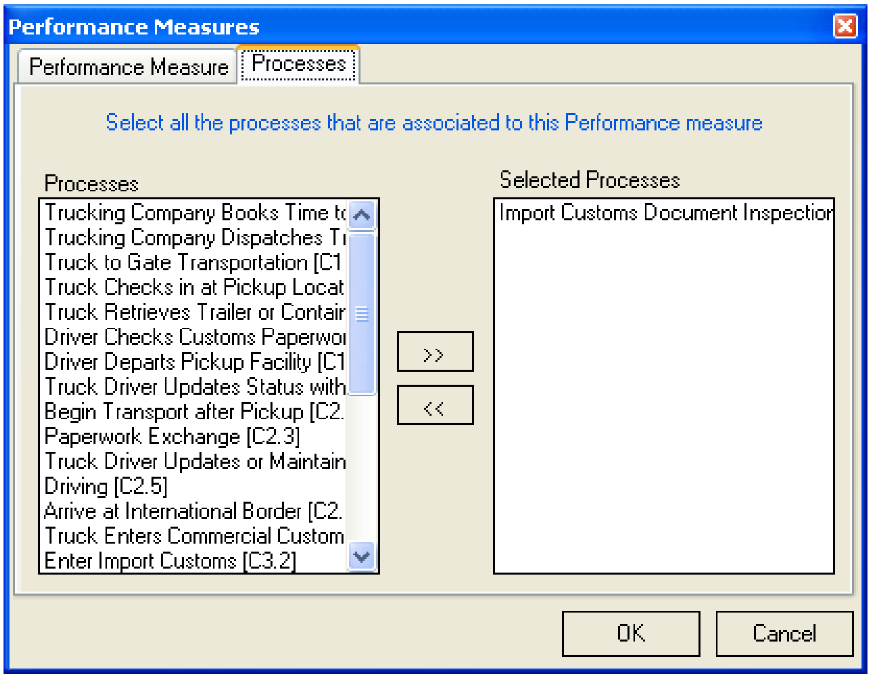
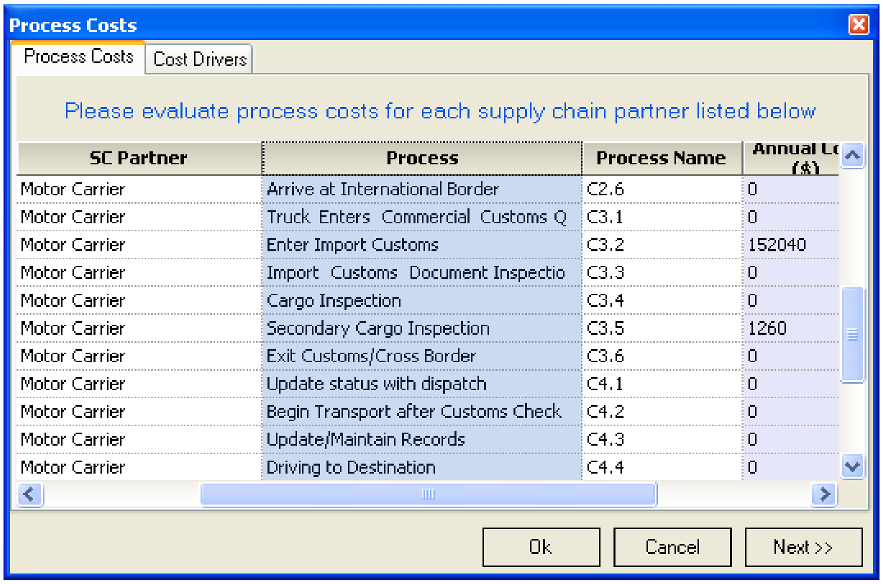


Figure 17. FTAT Screen Shot of Performance Measure Assignment to Subprocesses

4.1.1.4 Generating the Baseline Estimates

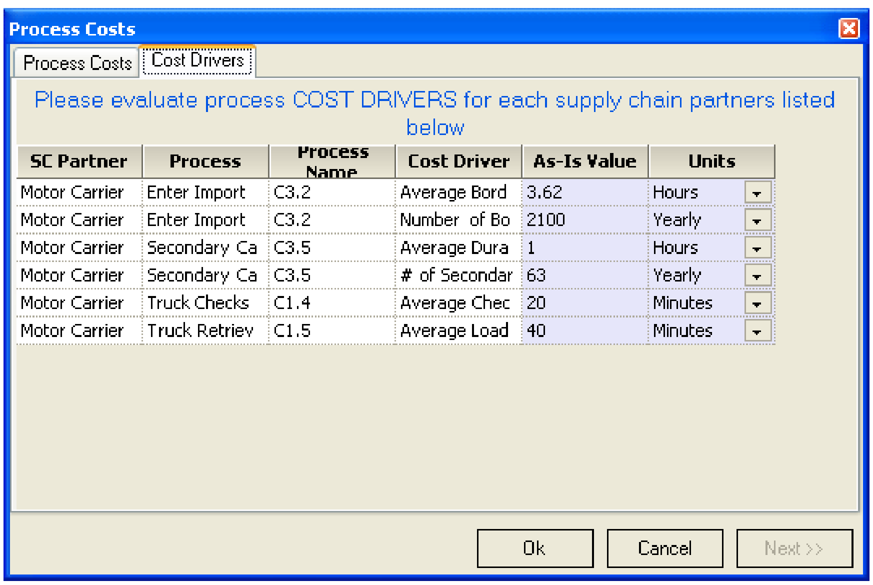
The Study Team then collected the supply chain segment data needed to populate the "as is" case for each of the analytical supply chain scenarios. These data were captured from motor carriers and through the Literature Review. This included the data necessary to build up the process costs, the initial cost driver values, and other data used to characterize the supply chain segments. The screen shots in Figure 18 and Figure 19 depict the "as is" characteristics of the International Border Crossing Supply Chain Segment modeled in FTAT.

Figure 18 shows a summary table of calculated costs for each of the subprocesses identified in the sample supply chain segment. The numbers in the Annual Cost column on the far right are values calculated using the cost driver input values, which are shown in part in the two columns on the right side of Figure 19.



SC Partner	Process	Process Name	Annual Lc ($)
Motor Carrier	Arrive at International Border	C2.6	0
Motor Carrier	Truck Enters Commercial Customs Q	C3.1	0
Motor Carrier	Enter Import Customs	C3.2	152040
Motor Carrier	Import Customs Document Inspectio	C3.3	0
Motor Carrier	Cargo Inspection	C3.4	0
Motor Carrier	Secondary Cargo Inspection	C3.5	1260
Motor Carrier	Exit Customs/Cross Border	C3.6	0
Motor Carrier	Update status with dispatch	C4.1	0
Motor Carrier	Begin Transport after Customs Check	C4.2	0
Motor Carrier	Update/Maintain Records	C4.3	0
Motor Carrier	Driving to Destination	C4.4	0

Figure 18. FTAT Screen Shot of Calculated Process Costs



SC Partner	Process	Process Name	Cost Driver	As-Is Value	Units
Motor Carrier	Enter Import	C3.2	Average Bord	3.62	Hours
Motor Carrier	Enter Import	C3.2	Number of Bo	2100	Yearly
Motor Carrier	Secondary Ca	C3.5	Average Dura	1	Hours
Motor Carrier	Secondary Ca	C3.5	# of Secondar	63	Yearly
Motor Carrier	Truck Checks	C1.4	Average Chec	20	Minutes
Motor Carrier	Truck Retriev	C1.5	Average Load	40	Minutes

Figure 19. FTAT Screen Shot of Cost Driver Input Values

4.1.1.5 Identifying the Wireless Solutions to be Included in the Study

Based on input from motor carriers, the Study Team created a list of inefficiencies detailing the areas in each supply chain segment that were most in need of improvement. During the Task 4 Inefficiencies Study, the MCES team examined the potential for improving each of these inefficiencies through the adoption of various wireless solutions. Once the wireless solutions were selected for analysis, the key characteristics of those technologies were input into FTAT.

This included identifying the technology costs and the processes that the technology could potentially affect. These costs include the required initial investment for equipment or infrastructure, the annual costs associated with operating and maintaining the solution, and the expected useful life of the technology. Examples showing how some of the technology characteristics are captured in FTAT, including basic descriptive information and cost data, are provided in the screen shots in Figures Figure 20 and Figure 21 below.

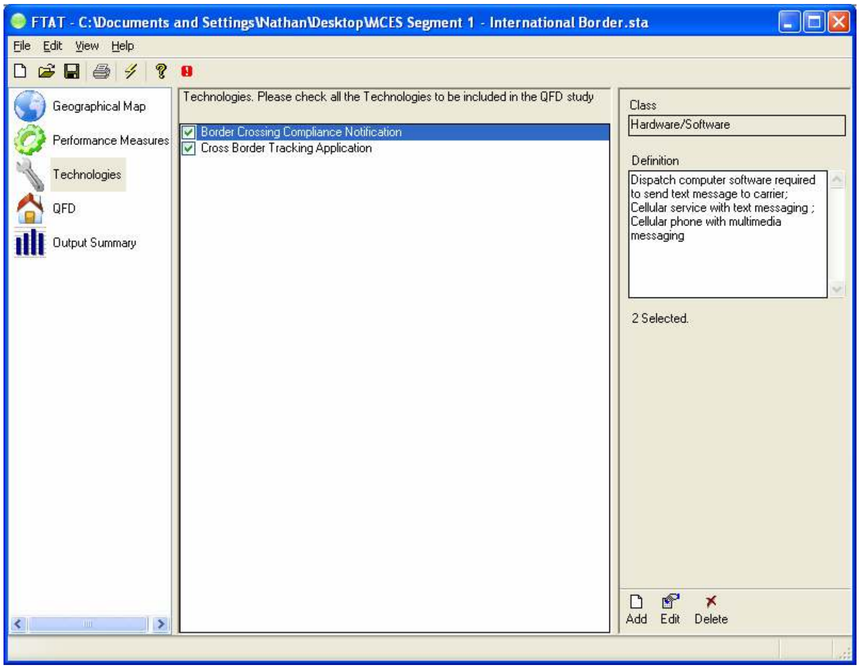


Figure 20. FTAT Screen Shot of Technology Application Listing

Figure 20 shows a summary listing of the technology applications that have been defined for the sample supply chain segment under review. Figure 21 depicts a data entry screen where descriptive information is entered for each of the applications.

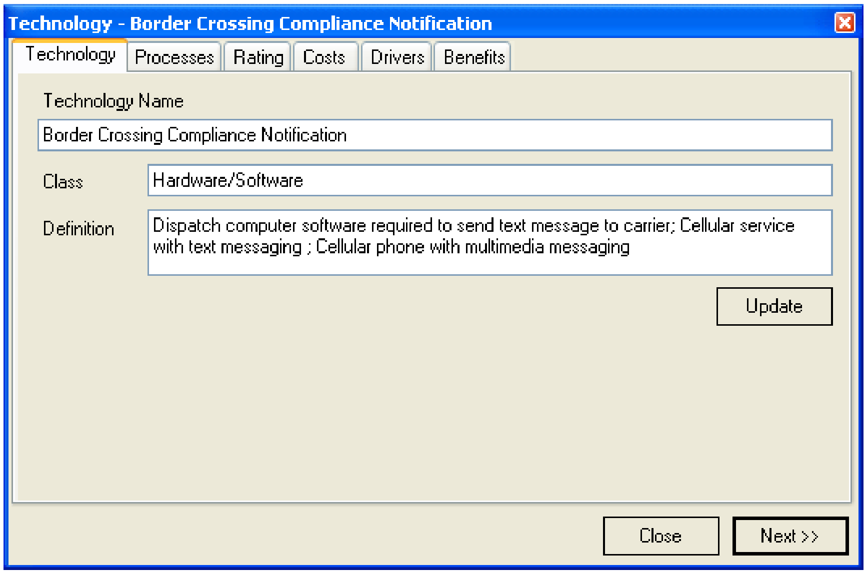


Figure 21. FTAT Screen Shot of Technology Application Data Entry

Figure 22 shows how the FTAT user selects the individual subprocesses that are likely to be affected by the implementation of each of the technology applications.

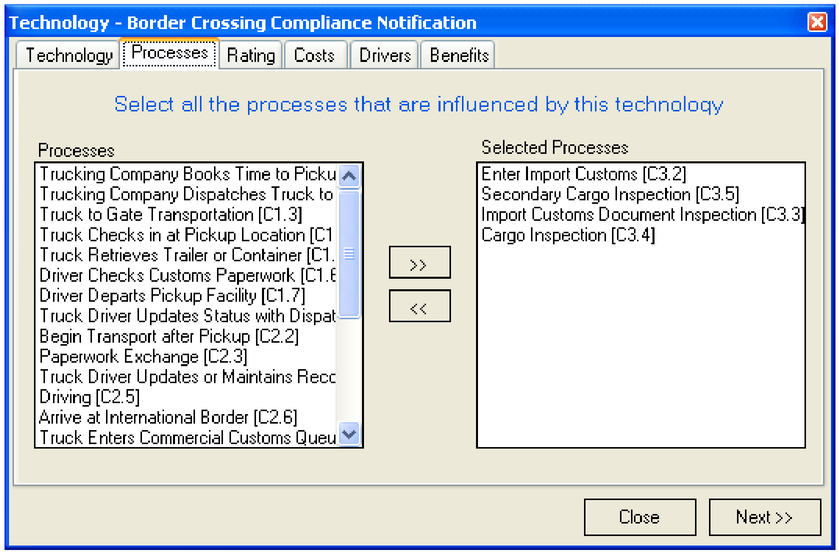


Figure 22. FTAT Screen Shot of Technology Application Assignment to Subprocesses

The final component to defining the technology applications is the input of investment requirements and of the anticipated useful life. Figure 23 shows a screen shot of the data entry screen for this input.

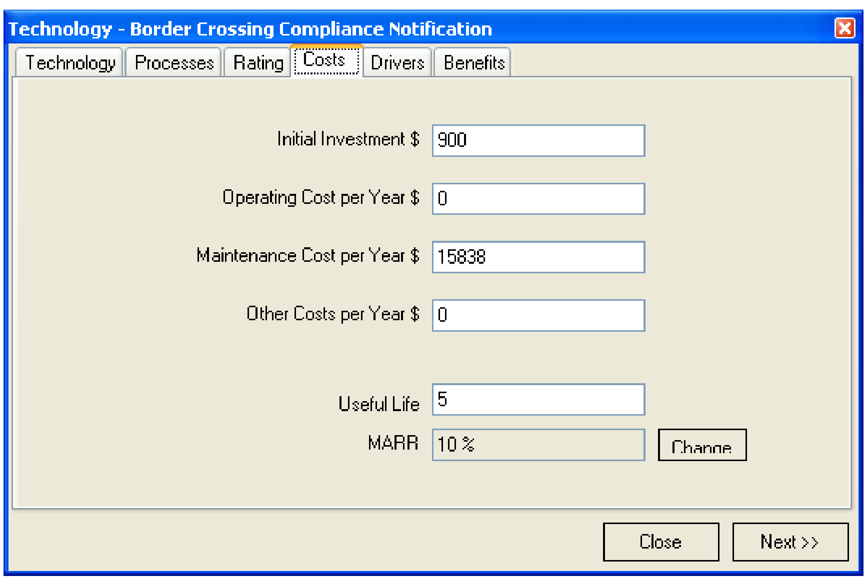


Figure 23. FTAT Screen Shot of Technology Application Investment Cost Input Form

4.1.1.6 Identifying the Impact of Wireless Solutions

Once the selected wireless technologies were defined, each of them was analyzed independently. The goal was to identify the impact of each technology on the supply chain—in particular, the impact of each technology on the business processes, the freight flow, and the information flow. From a cost standpoint, the effects arising from the technology are evidenced as a change in some process parameters or model variables, such as process time or the frequency of some event (i.e., chassis flips). From a performance measure perspective, this is accomplished by identifying the potential impact of the wireless technology on the relevant performance measures. Identifying these quantitative and qualitative impacts was carried out initially during the Stakeholder Sessions with additional data and information being collected during the ERGs that were convened during the Wireless Analysis Task (MCES Task 6).

4.1.1.7 Modeling the Wireless Solutions

Once the impact analysis was completed, the impact of each wireless technology was modeled and implemented in the baseline model. The data associated with each technology were analyzed and verified by the MCES team through follow-up interviews and were then used to populate the respective model. Once the “to be” cost driver values were identified, the tool calculated the potential annual process improvement benefit that could be derived from adoption of the wireless solution being examined. This calculation is performed using a linear algorithm that calculates the difference between the “as is” and “to be” process costs. An example application of this algorithm is provided below.

Example Process “as is” cost: $100,000/year

Example Process “as is” duration cost driver: 2 hours per move

- Example Process “as is” volume cost driver: 10,000 moves per year
- Example Process “to be” duration cost driver: 1.5 hours per move
- Example Process “to be” volume cost driver: 8,000 moves per year

Where:

$$\text{Process Improvement Benefit} = \frac{a \times ((b \times c) - (d \times e))}{(b \times c)}$$

Using the values identified above:

$$\text{Process Improvement Benefit} = \frac{\$100,000 \times ((2 \times 10,000) - (1.5 \times 8,000))}{(2 \times 10,000)} = \$40,000$$

This calculation is repeated for each of the processes identified as potentially affected by the wireless solution being examined and the benefits for each of these processes are summed to calculate the total potential process improvement savings. An example of how these potential impacts are modeled in FTAT is depicted in Figure 24, where the “as is” and “to be” values used in the quantitative analysis are shown side by side.

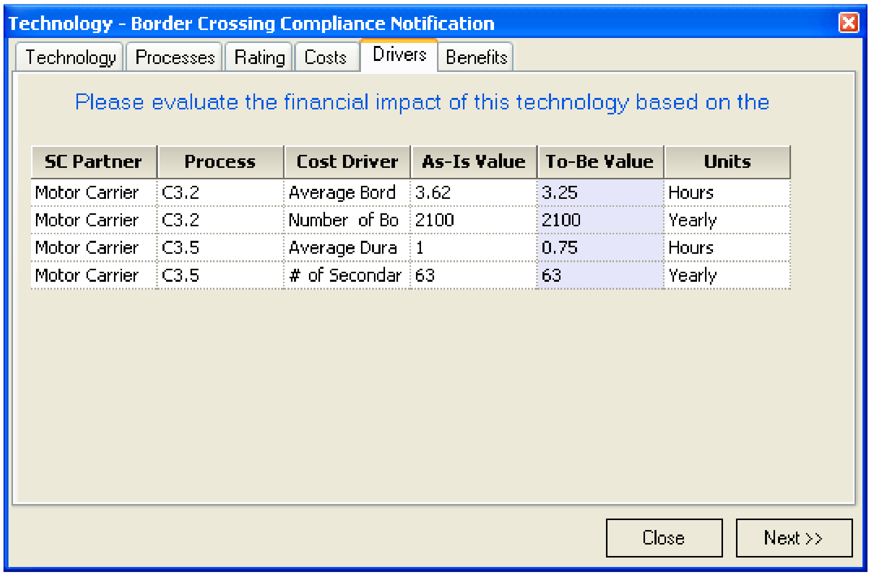


Figure 24. FTAT Screen Shot of 'To Be' Value Input

The screen shot in Figure 25 shows the screen where qualitative ratings for each of appropriate performance measures are input into FTAT.

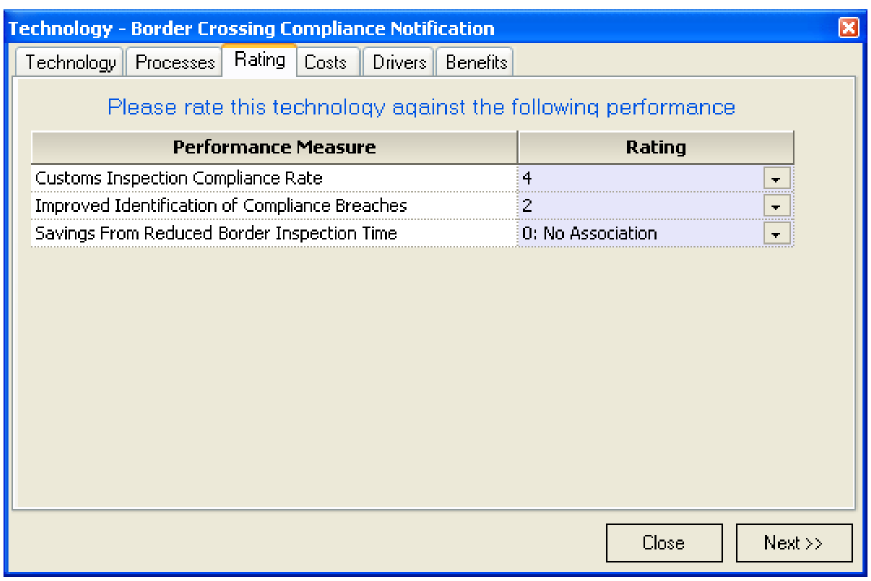


Figure 25. FTAT Screen Shot of Qualitative Rating Value Input

The screen shot in Figure 26 shows the calculated process improvement value of the particular technology application, based on all of the input provided to FTAT.

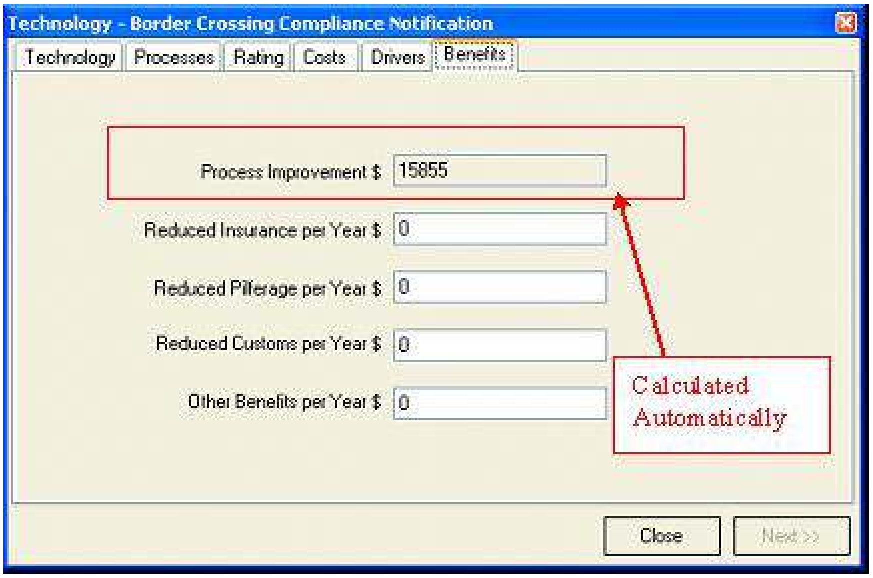


Figure 26. FTAT Screen Shot of Calculated Process Improvement Value

4.1.1.8 Generating Output Reports

Once all of the input values were entered into FTAT, the wireless solution scenarios were executed to report the potential quantitative and qualitative impacts of the wireless solutions. The quantitative outputs were generated using the techniques described in Section 1.2, and an aggregate score was calculated for the qualitative measures by summing the scores provided by the ERGs. Examples of the outputs generated by FTAT are provided in Figure 27 and Figure 28. The outputs for each supply chain segment and wireless solution are discussed in detail later in this section (Section 1).

		Border Crossing Compliance Notification	Cross Border Tracking Application
Quantitative Summary	Initial Investment	$900.00	$18,900.00
	Net Annual Cash Flow	$17.00	$14,000.00
	NPV	($835.56)	$67,123.94
	IRR	-48.05%	73.78%
	Payback	52.94	1.35
	Discounted Payback	0	1.52
	Benefit/Cost	0.07	4.55

Figure 27. FTAT Screen Shot of Quantitative Analysis Output

	Performance Measures	Border Crossing Compliance Notification	Cross Border Tracking Application
Cost	Savings From Reduced Border Inspection Time	0	2
Security	Customs Inspection Compliance Rate	4	5
	Improved Identification of Compliance Breaches	2	4
		Border Crossing Compliance Notification	Cross Border Tracking Application
	Score	6	11

Figure 28. FTAT Screen Shot of Qualitative Analysis Output

4.1.2 Data Gathering

4.1.2.1 Stakeholder and Task 4 Inefficiencies Data Collection Methodology

As described in previous sections, the data for the FTAT analysis were collected throughout the course of the project, starting in the Stakeholder Sessions and concluding with the ERGs, with various additional interviews and research supplementing these outreach activities. Because these data were collected from multiple sources, they provide a sample dataset for FTAT analysis; however, it is important to note that they are subject to a number of interpretations and assumptions, which are discussed in more detail in Section 4.1.3. Because FTAT allows for recalculation of benefits and related costs as data are updated and/or technology costs and assumptions change over time, adjustments to individual input items are both possible and relatively easy to make.

Table 17 below provides an overview of the progression of the logic employed for collecting data for the MCES, with industry stakeholders serving as the primary data source.

Table 17. Stakeholder Sessions—Data Collection Process and Identification of Inefficiency Data Points for FTAT Analysis

Supply Chain Segment	General Inefficiencies	"Problematic" Supply Chain Segment Identified	Sample "Bottom Line" Effects for Carriers and Society	Vetted Technology Applications
International Border	Cross-border wait times	Paperwork delays at international borders	• Reduced number of daily cross-border trips • Missed appointments • Fuel, idling, and lost driver productivity	• Border Crossing Compliance Notification • Cross-border tracking
Port to Inland Destination	Waiting time in container ports and vehicle Safety	Chassis roadability and "flipping" delays	• Reduced number of daily dray trips • Missed appointments • Fuel, idling, and lost driver productivity	• Chassis Roadability Notification • Virtual Queuing
Closed-Loop Pick-Up and Delivery	Traffic congestion and waiting for loading/unloading	Incident-related congestion and waiting at consignee locations	• Missed appointments • Fuel, idling, and lost driver productivity • Safety	• Truck-Specific Congestion Avoidance • Virtual Queuing
Rail Intermodal	Empty trips and waiting for loading/ unloading	Cross-town dray movements including empties and bobtails and waiting at rail terminals	• Fuel, idling, general productivity, and loaded move losses • Increased regional traffic congestion and air quality issues	• Cross-Town Intermodal Interchange • Virtual Queuing
Long-Haul Truckload	Fuel inefficiencies, safety, and cargo losses	Excessive speed and theft/pilferage	• Fuel losses • Increased crashes • Increased insurance costs	• Variable Speed Limiter • Untethered Trailer Tracking

In the Stakeholder Sessions, participants were presented with supply chain segments for vetting, but also for initial identification and quantification of inefficiencies. The Study Team then used these initial inefficiencies to identify the specific or "problematic" segments of the supply chain where more data would be needed for analysis. For example, cross-border stakeholders identified cross-border wait times as the key inefficiency for their supply chain segment. Within the supply chain, they identified specific problems in waiting for paperwork processing. These stakeholders were able to confirm total wait times at the border during the Stakeholder Session; however, specific waits for paperwork processing were not identified until the ERGs were held.

In Table 17 above, the sample "bottom line" for carriers and society provides a summary of the types of high-level data identified and collected either during the Stakeholder Sessions or via follow-up interviews and research for the Task 4 Inefficiencies Report. The preliminary data presented in the Task 4 Inefficiencies Report helped the Study Team analyze the potential benefits of overcoming the specific supply chain inefficiency identified.

These data allowed the Study Team to quantify the effects of overcoming the inefficiencies identified by motor carriers. Additionally, these data served as inputs into FTAT for some "generic" data and additional calculations required to run the model (as defined in Section 4.1.3). Note that in both cases, data were collected primarily from interviews and web searches and are not a representative sample nor an empirical data set collected in the field.

With the rolled-up economic benefits summarized in Task 4, in conjunction with the study objectives and additional basic criteria identified in the Task 4 Inefficiencies Report, the Study Team formulated eight technology concepts—based on input from motor carrier stakeholders—to be reviewed by the ERGs for additional data collection and preliminary vetting/industry acceptance.

4.1.2.2 Technology Concepts and Expert Resource Groups

In conjunction with the information presented in the Literature Review and Task 4 Inefficiencies Report, and the Study Team's knowledge of technology applications within the industry, the potential technology solutions were developed and vetted using a technology viability analysis. The final 10 technology solutions explored in the FTAT analysis were matched to the supply chain segments as detailed in Table 18, below.

Table 18. FTAT Analysis Scenarios

		Inefficiency	Solution
1	International Border	Paperwork Delay at Border	Border Crossing Compliance Notification
2	International Border	Processing Delay at Border	Border Crossing Tracking Compliance
3	Port to Inland Destination	Waiting Time in Container Ports	Virtual Queuing
4	Port to Inland Destination	Vehicle Safety (crashes, non-compliance)	Chassis Roadability Notification
5	Closed-Loop Pick-Up and Delivery	Incident-Related Congestion	Truck-Specific Congestion Avoidance

Scenario	Supply Chain Segment	Inefficiency	Solution
6	Closed-Loop Pick-Up and Delivery	Waiting, Loading, and Unloading	Virtual Queuing
7	Rail Intermodal	Empty Trips	Cross-Town Intermodal Interchange
8	Rail Intermodal	Waiting, Loading, and Unloading	Virtual Queuing
9	Long-Haul Truckload	Fuel Waste due to Excessive Speed	Variable Speed Limiter
10	Long-Haul Truckload	Theft and Pilferage	Untethered Trailer Tracking

Each technology application required a more detailed data set for benefit–cost modeling than was collected in Task 4. These data, used in the FTAT analysis, include the costs of the technology components to be implemented as well as more detailed data from carriers that link back to the inefficiencies addressed. Many of these industry detail data were collected during the ERG sessions.

The ERGs were divided according to industry segment, as shown in Table 19. Participants for the ERGs were identified from the interested stakeholders who took part in the Stakeholder Sessions and included additional members based on input from the FMCSA and the Study Team. Each ERG corresponded to a specific supply chain segment.

Table 19. ERG Participants

Supply Chain Segment	Participation by Industry Segment	Area of Expertise
International Border	Former cross-border owner/operator, cross-border dray operators, cross-border LTL, and long-haul	Operations, safety, and financial
Port to Inland Destination	Port dray operators	Planning, safety, and operations
Closed-Loop Pick-Up and Delivery	Private carriers, LTL, and pick-up and delivery	Operations, logistics, and technology
Rail-Truck Intermodal	Rail roads and rail intermodal carriers	Operations and safety
Long-Haul Truckload	Long-haul carries, owner/operators, and industry consultants	Operations and safety

Representatives from more than 30 areas of motor carrier operations as well as technology industry experts participated in ERG sessions and follow-up calls (or both). The ERG sessions were conducted in September 2007 with a two-hour (or longer) conference call. Participants were provided preliminary information for the call via e-mail, which included the identified inefficiencies within their respective supply chain segments as well as an explanation of the technology concept. This information is provided in the Appendix of this report.

Information collected during the ERG calls focused primarily on “as is” and “to be” process data. Participants were asked to identify the data points in the current process vs. those predicted if the technology application were to be implemented. A sample “as is” and “to be” for a cross-border trucker would include current wait times vs. a predicted wait time with the implementation of the compliance notification application.

In addition to these quantifiable data collected for FTAT analysis, the ERG Sessions also allowed the Study Team to capture additional performance data within the attributes identified by the Study Team. These data, collected on a scale of -5 to +5 with a score of 0 indicating no change and a score of +5 indicating a marked and positive change, provided a means of documenting information for related cost, security, efficiency, and safety attributes as a potential result of technology implementation. Scores for these non-quantifiable measures are discussed in more detail in Section 1.

4.1.2.3 Input from Technology Providers

The technology concepts to be analyzed in FTAT required not only inputs from motor carriers, but also inputs on technology costs from industry representatives. The data used do not provide a statistically significant sample or even an average representation of technology costs to be applied for each application; however, they do represent reasonable estimates derived from stakeholder information during an in-depth data collection process completed by the Study Team. This data collection process focused on industry interviews via phone with supporting data from industry websites for the following technology providers:

- Sprint/Nextel—costs of cellular service, devices, data service.
- Telcel (Mexico)—costs of Global System for Mobile Communications (GSM)/General Packet Radio Service (GPRS) service.
- Trak-It GPS—GPS-based tracking costs
- Quake Technologies—low-cost GPS-based tracking market availability.
- Calmar Technologies—GPS-based tracking costs—Mexico.
- Volvo trucks—technology feasibility of Variable Speed Limiter and estimated cost.
- Watkins Shepard—technology “pay-back” information.
- Eaton/Vorad—technology feasibility of speed limiter.
- PCMiler—cost of integrating real-time traffic data for Truck-Specific Congestion Avoidance.
- Trafficast (www.traffic.com), INRIX (www.inrix.com)—cost of real-time traffic data.

4.1.3 Key Analysis Considerations

Data collected for the FTAT analysis are largely based on an intensive stakeholder outreach effort with support of industry-accepted sources (such as the *Blue Book of Trucking Companies*). The technology applications explored in the FTAT analysis are those that may indeed overcome key motor carrier inefficiencies, but are not currently available in the marketplace or have not matured into viable solutions for motor carriers. For this reason, empirical data—data collected from actual deployment of the proposed technologies—are not abundant and are in some cases nonexistent. Therefore, stakeholder interviews and follow-up research provided a data set that is certainly relevant for analysis, but not statistically significant nor proven in the field.

In addition, the research was intended to show the potential benefits of applying wireless technologies to overcome inefficiencies for a wide range of motor carriers. Supply chain segments were developed to be generic for the general operation being studied, but not specific to the point at which an individual carrier's data were relevant. For antitrust and competitive reasons, carriers are uncomfortable communicating carrier-specific information. Therefore, data collected during the Stakeholder Sessions, follow-up interviews, and ERGs have the following limitations:

- "As is" and "to be" values are numbers based on documented sources that were agreed to and/or updated in the Stakeholder Sessions and ERGs. The sources of "as is" values varied, and included documents examined during the MCES Literature Review, supplemental documents identified later in the study, discussions with stakeholders during the Stakeholder Sessions, and discussions with participants in the ERGs. Verification and validation of these numbers were carried out during the ERG sessions. In some cases, the Study Team offered a value (driver pay, for example), and session participants commented and discussed until they agreed on a number that was a reasonable approximation of an industry-wide value. These numbers are not calculated averages. Rather, they probably represent agreed-upon industry-accepted average values or, more likely, assumed median industry values.
- Qualitative performance data were based on agreed-upon values documented during the ERG Sessions. These data provide an indication of the potential effects of the proposed technology on efficiency, cost, safety, and security performance measures that were deemed important to carriers during the Stakeholder Sessions. While these performance data help to gauge the potential effects of the technology on things like insurance costs, damage claims, and emissions, they do not represent a mathematical analysis of the relationship between the primary inefficiency and these secondary measures. In addition, it is highly likely that different groups of stakeholders have slightly different opinions as to the perceived value of the proposed technology. Moreover, there is no statistical significance associated with these indicators.
- Technology cost data are based on interviews and on online research of similar technologies and technology components. Again, the costs used for analysis do not represent a statistical average value of technologies in the marketplace, but rather, an assumed average or, more likely, assumed median cost. These assumptions were based on the Study Team's knowledge of the marketplace (for things like the cost of a cell phone of GPRS data service), in conjunction with baseline information found on the Internet or during a telephone interview.
- Sensitivity analysis results must be viewed with caution. Wireless solution sets that exhibit relatively large changes to the BCR when the independent variables are changed can be viewed as inherently having greater risk than solutions for which the BCR does not vary significantly. In other words, any errors that may occur in estimating the effects of a particular technology solution will be amplified when the variable exhibits a strong influence on the BCR. This is a critical consideration given the fact that these supply chain segments, and hence the independent variable data pertaining to them, are generic representations of common transportation networks and operations. Therefore, the values of these independent variables for actual supply chain segments will in all likelihood vary from the generic values, based on such factors as geographic location, fleet size, company policies and procedures, and myriad other factors or characteristics.

Table 20 below summarizes the data sources used for the FTAT analysis.

Table 20. Data Source Guide

Data source	Description
Stakeholder Sessions	Data collected from the Stakeholder Sessions; generally include high-level "as is" data for each supply chain segment; data are not statistically significant, but represent carrier perceptions as to the location and effects of inefficiencies within their respective supply chain segments.
Blue Book of Trucking Companies	*Blue Book* data elements as summarized in the 2004/2005 dataset; data based on annual report filings of motor carriers to the USDOT.
Technology Provider (examples include PC*Miler, Dell, and Nextel)	Data extracted from interviews and/or online research; represent the Study Team's understanding of the technology application versus similar technologies and/or technology components in the current marketplace.
Supply Chain Segment ERG	ERG for the supply chain segment analyzed; based on agreed-upon estimates during the group conference call and/or industry-accepted/assumed averages; generally include detailed "as is" data and assumed '"to be" data; data are not statistically significant, but represent carrier perceptions as to the location and effects of inefficiencies within their respective supply chain segments.
Annual Cost Data and Other Investment Criteria	Calculated based on the data inputs and assumed industry characteristics of fleet size, operating days per year, and potential number of additional miles traveled when not in waiting queue; assumptions made are detailed in Section 1.

Data collected directly from stakeholders have drawbacks as identified in the above table, and caution should be exercised when trying to conduct any statistical analysis using these data. However, because they come directly from industry, these data represent actual performance data in practice and provide a good baseline for the FTAT feasibility analysis. In addition to the limitations of the dataset, the data collected for FTAT modeling have the following characteristics:

- Data used in the FTAT analysis differ by supply chain segment, to reflect the actual and relevant processes for the segment. For example, data in the cross-border applications reflect processes that occur in transporting cargo across an international border, but do not apply to other supply chains. In addition, values for similar data elements may vary by supply chain depending on stakeholder inputs to individual processes
- Data used in the FTAT analysis have been vetted among carriers, owner/operators, FMCSA staff, and industry and technology experts and provide an excellent baseline for this initial FTAT technology feasibility analysis. The Study Team went to great lengths to understand the data and develop a data set that could provide a baseline for analysis. Aside from the formal Stakeholder Sessions and ERGs, the Study Team called and e-mailed various participants with additional questions to understand more thoroughly the data offered and their limitations

- FTAT data and subsequent analyses can be updated with empirical additions. A more detailed data set should be collected during the Phase II technology deployment. The Study Team recommends revisiting these analyses once the data are collected

In addition to the supply chain segment-specific data used in the FTAT analysis, three “generic” data elements were required to complete the relevant analyses for most supply chains. Assumed data points for fleet size, average miles per hour traveled when not in a queue, and annual days of operation were based on industry standards, web searches, and data documented in the Task 4 Inefficiencies Report. The specific sources and assumptions for these generic data elements are shown in Table 21 below.

Table 21. FTAT ‘Generic’ Data and Source

Description	Value	Unit	Data Source
Fleet size	6	trucks	Based upon statistics from the American Trucking Associations’ publication *Trucking Trends* indicating that 81.3 percent of trucking companies have 6 or fewer trucks
Average miles per hour traveled when not in queue	50	mph	Industry “rule of thumb” as defined during interviews with motor carriers
Expected life for cellular technology hardware	5	years	Anecdotal evidence (actual useful life could vary greatly based on operating environment)
Expected life for satellite/GPS-based technology hardware	10	years	Anecdotal evidence (actual useful life could vary greatly based on operating environment)
Number of operating days	350	/year	Based on 50 weeks in operation per year (2 weeks for any holidays and planned and unplanned maintenance)

It is important to note that the use of these figures is not meant to imply that the average fleet size for potential users is six trucks, nor that the average fleet operates 350 days per year. These are simply considered reasonable baseline values that allow the calculations to be executed within FTAT.

4.2 FINDINGS

This section details the findings for each of the wireless solutions examined as part of this study. A subsection is included for each of the supply chain segments, detailing the results for each of the wireless solutions proposed for that segment. In addition to the quantitative and qualitative tool outputs, the input data collected, the assumptions, and the calculations required to translate the data into the format utilized by FTAT are presented.

4.2.1 Supply Chain Segment 1—International Border Crossing (Scenarios 1 & 2)

The first supply chain segment represents a typical international border crossing for a commercial vehicle. The process flow begins with the pick-up of containerized goods (or a trailer) at a pick-up facility and ends with the drop-off of the container (or trailer) at a destination facility on the opposite side of an international border.

4.2.1.1 Related Inefficiencies

Paperwork Delay at Border Crossings: Since the North American Free Trade Agreement (NAFTA) entered into force in 1994, the volume of cross-border trade traffic has steadily increased. Even since the events of September 11, 2001, after which border security was tightened for inbound movements, the movement of goods across our borders with Canada and Mexico has continued to rise. Although changes have been made to practices and, more significantly, capacity at some crossings, delays are commonplace, particularly for inbound loads.

CBP has implemented special programs (e.g., FAST and C-TPAT, among others), which allow qualified carriers to move inbound loads more quickly through clearance at the border. Effective use of these arrangements requires rapid transmission of shipping documents from their Mexican or Canadian origin point to a customs broker, and then to CBP at the border. A carrier cannot make the best use of these programs unless these transmissions are made rapidly in electronic form, and the driver knows when he can arrive at CBP, and either move through under the special program, or be processed in the traditional fashion without delay. If the driver is not notified in advance of the status of his submission, he may be delayed at the border.

Processing Capacity at Border Crossings

Cross-border truck traffic, particularly traffic moving northbound and crossing into the U.S. from Mexico at the southern border, can experience extreme travel delays. These delays are directly related to infrastructure limitations, personnel limitations, and inspections. Many border crossings have, however, significantly expanded infrastructure to accommodate the influx of post-NAFTA northbound trucks. The World Trade Bridge in Laredo, for example, was built to accommodate cross-border commercial demands and is located on the outskirts of the crowded Laredo downtown area. In San Diego, where the Study Team held an MCES Stakeholder Session, infrastructure limitations still constrain freight and cause freight bottlenecks. Stakeholders identified the lack of available CBP staff to staff additional lanes and/or inspection facilities as the primary reason that this infrastructure has not been added. Additionally, interviews with CBP staff in Laredo, Pharr, and Brownsville confirm that cross-border inspections are the primary mission of CBP, whereby the search for illegal drugs, weapons, and people will always take precedent over expediting freight movements.

4.2.1.2 Potential Wireless Solutions

Border Crossing Compliance Notification: The frequency and severity of delays at international border crossings have been the subject of various studies, and the impetus for the test and deployment of a number of technology-based solutions. Most of these efforts have focused on reducing the delays associated with processing through the import vehicle, cargo, and driver compliance verification process managed by CBP. They include transponder-based pre-screening programs that allow shippers to pre-file paperwork with CBP, and have that filing evaluated in advance of the shipment reaching the border. Shipments for which all paperwork is in order, including that for the carrier and driver, can experience shorter processing times, thereby saving costs associated with shipment delays.

However, because the carrier is not the filing organization (this is typically handled by a licensed customs broker), the carrier and its drivers don't know whether the paperwork is in order before reaching the border. When it isn't in order (e.g., missing information, processing incomplete, etc.), the driver and shipment must stop at the border facility, and either wait for the processing to be completed, or interact directly with a customs inspector to rectify any paperwork issues. The result is delay and truck queuing at the border.

Carriers consulted during the study indicated that an application that made information regarding pre-screening status available prior to a driver's arrival at the border has the potential to significantly reduce delay and queuing, which would also likely reduce idling and improve safety. This capability would involve capturing processing status information from CBP and relaying it wirelessly to the driver, perhaps through the carrier's dispatch operation. Figure 29 illustrates both the current, or "as is," process for notification, and the proposed wireless compliance notification method.

The top portion of the diagram indicates those portions of the process that are common to both the "as is" and "to be" processes. Here, the motor carrier receives an inward cargo manifest from a customs broker, and files an electronic manifest (which contains all shipment information for a specific entry into the U.S.) through the ACE system. Once the ACE system has processed the entry to verify the completeness and format of the e-manifest filing (only edit checks are performed at this point—the veracity of the information is evaluated later in the process), a "cover sheet" that basically represents a confirmation of the filing is electronically returned to the carrier, who must print it out and hand it to the driver prior to departure from the shipper or carrier facility. The driver must carry the cover sheet with him/her and hand it to the Customs inspector at the primary inspection point. The net effect is that the driver is able to provide evidence that the e-manifest filing was completed according to filing rules, which specify the information that must be provided, and the time frame within which the filing must be made. Filings are required to be made at least one hour prior to the truck's arrival at the border, unless the carrier is a participant in the FAST program, in which case the filing must be received by Customs 30 minutes before the truck arrives at the border.

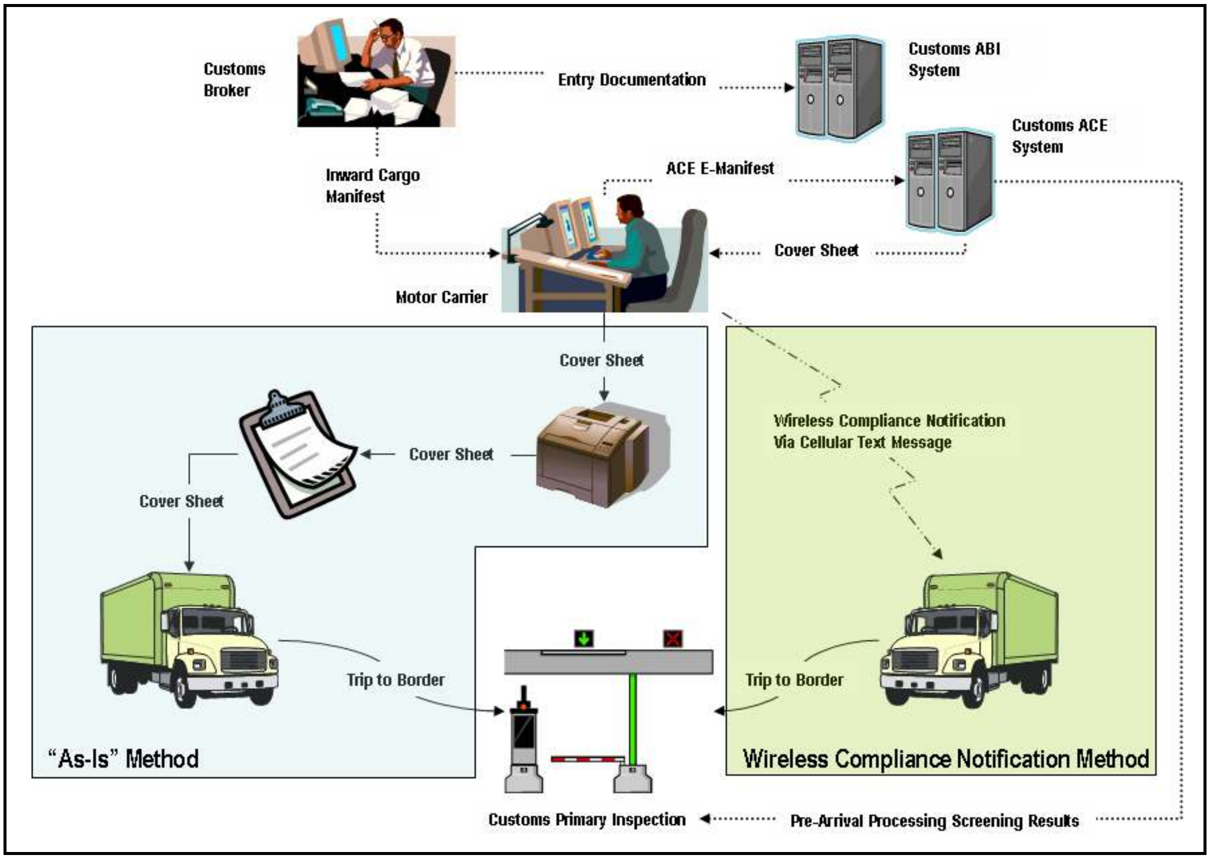


Figure 29. Border Crossing Compliance Notification Application

The wireless border crossing notification application basically replaces the transmittal, printing, and hand-carrying of the cover sheet with an electronic message, delivered directly to the driver via text message to a cellular phone. This message originates with the motor carrier dispatcher, and can be sent once verification of receipt is received from the ACE system. With this application, the driver no longer has to wait at the shipper or carrier location until the printed cover sheet is prepared. The main benefit of this approach is that the driver and vehicle no longer need to remain stationary while the e-manifest filing is made, examined, and verified by the ACE system.

Cross-Border Tracking: As the volume of international trade between the U.S. and Mexico and the U.S. and Canada has grown over the years, the actual movement of truck-based shipments across the border has become increasingly time-consuming. While measures have been taken to accommodate increases in cross-border trade movements—such as modernization and expansion of facilities and the implementation of technology systems to process entry documentation and automate certain screening functions—long queues of trucks waiting to cross into the U.S. are commonplace. These queues represent a significant source of delay for shipments, and hence have an adverse effect on the productivity and profitability of trucking operations.

As evidenced by the number of recent and current research efforts aimed at accurately measuring the amount of delay that motor carriers endure at international border entry points, the first step in addressing delay is to quantify its effect on cross-border trips. Both the FMCSA and the FHWA have cross-border truck tracking projects underway. Although these projects are being conducted for different reasons—the FMCSA is primarily interested in ensuring commercial vehicle safety, while the FHWA is focused on transportation network efficiency measurement—each offers a potential glimpse into the future regarding the use of vehicle tracking as a way to manage border crossing facilities more efficiently.

Additionally, to enhance its ability to provide for national security, CBP is interested in developing the capability of capturing time-based location information for individual shipments, and has indicated that the ability to do so will soon be mandated. The common link across these efforts is a system that provides the ability to tie together vehicle identification and location information on a time-based scale.

For the MCES, the Study Team and the motor carriers that it engaged during the Stakeholder Sessions considered such a capability as an opportunity for border crossing management entities—specifically CBP and crossing infrastructure owners (e.g., bridge owners that charge tolls)—to manage their operations better by applying more accurate information to make decisions about facilities. The assumption is that, with accurate travel time or delay information, these facility managers could make decisions to reallocate Customs inspectors to open more primary inspection lanes, or open more automated toll collection lanes to accommodate surges in vehicle demand.

The proposed wireless solution, termed the wireless tracking compliance application, provides a means for capturing and recording time and location data (which can be used to calculate travel time and delay) using a low-cost GPS-based solution. This solution would provide an automated means to provide data that meet the needs of FMCSA, FHWA, and CBP, and would replace the manual method of position verification where a motor carrier dispatcher conducts periodic voice conversations with drivers. This is depicted in Figure 30.

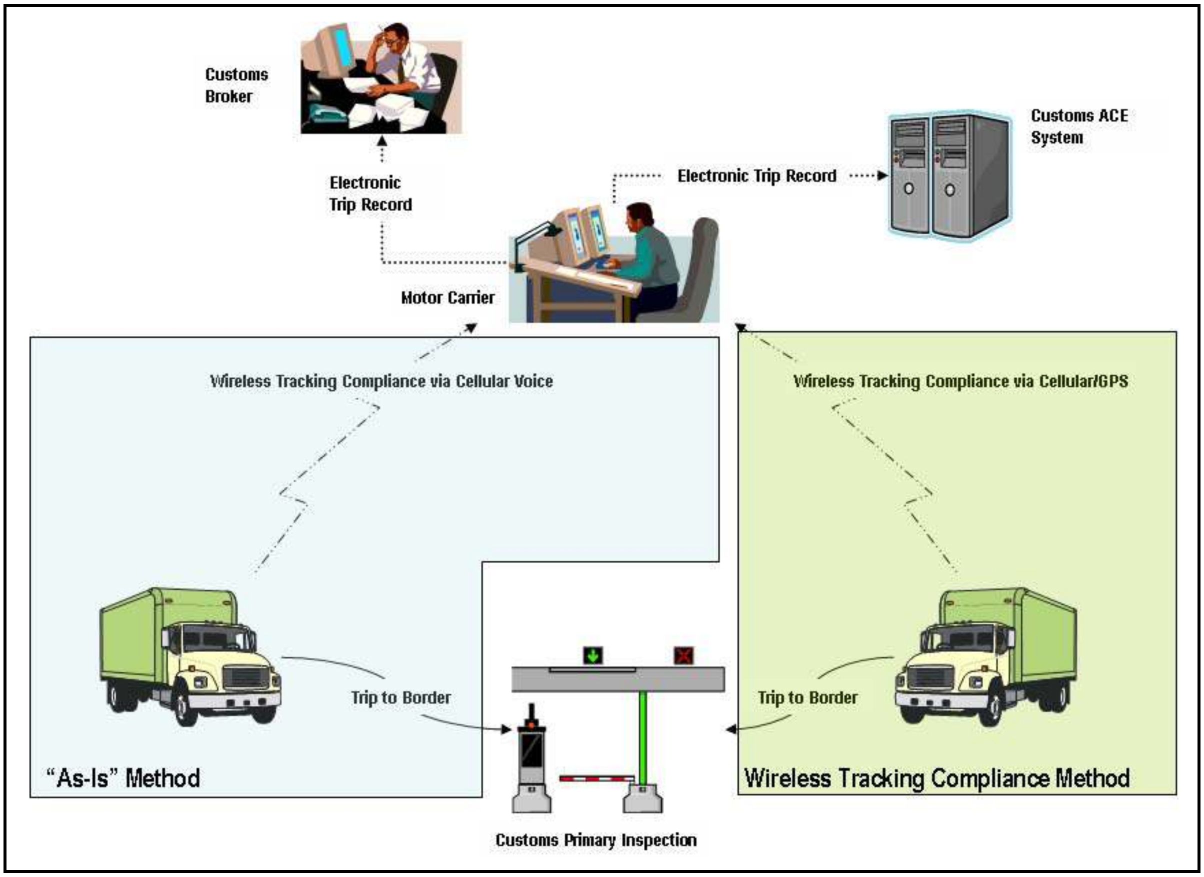


Figure 30. Cross-Border Tracking Application

4.2.1.3 Input Data

Input data for the analysis were collected from a variety of sources, including the Literature Review, the Stakeholder Sessions, ERGs conducted as part of Task 6, and additional research conducted by the MCES Team. The sources for the input data for Supply Chain Segment 1 are listed in Table 22.

Table 22. Supply Chain Segment 1 Input Data

				Source	Date
1	Average duration in import customs queue ("as is")	3.62	hours	International Border Stakeholder Session [2.5 hour average (70%), 1.5 hour min (15%), 11 hour max (15%)]	03/07
2	Average delay due to incomplete processing/paperwork ("as is")	1	hours	International Border Stakeholder Session	03/07
3	Frequency of arrival with incomplete processing/paperwork ("as is")	3	%	International Border Stakeholder Session	03/07
4	Average loaded driver salary	$19.06	/hour	*Blue Book of Trucking Companies*	2004–05

#	Description	Data Point	Unit	Source	Date
5	Variable fuel, maintenance, lubrication costs	$0.95	/mile	*Blue Book of Trucking Companies*	2004–05
6	Revenue per mile	$1.35	/mile	*Blue Book of Trucking Companies*	2004–05
7	Border Crossing Compliance Notification cellular hardware	$150	/unit	Nextel	09/07
8	Border Crossing Compliance Notification cellular service (including text messaging capability)	$99	/month	Nextel	09/07
9	Average administrative assistant loaded salary	$16.75	/hour	Salary.com	10/07
10	Cross-border tracking application hardmount	$900	/unit	Trackit-GPS	09/07
11	Cross-border tracking application network licensing fee	$8,000	/site	Trackit-GPS	09/07
12	Cross-border tracking application dispatch/accounting application	$4,000	/site	Trackit-GPS	09/07
13	Cross-border tracking application GSM/GPRS Service	$15	/month	AT&T	09/07
14	On-site training	$1,500	/site	TMW Systems (provider)	09/07
15	Average duration in import customs queue ("to be") with Border Crossing Compliance Notification	3.25	hours	International Border ERG	09/07
16	Average delay due to incomplete processing/paperwork ("to be") with Border Crossing Compliance Notification	.75	hours	International Border ERG	09/07
17	Average duration in import customs queue ("to be") with cross-border tracking application	2.925	hours	International Border ERG	09/07
18	Average delay due to incomplete processing/paperwork ("to be") with cross-border tracking application	1	hours	International Border ERG	09/07
19	Frequency of arrival with incomplete processing/paperwork ("to be") Border Crossing Compliance Notification	3	%	International Border ERG	09/07
20	Frequency of arrival with incomplete processing/paperwork ("to be") with cross-border tracking application	3	%	International Border ERG	09/07
21	Rating: Potential for increasing customs compliance rate (security) through Border Crossing Compliance Notification	+3	N/A	International Border ERG	09/07
22	Rating: Potential for increasing customs compliance rate (security) through border cross-border tracking application	+5	N/A	International Border ERG	09/07

#	Description	Data Point	Unit	Source	Date
23	Rating: Potential for improving identification of compliance breaches (security) through Border Crossing Compliance Notification	+2	N/A	International Border ERG	09/07
24	Rating: Potential for improving identification of compliance breaches (security) through cross-border tracking application	+4	N/A	International Border ERG	09/07
25	Rating: Potential for savings from reduced customs time (cost) through Border Crossing Compliance Notification	0	N/A	International Border ERG	09/07
26	Rating: Potential for savings from reduced customs time (cost) through cross-border tracking application	+2	N/A	International Border ERG	09/07

Once the data were collected and the key assumptions for the "generic" data were identified (as detailed in Section 1), several calculations were required in order to identify the costs associated with both the processes and the technologies. These are provided in Table 23 below.

Table 23. Supply Chain Segment 1 Generic Data

#	Description	Value	Formula	Applied
1	# of yearly border crossings	2,100	Fleet size × Crossings per day per truck × Operating days per year	6 × 1 × 350
2	Revenue per hour when traveling	\$67.50	Revenue per mile × Average driving speed	\$1.35 × 50
3	Variable cost per hour when traveling	\$47.50	Variable cost per mile × Average driving speed	\$0.95 × 50
4	Yearly # of delays due to incomplete paperwork	63	# of yearly border crossings × Failure rate due to incomplete paperwork	2,100 × .03
5	Annual cost of border crossing delays using opportunity cost	\$152,040	(Revenue per hour – Variable cost per hour) × Average duration in import customs × # of yearly border crossings	(\$67.50–\$47.50) × 3.62 × 2,100
6	Annual cost of border crossing delays using variable cost	\$144,894	Hourly driver salary × Average duration in import customs × # of yearly border crossings	\$19.06 × 3.62 × 2,100

#	Description	Value	Formula	Applied
7	Annual cost of paperwork delays using opportunity cost	$1,260	(Revenue per hour—Variable cost per hour) × Average delay due to incomplete processing/paperwork × Yearly # of delays due to incomplete paperwork	($67.50–$47.50) × 1 × 63
8	Annual cost of paperwork delays using variable cost	$1,201	Hourly driver salary × Average delay due to incomplete processing/paperwork × Yearly # of delays due to incomplete paperwork	$19.06 × 1 × 63
9	Initial investment for Border Crossing Compliance Notification	$900	Unit hardware costs × Fleet size	$150 × 6
10	Annual cost for Border Crossing Compliance Notification	$15,838	(Monthly service charges × Fleet size × Months per year) + [Administrative assistant salary × (Full time hours per year/portion of time dedicated to new tasks)]	($99 × 6 × 12) + [$16.75 × (2,080 ÷ 4)]
11	Initial investment for cross-border tracking application	$18,900	(Unit hardware costs × Fleet Size) + Network license fee + Dispatch/accounting application fee + On site training fee	($900 × 6) + $8,000 + $4,000 + $1,500
12	Annual cost for cross-border tracking application	$9,790	(Monthly service charges × Fleet size × Months per year) + [Administrative assistant salary × (Full time hours per year/portion of time dedicated to new tasks)]	($15 × 6 × 12) + [$16.75 × (2,080 ÷ 4)]

These calculations along with the "as is" and "to be" cost driver values served as the inputs to FTAT for the quantitative analysis.

4.2.1.4 Freight Technology Assessment Tool Output

Quantitative Results: The results that follow were obtained using the opportunity cost calculation described in the input data section above. These results reflect the assumption that any savings in time resulting from the adoption of the proposed wireless solutions can be used to generate additional revenues. The process improvement savings are, therefore, the result of the generation of additional revenue minus the variable costs associated with generating those revenues (fuel, maintenance, lubrication, etc.). Table 24 details these results.

Table 24. Supply Chain Segment 1 Quantitative Output

Quantitative Summary Items	Border Crossing Compliance Notification	Cross-Border Tracking Application
Initial Investment	$900.00	$18,900.00
Net Annual Cash Flow	$17.00	$14,000.00
NPV	-$830.30	$79,430.14
IRR	-48.05%	73.78%
Payback	52.94	1.35
Discounted Payback	0	1.47
Benefit/Cost	0.08	5.2

These figures indicate that, based on estimated costs and anticipated benefits at the subprocess level, the return on investment in an application that provides notification of compliance with Customs filing requirements would be of no value if a motor carrier was required to purchase devices (i.e., cell phones), and services (i.e., subscription and text message fees) solely for the purpose of gaining this capability. The estimated initial investment of $900 is based on a cost of $150 per truck for a fleet of six trucks.

While the initial investment for a GPS-based cross-border tracking application would be substantially higher ($3,150 per truck), benefits anticipated to accrue based on motor carrier estimates are also substantially higher, yielding a positive annual cash flow and a high IRR.

The supply chain segment was also analyzed based on the variable cost assumption that additional revenues could not be generated from any potential time savings derived from the adoption of the proposed wireless solutions, as would be the case if the motor carrier were not able to take on additional revenue-producing trips (e.g., due to lack of demand). Any process improvement cost savings would therefore be the result of savings of the applicable variable costs (loaded driver salary, fuel savings, etc.). Table 25 details these results.

Table 25. Supply Chain Segment 1 Quantitative Output (Excluding Additional Revenue Opportunity)

Quantitative Summary Items	Border Crossing Compliance Notification	Cross-Border Tracking Application
Initial Investment	$900.00	$18,900.00
Net Annual Cash Flow	-$728.39	$12,628.05
NPV	-$3,886.55	$69,794.12
IRR	0.00%	66.40%
Payback	0	1.50
Discounted Payback	0	1.64
Benefit–Cost	-3.32	4.69

These results reveal that when additional revenue opportunity from time savings (i.e., additional revenue-generating trips would not be possible) is excluded from the analysis, the Border Crossing Compliance Notification application becomes significantly less attractive, while the cross-border tracking application retains most of its appeal. Hence, the value of tracking application is apparent even when the time saved does not translate directly into the ability for a motor carrier to complete additional trips within a driver shift.

Additional scenarios were run to identify the effects of varying the fleet size. As discussed previously, a fleet size of six was assumed for the results presented above. For wireless solutions with higher fixed costs (software, training, etc.) the potential benefit can vary greatly based on the size of the fleet. Figure 31 below reflects the results of this analysis for the technologies evaluated for supply chain segment 1.

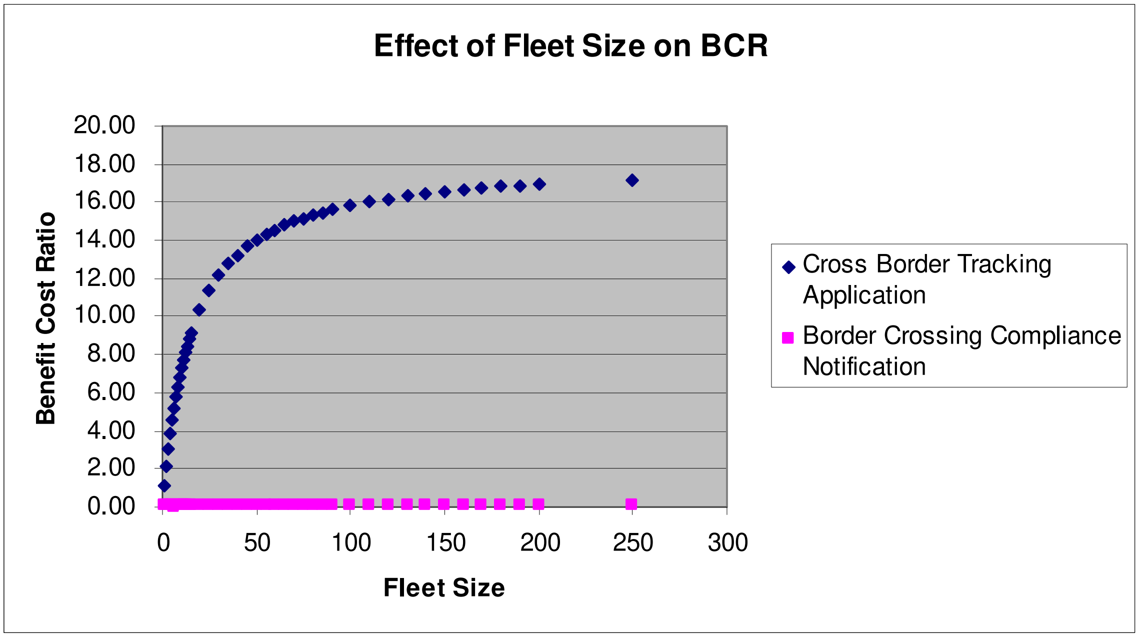


Figure 31. Effect of Fleet Size on Supply Chain Segment 1 Calculations

Because the costs associated with the Border Crossing Compliance Notification are all variable, the resulting BCR does not vary with fleet size; however, as the figure shows, the potential benefits resulting from adoption of the Cross-Border Tracking application rise dramatically with fleet size, due to the higher inherent fixed costs associated with adopting this solution.

Finally, additional scenarios were run to identify the effects of varying other independent variables used to calculate the BCR. For this supply chain segment, the Study Team ran four additional scenarios. For each scenario, one variable that represented a “to be” value was varied independently (all other variables were kept constant). Table 26 below reflects the results of this analysis for the technologies evaluated for supply chain segment 1.

Table 26. Supply Chain Segment 1 Sensitivity Analysis Results*

Independent Variable	% Change	Border Crossing Compliance Notification BCR	Cross-Border Tracking Application BCR	% Change	Border Crossing Compliance Notification BCR	Cross-Border Tracking Application BCR
Duration in Customs Queue	-5.00%	31.17	7.49	5.00%	-31.02	2.92
Average Duration in Secondary Inspection	-10.00%	0.51	5.20	10.00%	-0.35	5.20
Revenue per Mile	-10.00%	-24.30	1.54	10.00%	24.46	8.86
Fuel, Maintenance, Lubrication Costs per Mile	-10.00%	17.23	7.78	10.00%	-17.08	2.63

* Calculated using Baseline BCRs of 0.08 for the Border Crossing Compliance Notification Wireless Solution, and 5.20 for the Cross-Border Tracking Application Wireless Solution

For example, if the "to be" value for the amount of time spent waiting in the Customs queue is decreased by 5 percent (meaning that the technology application used yielded a slightly lower waiting time), then the BCR for the Border Crossing Compliance Notification application would increase to 31.17, a dramatic result. Under the same conditions, the BCR for the Cross-Border Tracking Application would increase to 7.49, a more modest result, but a notable improvement nonetheless. Similarly, an increase of 5 percent in waiting time (compared to the original "to be" value) yielded a dramatic reduction in BCR for the Border Crossing Compliance Notification to -31.02, and a reduction in BCR for the Cross-Border Tracking Application to 2.92.

These results indicate that the BCRs for these applications are particularly sensitive to three of the four independent variables examined.

Qualitative Results: The ERG participants were also asked to score the potential effects the wireless solutions could have on the performance measures identified during the Literature Review and the Stakeholder Sessions. Stakeholders assigned each performance measure a score ranging from -5 to +5, with -5 representing a strong negative effect, +5 a strong positive effect, and 0 representing no effect. Each of the performance measures is assigned to a performance attribute and these scores are aggregated in order to provide a robust view of the potential impact of the wireless solution. Table 27 shows the scores for the individual performance measures for the Border Crossing Compliance Notification system and the Cross-Border Tracking Application.

Table 27. Supply Chain Segment 1 Qualitative Output

Factors	Performance Measures	Border Crossing Compliance Notification	Cross-border Tracking Application
Cost	Savings from Reduced Border Inspection Time	0	2
Security	Customs Inspection Compliance Rate	4	5
Security	Improved Identification of Compliance Breaches	2	4
Total Score		**6**	**11**

The output from this computation shows that the ERG participants assigned a higher relative value to the cross-border tracking application, indicating that they estimate it will have a greater potential impact in both an overall qualitative regard (reflected by the total score) and for each of the individual performance attribute areas (cost and security). This outcome is explained largely by the content of two of the discussion threads that occurred during the ERG data collection session.

First, the discussion revealed that the ERG participants rarely incurred delay at the border due to incomplete ACE e-manifest filings. This is likely because the motor carriers consulted for the project are highly experienced, reputable companies for which noncompliance is rarely an issue. The results may be somewhat different for less experienced carriers that have higher noncompliance rates.

Second, the ERG motor carriers were aware of the potential benefits of automated cross-border tracking to their operations and to their ability to comply with emerging requirements from customs. The multiplying effect of this dual-use technology application exerted a strong influence on their ratings.

4.2.1.5 Analysis Summary

Based solely on the calculated results, an economic case cannot be made for motor carriers to adopt the Border Crossing Compliance Notification solution if they must purchase equipment for which the only use would be the delivery of compliance notification information. This is reflected by the negative NPV, the negative IRR, and the BCR of less than 1. It should be noted, however, that due to the nature of the wireless technologies associated with this solution (i.e., the cellular telephone), there is a high probability that motor carriers could realize a positive financial impact by using the technology they already possess and service that they already subscribe to with little or no additional cost. This would measurably affect the economic measures associated with the solution, and potentially make this option attractive from an economic perspective.

The results for the cross-border tracking application are attractive using any of the economic measures provided. The positive NPV, extremely high IRR, short payback periods, and BCR higher than 1 all indicate that this solution is a good investment, provided the estimated time savings can be realized through adoption of this solution. The key assumption inherent in this analysis is that, with accurate, high-quality information regarding border crossing travel times, CBP officials would have both the authority and the capacity to adjust local crossing operations (i.e., reallocate staff to open more primary inspection lanes) to reduce queuing at the border entry points. Because interaction with CBP staff on this issue was outside the scope of this study, the Study Team did not have the information necessary to examine the probability that this might occur. Therefore, any conclusions regarding the true net effect of the cross-border tracking application must be examined within that context.

4.2.2 Supply Chain Segment 2—Port to Inland Destination (Scenarios 3 & 4)

The second supply chain segment represents the processes required for a commercial truck to pick up goods from a seaport. In this example, trucks pick up containerized goods coming off a ship at a marine terminal. Based on inputs from stakeholders at the Port of Long Beach

Stakeholders Session, the supply chain segment was extended to include the transport of goods to a nearby destination facility and the return of the truck carrying an empty container to pick up another load at the marine terminal.

4.2.2.1 Related Inefficiencies

Waiting Time in Container Ports: Thousands of containers are moved out of terminals daily by draymen—short-haul trucking firms that move containers to nearby inland terminals, from which they are transferred to rail carriers or long-haul truckers for the move to market areas in the United States. Some dray moves are to final destinations near the port. Containers are placed on trucks, one at a time, for the move out of the port. At the best, this is not a rapid process. Therefore, it is important that the processes by which trucks move into and through a terminal be as efficient as possible, to maintain an orderly and high-volume flow out of the terminal.

Observers of these ports are unanimous in their agreement that trucks are moving into and through port terminals in an inefficient manner, with some terminals performing much worse than others. There are three places where a driver arriving at a marine terminal to pick up a container may wait in queues. There will usually be a queue at the gate for access to the terminal. Once inside the terminal, drivers may wait in another line for a chassis, and then, finally, in still another line to pick up a loaded container. These waits are frequently long and costly, and the costs are largely borne by the dray firms and their drivers.

Chassis Roadability: Vehicles improperly maintained or with undetected mechanical problems can fail while in service and cause crashes. The level of sophistication of carrier vehicle maintenance programs varies widely. Mechanical problems on older vehicles are often detectable only through close physical inspection. Wireless technologies have the potential to reduce the number and severity of crashes that are caused by mechanical factors.

4.2.2.2 Potential Wireless Solutions

Virtual Queuing: The inefficiency most often cited is that of drivers waiting to retrieve or drop a load at a terminal facility. According to carriers consulted during the study, these delays are often the result of terminal operators seeking to optimize their own operations. For example, terminal operators often schedule deliveries in such a manner that a queue of several trucks is waiting to be loaded at any given time. This ensures that terminal personnel are working nearly continuously, thereby maximizing the productivity of their operations.

During the MCES Stakeholder Sessions, carriers indicated that one possible solution to such a situation might be to use wireless tracking technologies, in association with technology that would allow for accurate estimation of travel time for each inbound truck, to construct a "virtual queue." Using such a system, terminal operators would be kept apprised of the ETA of each inbound load, and could dynamically reschedule dock operations to compensate for delays due to congestion, traffic incidents, or delays in a truck's departure from the inbound origin. Such a system might operate in a manner similar to an air traffic control system, although with less complexity, and theoretically at a lower cost. This application is depicted in Figure 32, alongside the current shipment management solution.

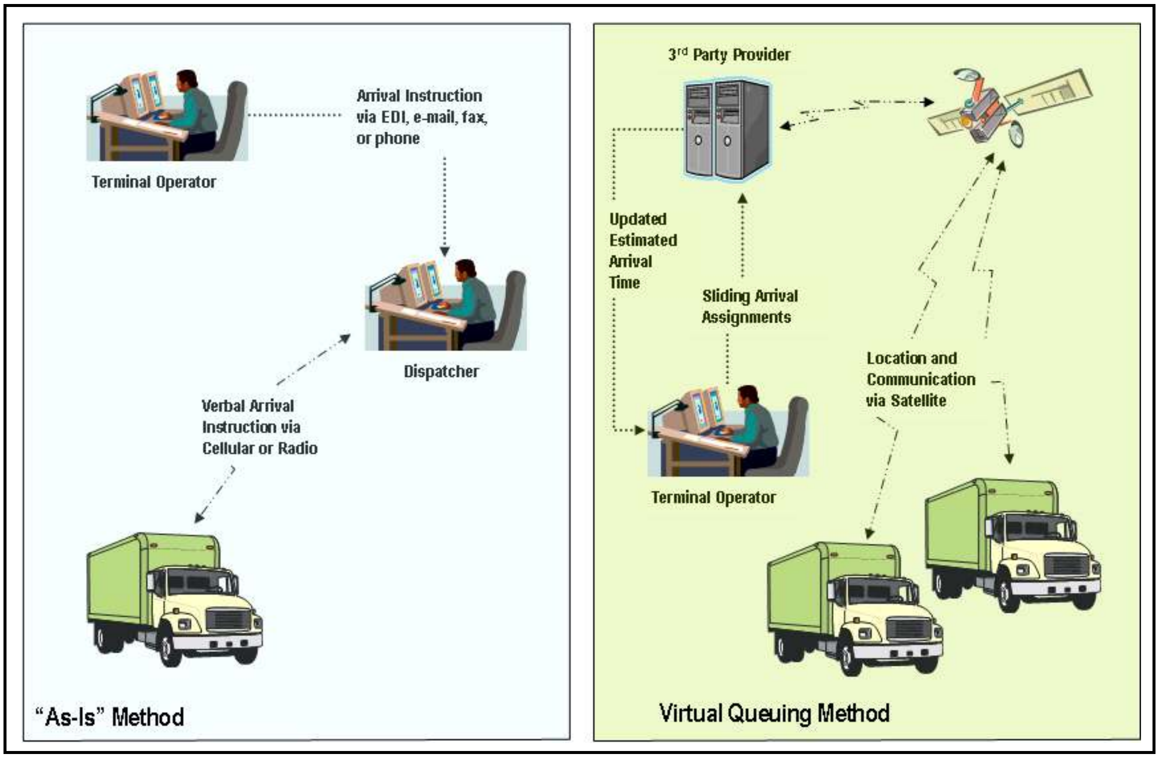


Figure 32. Virtual Queuing Application

The "as is" process, as depicted on the left side of the figure, typically consists of a motor carrier dispatcher receiving instructions from a terminal operator (or a facility manager) regarding when and where a load needs to retrieved or delivered. This information can come in the form of an e-mail message, a fax, a phone call, or an electronic data interchange (EDI) message directly from the terminal operator's information system. Once received, this information is relayed to the truck driver, often by radio or cellular telephone transmission, or through a message sent via a satellite-based fleet management device. Any changes in status are then relayed in both directions through the same channels, with significant changes requiring renegotiation of pick-up or delivery terms between the motor carrier and the terminal manager.

The Virtual Queuing application, in the iteration shown in the figure, would rely on the use of real-time location and status information obtained from inbound trucks, coupled with automated arrival assignment software, to adjust arrival appointments, and to provide the terminal operator with a way to ensure continuous operations without the need to physically queue trucks at the facility gate. Changes in arrival appointments, including such information as parking space number, would then be transmitted back to the drivers of the inbound trucks, thereby alleviating the pressure associated with potentially missing appointments as a result of waiting in long lines.

Chassis Roadability Notification: According to carriers that provide intermodal transportation services—particularly those that retrieve containerized cargo in seaports—they continue to struggle with problems associated with intermodal chassis. Specifically, chassis that fail driver walk-around inspections and/or are put out of service by safety enforcement personnel are an ongoing source of inefficiency. This is considered important by carriers, regardless of which party (the carrier or the chassis owner) is ultimately responsible for the payment of fines and the remediation of chassis deficiencies.

The Chassis Roadability Notification application depicted in Figure 33, alongside the “as is” method, would provide a means for drivers to wirelessly access chassis maintenance data and inspection history upon entering a storage facility or terminal.

Using a simple interface, such as a cellular telephone, the driver would enter the chassis number in to a query system to obtain information that might lead him to either retrieve an alternate chassis, or to focus additional attention on a certain component or subset of components that had not been recently serviced.

In addition to providing this information in incoming intermodal drivers, such a system would provide similar data to terminal hostler operators and chassis maintenance personnel. Hostler operators could avoid positioning chassis of questionable maintenance history for mounting of containers, and maintenance personnel could wirelessly access maintenance records to assist in narrowing in on the identification of problems.

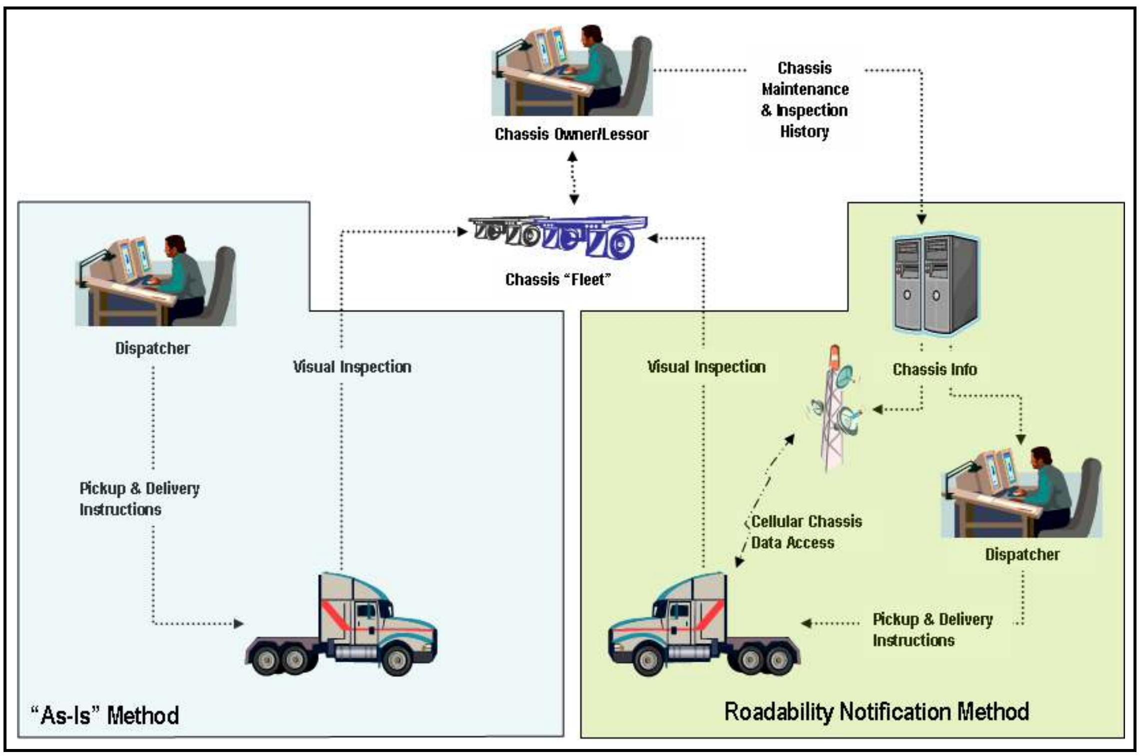


Figure 33. Chassis Roadability Notification Application

4.2.2.3 Input Data

Input data for the analysis was collected from a variety of sources including the Literature Review, the Stakeholder Sessions, ERGs conducted as part of Task 6, and additional research conducted by the MCES Team. The input data, as well as the source for each item, for Supply Chain Segment 2 is detailed in Table 28 below.

Table 28. Supply Chain Segment 2 Input Data

#	Description	Data Point	Unit	Source	Date
1	Average chassis flip duration ("as is")	40	minutes	Port to Inland Stakeholder Session (30-50 minutes)	03/07
2	Chassis flip due to maintenance problem frequency ("as is")	5	%	Port to Inland Stakeholder Session	03/07
3	Chassis flip due to mismatch frequency ("as is")	2	%	Port to Inland Stakeholder Session	03/07
4	Average load retrieval duration ("as is")	52	minutes	Port to Inland Stakeholder Session (30-50 minutes (85%) 2 hour max (15%))	
5	Average # of turns per shift	2.8	/shift	Port to Inland Stakeholder Session	03/07
6	Average shift length	10	hours	Port to Inland Stakeholder Session	03/07
7	Average transport distance	47.5	miles	Port to Inland Stakeholder Session (30 miles average (75%) 100 miles max (25%))	03/07
8	Average loaded driver salary	$19.06	/hour	*Blue Book of Trucking Companies*	2004–05
9	Variable fuel, maintenance, lubrication costs	$0.95	/mile	*Blue Book of Trucking Companies*	2004–05
10	Average revenue per turn	$165	/turn	Port to Inland stakeholder Session	03/07
11	Chassis Roadability Notification hardware (cellular)	$150	/unit	Nextel	09/07
12	Chassis Roadability Notification monthly service (cellular)	$99	/month	Nextel	09/07
13	Chassis Roadability Notification database management	N/A*	N/A	N/A	
14	Software to query database via cellular technology	N/A*	N/A	N/A	
15	Virtual Queuing satellite-based communication device average cost (hardware)	$2,500	/unit	Qualcomm	09/07
16	Virtual Queuing satellite monthly monitoring average fees	$80	/month	Qualcomm	09/07
17	Virtual Queuing appointment system	N/A**	N/A	N/A	09/07
18	On site training	$1,500	/site	TMW Systems (provider)	09/07
19	Average administrative assistant loaded salary	$16.75	/hour	Salary.com	10/07
20	Average chassis flip duration ("to be") with Chassis Roadability Notification	30	minutes	Port to Inland ERG	09/07
21	Chassis flip due to maintenance problem frequency ("to be") with Chassis Roadability Notification	4	%	Port to Inland ERG	09/07

#	Description	Data Point	Unit	Source	Date
22	Chassis flip due to mismatch frequency ("to be") with Chassis Roadability Notification	2	%	Port to Inland ERG	09/07
23	Average chassis flip duration ("to be") with Virtual Queuing	36	minutes	Port to Inland ERG	09/07
24	Chassis flip due to maintenance problem frequency ("to be") with Virtual Queuing	5	%	Port to Inland ERG	09/07
25	Chassis flip due to mismatch frequency ("to be") with Virtual Queuing	2	%	Port to Inland ERG	09/07
26	Average load retrieval duration ("to be") with Chassis Roadability Notification	52	minutes	Port to Inland ERG	09/07
27	Average load retrieval duration ("to be") with Virtual Queuing	46	minutes	Port to Inland ERG	09/07
28	Rating: Emissions per trip (safety) potential effect through Chassis Roadability Notification	+3	N/A	Port to Inland ERG	09/07
29	Rating: Emissions per trip (safety) potential effect through Virtual Queuing	+2	N/A	Port to Inland ERG	09/07
30	Rating: Crashes per mile (safety) potential effect through Chassis Roadability Notification	0	N/A	Port to Inland ERG	09/07
31	Rating: Crashes per mile (safety) potential effect through Virtual Queuing	0	N/A	Port to Inland ERG	09/07
32	Rating: Insurance costs per vehicle mile (cost) potential effect through Chassis Roadability Notification	0	N/A	Port to Inland ERG	09/07
33	Rating: Insurance costs per vehicle mile (cost) potential effect through Virtual Queuing	0	N/A	Port to Inland ERG	09/07
34	Rating: Damage rate per shipment (cost) potential effect through Chassis Roadability Notification	0	N/A	Port to Inland ERG	09/07
35	Rating: Damage rate per shipment (cost) potential effect through Virtual Queuing	0	N/A	Port to Inland ERG	09/07
36	Rating: Delays due to violations/OOS orders (efficiency) potential effect through Chassis Roadability Notification	+2	N/A	Port to Inland ERG	09/07
37	Rating: Delays due to violations/OOS orders (efficiency) potential effect through Virtual Queuing	0	N/A	Port to Inland ERG	09/07

*The Study Team assigned a cost of $0 for the motor carriers because it is assumed that the chassis owner would simply provide web access to an existing database, and would not charge carriers to access the information.

**The Study Team assigned a cost of $0 for the motor carriers because it is assumed that the facility operators would bear the direct cost of deploying the system, and carrier costs would be restricted to the appropriate vehicle tracking system.

Once the data were collected and the key assumptions for the "generic" data were identified (as detailed in Section 1), several calculations were required in order to identify the costs associated with both the processes and the technologies. These are provided in Table 29 below.

Table 29. Supply Chain Segment 2 Generic Data

#	Description	Value	Formula	Applied
1	# of yearly load retrievals	5,880	Fleet size × Turns per truck per shift × Operating days per year	6 × 2.8 × 350
2	Variable cost per trip	$45.00	Variable cost per mile × Miles per trip	$0.95 × 47.5
3	Hours per turn	3.57	Hours per shift ÷ Turns per shift	10 ÷ 2.8
3	Per hour contribution margin	$33.60	(Revenue per trip—Variable cost per trip) ÷ Hours per turn	($165–$45.00) ÷ 3.57
4	Yearly # of chassis flips	410	(Chassis flip due to maintenance problem frequency + Chassis flip due to mismatch frequency) × # of yearly load retrievals	(.05 + .02) × 5,880
5	Annual cost of chassis flips using opportunity cost	$9,184	(Average chassis flip duration ÷ Minutes per hour) × Per hour contribution margin × Yearly # of chassis flips	(40 ÷ 60) × $33.60 × 410
6	Annual cost of chassis flips using variable cost	$5,210	(Average chassis flip duration ÷ Minutes per hour) × Per hour driver salary × Yearly # of chassis flips	(40 ÷ 60) × $19.06 × 410
7	Annual cost of retrieving loads in port using opportunity cost	$171,226	(Average load retrieval duration ÷ Minutes per hour) × Per hour contribution margin × Yearly # of chassis flips	(52 ÷ 60) × $33.60 × 5,880
8	Annual cost of retrieving loads in port using variable cost	$97,130	(Average load retrieval duration ÷ Minutes per hour) × Per hour driver salary × Yearly # of chassis flips	(52 ÷ 60) × $19.06 × 5,880
9	Initial investment for Chassis Roadability Notification	$900	Unit hardware costs × Fleet size	$150 ÷ unit hardware × 6 fleet size
10	Annual cost for Chassis Roadability Notification	$3,208	(Monthly service charges × Fleet size × Months per year × Allocation to chassis roadability)	($99 × 6 × 12 × 45%)
11	Initial investment for Virtual Queuing	$16,500	(Unit hardware costs × Fleet size) + On site training costs	($2,500 × 6) + $1,500
12	Annual cost for Virtual Queuing	$14,470	(Monthly monitoring fee × Fleet size × Months per year) + [Administrative assistant salary × (Full time hours per year/portion of time dedicated to new tasks)]	($80 × 6 × 12) + [$16.75 × (2,080 ÷ 4)]

These calculations, along with the "as is" and "to be" cost driver values, served as the inputs to FTAT for the quantitative analysis. The details of the analysis performed using FTAT are provided in the following section.

4.2.2.4 Freight Technology Assessment Tool Output

Quantitative Results: The following results were obtained using the opportunity cost calculation described in the input data section above. This reflects the assumption that any savings of time resulting from the adoption of the proposed wireless solutions can be used to generate additional revenues. The process improvement savings is therefore the result of the generation of additional revenue minus the variable costs associated with generating those revenues (fuel, maintenance, lubrication, etc.). Table 30 details these results.

Table 30. Supply Chain 2 Quantitative Output

Quantitative Summary Items	Chassis Roadability Notification	Virtual Queuing
Initial Investment	$900.00	$16,500.00
Net Annual Cash Flow	$45.60	$6,205.13
NPV	-$713.03	$27,082.24
IRR	-33.29%	35.85%
Payback	19.74	2.66
Discounted Payback	0	3.04
Benefit/Cost	0.21	2.64

The figures in the results table indicate that, based on the expected benefits of the two applications provided by the ERG participants, the Virtual Queuing application has the potential to be a sound investment, although the initial cost of $2,750 per truck (based on a fleet size of six trucks) is quite high. However, with a net annual gain of approximately $1,000 per truck, the initial investment would be recovered in less than three years.

The Chassis Roadability Notification application scored significantly worse. While the initial investment of $150 per truck is quite reasonable, the FTAT calculations estimate that it would take nearly 20 years to recoup the investment.

The supply chain segment was also analyzed based on the variable cost assumption that additional revenues could not be generated from any potential time savings derived from the adoption of the proposed wireless solutions, as would be the case if the motor carrier were not able to take on additional revenue-producing trips (e.g., due to lack of demand). Any process improvement cost savings would therefore be the result of savings of the applicable variable costs (loaded driver salary, fuel savings, etc.). Table 31 details these results.

Table 31. Supply Chain Segment 2 Quantitative Output (Excluding Additional Revenue Opportunity)

Quantitative Summary Items	Chassis Roadability Notification	Virtual Queuing Application
Initial Investment	$900.00	$16,500.00
Net Annual Cash Flow	-$1,362.26	$2,741.69
NPV	$6,485.54	$35,756.50
IRR	0.00%	0.00%
Payback	0	0
Discounted Payback	0	0
Benefit/Cost	-6.21	-1.17

When the ability to capture additional revenue due to improved efficiency is removed from the calculations, the results indicate that both applications provide negative BCRs. These figures underscore the importance of opportunity cost to their relative value propositions.

Additional scenarios were run to identify the effects of varying the fleet size. As discussed previously, a fleet size of six was assumed for the results presented above. The analysis revealed that the BCR for the Virtual Queuing application increases measurably as fleet size increases, as shown in Figure 34.

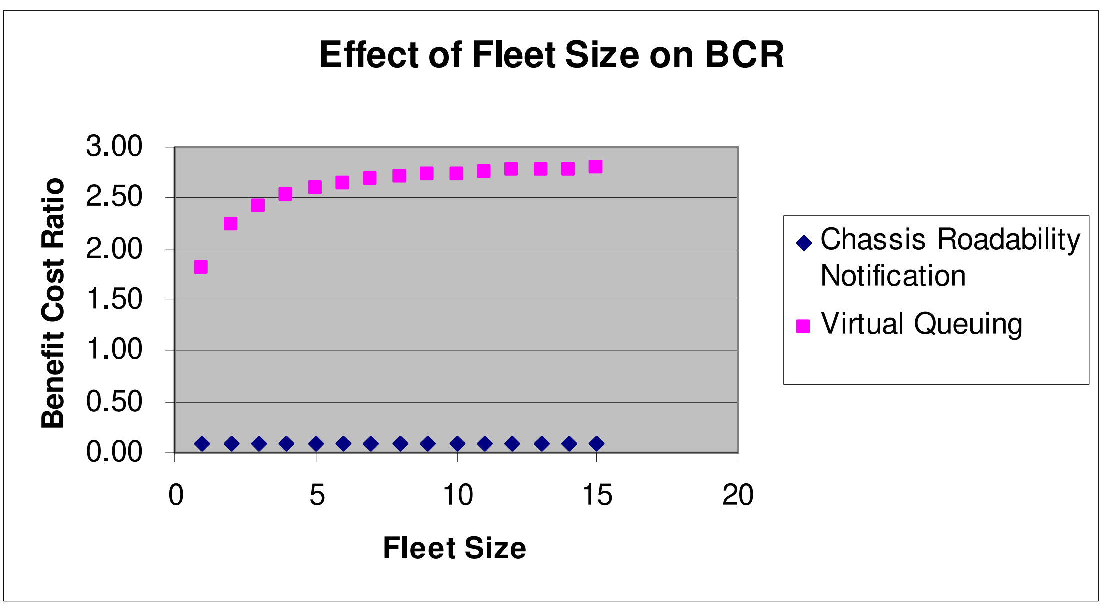


Figure 34. Effect of Fleet Size on Supply Chain Segment 2 Calculations

Finally, additional scenarios were run to identify the effects of varying other independent variables used to calculate the BCR. For this supply chain segment, the Study Team ran three additional scenarios. For each scenario, one variable that represented a "to be" value was varied independently (all other variables were kept constant). Table 32 below reflects the results of this analysis for the technologies evaluated for supply chain segment 2.

Table 32. Supply Chain Segment 2 Sensitivity Analysis Results*

Independent Variable	% Change	Chassis Roadability Notification BCR	Virtual Queuing Application BCR	% Change	Chassis Roadability Notification BCR	Virtual Queuing Application BCR
Flip Duration	-5.00%	1.56	2.82	5.00%	-1.14	2.47
Revenue per Turn	-10.00%	-1.83	1.43	10.00%	2.25	3.86
Fuel, Maintenance, Lubrication Costs per mile	-10.00%	0.75	2.97	10.00%	0.08	2.30

* Calculated using Baseline BCRs of 0.21 for the Chassis Roadability Notification Wireless Solution, and 2.64 for the Virtual Queuing Wireless Solution

For example, if the "to be" value for the amount of time spent waiting for a chassis flip is decreased by 5 percent (meaning that the technology application used yielded a slightly lower waiting time), then the BCR for the Chassis Roadability Notification application would increase to 1.56, a large percentage increase, but still a modest result. Under the same conditions, the BCR for the Virtual Queuing application would increase to 2.82, a much more modest result. Similarly, an increase of 5 percent in waiting time (compared to the original "to be" value) yielded a dramatic reduction in BCR for the Chassis Roadability Notification application, to -1.14, and a reduction in BCR for the Virtual Queuing application to 2.47.

These results indicate that the BCRs for these applications are sensitive to two of the three independent variables examined.

Qualitative Results. As was done for the first two scenarios, the ERG participants scored each performance measure with a value from -5 to +5, with -5 representing a strong negative effect, +5 a strong positive effect, and 0 representing no effect. Table 33 shows the scores for the individual performance measures for the Chassis Roadability Notification system and the Virtual Queuing application.

Table 33. Supply Chain Segment 2 Qualitative Output

Factors	Performance Measures	Chassis Roadability Notification	Virtual Queuing Application
Efficiency	Delays due to violations/OOS orders	3	0
Cost	Insurance costs per vehicle mile	0	0
Cost	Damage rate per shipment	0	0
Safety	Emissions per trip	3	2
Safety	Crashes per mile	0	0
Total Score		**6**	**2**

At first glance, the notably higher ratings given to the Chassis Roadability Notification application appear to contradict the FTAT computational output that shows that the attractiveness of the Virtual Queuing application is significantly higher. However, this can be explained at least in part because, although the Chassis Roadability Notification application was given a fairly positive score with respect to the reduction of delays due to OOS orders, motor carriers that participated in the ERG indicated that the frequency of OOS they experienced was actually quite low. So, while the per-occurrence value may be relatively high, the frequency of occurrence among the motor carriers that participated in the ERG offset the perceived benefits.

4.2.2.5 Analysis Summary

The results of this analysis clearly indicate that, based upon the expected benefits it would provide, the Chassis Roadability Notification application would be of little or no value to motor carriers. However, it is important to remember that, as is the case with each of these implementation scenarios, the benefits might be higher for some carriers, and in some locations. The experiences of the motor carriers that participated in the ERG for this scenario indicated that they are rarely responsible for retrieving bare chassis. In the overwhelming majority of instances in which they retrieve a load from an intermodal facility, the container is already loaded onto a chassis by the time they arrive at the pick-up point. The assumption here is that the port personnel responsible for retrieving the chassis for loading perform at least a cursory examination of the chassis for defects prior to placing a container on it. This reality is borne out by the ERG participants' estimate that only 2–3 percent of chassis have to be flipped (i.e., replaced with another chassis after being loaded). The calculated values may be different under different circumstances.

Based solely on the calculated results, an economic case cannot be made for motor carriers to adopt the Chassis Roadability Notification application if they must purchase equipment for which the only use would be to obtain chassis maintenance information. This is reflected by the negative Net Present Value, the negative IRR, and the BCR of less than 1. It should be noted, however, that due to the nature of the wireless technologies associated with this solution (i.e., the cellular telephone), there is a possibility that motor carriers could realize a positive financial impact by using the technology they already possess and service they already subscribe to with little or no additional cost. This would potentially affect the economic measures associated with the solution sufficiently to make this option economically attractive. It should also be noted that, while the participants in the ERG acknowledged the value of having access to chassis maintenance information, the general consensus was that they didn't feel that chassis roadability was the responsibility of the carrier and expressed resistance to adopting any solution addressing this issue.

By contrast, the Virtual Queuing application appears to have some promise for returning reasonable value for the investment. However, it should be noted that the BCR of 2.31 is not particularly high, and that the implementation of such a system—that is, for such a system to be a widely usable solution—would require not only a commitment from a port terminal operator, but also that a substantial percentage of port users implement it. In other words, such a system would have limited impact if it were not implemented in all or nearly all of the trucks that call on a particular facility. Such a deployment level would likely be necessary to allow the terminal operator to have sufficient flexibility in reassigning arrival appointments. Since a large percentage of the trucks that call on port facilities are operated by drivers who have cell phones, the development of a system that uses that technology might have more favorable returns, in terms of both BCR and level of operational efficiency of the system.

The results for the Virtual Queuing application are attractive when the opportunity cost metric is applied using any of the economic measures provided. The positive NPV, high IRR, short payback periods, and BCR higher than 1 all indicate that this solution is potentially a good investment, provided the estimated time savings can be realized through adoption of this solution. The key assumption inherent in this analysis is that the terminal would also adopt this solution and absorb any of the infrastructure costs associated with implementing an appointment system. It would in all likelihood be necessary to prove the economic viability of this solution from a terminal perspective as well, even though that falls outside the scope of this effort. It should also be noted that an economic case cannot be made for adopting this solution if the variable cost is used, as opposed to the opportunity cost. This is reflected by the negative NPV and BCR for this scenario. This indicates that this solution would achieve the greatest benefit in areas where there is sufficient demand to allow carriers to perform additional runs, as opposed to simply cutting driver hours.

4.2.3 Supply Chain Segment 3—Closed-Loop Pick-Up & Delivery (Scenarios 5 & 6)

The third supply chain segment represents a closed-loop supply chain where a trucking company picks up and drops off goods at multiple locations in a sequential process.

4.2.3.1 Related Inefficiencies

Loading, Unloading, and Waiting: For closed-loop operations, major costs are accrued while trucks are waiting in queues to reach the dock of a shipper or receiver. Average time, including waiting, for loading or unloading is estimated to be two hours, and much of this is waiting time. The problem concerns private carriers as much as it does for-hire carriers, because a preponderance of a private carrier's deliveries are to its customers, where its trucks will be treated in the same manner as any other trucks arriving with deliveries.

Some relatively small percentage of private carriers' deliveries are to their own facilities (e.g., Wal-Mart delivering to Wal-Mart distribution centers or stores), where they will be accorded priority, but this is not generally the case. It is also true that unnecessary waiting is not a significant problem for private carriers when picking up, since their trucks are loaded at their own facilities. According to carriers, the root of the problem is that shippers and receivers both seem indifferent to the costs incurred by carriers while waiting. Further, many of the carriers that participated in the Stakeholder Sessions suggested that shippers, receivers in particular, actually engage in practices that create queues so that their own internal operations can operate at peak efficiency. By ensuring that several trucks are lined up awaiting loading or unloading, shippers and receivers can operate uninterrupted, without the delays associated with waiting for the "next" truck to show up. This situation is similar to that described above regarding trucks waiting at port facilities.

Although on the surface it would appear that gate reservation or appointment systems might mitigate this problem, carriers argue that their use is geared toward providing shipper and receiver facilities with enhanced efficiencies at the expense of the carriers.

Incident-based Congestion: Crashes, breakdowns, and other incidents on heavily used roadways cause nonrecurring congestion and delays for truck traffic. Because nonrecurring congestion is unpredictable, trip planners and dispatchers cannot allow for these delays when planning and scheduling moves. These delays may significantly increase the cost of moving a load. Further, late deliveries and pick-ups will, at the least, disrupt schedules for tightly controlled movement of time-sensitive freight. At the worst, late delivery of such loads can have severe consequences. The inefficiency arises because of inadequate technology for real-time transmission of information incidents to dispatchers and for transmission of re-routing instructions from the dispatch center to affected drivers.

4.2.3.2 Potential Wireless Solutions

Virtual Queuing: Because of similarities in the inefficiencies introduced by the operating methods of shippers and receivers to those introduced by port terminals, the Study Team recommended to the Government team that the Virtual Queuing concept described earlier in this report be applied to the Closed-Loop Pick-Up and Delivery Supply Chain Segment. As the diagram in Figure 35 illustrates, the application would operate in the same manner as for port operations. Applying this solution to the Closed-Loop Pick-Up and Delivery Supply Chain Segment allows for an examination of its potential benefits under an economic model that differs from that which exists in the port environment.

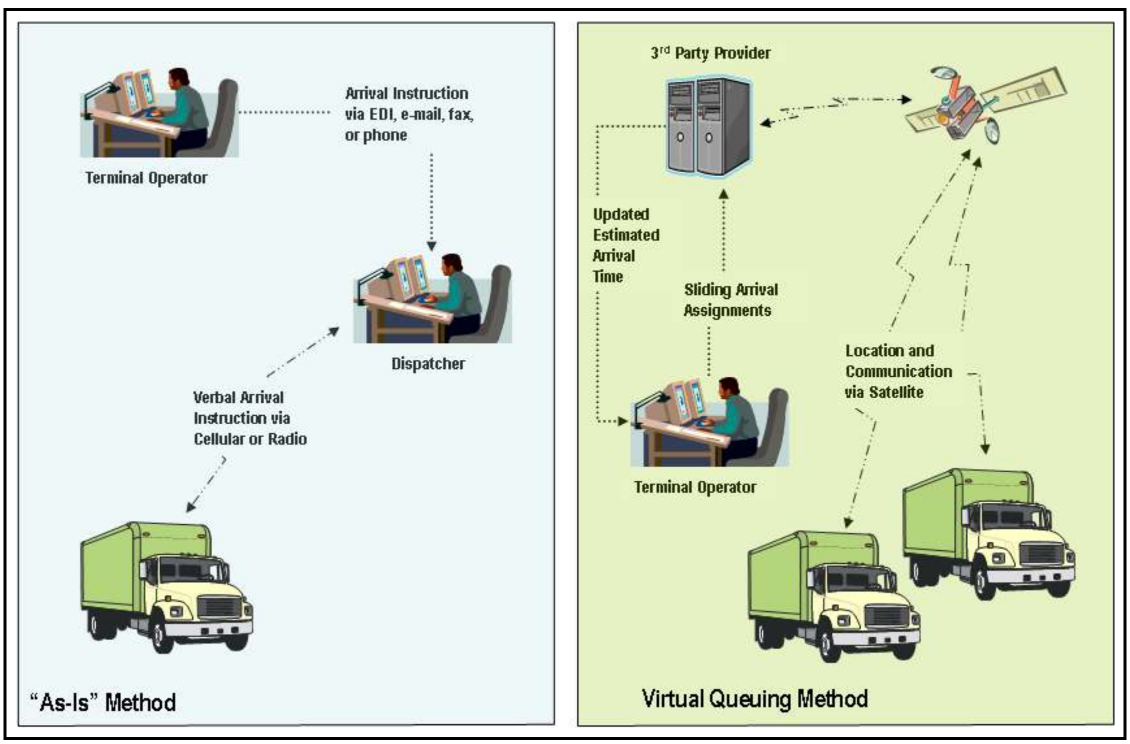


Figure 35. Virtual Queuing Application

Truck-Specific Congestion Avoidance: The carriers consulted for this study indicated an interest in a wireless application that would reduce the negative effects of congestion related to incidents, construction, and special events. With the increasing availability of in-vehicle navigation systems that incorporate traffic information, carriers are expressing a renewed interest in obtaining similar capabilities that cater specifically to the trucking community. Through a wireless link to existing traffic information, such an application would allow drivers to receive traffic data that are of particular applicability to their operations, and in the event that alternatives exist, would be provided truck-specific alternate routing information. Such information would be useful in reducing the likelihood that a driver would take an alternate route that includes insufficient clearances, bridge weight ratings that are too low, or roadway geometry that would be difficult to navigate with a tractor-trailer combination. The illustration in Figure 36 shows how this application would work.

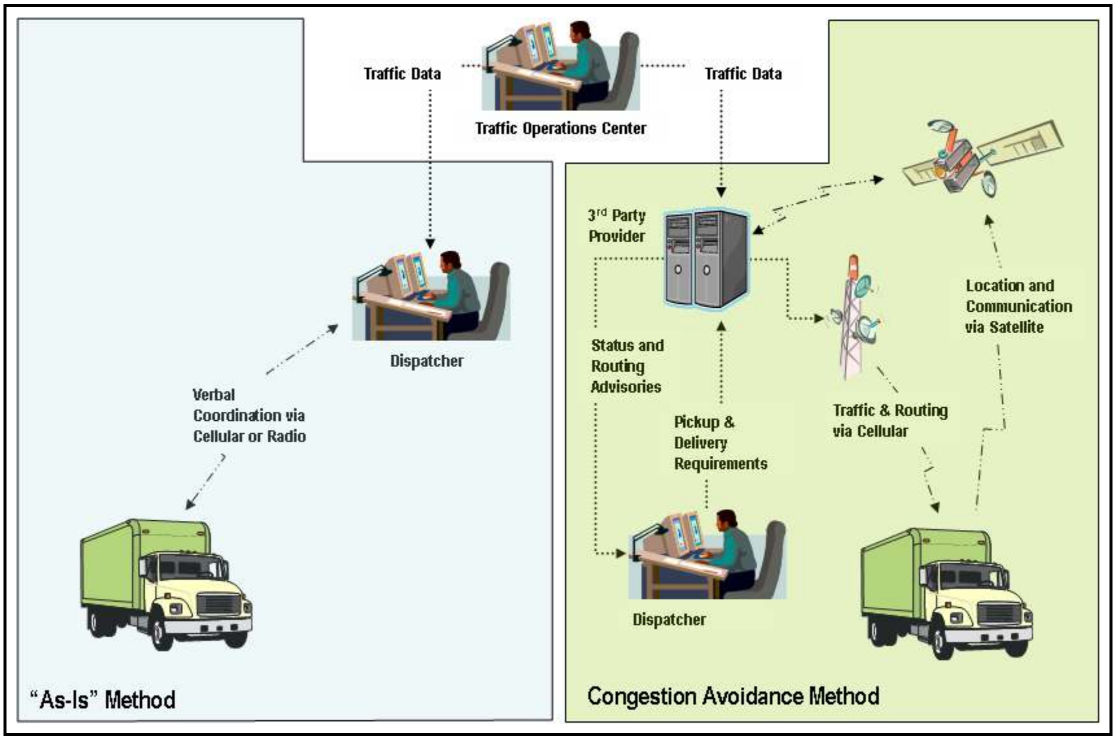


Figure 36.Truck-Specific Congestion Avoidance Application

In this example, information regarding the position of each of a motor carrier's vehicles would be used by a third-party provider to determine the most efficient route from each vehicle's current location to its planned destination (using pickup and delivery requirements resident in the motor carrier's dispatch system) by applying traffic data obtained from the appropriate traffic operations center. Each vehicle's location would be obtained either through a satellite-based asset tracking solution or a cellular technology application. Traffic updates and routing advisories would be generated by the third-party provider, and relayed to the drivers through the same wireless technology that is used to track their position.

4.2.3.3 Input Data

Input data for the analysis were collected from a variety of sources including the Literature Review, the Stakeholder Sessions, ERGs conducted as part of Task 6, and additional research conducted by the Study Team. The input data sources for Supply Chain Segment 3 are detailed in Table 34 below.

Table 34. Supply Chain Segment 3 Input Data

#	Description	Data Point	Unit	Source	Date
1	Average drop-off/pick-up duration ("as is")	40	minutes	Port to Inland Stakeholder Session (30–50 minutes)	03/07
2	Average # of drop-offs/pick-ups ("as is")	12.25	/day	Closed-Loop Stakeholder Session	03/07
3	Average incident-based congestion time ("as is")	2.5	/day	Closed-Loop Stakeholder Session	03/07
4	Frequency of incident-based congestion occurrences ("as is")	90	%	Closed-Loop Stakeholder Session (per driver per day)	03/07
5	Average driving speed	23	mph	Closed Loop Stakeholder Session (15–30 miles per hour)	03/07
6	Average transport loop distance	165	miles	Closed-Loop Stakeholder Session	03/07
7	Average loaded driver salary	$19.06	/hour	*Blue Book of Trucking Companies*	2004–05
8	Variable fuel, maintenance, lubrication costs	$0.95	/mile	*Blue Book of Trucking Companies*	2004–05
9	Average revenue per mile	$2.09	/mile	*Blue Book of Trucking Companies*	2004–05
10	Truck-Specific Congestion Avoidance hardware (PC Miler)	$299	/unit	PC Miler	09/07
11	Truck-Specific Congestion Avoidance hardware (laptop computer)	$1,177	/unit	Dell	09/07
12	Data Costs	$99	/year	PC Miler	09/07
13	Communication Costs	$59.99	/month	AT&T Wireless	09/07
14	Virtual Queuing satellite-based communication device average cost (hardware)	$2,500	/unit	Qualcomm	09/07
15	Virtual Queuing satellite monthly monitoring average fees	$80	/month	Qualcomm	09/07
16	Virtual Queuing appointment system	N/A*		N/A	09/07
17	On-site training	$1,500	/site	TMW Systems (provider)	09/07
18	Average administrative assistant loaded salary	$16.75	/hour	Salary.com	10/07
19	Average pick-up/drop-off time ("to be") with Virtual Queuing	13.6	minutes	Closed-Loop ERG (15% reduction)	09/07
20	Average incident-based congestion time ("to be") with Virtual Queuing	2.5	hours	Closed-Loop ERG	09/07
21	Frequency of incident-based congestion incidents ("to be") with Virtual Queuing	90	%	Closed-Loop ERG	09/07

#	Description	Data Point	Unit	Source	Date
22	Average pick-up/drop-off time ("to be") with Truck-Specific Congestion Avoidance	16	Minutes	Closed-Loop ERG	09/07
23	Average incident-based congestion time ("to be") with Truck-Specific Congestion Avoidance	2.125	Hours	Closed-Loop ERG (15% reduction)	09/07
24	Frequency of incident-based congestion incidents ("to be") with Truck-Specific Congestion Avoidance	90	%	Closed-Loop ERG	09/07
25	Rating: Traffic congestion delay (efficiency) potential effect through Virtual Queuing	+0	N/A	Closed-Loop ERG	09/07
26	Rating: Traffic congestion delay (efficiency) potential effect through Truck-Specific Congestion Avoidance	+5	N/A	Closed-Loop ERG	09/07
27	Rating: Emissions per trip (safety) potential effect through Virtual Queuing	0	N/A	Closed-Loop ERG	09/07
28	Rating: Emissions per trip (safety) potential effect through Truck-Specific Congestion Avoidance	+5	N/A	Closed-Loop ERG	09/07
29	Rating: Loading/unloading time (efficiency) potential effect through Virtual Queuing	+4	N/A	Closed-Loop ERG	09/07
30	Rating: Loading/unloading time (efficiency)potential effect through Truck-Specific Congestion Avoidance	0	N/A	Closed-Loop ERG	09/07
31	Rating: Crashes per mile (safety) potential effect through Virtual Queuing	0	N/A	Closed-Loop ERG	09/07
32	Rating: Crashes per mile (safety) potential effect through Truck-Specific Congestion Avoidance	+2	N/A	Closed-Loop ERG	09/07
33	Rating: Driver satisfaction/retention (safety) potential effect through Virtual Queuing	0	N/A	Closed-Loop ERG	09/07
34	Rating: Driver satisfaction/retention (safety) potential effect through Truck-Specific Congestion Avoidance	+4	N/A	Closed-Loop ERG	09/07
35	Rating: Asset utilization (efficiency) potential effect through Virtual Queuing	+4	N/A	Closed-Loop ERG	09/07

#	Description	Data Point	Unit	Source	Date
36	Rating: Asset utilization (efficiency) potential effect through Truck-Specific Congestion Avoidance	+5	N/A	Closed-Loop ERG	09/07
37	Rating: Insurance costs per vehicle mile (cost) potential effect through Virtual Queuing	0	N/A	Closed-Loop ERG	09/07
38	Rating: Insurance costs per vehicle mile (cost) potential effect through Truck-Specific Congestion Avoidance	+2	N/A	Closed-Loop ERG	09/07

*The Study Team assigned a cost of $0 for the motor carriers because it is assumed that the facility operators would bear the direct cost of deploying the Queuing system, and carrier costs would be restricted to the appropriate vehicle tracking system.

Once the data were collected and the key assumptions for the "generic" data were identified (as detailed in Section 1), several calculations were required in order to identify the costs associated with the processes and with the technologies. These are provided in Table 35 below.

Table 35. Supply Chain Segment 3 Generic Data

#	Description	Value	Formula	Applied
1	# of yearly pick-ups/drop-offs	25,725	Fleet size × Pick-ups/drop-offs per truck per shift × Operating days per year	6 × 12.25 × 350
2	Variable cost per hour when traveling	$21.85	Variable cost per mile × Average driving speed	$0.95 × 23
3	Revenue per hour	$48.07	Revenue per mile × Average driving speed	$2.09 × 23
4	Per-hour contribution margin	$26.22	Revenue per hour - Variable cost per hour	$48.07 – $21.25
5	Yearly # of incident-based congestion occurrences	1,890	Frequency of incident-based congestion occurrences × Fleet size × Operating days per year	90% × 6 × 350
6	Annual cost of pick-ups/drop-offs using opportunity cost	$179,869	Per hour contribution margin × (Average drop-off/pick-up duration ÷ Minutes per hour) × # of yearly pick-ups/drop-offs	$26.22 × (16 ÷ 60) × 25,725
7	Annual cost of pick-ups/drop-offs using variable cost	$130,752	Hourly driver salary × (Average drop-off/pick-up duration/Minutes per hour) × # of yearly pick-ups/drop-offs	$19.06 × (16 ÷ 60) × 25,725
8	Annual cost of incident-based congestion using opportunity cost	$123,890	Per-hour contribution margin × Average Incident based congestion time × Yearly # of incident based congestion occurrences	$26.22 × 2.5 × 1,890
9	Annual cost of incident-based congestion using variable cost	$90,059	Hourly driver salary × Average Incident based congestion time × Yearly # of incident based congestion occurrences	$19.06 × 2.5 × 1,890

#	Description	Value	Formula	Applied
10	Initial investment for Truck-Specific Congestion Avoidance	$10,356	(Unit hardware costs (PC Miler) + Unit hardware costs (laptop)) × Fleet size + On site training fee	($299 + $1,177) × 6 + $1,500
11	Annual cost for Truck-Specific Congestion Avoidance	$13,623	(Yearly data service × Fleet size) + (Monthly communication service × Fleet size × Months per year) + [Administrative assistant salary × (Full time hours per year/portion of time dedicated to new tasks)]	($99 × 6) + ($59.99 × 6 × 12) + [$16.75 × (2,080 ÷ 4)]
12	Initial investment for Virtual Queuing	$16,500	(Unit hardware costs × Fleet size) + On site training fee	($2,500 × 6) + $1,500
13	Annual cost for Virtual Queuing	$23,180	(Monthly monitoring fee × Fleet size × Months per year) + [Administrative assistant salary × (Full-time hours per year/portion of time dedicated to new tasks)]	($80 × 6 × 12) + [$16.75 × (2,080 ÷ 2)]

These calculations, along with the "as is" and "to be" cost driver values, served as the inputs to FTAT for the quantitative analysis. The details of the analysis performed using FTAT are provided in the following section.

4.2.3.4 Freight Technology Assessment Tool Output

Quantitative Results: The following results were obtained using the opportunity cost calculation described in the input data section above. This reflects the assumption that any savings of time resulting from the adoption of the proposed wireless solutions can be used to generate additional revenues. The process improvement savings is therefore the result of the generation of additional revenue minus the variable costs associated with generating those revenues (fuel, maintenance, lubrication, etc.). Table 36 details these results.

Table 36. Supply Chain Segment 3 Quantitative Output

Quantitative Summary Items	Truck-Specific Congestion Avoidance	Virtual Queuing
Initial Investment	$10,356.00	$16,500.00
Net Annual Cash Flow	$4,960.50	$3,800.38
NPV	$9,983.03	$10,192.28
IRR	38.50%	18.98%
Payback	2.09	4.34
Discounted Payback	2.34	5.35
Benefit/Cost	1.96	1.62

The results for both applications reflect modest gains, although the lower price of the Truck-Specific Congestion Avoidance System results in a payback period of less than half that for the Virtual Queuing application. In both cases, the initial system investment exceeds $1,700 per truck. This outcome suggests that if these systems could be offered as additional features on an existing system, or if additional features could be added to existing systems at a reasonable price, the increased return on investment might increase their attractiveness.

The supply chain segment was also analyzed based on the variable cost assumption that additional revenues could not be generated from any potential time savings derived from the adoption of the proposed wireless solutions, as would be the case if the motor carrier were not able to take on additional revenue-producing trips (e.g., due to lack of demand). Any process improvement cost savings would therefore be the result of savings of the applicable variable costs (e.g., loaded driver salary, fuel savings, etc.). Table 37 details these results.

Table 37. Supply Chain Segment 3 Quantitative Output (Excluding Additional Revenue Opportunity)

	Truck-Specific Congestion Avoidance	Virtual Queuing
Initial Investment	$10,356.00	$16,500.00
Net Annual Cash Flow	-$114.15	-$3,567.20
NPV	-$10,824.04	-$41,554.52
IRR	0.00%	0.00%
Payback	0	0
Discounted Payback	0	0
Benefit/Cost	-0.05	-1.52

The figures in this table indicate that if a motor carrier were unable to realize the benefit of adding revenue-producing trips, then all justification for investment in either wireless application disappears.

Additional scenarios were run to identify the effects of varying the fleet size. The results of the fleet size on the BCRs for supply chain segment 3 are shown in Figure 37. The curves indicate that the BCR for the congestion avoidance application increases markedly as more trucks are equipped. The BCR for the Virtual Queuing application also increases with fleet size, although at a lower rate.

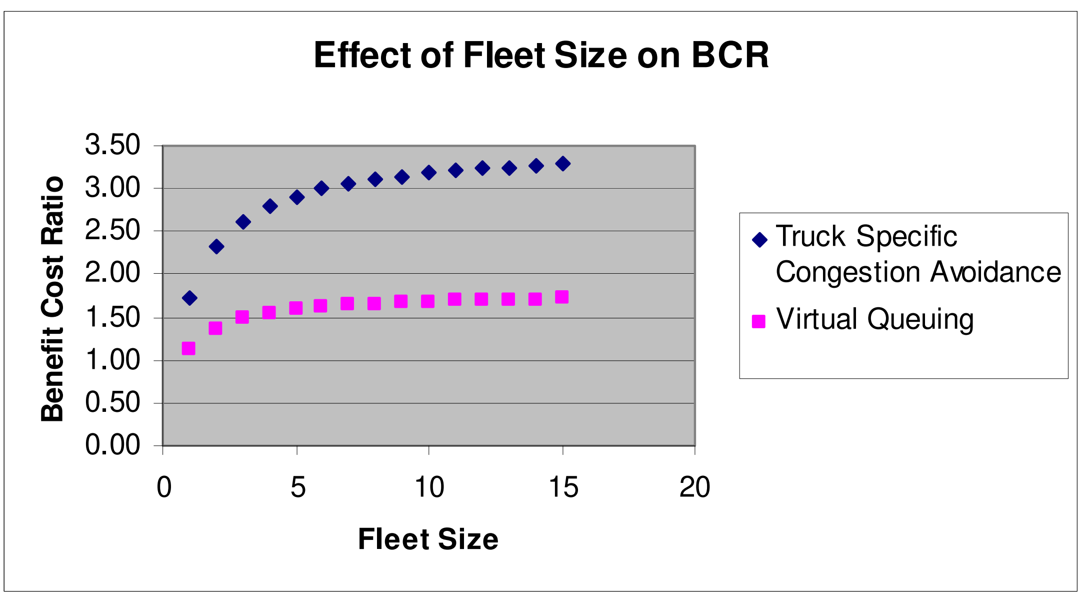


Figure 37. Effect of Fleet Size on Supply Chain Segment 3 Calculations

Finally, additional scenarios were run to identify the effects of varying other independent variables used to calculate the BCR. For this supply chain segment, the Study Team ran three additional scenarios. For each scenario, one variable that represented a "to be" value was varied independently (all other variables were kept constant). Table 38 below reflects the results of this analysis for the technologies evaluated for supply chain segment 3.

Table 38. Supply Chain Segment 3 Sensitivity Analysis Results*

					Truck-Specific Congestion Avoidance BCR	Virtual Queuing BCR
Pickup Drop Off Duration	-5.00%	2.99	4.87	5.00%	2.99	-1.64
Incident Duration	-5.00%	4.05	1.62	5.00%	-0.12	1.62
Revenue per mile	-10.00%	1.46	-0.49	10.00%	4.53	3.72

* Calculated using Baseline BCRs of 2.99 for the Truck-Specific Congestion Avoidance Wireless Solution, and 1.62 for the Virtual Queuing Wireless Solution

For example, if the "to be" value for the amount of time spent waiting to pick up or drop off a load is decreased by 5 percent (meaning that the technology application used yielded a slightly lower waiting time), then the BCR for the Truck-Specific Congestion Avoidance application would not change—a logical result, given the nature of the application. Under the same conditions, the BCR for the Virtual Queuing application would increase to 4.87, which represents a significant result, and one that is also logical, since the application is intended to reduce waiting. Similarly, an increase of 5 percent in waiting time (compared to the original "to be" value) yielded no change in BCR for the Truck-Specific Congestion Avoidance application, and a reduction in BCR for the Virtual Queuing application to -1.64. When examining the results for variation in the duration of a traffic incident, the results are reversed—the Truck-Specific Congestion Avoidance application BCR is very sensitive, while the Virtual Queuing application BCR is not.

Qualitative Results: The ERG participants scored each performance measure with a value ranging from -5 to +5, with -5 representing a strong negative effect, +5 a strong positive effect, and 0 representing no effect. These scores are aggregated in order to provide a robust view of the potential impact of the wireless solution. Table 39 shows the scores for the individual performance measures for the Truck-Specific Congestion Avoidance system and the Virtual Queuing application.

Table 39. Supply Chain Segment 3 Qualitative Output

		Truck-Specific Congestion Avoidance	Virtual Queuing
Efficiency	Traffic Congestion Delay	5	0
Efficiency	Loading/Unloading Time	0	4
Efficiency	Asset Utilization	5	4

Factors	Performance Measures	Truck-Specific Congestion Avoidance	Virtual Queuing
Safety	Emissions per Trip	5	0
Safety	Crashes per Mile	2	0
Safety	Driver Satisfaction/Retention	4	0
	Total Score	**21**	**8**

The output from this computation shows that the ERG participants assigned a much higher relative value to the Truck-Specific Congestion Avoidance application, indicating that they estimate it will have a greater potential impact both in overall qualitative aspects (reflected by the total score) and in the individual performance attribute areas of efficiency and safety.

4.2.3.5 Analysis Summary

Based on the calculated results an economic case can be made for both the Truck-Specific Congestion Avoidance and the Virtual Queuing solutions using the opportunity cost as the basis for calculation. This is reflected by the positive NPVs of $9,983.03 and $10,192.28 respectively, and BCRs higher than 1 at 1.96 and 1.62 respectively. Due to the higher initial investment required for adopting the Virtual Queuing solution, the BCR ratio is more attractive for the Truck-Specific Congestion Avoidance application, in spite of the lower NPV. It is worth noting that the marginal change to the BCR due to increased deployment levels increases at a greater rate for the Truck-Specific Congestion Avoidance solution than it does for Virtual Queuing (it is also worth noting that the BCR is greater for the Truck-Specific Congestion Avoidance application, regardless of the fleet size). These results are consistent with the views expressed by the ERGs and the Stakeholder Sessions, that incident-based congestion was the greatest inefficiency for operators working in this type of supply chain segment. Because the input figures for congestion effects were provided by motor carriers that operate in very busy urban areas, care should be taken when applying these returns to the larger population. In such cases, it is reasonable to assume that the BCR for the Truck-Specific Congestion Avoidance application would be more modest under such circumstances.

4.2.4 Supply Chain Segment 4—Rail Intermodal Terminal (Scenarios 7 & 8)

The fourth supply chain segment represents a common set of actions for a typical movement of containerized or trailered goods by rail, through a rail terminal, and delivered by truck. The process flow begins with the transportation of the goods via rail and ends with exit of the loaded truck from the intermodal facility.

4.2.4.1 Related Inefficiencies

Loading, Unloading, and Waiting: As is the case with port operations and Closed-Loop Pick-Up and Delivery Operations, motor carriers that service railroads indicated that waiting for loading and unloading at rail intermodal terminals is a significant inefficiency. Motor carriers that participated in the MCES cited delays associated with servicing railroad customers that were similar in nature and effects to port-related operations, and indicated that such delays were caused by railroads' efforts to optimize their internal terminal operations.

Empty Intermodal Moves: The exchange of freight between intermodal facilities often occurs between terminals located in and around congested urban areas. Much of this interchange activity is conducted using trucks to ferry containers, intermodal chassis, and trailers between rail terminals, or between ports and rail terminals. These entities support goods moves for a variety of different supply chains that may be individually well-coordinated, but for which little or no coordination exists in the back-and- forth moves between facilities that are necessary to keep the freight moving. The result is an overabundance of one-way moves, and a measurable percentage of empty moves. These "cross-town" moves represent a significant contributor to congestion, and are a significant source of inefficiency and adverse safety effects.

4.2.4.2 Potential Wireless Solutions

Virtual Queuing: Because of similarities between the inefficiencies introduced by the operating methods of rail terminals and those introduced by port terminals, the Study Team recommended to the Government team that the Virtual Queuing concept described earlier in this report be applied to the Rail Intermodal Supply Chain Segment as well. As the diagram in Figure 38 illustrates, the application would operate in the same manner as for port operations. Applying this solution to the Rail Intermodal Supply Chain Segment allows for an examination of its potential benefits under an economic model that differs from that prevailing in the port environment.

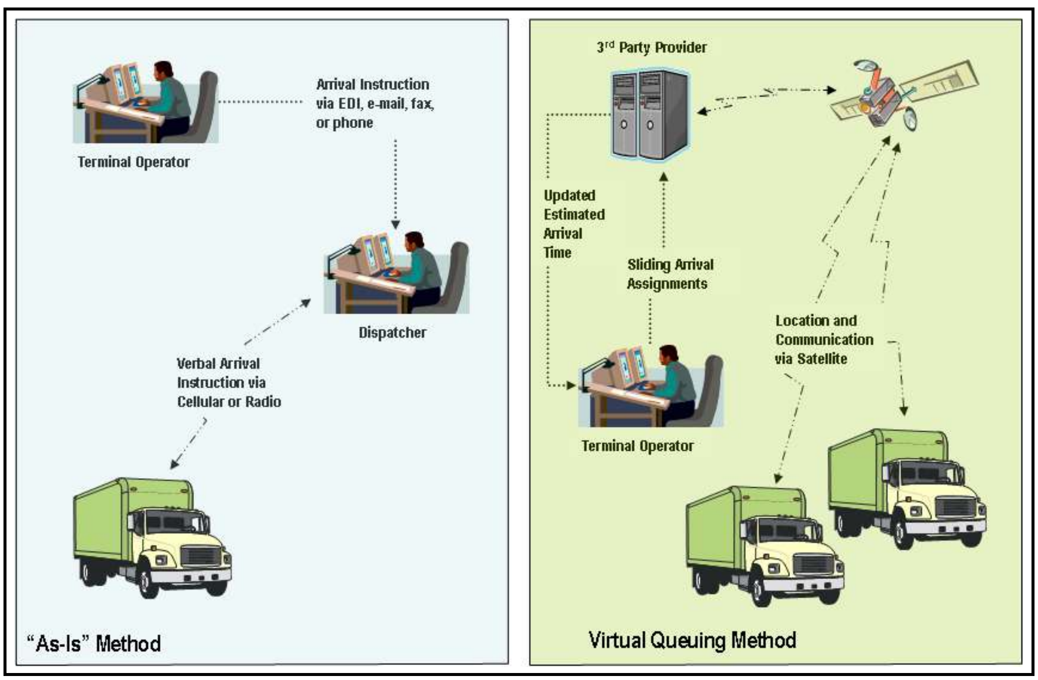


Figure 38. Virtual Queuing Application

Cross-Town Intermodal Interchange: The Cross-Town Intermodal Interchange application would provide motor carriers that service rail intermodal terminals with a way to reduce empty trips by promoting coordinated operations. In effect, all motor carriers providing cross-town exchanges between railroad terminals would subscribe to a collaborative application that manages load assignments to maximize the percentage of loaded moves by reducing one-way trips.

As Figure 39 shows, railroads currently operate independently of each other when it comes to booking load movements out of their terminal facilities. All outbound movements are booked with motor carriers to be one-way trips to other railroad terminals, the exception being instances in which the motor carrier is instructed to retrieve an empty intermodal chassis from the other terminal. The truck dispatched to deliver the load to the second terminal typically returns to the originating terminal in a bobtail configuration.

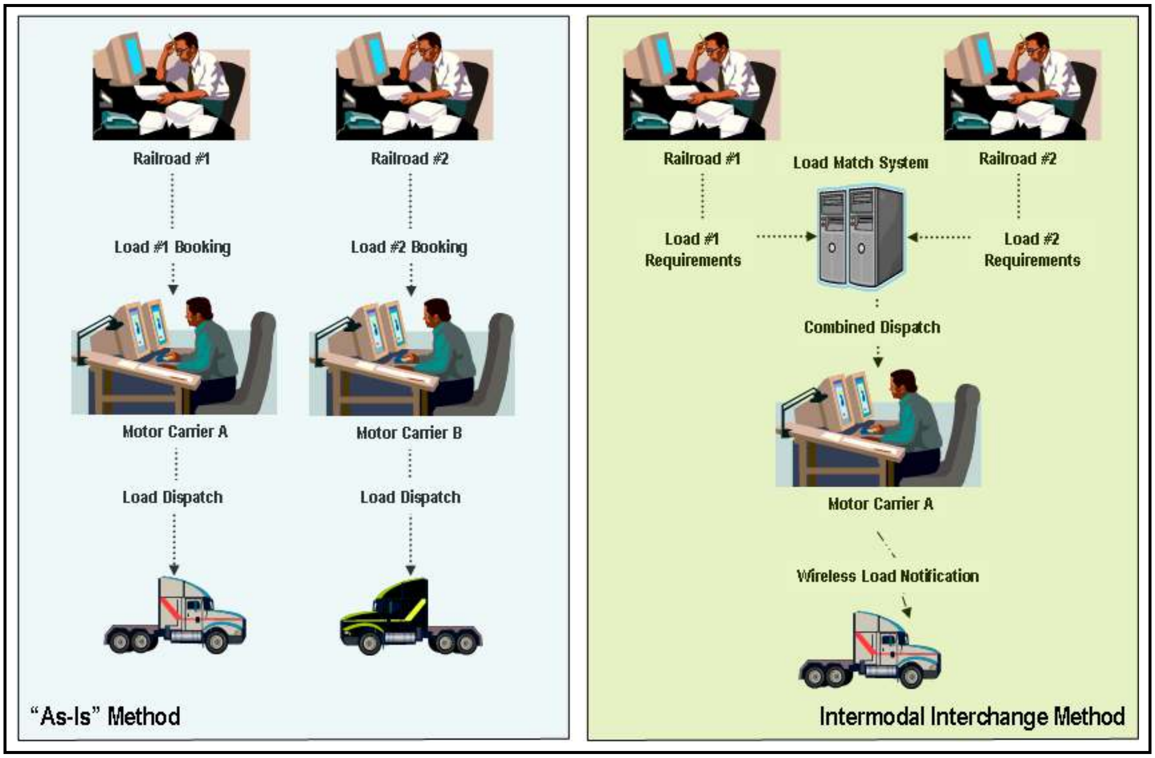


Figure 39. Cross-Town Intermodal Interchange Application

The Cross-Town Intermodal Interchange application would allow railroads and motor carriers to coordinate operations so that trucks returning to the originating terminal could bring a return load, rather than returning empty, by employing a combined load matching application—most likely operated by a third party. Railroads would post their load movement needs in advance, and motor carriers would log onto a web site and indicate which loads they could support within their resource constraints (i.e., the number of available trucks and drivers during the needed movement window). The system would apply business rules agreed upon by the participating railroads and motor carriers, and provide the resulting load assignments to each motor carrier in a combined dispatch format. The motor carrier dispatcher would then assign loads to individual truck and driver combinations based on current location, proximity to the originating facility, and ETA information, and transmit the information wirelessly, as shown in the right side of the figure.

4.2.4.3 Input Data

Input data for the analysis were collected from a variety of sources, including the Literature Review, the Stakeholder Sessions, ERGs conducted as part of Task 6, and additional research conducted by the Study Team. The input data sources for Supply Chain Segment 4 are detailed in Table 40.

Table 40. Supply Chain Segment 4 Input Data

#	Description	Data Point	Unit	Source	Date
1	Truck check-in at gate duration including queue time(“as is”)	17	minutes	Rail Intermodal Stakeholder Session (15–20 minute average)	03/07
2	Average # of weekly cross-town moves (“as is”)	210	/week	Rail Intermodal Stakeholder Session	03/07
3	Average # of bobtail moves (“as is”)	21	/week	Rail Intermodal Stakeholder Session	03/07
4	Truck check-in at gate duration including queue time(“as is”)	17	minutes	Rail Intermodal Stakeholder Session (15–20 minute average)	03/07
5	Average bobtail move duration	19	minutes	Rail Intermodal Stakeholder Session	03/07
6	Average cross-town move distance	25	miles	Rail Intermodal Stakeholder Session	03/07
7	Average loaded driver salary	$19.06	/hour	*Blue Book of Trucking Companies*	2004–05
8	Variable fuel, maintenance, lubrication costs	$1.12	/mile	Rail Intermodal Stakeholder Session	2004–05
9	Average revenue per cross-town move	$60.00	/move	*Blue Book of Trucking Companies*	2004–05
10	Cross-Town Intermodal Interchange hardware (cellular)	$150	/unit	Nextel	09/07
11	Cross-Town Intermodal Interchange service (cellular)	$99	/month	Nextel	09/07
12	Virtual Queuing satellite-based communication device average cost (hardware)	$2,500	/unit	Qualcomm	09/07
13	Virtual Queuing satellite monthly monitoring average fees	$80	/month	Qualcomm	09/07
14	Virtual Queuing appointment system	N/A*		N/A	09/07
15	On-site training	$1,500	/site	TMW Systems (technology provider)	09/07
16	Average administrative assistant loaded salary	$16.75	/hour	Salary.com	10/07
17	Truck check-in at gate duration including queue time(“to be”) with Cross-Town Intermodal Interchange	17	minutes	Rail Intermodal ERG	09/07
18	Truck check-in at gate duration including queue time (“to be”) with Cross-Town Intermodal Interchange	17	minutes	Rail Intermodal ERG	09/07

#	Description	Data Point	Unit	Source	Date
19	Average # of weekly cross-town moves ("to be") with Cross-Town Intermodal Interchange	210	/week	Rail Intermodal ERG	09/07
20	Average # of bobtail moves ("to be") with Cross-Town Intermodal Interchange	12.6	/week	Rail Intermodal ERG (40% reduction)	09/07
21	Truck check-in at gate duration including queue time ("to be") with Virtual Queuing	15.5	minutes	Rail Intermodal ERG (8–10% reduction)	09/07
22	Truck check-in at gate duration including queue time ("to be") with Virtual Queuing	15.5	minutes	Rail Intermodal ERG (8–10% reduction)	09/07
23	Average # of weekly cross-town moves ("to be") with Virtual Queuing	210	/week	Rail Intermodal ERG	09/07
24	Average # of bobtail moves ("to be") with Virtual Queuing	21	/week	Rail Intermodal ERG	09/07
25	Rating: Traffic congestion delay (efficiency) potential effect through Cross-Town Intermodal Interchange	+5	N/A	Rail Intermodal ERG	09/07
26	Rating: Traffic congestion delay (efficiency) potential effect through Virtual Queuing	0	N/A	Rail Intermodal ERG	09/07
27	Rating: Emissions per trip (safety) potential effect through Cross-Town Intermodal Interchange	+3	N/A	Rail Intermodal ERG	09/07
28	Rating: Emissions per trip (safety) potential effect through Virtual Queuing	+1	N/A	Rail Intermodal ERG	09/07

*The Study Team assigned a cost of $0 for the motor carriers because it is assumed that the facility operators would bear the direct cost of deploying the Queuing system, and carrier costs would be restricted to the appropriate vehicle tracking system.

Once the data were collected and the key assumptions for the "generic" data were identified (as detailed in Section 1), several calculations were required in order to identify the costs associated with the processes and with the technologies. These are provided in Table 41.

Table 41. Supply Chain Segment 4 Generic Data

#	Description	Value	Formula	Applied
1	# of daily moves	30	# of weekly moves ÷ Days per week	210 ÷ 7
	# of daily bobtail moves	3	# of weekly bobtail moves ÷ Days per week	21 ÷ 7
2	# of yearly moves through gate	10,500	# of daily moves × Operating days per year	30 × 350
3	Revenue per hour	$80.00	Revenue per trip ÷ (Minutes per trip ÷ Minutes per hour)	$60.00 ÷ (45 ÷ 60)
3	Variable cost (fuel, maintenance, etc.) per trip	$28.00	Variable cost per mile × Miles per trip	$1.12 × 25

#	Description	Value	Formula	Applied
4	Variable cost (fuel, maintenance, etc.) per hour	$42.00	Variable cost (fuel, maintenance, etc.) per trip ÷ (Per-trip travel time ÷ Minutes per hour)	$28.00 ÷ (40 ÷ 60)
5	Contribution margin per hour	$38.00	Revenue per hour – Variable cost (fuel, maintenance, etc.) per hour	$80 – $42
6	Annual cost of waiting for check-in at gate using opportunity cost	$113,050	Contribution margin per hour × (Truck check-in at gate duration including queue ÷ Minutes per hour) × # of yearly moves through gate	$38.00 × (17 ÷ 60) × 10,500
7	Annual cost of waiting for check-in at gate using variable cost	$56,703.50	Hourly driver salary × (Truck check-in at gate duration including queue ÷ Minutes per hour) × # of yearly moves through gate	$19.06 × (17 ÷ 60) × 10,500
8	Annual cost of waiting for check-out at gate using opportunity cost	$113,050	Contribution margin per hour × (Truck check-out at gate duration including queue ÷ Minutes per hour) × # of yearly moves through gate	$38.00 × (17 ÷ 60) × 10,500
9	Annual cost of waiting for check-out at gate using variable cost	$56,703.50	Hourly driver salary × (Truck check-out at gate duration including queue ÷ Minutes per hour) × # of yearly moves through gate	$19.06 × (17 ÷ 60) × 10,500
10	Annual cost for bobtail moves using variable cost	$29,400	Variable cost (fuel, maintenance, etc.) per trip × # of daily bobtail moves × Operating days per year	$28.00 × 3 × 350
11	Annual cost for bobtail moves using opportunity cost	$33,600	(Revenue per trip - Variable cost (fuel, maintenance, etc.) per trip) × # of daily bobtail moves × Operating days per year	($60.00 – $28.00) × 3 × 350
12	Initial investment for Cross-Town Intermodal Interchange	$900	Unit hardware costs × Fleet size	$150 × 6
13	Annual cost for Cross-Town Intermodal Interchange	$11,483	(Monthly service charges × Fleet size × Months per year) + [Administrative assistant salary × (Full-time hours per year/portion of time dedicated to new tasks)]	($99 × 6 × 12) + [$16.75 × (2,080 ÷ 8)]
14	Initial investment for Virtual Queuing	$16,500	(Unit hardware costs × Fleet Size) + On-site training fee	($2,500 × 6) + $1,500
15	Annual cost for Virtual Queuing	$14,470	(Monthly monitoring fee × Fleet size × Months per year) + [Administrative assistant salary × (Full-time hours per year/portion of time dedicated to new tasks)]	($80 × 6 × 12) + [$16.75 × (2,080 ÷ 4)]

These calculations along with the "as is" and "to be" cost driver values served as the inputs to FTAT for the quantitative analysis. The details of the analysis performed using FTAT are provided in the following section.

4.2.4.4 Freight Technology Assessment Tool Output

Quantitative Results: The following results were obtained using the opportunity cost calculation described in the input data section above. This reflects the assumption that any savings of time resulting from the adoption of the proposed wireless solutions can be used to generate additional revenues. The process improvement savings is therefore the result of the generation of additional revenue minus the variable costs associated with generating those revenues (fuel, maintenance, lubrication, etc.). Table 42 details these results.

Table 42. Supply Chain Segment 4 Quantitative Output

Quantitative Summary Items	Cross-Town Intermodal Interchange	Virtual Queuing
Initial Investment	$900.00	$16,500.00
Net Annual Cash Flow	$1,957.00	$5,480.00
NPV	$7,124.09	$21,989.23
IRR	216.76%	30.98%
Payback	0.46	3.01
Discounted Payback	0.48	3.50
Benefit/Cost	8.92	2.33

The supply chain segment was also analyzed based on the variable cost assumption that additional revenues could not be generated from any potential time savings derived from the adoption of the proposed wireless solutions, as would be the case if the motor carrier was not able to take on additional revenue-producing trips (e.g., due to lack of demand). Any process improvement cost savings would therefore be the result of savings of the applicable variable costs (loaded driver salary, fuel savings, etc.). Table 43 details these results.

Table 43. Supply Chain Segment 4 Quantitative Output (Excluding Additional Revenue Opportunity)

	Cross-Town Intermodal Interchange	Virtual Queuing
Initial Investment	$900.00	$16,500.00
Net Annual Cash Flow	$277.00	-$4,463.50
NPV	$235.75	-$47,849.76
IRR	16.33%	0.00%
Payback	3.25	0
Discounted Payback	3.81	0
Benefit/Cost	1.26	-1.9

Additional scenarios were run to identify the effects of varying the fleet size. As discussed previously, a fleet size of six was assumed for the results presented above. The results of the fleet size on the BCRs for Supply Chain Segment 4 are shown in Figure 40.

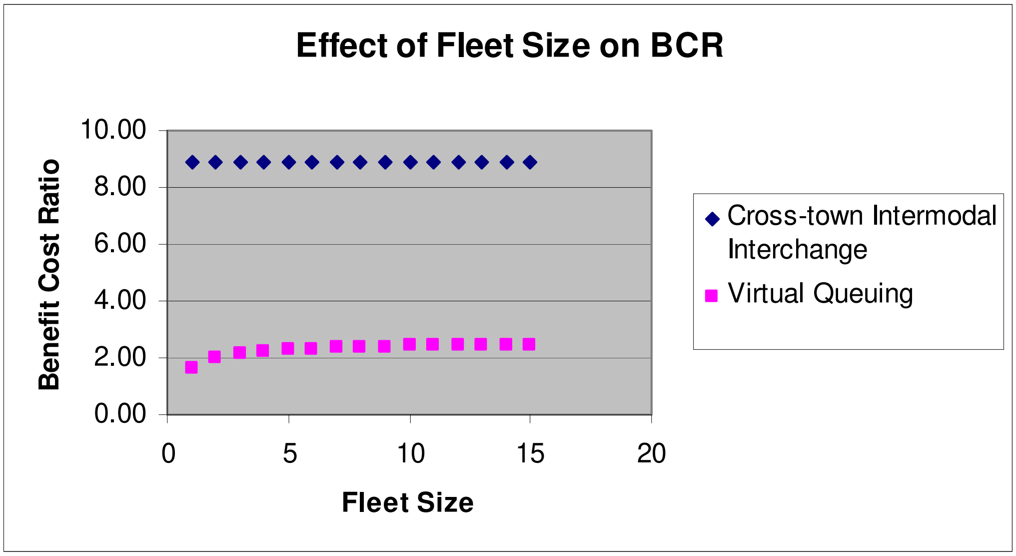


Figure 40. Effect of Fleet Size on Supply Chain Segment 4 Calculations

As noted previously, the relative value of the Virtual Queuing application increases with the level of deployment. The same cannot be said for the Intermodal Interchange application, which remains effectively constant in value regardless of the number of vehicles equipped.

Finally, additional scenarios were run to identify the effects of varying other independent variables used to calculate the BCR. For this supply chain segment, the Study Team ran three additional scenarios. For each scenario, one variable that represented a "to be" value was varied independently (all other variables were kept constant). Table 44 below reflects the results of this analysis for the technologies evaluated for supply chain segment 4.

Table 44. Supply Chain Segment 4 Sensitivity Analysis Results*

					Cross-Town Intermodal Interchange BCR	Virtual Queuing BCR
Checkin Checkout Duration	-5.00%	8.92	6.72	5.00%	8.92	-2.05
Weekly Bobtail Moves	-5.00%	13.51	2.33	5.00%	4.32	2.33
Revenue per Mile	-10.00%	-24.30	1.54	10.00%	24.46	8.86

* Calculated using Baseline BCRs of 8.92 for the Cross-Town Intermodal Interchange Wireless Solution, and 2.33 for the Virtual Queuing Wireless Solution.

For example, if the "to be" value for the amount of time spent waiting for terminal check-in or check-out is decreased by 5 percent (meaning that the technology application used yielded a slightly lower waiting time), then the BCR for the Cross-Town Intermodal Interchange application would remain at 8.92, which is logical, since the application would not affect check-in or check-out. Under the same conditions, the BCR for the Virtual Queuing application would increase to 6.72, a measurable increase. Similarly, an increase of 5 percent in waiting time (compared to the original "to be" value) again yielded no change in BCR for the chassis Cross-

Town Intermodal Interchange application, and a reduction in BCR for the Virtual Queuing application to -2.05.

Not surprisingly changes in the estimated “to be” value for the number of cross-town bobtail moves produces a measurable change in the BCR for the Cross-Town Intermodal Interchange application, while the same adjustment produces no change in BCR for the Virtual Queuing application.

Qualitative Results: The ERG participants were also asked to score the potential effects the wireless solutions could have on the performance measures identified during the Literature Review and the Stakeholder Sessions. Each performance measure is given a score ranging from -5 to +5, with -5 representing a strong negative effect, +5 a strong positive effect, and 0 representing no effect. Table 45 shows the scores for the individual performance measures for the Cross-Border Compliance Notification system and the Cross-Border Tracking application.

Table 45. Supply Chain Segment 4 Qualitative Output

Factors	Performance Measures	Cross-Town Intermodal Interchange	Virtual Queuing
Safety	Emissions	3	1
Efficiency	Congestion	5	0
	Total Score	**8**	**1**

4.2.4.5 Analysis Summary

The quantitative results show that an economic case can be made for both the Cross-Town Intermodal Interchange and the Virtual Queuing solutions using the opportunity cost as the basis for calculation. This is reflected by the positive Net Present Values, $7,124.09 and $21,989.23 respectively, and BCRs higher than 1 at 8.92 and 2.33, respectively. Based on these calculated results, the Cross-Town Intermodal Interchange proves to be more attractive using both the total net effect (NPV) and the relative effect (BCR); this indicates that for carriers that can afford the initial investment associated with this solution, the financial returns will be substantial. The application becomes even more attractive if the motor carrier is able to use existing cellular communications equipment.

It is also worth noting that the BCR for the Virtual Queuing system increases with fleet size, while the BCR for the Cross-Town Intermodal Interchange is not affected. However the marginal BCR increases for the Virtual Queuing system begin to level off at a fleet size of around six, and the effects of the BCR are minimal, regardless of the increasing fleet size. Fleet size does not affect the BCR for the Cross-Town Intermodal Interchange solution because any fixed infrastructure costs would be assumed by the intermodal terminals, and all initial investment costs to the carriers would be variable.

When the quantitative analysis was performed using the variable costs as opposed to the opportunity costs, the Cross-Town Intermodal Interchange solution remained the more attractive of the two. However, the return for this technology in this scenario, while still attractive, decreased greatly from the returns provided using the opportunity cost. This is due to the fact that the overwhelming benefit of such a solution would result from dramatically increased asset productivity rates (i.e., reduction in the number of empty trips). Even minor changes to the yearly cash flow have a significant effect on both NPV and BCR. This indicates that actual returns for this solution could vary greatly, based on demand fluctuations or changes in cost such as fuel, tires, or labor.

The economic viability of the Virtual Queuing system is greatly affected by using variable costs. In fact, an economic case cannot be made for this solution under these circumstances, as reflected by the negative NPV and BCR less than 1. This indicates that this solution would achieve the greatest benefit in areas where there is sufficient demand to allow carriers to perform additional runs, as opposed to simply cutting driver hours.

A key assumption inherent in this analysis is that the intermodal terminals would also adopt these solutions and absorb any of the infrastructure costs associated with implementing a shared database for the Cross-Town Intermodal Interchange or an appointment system for the Virtual Queuing system. It would in all likelihood be necessary to prove the economic viability of these solutions from a terminal perspective as well, although that fell outside the scope of this effort.

4.2.5 Supply Chain Segment 5—Long-Haul Truckload and Less-Than-Truckload Operation (Scenarios 9 & 10)

The fifth supply chain segment represents a typical long-haul over-the-road operation where a commercial trucking company picks up and drops off goods at points that are geographically distant.

4.2.5.1 Related Inefficiencies

Cargo Theft and Pilferage: Evidence exists to suggest that estimates of theft and pilferage in the freight transportation system likely exceed the \$15–\$30 billion reported by the Federal Bureau of Investigation. A 1999 study issued by the John A. Volpe National Transportation Systems Center estimates that only 40 percent of all businesses and individual freight owners report thefts that occur. Actual losses due to theft, including costs associated with investigation, redelivery, and penalties, approach \$60 billion annually (Kilcarr, 2002).

Much of the reported theft (as much as 80 percent, according to the Volpe report) occurs at freight interchange and storage facilities, and is assisted by individuals with authorized access to the facilities. Stakeholders at the sessions indicated that freight is at greatest risk of theft (and security infiltration) at locations where it sits untended for periods of time.

Excessive Speed: Excessive speed has long been identified by the FMCSA as a primary contribution to motor- vehicle-driver-caused crashes. FMCSA's *Large Truck Crash Causation Study* shows that driver decisions related to excessive speed (and/or driving too fast for conditions, misjudging the speed of other vehicles, following other vehicles too closely, and making false assumptions about the actions of other drivers) contribute to 38 percent of truck crashes annually (USDOT 2006b). While speeding is only one component of these driver-related actions, it is certainly a critical component.

From the motor carrier perspective, excessive speed also contributes to fuel inefficiency. The general industry rule of thumb is that for every mile per hour over 50 mph, fuel mileage will be reduced by 0.1 mpg. At the same time, carriers must balance the "money value of time" associated with getting shipments to the customer with potential fuel efficiency losses, especially in states where the speed limit has been raised to 65 mph or beyond.

4.2.5.2 Potential Wireless Solutions

Untethered Trailer Tracking: One of the challenges associated with monitoring the security of trailers and their contents is that they may sit for extended periods of time not connected to a power unit, which often serves as the only means for obtaining information about the status of the trailer. This situation has been at least partially addressed through the development and deployment of solutions that allow for independent monitoring of the trailer. Two of the most prominent methods examined are wireless-based Untethered Trailer Tracking systems, and electronic container and trailer intrusion detectors, generally referred to as e-seals.

In a functional test managed by FMCSA, a Untethered Trailer Tracking device was examined under several different configurations to understand better its technical capabilities, and to allow motor carriers to assess its operational viability (USDOT, 2005c). These devices rely upon remote positioning and status monitoring technologies (e.g., satellite tracking, "geo-fencing" [the use of geographically encoded reference information in conjunction with a geolocation device to determine if an item crosses a reference boundary], on-board alarms) to provide asset owners with near-real-time information about their trailers, and allow them to set reporting thresholds that indicate such events as unauthorized movement. The diagram in Figure 41 illustrates how such a system functions, alongside the "as is" method where trailers are not monitored unless connected to a power unit.

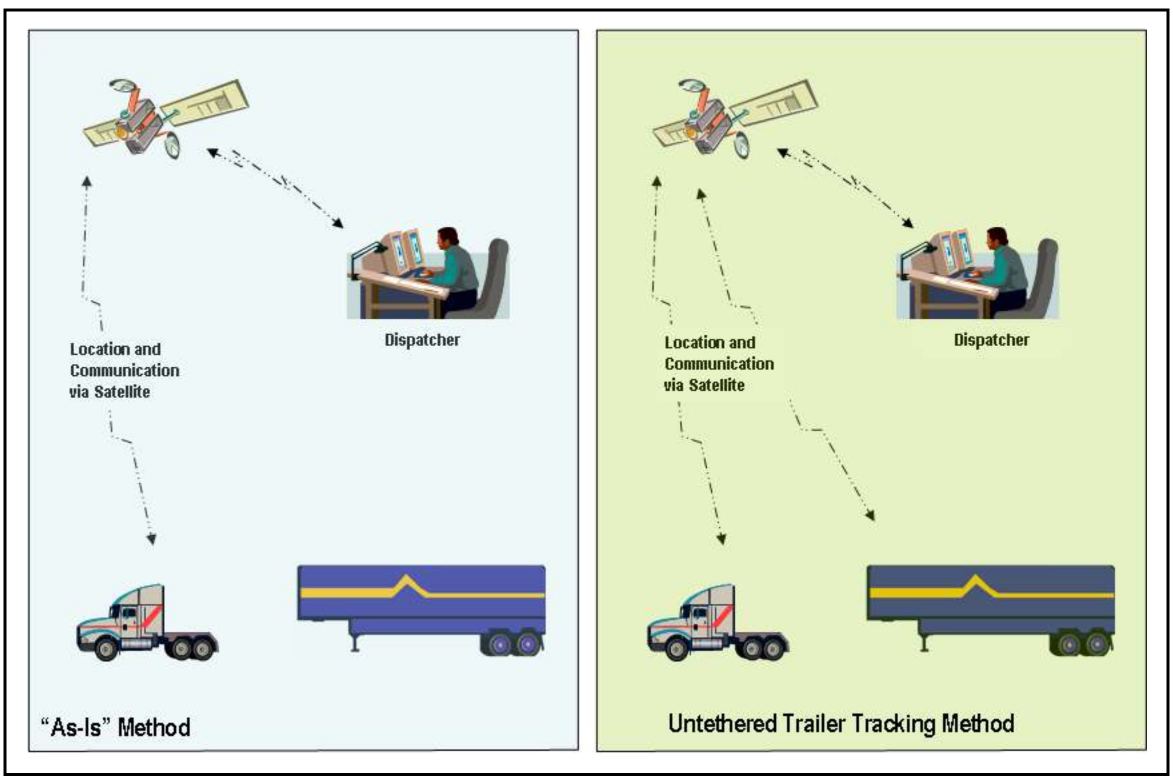


Figure 41. Untethered Trailer Tracking Application

The Untethered Trailer Tracking solution depicted on the right side of the figure employs a trailer-mounted device that has a location determination capability, along with the ability to regularly report status information (e.g., doors open or closed, stationary or moving, etc.) via cellular wireless or satellite.

Variable Speed Limiter: Many carriers already use speed governors on their equipment. Some even use them to implement incentive programs that reward drivers by raising the maximum speed limit. Wireless technologies could be applied to automatically adjust speed governors on vehicles, based on the posted speed limit of the facility. Location-based systems linking GPS satellite location to GIS (geographic information system) databases would enable this functionality. It would also be possible to alter allowable speed maximums based on time of day, weather conditions, and/or traffic conditions, and to link these factors with other known safety criteria. The potential outcome could decrease the frequency and severity of speeding events and/or present motor carriers, with an option for monitoring/influencing fuel efficiency.

Figure 42 contains an illustration of how this might be deployed. The current method for setting maximum vehicle speed is shown on the left side of the figure, where a motor carrier technician sets the speed using a wired interface to the truck. The right side of the figure depicts the proposed method, in which an on-board navigation device determines the vehicle location, evaluates that position against a database within the device that contains speed limit setting parameters (e.g., posted speed limit and a reduction factor), and has the ability to wirelessly communicate with the engine control unit via Bluetooth.

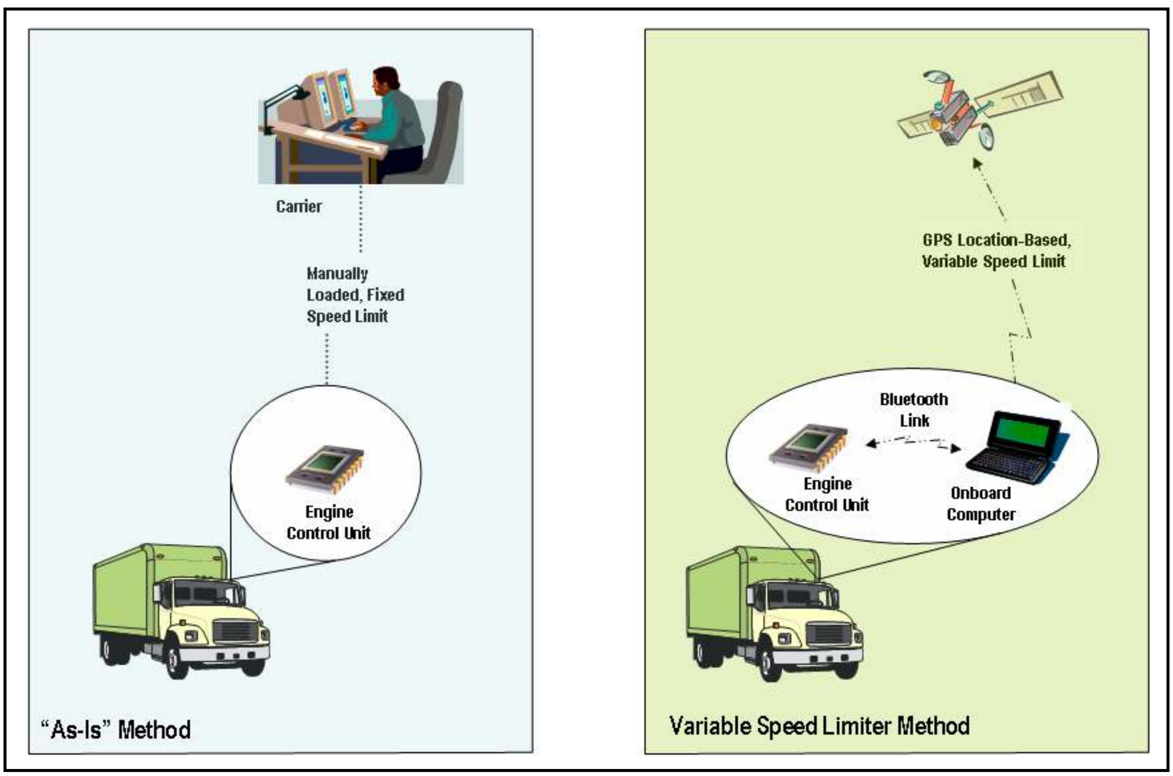


Figure 42. Variable Speed Limiter Application

When an equipped vehicle enters a zone where the speed limit is below the regular maximum operating speed of the vehicle, the device would first warn the driver of the need to slow down, and eventually adjust the maximum speed to a lower setting.

4.2.5.3 Input Data

Input data for the analysis were collected from a variety of sources including the Literature Review, the Stakeholder Sessions, ERGs conducted as part of Task 6, and additional research conducted by the MCES Team. The input data and sources for Supply Chain Segment 5 are provided in Table 46.

Table 46. Supply Chain Segment 5 Input Data

#	Description	Data Point	Unit	Source	Date
1	Average annual miles driven per truck (“as is”)	111,585	miles	Long-Haul Expert Resource Group	09/07
2	Average miles per gallon (“as is”)	5.7	/mpg	Long-Haul Expert Resource Group	09/07
3	Average # of trailer thefts per year (“as is”)	2	/year	Watkins Shepard (1,200-trailer fleet size)	09/07
4	Average # of unauthorized trailer movements (“as is”)	5	/year	Watkins Shepard (1,200-trailer fleet size)	09/07
5	Average driving speed (“as is”)	54	/mph	Long-Haul Expert Resource Group	09/07
6	Average cost for new trailer	$25,000	/trailer	Watkins Shepard	09/07
7	Average amortized monthly trailer cost	$325	/month	Watkins Shepard	09/07
8	Average diesel fuel cost	$2.95	/gallon	Energy Information Administration	09/07
9	Average revenue per mile	$1.60	/mile	Long-Haul Expert Resource Group	09/07
10	Untethered Trailer Tracking device and (hardware)	$600	/unit	FMCSA Untethered Trailer Tracking and Control Systems Report	12/05
11	Untethered Trailer Tracking sensors and mounting hardware	$230	/unit	FMCSA Untethered Trailer Tracking and Control Systems Report	12/05
12	Untethered Trailer Tracking monthly monitoring service	$12	/month	FMCSA Untethered Trailer Tracking and Control Systems Report	12/05
13	Untethered Trailer Tracking installation	$300	/unit	FMCSA Untethered Trailer Tracking and Control Systems Report	12/05
14	Variable Speed Limiter hardmount (satellite)	$3,000	/unit	Eaton Vorad	09/07
15	Variable Speed Limiter acceleration control unit	$400	/unit	Eaton Vorad	09/07
16	Variable Speed Limiter on board computer	$1,177	/unit	Dell	09/07
17	Variable Speed Limiter monthly monitoring service	$80	/month	Qualcomm	09/07

#	Description	Data Point	Unit	Source	Date
18	On-site training	$1,500	/site	TMW Systems (provider)	09/07
19	Average administrative assistant loaded salary	$16.75	/hour	Salary.com	10/07
20	Average miles per gallon ("to be") with Untethered Trailer Tracking	5.7	/mpg	Long-Haul Expert Resource Group	09/07
21	Average miles per gallon ("to be") with Variable Speed Limiter	6.3	/mpg	Long-Haul Expert Resource Group	09/07
22	Average driving speed ("to be") with Untethered Trailer Tracking	54	/mph	Long-Haul Expert Resource Group	09/07
23	Average driving speed ("to be") with Variable Speed Limiter	51	/mph	Long-Haul Expert Resource Group	09/07
24	Average # of trailer thefts per year ("to be") with Untethered Trailer Tracking	1	/year	Watkins Shepard (1,200 trailer fleet size)	09/07
25	Average # of unauthorized trailer movements ("to be") with Untethered Trailer Tracking	5	/year	Watkins Shepard (1,200 trailer fleet size)	09/07
26	Average % trailer reduction ("to be") with Untethered Trailer Tracking	25%	N/A	Watkins Shepard	09/07
27	Rating: Crashes per vehicle mile (safety) potential effect through Untethered Trailer Tracking	0	N/A	Long-Haul Expert Resource Group	09/07
28	Rating: Crashes per vehicle mile (safety) potential effect through Variable Speed Limiter	+1	N/A	Long-Haul Expert Resource Group	09/07
29	Rating: Insurance costs per vehicle mile (cost) potential effect through Untethered Trailer Tracking	+2	N/A	Long-Haul Expert Resource Group	09/07
30	Rating: Insurance costs per vehicle mile (cost) potential effect through Variable Speed Limiter	+1	N/A	Long-Haul Expert Resource Group	09/07
31	Rating: Annual theft, pilferage, and misuse (cost) potential effect through Untethered Trailer Tracking	0	N/A	Long-Haul Expert Resource Group	09/07
32	Rating: Annual theft, pilferage, and misuse (cost) potential effect through Variable Speed Limiter	+1	N/A	Long-Haul Expert Resource Group	09/07
33	Rating: Driver satisfaction and retention (safety) potential effect through Untethered Trailer Tracking	0	N/A	Long-Haul Expert Resource Group	09/07
34	Rating: Driver satisfaction and retention (safety) potential effect through Variable Speed Limiter	-2	N/A	Long-Haul Expert Resource Group	09/07

Once the data were collected and the key assumptions for the "generic" data were identified (as detailed in Section 1), several calculations were required in order to identify the costs associated with the processes and with the technologies. These are provided in Table 47.

Table 47. Supply Chain Segment 5 Generic Data

#	Description	Value	Formula	Applied
1	Annual miles driven per carrier	669,510	Annual miles driven per truck × Fleet size	111,585 × 6
2	Annual fuel consumption (gallons)	117,457.89	Annual miles driven per carrier ÷ Miles per gallon	669,510 ÷ 5.7
3	Annual fuel cost	$346,500.79	Annual fuel consumption (gallons) × Cost per gallon	111,747.89 × $2.95
4	Trailer theft frequency	0.17%	Trailer thefts per year ÷ Fleet size (trailers)	2 ÷ 1,200
5	Number of trailers per truck	2.5	Total trailers ÷ Fleet size	1,600 ÷ 640
6	Number of trailers per carrier	15	Number of trailers per truck × Fleet size (assumed)	2.5 × 6
7	Annual cost of trailer theft per carrier	$625.00	Number of trailers per carrier × Trailer theft frequency × Cost per trailer	15 × 0.0017 × $25,000
8	Annual benefit from reduced trailer theft with Untethered Trailer Tracking	$312.50	Annual cost of trailer theft per carrier × Average % trailer theft reduction ("to be") with Untethered Trailer Tracking	$625.00 × .5
9	Annual benefit from reduced # of trailers	$14,625	Average % trailer reduction ("to be") with Untethered Trailer Tracking × Number of trailers per carrier × Amortized monthly trailer cost × Months per year	.25 × 15 × $325 × 12
10	Initial investment for Untethered Trailer Tracking	$11,550	(Tracking device hardware + Activation per device) × Number of trailers per carrier + [Unit cost hardware (laptop) × Fleet size] + On-site training fee	($300 + $230) × 15 + ($600 × 6)
11	Annual cost for Untethered Trailer Tracking	$10,870	(Monthly service charges × Fleet size × Months per year) + [Administrative assistant salary × (Full time hours per year ÷ portion of time dedicated to new tasks)]	($12 × 15 × 12) + [$16.75 × (2,080 ÷ 4)]
12	Initial investment for Variable Speed Limiter	$28,962	[Tracking device hardware (satellite) + Acceleration control unit hardware + Unit cost hardware (laptop)] × Fleet size + On site training fee	($3,000 + $400 + $1,177) × 6) + $1,500
13	Annual cost for Variable Speed Limiter	$14,470	(Monthly monitoring fee × Fleet size × Months per year) + [Administrative assistant salary × (Full-time hours per year/portion of time dedicated to new tasks)]	($80 × 6 × 12) + [$16.75 × (2,080 ÷ 4)]

These calculations, along with the "as is" and "to be" cost driver values, served as the inputs to FTAT for the quantitative analysis. The details of the analysis performed using FTAT are provided in the following section.

4.2.5.4 *Freight Technology Assessment Tool Output*

Quantitative Results: The following results were obtained using the cost calculations described in the input data section above. This supply chain segment was examined strictly from a variable cost perspective, since the benefits derived from applying to either of these wireless solutions were related to savings on variable costs such as fuel or equipment, as opposed to the time savings typically associated with process improvement. Hence the calculation of opportunity-based benefits was not performed. Table 48 details these results.

Table 48. Supply Chain Segment 5 Quantitative Output

Quantitative Summary Items	Untethered Trailer Tracking	Variable Speed Limiter
Initial Investment	$11,550.00	$28,962.00
Net Annual Cash Flow	$4,067.50	$15,924.81
NPV	$17,018.42	$82,887.17
IRR	33.22%	54.26%
Payback	2.84	1.82
Discounted Payback	3.28	2.01
Benefit/Cost	2.47	3.86

Additional scenarios were run to identify the effects of varying the fleet size. The effects of the fleet size on the BCRs for Supply Chain Segment 5 are shown in Figure 43. The results show that Variable Speed Limiter application offers dramatically increased BCR values as the number of deployed units increases, while the BCR for the Untethered Trailer Tracking application is unaffected, due to the absence of fixed initial investment costs.

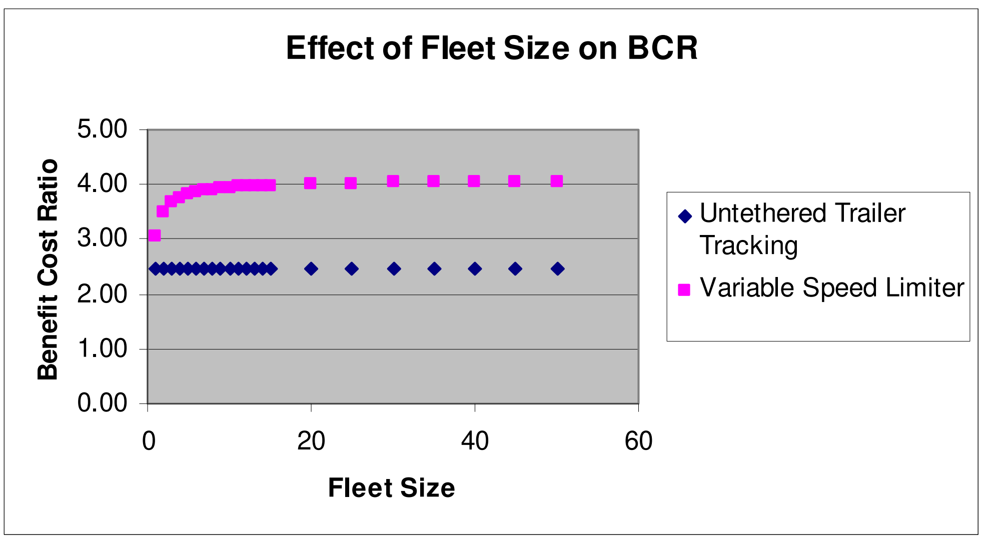


Figure 43. Effect of Fleet Size on Supply Chain Segment 5 Calculations

Finally, additional scenarios were run to identify the effects of varying other independent variables used to calculate the BCR. For this supply chain segment, the Study Team ran two additional scenarios. For each scenario, one variable that represented a “to be” value was varied independently (all other variables were kept constant). Table 49 below reflects the results of this analysis for the technologies evaluated for supply chain segment 5.

Table 49. Supply Chain Segment 5 Sensitivity Analysis Results*

Independent Variable	% Change	Untethered Trailer Tracking BCR	Variable Speed Limiter BCR	% Change	Untethered Trailer Tracking BCR	Variable Speed Limiter BCR
Diesel Fuel Cost/Gallon	-10.00%	2.47	3.12	10.00%	2.47	4.60
Reduction in Fleet Size %	-5.00%	2.03	3.86	5.00%	2.92	3.86

* Calculated using Baseline BCRs of 2.47 for the Untethered Trailer Tracking Wireless Solution, and 3.86 for the Variable Speed Limiter Wireless Solution

For example, if the "to be" value for the cost of a gallon of diesel fuel is decreased by 10 percent (meaning that fuel costs declined), then the BCR for the Untethered Trailer Tracking application would remain at 2.47, which is logical since the application would not improve fuel economy. Under the same conditions, the BCR for the Variable Speed Limiter application would decrease to 3.12, a modest change. Similarly, an increase of 10 percent per gallon in fuel cost (compared to the original "to be" value) again yielded no change in BCR for the Untethered Trailer Tracking application, and an increase in BCR for the Virtual Queuing application to 4.60. The sensitivity analysis using a reduction in fleet size produced a measurable change in BCR for the Untethered Trailer Tracking application, and no change in the BCR for the Variable Speed Limiter.

Qualitative Results: The ERG participants assigned each performance measure a score ranging from -5 to +5, with -5 representing a strong negative effect, +5 a strong positive effect, and 0 representing no effect. These scores are aggregated in order to provide a robust view of the potential impact of the wireless solution. Table 50 shows the scores for the individual performance measures for the Untethered Trailer Tracking system and the Variable Speed Limiter application.

Table 50. Supply Chain Segment 5 Qualitative Output

Factors	Performance Measures	Untethered Trailer Tracking	Variable Speed Limiter
Cost	Insurance costs per vehicle mile	2	1
Cost	Annual theft, pilferage, or misuse	1	0
Safety	Crashes per vehicle mile	0	1
Safety	Driver satisfaction/retention	0	-2
Total Score		**3**	**0**

4.2.5.5 Analysis Summary

The quantitative results show that a strong economic case can be made for both the Untethered Trailer Tracking and the Variable Speed Limiter solutions. This is reflected by the positive Net Present Values, $4,067.50 and $15,924.81, respectively, and BCRs higher than 1 at 2.47 and 3.86, respectively. Based solely on these calculated results, the Variable Speed Limiter actually appears to be more attractive using both the total net effect (NPV) and the relative effect (BCR); this indicates that for carriers that can afford the higher initial investment associated with this solution, the financial returns will be much greater.

Further, it is important to note that the BCR for the Variable Speed Limiter is based on the assumption that the motor carrier would want to have remote access to oversee (and perhaps approve) any changes to vehicle speed governor settings before allowing them to take effect. If the carrier is willing to allow such changes to be made independent of real-time input from the carrier's home office (i.e., to allow all changes to be made by systems and logic resident on the vehicle), the BCR would significantly increase, because it would no longer be necessary to provide a communications link between the truck and the carrier's location. Under this configuration, per-vehicle equipment costs might be reduced by as much as $4,200. This would have a dramatic effect on the BCR, as well as the other financial indicators.

Aside from the benefits associated with improved asset utilization and security, which are included in the above analysis, it should be noted that additional benefits might accrue from the use of the Untethered Trailer Tracking solution, as discussed in detail in the FMCSA Untethered Trailer Tracking and Control Systems final project report (USDOT 2005c). Specifically, the MCES analysis did not include the value associated with the reduction in cargo theft, which may significantly increase the net benefit to motor carriers. This parameter was not included in the FTAT analysis primarily because of a lack of specific, reliable data regarding the value of cargo stolen from trailers, or along with trailers.

Motor carriers that participated in the ERG for this supply chain segment offered generally tepid assessments of the potential qualitative improvements presented by the two applications. These results seem odd, given the quantitative value placed on the applications by the same carrier participants. However, it is entirely possible that they were unaware that even small changes in quantitative cost drivers would have such a measurable effect on overall investment value.

It is worth adding that the motor carriers that participated in the ERG session were unanimous in their assumption that average fleet speed would decrease as a result of using the Variable Speed Limiter. This was perceived as potentially harming their ability to attract and retain drivers, as indicated by the -2 rating shown in the qualitative analysis results table. This result was due at least in part to carriers' concerns about how such devices would be perceived by drivers, indicating that the presence of such a device might signal the driver that the carrier inherently distrusts his or her judgment.

5. WIRELESS OPPORTUNITIES

5.1 INTRODUCTION

This section contains a high-level summary of the findings from each of the major MCES Phase I study components. As discussed at the beginning of this report, the intent of the MCES is to enter into partnership with the motor carrier and wireless technology industries to cooperatively identify and test promising applications and devices in a "real-world" environment and to promote the adoption and use of successful solutions by an array of motor carriers.

The specific objectives of the program are to:

- Identify inefficiencies in freight transportation.
- Evaluate safety and productivity improvements made possible through wireless technologies.
- Demonstrate wireless technologies in field tests.

Phase I of the project was aimed at accomplishing the first two objectives. As the sections below indicate, the collaborative efforts of the Study Team, the Government project team, and a number of representatives from the motor carrier community succeeded in performing these tasks.

The findings from the various portions of the study are highlighted in Section 5.2. The conclusions drawn from the findings by the Study Team are detailed in Section 5.3. Finally, the Study Team in Section 5.3 offers a series of recommendations for Phase II of the study.

5.2 SUMMARY OF FINDINGS

Through a combination of exhaustive research of published documentation, extensive discussions with representatives from the motor carrier community, wireless systems and service providers, and Government agencies, and intensive efforts to collect empirical data, the Study Team was able to formulate a comprehensive knowledge base of motor carrier inefficiencies and wireless technologies. The Team was also able to apply the information to evaluating the potential benefits and costs of a series of supply-chain-based wireless solutions. The sections that follow contain a high-level summary of the output from these efforts.

5.2.1 Motor Carrier Inefficiencies

The MCES Literature Review revealed that motor carrier operations, specifically profitability and safety, are subject to a broad array of inefficiencies. In all, the Study Team identified a total of 43 separate types of inefficiencies across seven different categories:

- Equipment/asset utilization.
- Fuel economy and fuel waste.
- Loss and theft.

- Safety losses (i.e., crashes).
- Maintenance inefficiencies.
- Data and information processing.
- Business and driver management.

The combined effects of these inefficiencies are staggering. Based on high-level calculations performed by the Study Team, it is estimated that the motor carrier community incurs financial losses of tens of billions of dollars per year.

At a high level, the nature of responses captured during the Stakeholder Sessions and supplemented by discussions with carrier representatives suggests that there truly are a small number of very-high-priority efficiency-related concerns among carriers. Not surprisingly, the majority of these issues involve inefficiencies that prevent carriers from extracting the greatest productivity from their on-road assets—their trucks and their drivers.

Based on the combined responses from carriers, it appears that the only condition worse than one in which a driver is on the clock and stationary is one in which his truck is also idling. Carriers that participated in the Study Team's data collection effort consistently considered waiting for loading and unloading, whether at a customer facility or an intermodal terminal, to be the highest-priority inefficiency. Of the other inefficiencies mentioned by carriers, many represented variations on the theme:

- Paperwork delay at international border crossings.
- Processing delay at international borders.
- Waiting at weigh and inspection stations, as well as at ports and consignee locations.
- Congestion-related delay.
- Lost time due to routing problems.

In addition to the priority inefficiencies documented, the results of the Stakeholder Sessions Outreach and Inefficiencies Analyses tasks seem to indicate that the primary means by which carriers evaluate internal performance is through a subset of measures that describes rates of productivity, regulatory compliance, consumption, and loss. These measures helped the Study Team understand that in conducting the Task 6 FTAT modeling, the measures chosen to examine costs and benefits of potential wireless solutions should be able to be classified according to one of these categories.

5.2.2 Wireless Technology

The Study Team performed an in-depth review of the various wireless technologies available across the broad spectrum of application areas, not just in transportation. The result was the identification of 10 different classifications of wireless communications:

- Radio Frequency Identification (RFID)
- Digital cellular

- Bluetooth®
- Wireless Local Area Networks (WLAN) / Wireless Fidelity (Wi-Fi)
- Satellite (for position/navigation and communications)
- Ultra-wideband
- Worldwide Interoperability for Microwave Access (WiMAX)
- Optical wireless technologies—Free Space Optics (FSO)
- Zigbee®
- Two-way radio

The only qualifier for a technology type to be considered in the analysis was that a given technology had to be able to move information (voice or data or both) between points without a wired connection.

The technologies examined offer various combinations of performance capabilities, such as range, data transfer rate, and power consumption, and imposed some preconditions on usage in the form of information exchange format and standards. They also have varying levels of technology maturity and user deployment. These characteristics, which are discussed in detail in Section 3.2, are summarized in Table 51.

Table 51. Wireless Technology Characteristics

Technology	Data Rate	Range	Power Consumption	Maturity	Deployment Level
RFID	Low	Medium	Low	High	High
Digital Cellular	Moderate	Medium	Low	High	High
Bluetooth®	Moderate	Short	Low	Moderate	Low
WLAN/Wi-Fi	High	Short	Moderate	High	High
Satellite Tracking	Low	Long	Low	High	High
Satellite Communications	Low	Long	Moderate	Moderate	Moderate
Ultra-wideband	High	Short	Moderate	Low	Moderate
WiMAX	Moderate	Medium	Moderate	Low	Low
Optical	Moderate	Short	Low	Moderate	Moderate
Zigbee®	Low	Short	Low	Low	Low
Two-Way Radio	Low	Long	Moderate	High	High

In addition to the characteristics illustrated in the table, it is important to recognize that the level of supporting infrastructure—and the investment necessary to install and maintain it—can have a profound effect on a technology's usefulness as an enabler for needed capabilities. For example, satellite-based communications systems remain among the most expensive, with respect both to the purchase of hardware, and to the use of the supporting infrastructure of satellites. By contrast, digital cellular user hardware (e.g., cellular handsets) is relatively inexpensive, and the land-based cellular network is less expensive to users because of its relative simplicity, ease of maintenance, and large user base.

Perhaps the most appropriate interpretation of the characteristics in the table is that there are tradeoffs to be made in selecting which wireless technology is most appropriate for a given application. The motor carriers that participated in the various stakeholder activities indicated that it is the combination of these tradeoffs with the price of deployment and the expected return on investment that most often affects their decision to invest.

The technologies currently most popular among these carriers (based on the observations of the Study Team, as opposed to a statistical analysis) appear to be digital cellular, satellite tracking, and RFID. Digital cellular, although its use in other applications is expanding, remains largely a voice and text message communications medium. Satellite tracking of carrier power units has grown increasingly popular as the customers of motor carriers demand greater levels of visibility into shipment location and status. Trailer tracking using satellite-based systems has not yet reached a comparable level of deployment due to a combination of factors, including system cost, and later entry into the marketplace. RFID has found multiple applications—electronic tolling, weigh station bypass, inventory control, and cargo security seals, among others—but these systems offer little to no interoperability, so multiple applications means multiple deployments.

In spite of the fact that many of the most popular current applications are configured to use one of these three technologies, system vendors are actively pursuing the use of several of the wireless technologies identified in Table 51. The supporting technologies of Ultra-Wideband and Zigbee are seeing increased use, as is Wi-Fi, which is already in widespread use for home and office wireless networking. Table 52 illustrates some of the instances in which these technologies are being used.

Table 52. Wireless Technology Usage Examples

Functional Area	Description	Systems and Applications	Supporting Technologies
Fuel Monitoring and Operations Management Systems	Monitor, record, report, electronically control, various vehicle systems to improve vehicle and driver safety, improve vehicle and driver management, security, performance, and fuel efficiency.	On-board computer and communications (fleet management) systems, electronic tacograph, ECM (J1708, J1939) interfaces and data link devices, and sensors, vehicle and driver safety systems	*Established:* RFID, Digital Cellular, Satellite, GPS *Emerging:* Ultra-Wideband, Zigbee
Electronic Manifest Systems	Exchange cargo manifest, bill of lading, billing data electronically to improve accuracy and expedite data exchange.	Customs and Border Protection ACE System—transponders, reader infrastructure, and web portal software (includes third-party providers of back office supporting software)	RFID, Cellular, Wi-Fi

Functional Area	Description	Systems and Applications	Supporting Technologies
Cargo Theft Prevention Systems	Monitor, record, report, and electronically control security of cargo in trucks, trailers, and containers.	Cargo container seals, vehicle disabling systems, tractor and untethered trailer tracking	*Established:* RFID, Satellite/GPS, Cellular *Emerging*: Ultra-wideband, Zigbee
Roadside Safety Inspection Systems	Provide electronic interchange of driver, vehicle, and carrier status data with roadside safety inspections systems.	Inspection station bypass programs, law enforcement mobile data terminal systems	*Established:* RFID, Digital Cellular *Emerging*: Ultra-wideband

During the study, discussions with motor carriers regarding potential new wireless technology applications focused primarily on the capabilities that they indicated would possibly be valuable for their operations, rather than on the technologies themselves. Specific technologies typically entered into the discussion when motor carrier representatives suggested a preference for leveraging technology they already possessed (e.g., satellite tracking and communications, cellular, etc.) by adding new applications. These preferences were reflected in the applications that carriers suggested for analysis during the Phase I benefit/cost study. These applications are described in Table 53, along with the primary wireless enabling technologies.

Table 53. Proposed Wireless Applications for Phase I Cost/Benefit Analysis

Application	Description	MCES Functional Area	Supporting Technologies
Variable Speed Limiter	A device to alter vehicle maximum speed remotely, based on a geographic referencing capability tied to a database of speed zones in which the speed governor would be adjusted automatically.	Fuel monitoring and operations management systems	Satellite-based location determination, Bluetooth link to engine control unit
Border Crossing Compliance Notification	An application that sends pre-screening status information prior to a driver's arrival at the border. This would involve relaying processing status information from CBP wirelessly to the driver.	Electronic manifest systems	Digital cellular transmission of verbal or text messages
Truck-Specific Congestion Avoidance	Through a wireless link to existing traffic information, such an application would allow drivers to receive traffic data that is of particular applicability to their operations, and in the event that alternatives exist, would be provided truck-specific alternate routing information.	Fuel monitoring and operations management system	Digital cellular or satellite transmission of verbal or text messages, or graphical display on navigation device

Application	Description	MCES Functional Area	Supporting Technologies
Chassis Roadability Notification	An application that would allow a driver to query a maintenance database to obtain information regarding the service history and repair status of a given chassis.	Roadside safety inspection systems	Digital cellular access to web-accessible data via wireless application protocol
Cross-Town Intermodal Interchange	An application that provides for coordinated dispatch operations, real-time traffic monitoring, and shared intermodal asset (chassis) management in an intermodal exchange environment.	Electronic manifest systems, fuel monitoring and operations management systems	Digital cellular access to web-accessible data via wireless application protocol, satellite-tracking-based traffic data exchange
Untethered Trailer Tracking	An application that allows motor carriers to obtain location and status information for trailers when not connected to tractors.	Cargo theft prevention systems	Satellite location, cellular communications
Border Crossing Tracking Compliance	An application that allows for capturing and recording time and location data and an automated means to provide data that meets the needs of Federal agencies, replacing the manual method of position verification.	Electronic manifest systems, roadside safety inspection systems	Cellular GPRS or satellite-based GPS
Virtual Queuing	An application that combines wireless tracking and travel time estimation for inbound trucks to construct a "virtual queue," allowing terminal operators to dynamically manage and schedule dock operations.	Fuel monitoring and operations management systems	Cellular GPRS or satellite-based GPS, satellite or cellular text or voice communications

The resulting set of applications for analysis using the FTAT benefit/cost tool represented a broad collection of capabilities spanning the four MCES functional areas. Because of the limited scope of the Phase I study—which allowed for only 10 FTAT analysis scenarios—several significant motor carrier inefficiencies (and the technologies that address them) were not analyzed to this depth. However, the Study Team did examine them to the extent possible using available empirical data. Table 54 highlights the potential gains of applying advanced technology (i.e., wireless and other types) to some of these other areas of inefficiency.

Table 54. Additional Efficiency Gain Opportunities

Inefficiency	Opportunity	Wireless Technology Options
Time in Weigh Stations	Increasing the total proportion of the U.S. truck population using electronic screening systems to 75 percent would reduce total daily waiting by nearly 34,000 hours. This is equivalent to $215 million annually.	Expanded deployment of low-cost RFID-based screening systems; leveraging of other technologies such as cellular or satellite tracking systems.
Maintenance-Related Vehicle Crashes	Reducing by 50 percent the crashes (20,150 crashes) caused at least in part by preventable brake failure. This is equivalent to $1.85 billion annually.	Low-cost remote vehicle monitoring systems using emerging wireless technologies such as Zigbee.
Driver-Error-Related Vehicle Crashes	Reducing by 5 percent the crashes (18,000 crashes) caused by driver error. This is equivalent to $1.66 billion annually.	Wireless-based real-time driver behavior and acuity evaluation systems.
Border Processing Delay	Reducing border travel time to increase the number of revenue producing trips completed per day by more than 100 percent. This is equivalent to $211,000 in additional revenue annually per truck.	Wireless measurement of border travel and wait times for use in planning and managing crossing facilities (similar to Border Crossing Tracking Compliance application evaluated with FTAT).
Driver Turnover	Undetermined. Turnover costs per driver have been estimated to exceed $8,000.	Wireless applications that enhance driver productivity sufficiently to significantly affect driver employer selection.
Empty Miles	Undetermined. Some large truckload firms attain empty ratios of 10 percent. Reducing total empty ratios across the industry by one percentage point could reduce empty miles by 1.7 billion annually. This is equivalent to $2.7 billion annually.	Deployment of more ubiquitous, platform-independent wireless applications that allow for flexible, optimized dispatch operations.
Fuel Waste due to Excessive Speed	Reducing average truck travel speed from 70 mph to 60 mph improves fuel efficiency by approximately 1 mpg. One carrier interviewed for the MCES reported annual savings from the use of Eaton/Vorad system to monitor driving habits to be $5,500 per truck (due to increase from 5.7 to 6.3 mpg).	Combination of expansion of capabilities of deployed technologies and increased economies of scale from higher deployment levels.

5.2.3 Benefit-Cost Analysis

The results of the execution of the FTAT calculations offer some interesting insights into the potential benefits of the various proposed applications. As the information in Table 55 shows, the BCRs and internal rates of return for the applications span a broad range of values.

Table 55. Combined FTAT Calculation Results

Scenario	Supply Chain Segment	Inefficiency	Solution	BCR	IRR
1	International Border	Paperwork delay at border	Border Crossing Compliance Notification	0.08	-48.05%
2	International Border	Processing delay at border	Border Crossing Tracking Compliance	5.20	73.78%
3	Port to Inland Destination	Waiting time in container ports	Virtual Queuing	2.64	35.85%
4	Port to Inland Destination	Vehicle safety (crashes, noncompliance)	Chassis Roadability Notification	0.21	-33.29%
5	Closed-Loop Pick-Up and Delivery	Incident-related congestion	Truck-Specific Congestion Avoidance	1.96	38.50%
6	Closed-Loop Pick-Up and Delivery	Waiting, loading, and unloading	Virtual Queuing	1.62	18.98%
7	Rail Intermodal	Empty tips	Cross-Town Intermodal Interchange	8.92	216.76%
8	Rail Intermodal	Waiting, lading, and unloading	Virtual Queuing	2.33	30.98%
9	Long-Haul Truckload	Fuel waste due to excessive speed	Variable Speed Limiter	3.86	54.26%
10	Long-Haul Truckload	Theft and pilferage	Untethered Trailer Tracking	2.47	33.22%

Several of the applications—notably the Border Crossing Tracking Compliance, Virtual Queuing, Variable Speed Limiter, Cross-Town Intermodal Interchange, and Untethered Trailer Tracking systems—offer estimated BCR values in excess of 2:1. These are promising results, particularly when the lowest IRR for these applications exceeds 30 percent (it is noted that the application of Virtual Queuing to the Closed-Loop Supply Chain Segment results in a lower value). The results for most of the applications improve as the level of deployment increases, and also improve if they can be deployed by carriers already using wireless devices (e.g., cellular telephones or satellite tracking systems) for other purposes.

Caution is warranted when examining these figures, for a number of reasons. First, the Study team assumed in the calculation of the figures that the operating environment would be conducive to the use of application, and that the maximum estimated benefits would be realized. This is not likely to be the case in all scenarios. For instance, because making the necessary staffing changes within international border crossing compounds (namely, the reassignment or increase in number of staff by Customs) presents a number of challenges, and because a large portion of the border user population would need to be equipped with devices, it is unlikely that the full benefit will be realized from the deployment of the Border Crossing Tracking Compliance application. Hence, the calculated BCR of 5.2 is very likely higher than might be possible.

Similar limitations are likely to be applicable to the Virtual Queuing application, since facility operators would need to deploy the "ground traffic control" application that would govern the assignment and reassignment of arrival appointments, and a large percentage of carriers accessing the facility would need to be equipped to participate.

Among the most promising of the applications is the Variable Speed Limiter system. According to the FTAT output, such a device could provide significant monetary benefit to the carriers that choose to deploy it. Additionally, lower overall truck speeds are likely to reduce the number of crashes caused by drivers operating vehicles at speeds in excess of those that are appropriate for conditions. Further, due to the independent nature of the application (i.e., it is not necessary that it be added to a large percentage of the truck population in order to function properly), benefits should be attainable even at modest deployment levels.

Finally, based on the results, it appears that there is likely to be little value gained from the deployment of the Border Crossing Compliance Notification system or the Chassis Roadability Notification application. Both have BCRs of less than 1, and significantly large negative IRRs.

5.3 CONCLUSIONS

This section contains a series of conclusions derived from the combined findings from the Phase I study. As has been discussed throughout this report, the results contained herein should be viewed with a full awareness that none of the figures constitutes a statistically representative value. This is the case because, although a portion of the input is drawn from empirically derived and measured data, much of it is not. The motor carriers consulted throughout the MCES are most likely at or near the exceptional end of the performance scale in all measurable categories. Their participation in this and similar studies is reflective of a predisposition to employ practices and systems that enhance their operational efficiency and overall fleet safety.

5.3.1 Motor Carrier Inefficiencies

With few exceptions, the common thread running through the priority inefficiencies is delay that arises at least in part from the actions (or lack thereof) of a party external to the carrier. Perhaps even clearer is the fact that each of these inefficiencies has the potential to be mitigated by improving the quality, accuracy, and timeliness of data held by one or more of the stakeholders (public and private sector), and the degree to which it is exchanged and used for decision-making.

Under such circumstances, it would appear that wireless technologies, which are first and foremost mechanisms to accurately capture and exchange information, could offer the means to extract significant relief for the carrier community. Given that an enhanced level of situational awareness is vital to mitigating these inefficiencies, it is logical that wireless systems that promote that enhancement would be of some value to motor carriers experiencing these inefficiencies.

In fact, enhanced situational awareness would likely have a profound positive effect on several other inefficiencies—namely, those associated with vehicle and driver safety. Better knowledge about vehicle, operator, and roadway conditions should contribute significantly to reducing driver- and vehicle-caused crashes, and reducing the frequency of instances in which drivers operate at speeds in excess of those warranted by roadway conditions.

Better situational awareness can be a key means to counter cargo theft and pilferage, and to reduce empty moves, both of which represent significant costs for motor carriers. Simply knowing when and/or where a shipment has been tampered with or infiltrated would allow carriers to define and implement more effective security solutions. Similarly, knowing the locations and delivery requirements of other intermodal loads would likely allow dray haulers to better allocate resources to meet customer needs.

Evidence presented in this section clearly indicates that the effects of the relatively few inefficiencies discussed herein are quite significant. Taken individually, each presents an opportunity to dramatically reduce the costs of motor carrier inefficiencies.

Even in those instances where actual data are difficult to acquire, anecdotal evidence suggests that carriers, and by extension those they serve, incur substantial adverse effects due to various operational conditions and business arrangements. Quite often, carriers participating in the study were not able to quantify the effects of a specific inefficiency (e.g., incident-related congestion, urban routing problems); however, they consistently indicated that they were confident that their operational efficiency was significantly degraded, and were interested in identifying tools that would mitigate their effects.

5.3.2 Applying Wireless Technologies

Based on the evidence gathered during the identification of industry inefficiencies during Phase I of the MCES, it is reasonable to conclude that ample opportunity exists for applying technology to construct creative solutions to address real, specific needs within the carrier community. What role wireless systems might play seems less clear, but the analysis suggests that the potential exists for measurable positive effects.

The BCR and IRR values summarized in Section 0, while based on estimated values for both costs and potential effects, indicate that wireless applications possess the potential for encouraging dramatic improvements in motor carrier efficiency. These figures suggest that this is the case even for systems that would be considered rather expensive on a per-unit basis. These figures can reasonably be expected to improve further as technology matures, deployed volume increases, and prices drop.

5.3.2.1 Near-Term Opportunities

In the near term, which we will define as a period extending less than 10 years from today, the combination of a large existing deployed base, mature infrastructure, and high levels of user confidence make technologies such as satellite tracking, digital cellular, and RFID attractive as foundations on which additional applications might be successfully layered. The applications suggested and supported as viable by the motor carriers that participated in the study reinforce their preference for leveraging existing systems over the development and deployment of entirely new systems.

One important uncertainty in this construct is the ability of these systems to accommodate future information exchange needs, both on an individual device basis and on a network-wide basis. As more users seek out increasingly sophisticated capabilities, the overall demand for information will increase, leading to the need for more robust systems and networks.

Additionally, based on the figures in Table 54, there exists a significant opportunity to enhance motor carrier efficiency by expanding the use of currently available systems. Two such systems, RFID for weigh station bypass and Untethered Trailer Tracking, are already yielding significant net effects for users. The Study Team did not examine the reasons these systems are not more widely deployed, but the analysis contained in this report suggests that the return on investment for users of both applications appears significant.

5.3.2.2 Longer-Term Opportunities

Many of the wireless technologies examined in this study have barely begun to be deployed. Some of them offer compelling combinations of data transfer capacity, range, and potential convenience of use, but too little is known about how useful they may be in the trucking environment, where reliability, ruggedness, and low cost are of paramount importance.

Two particularly promising technologies are WiMAX and Zigbee®. The high-data-transfer-rate performance of WiMAX might eventually allow for the exchange of very large amounts of data between moving vehicles and fixed points, opening up opportunities for increasingly sophisticated fleet and cargo management and decisions support systems, provided that the infrastructure can be deployed on a large enough scale to allow trucks to pass through service areas on a frequent basis. At the least, deploying such a capability at weigh and inspection stations, truck stops, and rest areas would increase its appeal dramatically.

For vehicle-based systems monitoring—for such applications as safety and security monitoring—Zigbee® seems to hold significant promise. Its low power requirements, coupled with the ability of components to easily form ad-hoc networks, would appear to provide a platform for the connection of multiple on-vehicle components, such as tire pressure and brake stroke monitoring devices, electronic cargo seals, and item- or pallet-level RFID tags.

Over the next 10 to 20 years, it is reasonable to expect that a number of significant advances will take place that will improve both the performance and the affordability of wireless technologies. As has been the case with cellular, RFID, and satellite-based systems, which have advanced dramatically over the last 20 years, components are likely to continue to be made smaller and more energy-efficient. Battery life, which has long been a challenge to deploying standalone devices for tracking and security of trailers, will be extended due to the significant investment being made in other sectors—most notably automotive manufacturing.

As wireless networks become increasingly ubiquitous, and commercial entities continue to seek to add new services to existing networks, it is likely that information systems will not only become more easily accessible, but will also perform at higher speeds and deliver increasing value to users. It is also reasonable to expect that commercial vehicle manufacturers will continue to package on-board electronics that will rely on wireless communications for remote monitoring and control of vehicle systems, including safety-related items such as brake performance, tire pressure, and driver awareness monitoring, and efficiency-related items like fuel delivery, engine control parameters, and driver evaluation and education tools.

This new level of transparency will likely enable motor carriers to continue to incrementally lower operating costs and improve profitability. Decisions regarding routing, driver assignment, and maintenance scheduling will be made more effectively, and component failures will be detected before trucks are put out of service—either due to inspection violations or to the failures themselves. As fleets are turned over (i.e., more new trucks are delivered and the oldest trucks in service are retired), the level of deployment of wireless systems—although including some that are several generations old—will expand to include a larger percentage of the trucks on the nation's roadways.

Perhaps the most significant advances with respect to wireless technology will come in the form of a new level of connectivity between fleet owners and assets (both equipment and personnel), between fleet assets and customers, between different assets, and between the assets and the cargo being transported. This connectivity will allow for operations that are significantly more coordinated, which will enable greater asset productivity across all segments of the motor carrier community. This level of connectivity will also permit the development of intelligent freight delivery management tools that can make full use of real-time information regarding prevailing business conditions, traffic congestion, weather, traffic incidents, and public safety conditions, and allow trucks and cars to operate safely in close proximity.

To this point, the catchphrase associated with freight efficiency has been visibility. The next generation of wireless devices will be tasked with facilitating the evolution to intelligent freight—freight that knows where it is, where it needs to go, and how best to transport itself to its destination in a safe, efficient, secure manner, including which carriers and drivers are suitable to move it. This can occur only when the universe of wireless systems is made in a manner that removes barriers to communication, and allows for unimpeded interconnectivity and interoperability.

5.3.3 MCES Phase II Options

Based on the results of the research and analysis conducted during Phase I, a number of conclusions can be drawn regarding the potential investment of Phase II research funds. Several viable pilot project candidates emerged as promising. These are discussed below.

5.3.3.1 New Technology Applications

A review of the wireless technology-based applications endorsed by the motor carriers that participated in the study for analysis using the FTAT benefit/cost tool reveals some important considerations in moving forward into Phase II. The first is that, with regard to the implementation of new technologies in their operating environment, the carriers demonstrated a bias toward incremental systems enhancement. Even in cases where the financial investment for deploying and operating a system was relatively large (e.g., first-year costs for cross-Border Tracking at $3,150 per unit, Truck-Specific Congestion Avoidance at $1,725 per unit, and Variable Speed Limiter at as much as $4,827 per unit), the actual level of technical sophistication of the overall system would not be considered advanced over what is currently in use. In fact, the carriers exhibited a clear preference for the addition of new capabilities to existing technologies, even if these were technologies that they do not currently use in their own fleets.

Further, because carriers' prioritization of inefficiencies reflected their beliefs that the most significant sources of inefficiency are external to their own operations (e.g., traffic congestion, border processing delay, waiting for loading and unloading), they indicated a preference for applications that allowed them to overcome the burdens imposed by others. It is unclear, based on the findings of this study, whether they have confidence that they have already optimized their own internal operations, or have resigned themselves to the fact that any further investment in internal improvement would be subject to the law of diminishing returns. Among the wireless applications that do focus on operations within the carriers (Variable Speed Limiter, Untethered Trailer Tracking), there continues to be a preference for applications that manage the behavior of those that use a carrier's assets.

Even within these somewhat limited boundaries, there exist several promising alternatives for examination during Phase II. Seven of the 10 scenarios evaluated using FTAT had estimated IRRs of more than 30 percent. Based on the relatively conservative estimates of potential gain, and the use of system implementation and use costs that assumed a carrier would have to purchase all of the necessary hardware (vs. leveraging current systems), each of these seven warrants further examination through a pilot demonstration. Among them, the Cross-Town Intermodal Interchange, Border Crossing Tracking Compliance, and Variable Speed Limiter posted the largest estimated investment returns. The BCRs and IRRs for each of these suggest that, even if cost and benefit estimates are modestly optimistic, motor carriers would likely find them attractive as pilot test subjects.

5.3.3.2 Existing Technology Applications

Both of the systems that demonstrated large potential returns—RFID for weigh station bypass and Untethered Trailer Tracking—have already exhibited empirical proof of their value. From the findings obtained during this study, it is not clear why such systems have not gained greater levels of deployment. In the case of the Untethered Trailer Tracking application, it may be due in part to a combination of a relatively high per-unit price and the historically slow adoption of new technology among all but a few more advanced motor carriers. Historical precedent suggests that cash available for technology investment, and management predisposed to actively pursue technology enhancement, are limited to a relatively few large carriers.

As for RFID-based weigh station bypass—again, this study did not focus specifically on determining the conditions under which more expansive deployment might take place. There appears to be sufficient financial incentive for carriers to take part in such systems. Figures published by one of the bypass program management organizations, HELP, Inc., suggest that since 1997, motor carriers enrolled in the organization's PrePass® program have accrued reductions of nearly 20 million hours in delay, and savings of nearly 120 million gallons of fuel. Based on an operational cost estimated at $5 per stop, it is estimated that PrePass-enrolled carriers have saved more than $1.1 billion since 1997 (HELP, Inc. 2006).

5.3.3.3 The USDOT/Motor Carrier Partnership

From the input received from motor carriers throughout the project—beginning with the industry meeting prior to the start of the Phase I study—it appears clear that there is substantial interest in assisting FMCSA in characterizing systemic inefficiencies, and in participating in pilot tests of wireless technologies aimed at addressing them. The willingness of motor carrier representatives to participate and offer suggestions regarding where research should be directed serves as evidence of this.

One possible exception was investment in technology applications that required the release of sensitive information or the surrendering of operational control to a Government agency. For instance, in the case of the Variable Speed Limiter application, some carriers expressed concern that such an application might be looked upon as a method for speed enforcement. Excluding this and other minor concerns regarding data security, participating motor carriers generally welcomed the idea of public investment aimed at providing cost-effective solutions to the inefficiencies they encounter.

5.4 RECOMMENDATIONS

The Study Team recommends, as the MCES moves forward, and the Government evaluates which applications to pursue during Phase II (either from applications contained herein or from those detailed in other project documents), that the Government take into account a number of important considerations. These considerations include practical programmatic and technical analysis-related issues revealed during the Phase I study. These considerations are discussed in the sections that follow.

5.4.1 Analysis Recommendations

Actual benefits could vary significantly from those reflected in this report. The assumptions related to costs and potential benefits are based on a statistically insignificant number of inputs, many of which are based on estimates provided by stakeholders. This sort of method, while very useful for estimation, is by its nature imperfect. For future instances where FTAT is to be employed, the Study Team recommends focusing on fewer scenarios, capturing more statistically significant input, and exploring a greater number of sensitivity analyses than was possible under this study.

Even in cases where hard data exist regarding systems and service costs, these costs often decrease as the number of units of a particular application are deployed, resulting in lower overall costs to carriers. The net result would logically be increases in BCR and other financial measures. The Study Team recommends that economies of scale be employed as one dimension of sensitivity analysis in future FTAT use. Further, as the sensitivity analysis revealed, BCR, and hence other measures such as IRR, can be greatly affected by relatively modest changes to the independent variables used in the BCA. Additionally, because wireless technology, and the applications that leverage it, are evolving so rapidly, some of the data points used in the FTAT analysis may potentially be replaced with more accurate numbers. This is likely to be true especially with regard to functions that might be added to existing systems. For this reason, the Study Team recommends that Phase II activities include the re-evaluation of the selected technologies using FTAT once more specific information is obtained from those proposing solutions. The FMCSA may also want to consider using this analysis as an initial decision point regarding follow-through with the proposed Phase II deployment.

5.4.2 MCES Phase II Program Recommendations

As the FMCSA and its USDOT partner agencies move forward with Phase II of the MCES program, it will be important that the program's leaders recognize that although the potential solutions identified in this report do not necessarily cover the spectrum of possibilities, they do address the specific, stated concerns of the motor carrier representatives that took part. As such, they reveal a desire on the part of the members of the various industry segments to examine alternatives that will mitigate the effects of a small subset of the universe of inefficiencies explored during the Phase I study. With that in mind, the Study Team recommends that Phase II pilot demonstration projects focus on delivering capabilities that allow motor carriers to:

- Reduce the amount of time waiting to be loaded or unloaded, or to access the facilities where these activities are performed. Where possible, pilot projects aimed at addressing this inefficiency should include participation from facility owners and operators, since motor carriers indicated that they represent the primary source of delays
- Reduce empty trips, particularly when interchanging loads between intermodal facilities. Again, participation by parties outside of the motor carrier community (e.g., terminal operators, railroads) will be essential to addressing inefficiencies
- Reduce delays entering the U.S. at international border crossings. The participation of CBP representatives, and cooperation with CBP headquarters staff, will be critical to the success of any efforts in this area, since benefit calculations are based on the assumption that CBP, in particular, will take action to reduce delays
- Reduce the frequency and duration of delays associated with congestion—particularly congestion associated with traffic incidents
- Reduce fuel consumption. This need can be addressed through a wide variety of means, including addressing the three inefficiencies listed above. It can also be addressed by providing motor carriers a means to better control the speed at which its trucks are operated

Despite the fact that some of the applications examined to address the other inefficiencies cited by motor carriers are likely to provide modest returns (according to FTAT), there are valid reasons to seek creative solutions that address a number of other important inefficiencies, including the need to:

- Reduce the risk of having a crash or being placed out of service due to failures of equipment—particularly equipment owned and maintained by others
- Reduce the risk of having a crash due to excessive speed or other driver errors
- Reduce empty miles

Some of the wireless solutions examined during Phase I represent a significant departure from the way motor carrier operations are currently conducted. Further, most of them assume that technological solutions to address such issues as communications among vehicle-based systems, and between these systems and the stationary communications infrastructure, can be fashioned from existing technology, such as digital cellular, satellite location and communications, and Bluetooth. As such, efforts to deploy them as they are defined in this study are likely to encounter challenges that are predominantly operational or institutional in nature, rather than technical.

As such, the Study Team recommends that FMCSA consider mandating that teams proposing to deploy pilot projects under Phase II of the MCES be required to, at a minimum, include a detailed plan for engaging the organizational entities necessary for a cooperative solution to be implemented, and that the evaluations conducted during Phase II include a system sustainability analysis that explores the following:

- The level of process change that will be necessary to adopt and use the solution
- The degree to which the organizations participating in the pilot are likely to agree to adopt practices and policies that will facilitate long-term success
- The likely solution adoption rate, both within the targeted industry segment and within other segments
- The risks associated with the inability to achieve a deployment level below that at which measurable benefits will accrue to the system's users
- A time-based BCA profile that examines how benefits and costs may change over time

Finally, the Study Team recommends that any pilot demonstrations pursued during Phase II be evaluated with an eye toward affordability. Despite the fact that the FTAT analysis revealed significant potential for positive returns for several of the solutions examined, it is important to remember that regardless of the BCR and IRR figures, the cost of deployment for a given solution may be higher than many carriers could afford. Therefore, it will be important that any sustainability analysis examine the effects of per unit implementation, operation, and maintenance costs, and seek to identify a cost threshold acceptable to motor carriers.

Wherever possible, opportunities to further leverage deployed systems should be pursued as a means to reduce costs, and improve overall payback to the motor carriers. This may mean that adding a function to an existing system will yield better investment returns, even if the existing system costs more than the proposed system. For example, many of the applications described herein might be deployable as add-on features to cellular telephone services, provided the devices in use by carriers possess the necessary location referencing and information processing capabilities. Similarly, the FMCSA may also find it advantageous to "piggyback" on other efficiency enhancement projects, particularly within the USDOT.

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