Technology and Intelligent Transportation Systems (ITS): The Implications for Future Transportation

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16. Abstract

The main thrust for innovation in the transportation field will emerge from persistent pressures to reduce congestion and its impacts on the environment. Future transportation systems will need to provide travelers with individualized and speedier trips that are actually longer in distance due to globalization. At first glance, a satisfactory solution to all of these requirements appears unattainable. However, current research and development in transportation technologies provides clues to the form that the transportation infrastructure could take in the future.

This report evaluates the most probable technologies to triumph within future Intelligent Transportation Systems. This evaluation involves two steps. First, current and emerging technologies are "weeded out" by applying VisionEcon's process for measuring multi-dimensional resistance factors. Second, these results are merged with the results of a survey of six experts within the field of ITS. While many ITS experts may be tempted to dismiss the results of this futuristic outlook as whimsical, it is conventional wisdom that business leaders have often been caught off guard by transformations occurring outside their area of expertise. [One only needs to look at the computer expert's forecast in 1943 that there was "a world market for maybe five computers".] And yet, these peripheral changes that are occurring often have immense and lasting effects on the way the world works.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

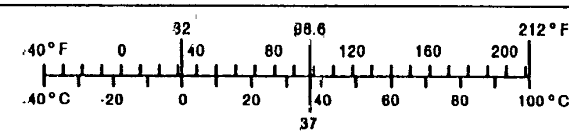
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Innovations in transportation systems can be expected to accelerate in the near future. Persistent pressures to reduce congestion and its impact on the environment, and yet still, to provide travelers with individualized and speedier trips that are actually longer in distance will promote these innovations. At first glance, a satisfactory solution to all of these requirements may appear to be unattainable. However, current research and development in transportation technologies provides clues to the form that the transportation infrastructure will take in the future.

This report attempts an evaluation of current Intelligent Transportation System programs in place and the research and development currently being undertaken in transportation technology. First, **an economics-based** overview of the current status of transportation technology is presented. This overview looks at Intelligent Vehicle Systems and Intelligent Highways Systems. Also, it hopes to shed some light on the rationality of placing prominence upon the operations control centers of the nation's transportation management organizations. This overview provides analysts with some insights into which technological evolutions are the most likely to possess longevity in the transportation engineering of the future.

Second, an overview is presented on the current innovative research and development occurring around the world in the field of Intelligent Transportation Systems (ITS). An excellent, up-to-the-minute overview has been provided by Jerry Schneider of University of Washington and his synopsis is presented on the Internet. Much of the groundwork for this section is drawn upon Schneider's work.

Lastly, an evaluation is performed to obtain the most likely technologies to survive in ITS. This evaluation involves two steps: 1) weeding out the current and emerging technologies by applying VisionEcon's process for measuring multi-dimensional resistance factors and 2) merging these results with the results of a survey of six experts within the field of ITS. While many ITS experts will be tempted to dismiss the results of this process as whimsical, many times insiders in a field are astounded by transformations that occur outside their area of expertise. One only needs to recall the forecast produced by a computer insider in 1943 that there was "a world market for maybe five computers"[1] to see this paradox.

This reports contends that the process of evolution in ITS will be similar to that of the steam locomotive. While many of the innovators between 1630 and 1822 may have been looked upon as eccentric, eventually the conglomeration of their successful **and** unsuccessful efforts lit the path for the George Stephenson in 1822. And, the transportation world was forever changed. All indicators suggest that this pattern of perseverance and innovation will repeat itself for the transportation field within the next 25 years.

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[1] "Things People Said: Bad Predictions." RinkWorks Online Entertainment. Accessed 4/11/02. <http://www.rinkworks.com/>

I. INTRODUCTION

> "Ask any local or regional political official [what the public wants in the way of highway transportation]—the public wants to be rid of traffic congestion.[2]" – Richard Bishop, a consultant within the fields of intelligent vehicle and highway systems.

The above quote provides the most telling prophecy of the evolution that will eventually emerge in transportation technology. Consultant Richard Bishop, in his article entitled "Whatever Happened to Automated Highway Systems (AHS)?"[3], points out that while all of the newest available auto safety features are beneficial, transportation technologies still have yet to address the issues regarding the traffic problems associated with driving. While many drivers may not be willing to give up the freedom and independence of their own vehicle, they will still demand a solution to traffic congestion as it continues to worsen in the future. And, this report asserts that **a reduction in traffic congestion and its environmental impact** will be the motivating thrust of transportation technology in the future.

A review of the technological advancements occurring today suggests that many diverse solutions appear available to solve this congestion problem. Yet, the ultimate survivor in the quest for congestion-reducing transportation technology will be the innovation that profitably addresses four different dimensions of resistance within the current transportation system:

1. The driver's desire to travel farther, faster, independently and on an individualized schedule.
2. The manufacturers' and transportation planners' vested interest in minimizing adaptations of the current vehicular systems.
3. The cost of infrastructural changes imposed on transportation planning organizations.
4. The need for fast, inexpensive movement of labor and goods within a globalized economy.

Hence, this report follows the flowchart in Figure 1 in evaluating the research of transportation technology. First, the report presents **an economics-based** overview of the current status of transportation technology. Since this report does not pretend to be a meticulous engineering dissertation—the goal is different from what many transportation analysts may be expecting. The goal of this report is to merge the current state of transportation engineering with the technological and economic trends that are currently in the midst of a churning state of evolution. Thus, it provides analysts insight into the technological evolutions that are most likely to survive within the transportation engineering systems of the future.

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[2] Bishop, Richard. "Whatever Happened to Automated Highway Systems (AHS)?" *Traffic Technology International.* August-September 2001. Accessed 3/14/02. <http://faculty.washington.edu/jbs/itrans/bishopahs.htm>

[3] Ibid.

Second, the report offers an overview of the current innovative research occurring around the world in the field of Intelligent Transportation Systems (ITS). An excellent, up-to-the-minute synopsis is presented on the Internet by Jerry Schneider of University of Washington.[4] Much of the groundwork for this section is drawn from Schneider's work.

Lastly, the report introduces a method of evaluating the most probable victors in ITS technology. This evaluation includes the results of a survey of six experts within the field of ITS. Also, a schematic is presented to quantify the strength of many of the current innovative technologies in relation to the four-dimensions of resistance mentioned above.

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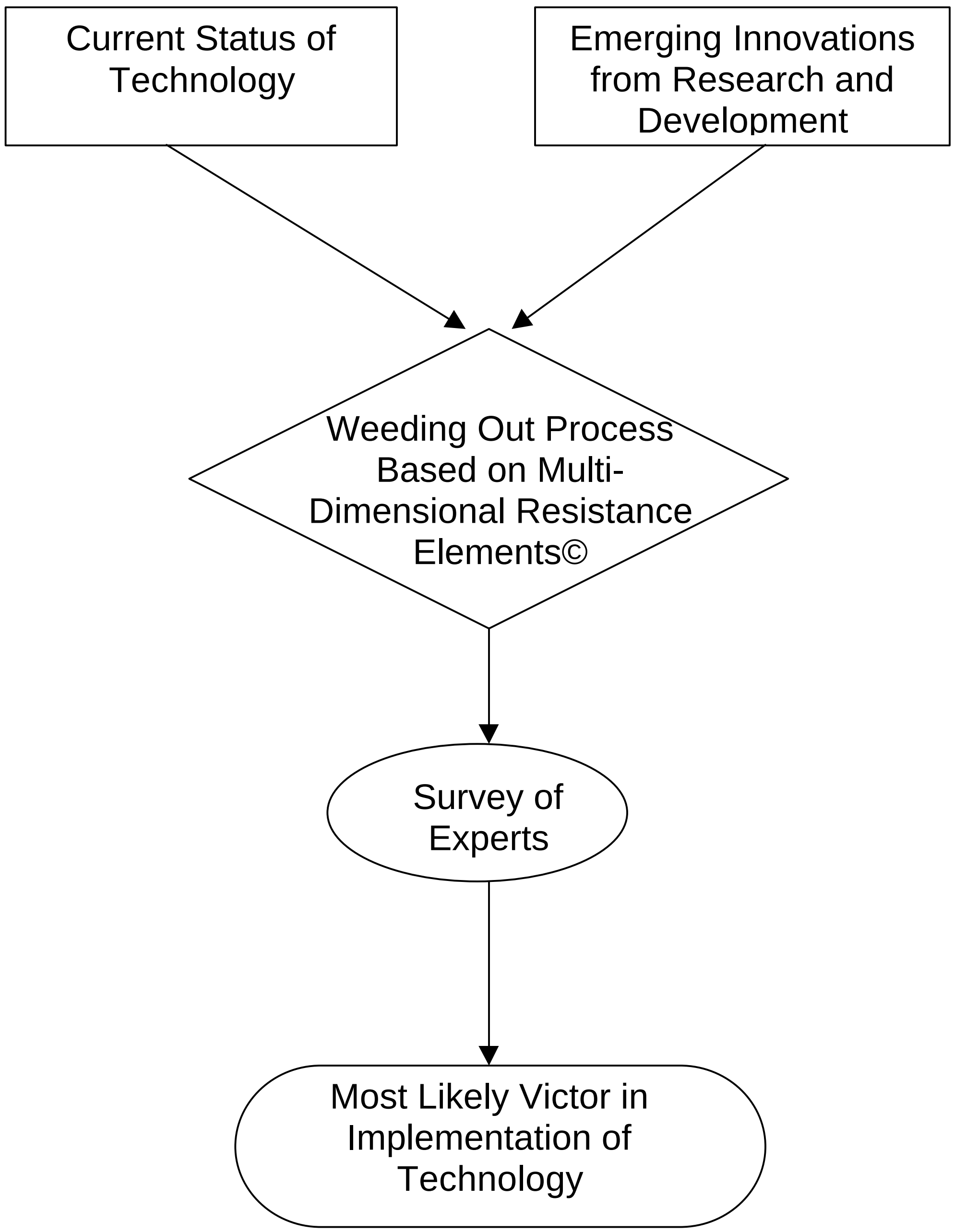
[4] Schneider, Jerry. "Innovative Transportation Technologies". Accessed 3/14/02. <http://faculty.washington.edu/~jbs/itrans/>.

Figure 1: VisionEcon's Evolution of Innovations©



However, in the end, transportation experts perusing this document need to understand that this document was prepared by **an economist.** Thus, the goal of this report is to harvest a vision of all of the trends germinating in the field of transportation engineering. This economist would be the last to make a claim of engineering prowess.

Nonetheless, many times the most accurate visions of the future emerge from generalists outside of a particular field of study. One needs only to look as far as the prediction of Thomas Watson, chairman of IBM in 1943 that there was "a world market for maybe five computers".[5] Many times, experts within a field get so immersed in the "here and now" within their own industry that they cannot see the evolutions quietly occurring around them. Thus, the report attempts to evaluate probable trends occurring over the next 25 years by applying a "weeding out" process. And, no one is more familiar with the "weeding out" process of a competitive economy than economists. Successful economists are pushed to excel in viewing the "forest through the trees".

[5] "Thing People Said: Bad Predictions." RinkWorks Online Entertainment. Accessed 4/11/02. <http://www.rinkworks.com/>

II. LESSONS FROM THE RAILROAD ERA

Any ITS system that eventually evolves into the future is certain to follow a path of fits and starts. The system will butt up against the static human elements of drivers, manufacturers, transportation planners and the enormous obstacle of obtaining fickle investment capital for research and development. Yet, the "New Economy" needs of faster, more efficient and individualized transportation will continue to motivate the few transportation innovators that have the strength to persevere against the odds.

No other example in history is more appropriate to the challenge faced in the ITS field than the evolution of railroads. An outstanding synopsis of the railroad industry is entitled *The History of the First Locomotives in America* by William H. Brown.[6] Brown tells the story of the man looked upon as the father of the locomotive system in England. George Stephenson's perseverance in pursuing the dream of building a locomotive system, despite all of the practical failures that preceded him, eventually bore fruit and impacted the whole world economy on a grandiose scale. Yet, his efforts were built upon and molded by the efforts of many successful and <u>unsuccessful</u> inventors that had the same dream of using steam power to replace the horse in the transportation field. Many of these projects were labeled "practical failures", yet provided stepping stones to the final successful launching of the railroad. The following table presents many of those major "stepping stones" of development and what they contributed to the invention of the steam locomotive.

[6] Brown, William H. "The History of the First Locomotives in America". New York: D. Appleton and Company. 1871.

Table 1: Lessons from the Railroad Era

Inventor/Date	Description of Event and Invention	Contributions to Final Product
Unknown innovator in Beaumont, England Around 1630	Used rails to transport coal from mines	Concept of lessening the burden on a horse by providing smooth, level path for carts on rollers.
James Watt, 1776	Steam engine perfected	Concept of replacing horse power for steam power.
Mr. Thomas, 1800	Presented the idea of using coal/mining tram roads for transporting passengers and merchandise	Mining transportation mediums became general use mediums.
Richard Trevithick, 1802-1804	Steam carriage to run on common roads or tram roads	Revealed that common roads were too rough; introduced the problems of slip on tram roads.
Mr. Blankensop of Leeds, 1811	Locomotive with cogged wheels and rails	Tooth driving concept and dedicated railways.
Mr. Blackett of Wylam, 1813	Tested adhesive power of smooth-surfaced driving wheels with smooth-surfaced rails	Success in propelling wagons on smooth-surfaced driving wheels with smooth-surfaced rails with out slippage.
George Stephenson, 1822	Locomotive with smooth wheels	Engineered first locomotive coal railroad.

In the end, the modern-day railroad resulted from over 200 years of research and development. However, today's learning processes have been condensed and new capabilities are introduced at breakneck speeds. According to the transportation experts surveyed for this project, an established ITS system will become a reality in less than 25 years. Most believed the induction of cooperative, intelligent vehicles will occur within 10 years.

Consequently, in any emerging field, such as ITS, even those experiments that are presumed as "practical failures" need to be reviewed since they give clues as to the final outcome for an innovation. And, this report does just that. By reviewing the most renowned of the current transportation projects that are still at the research and development stage, we can develop a glimpse of the vision that ITS holds in the future.

III. CURRENT STATUS OF INTELLIGENT TRANSPORTATION SYSTEMS

A. TRANSPORTATION DEMANDS

The current forms of transportation can be classified in many different ways: by the end user (consumer, type of business, government, etc.), by transportation medium (air, water, rail, and road) or by function (consumer passenger service, work-day commuting, delivery of goods, high-speed document delivery, etc.) However, as suggested by Phase 1--"Survey of Futurist Trends"-- of this project, changes in our economy are indicating that a new classification system of transportation services will become more practical in the years ahead. According to this research on the "New Economy", four needs will dictate future transportation:

1. Speed: "As the learning-curve process speeds up and time becomes more of a competitive edge to firms, organization and individuals—pressure will continue to build to do something to save that time."[7]

2. Connections: In addition, according to Glen Hiemstra, a writer for **The Futurist** magazine, as computer chips become cheaper and more integrated into dumb appliances, cars will become "smart". Cars will have the capabilities of sensing safe zones-- "braking or accelerating when deemed necessary, or telling direction using Global Positioning Satellite Systems (GPS) and eventually will be driving themselves on interstate 'Guideways'" [8].

3. Globalization: As firms can do business from anywhere and send goods to anywhere—the pressures will be immense to cut the costs and time involved in transporting goods from halfway around the globe.[9]

4. Convenience: As transportation costs less in terms of time and money, we may actually begin to travel and ship more. [10] Hence, transportation is likely to become more important in the future—not less.

These needs suggest that transportation modes should begin to be classified by whether the transport demanded is short, convenient, and task oriented; intermediate-range, prearranged commuter and event traffic; or long-distance, fast and global delivery of labor and goods. The majority of these movements will require interactive connections—either Internet, Global Positioning Systems, centralized dispatching or other communication protocols.

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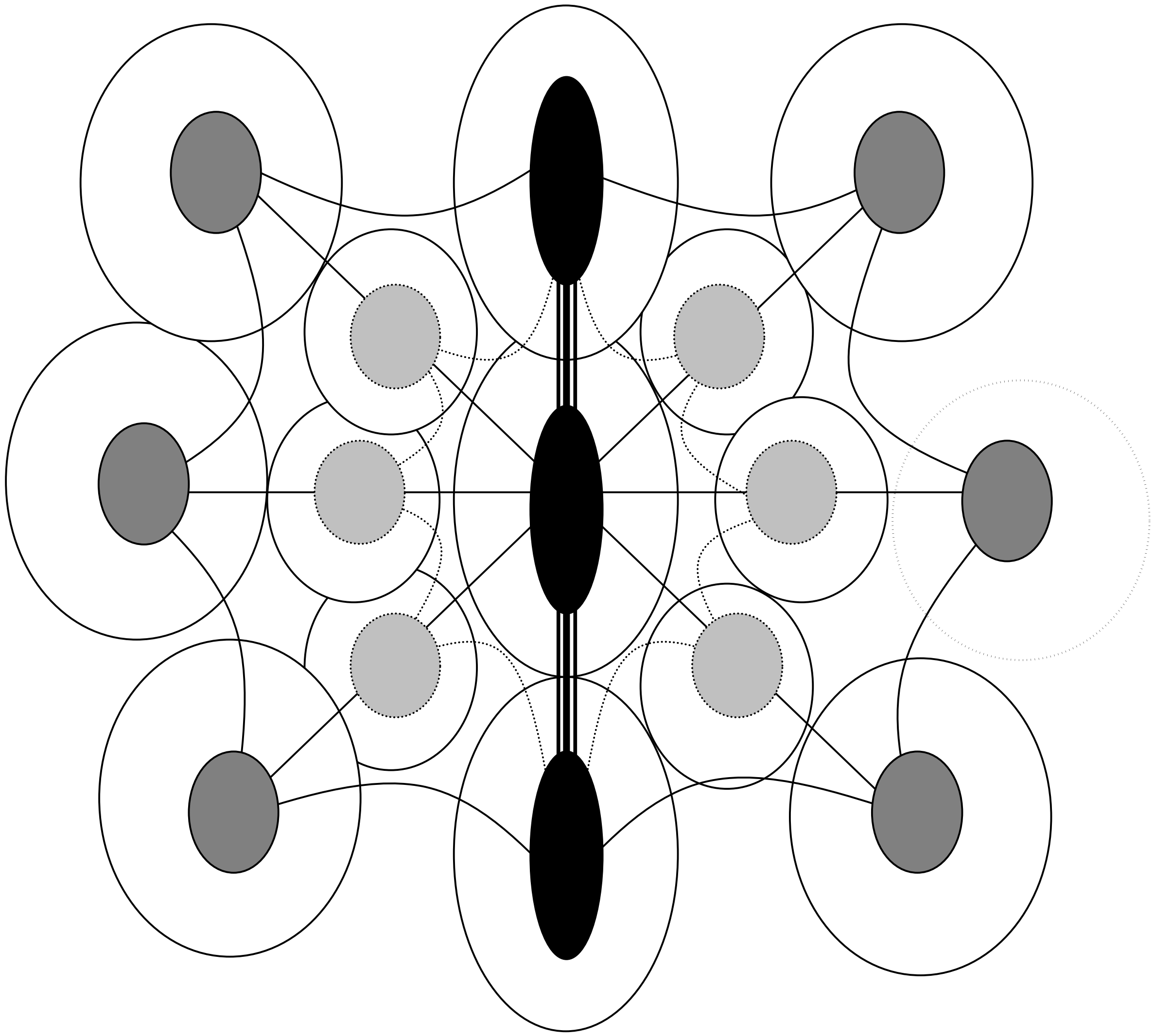
[7] Roubik, Debra. "Survey of Futurist Trends". Arizona Department of Transportation. February 2001.
[8] Hiemstra, Glen. *The Futurist.* September-October 2000.
[9] Roubik, Debra. "Survey of Futurist Trends". Arizona Department of Transportation. February 2001.
[10] Kelly, Kevin. *New Rules for the New Economy*. New York: Penguin Books. 1998.

In addition to these economic transformations being demanded by the "New Economy" information revolution, another transformation is being demanded from transportation structures due to evolving land-use models. In the land-use and second phase of this project, the report entitled "Movements in Land-Use Regulations" referred to cities and towns as nodes in a network. These nodes are connected through a spider web of Internet, road and telephony networks. As the national trend for environmentalism and escapism proliferates, the desire for open space will create greater distances between the nodes. This push for more vastness is occurring just as the residents are clamoring for less traffic congestion. The dichotomy of these desires will continue to pressure transportation innovators to find a solution.

With these forces pressuring the transportation system, it will behoove transportation planners to partner with economic development and land-use planners in the conception of a community's evolving design. Transportation demands **are** going to increase, and the distances traveled **are** going to increase as well. Nonetheless, by encouraging a community to strive for a goal of "self-containment" as explained in the land-use phase of these reports, planners can mitigate the strains that short, convenient, and task oriented traffic place on the overall transportation system.

In this way, transportation analysts could focus more resources on the demands of intermediate-range, prearranged commuter/event traffic; and long-distance, fast and global delivery of labor and goods.

Figure 2: Evolving Land-use Network Systems



Major Population, Industrial and Warehousing Centers

Communities With Knowledge-Based Employment Centers,
Retail Employment and Mixed Uses

Small, Established "Bedroom" Communities with Some
Retail and other Community-driven Mixed Uses

B. TRANSPORTATION VEHICLES

1. Type 1 Traffic: Short, convenient, and task-oriented traffic

Type 1 traffic can be illustrated as the movement **within** the nodes. Walking, bicycling, roller blading, skateboarding, scooters (manual, electric, gas), electric carts and (in Arizona) even horse-back riding, all lend themselves to these types of trips. Thus, auto traffic congestion can be alleviated by encouraging paths to the goal destinations for this type of travel. Usually, the goal destinations are retail, entertainment, restaurants or social venues, and the points of departure and destination are so varied that a single system of transportation is not economical or practical.

Obviously, currently in Arizona, the auto is the most popular vehicle of choice in this traffic type. In fact, the auto has been the vehicle of choice for all three types of transportation. Fortunately, the climate of many Arizona cities is temperate compared to many other places in the country. This temperance lends itself to encouraging alternative vehicles for the short-distance, convenient and task-oriented Type 1 traffic.

In order to reduce this short-distance, task-oriented type of traffic, more deliberate arrangements must be made for transportation options within a community's overall plan.[11] Thus, it will befit the transportation planner's best interest in the future to get involved in helping communities to envision these pathways. By doing so, transportation systems will free up the resources to serve the other two compounding areas of concern—commuter/event traffic and long-distance global traffic.

Usually, when planning deliberately improves the non-auto accessibility of the goal destinations, Type 1 travel does not need to be "connected" nor state-of-the-art. In the long-run, investments in non-auto, Type 1 travel systems essentially free up future transportation dollars and transportation operations for the other two areas of escalating concern.

2. Type 2 Traffic: Intermediate-range, prearranged commuter and event traffic

This type of traffic can be illustrated as the movement between the nodes in Figure 2. These movements occur on a predictable basis and represent the type of traffic where public pressures are the highest. In addition, the success or failure rates in averting this type of traffic are exponential. Poor performance in one community's dealing with Type 1 traffic places pressures on surrounding communities as the residents add to auto traffic on existing roads within and between the nodes. Not only are the effects multiplicative, they are multidimensional. The increased traffic on the existing roads affects the general public through increased pollution, loss of environmental self-discipline due to the

[11] Roubik, Debra. "Movements in Land-Use Regulations". Arizona Department of Transportation. June 2001.

necessity to build more road capacity, and economic development disincentives due to longer commute times and traffic congestion. However, when communities perform well in Type 1 traffic alleviation, transportation planners can better target the travelers on the roads as Type 2 travelers.

This segmenting of the market usually provides the numerical justification for light-rail, bus or HOV (high occupancy vehicle) transportation systems. While the goals of light-rail and bus systems are commendable—providing efficient and environmentally friendlier systems to the masses— such systems tend to neglect the actual wants of consumers in the transportation market. Type 2 travelers want fast, hassle-free, individualized, thus safe, transportation vehicles. Light-rail and bus systems run on schedules, sometimes require transfers, usually lack the comfort/amenities of private autos and have a reputation for promoting undesirable activities such as loitering, begging or pilfering. Currently, the auto wins hands-down in these criteria.

With this in mind, the most viable competitor would appear to be HOV travel, or carpools. However, the carpool audience is significantly reduced when the individuals' need for flexibility and status are considered.

Current technological innovations in the auto sector suggest that carmakers and transportation planners have acquiesced to the traveler's preference for the flexibility, comfort and individuality of the automobile. The greatest advances we have seen thus far can be classified into two different areas: 1) Intelligent Vehicle Systems, 2) Intelligent Highway Systems. The "smart" vehicles envisioned by Kevin Kelly in 1998 are quickly coming to fruition[12]. Today, you can purchase Global Positioning Systems to guide your journey, dial 5-1-1 to get traffic congestion or construction information on the designated route, order adaptive cruise control that distances your car from the car ahead of you, install lane- or road-departure warning systems, or obtain sensors that detect your driving awareness, and of course, obtain other information through telematics—the interface between IT systems and your car. A table summarizing the current technological advances in Intelligent Vehicle Systems is presented at the end of this section.

Although these innovations are intriguing and exciting, a logical and objective analysis would suggest that they will do little to reduce heavy congestion. Early studies by the U.S. Department of Transportation point out that adaptive cruise control and collision warning systems have the potential to reduce motor vehicle crashes by one-sixth[13]. The Texas Transportation Institute's Urban Mobility Study produces an estimate of the volume of traffic that is "incident" related. In 1999, 44 percent of congestion is due to "incidents" on Phoenix highways and 52 percent of Phoenix arterial street congestion is due to incident delays. Mathematically, this implies that about seven to nine percent of traffic congestion could be reduced by these Intelligent Vehicle Systems. With the number of person-hours spent in Phoenix congestion growing at an 8 percent annual rate according to the most recent data released, the Intelligent Vehicle Systems by themselves will only save Phoenix one year of growth. Obviously, applying both Intelligent Vehicle

[12] Kelly, Kevin. Ibid.

[13] "Intelligent Vehicle Initiative Business Plan". Intelligent Transportation Systems Joint Program Office, U.S. Department of Transportation. July 2000.

and Highway Systems could boost this rate. Nonetheless, while no one would argue against the value of saving lives—obviously these current technologies could not possibly be effective in addressing more than half of the traffic congestion. In Phoenix, Arizona, these technologies could "buy" us out of about five years of congestion caused by traffic growth, at the most.

This concession—that Intelligent Vehicle Systems would save lives but not necessarily commute time-- became the impetus for the establishment of the "Cooperative Vehicle-Highway Automation Systems" (CVHAS) program by the California Department of Transportation (Caltrans). This program was designed to pool resources to facilitate the development of a transportation system that automates the connection between vehicles and their highways. According to the Caltrans proposal for CVHAS—"The primary goal of the IVI [Intelligent Vehicle Initiative directed by the U.S. Department of Transportation] program is to improve the safety of vehicle travel through the development of autonomous intelligent vehicles. While this goal is noble and should be pursued, it does not consider the long-term societal need for traffic congestion relief."[14] Thus, the CVHAS program leaves congestion relief to be addressed in the future.

Fortunately, in other parts of the world, there <u>are</u> other current transportation systems being developed that could become the auto's most plausible competitors. Despite the massive influx of money into light-rail and buses—the biggest competitors to the auto will need to be systems that are fast, hassle-free and individualized. The following table could be used as a measure of any alternative transportation system's "marketability" to the auto-dependent traveler.

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[14] Larson, Greg. "Establishment of a Program to Support the Research, Development and Deployment of Cooperative Vehicle-Highway Automation Systems". California Department of Transportation New Technology and Research Program. May 10, 2000.

Table 2: Marketability of Type 2 Transit Systems

	"I do not use public transit to travel to work because…"	Percentage of Respondents in Agreement
1.	I don't like to use it	39%
2.	It is not available at work	35%
3.	Its schedule is not convenient	24%
4.	I need my own vehicle to do other things	17%
5.	It takes too much time	14%
6.	It stops too far from home	7%

Source: "Public Transit in America: Findings form the 1995 Nationwide Personal Transportation Survey." Center for Urban Transportation Research, University of South Florida.

Enter the ULtra in London—Urban Light Transport—as a personalized, high-tech taxi system. Passengers "hail" battery-powered pods from designated stops, swipe smart cards that give the travel details and pay for the service and receive safe, small party, quiet rides on designated tracks. According to an article in Reuters, the efficiency of ULTra stems from the large number of pods in circulation, non-stop journeys and shortened journey times since the pods will not be confronted with conventional traffic congestion. In addition, the network costs about one-third to one-half of the amount needed for light railway.[15]

While ULTra may not have all the characteristics of the next generation of transportations systems, we can speculate on the contribution it will make to the final product. This gleaning process will be covered in Section III.

[15] Voorobyova, Toni. "Britain to Test Driver-Free Taxis". Reuters. February 25, 2002.

Table 3: Current Intelligent Vehicle System Technologies

Type of Technology	Description of Technology	Effects on Overall Transportation System	Contribution to ITS
Global Positioning Systems (GPS)	Provides navigational directions to desired destinations	Avoids collisions attributable to lost drivers and lessens traffic by providing "shortest" route	GPS provides location detection of specific vehicle
Telematics	Connects auto to Internet for real-time traffic information or routing suggestions	Allows callers to adjust route based on updated information—thus lessening "incident" traffic congestion	Connects cars to central source of information
5-1-1 Traffic Information Hotline	Provides callers with latest traffic updates, current road conditions, public transportation information and weather forecasts	Allows callers to adjust route based on updated information—thus lessening "incident" traffic congestion	Encourages interactive communication in route planning
Adaptive Cruise Control	Sends auto into coasting or downshifting mode when the presence of object signals risk of collision	Avoids rear-end collisions and resultant "incident" congestion	Development of multiple sensors (both radar and optical), and the practice of sensor fusion
Lane-Change and Merge Collision Avoidance Systems	Monitor lane position and relative speed and position of vehicles around auto	Collision avoidance and resultant "incident" congestion	Use of sonic and radar sensor technologies, will foster the detection of fast-moving vehicles
Road-Departure Warning Systems	Provides warning and control assistance to driver when deviation from road is detected	Collision avoidance and resultant "incident" congestion	Merging map database, GPS and other sensor systems
Driver Condition Warnings	Monitor detects driver drowsiness by measuring eyelid closures	Collision avoidance and resultant "incident" congestion	Could foster driver recognition programs
Vision Enhancement Systems	Investigations into the use of military vision enhancement systems	Collision avoidance and resultant "incident" congestion	Infrared vision prototypes from U.S. Army
Vehicle Stability Systems	In-cab device for commercial vehicles, applying braking at individual wheels	Collision avoidance and resultant "incident" congestion	Minimize "rearward amplification" for coupled vehicles

Type 3 Traffic: Long-distance, fast and global delivery of labor and goods

One 1990's catchphrase that will surely go down in economic history will be term "globalization". However, historically, it was much more than a catchphrase. According to data released by the International Monetary Fund, the secular, or non-cyclical component of the exports of goods and services between countries increased by almost 70 percent during those ten years. In addition, the secular international travel market gained by almost 38 percent. Thus, business is demanding greater distances from its transportation systems. And, according to most of the experts surveyed in Phase 1 of this project, this trend will persist. The experts also stressed that business will continue to pressure the system to transport goods and knowledge workers greater distances, at greater speeds and lower costs on into the future.

C. TRANSPORTATION MEDIUMS

Type 1 travelers have little choice in their travel medium. Pending the invention of personal aircraft—Type 1 travelers need paths. And, they need paths that are easily accessible. In addition, Type 1 travelers can be severely hampered by climate, accessibility and carrying capacity. Thus, local officials need to adjust their ambitions for encouraging Type 1 traffic by these obstacles.

On the other hand, Type 2 travelers have two options. Auto, bus and carpool traffic need roads. The only other option for commuter and event travel is rail. As stated in the previous section on Type 2 Traffic, transportation planners have seemed to succumb to the fact that event/commuter travelers are attached to the auto as their option of choice. In response, planners have begun to downplay rail and turned instead to Intelligent Highways Systems (IHS) to help lighten the load of Type 2 traffic. IHS encompass projects such as traffic signal synchronization, loop detectors measuring traffic volume, road condition sensors, message signs and 5-1-1 which notify drivers of delays, electronic toll collection, programmed emergency notification and response systems.

While Intelligent Vehicle Systems are being adopted in order to avoid collisions, at this point, Intelligent Highway Systems are being focused toward minimizing the impact of collisions and other factors on congestion. By minimizing collisions and their effects on traffic, transportation analysts posit that congestion will lessen. However, as stated in the previous section, these measures simply "buy Phoenix some time" in dealing with traffic congestion.

Table 4: Current Intelligent Highway/Transit System Technologies

Type of Technology	Description of Technology	Effects on Overall Transportation System	Contribution to ITS
TRANSIT-BASED SYSTEMS:			
Signal control for buses and other traffic	Detectors on buses or traffic control operators adjust signal timing to reduce delays	Encourages ridership by creating an aura of nonstop service, creates more efficient traffic flow	Detection system innovations could cross-migrate to autos/other vehicles
Global Positioning System information available on the Internet	Potential passengers can track buses on the Internet and make travel adjustments	Encourages ridership since passengers can adjust schedules to reduce "wait" times	Real-time tracking experience could provide the focus for central or automated control systems
Smart cards for fare	Chip-enabled fare cards	Speeds up boarding process	Quick, easy collection system for providing transportation services
Mobile Data Terminal	Serves as communication hub between vehicle and control center	Collects information on vehicle and shares it with operations control center	Could provide the focus for future of central or automated control
ALL OTHER VEHICULAR SYSTEMS:			
Operations Control Centers	Central processing site of traffic management information	Provides real-time updates to traffic problems: updating variable message signs, Internet, radio or 5-1-1 information	Could contribute groundwork for variable speed limits/speed management systems and other cooperative vehicle-highway information systems

Loop Detectors and Video Detection Systems	Systems measure traffic volume, occupancy and detect incidents	Help to inform travelers and emergency response teams	Could contribute groundwork for other cooperative vehicle-highway information systems
Electronic Toll Lanes	Electronic readers collect data from vehicle stickers	Quicker movement through check-out points. (Applied on the NY/Ontario border to speed up customs and freight clearance as well.)	Provides groundwork for identification of individual vehicles and provides a way to access fees for transportation services
5-1-1 Traffic Information Hotline	Provides callers with latest traffic updates, current road conditions, public transportation information and weather forecasts	Allows callers to adjust route based on updated information—thus lessening "incident" traffic congestion	Encourages interactive communication in route planning

D. ROUTING DECISION CONTROL SYSTEMS

As the above Intelligent Highway System table suggests, recent advancements in transportation information technology have placed an elevated preeminence on operations control centers for traffic management. Until the process becomes 100% automated and seamless, the operations control centers will be the synthesizer of information on congestion and traffic incidents including construction and weather. They will also play the role as the disseminator of this information to variable message signs, the Internet, radio waves or to emergency response groups, if need be. If such operations control centers around the country are held accountable for success in reducing congestion, their processes will begin to converge toward a more mechanized, seamless standard.

In the end, this standard is likely to include some type of automated driving or cooperative vehicle-highway systems as advocated by Caltrans and transportation experts such as Richard Bishop.[16] According to Bishop, the simplest, lowest risk versions of automated driving will be more likely to be implemented in the near-term. One example of this would include a type of dedicated lane for vehicles equipped with next generation Automatic Cruise Control.

Yet, the long-term vision embraces the "New Economy" paradigm of taking fairly repetitive, predictable tasks and automating them. As the following section will discuss, this will, someday, include driving.

[16] Bishop, Richard. "Beyond Safety: The Potential of Intelligent Vehicle Systems to Contribute to Improvements in Traffic Flow." Bishop Consulting. 2002.

IV. ARRAY OF EMERGING INNOVATIONS

The array of emerging innovations in transportation is exhilarating. An exhaustive matrix of these technologies was accumulated by Jerry Schneider of University of Washington. While many of these projects focus on public transit systems, a substantial number of them envision a mode of transportation known as dual mode transportation. According to Schneider, dual mode transportation systems feature vehicles that can be driven both as single-occupancy vehicles on conventional streets and can operate on high-speed automated guideways. Some of these projects represent suspended technologies, some magnetic levitational systems. The following table is a segment of Schneider's complete table which is available in Appendix A. The following table only includes those technologies that Schneider rates as high in either vehicle or guideway development.

Table 5: Highly Developed Transportation Technologies

System Name	Location	Status of Design Engr.&Testing				Cost Target	Active Mkting?	Operating?
		Vehicle	**Guideway**	**C&C Software**	**Test Program**			
Aerobus	**USA, TX**	**Currently for sale, was operational several years ago in Europe and Canada. System currently being constructed in China**						
Aeromobile-Aeroduct	**USA**	**H**	**H**	**L**	**M**	**VL**	**M**	**M - ops. prototype available**
Aeromovel	**USA/Brazil**	**For sale, has been operating in Brazil for several years**						
Austrans	**Australia**	**M/H**	**H**	**M**	**H**	**M**	**H**	**M**
Cabintaxi	**USA, MI**	**Extensive test facility and program completed in Germany in 1970's, control system needs update, shuttle version operational since 1976**						
CyberCab	**Netherlands**	**H**	**H**	**H**	**H**	**L**	**H**	**H**
CyberTran	**USA, CA,NY**	**H**	**H**	**M/H**	**M/H**	**L**	**M/H**	**M/H**
HSST maglev	**Japan**	**For sale, extensive test and demo program completed, first application in Japan is underway**						
Modern Transport System Corporation	**USA, CA**	**Developing novel maglev system, some prototype components currently operational**						
Magplane pipeline	**USA, MA**	**H**	**H**	**H**	**H**	**VL**	**M**	**H**
MEGARAIL	USA, TX	**M**	**M/H**	**L**	**L**	**VL**	**H**	**L/M, Video available**
MICRORAIL	**USA, TX**	**M**	**H**	**L**	**L**	**VL**	**H**	**Prototype early '02**

Mitchell	USA, VA	M	H	M	H	L	M	N - but video avail.
ParkShuttle	Netherlands	Two systems in full operation (Amsterdam Airport since late 1997 and Rotterdam since early 1999; more systems being deployed						
PRT 2000	USA, MA	Development and test program completed in 2000, awaiting market interest						
PERSONAL ELECTRIC RAPID TRANSIT SYSTEM (PERTS)	VIRGINIA,USA	Maglev, dual mode concept, developed at VPI, scale model constructed, video available						
System Name	Location	Vehicle	Guideway	Software	Test ?	Cost	Mkting?	Operating?
RUF	Denmark	M/H	H/M	L	H	M	M	H
Serpentine	Switzerland	H	H	H	M	VL	M	M
Sky Train	USA, FL	Redesigned to incorporate fully proven light rail components				MH	M/H	N
Synchro-Rail	U.K.	Development of full-size prototype started in 2000 under government Smart grant, 1st transport version (an Inclinator) to be installed end of 2001, awaiting market interest						
System 21	USA, SC	M	H	M	L	MH	H	M/L
TAXI 2000	USA, MN	M	H	H	N	L/VL	H	L
ULTra	U.K.	H	H	H	H	L	H	M
Urbanaut	USA, OR,WA	M	M/H	M/H	MH	H	M	M

Symbols Used to Describe the Status of Design Engineering and Testing Programs for Each Technology

Dual mode systems in all capital letters.

Vehicle Development
H = Highly developed, fully built, being tested or ready for testing **M = Partially developed, some components and/or reduced scale prototype built and tested** **L = Still mostly on paper, some engineering studies completed** **N = All on paper or elsewhere**
Guideway
H = Highly developed, full scale or scale model built, some testing accomplished **M = Engineering design, analysis and cost studies completed** **L = Still mostly on paper, some engineering studies completed** **N = All on paper or elsewhere**
Command and Control Software
H = Software fully developed, simulation capability tested and available for application studies

M = Software designed, partially developed, no simulation capability available as yet **L = Concepts in mind, some preliminary studies completed** **N = Not much progress yet**
Testing Program
H = Test track built and being used for vehicle and software testing and demonstrations **M = Section of test track built, some testing accomplished** **L = Only small scale or prototype test facilities available** **N = No progress on test program other than planning so far**
Cost Target (rough estimate of system capital cost, which includes all necessary components for operational system - contact vendor for specifics)
H = More that $30 million/mile ($18.75/km) **MH = $20-30 million/mile ($12.5-$18.75/km)** **M = $10-20 million/mile ($6.25-12.5/km)** **L = $5-10 million/mile ($3.125-6.25/km)** **VL = Less than $5 million/mile ($3.125/km)**
Active Marketing Program?
H = Established and active sales/marketing program, some market research undertaken **M = Brochures, videos, extensive written materials, active website** **L = Some details and illustrations available** **N = Not ready for this yet**
Operational System Available for Inspection?
H = Test facility in operation and can provide rides and be inspected **M = Operating prototype available as are simulation results** **L = Illustrations and/or static models available** **N = Nothing available so far**

Source: Jerry Schneider, Emeritus Faculty Member, University of Washington, College of Engineering.

A. The Weeding-Out Process

As mentioned in the introduction of this report, all the existing and emerging technologies will experience a weeding-out process based on four dimensions. The victor technology will be one that either can satisfy all four dimensions adequately or one that receives a boost from a technological advance from outside the industry. The four dimensions of resistance were posited to be:

1. The driver's desire to travel farther, faster, independently and on an individualized schedule.
2. The manufacturers' and transportation planners' vested interest in minimizing adaptations of the current vehicular systems.
3. The cost of infrastructural changes imposed on transportation planning organizations.
4. The need for fast, inexpensive movement of labor and goods within a globalized economy.

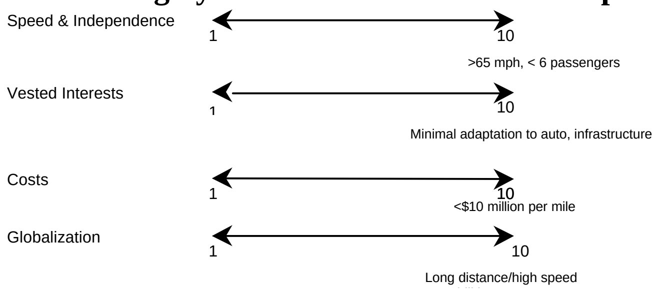
The following table merges Schneider's observations with VisionEcon's observations on the above four dimensions.

Table 6: VisionEcon Resistance Ratings©

System Name	Traveler's Desire for Speed, Independence (Rating 1-10)	Manufacturer's/ Planners' Vested Interests (Rating 1-10)	Costs of Infrastructure (Rating 1-10)	Ease of Globalization of Labor/Goods (Rating 1-10)	AVERAGE (Rating 1-10)
Aerobus	1	1	Unknown	1	1
Aeromobile-Aeroduct	10	1	10	10	7.75
Aeromovel	5	1	Unknown	10	5.3
Austrans	10	1	5	5	5.25
Cabintaxi	5	5	Unknown	5	5
CyberCab	5	8	10	5	7
CYBERTRAN	8	1	10	10	7.25
HSST maglev	10	1	1	10	5.5
Modern Transport System Corporation	Unknown	1	1	10	4
Magplane pipeline	5	1	10	10	6.5
MEGARAIL	10	8	10	10	9.5
MICRORAIL	10	8	10	10	9.5
Mitchell	5	1	10	1	4.25
ParkShuttle	1	1	Unknown	1	1
PRT 2000	10	1	Unknown	1	4
PERSONAL ELECTRIC RAPID TRANSIT SYSTEM (PERTS)	10	8	10	10	9.5
RUF	10	5	5	10	7.5
SERPENTINE	5	10	10	1	6.5
Sky Train	5	1	1	Unknown	2.33
Synchro-Rail	10	5	0	10	6.25
System 21	5	1	1	1	2
TAXI 2000	8	1	10	8	6.75

ULTra	10	1	10	1	5.5
Urbanaut	10	1	1	10	5.5

Rating System for Resistance of Transportation System:



An assessment of the above table shows that the systems that create the least resistance for success are all systems that profess high-speed, yet individualized service. The system that seems to reflect the most positive future is the Personal Electric Rapid Transit System (PERTS) program from Virginia Tech. PERTS resembles a pallet system for transporting vehicles. The system automates the transport by locating intelligent systems on each pallet. Thus, control is decentralized. In addition, the pallets exercise destination control and emergency management over pallet operations. This reduces the need for vehicle manufacturers to develop and embed new technologies into the vehicles. With the pallet system, there are minimal transition costs and barriers to adoption. The system can be placed on highway medians and pose little burden on shrinking urban real estate. Yet, travelers still receive what they strive for—high speed, in individualized vehicles, on their own schedules.

The only other systems that could approach the low resistance factors of PERTS were the Aeromobile/Aeroduct, Megarail and Microrail projects, Cybertran, the RUF system in Germany and the Serpentine in Switzerland. Both the Aeromovel and Aeromobile systems do not seem as attractive however. The Aeromovel system is simply a high-speed public mass transit system and, the Aeromobile system would require complete overhaul of the transportation system. In contrast, the Megarail and Microrail are close cousins to the PERTS concept—but, the development is at a much less advanced stage. The Cybertran is based on large numbers of small vehicles traveling on elevated guideways at speeds of up to 150 miles per hour. However, the Cybertran leaves the traveler with the age-old problem of finding their own way from the station.

In contrast, the RUF (Rapid, Urban, Flexible) system being built in Denmark consists of an electric car to run Type 1 travel; the car also possesses the ability to become part of a highly efficient "train" on an elevated guideway. The only drawback with RUF is that the vehicles require changes to the looks and the production of today's auto. Lastly, the Serpentine in Switzerland links small electric carts to transport travelers to destinations within town centers. Thus, it does not lend itself to globalized transportation needs.

Instead, this system represents a great option for Type 1 travelers within communities that experience inclement weather.

B. SURVEY OF EXPERTS

To support the evaluations made in the previous section, VisionEcon conducted a survey of transportation experts around the world. (The survey questionnaire can be found in Appendix B.) The six experts who responded with their opinions represented a perfect split between the private and public sectors. Two were transportation consultants, one was the innovator of the RUF system, two were managers within transportation-related agencies and the final response was from an academician.

The purpose of the survey was to separate the futuristic prophecies of the previous summary from the reality faced by Intelligent Transportation System experts on a daily basis. Most of the questions were formatted on a 1-10 rating system (1 = no truth to a statement, 10 = obvious truth). However, the experts were allowed to express their thoughts and opinions in other open-ended questions. One expert did not complete the rating questions. Thus, this expert's views were all based upon responses to the open-ended questions.

The overwhelming consensus of the survey suggested that all of the technology necessary to make the current transportation system more efficient and safe was currently available. The average rating (1 = no truth to statement, 10 = obvious truth) on this question was the highest of any question, at 8.8. The biggest hurdles to a safer, more efficient transportation system were professed to be cost (7.6 average rating) and the lack of a nationwide standard (6.4 average rating).

Most of the experts surveyed did not support the direction of the majority of the projects mentioned above. Many of those projects involved the centralized control of traffic. The average rating for the statement suggesting that transportation will become centrally controlled was 4.2 (1 = no truth to statement, 10 = obvious truth). However, one expert pointed out that the statement was ambiguous since it used the phrases "centrally controlled" and "automated highway systems" simultaneously. Some guideways and highways can become automated without central control, as the PERTS system exemplifies. Nonetheless, the tone of the respondents suggested that central control will not succeed in the transportation arena. As mentioned by Sarath Joshua of the Maricopa Association of Governments, a regional council of governments, there are many issues holding back the advancement of Intelligent Transportation Systems (ITS) in the U.S. Some are legal issues—such as liability, some are logistical issues—such as vehicular adaptability and costs, some are security issues and some are societal such as the differences between rural and urban transportation needs.

The experts believed that autos will continue to be the transportation system of choice (6.7 average rating), yet the autos will be reconfigured to include GPS, interactive traffic information and collision avoidance systems (7.3 average rating).

While the experts overwhelmingly agreed that the transportation system in aggregate would not lend itself to central control, they fishtailed on this issue for trucking. When asked whether they agreed that interstate trucking would become automated and centrally controlled they produced an average rating of 6.75. None of the experts had much faith in the establishment of an efficient public transit system (2.75 average rating).

The experts unanimously answered in the open-ended question concerning obstacles that the lack of funding or financial incentives was the largest obstacle. Richard Bishop, a transportation consultant, mentioned that an activist role from the public sector was needed to increase the market penetration of the new technology. He suggested two ways: "incentivize" buyers to buy and promote standards for cooperative sharing of data between vehicles and the overall system. Greg Larson of Caltrans backed up the views of Bishop reiterating that the first generation of ITS would be safety enhancement features advanced by the Intelligent Vehicle Initiative of the U.S. Department of Transportation and the second generation systems would entail cooperation between vehicles and the infrastructure. Larson agreed that there was a "suspicion" on the part of politicians and other decision makers concerning the benefits of ITS. Larson also mentioned the need for standards and interjurisdictional cooperation to assure a seamless system to the end user.

The main message from the experts: public transit innovations will not be the propellant of transportation systems in the future. The answer will be to automate current vehicles and infrastructure. Unfortunately, the future of dual mode transportation systems was not clear according to the experts. Two of the experts gave the validity of dual mode transportation a 1 rating, two experts did not rate dual mode, and the final two experts gave it a 5 and a 10!

C. A SUMMATION OF THE RESEARCH

As stated in previous section on routing decisions, until some type of synergy is achieved in ITS standards and between jurisdictions involved in ITS, the operations control centers will be of utmost importance in merging the collection and dissemination processes of travel information. As reiterated by Bishop and Larson, the cooperation between vehicles and the infrastructure would be the most natural and essential step in reducing congestion. Most of the other innovations neglect to handle one or more of the dimensions of resistance mentioned in the introduction. However, just as Larson pointed out, until there exists some recognition of the importance of the connections between vehicles and the transportation infrastructure, the operations control centers will play a monumental role of filling the void.

The successful cooperative vehicle-highway system will help address the resistance issues, while still allowing travelers freedom and choice.

V. THE MOST LIKELY VICTORS IN TRANSPORTATION TECHNOLOGY

Based on the analysis of the literature and the expert responses to the survey, the following seven technological developments seem most probable.

A. GPS

Global positioning systems (GPS) are here to stay. In fact, technologies that integrate GPS with routing decisions, GIS mapping or other applications will begin to proliferate. A great example of the importance of GPS comes from an industry that has been very resistant to change since the middle of the last century. Since the 1950s, the railroad industry has not evolved much. Yet, today the railroads are using streams of data including GPS to tell of a train's condition and location.[17]

B. TELEMATICS

In order to support an interactive environment between vehicles and the transportation infrastructure on which they are transported, vehicles MUST be connected. Thus, the telematics fields promise to be areas of great innovation and promise. A great example of such a network was achieved in December 2001 by the Munich-based company Definiens. Fifty cars were equipped with GPS, radio modems and car PCs. The cars sent images and messages between them and the system used this information to assign them to certain road sections. This decentralized traffic routing system optimized the route guidance even with only one percent of all vehicles equipped.[18] This work builds on another automation project, CHAUFFEUR, executed in Germany in 1999 where a lead truck was followed by a second truck under fully automated control on public highways. Funded by the European Commission, CHAUFFEUR II began in early 2001. Hence, more improvements will be on the way.

C. ADAPTIVE CRUISE CONTROL AND OTHER COLLISION AVOIDANCE SYSTEMS

One of the requirements of cooperative vehicle-highway systems is that information is collected on traffic conditions, and this information provides input into the algorithms that dictate speed or other repetitive driving actions. Without these external interventions, nothing will change on the congestion side of traffic management. However, due to resistance, liability and security concerns, individuals will always want the option of buying out of the new technology. Freedom and individuality will always be the key to participation in any new transportation systems.

[17] Phillips, Don. "Digital Railroad". *Technology Review.* March 2002.
[18] "Cars Exchange Information Without Centralized Infrastructure". *ITS View* Feature Article. ITS America. February 2002. <http://www.itsa.org/itsview.nsf>.

This area of cooperative vehicle-highway systems will require the most research. Reliability must increase and costs must decline before the technology will be ripe for such a system. Yet, strides are being made. Motorola Labs recently announced the breakthrough of a new chip design that will allow higher frequencies than the old circuitry. This will help to avoid problems with interference and also will help to lower the cost of the systems. Since cost was one of the most prominent obstacles mentioned by our experts—this breakthrough is significant.[19]

D. Loop and Video Detectors

In order for the above elements to work, the infrastructure must be set to detect traffic volume, obstructions and weather conditions. Thus, these pieces to the puzzle are of vital importance. Virginia Tech seems to be on top of this research, building a "Smart Road" as a research test bed.

E. Signal Control

Signal controls will be the key to automatically cut down on local congestion. This type of control is important for both Type 1 and Type 2 traffic.

F. Smart/Electronic Toll Collection tags

Many of the innovations occurring in Intelligent Transportation Systems seem to be imperceptible to the general public. As the technologies of electronic toll collection and smart card fare make revenue collection more effortless—more fee-based transportation services will begin to proliferate. Sarath Joshua of Maricopa Association of Governments believed that user fees based on time of day, road type and distance would replace gasoline taxes within 15 years.

G. Dual-mode Guideway Systems

While the experts downplayed the importance of these systems, VisionEcon begs to differ. With the all the transformations occurring in the "New Economy" as mentioned earlier in this report, there will be incessant pressure to find faster, cheaper ways to move labor and goods around the globe. In addition, there will be incessant pressure for transportation providers to recover costs for transportation infrastructure. On top of those pressures, environmental pressures will continue to escalate encouraging an alternative to the gasoline engine. Yet, travelers will still want speed and freedom, customization and choice. The only way to accommodate all these requirements is through some type of dual mode transportations system.

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[19] "The Next Workhorse". *ITS View* Feature Article. ITS America. November 2001. < http://www.itsa.org/itsview.nsf>

While many of the dual mode transportation system designs reviewed are overlooking at least one of the four resistance factors mentioned earlier in the report, the dual-mode concept is still very solid. Travelers want speed and freedom. Manufacturers, planners and current transportation providers want to keep adaptations to a minimum. Costs need to be practical and measurable. But, most of all, the Internet has turned our globe into a smaller place. Thus, people want to be able to purchase goods they find on the Internet from half-way around the globe. And, with a study of the subsequent generations completed in Phase 3 of this project—the next generations will become even more impatient for the delivery of their favorite products and people. Thus, pressures will build to merge some type of high-speed transportation alternative to the traditional trucking industry. Once again, Virginia Tech appears to be right on the mark with their PERTS system.

As mentioned in his article for The Futurist magazine, Francis D. Reynolds asserts that the dual mode concept has been envisioned by more than two dozen inventors.[20] Thus, just as the concept of a locomotive steam engine motivated many innovators to continue to delve into the possibilities despite many failures before them, dual mode enthusiasts will persevere. And, one of these inventors will probably succeed just as George Stephenson succeeded with his revolutionary concept of the steam locomotive in 1822.

Table 7: Likely Victors in Transportation Technology

Technology	Contribution to Future Technology Transportation
Global Positioning Systems (GPS)	Location detection of specific vehicles
Telematics	Connects cars to each other and a central source
Adaptive Cruise Control and Other Collision Avoidance Systems	Development of multiple sensors (both radar and optical), and the practice of sensor fusion
Signal control	Technologies to provide automatic control of traffic
Loop Detectors and Video Detection Systems	Groundwork for other cooperative vehicle-highway information systems
Smart/Electronic Toll Collection tags	Quick, easy collection system for providing transportation services
Dual mode Transportation Systems	Travelers are granted both individuality and speed with a minimization of congestion

[20] Reynolds, Francis D. "The Transportation System of the Future". *The Futurist*. September-October 2001.

VI. CONCLUSION

While transportation experts need to be reminded that this analysis was completed by an economist, it is clear that pressures will continue to build to create a transportation system that can move even more labor and goods with less congestion. On the surface it seems as though this mandate would represent an impossible wish list, but technologies are unfolding that could make such a system a reality.

In the meantime, transportation planners will benefit by working with communities to create more self-contained nodes that reduce the strain on traditional infrastructure for short, convenient and task-oriented trips. By freeing traditional infrastructure from this type of travel (Type 1), more resources can be dedicated to commuter/event travel (Type 2) and globalized travel (Type 3).

In this arena, the emerging innovations seem to point to the cooperative vehicle-highway system as the most likely victor in the transportation technology contest. This type of arrangement satisfactorily addresses the resistance factors placed by travelers, manufacturers, planners, service providers and cost structures. Still, transportation planners will need to set up surveillance systems to keep tabs on the highly innovative transportation technology fields. This area will become an area of innovation in the future as globalization places intensified pressure on the transportation system to move goods more quickly and inexpensively. Any breakthrough in magnetic levitation or automatic throttling will dictate the landscape of future transportation.

Until then, a continuous perusal of the transportation R&D occurring around the globe will provide planners with pieces of the puzzle that will compose the portrait of future transportation. As it took almost 200 years of connected “stepping stones” to piece together the first steam locomotive, it will take years of innovational steps to help produce a new transport for the “New Economy”. But, many clues will be unveiled by inventors along the way—for those planners that take heed.

Appendix A: Advanced Transportation Technologies

System Name	Location	Status of Design Engr.&Testing				Cost Target	Active Mkting?	Operating?
		Vehicle	**Guideway**	**C&C Software**	**Test Program**			
Aerobus	**USA, TX**	**Currently for sale, was operational several years ago in Europe and Canada. System currently being constructed in China**						
Aeromobile-Aeroduct	**USA**	**H**	**H**	**L**	**M**	**VL**	**M**	**M - ops. prototype available**
Aeromovel	**USA/Brazil**	**For sale, has been operating in Brazil for several years**						
Aerorail	**USA, TX**	**Conceptual only**						
Airtrain	**USA**	**Conceptual only**						
Austrans	**Australia**	**M/H**	**H**	**M**	**H**	**M**	**H**	**M**
Autoshuttle	**Germany**	**M**	**M**	**L**	**L**	**M/MH**	**M**	**M**
Autran	**USA**	**M**	**M**	**M**	**N**	**L**	**L**	**N**
AVT-Train	**USA**	**Conceptual only - high speed train that carries autos and people**						
Cabintaxi	**USA, MI**	**Extensive test facility and program completed in Germany in 1970's, control system needs update, shuttle version operational since 1976**						
City Mobility	**Netherlands**	**Conceptual Only**						
CULOR	**USA**	**L**	**L**	**L**	**L**	**L**	**L**	**L**
CyberCab	**Netherlands**	**H**	**H**	**H**	**H**	**L**	**H**	**H**
CyberTran	**USA, CA,NY**	**H**	**H**	**M/H**	**M/H**	**L**	**M/H**	**M/H**
Dragonfly MonoMetro	**U.K.**	**Suspended monorail, final stages of design, prototype to follow, patents pending**						
Electronic Guideway System (EGS)	**USA, CA**	**Conceptual Only - Quadmode small vehicle system**						
Evac. Tube Transport	**USA, FL**	**L/M**	**L/M**	**L/M**	**L**	**VL-MH**	**M/H**	**L/M**
Fast Tube System	**U.K.**	**L**	**L**	**L**	**N**	**-**	**M/L**	**L**
FlexiTrain	**New Zea.**	**M**	**M**	**M**	**L**	**VL**	**M**	**L**
Flyway	**Sweden**	**L**	**L**	**L**	**N**	**VL**	**M**	**L**
Higherway	**USA, WA**	**N**	**N**	**N**	**N**	**L**	**L**	**N**
HighRoad	**USA,GA**	**L**	**H**	**H**	**N**	**MH**	**H**	**N**

HiLoMag	USA, WA	National dual mode system with high-capacity synchronous maglev guideways (conceptual only)						
HSST maglev	Japan	For sale, extensive test and demo program completed, first application in Japan is underway						
Modern Transport System Corporation	USA, CA	Developing novel maglev system, some prototype components currently operational						
Modular Automated Individual Transport	European	L	L	M	L	VL/L	M	N - good documents
InTransSys	USA, CO	Dual mode concept, extensive documentation and video available						
MAGLEV 2000	USA, FL.	M	M/H	L	L	L/M	L	L
Magnetrans	USA, CA	H	M	H	M	M	H	M
Magplane pipeline	USA, MA	H	H	H	H	VL	M	H
Magplane passenger	USA, MA	M	M	M	L	MH	H	N
MegaRail	USA, TX	M	M/H	L	L	VL	H	L/M, Video available
MicroRail	USA, TX	M	H	L	L	VL	H	Prototype early '02
Mitchell	USA, VA	M	H	M	H	L	M	N - but ops. video avail.
Monomobile	USA, OH	M	M	L	M	VL	M	M
ParkShuttle	Netherlands	Two systems in full operation (Amsterdam Airport since late 1997 and Rotterdam since early 1999; more systems being deployed						
Pathfinder	USA, MI	M	L	L	L	M	M	L
PRT 2000	USA, MA	Development and test program completed in 2000, awaiting market interest						
Personal Electric Rapid Transit System (PERTS)	Virginia,USA	Maglev, dual mode concept, developed at VPI, scale model constructed, video available						
Rideway	USA, CA	Conceptual only, moving beltway with passive vehicles						
Roadrunner	USA/UK	A very large bus concept						
RUF	Denmark	M/H	H/M	L	H	M	M	H
RUMBA	Germany	Conceptual only, tube transport concept						
Segway	USA	Conceptual only - a palletized dual mode concept						
Serpentine	Switzerland	H	H	H	M	VL	M	M
Skybikes, Bike Trains	USA	Conceptual only- specially designed facilities for serious bike transport						

Sky Train	**USA FL**	**Redesigned to incorporate fully proven light rail components**				**MH**	**M/H**	**N**
SkyTran	**USA**	**Conceptual only - high speed, small vehicle, low cost, maglev**						
SmartSkyways	**USA, CO**	**L**	**L**	**L**	**N**	**L**	**L**	**L**
Synchro-Rail	**U.K.**	**Development of full-size prototype started in 2000 under government Smart grant, 1st transport version (an Inclinator) to be installed end of 2001, awaiting market interest**						
System 21	**USA, SC**	**M**	**H**	**M**	**L**	**MH**	**H**	**M/L**
TAXI 2000	**USA, MN**	**M**	**H**	**H**	**N**	**L/VL**	**H**	**L**
ULTra	**U.K.**	**H**	**H**	**H**	**H**	**L**	**H**	**M**
Urbanaut	**USA, OR,WA**	**M**	**M/H**	**M/H**	**MH**	**H**	**M**	**M**
VMTS	**USA, WA**	**Conceptual only - uses large truck to haul small electric vehicles on freeways**						
Whoosh	**U.K.**	**Conceptual only - monorail that uses compressed air for propulsion**						

Symbols Used to Describe the Status of Design Engineering and Testing Programs for Each Technology

Vehicle Development
H = Highly developed, fully built, being tested or ready for testing **M = Partially developed, some components and/or reduced scale prototype built and tested** **L = Still mostly on paper, some engineering studies completed** **N = All on paper or elsewhere**
Guideway
H = Highly developed, full scale or scale model built, some testing accomplished **M = Engineering design, analysis and cost studies completed** **L = Still mostly on paper, some engineering studies completed** **N = All on paper or elsewhere**
Command and Control Software
H = Software fully developed, simulation capability tested and available for application studies **M = Software designed, partially developed, no simulation capability available as yet** **L = Concepts in mind, some preliminary studies completed** **N = Not much progress yet**
Testing Program

H = Test track built and being used for vehicle and software testing and demonstrations **M = Section of test track built, some testing accomplished** **L = Only small scale or prototype test facilities available** **N = No progress on test program other than planning so far**
Cost Target (rough estimate of system capital cost, which includes all necessary components for operational system - contact vendor for specifics)
H = More that $30 million/mile ($18.75/km) **MH = $20-30 million/mile ($12.5-$18.75/km)** **M = $10-20 million/mile ($6.25-12.5/km)** **L = $5-10 million/mile ($3.125-6.25/km)** **VL = Less than $5 million/mile ($3.125/km)**
Active Marketing Program?
H = Established and active sales/marketing program, some market research undertaken **M = Brochures, videos, extensive written materials, active website** **L = Some details and illustrations available** **N = Not ready for this yet**
Operational System Available for Inspection?
H = Test facility in operation and can provide rides and be inspected **M = Operating prototype available as are simulation results** **L = Illustrations and/or static models available** **N = Nothing available so far**

Source: Jerry Schneider, Emeritus Faculty Member, University of Washington, College of Engineering

Appendix B: A Survey of Experts

Name		
Title		
Orga nizati on		
Part 1:	**ITS Systems: Safer, More Efficient Movement Within Current Transportation Systems**	
Please rate your acceptance of the following statements on a scale of 1-10. 1 = No truth to statement, 10 = Obvious truth		**Rating**
1	The technologies necessary for making the current transportation system more efficient and safe are already available.	
2	The biggest hurdle for implementation of this phase of ITS is:	
	• Cost	
	• Driver resistance to new technology	
	• Driver resistance to changing transportation habits	
	• Automobile manufacturers' inertia	
	• Lack of nationwide standard for equipment, software or telecommunications protocol	
	• Telecommunication bottlenecks (lack of spectrum)	
3	Please write a summary of your visions for the traffic management and safety phases of future ITS. Also, please give your best estimate on the time requirements for their possible implementation.	**Time period for impleme ntation**
	Vision	

Part 2:	**ITS Systems: New Methods of Transportation**	
Please rate your acceptance of the following statements on a scale of 1-10. 1 = No truth to statement, 10 = Obvious truth		**Rating**
1	Eventually, transportation will become centrally controlled. Automated highway systems will become the predominant means of transport.	
2	A summary of the evolution of transportation technology suggests that there could be four paths to future transportation systems. Please rate the probability of the following paths and sub-statements on a 1-10 basis.	
	Path 1: Continuation of the Current System with ITS features that focus on improving safety and efficiency within current transportation modes, requiring minimal new equipment to automobiles, and demanding minimal modifications to driver behavior.	
	• The majority of autos will be equipped with high-tech navigational systems such as GPS, interactive traffic detection and collision avoidance systems.	
	• U.S. drivers will not willingly sacrifice the image and freedom offered by the current automobile industry despite promises of time savings and convenience from other future transportation systems.	
	Path 2: Slight Changes to Current System of automobile transportation.	
	• Platooning will be the closest the auto industry will get to automated, centrally controlled systems.	
	• Interstate trucking will become automated and centrally controlled.	
	Path 3: Predominance of a Public Transit Systems characterized by high-speed trains, smart card payments, programmed routes and individualized scheduling.	
	• Magnetically levitated trains will become the public transit of choice.	
	• Train cars will be more individualized modules rather than large vehicles to move the masses.	
	Path 4: Dual-mode Transportation Systems that allow an individual freedom and vehicle ownership, but centrally program highway driving.	

Other promising developments in ITS and your estimate of the time requirements of implementation. **Time Period for Implementation**
Please list all obstacles to any/all ITS systems and what would be required to overcome them. **Required Environment to Overcome**