CONTRIBUTION OF A VEHICLE INFRASTRUCTURE INTEGRATION SYSTEM TO THE ECONOMY OF MICHIGAN:

ECONOMIC AND INDUSTRIAL IMPACTS UPDATE AND BENEFIT-COST ANALYSIS

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The statements, findings, and conclusions herein are those of the authors and do not necessarily reflect the views of the project sponsor

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EXECUTIVE SUMMARY

Vehicle infrastructure integration (VII) consists of applying both vehicle-to-vehicle and vehicle-to-infrastructure communication to the tasks of improving safety, enhancing mobility and improving quality of life. VII is a promising use of new and available technologies that could benefit Michigan as the home of the U.S. automotive industry. As a result, the Michigan Department of Transportation (MDOT) requested that the Center for Automotive Research (CAR) conduct a study of the economic impacts of VII on the State of Michigan, including the effects on employment and a comparison of net costs and benefits.

This report presents the results of that research and is an examination of the economic feasibility of a Vehicle Infrastructure Integration (VII) system in the State of Michigan. Building on a previous study, the report determines the costs of developing the VII network, as well as the annual operating and maintenance costs. It also takes into account the expected benefits derived from such a system and offers a benefit-cost analysis with a breakeven threshold.

This study determines that the annual costs to the State of Michigan of deploying, operating, and maintaining a VII system could cost roughly $370 million. This figure assumes that no new buildings (greenfield development) would be built for deployment, which could have driven costs even higher. Ongoing annual costs include compensation for an estimated 6,000 direct employees as well as equipment replacement. Despite these high estimates of costs, the benefits are shown to easily outweigh them in a relatively short period of time. In fact, it is estimated that a mere 2.5% annual reduction in a short list of negative externalities would be necessary to offset the annual cost of nearly $640 million ($370 million of public funds and $270 million for private sector spending) for the statewide VII system.

A previous study shows the system will contribute more than 16,000 annual full-time jobs, and contribute $177 million in state income tax revenues.

While it may seem obvious to proceed on developing and deploying a comprehensive statewide VII system, there are still a few serious questions (not resolved in this analysis) that should be considered in the decision-making. Who will pay for the VII system? Is government funding a key enabler of the system, or will there need to be a level of private sector mandates on the automotive and communications industries? In order to implement this system there has to be a coalescence of political will; there may be other worthwhile programs competing for the funding necessary for installing the VII system.

Lastly, consumers of the system—the drivers on the road—have to be represented in the decision process. Unless the VII system is installed at a rate that will ensure an adequate saturation level throughout the vehicle fleet, the early users of the system will realize very few benefits, jeopardizing long-term support for the system. Serious thought should be given to various methods of incentivizing the system – adding substantially to the start-up costs. This report suggests that portable communication devices be added to current vehicles in order to reach the necessary adoption rate quickly, rather than installation in new cars only. Otherwise, it could take many years to reach a comparable saturation level. Lastly, society is very worried these days about privacy issues and a survey of literature suggests at least a moderate level of concern among potential users regarding ownership and sharing of data gathered by the VII system.

It appears the business case for installing and operating a VII system is quite strong given the benefits that could be derived from the system. A concentrated effort to educate the users of the system and to understand and react to their concerns could be the final, crucial element to realizing a safer more efficient on-road transportation environment.

INTRODUCTION

Since the 1970s, vehicle miles traveled have more than doubled, while road capacity has increased by only 50%.[1] Additionally, the number of households, the number of vehicles per household, and the number of miles driven per vehicle have all increased; these trends show no sign of abating. More vehicles, more variety in vehicle size, and a relatively smaller road area make driving today significantly more challenging than when the baby boomers were taking their driving exams. Even with the high cost of gasoline and the uncertainty of future prices, the demand for mobility and the pressures on highway infrastructure continue to rise. It is vital to develop options that alleviate road congestion, improve road travel safety and allow for cost-effective infrastructure maintenance.

A Vehicle Infrastructure Integration (VII) system allowing vehicles to communicate with each other and with a central switchboard may now be a feasible option. A VII system would use several different technologies and has tremendous potential to improve traffic safety, decrease highway and road congestion, improve the flow of goods and people, and provide greater conveniences to vehicle operators. The state that is first to coordinate all of the available technologies, infrastructure and vehicles into a fully functioning VII system will be recognized as a leader in an emerging industry and will have the opportunity to export its knowledge and products to other states and countries. [2]
This report, prepared by the Center for Automotive Research, is an attempt to understand the initial costs of deploying such a system, look at the benefits and costs of having a fully operational VII system in the state of Michigan, and finally, understand consumer acceptance issues that might arise from the implementation and use of such a system.

This report is both a continuation of a previous study—which examined the positive economic and employment impacts of a statewide VII system—and an in-depth look at the complete business case for installing and operating such a system. The previous study, entitled, "Evaluation of Economic Impacts of The State of Michigan's Vehicle Infrastructure Integration Program", focused on quantifying the long-term impacts of statewide employment resulting from operation and maintenance of the VII system. This follow-up to that study calculates the start-up costs and short-term employment impacts of developing and installing the system. Once these impacts were determined, they were included in a comprehensive benefit-cost analysis to determine a threshold level of benefits necessary to justify the initial and ongoing costs of the system.

Merely attaining an equilibrium level of benefits and costs is not the sole justification necessary to proceed with the installation and deployment of a VII system. The support

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[1] Parry, Ian, Walls, Margaret and Harrington, Winston. "Automobile Externalities and Policies." *Journal of Economic Literature*, Vol. XLV, no. 2 (June 2007): 379.

[2] Department of Electrical and Computer Engineering, Michigan State University and the Center for Automotive Research. *Evaluation of Economic Impacts of The State of Michigan's Vehicle Infrastructure Integration Program.* A Study Prepared for the Michigan Department of Transportation. Ann Arbor, September 2007.

of the users of the system is imperative. The users of the system are, for the most part, the taxpayers who will fund some or all of the VII system, and they will be the most impacted by the free flow of data and information resulting from wholesale monitoring of the over-the-road transportation system. Inevitably, those who will most benefit from a VII system may have misgivings with the overall cost, the question of how that money could have been spent elsewhere, and the fear that they might lose some of their privacy. These three issues could derail even the most beneficial VII system. The interplay between costs, benefits, and users is addressed in this report.

ASSUMPTIONS

Since a robust, large-scale VII system is not yet in place anywhere, it is necessary to make certain assumptions in order to develop a deployment cost estimate and business case models. The approach taken by this study builds upon the earlier study completed by CAR, in that it is neutral as to the hardware and software required to implement the system. Two approaches were developed to estimate deployment costs. First, a search of existing literature was conducted to understand estimates already created by experts in the field. This approach yielded a range of costs from $60 to $340 million for initial system deployment in the state of Michigan. In another example, deployment cost estimates for a VII system in California were about $400 million.[3] A second approach was then undertaken to verify this cost range. Using a federal database, costs for typical system elements (equipment) were gathered. The information on these costs is based on actual installations of various system elements across the U.S. over the past 15 years. This method yielded an estimate of deployment costs of roughly $370 million for equipment installation and capital investment (excluding commercial fleet and private sector upgrades and retrofits) – within the range of cost estimates in the literature. A conservative estimate of maintenance costs which captured every category of known potential costs put the annual ongoing costs at approximately $370 million. These ongoing costs factor in the compensation for 6,000 direct employees and equipment replacement. The cost and employment estimates represent the most plausible scenario as developed in a study completed by CAR and MSU for MDOT, "Evaluation of Economic Impacts of The State of Michigan's Vehicle Infrastructure Integration Program."[4] This study looked at more than a dozen scenarios, representing a wide range of feasible costs and employment scenarios.

Within the determination of costs, a high level of uncertainty exists in trying to estimate the necessary infrastructure and employment associated with deploying and staffing a system that does not presently exist. However because the benefits have been much more intensely studied and quantified, they allow a firm counterbalance to the uncertain cost estimates. Furthermore, the benefits of a VII system are estimated to be at such levels to thus render the cost estimates to be less of a factor. The important component is payback time – when would costs be recouped. It seemed reasonable to be on the high side in estimating the costs of the system, which allows for considerable leeway in determining future capital and labor costs, while instead concentrating on calculating the length of time needed to recover the costs. Therefore, in this analysis, lower ongoing costs will shorten the payback period.

For the benefit-cost analysis, the assumption is that a VII system will alleviate some of the larger and more costly societal problems of motor vehicle transportation. These problems are accident losses (life, injury and property damage), congestion costs, and

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[3] Steve Heminger. *A Silicon Valley View of VII*. Presentation to IBTTA 74th Annual Meeting. Dallas, Texas. September 2006.
[4] Ibid

pollution damages. The benefits from reducing the costs due to these externalities[5] were quantified, monetized and compared to the cost of system deployment as well as operations and maintenance costs to arrive at a benefit-cost analysis. The discount rate used in the business case models is based on the Consumer Price Index (CPI) for Inflation. Using these assumptions, this paper will map out the important effects a VII system could have on automobile travel and the economy.

When examining the business case for a VII system, the assumption was made that the costs and benefits of externality abatement would reach equilibrium within a set period of time.

[5] An externality is an economic side effect. Externalities are usually societal costs or benefits arising from an economic activity that affect somebody other than the people engaged in the economic activity. Externalities are not reflected fully in prices of activities. Examples are: smoke pumped out by a factory may impose clean-up costs on nearby residents; bees kept to produce honey may pollinate plants belonging to a nearby farmer, thus boosting his crop.

DEPLOYMENT COSTS

This section of the report examines the initial costs of deploying a Vehicle Infrastructure Integration (VII) System in the state of Michigan. This information updates a previous study (completed by CAR and MSU for MDOT[6]) focusing on the employment impacts and benefits to the Michigan economy. The capital investment required was estimated, but was not netted for the economic benefits of increased employment, increased wages in the economy, increased tax revenues from supporting this emerging industry or the societal benefits of a more efficient motor vehicle transportation system.

To estimate the cost of building and deploying a VII system, such a system must first be defined. With the current state of advanced technology and the rapid pace of technological development, one need only look at the histories of cell phones and the internet to understand that the potential of a VII system is limited only by one's imagination. With the technologies now available, and with the understanding of how rapidly new information and capabilities are being developed, the potential for a fully integrated VII system offers the imagination much to think about relative to what might be achievable. Could we see driverless vehicles, with occupants speeding toward their desired destinations while happily connected to their infotainment devices—oblivious to traffic, safe from accidents and causing minimal damage to the environment? A fully integrated VII system can be defined in a myriad of ways, with a multitude of goals. The quandary is to define a system broad enough to encompass a huge array of capabilities, but narrow enough to make cost estimates realistic.

Building upon CAR's earlier study, this report is neutral as to the hardware and software required to implement the system. It may seem counterintuitive to estimate capital and deployment costs without defining the precise elements required for such a system. However, the prime reason for not defining the specific elements is so that the system itself is not limited. Over the years, many applications (installed worldwide) can be termed VII system applications. Experts have suggested reasonable cost requirements for a VII system based on these applications. The cost estimate for full deployment of a VII system nationwide ranges from $3 to $17 billion. For Michigan, this translates to a potential cost of $60 to $340 million.

In addition to the above survey (a macro point of view of system costs), a micro-economic approach to developing system costs was utilized. Over 200 potential uses or applications for a VII system were identified using numerous sources.[7] It is crucial to consider all of these applications so that the potential benefits of a VII system are not limited to a few applications only. As with the internet, the real benefit of a VII system will be realized as consumers, entrepreneurs, businesses, policymakers and law

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[6] Ibid

[7] Intelligent Transportation Systems Joint Program Office, United States Department of Transportation. ITS Applications Overview, and all associated program documents, available online at www.itsoverview.its.dot.gov. Washington, D.C., 2007

enforcement (as well as city, county, state and federal planners) begin to understand the potential uses and adaptations that might be possible.

The 200 potential applications were culled into a list of slightly over 100 distinct end-use applications that could be supported by a VII system. (See Table 1).

Table 1: VII System End-use Applications

Collision Avoidance and Safety	***In-Vehicle Driver Assistance Applications***	***Commercial and Public Vehicle Applications***
Infrastructure-based Signalized Intersection Violation Warning	Safety Recall	Commercial Vehicle Safety Data
Infrastructure-based Signalized Intersection Turn Conflict Warning	Just-in-Time Repair Notification	Commercial Vehicle Advisory
Infrastructure-based Curve Warning	Vehicle-based Signalized Intersection Violation Warning	Commercial Vehicle Electronic Clearance
Highway Rail Intersection Warning	Low Parking Structure Warning	Driver's Daily Log
Emergency Vehicle Preemption at Traffic Signals	Visibility Enhancer	Locomotive Fuel Monitoring
Stop Sign Violation Warning	Cooperative Vehicle-Highway Automation System	Locomotive Data Transfer
Stop Sign Movement Assistance	Cooperative Adaptive Cruise Control	Unique Commercial Vehicle Fleet Management
Pedestrian Crossing Information at Designated Intersections	Adaptive Headlight Aiming	Commercial Vehicle Truck Stop Data Transfer
Low Bridge Warning / Alternate Routing	Adaptive Drivetrain Management	Weigh Station Clearance
Work Zone Warning	Pre-crash Sensing	Cargo Tracking and Management
Incident Warning	Cooperative Glare Reduction	Border Crossing Management
Icy Bridge Warning	Curve Speed / Rollover Warning	Download Data to Support Public Transportation
Wrong Way Driver Warning	Lane Departure - Inadvertent	Transit Vehicle Priority at Traffic Signals
Vehicle to Vehicle Cooperative Adaptive Cruise Control	Speed Limit Assistant	Electronic Payment: Transit Fares
Vehicle to Vehicle Blind Merge Warning	Access Control (secure access via remote control)	Public Sector Vehicle Fleet / Mobile Device Asset Management
Vehicle to Vehicle Highway Merge Assist	Emergency Electronic Brake Lights	Transit Vehicle Refueling
Vehicle to Vehicle Cooperative Collision Warning	Turn Assistant	
Vehicle to Vehicle Lane Change Warning	Beacon for Child Left in Vehicle	***Commercial and Business Considerations***
Vehicle to Vehicle Road Condition Warning	Drowsy Driver Advisory	Customer Relations Management
Approaching Emergency Vehicle Warning	Overhead Storage Reminder (height clearance)	
In-vehicle Amber Alert	Mechanical Failure Warning	***Traveler Information***
Crash Data to Public Service Answering point	On-Call Mechanic	Travel Time Data to Vehicles
Crash data to Transportation Operations Center	Vehicle Safety Inspection	Enhanced Route Navigation: Point of Interest; Food; Maps; Hotels
SOS Services	Electronic Payment: Tolls; Gas; Drive-thru; Parking Lot	Off-Board Navigation
On-Board Safety Data Transfer	In-Vehicle Signage	Parking Spot Locator
Safety Event Recorder		Advertisements and Location-Based Shopping
Stolen Vehicle Tracking	***Roadway Operations, Maintenance or Management***	Instant Messaging
Roadway Incidence Assistance	Intelligent Traffic Flow	Data Transfer - Diagnostic Data
Post Crash Warning	Green Light Optimal Speed Advisory	Data Transfer - Repair Service Record
Emergency Vehicle Video Relay	Vehicles as Traffic Probes	Data Transfer - Vehicle Computer Program Updates
Emergency Vehicle Initiated Traffic Pattern Change	Signal Phasing (traffic flow optimization)	Data Transfer - Rental Car Processing
Hazardous Material Path Enforcement	Remote Traffic Camera	Data Transfer - Video/Movie and Media Downloads
	Intelligent On-Ramp Metering	Data Transfer - Internet
Environmental Applications	Highway Infrastructure Planning	GPS Correction
Dynamic Emissions Tests	Origin and Destination Data to Traffic Operations Center (TOC)	Airline Travel Information
	Road Condition Warning	Vehicle to Vehicle Road Feature Notification
	Vehicles as Road Surface Condition or Weather Probes	Weather Alert Notifications

End-use cases with similar attributes were combined into larger groups of applications. For example, the end-use cases or applications of a) a beacon for a child left in a vehicle, b) a drowsy driver advisory and c) a speed limit assistant were combined into a larger grouping of In-Vehicle Driver Assistance applications. The attributes or end-use cases in the original list were combined into larger groupings since most of these similar applications will likely use the same equipment and networks.

Once the basic characteristics and larger application groupings for a VII system were completed, CAR developed a cost structure, and then estimated a range of projected VII system costs by determining types of elements that might define a VII system and putting them into the broader categories of roadside equipment, network infrastructure and vehicle-based equipment. These broader categories represent the equipment that will deliver the end-uses or applications. The categories include new system elements for the following:

- highway infrastructure
- public transportation
- government management of commerce, freight and trucks
- private sector management of commerce

- internet service providers and call center operations
- roadway communications management, regional data collection and analysis
- vehicle on-board equipment

There are a multitude of studies available that describe the technologies that could, and sometimes do, make up an intelligent vehicle / connected vehicle / intelligent infrastructure system. The U.S. Department of Transportation (USDOT) maintains an Intelligent Transportation System (ITS) website with extensive data on a variety of ITS implementations that have been installed by municipalities, counties and states since the early 1990s. This is the U.S. DOT Intelligent Transportation Systems Costs Database (http://www.itscosts.its.dot.gov/). The database has an astonishing array of statistics, costs, experiences, lessons learned, and estimated benefits experienced by hundreds of communities which have implemented VII-related elements within the past 15 years.[8]

The data is presented on a case-by-case basis (in current dollars at the time of installation). The VII systems installed in these communities vary substantially in the type of information provided, the programs and experiences related, and the dollar amounts indicated. Specific cost data from each of the hundreds of cases in the ITS database were compiled and organized into the categories described above in Table 1. Many of the examples in the ITS database had estimates of FTE labor requirements; these were also collected. More than 300 distinct system elements were classified into system cost estimates for the above broadly defined categories. All dollars used were then adjusted to 2005 dollars. (Please see Table 2 below.)

[8] Intelligent Transportation Systems Joint Program Office, United States Department of Transportation. ITS Benefits and Costs Database, available online at www.benefitcost.its.dot.gov. Washington, D.C., 2007.

Table 2: Estimated Installation Costs for Elements of a VII System

Elements	Capital Cost Per Installation	
Highway (Roadside) Infrastructure	**750,000**	
Cables and Communications, per terminus (15 miles)		250,000
Intersection and Corridor Sensors, Signal Upgrades		75,000
Environmental Sensing Station (weather station)		50,000
Portable Traffic Management System		100,000
Lane Controls and Anti-icing Systems		200,000
Roadside Messaging Systems		50,000
Remote Location Kiosks		25,000
Public Transportation	**100,000**	
Transportation Management Center Facilities		Existing assumed
Center Hardware and Software		100,000
Government Sector Management of Commerce	**750,000**	
Weigh Station Upgrade (per station)		750,000
Internet Service Providers and Call Centers	**1,250,000**	
Information Service Provider Facilities		Existing assumed
Information Service Provider Hardware & Software		500,000
Information Service Provider Labor, 10 people		750,000
Roadway Communications Management	**100,000**	
Transportation Management Center Facilities		Existing assumed
Transportation Management Center Hardware & Software		100,000
Private Sector Commerce	**250,000**	
Fleet Center Hardware & Software		250,000
Vehicle On-Board	**3,000**	
In-Vehicle Navigation & Communication System, Sensors		3,000

Using this approach, the specific costs for any proposed VII system can be extracted to develop a new range of costs.

Finally, CAR researchers estimated the number of VII system elements to be installed within the state of Michigan. From this estimate, CAR made predictions for the cost and labor required to fully install a VII system. The quantity of elements to be installed was estimated based on various proxies (e.g. the number of large hospitals in Michigan was used as a proxy for the number of potential regional transportation centers for roadway communications and public transportation management).

Table 3: Total Estimated Costs for System Deployment in Michigan

Elements	Capital Cost Per Installation	# Installations	Total Cost for Michigan
Highway (Roadside) Infrastructure	750,000	420	315,000,000
Public Transportation	100,000	150	15,000,000
Government Sector Management of Commerce	750,000	14	10,500,000
Internet Service Providers and Call Centers	1,250,000	10	12,500,000
Roadway Communications Management	100,000	150	15,000,000
Private Sector Commerce	250,000	*	
Vehicle On-Board	3,000	*	
TOTAL ESTIMATED SYSTEM DEPLOYMENT COST			368,000,000

* These costs are included in the Benefit-Cost analysis on a per Vehicle Mile Traveled basis, and not as part of system deployment costs

The estimated public cost for deployment of a VII system in Michigan is $368 million. This cost is about 10 percent higher than the results from literature and studies that have been devoted to the topic.

BENEFIT-COST ANALYSIS

Since the automobile-era began, the costs of ownership and the costs to society of motor vehicle transportation have been examined in great depth and detail.[9] This study does not attempt to re-create that work, but rather, using societal costs that have already been estimated, it examines the benefits of lessening those costs (or externalities[10]) through the deployment and use of a VII system in the State of Michigan.

At best, a benefit-cost analysis seeks to maximize net social benefits in such a manner that the gain to consumers is greater than the cost to taxpayers or the losses to displaced businesses. At a minimum, a benefit-cost analysis seeks to find that threshold where benefits equal costs. By examining the benefits of alleviating vehicle use externalities, such an analysis can allow for shifts in the demand function or the timeline of the adoption of system elements. The effect of shifts in the utility of the system and market distortions can also be readily understood.

A literature survey was conducted to assess what societal costs might be reduced using a VII system,[11] and the original list of VII applications (see Table 1) was considered. The benefits of a VII system, therefore, are assessed in this study as a potential decrease in the societal costs of motor vehicle transportation. The greatest benefit from a VII system was determined to be the savings made by lowering costs in the following areas:

Table 4: Externalities That May Be Reduced by a VII System

Air pollution
Dependence on foreign oil, including military expenses
Traffic congestion
Human life
Human injury
Property damage
Disposal of old cars and car parts
Land use

[9] For instance, Parry, op. cit.; ITS, op. cit.; Porter, Richard C., *Economics at the Wheel*. Ann Arbor, 1999.; John A. Volpe National Transportation Systems Center. *Vehicle-Infrastructure Integration Initiative, Benefit-Cost Analysis: Pre-testing Estimates.* A draft report prepared for the U.S. Department of Transportation. Cambridge, Massachusetts. March, 2007.
[10] An externality is an economic side effect. Externalities are usually societal costs or benefits arising from an economic activity that affect somebody other than the people engaged in the economic activity. Externalities are not reflected fully in prices of activities. Examples are: smoke pumped out by a factory may impose clean-up costs on nearby residents; bees kept to produce honey may pollinate plants belonging to a nearby farmer, thus boosting his crop.
[11] Ibid

Other areas identified in the literature search[12] but not considered in this analysis are:

- water pollution, not included because the effects from motor vehicle transportation are too far downstream;
- noise pollution, not included because most infrastructure planning includes some level of abatement;
- litter from automobiles, not included because it may not be significantly affected by a VII system;
- police and court costs, not included because these are somewhat self-supporting through fees and fines.

All of the costs of the above externalities were stated in cents-per-vehicle-mile traveled. Depending on the externality cost and the underlying research, original data might have been provided as one sum for the nation, or as a per gallon or per vehicle or per mile traveled metric. This information was recalculated to an average cost, in 2005 dollars, of per-vehicle-mile traveled. This unit of measure offers a ready determination of externality costs for Michigan.

Externalities

The premise of both the alleviation of air pollution and traffic congestion through a VII system is that, by providing drivers with real-time information on road conditions, weather and traffic, these drivers will be able to re-route their trip around problem areas – making for both a safer and a shorter journey. Particularly as this relates to daily commuters, both time and gas should be saved.

The cost congestion is comprised of the cost of gasoline and the cost of driver time lost to waiting in traffic. Several studies were consulted for determining these costs. The Journal of Economic Literature[13] was used as the primary source, because of the timeliness and comprehensiveness of the data provided. Other studies were used to confirm the data.

As the data show, approximately 6 percent of the time spent driving and approximately 3 percent of the fuel used are wasted because of traffic congestion. On average, the cost of congestion to all drivers is about 2.7 cents per vehicle mile traveled.

[12] Porter, op. cit. pp. 18, 182, 183, 184
[13] Parry, op. cit.

Table 5: Cost of Traffic Congestion in the U.S.[14]

Cost of congestion	$63,000,000,000
Number vehicle miles traveled (VMT) per year, U.S.	2,300,000,000,000
Cost of congestion per VMT	$0.0274
Hours lost per year due to urban congestion	3,700,000,000
Gasoline wasted in congestion, gallons	3,700,000,000
Number gallons used per year, U.S.	113,100,000,000
Average miles / gallon	20.3
Number of drivers, U.S.	190,625,023
Hours spent driving	57,500,000,000
Miles per hour, average	40

The cost of traffic accidents consists of the cost of injuries, fatalities and property damage from traffic accidents. Based on previous studies, the value of saving a life is determined to be approximately $3 million.[15] As can be seen in Table 6, approximately 40,000 people die each year in the United States in vehicle accidents, another 2.7 million are injured. The overall cost of accidents (including property damage) is estimated to be well over $400 billion – or nearly 19 cents per vehicle mile traveled. Avoiding the inconvenience (in the best of circumstances), heartache (in the worst cases) and expense of traffic accidents are the most compelling benefits of installing an effective VII system.

Table 6: Cost of Traffic-Related Accidents in the U.S.

Annual traffic fatalities	40,000
Annual number of traffic-related injuries	2,700,000
Total annual cost of accidents	$433,000,000,000
Number vehicle miles traveled (VMT) per year	2,300,000,000,000
Cost of accidents, $ per VMT	$0.18826

Other aspects of motor vehicle travel creating costs that are borne by society as a whole (rather than the individual driver) are listed in Table 7 below. Land use for roadways and parking precludes other competing uses for the land. Roadway infrastructure also interrupts the biodiversity of an area by dissecting open space and creating hazards for nearby wildlife.

The costs of air pollution are also well documented. Emissions from burning one gallon of gas have been determined, leading to the calculation of total emissions from vehicle

[14] Parry, op. cit.
[15] Volpe, op. cit.

gasoline usage. Other industries, particularly the electric power generation industry, buy and sell allowances for the same air pollutants (e.g., carbon monoxide, carbon dioxide, nitrogen oxides and sulfur oxides). This market for allowances gives a current, actual value to the cost of reducing emissions of these pollutants.

The cost of using foreign oil includes the estimated burden of military readiness to defend oil sources, as well as the estimated threat to society from dependence on a foreign source for critical energy supplies. Other environmental externalities include (primarily) the upstream costs of manufacture not captured elsewhere, and the final costs of disposal of old vehicles and vehicle parts, including tires.

Table 7: Other Costs Related to Motor Vehicle Usage, cents-per-vehicle-mile traveled[16]

Land use for roadways and parking	3.000
Air pollution	2.300
Dependency on foreign oil	0.500
Other environmental externalities	0.003

Business Case Models

CAR utilized two different models to target the minimum abatement rate of the negative externality factors necessary to offset the deployment and maintenance costs. Each of these models was run using 5 and 10 year horizons. The first model assumes that the abatement rate is constant over ten years. Using this assumption, CAR was able to deduce the minimum abatement rate such that the program was cost neutral in five and ten years respectively. This model, the more simplistic of the two, provides a baseline with which to view the business case for a VII system.

The second model assumes that the abatement grows linearly with time. This model provides a more accurate depiction of the program's effectiveness as different components are phased in—particularly those components that depend on consumer acceptance.

It should be noted that these models are not forecasts regarding the effectiveness of a VII system, but rather business case models. They are intended to study the economic feasibility of a program to install a VII system in Michigan and to estimate the program benefit returns necessary for a VII system to be cost neutral over the specified time horizons.

[16] Parry, op. cit., Volpe, op. cit.

Constant Savings Rate Model

The constant savings rate model acts as the baseline model. This model enumerates the minimum reduction in aggregate externalities necessary for the VII system to cover its costs.

For the purposes of this model, CAR utilized six externality categories (see Table 8 below) to calculate the aggregate externality amount. CAR calculated the dollar-per-vehicle-mile-traveled ($/VMT) value of each category based upon overall cost data from "Automotive Externalities and Policies"[17] as well as national-vehicle-miles-traveled (VMT) data.[18] These ratios were then used to calculate the dollar value of each externality for the state of Michigan alone. As shown in Table 8, the aggregate cost of the six externality categories is approximately 27 cents per mile.

Table 8: Total Externality Costs ($/VMT)

Externality Costs ($/VMT)	
Pollution	0.02300
Use of oil	0.00500
Congestion	0.02739
Accidents	0.18826
Other environmental factors	0.00003
Land use / parking	0.03000
Total	0.27368

In order to project the aggregate dollar value of negative externalities into the future, CAR used historical Michigan vehicle-miles-traveled data (VMT)[19] to calculate the average growth rate of VMT. This growth factor was used to estimate the future dollar value of negative externalities.

Using this data, CAR was able to extrapolate the constant rate of abatement of externalities—such that the present discounted value of the improvements equals the present discounted value of deployment—as well as operating and maintenance costs of the system.

[17] Parry, op. cit.

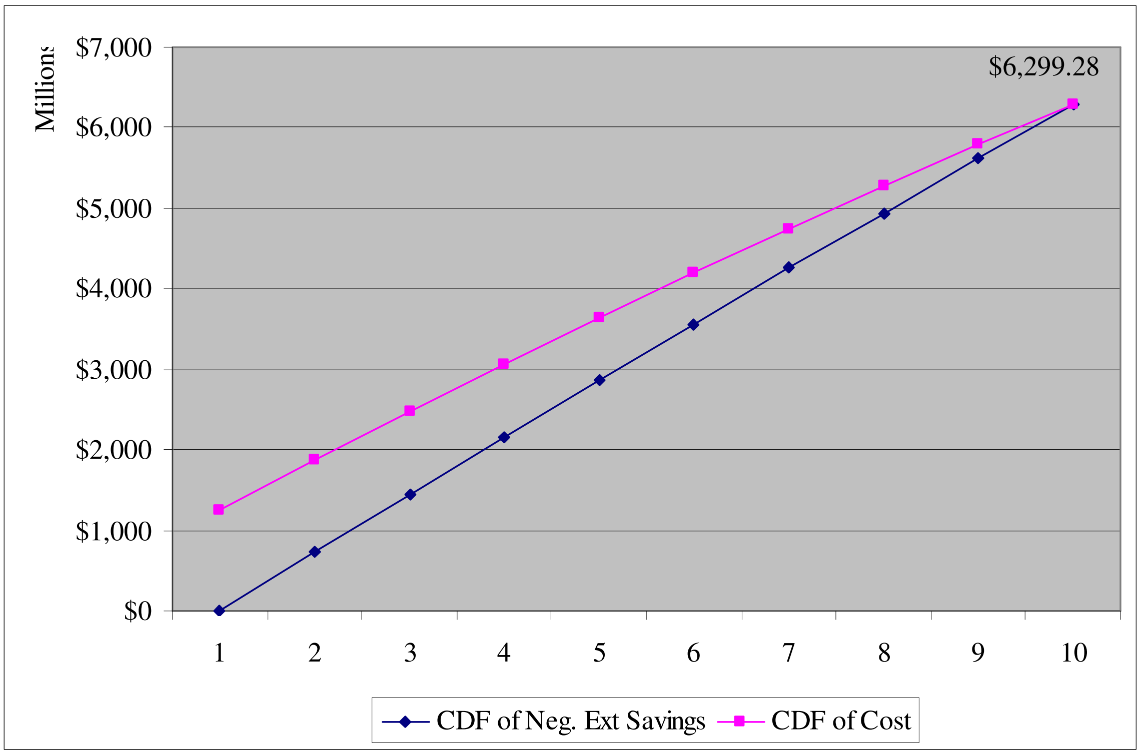
[18] Bureau of Transportation Statistics, U.S. Department of Transportation. "U.S. Highway Vehicle Miles Traveled. 2005." http://www.bts.gov/publications/white_house_economic_statistics_briefing_room/october_2005/html/highway_vehicle_miles_traveled.html

[19] The Office of Highway Safety Planning. 2006 Michigan Traffic Crash Facts. http://www.michigantrafficcrashfacts.org. A website maintained by the University of Michigan for the Office of Highway Safety Planning. 2007.

Constant Savings Rate Ten-Year Model

Our results show that a VII system in Michigan must yield a 2.56 percent annual rate of externality abatement (see Table 9) in order to match the deployment and maintenance costs of the system within ten years. The annual 2.56 percent abatement rate translates into a cumulative $6.3 billion (stated in 2005 dollars) of aggregate savings over the ten-year horizon.

Figure 1: Constant Rate of Savings, 10 Year, Revenue Neutral Model[20]



[20] CDF is Cumulative Distribution Function

Table 9: Constant Rate of Savings, Cumulative Savings and Costs over 10 Years, Balanced Budget in Year 10

Abatement Rate	2.56%
Present Discounted Value of Abatement	$6.299 Billion
Present Discounted Value of Cost	$6.299 Billion
Net Balance (PDV Abatement – PDV Cost)	$0.00

Constant Savings Rate Five-Year Model

In order to fully offset the deployment and maintenance costs of the system within five years, a VII system in Michigan would need to yield a 3.26 percent annual rate of abatement (see Table 10). This savings rate translates into approximately $3.6 billion (stated in 2005 dollars) of aggregate externality abatements over the five year period and would actually net a positive surplus of $1.718 billion in externality abatements over ten years.

Figure 2: Constant Rate of Savings, 5 Year, Revenue Neutral Model

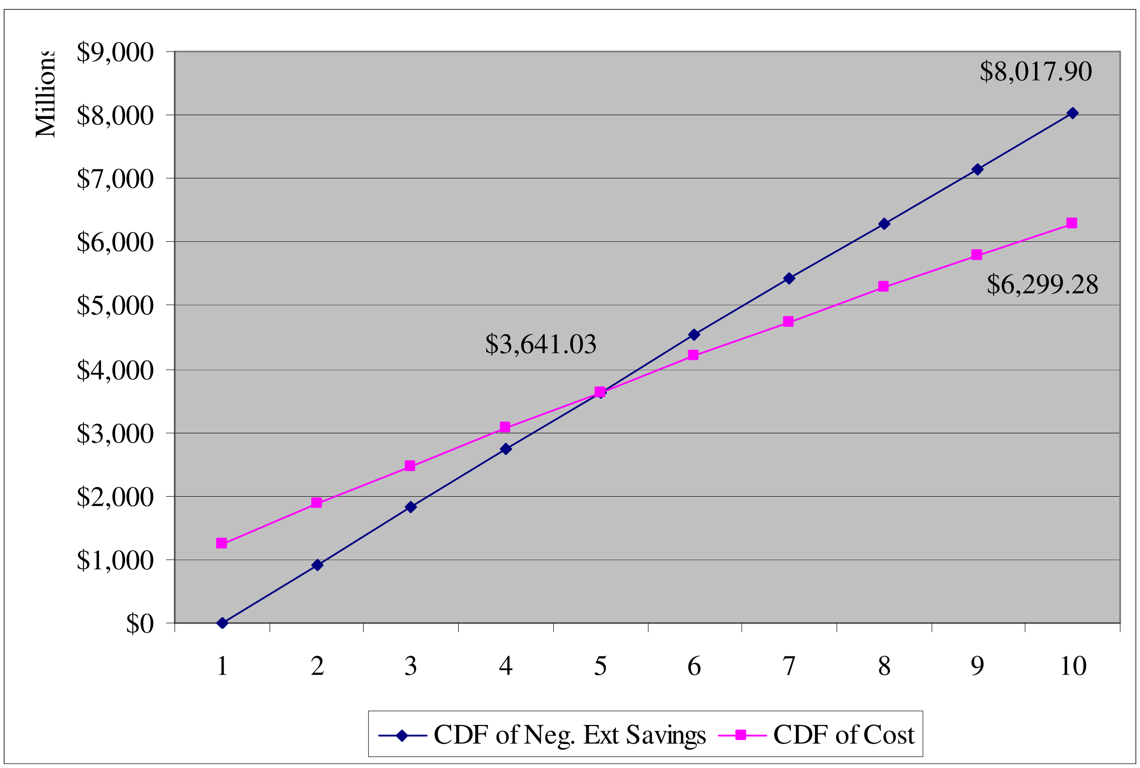


Table 10: Constant Rate of Savings, Cumulative Savings and Costs over 10 Years, Balanced Budget in Year 5

Abatement Rate	3.26%
Present Discounted Value of Abatement	$8.017 Billion
Present Discounted Value of Cost	$6.299 Billion
Net Balance (PDV Abatement – PDV Cost)	$1.718 Billion

Linear Growth Rate Model

In addition to the constant rate of abatement model, which serves as a baseline, CAR created a second model which assumes that the rate of abatement increases linearly over time. This model is intended to more realistically simulate the improved performance of a VII system as components of the system are adopted by consumers and put to use. The model enumerates particular growth targets in order to maintain a balanced budget. It is important to note the growth in abatement over each time horizon.
The same deployment cost structure was utilized as for the constant rate of abatement model, as well as all assumptions about externalities. The principal difference between the linear growth model and constant rate model is the rate of abatement equation.

Linear Growth Rate Ten-Year Model

Rate of Abatement $\cong \beta \bullet t \pm c$

$\beta \cong 0.005192871$ $\quad\quad$ $c \cong 0$

Figure 3: Linear Growth Rate of Savings, 10 Year Revenue Neutral Model

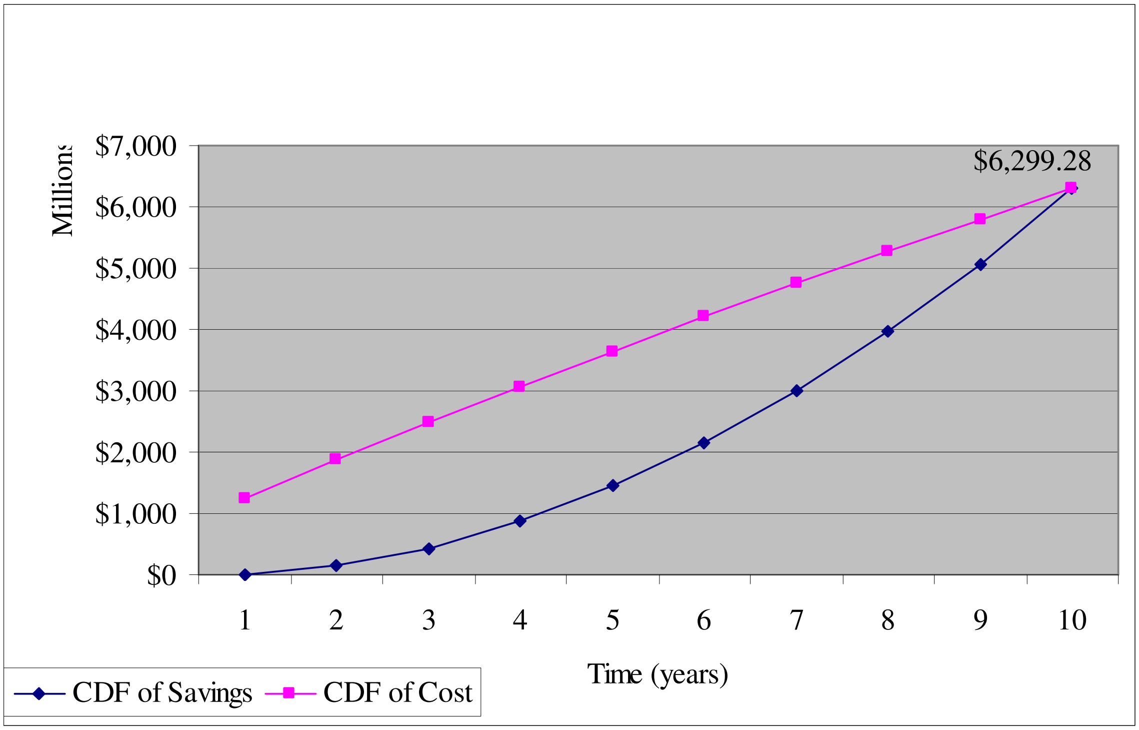


Table 11: Abatement Rate vs. Time

Rate (%)	0	0.52	1.04	1.56	2.07	2.6	3.12	3.64	4.15	4.67
Time (Years)	1	2	3	4	5	6	7	8	9	10

Table 12: Linear Growth Rate of Savings, Cumulative Savings and Costs over 10 Years, Balanced Budget in Year 10

Present Discounted Value of Abatement	$6.299 Billion
Present Discounted Value of Cost	$6.299 Billion
Net Balance (PDV Abatement – PDV Cost)	$0.00 Billion

As can be seen in Figure 3 above, over the ten year period there is a steady increase in the abatement rate—from 0 percent in the first year to 4.67 percent in the tenth year. This model demonstrates that over a ten year time period only modest improvements each year would be necessary in order for a VII system to be cost neutral (see Tables 11 and 12).

Linear Growth Rate Five-Year Model

Rate of Abatement $\cong \beta \bullet t \pm c$

$\beta \cong 0.013123134$ $c \cong 0$

Figure 4: Linear Growth Rate of Savings, 5 Year Revenue Neutral Model

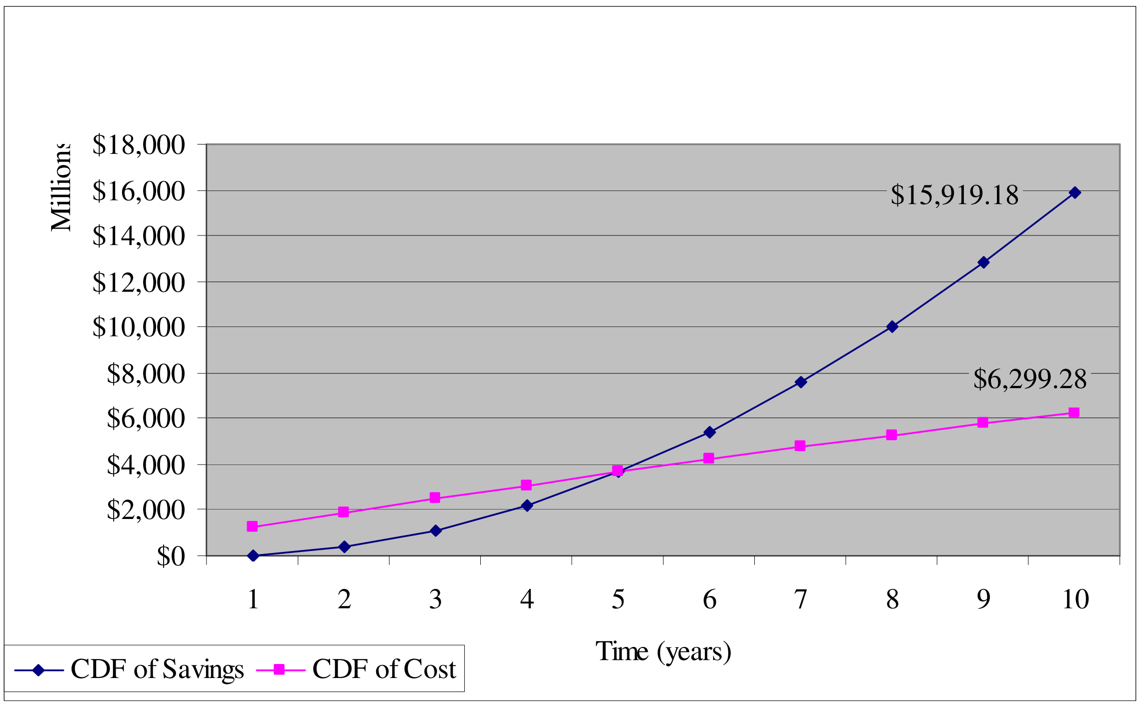


Table 13: Abatement Rate vs. Time

Rate (%)	0	1.31	2.62	3.94	5.25	6.56	7.87	9.12	10.5	11.81
Time (Years)	1	2	3	4	5	6	7	8	9	10

Table 14: Linear Growth Rate of Savings, Cumulative Savings and Costs over 10 Years, Balanced Budget in Year 5

Present Discounted Value of Abatement	$15.919 Billion
Present Discounted Value of Cost	$6.299 Billion
Net Balance (PDV Abatement – PDV Cost)	$9.619 Billion

As is indicated in Figure 4 and Table 13 above, in order for a VII system to run a balanced budget within five years it would be necessary to see a 5.25 percent abatement rate by year 5. Assuming continued increases in the abatement rate after year 5, the program would yield a cumulative net benefit of $9.619 by year 10 (see Table 14). This model assumes much quicker growth in abatement rate with aggressive improvements by year 10.

Model Results

The two different models demonstrate that with modest improvements in the abatement of externality factors, a VII system can be cost neutral. In fact, one model shows that a mere 2.56 percent improvement will offset the system's costs. It is impossible to predict precisely the effectiveness of such a system given the number of random variables. However it is safe to say that a well-executed VII system could, with high probability, meet the modest abatement rate milestones above.

Again, it is important to note that the above results are not CAR's predictions, but rather business case models intended to delineate the results that would be necessary for a VII system to be cost neutral.

CONSUMER ACCEPTANCE

An integrated VII system that connects vehicles to one another and to the road will only be successful if it is accepted, implemented and ultimately used by consumers. However, consumer acceptance of a VII system has not been studied in great detail. There are a host of issues related to the implementation of a VII system regarding consumer reaction to the system. In most instances where consumers of a VII system are even mentioned, the coverage of consumer acceptance and attitudes has been a small section in larger journal articles discussing other aspects of a VII system. The Federal Highway Administration, Journal of Transportation Engineering, the U.S. Department of Transportation and the Intelligent Transportation Society of America have all written articles on the state of VII technology that have contributed to this study.

The most comprehensive study related to consumer acceptance is "An Alternative Perspective on VII" conducted by Northeastern University.[21] Beyond journal studies, the popular media has devoted considerable effort in predicting the future of VII systems. The media has followed the successes and failures of the industry's experimentation with advanced technology with several articles suggesting that the future looks bleak for advanced technology. These articles question consumers' need for technology, their willingness to pay, and their suspicions of the reasons for a VII system. The tone of articles from general media outlets is a "wait and see" attitude as to whether VII systems can really overcome these doubts and obstacles to become successful. [22]

It is clear there are several issues that should be studied when determining whether a VII system can be integrated into today's present system of roads, transportation networks and commerce. These issues are: will consumers be willing to rapidly accept a VII system; how much will consumers need to pay for a VII system; and are consumers willing to pay the cost? Beyond cost, the question is whether consumers will implement the various elements of a VII system (such as installing the equipment in their vehicles or purchasing new vehicles that are already equipped) rapidly enough to reap a reasonable level of benefits that justify the costs.

Adoption and Integration of a New System

General Motors' OnStar program offers an example of consumer behavior in regard to vehicle technology – both in general acceptance and in willingness to pay. The OnStar model could help in understanding the validity, effectiveness, and consumer acceptance of a VII system. As with any technology, there is a sliding scale: the less expensive, easy to use and reliable the system is, the more consumers will accept it. The most cost-effective system will be the one that is accessible by the greatest number of consumers and provides the greatest value to individual users. A VII system will only be successful if it meets the consumer's cost and use standards.

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[21] Northeastern University. *An Alternative Perspective on VII*. Massachusetts. August, 2007.
[22] Please see Reference section for full list of articles used.

As with all new technologies, consumers tend to adopt new systems at different rates. This has been seen with the acceptance of color televisions, computers and cell phones, to name just a few. The first consumers to adopt a VII system will likely be those who spend substantial time in congested traffic and are more eager than others to save time through advanced notification systems. Additionally, those who value their time at higher rates will be more willing to accept and pay for new technology. Those who have experience with advanced technologies may also accept the system earlier than others. Consumers, who own navigation systems or cell phones with an internet connection, may be more willing to accept monthly service fees to enhance their real time information – provided they can access information using the technology they already own. For others, the initial cost to access a VII system may deter them from testing the system as quickly. Adoption rates are ultimately determined by the actual cost to consumers. If a VII system requires users to both purchase a device and pay a monthly service fee, it may be harder to convince them to invest.

Northeastern University conducted a study entitled "An Alternative Perspective on VII."[23] In this study, consumers were divided into five categories.

Innovators: Willing to experiment with new technology
Early Adopters: Will adopt because they have special problems to solve
Early Majority: Will adopt once an innovation is considered mainstream
Late Majority: Come late to adoption because they are risk averse
Traditionalists: May never adopt the innovation

This is a pattern of adoption traditionally seen with the introduction of most new technologies. It would suggest that the majority of people will accept and implement a VII system element only after innovators use it and early adopters approve it as a solution to transportation problems. However, a VII system will rely on information from multiple sources and will be most useful (or successful) when the majority of vehicles on the road are participating. A VII system may not be sustainable with a slow rate of adoption.

In sociology, a concept known as Metcalfe's Law examines the adoption rates of technology. Robert Metcalfe founded the Ethernet and argued that through the creation of networks, such a thing as a ""network effect"" also emerged. The "network effect" says that the value of the good or service is directly related to the number of users and, the more users there are, the more valuable the good or service becomes. For example, every time a new user joined the Ethernet, the connections of those who already subscribed became all the more valuable. The same concept can be demonstrated for cell phones, fax machines and (potentially) a VII system. Metcalfe stated that there is a critical mass point where the value of using the good or service becomes greater than the cost of using it.

[23] Northeastern University, op. cit.

The "bandwagon effect" refers to the notion that the likelihood a person will adopt a certain technology increases with the number of people who have already adopted it. Non-users are more readily convinced of the value of a technology product or service if a significant number of other people are already using it. Both of these theories would be evident with a VII system. The rapid development of such a system would make the services and features used by early adopters more valuable as better information from more vehicles became available. At the same time, the greater the number of VII users, the easier it is to convince non-users that they should adopt. Creating excitement and enthusiasm for a VII system, as well as uses and benefits that are not dependent on information from many vehicles, will be important to attracting early adopters and eventually reaching a critical mass.

Northeastern University examines the integration of the cell phone; the two theories of Metcalfe's Law and the "bandwagon effect" are evident. Cell phones took almost twenty years to become universally used. As cell phones were adopted by the mainstream, it became more practical for more people to use them. The more people who owned cell phones, the more people you could call from your own cell phone and thus the more useful and cost-effective the device became. The cell phone, however, was always useful – to some extent. Even those who first used the cell phone were able to call home phones and business phones. This success, before full implementation, may be more difficult to replicate for a VII system. Since a VII system relies on communication from multiple vehicles, its success relies on its ability to penetrate the market. Can a VII system be successful without full implementation by a majority of vehicles on the road? If only a handful of "innovators" adopt the system and only a few (if any) vehicles communicate with each other and the road, will they still receive satisfactory service? If not, the system is likely to crumble. If innovators cannot use the system to its fullest, other consumers may never decide to join the market. This may mean that incentives will be needed to spur adoption. It may ultimately be necessary to incentivize consumers in order to induce mass use of the VII system. Unlike the cell phone industry, a VII system may not be able to wait for the natural progression of technology adoption and may, instead, need to find ways to encourage rapid adoption.

Consumer-driven Industry

The VII system will likely be a consumer-driven industry. Consumer acceptance is going to rely heavily on the industry's ability to tailor certain services to meet individual needs. If consumers can subscribe to services that fit their needs, and avoid paying for other services not relevant to their needs, VII systems and programs should be more successful. A VII system will need to be consumer-friendly. Consumers are more willing to accept products that are easy to use. In today's fast-paced society, consumers are no longer willing to spend hours trying to learn new technology. A VII system, therefore, needs to be relatively simple to use and require little consumer programming to install or set up. System elements must have little chance of malfunctioning. Since a VII system requires partnerships between manufacturers, satellites services and government entities, there is no one entity to go to in the event of system error or component failure. As long as consumers are unsure where to report problems, the system must be user-friendly and trouble-free. If a VII system component is installed in new vehicles, dealerships must have trained personnel to offer service and repairs. The same is true of any software company or government agency providing VII information.

The consumer's constant desire for the newest and easiest technology may make handheld systems more successful than built-in systems. The auto industry takes years to get concept vehicles to consumers, whereas technology companies have much faster turn-around times – often just months. The ability to update and mass-produce hand-held systems easily may make them more widespread. In addition, handheld systems offer portability and could be more economical.

One article stated that only 3 percent of consumers said they would pay more than $2,000 for new technology features, while 6 percent said they would spend between $1,000 and $2,000 and 25 percent said they would spend between $250 and $1,000.[24] Integrated navigation systems in cars can cost upwards of $2,000, whereas handheld navigation systems are much cheaper. Handheld systems could potentially be coupled with cell phone services to provide real-time traffic information. Hand-held systems may be the more practical choice, to reach as many people as possible. If the auto industry began installing VII components into new cars tomorrow, it could take a decade before the majority of cars on the road are equipped with a VII system. As with the introduction and adoption of complex new technology systems, the actual implementation will probably involve some combination of installed components and hand-held versions. Consumers buying new cars may like the luxury of an installed version, but those already on the road may look for an alternative.

Manufacturer Contributions

Some auto manufacturers will charge forward – as GM has done with OnStar or Volvo with their new driver-assist sensor systems. Others will be more reluctant. To paraphrase one manufacturer who confidentially said, "our level of interest is that we have 6 people, out of thousands in the entire company, devoted to VII systems work.[25] If a VII device costs more than $3.00 per unit, we are going to be opposed to implementation". Yet, private initiatives for development of a VII system could come from the electronics or the telecommunications industries rather than the automotive industry. PDAs, cellphones and laptops may become cost-effective and ubiquitous to the point where the role of the OEM is not critical. In 2007, the value of the output of the automotive electronics industry in the United States was estimated at $41.0 billion[26], and the average electronic content per vehicle was valued at slightly more than $2,000. The

[24] Howard, Bill. The Future of Telematics: It's Entertaining. PC Magazine. January 4, 2006.
[25] VII program interviews with corporate VII stakeholders conducted by the Center for Automotive Research, May – August 2007, Michigan

[26] Strategy Analytics

electronics content in vehicles has tripled in the past ten years and is projected to quadruple in the next five years.[27] Electronics and software advances will represent 80 – 90 percent of vehicle innovation through 2010.[28]

It may be more effective to determine the best areas for government investment to "pull" technology, rather than develop a preconceived notion of how manufacturers will become involved with the industry. Providing communication and equipment standards, as well as building consumer enthusiasm for a VII system, are tactics that will most likely enable manufacturers to participate in deployment of such a system with the greatest level of confidence.

Privacy

The power of a VII system also raises the issue of privacy. The National Transportation Safety Board has suggested putting black boxes – similar to those in airplanes – in passenger cars, trucks and school buses. Some articles have suggested that there are privacy issues to consider, and that consumers may be concerned over who is given access to information regarding traffic accidents. For example, is it fair for insurance companies and law enforcement agencies to be able to monitor a driver's speed at all times, and is it reasonable for that information to be used against the driver? While driving is a privilege and not a right and while it is reasonable for all users of the transportation system (drivers on the road) to expect that all other users behave safely and legally, to some extent, 'gaming' of the system has become a de-facto right in the minds of many drivers. The availability of information on driver behavior next becomes an issue of ownership of information.

Assuming a VII system provides more detailed knowledge of individual car performance, this information could affect maintenance work, insurance premiums, etc. Who has the right to this information? If the VII system is not fully integrated into all vehicles, do some people unfairly suffer? While this may not be an issue that outweighs the benefits of a VII system, it is a possible side effect.

In the "Five Year ITS Program Plan"[29] the U.S Department of Transportation includes a policy phase that is designed to "address issues on protecting the privacy of the public, liability and data ownership that may stand in the way of consumer acceptance and deployment." The department understands that an ideal system will meet the transportation needs of consumers but will not jeopardize their freedoms or privacy. The plan also includes an outreach phase that aims to keep consumers and investors continually aware of the developments within the VII system.

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[27] Center for Automotive Research. Presentation to CVPC, December 10, 2007. Ann Arbor, Michigan
[28] Ibid.
[29] Intelligent Transportation Systems, U.S. Department of Transportation. *The Five Year ITS Program Plan*. Washington, D. C., 2005.

The OnStar Model

The OnStar system is the best example we have to predict the possible future of a VII system. OnStar's monthly statistics include:

- 20,000 roadside assistance calls
- 300,000 routing support calls
- 7,000,000 personal calls
- 13,000 emergency calls
- 23,000 remote diagnostics
- 60,000 weather requests

As of 2005, the OnStar program had 4 million subscribers and had become a staple feature on many GM vehicles[30]. It is important to consider, however, that General Motors had to give away many OnStar subscriptions to build the system into widespread usage. Even today, most vehicles come equipped with the OnStar system and with free service for up to a year followed by a low-cost subscription rate thereafter. OnStar is continuing to develop its technology and capabilities and recently established a relationship with XM Satellite Radio to develop the use of XM radio as a pipeline for data transfer and to offer real time traffic information for download.

GM has always kept quiet on its returning subscriber rate, and many have suggested that it is not high. This may mean that consumers do not feel the advanced technology provided is worth the added expense. A VII system will require continuing investment and will likely rely on consumers eventually being willing to subsidize some of the cost. OnStar has enjoyed most of its success with mid-range and premium vehicles rather than with economy vehicles – another hint that full implementation of a VII system may be challenging. Nonetheless, many other car companies and technology companies have begun to offer similar services.

The Future of VII

OnStar may serve as evidence that a VII system could face a struggle to gain mass adoption. Since majority implementation is important to the success of a VII system, VII system deployment may need to offer free systems and services to new users. It remains to be seen whether private enterprises, such as OnStar and Ford's Sync system, will be competition or will build more interest for a publicly funded VII system.

The OnStar model demonstrates that the success of a VII system cannot rely solely on consumer spending. Until consumers feel there is a strong need for such a system, they will not be willing to pay for it. Since mass acceptance of a VII system is so critical, deployment will likely require funding from other sources. Surprisingly, there have been

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[30] Reid, Hal. *Telematics Detroit 2005*. Directions Magazine. May 22, 2005.

very few formal or informal studies to determine exactly what consumers might be willing to pay. A further, in-depth study is recommended to make sure consumer acceptance is high enough for a VII system to be successful. It is important to look at the technology already available on the market and do a separate study to determine what the desires of the consumers are and how that affects the realistic future of the industry. While consumers may benefit from a VII system, those benefits may not be enough incentive to facilitate or pay for the deployment and operations. Consumers need to be surveyed to determine whether the safety, congestion, and overall driving advances outweigh the drawbacks such as cost and lost privacy. This benefit cost study is the first step in establishing the business case for a VII system; the next step is to educate consumers on what is possible in the future and then establish a meeting point of desire, feasibility and cost.

CONCLUSION

This is an industry that is new and unfamiliar. Developing a robust, statewide system will require large capital investment. In addition, the use of a VII system will involve nearly everyone who uses a vehicle. There are numerous entities that will be affected by the deployment of a VII system, and a myriad of interests. This system could be the next wonder – akin to the internet and cellphones. It could also be much ado about nothing – sometimes technology moves so fast that one era overruns an earlier stage before the first can be fully implemented. There are a number of risks, obstacles and unknown factors.

While this paper determines that the annual cost of offering a VII system in the state of Michigan is roughly $370 million (excluding commercial fleet and private sector upgrades and retrofits), it also finds that the system will add over 16,000 annual full-time jobs to the state and will contribute $177 million in income tax revenues. The estimated jobs impact assumes that Michigan will be first state to implement a VII system. If Michigan is not the first state, many of these jobs will be located in the state that is first, and the product will be exported from there. Additionally, it is calculated that to offset the $640 million total societal annual cost (including private sector and commercial fleet spending) of deploying and maintaining the statewide VII system, a mere 2.5 percent annual reduction in a short list of negative externalities must occur.

It seems obvious that it is a good idea for the state of Michigan to proceed on developing and deploying a comprehensive VII system. However, there are still a few questions not resolved in this analysis that should be considered in a decision-making context. It is recommended that before the state proceeds with deployment of a VII system, that it resolve (or at least consider) the ramifications of the following issues:

- Who will pay for the VII system?
- Are government funding and research key enablers to installing the system?
- Is a private sector mandate of the auto and communication industries necessary? Standards must by set and agreed upon to remove potential barriers to entry and production for manufacturers.
- Identify the level of support for the VII system. Will it have to compete with other policy programs for funding?
- Will the funding stream be long enough to reach saturation? If not, the system could be doomed to failure, because it is critical that the number of users on the road must reach a critical mass in order for the users of the system to realize the benefits of the system
- Consumers must be a part of the debate as they are the ones who will be most impacted by implementation of the system. A comprehensive survey of consumers addressing their concerns regarding who owns the data, and whether there will be cross-agency/cross-industry exchange of the data is necessary.

The payback of installing and operating a VII system in Michigan is rapid, due primarily to immediate safety improvements and accident reductions. If the issues and concerns of all parties are addressed, these benefits would seem to justify the high level of initial investment required. Building an industry in which Michigan can be the leader and an industry that uses state expertise in all things automotive and R&D would appear to be further justification.

APPENDIX A Glossary of Terms

CAR	Center for Automotive Research
CDF	Cumulative Distribution Function
CPI	Consumer Price Index
FTE	full-time equivalent (employee)
ITS	Intelligent Transportation Systems
MDOT	Michigan Department of Transportation
MSU	Michigan State University
PDV	Present Discounted Value
R&D	Research and Development
REMI	Regional Economic Modeling, Inc.
TOC	Traffic Operations Center
USDOT	United States Department of Transportation
VII	Vehicle Infrastructure Integration
VMT	Vehicle Miles Traveled
$/VMT	dollar per vehicle mile traveled

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