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16. Abstract

This report summarizes the results of research aimed at advancing the commercial readiness of a new hybrid mode of intermodal freight transportation called the Freight Shuttle System (FSS). The FSS represents a unique combination of the best features of rail and truck transportation designed to mitigate many of the adverse impacts of over-the-road truck transportation; pavement damage, diesel emissions, congestion, and safety issues. A FSS business model has been developed that lends itself to private financing and operations, in keeping with the commercial nature of goods movement. A modular system design has emerged that facilitates implementation in numerous settings, such as border crossings, marine terminals, or heavily traveled commercial corridors between markets ranging in distance from 10–500 miles. The FSS has been developed to provide a lower-cost and more reliable mode of freight transportation that will induce traffic through pricing and time-certain delivery schedules. The FSS has also been shown to have the potential to play an important role in attracting private capital to the transportation infrastructure. The public benefits projected to accrue from a single FSS are significant and are detailed in the report.

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THE FREIGHT SHUTTLE SYSTEM: ADVANCING COMMERCIAL READINESS

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CHAPTER 1: INTRODUCTION

BACKGROUND

Opposition to additional truck traffic at many freight-intensive locations around the country has created the need to find and implement new methods and systems to move large volumes of freight in either existing containerized loads or truck trailers. Proposed new systems of freight transport must also be both environmentally-sound and economically sustainable. Environmentally, it must mitigate the adverse impacts of truck diesel emissions and those associated with traffic congestion, pavement damage, and noise on local and regional roadways. Economically, such a system must provide sufficient capacity to accommodate the anticipated growth in traffic and do so in an efficient and cost-competitive manner. Further, the alternative approach must interface with existing intermodal systems in ways that allow traditional operations to be effectively integrated with the new approach.

The Freight Shuttle concept developed by the Texas Transportation Institute (TTI) provides the features outlined above—expanding freight operations between cargo hub locations, to and from rail intermodal facilities, from ports to inland terminals, or across international borders with very few negative environmental and traffic impacts. This is accomplished by employing new technologies that couple emission-free propulsion systems with proven freight transport methods.

PRIOR RESEARCH AND FUNDING SOURCES

The initial research resulting in the Freight Shuttle concept was begun in 1999 under funding directed to TTI through the Transportation Equity Act for the 21st Century (TEA-21), which was passed by the U.S. Congress in 1998. The first effort investigated the technical and economic feasibility of a "freight pipeline" system—an underground alternative freight movement concept to intercity trucking in the Interstate 35 (I-35) corridor. TxDOT supported the original research effort that resulted in TxDOT Research Reports 9-1519-1, 2, 3, and 4. Follow-on funding was provided in the next federal transportation allocation bill, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Act passed in 2005, which has been administered under TxDOT Research Project 9-1528 and whose activities are the subject of this report.

The conclusions reached in the freight pipeline research were that while technically feasible, underground freight movement was inordinately expensive and thus not economically viable. This was found to be particularly true in light of the fact that the goods-movement industry is a private commercial undertaking while large-scale transportation infrastructure projects usually fall into the purview of public sector transportation agencies such as TxDOT. Therefore, even when projections of truck traffic reached significant levels, the costs associated with trenching and material handling negated almost all of the public and private benefits of such a system.

In the final year of research, as documented in Report 9-1519-4, the research team decided to test two alterations to the basic design of the freight pipeline system and assess the effects of the changes on project viability. First, the system was moved to all surface operations to negate the vast resources expended on excavation, tunneling, conduit construction, ventilation, and water protection. Second, rather than carry palletized freight, as was the design for the underground system, the new embodiment would deal exclusively with intermodal containers, the default standard for goods movement for a wide and expanding range of commodities. The basic propulsion system and vehicle-guideway configuration was rescaled to accommodate larger, single-unit intermodal transports. Surface operations coupled with increased capacity and reduced material handling costs were then examined to determine the economic impact on overall project viability—affordability, service performance levels, operating costs, capacity, and the ability to divert significant numbers of trucks.

The impact of these changes on concept viability was dramatic, moving the project's financial status from "marginal" to commercially attractive at near investment-grade levels of return on capital. Initial assessments were made for operations within existing or planned highway corridors, including the concept Trans Texas Corridor (TTC) routes that were being contemplated at the time between the major markets of Dallas-Ft. Worth, Houston, and San Antonio with varying levels of diversion to the new system from highways. Subsequent analysis showed that significant quantities of containerized freight emanated from and were delivered to port complexes involved in international trade. These settings emerged as particularly viable applications for a new, automated technology that could deliver containers to inland distribution facilities or rail intermodal terminals. In addition to being commercially attractive (i.e., high margin operations), they often carried large positive public and private benefits in the form of traffic and air quality mitigation and improved service levels.

SYSTEM DESCRIPTION

The Freight Shuttle is an automated conveyance designed to transport standard intermodal containers over a specially configured, fixed guideway. The guideway-vehicle combination comprises the elements necessary for an electrically-powered linear induction motor—with the stator positioned as a vertical element in the center of the guideway and the motor windings positioned on either side of the stator as opposing linear motors on each shuttle vehicle. The shuttle vehicle is positioned across and straddles the vertical guideway in a manner that prevents decoupling from the guideway. The system is further characterized by steel wheels operating on a continuous steel running surface. The guideway's track surface consists of a reinforced concrete structure of sufficient thickness and width to support fully-loaded intermodal containers. The guideway can be elevated or installed alongside existing roadways or other facilities, thereby utilizing existing highway or other rights-of-way.

The shuttle vehicles are designed to operate as single-unit transports; each dispatched to its destination as the loading process is completed. The overall system is designed to operate as a continuously circulating conveyor of containers or truck trailers over distances ranging from a few miles up to 500 miles. The infrastructure is designed to support multiple vehicles operating simultaneously, with the upper range in vehicle numbers established by customer demand, economic operating velocity, and guideway length. Figure 1 depicts the basic system elements: an automated vehicle, elevated guideway, and cargo bay designed to support and transport one intermodal container or truck trailer.

Figure 1. Concept Drawing of the Freight Shuttle System.

THE NEED AND MARKET FOR THE FREIGHT SHUTTLE SYSTEM

The Freight Shuttle System (FSS) meets a growing need within the transportation community to address short- and medium-length freight movement of containers and trailers. According to a recent report by the American Association of State Highway and Transportation Officials (AASHTO), points out the following forecasts (*1*):

- By 2020, the U.S. trucking industry is expected to move more than three billion more tons of freight than today resulting in a projected increase of over 1.8 million trucks on the road to address this additional demand.
- Within 20 years, the number of trucks will increase by an additional one-third over current levels.
- Within 40 years, freight demand will double from today’s 15 billion tons to over 30 billion tons per year moving on the nation’s roadways.

The AASHTO report also points out that highway infrastructure alone will have a difficult time keeping up with this expanding freight volume demand. Between 1980 and 2006, traffic on the U.S. Interstate Highway system increased by 150 percent while Interstate capacity increased by only 15 percent. It also states that an average of 10,500 trucks per day travel the Interstate Highway System with some heavily used segments carrying over 50,000 trucks per day. Texas is one of six states that, together, account for over 88 percent of the freight movement in the nation (*1*).

TxDOT officials have long noted the increasing numbers and percentage that truck movements have played in congestion on the state's existing high traffic corridors. As can be seen in Table 1 below, several intercity locations along the major highways have high through-truck counts. Many of these trucks are potentially divertible to the Freight Shuttle. Urban truck counts can be even higher due to local deliveries. Removal of the intercity, through-trucks can also help reduce the overall congestion due to trucks in such locations.

Table 1. Sample Truck Average Daily Truck Traffic (AADTT) Counts at Selected Rural Intercity Locations along Major Texas Corridors in 2008.

I-35 Corridor		I-45 Corridor		I-10 Corridor	
Nearby City	**2008 AADTT**	**Nearby City**	**2008 AADTT**	**Nearby City**	**2008 AADTT**
Cedar Hill	17715	Ennis	12279	Seguin	8662
Hillsboro	16593	Angus	11046	Flatonia	8792
Lorena	16168	Centerville	9277	Columbus	9313
Georgetown	16050	Madisonville	9449		
Buda	12512	Willis	10511		
Shertz	13964				

Source: Texas Department of Transportation (*2*)

The historical counts shown in Table 1 will rise drastically in the coming decades as the freight demand and population increases in these corridors. At the same time this growth is expected, the nation is experiencing a truck driver shortage that is affecting the ability of trucking companies to address growing demand. Turnover at trucking companies has been over 100 percent at many trucking companies each year before the current economic slowdown, but even at its record low of 43 percent for the third quarter 2009, during a time when jobs are scarce, turnover remains quite high (*3*). Constant turnover results in a more inexperienced driver workforce and potential safety and operational impacts to the highways in the state.

As a result of these trends, moving a percentage of the existing truck traffic to an alternative mode of freight conveyance is of great interest to both state-level and local transportation planners. Much of the remaining freight requires moves over distances less than 500 miles, remaining clearly in the domain of what has traditionally been truck transport. While options such as moving longer-distance freight to rail or the construction of additional general purpose highway lanes or truck-only facilities along existing corridors, the cost of doing so is daunting. Alternatively, the Freight Shuttle System provides a way to move containerized and truck trailer freight off the roadways while generating revenue for the public sector through leasing of the airspace associated with highway rights-of-way. The private sector will invest in the infrastructure and pay for the full capital and operational costs of implementing the system.

PROJECT RESEARCH EMPHASIS AREAS

The project consisted of a program of tasks that extended the research work accomplished between 1999 and 2006 and moved the Freight Shuttle system toward commercialization. Seven areas of emphasis were identified at the outset of the project:

1. Detailed engineering design – the project will work to finalize the functional specifications developed for the Freight Shuttle and through appropriate contracts with engineering design firms, develop detailed engineering specifications.
2. Develop a model and design for rail intermodal terminal automation (RITA) – the productivity of railroad intermodal terminals can be improved by integrating the SAFE Freight Shuttle into container delivery, loading, and storage functions that are currently undertaken by trucks.
3. Formation of strategic partnerships – Commercialization of the system will require the participation of strategic partners in the technology and freight transportation arena.
4. Identification of potential venues – the project will work to identify the optimal location(s) for initial implementation of the system. Numerous candidate sites have been identified previously and the research undertaken in this task will refine the quantification of need, political atmosphere, and capital requirements associated with each.
5. Definition of operational strategies – operating an automated container conveyance will create several new challenges, among them corridor security. This task will examine the operational needs of the system relative to power requirements, right-of-way, control systems, and access to the system by customers.

6. Establishment of funding options – the potential for public-private partnerships, private equity funding, and financing from various government programs will be assessed in detail during this task.
7. Create a detailed plan for the construction/fabrication and testing of the system prototype by a selected vendor or vendor team – the research will culminate in the development of a prototyping project that will build and test the Freight Shuttle.

The following chapters describe the progress made toward the completion of each of these areas during Project 9-1528.

CHAPTER 2: FREIGHT SHUTTLE SYSTEM DEVELOPMENT

RECENT PROGRESS

Development of the FSS has been undertaken on multiple fronts; technical, commercial, and financial. On the technical front, progress has been made in defining the operating plan, the terminal layouts and cargo-exchange strategies, and in obtaining patent protection for a number of features that are important for commercialization. In February 2010, the U.S. Patent Office issued U.S. Patent No. 7654308 to the Texas A&M University System. This patent defines the FSS and spells out critical elements such as the linear induction propulsion system, steel wheels and steel running surfaces, and automated control within the context of goods movement as unique to the FSS.

On the commercial front, the needs and constraints of shippers and trucking companies are cataloged and factored into the pricing, operating plan, and service offerings of the system to ensure commercial viability. On the financial front, based on business case analyses and operating plans, institutional financing has been arranged at levels that will allow the infrastructure and operating systems to be built on a purely private basis.

ESTABLISH FUNDING OPTIONS

A key factor, critical to establishing the commercial viability of the FSS has been the development of a business model that:

1. Positions the FSS as a privately-financed, privately-operated commercial entity.
2. Provides an investment vehicle that attracts private capital in quantities sufficient to implement the system in congested corridors.
3. Positions the system as a lower-cost, higher-performance option for shippers.
4. Provides the public-sector with a method to monetize the longitudinal air-space along existing highway rights-of-way – currently a substantially under-performing asset.
5. Creates significant public benefits in the form of *avoided costs* for truck-induced pavement and infrastructure wear, safety issues, vehicle emissions, and congestion.

6. Alleviates a large portion of the growing commercial transportation demand in key corridors, thereby off-setting an immediate need for TxDOT to expand facilities.
7. Promotes local/regional trucking operations as an option to intercity or inter-regional transport over highways.

The FSS Business Model

Freight transportation in the U.S. is a private, commercial undertaking that is highly efficient in its use of resources. Underlying this efficiency is the understanding that freight generally follows a "lowest-cost" path, with both time and money being considered in transportation decisions. In fact, a principal role of third-party logistics firms (3PLs) is to find the best transportation option (value) for their customers. As a highly competitive market, goods movement is characterized by low margins, carrier efficiency, and dynamic shifts in trade and transport patterns that seek to take advantage of new opportunities in transportation and/or avoid escalating costs. In addition to the focus on cost, most freight transportation is highly attuned to the reliability (predictability) of transportation services. Trucks, in particular, have been characterized as "rolling warehouses" providing just-in-time delivery of goods and material to a growing portion of the economy in both retail and manufacturing, sectors that depend on the accurate timing of deliveries to maximize productivity and minimize inventory holding costs.

In recognition of the private nature of freight transportation, the FSS business model is designed to provide shippers with the performance parameters important to business operation—competitive rates, time-certain delivery, safety, and security. The system will charge customers a per-mile rate (or equivalent) that is at or below the prevailing market rate and provide time-certain delivery as a function of scheduled departure and arrival times. The scheduling of shipments will ensure two important things: time-certain delivery, which is very important to most shippers, and uncongested system operations, which is critical to the market viability of the FSS.

The FSS Business Model is also predicated on attracting *private* financing to build, maintain, and operate the system based on ensuring investors a stable return on their capital. Figure 2 presents the basic business model and shows the interrelated benefit stream, financial flows, and transactions.

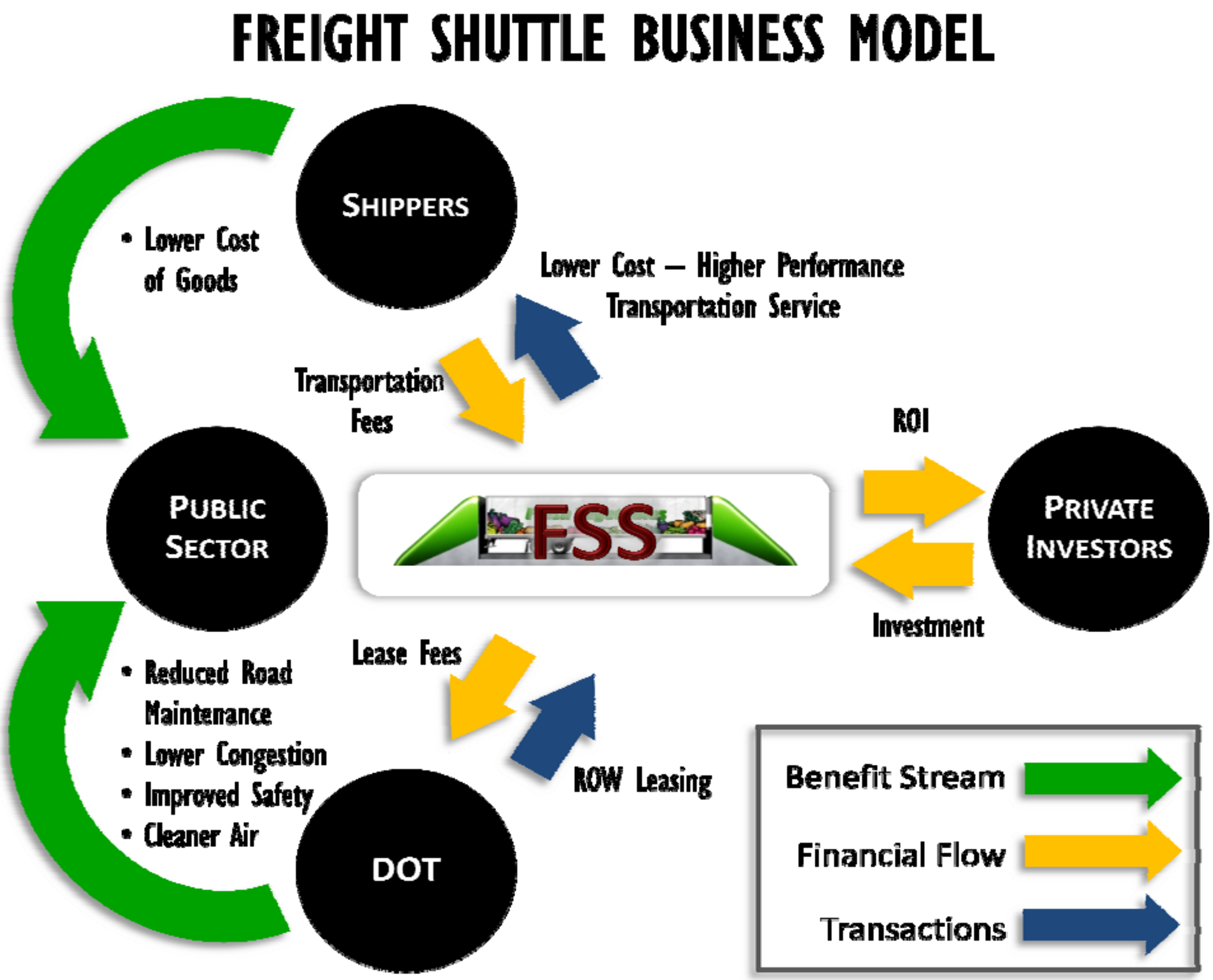

Figure 2. Business Model Components and Flow.

The ability to attract private capital is central to the FSS business model. The prospect of long-term, stable returns on investment derives from the constancy of goods movement and the single-element nature of mode selection in freight transportation—the lowest-cost option offering the best performance characteristics will invariably attract the majority of shipments. Thus, the FSS business model is being formulated with four key components to ensure that FSS traffic levels and profitability is maintained:

- Substantial public sector benefits from avoided costs and no cost to the public.
- DOT revenue generated from underperforming assets (existing highway rights-of-way) at no cost to the DOT.
- Shipper benefits derived from a lower-cost, higher performing transportation option.
- Long-term, stable investor returns on capital.

IDENTIFY POTENTIAL VENUES FOR IMPLEMENTATION OF THE SYSTEM

To recoup infrastructure cost, ideal FSS venues are those involving shorter, high-traffic, congested freight corridors. These corridors need to be less than 500 miles long and to have at least 10,000 daily truck trips. The impact of congestion in such a corridor on shippers and the efficiency provided by a FSS to its clients would enable a traffic capture rate sufficient to a profitable FSS operation.

The gathered information and developed metrics indicate that FSS's candidate venues fall in two categories: marine ports to inland ports connections and congested stretches of commerce corridors. In each of these categories, communications to establishing a FSS as a transportation alternative have identified several target markets. The most promising of those have been pursued as detailed below.

Connecting Inland Ports to Marine Ports

The locations of marine ports have often been chosen for their geographic advantages. Inevitably, a marine port induces a self enforcing cycle of nearby economic and population growth. Unfortunately, operating a marine port creates nuisances and dangers to its surrounding densely populated communities. Escalating public backlash motivates relocating the ports' most disturbing activities inland away from population centers. This creates a need to shuttle containers between the inland and marine ports in an efficient and socially responsible manner.

Inland ports are usually located 70 to 150 miles inland, which is within the target FSS's trip range. Marine ports generate enough container traffic to keep a FSS profitable. The FSS's capture rate would be significant since it would offer competitive pricing as compared to trucking. Trucks would be relieved from traveling the intra-city congested corridor and instead would concentrate on delivering containers from the inland port to nearby distribution centers. Communities surrounding the marine port would benefit from the reduced congestion, pollution, and traffic hazards.

The ports of Long Beach and Los Angeles have been among the earliest marine ports to seek socially responsible transportation modes. The Freight Shuttle Partners FSP—an entity developed to commercialize the FSS technology—responded to their request for concepts and solutions in regard to their effort in adopting a zero-emission container mover system (ZECMS).

After evaluating ZECMS alternatives, the staff of the port of Long Beach recommended to partake in advancing ZECMSs by adopting the following measures:

- Develop a performance matrix based on actual duty cycles operating requirements at the ports to assist ZECMS vendors design and test their systems.
- Help ZECMS vendors to pursue funding assistance by state or federal agencies.
- Pay a third party consultant to design and implement a structured test regimen, measurement, and reporting program.

The FSP continues to collaborate with the ports of Long Beach and Los Angeles toward the implementation of these measures.

Congested Commercial Corridors

The FSS will serve congested transportation corridors less than 500 miles long. Trucks typically transport goods fewer than 500 miles, while railroads dominate long-distance shipping. Long-term trends indicate that trains are increasing their average distance travelled. In 2004, the average length of haul was 902 miles per ton, up from 616 miles per ton in 1980 (*4*). This trend is driven by the fact that railroads improve their operational efficiency as they carry loads farther (*4*).

The I-35 corridor may be an ideal location for a first phase of a FSS in Texas. Ultimately, a multi-segment system could connect Laredo, San Antonio, Austin, and Dallas/Fort Worth, in addition to potentially linking these areas to the major Texas ports. Removing trucks from this corridor of statewide economic significance would not only reduce congestion in some of the most constrained areas of the Texas transportation system, but also help mitigate the detrimental effects that trucking has had on some of the cities located along this corridor. Dallas, San Antonio, and Austin have all been identified as experiencing some level of unhealthy air quality (*5*). The FSS will help Texas achieve the standards established for air quality by the Environmental Protection Agency, thereby reducing the risk of losing critical federal funding for highways.

There is ample existing demand in Texas and the potential for significant future growth. In order to quantify the size of individual FSS opportunities, FSP analyzed truck traffic on highways, which was compiled by the TxDOT (*6*). FSP used actual truck counts for 2007 and projected truck counts for 2015, based on the assumption of 3 percent annual growth. A

35 percent capture rate is used to calculate a system's potential market share on a given highway segment. This figure is similar to the market capture rate achieved by the recently completed Alameda Corridor in Los Angeles, a short-line railroad connecting the Los Angeles and Long-Beach Ports to downtown (*7*). This analysis concludes that the I-35 corridor provides a venue for a profitable FSS application and result in many benefits for the state of Texas and the communities surrounding the I-35.

ENGINEERING DESIGNS FOR THE FSS

A proposal solicitation process was undertaken by TTI during this research to identify qualified vendors for key components of the system. The vetting of vendors began with interviews for firms corresponding to the major sub-systems of the FSS: guideway, transporter, terminals, and communications, command, and control (C3) functions along with power distribution. Proposals were submitted by vendors and team members were selected on the basis of firm capability, engineering design, and projected cost.

Ultimately, the initial guideway concept was designed under collaboration with the Texas A&M University Department of Civil Engineering. These design plans were tailored to the specific loading and operating conditions for the FSS and represent a state-of-the-art, fully elevated structure capable of supporting thousands of daily transporter trips. The design is an elevated, bi-directional and modular system of components that can be manufactured off-site and transported to the construction location over existing infrastructure. Current work is underway with private sector firms to advance these initial concepts and include features that facilitate "end-on" construction. End-on construction employs those completed portions of the guideway to transport and position subsequent, modular components for installation, avoiding as much on-the-ground construction as possible and thereby minimizing disruptions to motor vehicle traffic.

The transporter has been designed to provide a stable platform for both over-the-road trailers and intermodal containers. The transporter system is characterized by two sets of double-sided linear induction motors (LIMs) and two "tractor" units linked to an articulated cargo bay. The transporter is equally capable of travel in either the forward or backward direction and has a design velocity of approximately 100 kpm.

Terminals were designed by TTI and consist of a combination of small, modular load-transfer units (LTUs) of approximately 2.5 acres in area. The throughput needs of a particular terminal configuration will determine the number of LTUs constructed, with additions or eliminations possible as traffic levels at a particular site change. Two varieties of LTUs have been developed: one to accommodate container transfers using standard overhead cranes and a second to allow the loading and unloading of trailers.

Communications, command, and control (C3) functionality has been developed at the functional specification level and will not be completed until prototyping is underway. The C3 system will be implemented as a distributed system with redundant communications modalities and substantial autonomous capabilities given to the transporters. Both radio frequency (RF) and fiber optic systems will be employed to ensure uninterrupted communications.

RAIL INTERMODAL TERMINAL AUTOMATION (RITA) MODEL

Rail intermodal terminal automation (RITA) is the use of the automated FSS to pick up or deliver intermodal cargo to a traditional rail intermodal terminal. The standard arrangement for pick-up and delivery at these facilities relies on over-the-road dray vehicles that arrive according to a schedule driven largely by railroad cut-off times for departing trains. As such, the traffic patterns into and out of the terminal are subject to periods of surges followed by periods of inactivity. Organizing shipments in intermediate buffers or parking facilities and subsequently pulling the appropriate trailer or container entails additional time, space, and labor.

The RITA model partially replaces dray vehicles with the elevated FSS in an organized and scheduled sequence of pick-ups and deliveries that eliminates the need for substantial on-site storage and reduces labor costs through direct placement of cargo using overhead cranes. Figure 3 shows the physical arrangement of FSS transporters to a double stack train and two pairs of rail-mounted gantry cranes. The FSS transporters can be positioned on elevated guideway allowing ingress and egress to the terminal without interrupting surface transportation activities in the terminal. This arrangement will allow a single transporter to both deliver out-bound cargo and pick up in-bound shipments. The sequencing of moves is systematic and repeated each time the cranes advance down the length of the train.

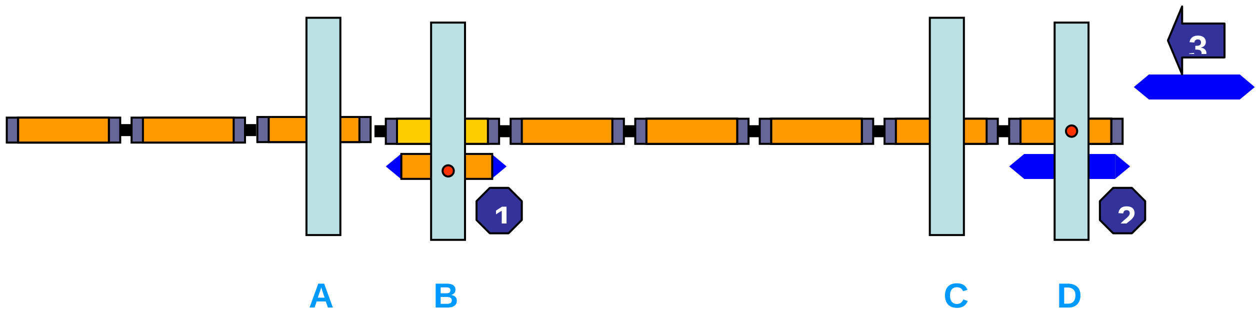

Figure 3. Schematic Sequencing for RITA: Shuttle-Rail Interface and Crane Position.

PROTOTYPING PLANS

The prototyping of an FSS requires a multi-disciplinary team working together in a highly complex environment. Before specific tasks were created, TTI developed a prototyping plan (see Figure 4) that describes the process involved for each of the major prototyping phases: Project Planning, System Design, and Construction & Testing. During Project Planning, the vision, goals, and scope of the Freight Shuttle System were finalized. This allowed for the development of each major subsystem, and subsequently the selection of each technology subcontractor.

TTI developed a Request for Qualifications and a Request for Proposal from which subcontractors were evaluated and selected. The FSS has four major subsystems: the propulsion system package (PSP), the communication, command, and control (C3) system, the guideway, and the transporter. Curtiss-Wright is a $1.6 billion global provider of highly engineered technologies for critical applications, is a major supplier of LIMs to the defense industry, and has been selected as the subcontractor for the PSP. Transdyn is a leading systems integrator of command, communication, and information systems, has experience with automated vehicle control, and has been chosen as the subcontractor for the C3 system. Deaton Engineering, Inc., is a full-service engineering company based in Georgetown, Texas, and was selected as the subcontractor for the development of guideway switches and transporters. Texas A&M's Civil Engineering department completed the design specifications for the guideway.

Once the technology subcontractors were selected, a Work Breakdown Structure (WBS) was developed from the process outline in Figure 4. The WBS, shown in Table 2, describes high level tasks in addition to the lower level subtasks involved in executing the proposed project.

Construction & Testing

Once the design has been finalized, technology subcontractors will build out and test each subsystem individually to ensure performance requirement are met. If no modifications are required, the full Freight Shuttle System will be assembled, tested, and evaluated at the demonstration site.

System Design

The design of the Freight Shuttle System will proceed according to three phases: Advanced Planning, Detailed Design, and Integration. During these design phases, the subcontractor team will engage in a highly collaborative effort to advance each subsystem. The System Design phase will end with a design audit to ensure that the proposed design conforms to the vision and scope developed during Project Planning.

Project Planning

Five years of research has allowed the Freight Shuttle to advance from a concept to a fully defined system with a subcontractor team that is ready to design, build, and test the initial demonstration. Project Planning shows progress to date.

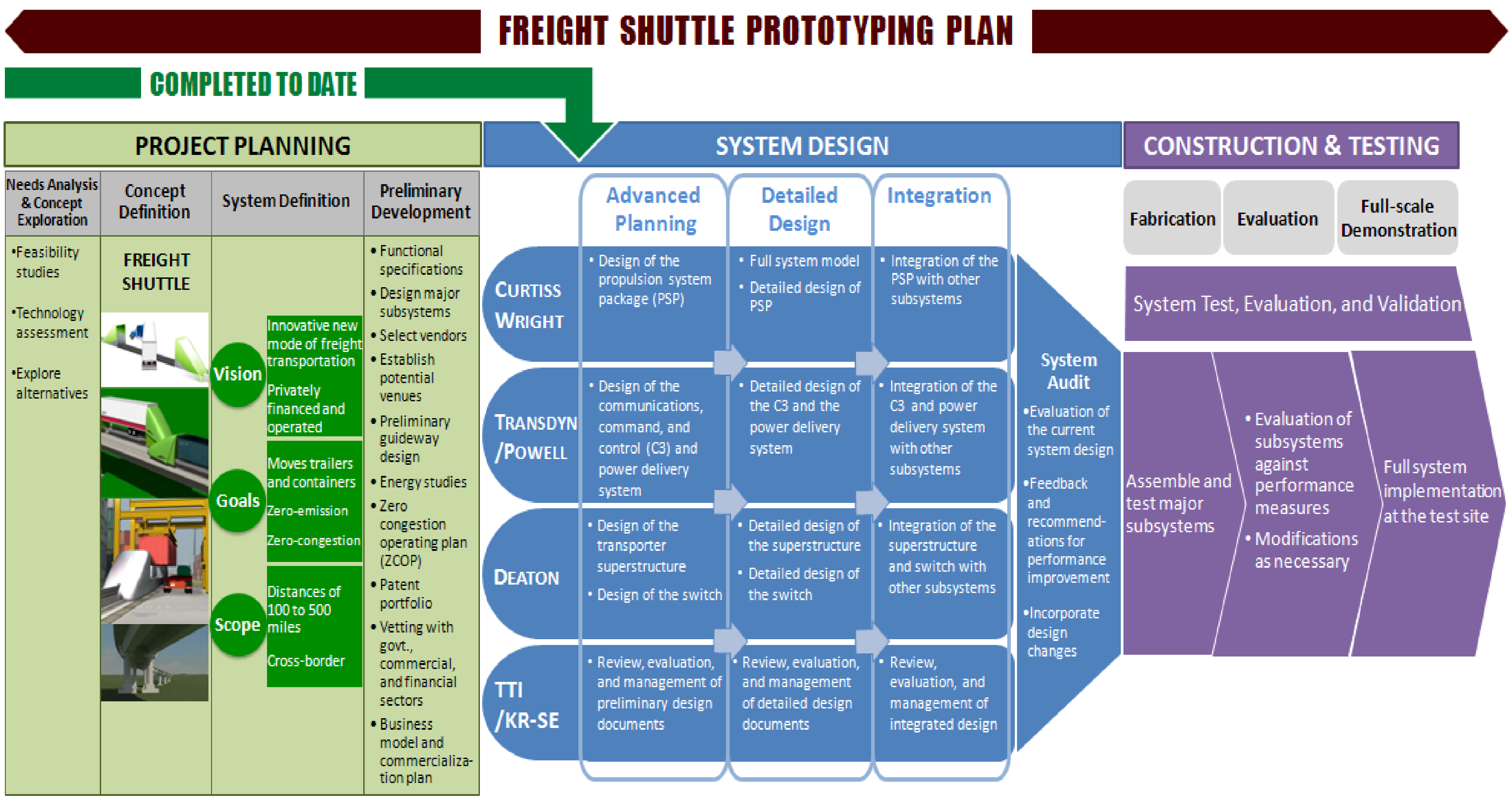

Figure 4. Freight Shuttle Prototyping Plan.

Table 2. Work Breakdown Structure for the Prototyping of the Freight Shuttle System.

PROJECT TASK	TASK DESCRIPTION	SUCCESS CRITERION
1. Project Planning	Definition of scope, task sequencing, and budget.	Completed
2. Contractor Identification & Selection	Selection of technology subsystem subcontractors.	Completed
3. Program Management & Oversight 3.1. Schedule Monitoring and Cost Control 3.1.1. TTI 3.2. Technical Interface Management 3.2.1. KR-SE	Active monitoring of task progress and project expenditures as well as the management of design change impacts on subsystem interfaces.	Project completion on time, within scope, and on budget. Conformity to the design envisaged by TTI. Exhaustive definition of requirements, interfaces, and risks associated with combining subsystems.
4. System Design 4.1. Design Requirements Development 4.1.1. Curtiss-Wright 4.1.2. Deaton 4.1.3. Transdyn/Powell 4.2. Interface Definition 4.2.1. Curtiss-Wright 4.2.2. Deaton 4.2.3. Transdyn/Powell 4.3. Detailed Design 4.3.1. Curtiss-Wright 4.3.2. Deaton 4.3.3. Transdyn/Powell 4.4. Test Procedures 4.4.1. Curtiss-Wright 4.4.2. Deaton 4.4.3. Transdyn/Powell	Each major subsystem will progress according to a four stage process: design requirements development, interface definition, detailed design, and development of test procedures. The successive completion of each design stage will result in a report documenting subcontractor progress. The following is a description of each design stage document: Requirements Document - This document will outline the specific functional requirements of each subcontractor portion of the demonstration. These requirements will be developed jointly with all participants. Interface Definition Document (IDD) - The IDD will provide detailed information on the interfaces between each subsystem. The IDD will include interfaces both internal and external to each subsystem. Detailed Design Document - This document will provide software design details and system models for each subsystem. This document will be used to design the software and hardware components that will meet the functional requirements. All components will be traced back to the Requirements Document. Test Procedures - The Test Procedures will provide the steps, configuration, equipment and personnel required to validate the system performance and functionality both during development and at the final evaluation and validation stage of the project. All test procedures will be linked to the respective performance or functional requirement in the Requirements Document.	Success for each subtask will be determined by the completion of each design phase document and the ability of these documents to allow each subcontractor to proceed to the next design phase.

Table 2. Work Breakdown Structure for the Prototyping of the Freight Shuttle System (Continued).

5. Subsystem Construction 5.1. Fabrication of Major Subsystems 5.1.1. Curtiss-Wright 5.1.2. Deaton 5.1.3. Transdyn/Powell	The technology subcontractors will build out and test each subsystem individually to ensure that the functional requirements developed in the Requirements Document are met. If not, the subcontractor will produce modification and rework as necessary to meet the functional requirements.	Each subsystem satisfies the functional requirements outlined in the Requirements Document.
6. Full System Testing & Evaluation 6.1. Performance Measure Validation 6.1.1. Curtiss-Wright 6.1.2. Deaton 6.1.3. Transdyn/Powell	After each subsystem has been vetted against the functional requirements, the full Freight Shuttle System will be constructed and tested against the performance measures based on the project scope developed in Task 1.	The FSS meets or exceeds the performance measures outlined in the project scope and revised throughout the System Design phase.

Table 2 also provides a description for each task in the WBS and their associated success criterion.

Using the tasks developed in the WBS, a schedule was created that shows the durations and sequencing for each task (see Table 3). The prototyping of the FSS is scheduled to take 21 months, which includes three months for testing and evaluation at the demonstration site.

Table 3. Freight Shuttle System Prototyping Schedule.

Task	Duration	Schedule (Months)																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Project Planning	Complete																					
2. Contractor Identification & Selection	Complete																					
3. Program Management & Oversight	21																					
3.1. Schedule Monitoring and Cost Control																						
3.1.1. TTI	21	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3.2. Technical Interface Management																						
3.2.1. KR-SE	21	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4. System Design	12																					
4.1. Design Requirements Development																						
4.1.1. Curtiss-Wright	4	■	■	■	■																	
4.1.2. Deaton	3	■	■	■																		
4.1.3. Transdyn/Powell	2	■	■																			
4.2. Interface Definition																						
4.2.1. Curtiss-Wright	3					■	■	■														
4.2.2. Deaton	4				■	■	■	■														
4.2.3. Transdyn/Powell	5			■	■	■	■	■														
4.3. Detailed Design																						
4.3.1. Curtiss-Wright	4								■	■	■	■										
4.3.2. Deaton	4								■	■	■	■										
4.3.3. Transdyn/Powell	4								■	■	■	■										
4.4. Test Procedures																						
4.4.1. Curtiss-Wright	1												■									
4.4.2. Deaton	1												■									
4.4.3. Transdyn/Powell	1												■									
5. Subsystem Construction	6																					
5.1. Fabrication of Major Subsystems																						
5.1.1. Curtiss-Wright	6													■	■	■	■	■	■			
5.1.2. Deaton	6													■	■	■	■	■	■			
5.1.3. Transdyn/Powell	6													■	■	■	■	■	■			
6. Full System Testing & Evaluation	3																					
6.1. Performance Measure Validation																						
6.1.1. Curtiss-Wright	3																			■	■	■
6.1.2. Deaton	3																			■	■	■
6.1.3. Transdyn/Powell	3																			■	■	■

CHAPTER 3: QUANTIFICATION OF PUBLIC BENEFITS OF THE FSS

INTRODUCTION

Truck traffic on publically provided roadways has both positive and negative ramifications. On the positive side of the ledger, trucks transport the lion's share of the goods we produce, purchase, and consume. Our economy is dependent on this critical transportation function and it is served flexibly and efficiently by a highly responsive trucking industry. On the negative side of the equation, trucks adversely impact the highway system in several ways: they produce diesel emissions at relatively high levels, they damage and wear the infrastructure over which they operate, they contribute to congestion on roadways, they represent an additional risk factor in highway safety, and they consume large quantities of oil-based diesel fuel. This chapter analyzes the public benefits associated the avoided costs projected for an example corridor with the Freight Shuttle System inducing a portion of the truck traffic off of the highway and on to the FSS. These public benefits arise directly from the reduced levels of heavy duty diesel trucks on a congested highway. The categories of public benefits analyzed are:

- Energy.
- Air quality.
- Infrastructure.
- Congestion.
- Safety.
- Noise.

PUBLIC BENEFITS CASE STUDY

In order to calculate the public benefits of a typical FSS, a hypothetical 250-mile Freight Shuttle System is evaluated. The different location options for implementation of the FSS are previously discussed in this report, but for this analysis a commercial corridor is assumed. The example system is defined in a manner that makes it similar to several heavily traveled commercial corridors in Texas. The similar corridors include Interstate Highway 35 (I-35) corridor between Dallas and Laredo, I-45 between Houston and Dallas, or I-10 between Houston and San Antonio. The characteristics of the hypothetical corridor are discussed below.

The analysis assumes a 2015 implementation year, with a 10-year analysis period. By the year 2015, truck traffic on the corridor is expected to be 10,000 trips per day with an annual average growth rate of 2.5 percent. The analysis is developed around an initial capture rate of 25 percent of the daily truck trips, resulting in 2,500 shipments a day. Annual market growth is expected to be 15 percent for the five years following the initial start-up year and 3 percent annually, thereafter.

The analysis assumes 360 days of operations each year, resulting in 900,000 trips in the first year and over 2 million by Year 10. By the tenth year of FSS operations, it is projected that there will be 5,660 daily freight shuttle (FS) trips. Annual vehicle miles traveled (VMT) is assumed to increase from 225,000,000 miles in Year 1 to over 500,000,000 in Year 10.

PUBLIC BENEFIT CALCULATIONS AND FINDINGS

The analysis calculates the net present value (NPV) to estimate the overall value of benefits to the public sector for FS operations during the first 10-year period of operations. The discount rate is 6 percent, compounded annually. An analysis is also performed on the federal fuel tax revenue that would be lost to Texas for diesel fuel not sold and consumed and shows that right-of-way (ROW) lease rates tied to FSS VMT can replace these diminished revenues. TxDOT estimates that the Federal Highway Trust Fund returns to Texas approximately 80 percent of the federal fuel taxes collected in the state.

Public benefit calculations are based on the Federal Highway Cost Allocation study updated in 2001. Individual item values in this study correspond to the benefit categories identified above and are attributable to each truck VMT. To account for inflation, the Bureau of Labor Statistics (BLS) producer’s price index (PI) for inflation from 2000 to 2009 is applied to the base price from the Federal Highway Cost Allocation Study. The BLS PI inflation over the 10-year period is equivalent to a 50 percent increase from the 2001 Cost Allocation Study. To account for the cost distinction identified between urban and rural roadways, the 250-mile FSS is assumed to be distributed as 30 percent urban and 70 percent rural mileage.

In order to provide as comprehensive a treatment as possible, the analysis evaluates the avoided cost of pavement damage, traffic congestion, traffic noise, roadway crashes, oxides of nitrogen (NO_x) due to truck operations, NO_x from the electric power generating plants required to provide power to the FSS, and the amount of federal fuel taxes not collected as a result of truck operations, but replaced to the state through ROW lease fees.

Estimating net emissions reductions proved to be difficult because mobile source emissions (trucks) and stationary source emissions (power plants) are not treated the same. Both carbon dioxide (CO_2) and NO_x emissions were evaluated because of their relevance to global warming and air pollution. The specific emission category chosen for comparison in the analysis was NO_x due to its higher avoidance cost. The analysis treats this emission conservatively for trucks and for the FSS. Truck-generated NO_x is estimated using the U.S. Environmental Protection Agency (EPA) Mobile 6 model for 5-axle heavy duty diesel trucks. The FSS emissions were based on an average emissions rate for all generation sources in the U.S., from National Electric Research Council (NERC) Region Emission Rates for 2004 Report, using the latest eGRID2006 Version 2.1, April 2007 update. The value for NO_x reduction was based on current EPA estimates for avoided cost per ton of NO_x.

Fuel Tax Lost Revenue

The public supports the development, construction, and maintenance of the entire roadway system through fuel taxes levied on gasoline and diesel fuel on a per gallon basis. The taxes are levied separately by federal, state, and local governments (*8*). The federal tax on fuel is constant throughout the United States, but each state taxes fuel at a rate approved by its appropriate taxing authority.

The federal excise tax on each gallon of gasoline is $0.184 but is $0.244 for each gallon of diesel fuel. The federal excise tax collected on fuel in the various states is distributed back to the states according to a complex series of calculations that are periodically adjusted (*9*).

The formula-based distribution of the federal motor fuel tax benefits some states at the same time it penalizes others. That is, some states collect less federal motor fuel tax than they receive (referred to as “donee” states) while others collect more than they receive (“donor” states). The inequities in the redistribution of fuel taxes have long been debated. The short-changed donor states are typically those with greater population growth and hence, those with greater transportation needs, while states receiving a disproportionate share of revenue are often those with slower population growth. Texas is a donor state and receives only 80–85 percent of its motor fuel taxes back from the federal government. Table 4 shows the amount of motor fuel tax generated on a per gallon basis and on a per miles basis for diesel trucks. As can be seen, given the average miles per gallon for over-the-road diesel trucks (approximately 6.4 miles per gallon), Texas should receive $0.069 for every mile traveled by trucks on TxDOT maintained highways. The actual amount received is approximately $0.058. Thus, by providing an alternative, off-highway mode for freight transportation, Texas would lose tax revenue as it benefitted from reduced truck traffic levels. This reduction in tax revenue however, would be off-set by a per-mile fee paid to the state for shipments on the FSS, producing a double win for the public sector.

Table 4. Diesel Fuel Tax Revenue per Gallons and per Mile.

	Fed Tax/Gal	Texas Tax/Gal	Total Tax
1 gal.	0.244	$0.20	0.444
1 mi.	0.038	0.031	0.069
Per 100 million mi.	$3,812,500.00	$3,125,000.00	$6,937,500.00

Energy and Air Quality

A low carbon emitting, electric propulsion system provides one means to greatly reduce the energy requirements associated with freight movement. Figure 5 shows that the calculated energy cost per mile for the FSS, based on motor efficiency, shipment mass, rolling and wind resistance, is about 12 times less than heavy duty diesel (HDD) trucks, as calculated by the American Transportation Research Institute (ATRI) (*10*). In order to contrast the range achieved by the FSS to that of a standard HDD truck on a per gallon of diesel basis, FSS energy consumption was converted to British Thermal Units (BTUs) and compared to the equivalent value for 1 gallon of diesel. HDD trucks are able to travel approximately 6.4 miles per gallon of diesel. The comparison shows that the FSS can travel almost 50 miles per equivalent gallon of diesel. Figure 6 shows this comparison graphically.

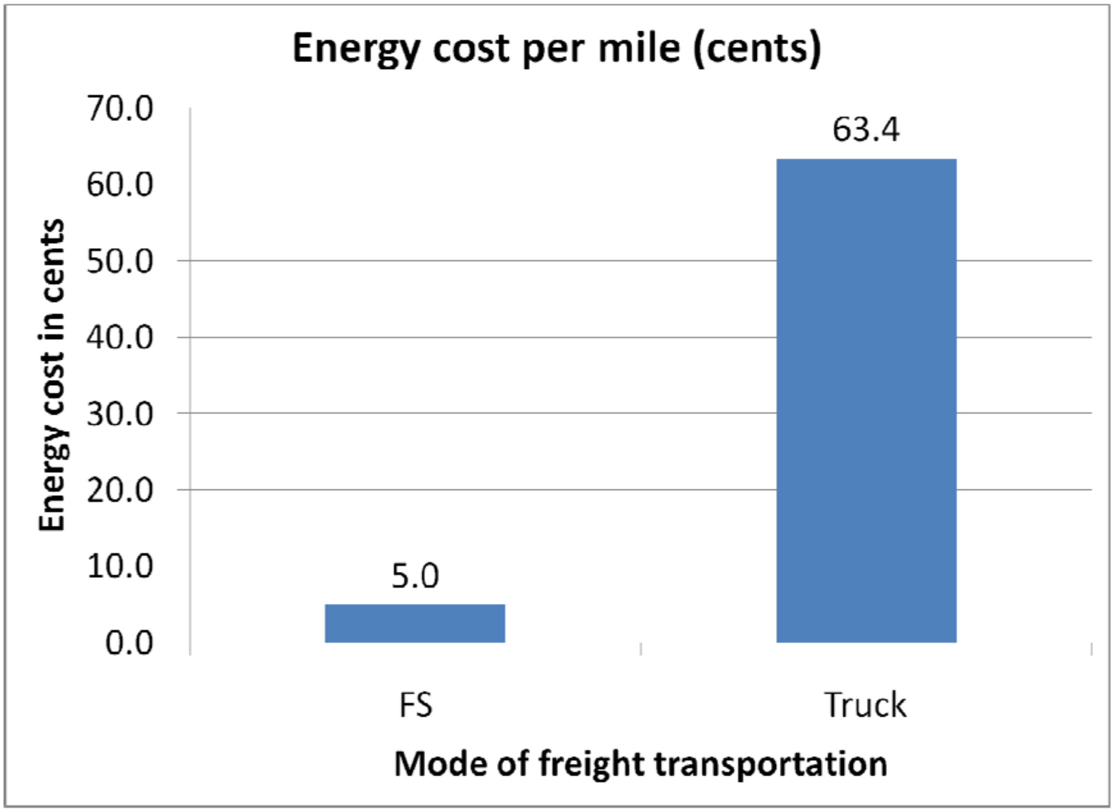

Figure 5. Energy Cost per Mile Comparison between FSS and HDD Truck.

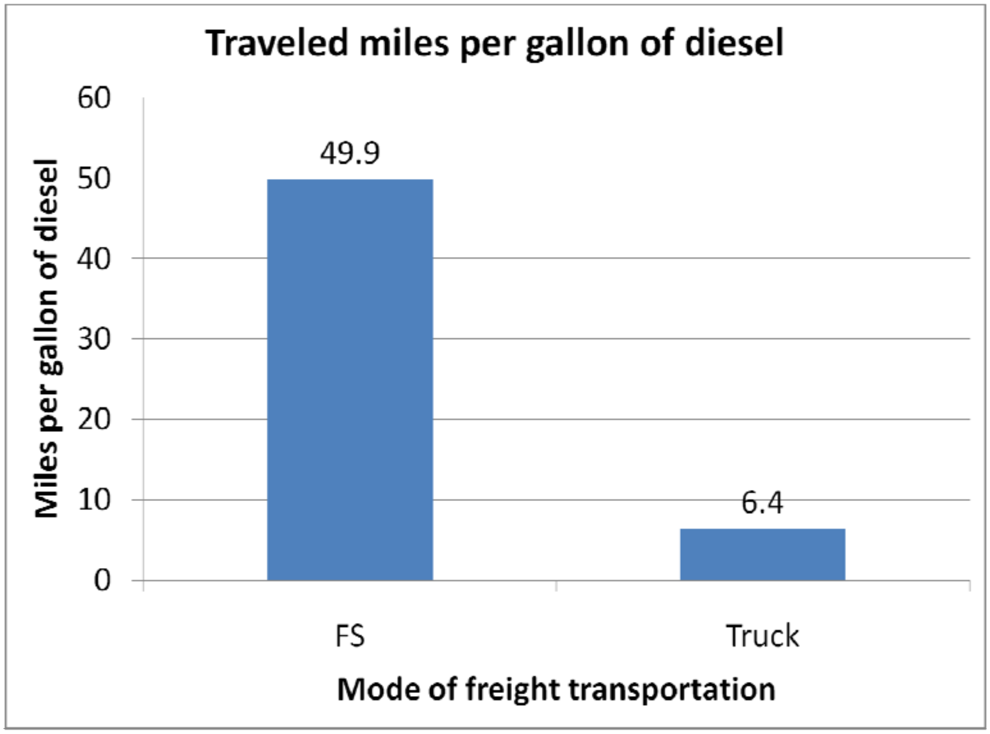

Figure 6. Traveled Miles per Gallon of Diesel for FSS and HDD Truck.

Figure 7 demonstrates the estimated number of eliminated truck trips captured by the example, 250-mile FSS system and the estimated reduction in diesel fuel consumption. The last year alone in the 10-year analysis shows a reduction of over 80 million gallons of diesel fuel use. The cumulative quantity of diesel fuel use is 622,176,776 gallons for the 10-year analysis period.

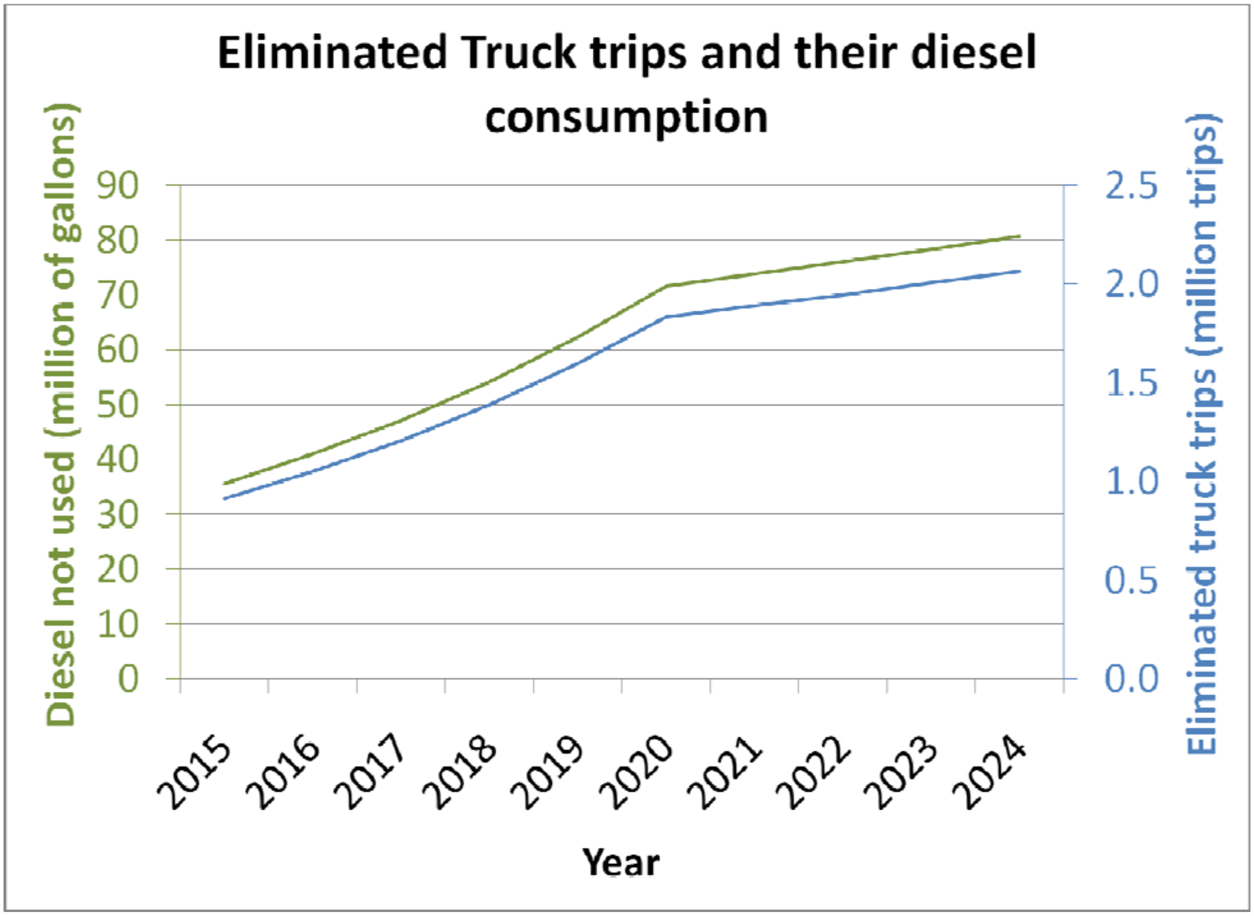

Figure 7. Eliminated Truck Trips and Consumed Diesel from FSS Implementation.

The projected low energy consumption of the FSS, as compared to the relatively high energy requirements of HDD trucks, provides a substantial net benefit in reduced air emissions. NO_x and CO_2 for both HDD trucks and the FSS were evaluated and compared. The emission rates for electric generating power plants are monitored and regulated on a "pound per million watt hours" basis, and HDD trucks emission rates are calculated as "grams per horsepower hour."

Power plant emissions were estimated from the eGRID2006 Version 2.1, April 2007 using the U.S. Output Emission Rate of 2.103 pounds per MWh for NO_x. HDD truck emissions were evaluated using the EPA Mobile 6 Class VIII truck emission rates per VMT. Table 5 below shows the calculations for determining the net reduction in NO_x associated with FSS operations.

HDD truck and FSS emissions were evaluated on an equivalent basis. FSS kWh use was converted to tons of emissions per 1,000,000 miles using the eGRID2006 power plant emission rate. Mobile 6 output for HHD trucks provides grams/VMT, which was converted to pounds/VMT[1]. The VMT for both trucks and FSS are equal because the FSS replaces truck mileage on a one-to-one basis for the designated number of trips.

Table 5. Freight Shuttle System NOx Savings.

Year									
2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Annual 250 mi. Trips (in millions)									
0.900	1.035	1.190	1.369	1.574	1.810	1.865	1.920	1.978	2.037
Annual VMT (in millions)									
225.0	258.75	297.56	342.20	393.52	452.56	466.13	480.12	494.52	509.36
Annual Truck NO_x Emissions @ 14.76 tons/million VMT									
3,322	3,820	4,393	5,052	5,810	6,682	6,882	7,088	7,301	7,520
Annual FSS NO_x Emissions @ 0.34 tons/million VMT									
75.98	87.38	100.48	115.55	132.89	152.82	157.40	162.13	166.99	172.00
Truck NO_x cost @ $13,000 per Ton (in millions)									
$43.19	$49.66	$57.22	$65.68	$75.53	$86.87	$89.47	$92.14	$94.91	$97.76
FSS NO_x cost @ $13,000 per Ton (in millions)									
$0.99	$1.14	$1.31	$1.50	$1.73	$1.99	$2.05	$2.11	$2.17	$2.24
Net Annual NO_x Savings FSS versus HDD Truck (in millions)									
$42.20	$48.52	$55.91	$64.18	$73.80	$85.88	$87.42	$90.03	$92.74	$95.52
10-year NPV at 6% discount rate for FSS NO_x Savings									
$518,535,811									

[1] Conversion factor to convert grams to pounds (lb) = 453.59 g/lb

The same method was used to evaluate the public benefit for the reduction of CO_2 emitted by trucks. The quantity of CO_2 generated by HDD trucks is 100 times more than the amount of NO_x generated. However, the avoided cost of CO_2 is set at only $33.00 per ton compared to $13,000 per ton for NO_x, a 400:1 ratio in avoided public costs for reducing NO_x. Nonetheless, the very large quantity of CO_2, results in an NPV for reducing CO_2 during the 10-year analysis of $130,151,026, nearly 25 percent of the public benefit value of NO_x. Figure 8 demonstrates the amount of NO_x and CO_2 emissions eliminated by the use of the FSS.

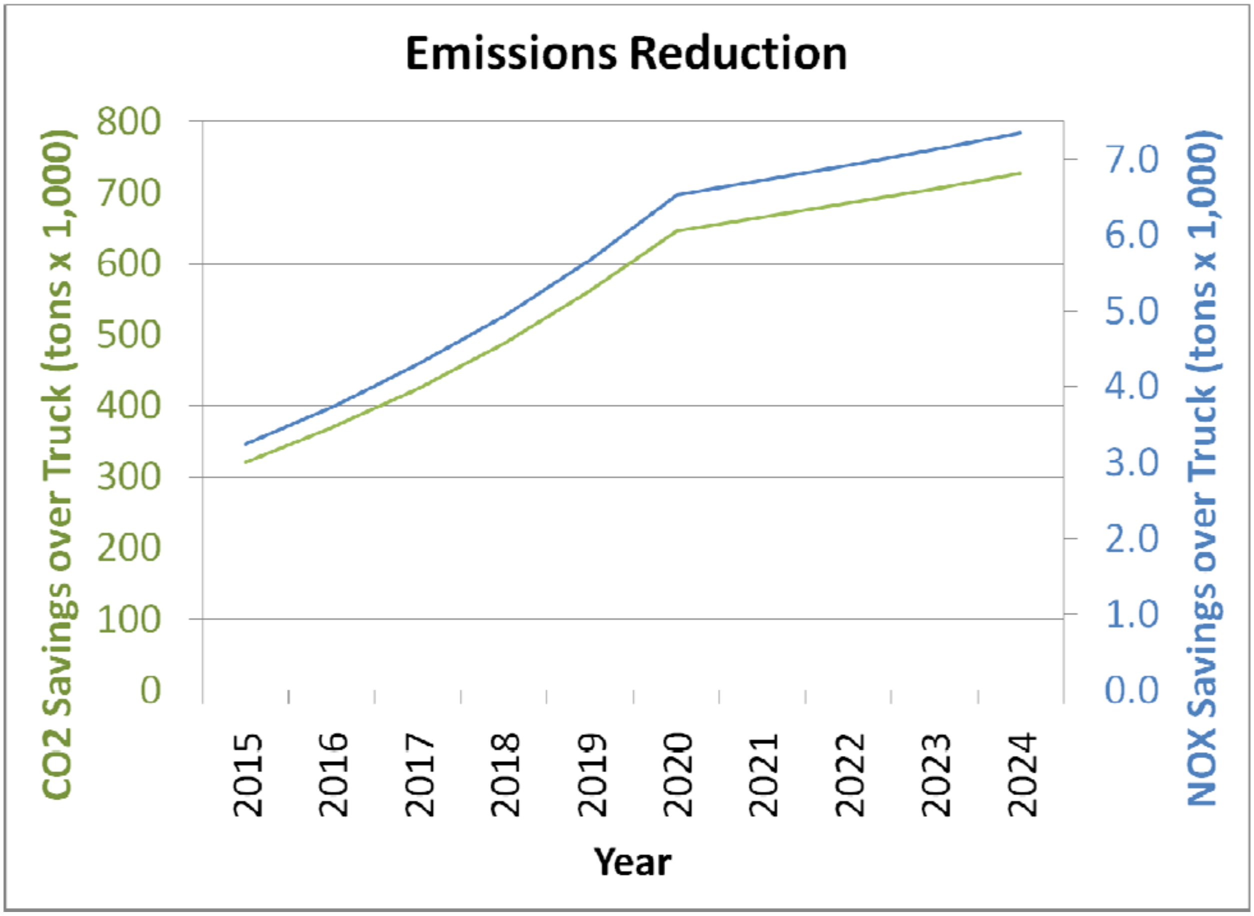

Figure 8. Tons of Emissions Reduction from Reduced HDD Truck Operations.

Infrastructure

The weighted Average Marginal Cost of Highway Damage due to the operation of 80 kip combination trucks is determined by multiplying the annual VMT that HDD trucks will travel per year by the marginal cost of pavement damage per mile. The NPV is evaluated over the 10-year operating period at a 6 percent discount rate.

The U.S. Department of Transportation, Federal Highway Administration *Addendum to the 1997 Federal Highway Cost Allocation Study Final Report May 2000,* provides individual costs for rural and urban pavement damages. The 2000 cost for rural pavement damage is $0.127 per mile and urban cost was $0.409 per mile. The FSS route evaluated for this research is a 250-mile system with 70 percent of the operations assumed to be in rural areas and the remaining 30 percent of the route miles considered to be in urban areas. Thus, the average pavement damage cost is estimated to be a weighted average drawn from 70 percent times the rural cost per mile plus 30 percent times the urban cost per mile or $0.2116 per mile.

The Freight Shuttle System is not expected to begin commercial operations until 2015 when pavement damage costs are anticipated to be significantly higher than the 2000 cost per mile provided in the FHWA report. Using the Bureau of Labor Statistics, Producers Price Index inflation from the years 2000 to 2009, there has been an approximate 50 percent increase in the prices of materials going into highway maintenance and repair. Therefore, the current analysis increases the 2000 cost allocation estimate by a corresponding 50 percent to arrive at an aggregate cost estimate of $0.3174 per mile for HDD-induced infrastructure damage.

In the example FSS, the first year of commercial Freight Shuttle operations is projected to capture 25 percent (2,500 shipments) from the highway to the alternative Freight Shuttle. Commercial operations were assumed to occur 360 days per year so the first year's total truck trips diverted was estimated to be 900,000. For a 250-mile system, this equates to 225,000,000 total annual truck miles removed from the highway. Each of the next five years the FSS is projected to attract an additional 15 percent of the truck traffic, that itself is growing at a rate of 2.5 percent per year. The final four years of the analysis projects that the Freight Shuttle growth rate will be a more conservative 3 percent. Table 6 below presents the calculations and shows that the 10-year NPV for avoided infrastructure damage on a typical FSS is in excess of $585 million.

Table 6. Freight Shuttle System Pavement Damage Savings.

Year									
2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Truck Trips									
10,000	10,250	10,506	10,769	11,038	11,314	11,597	11,887	12,184	12,489
Annual FSS Trips									
2,500	2,875	3,306	3,802	4,373	5,028	5,179	5,335	5,495	5,660
Annual FSS Miles (**in millions**)									
225.0	258.75	297.56	342.20	393.52	452.56	466.13	480.12	494.52	509.36
FSS Pavement Damage Savings @ $0.3174 per mi. (**in millions**)									
$47.61	$54.75	$62.96	$72.41	$83.27	$95.76	$98.63	$101.6	$104.6	$107.8
10-year NPV at 6% discount rate for FSS Pavement Damage Savings									
$585,053,488									

Congestion

The Texas Transportation Institute estimates that, in 2003, the 85 largest metropolitan areas experienced 3.7 billion vehicle-hours of delay, resulting in 2.3 billion gallons in wasted fuel and a congestion cost of $63 billion (*11*). Traffic volumes on major U.S. roadways are projected to continue growing. The volume of freight movement alone is forecast to nearly double by 2020. Congestion is largely thought of as a problem restricted to large cities, but delays are becoming increasingly common along heavily traveled intercity commercial corridors. Congestion results when traffic demand approaches or exceeds the available capacity of the system. While this is a simple concept, it is not constant. Traffic demand varies significantly depending on the time of day, the day of the week, and even the season of the year (*12*).

The FSS is expected to attract 25 percent of the freight truck traffic in the study corridor in the initial year of operation with a resulting reduction in congestion. The avoided congestion cost is estimated using the same technique as described for the pavement damage above. At the FHWA per mile values for congestion ($0.20 urban, $0.023 rural), an inflation-adjusted $0.16/mile value results in a 10-year NPV for avoided public costs for congestion reduction of almost $211 million.

Safety

Highway engineers and administrators are continually faced with decisions concerning the design and operation of the highway system. An important part of the decision making process is the potential impact on the safety of the highway users. Informed decision making requires an understanding of how safety is affected by the geometric design of the roadway, the selection and placement of roadside hardware, the use of traffic control measures, the size and performance capabilities of the vehicles, and the needs and abilities of the users. This understanding can be developed through sound analysis of information about crashes, roadway geometrics, traffic control devices, traffic volume data, and the location of hardware and obstacles on the roadside.

By providing an alternative mode of travel for 25 percent of the HHD truck traffic in the study corridor, an improvement in overall safety can be expected. The FHWA value applied to HDD truck operations, weighted by 70 percent rural and 30 percent urban and adjusted for inflation, is $0.0203/mile. The method employed to develop a 10-year NPV value for avoided public costs associated with safety is described above. The calculation shows that by attracting HDD truck traffic to the FSS, over $26 million in crash-related costs are avoided.

Noise

Highway noise affects those individuals' located adjacent to major highways and terminals serving large volumes of trucks. This is true for both in the urban and rural environment. As with the other public cost measures addressed for HDD truck operations, the FHWA has assigned a cost to noise. The inflation adjusted marginal cost developed for this impact element is $0.022/mile. Diverting shipments from HDD trucks to the FSS enhances the quality of life for those located adjacent to the corridor highways. As with several of the other calculations, the public benefits associated with reduced noise are associated with the reduction of truck travel. The 10-year NPV associated with noise reduction for the example FSS is estimated at over $28 million.

REVIEW OF PUBLIC BENEFITS OF FSS

Table 7 summarizes the avoided public costs associated with the Freight Shuttle System over the 10-year period. The net present value for each public benefit item is calculated using a

6 percent discount rate. The total NPV was summed to arrive at the total saving for the public benefit stream attributable to FSS commercial operations beginning in 2015. The resulting comparison between the environmental benefit value for Nitrous Oxide (NO_2) and CO_2 reduction indicates the avoided cost benefit for reduction of NO_x to be the larger public benefit.

Table 7. Total NPV of Benefits Attributable to FSS Operations.

Benefit Category	Public Benefits Attributable to FSS
Pavement	$585,053,488
Congestion	$210,906,805
Noise	$28,893,237
Crash	$26,570,718
Oxides of Nitrogen *Carbon Dioxide*	$518,535,811 *$130,151,026*
Total NPV with NO_x Benefit *With CO_2 Benefit*	**$1,369,960,061** ***$981,575,276***

Adjustment for Inflation

An additional calculation is performed to estimate the scale of the public benefit when an inflation rate of 3 percent is applied and compounded for the period from 2011 to 2024. The inflation rate is applied to the cost of pavement maintenance (damage), congestion costs, noise pollution and crashes.

Table 8 presents the adjusted NPV for these costs. The NO_x cost avoidance value is subject to the same adjustment because the EPA establishes the cost estimate for emissions on a periodic basis as necessary to meet requirements. Table 8 shows the total public benefits over the period utilizing the compounded producer price index analysis.

Table 8. NPV of Benefits Attributable to FSS with 3 Percent Inflation Rate.

Benefit Category	Public Benefits Attributable to FSS
Avoided Pavement Maintenance	$1,210,521,347
Avoided Congestion Costs	$436,382,648
Avoided Noise Costs	$59,782,363
Avoided Crash Costs	$54,976,891
Credit for reduction in Oxides of Nitrogen	$518,535,811
Total 10-Year NPV with NO_x Benefit	**$2,280,199,060**

RESULTS

The analysis of FSS operations over a 10-year period using the base assumptions described above provide an avoided-cost benefit to the public of at least $1,369,960,000. The two major contributors to this benefit value are the avoided cost of pavement damage and the credit for mitigating NO_x emissions. The NPV of avoided pavement damage for the 10-year period was $585,053,488. The NPV of the avoided cost for NO_x over the 10-year period was an additional $518,535,811. Together these two avoided cost items exceed a billion dollars, totaling $1,103,589,299.

When the analysis includes the increased construction values based on the BLS producers price index, the NPV for the total public benefit amounts to $1,796,672,000. This is $426,712,000 more than the conservative estimate using 1997 dollar values.

Replacement of lost motor fuel tax based on a VMT-driven ROW lease fee is projected to provide the state revenue amounting to $193,543,000 (10-year NPV for cash payments). The actual accumulated cash payment over that 10-year period is $274,380,000.

Adjusting for inflation with a 3 percent annual increase for pavement, congestion, noise and crash cost factors and compounded for each year through the year 2024, a more realistic NPV can be developed. This calculation is not applied to the federal fuel tax or the EPA NO_x avoided-cost estimates since these items are not regularly adjusted. The new NPV for adjusted public benefits amounts to $2,473,742,060. Figure 9 shows the combined public benefits by year expected from the implementation of the FSS.

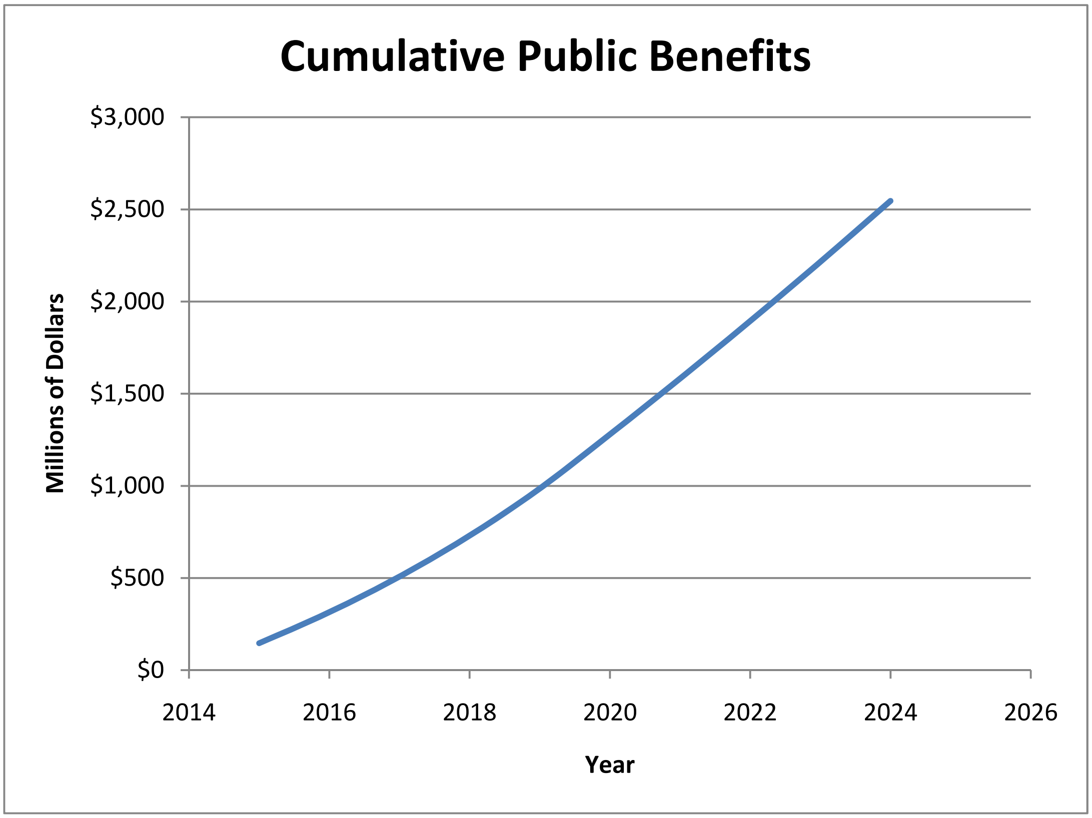

Figure 9. Public Benefits of FSS Implementation.

CHAPTER 4: CONCLUSIONS/RECOMMENDATIONS

CONCLUSIONS

This report documents the advancements made in the development of the FSS over the course of the project. The technology, coupled with a business model predicated on private-sector investment and operations, addresses issues that are emerging as critical transportation challenges facing stakeholders in both state and national venues.

The Freight Shuttle System is designed to facilitate short and intermediate distance freight transportation, the bulk of which moves over increasingly congested and stressed infrastructure. When goods and material flow efficiently, economic growth generally follows. Rising fuel costs, higher labor costs, and congestion are reducing the efficiency of the goods movement industry, which now accounts for more than 10 percent of GDP. Given all that we know of the challenges, a new approach to freight transportation in congested freight corridors is desperately needed. Ideally, the approach should:

- Be privately financed and operated in keeping with the commercial nature of goods movement and, at the same time, help sustain the highway trust fund.
- Reduce infrastructure deterioration by providing an alternative to over-the-road trucking.
- Reduce congestion on over-burdened roadways and improve safety.
- Enhance economic competitiveness by providing a more efficient goods movement system.
- Reduce dependence on foreign oil and provide for long-term sustainability.
- Enhance community livability by creating far fewer emissions.
- Create new industry and new jobs.

Our proposed solution is the Freight Shuttle System, a "ready-for-development" and transformational approach that accomplishes all of these goals. The FSS is privately-financed and, through air-space leasing of existing highway rights-of-way, creates value for the public from underperforming assets. With the trucking industry and short and intermediate distance shippers as its customer base, the FSS will induce thousands of truck trips each day onto a lower-cost, more predictable conveyance. Operating 24/7 at a constant 62 mph and generating no emissions, shipments will be delivered to customers, saving fuel, tires, and time. Perhaps most importantly, the all electric propulsion system will represent the first, large-scale step away from oil in our transportation sector—a strategic national priority.

The FSS will help alleviate the adverse impacts associated with over-the-road freight transport—highway congestion and safety, infrastructure damage, air quality, carbon emissions, and fossil fuel dependency. It will also help lower the cost of everyday consumer goods by enabling trucking interests, retailers, and manufacturers to improve their supply chain efficiency. By automating freight movement, the FSS will greatly improve freight security, lower costs, and reduce the number of trucks on our nation's highways. In order to show specific benefits, TTI conducted an economic benefit analysis for one typical 250-mile FSS. With a 25 percent initial market capture rate, 15 percent growth for the next five years, and 3 percent annual growth thereafter, the assessment showed that the total value of avoided costs and economic stimulus over a 10-year period amounted to more than $15 billion. In addition, TTI estimates that the same 250-mile FSS, with initial capture of 2,500 shipments a day, can achieve the following public benefits:

- **Improve Highway Safety:** Reduce traffic fatalities involving trucks. One out of nine traffic fatalities in 2007 resulted from a collision involving a large truck (*13*).
- **Reduce Infrastructure Damage:** Prevent millions of dollars in truck-induced infrastructure damage every year.
- **Reduce Congestion:** Create 12,000 to 22,800 highway "slots" for passenger traffic every day[2].
- **Improve Air Quality:** Reduce air pollution and eliminate the known and suspected carcinogens that are byproducts of diesel trucks and will not be present in the FSS.
- **Decrease Greenhouse Gas Emissions:** Cut CO_2 emissions by millions of tons each year.
- **Decrease Oil Dependency:** Reduce diesel fuel consumption by 97 million gallons per year.

[2] Based on 1 HDD = 2-3 passenger car "slots" with an assumed FSS demand of 1,500 to 10,000 trucks per day.

RECOMMENDATIONS

The implementation of the FSS will require a demonstration of the technical/operational, commercial, financial, and public safety aspects of the system. TTI recommends that the demonstration of any alternative system include a focus on the following attributes:

- **Public Safety –** systems that are intended to provide an alternative to over-the-road transport of trailers and containers and that co-locate in public rights-of-way, particularly those that are automated or driverless, must demonstrate a level of system safety that ensures the system provides large net improvements over traditional transportation strategies.
    - Automated vehicles must demonstrate a positive interlocking with the guideways or tracks over which they operate.
    - The system should demonstrate that components will not collide in a manner that poses risk or danger to those individuals in proximity to operations.
    - The demonstration should highlight safety systems for employees.
    - Systems must demonstrate a viable and secure approach to discouraging intrusion by pedestrians, animals, or individuals with malevolent intensions.
    - For elevated systems, a strategy for protection of motor vehicles from impact with the system's infrastructure.
- **Reliability –** alternative systems must demonstrate a level of operational reliability and availability that ensures consistent service to their customer base.
    - Backup systems should be demonstrated that provide continuity of operations for, at a minimum:
        - Power systems.
        - Communications, command, and control.
    - Redundancy in essential features should be demonstrated that provides elevated reliability for vehicles, switch mechanisms, and loading/unloading operations.
    - Provisions for real-time health monitoring of vital components should be addressed.
- **Throughput –** alternative systems must demonstrate the technical basis in operations for traffic throughput sufficient to positively impact the highway system by inducing

freight traffic that would otherwise have only an over-the-road option, to use the alternative system.

  - Throughput should be measured in terms of the projected number of shipments per day potentially diverted to the alternative.
  - Transit velocities should be demonstrated at a minimum of ½ the commercial target.
  - Multi-vehicle operations need to be demonstrated.
  - Loading/unloading methods acceptable to commercial interests should be demonstrated.
  - Load carrying capacity should be demonstrated—encompassing over-the-road weight limits.
- **Environmental impacts** – one of the principal reasons for encouraging alternative freight transportation system development is to mitigate the adverse impact diesel emissions has on air quality in heavily traveled freight corridors.
  - The demonstration should provide clear indication of energy source and amount of energy consumed with net emissions reduction derived from these values.
  - Noise levels created by alternative systems need to fall within acceptable limits, ideally providing a net reduction in ambient sound levels when compared to traditional (trucking) systems.
- **Constructability** – the use of existing highway rights-of-way suggest that an alternative system must be constructed within or above current established boundaries. The presence of existing motor vehicle traffic suggests that alternative systems should strive to minimize the interruption to traffic that could result from construction activities associated with implementation.
  - Removability – the ability for components to be removed from public rights-of-way should be demonstrated either directly or indirectly through modular construction techniques.

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