Beyond Traffic – Choosing the Future

Introduction

US DOT's report *Beyond Traffic, 2045, Trends and Choices* (*Beyond Traffic*) ends with the insightful statement "The future is always a choice". The document provides a comprehensive look at current trends impacting transportation today and paints an unappealing picture of where we might be headed if these trends continue. Already, 65% of roads are rated in less than good condition, 45% of people lack access to transit, and "new financing mechanisms" are needed.

The specific predictions for 2015-2045 include:

- Growth of people and freight
  - 70 million more people of which 75% are absorbed by emerging megaregions
  - 45% more freight volume
- Energy production and export growth by rail
- Negative impacts on infrastructure from climate change
- As a result, according to DOT Secretary Foxx's introduction:
  - "the transportation system will slow us down"
  - "transit systems will be backed up…riders will wonder if they will get there at all"
  - "at airports and on the highway, every day will be like Thanksgiving day now"

Some specific problems might best be addressed through advanced transit systems, yet they are not mentioned (though robotic cars are).

This paper has been developed in order to bring attention to different driverless car-centric and driverless transit-centric futures that could emerge. While the differences have been deliberately emphasized here, it is believed to be important to seriously consider and evaluate these differences and their potential impacts on quality of life. Driverless technologies will doubtless bring radical changes to all forms of transportation. Only by understanding the significantly different changes that could emerge can we even begin to think about influencing future outcomes. The path of least resistance may lead to a future that is less than optimal.

While *Beyond Traffic* briefly recognizes recent trends towards driverless automobiles and cautiously speculates as to how they may impact transportation in the future, it does not recognize similar trends in transit and the potentially huge impact driverless vehicles could have as part of advanced transit systems. In addition, while it recognizes that our transportation infrastructure is crumbling, it never considers that the time may be ripe for a change toward a different infrastructure. Finally, while it seeks public input, it does so in an unstructured manner and without providing the public with alternative future scenarios from which to choose.

This document recognizes that *Beyond Traffic* provides invaluable information and motivation to consider the changes that need to be made to secure a better transportation future. It attempts to build on this background information, as well as recent emerging trends in driverless transit, to speculate on two very different futures that could emerge.

In one of these futures driverless cars predominate, vehicle miles traveled continue to increase and cities continue to devote some 50 percent of land area to transportation. Driverless taxis serve a transit role augmenting conventional transit which is scaled back to serve high-demand situations.

In the other future, transit has mostly evolved into small driverless vehicles providing a very high level of service and running on mostly-elevated, lightweight guideways (often called automated transit networks or ATN, but referred to here as driverless transit). Public transit mode share increases significantly and cars are still used, but in greatly reduced numbers. Many existing rail-based transit systems continue to operate and are integrated with the new networked systems.

Much work is needed to evaluate the pros and cons of these two different futures as well as other scenarios that may lie between, or beyond, them. It is possible that no evaluation will ever reveal that one is significantly advantageous over another. However, what we can do now is to paint "pictures" of different scenarios and imagine what life would be like in these future situations. We can hold public workshops to develop and discuss these different scenarios. We can gauge public opinion about them. If we find the public generally has a preferred future and if studies show this scenario is practically better, or not much worse, than others, then it seems we owe it to ourselves to work towards this future in any way we can, especially if it is more environmentally sustainable (a goal frequently mentioned in the report).

The approximate timeframe for this analysis is 2045. The purpose is not to undertake an exhaustive analysis that will withstand all scrutiny, but rather to begin a debate about the future we may be headed for and the possible future(s) for which to strive. Regardless of which of the futures addressed here is preferred, it seems that both have their pros and cons, but current market forces appear to favor driverless cars over driverless transit. Leveling the playing field may be a wise approach that could help protect the best of both futures for following generations.

Comparison of Driverless Car- and Transit-Centric Futures

This section evaluates how the different futures could impact significant transportation issues. For each issue both futures are considered and, based on the arguments made, a winner is determined if there is a fairly clear choice. In both scenarios, it is assumed that there is a concerted move towards driverless vehicles.

Table 1. Scenario Comparison Summary

Driverless Car-Centric Future	**Driverless Transit-Centric Future**
Transportation infrastructure remains unchanged	Some roads and road widening are replaced by overhead lightweight guideways
Vehicle types remain unchanged despite becoming automated	There is strong trend towards smaller vehicles (transit and goods/freight) enabled by automation
Automobile miles traveled increase	Automobile miles traveled decrease
Pavement dominates land use (but with some reduction in parking needs)	Communities become more walkable with some being entirely car-free

In the Driverless Car-Centric Scenario, it is assumed that present transportation infrastructure remains much the same, as do vehicle types. The difference is that cars, trucks, buses and trains convert to being driverless as market forces dictate (regulations are not assumed to be a barrier).

The present decoupling of infrastructure use and cost remains unchanged such that large vehicles continue to not entirely shoulder the burden of the damage they do to infrastructure. Road infrastructure and transit capital and operating costs continue to be heavily subsidized.

Driverless cars predominate, vehicle miles traveled continue to increase and cities continue to devote some 50% of land area to transportation. Driverless taxis serve such an effective transit role that conventional transit survives only because it is subsidized and needed by captive users. Freight and goods transportation utilize driverless large vehicles which continue to pound the roads and still cause (though much less frequent) fatal accidents.

Google's Driverless Car

In the Driverless Transit-Centric Scenario, it is assumed that infrastructure use and cost is more closely coupled. This is assumed to result in many large transit, goods and freight vehicles being replaced by much smaller driverless vehicles with dramatically less impact on infrastructure. These smaller vehicles travel on lightweight guideways that are mostly elevated, but sometimes at, or even below, grade.

Vectus's Driverless Transit

Cars are still used, but in greatly reduced numbers. In some new neighborhoods there are no roads. Transit stops are at grade in the back yard of every single-family home (six to eight homes are clustered around a station) and attached to an upper floor of all larger buildings. The transit system carries people and goods, while also removing trash and responding to most emergencies. Large freight vehicles are much fewer in number, used only for large items, and travel on restricted routes/lanes only. Much freight, even bulk items like coal and oil, is transported in numerous small vehicles.

Driverless transportation has disaggregated passengers and goods and the new infrastructure costs less to build and maintain because it carries maximum vehicle loads that are about 10 percent of present-day loads. In this scenario the land surface is gradually reclaimed from transportation, walking and biking become much more viable and the quality of life is quite different, possibly dramatically so.

The following sections compare the two scenarios on the basis of key factors, beginning with safety.

Safety

Driverless Car Scenario

No one would fly if airplanes killed as many per passenger mile as do automobiles. Somehow we have come to accept this horrendous accident rate and just live with it. Fortunately, this is an issue where driverless cars are likely to have a very significant impact. Much of the automation already implemented in cars is aimed at making them safer and, judging by recent statistics, is already having an effect. This is the primary factor generally touted by automakers when they discuss their moves towards driverless cars.

Safety benefits are likely to be significant well before driverless cars are in the majority. It seems probable that many multi-vehicle accidents will be avoided if only one of the vehicles in the potential crash is driverless.

Driverless Transit Scenario

Driverless transit has an impeccable safety record with zero injury accidents in approximately 200 million passenger miles. The safety requirements for driverless transit are orders of magnitude higher than those for cars and likely much higher than those for driverless cars. Indeed, if driverless transit requirements were applied to driverless cars, they would be unable to operate at today's speeds and following distances and would become a major cause of added congestion.

This scenario has more people using transit, which is even safer than driverless cars.

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Driverless Transit Scenario

Capacity/Congestion

Driverless Car Scenario

Many think that capacity increases and congestion decreases will result from automated cars. This could be true but, unlike safety, these benefits may take decades to appear, if at all, since they are dependent on many complex factors.

Headway. The capacity of a lane of roadway is simply a factor of the number of vehicles passing a point in an hour. A freeway lane typically has a capacity of a little over 2,000 cars per hour. This equates to about a car every second or two (let's use 1.5 seconds). Another way of saying this is that the average headway (time between cars) is 1.5 seconds. For driverless cars to increase capacity, headways must be reduced below an average of 1.5 seconds. There is one factor which may make this feasible – the much faster reaction time of a driverless car than a human driver. However, widespread achievement of sub-second headways may be a long time coming, for the following reasons:

- Traveling at sub-second headways will feel like following too close to the occupants of the driverless car. Perhaps they will become accustomed to this with time. However, it will feel like being tailgated to the car ahead. If this car is not also driverless, the driver is likely to react in some way – probably by tapping the brakes, slowing down and elongating the headway in front of him/her. Thus sub-second headways may not be practical until (almost) all cars are driverless.

- Perhaps even more of a hurdle is the motivation of the car manufacturers, which is simply to sell more cars. The primary computer-enabled feature they are focused on is safety. Reducing congestion is a noble cause, but one that must be solved by the community as a whole, not the individual manufacturer and especially not at the cost of safety. Thus it would seem that manufacturers will be motivated to provide the longest headway possible commensurate with their vehicles being able to operate seamlessly in mixed traffic. This is very likely to be greater than one second. Furthermore, given the laws of physics, this headway is likely to be even longer at higher speeds and in inclement weather. If driverless cars are more cautious than humans in inclement weather, they could dramatically increase congestion in these conditions.

- Vectus PRT developed its personal rapid transit (PRT) system using linear induction motors for both propulsion and breaking – rendering it independent of the wheel/track interface (and thus inclement weather) for safety. Nonetheless they use a minimum headway in the 3 – 4 second range for speeds up to 43 mph, despite capacity being an important factor. This casts significant doubt on the ability of a driverless car to safely achieve sub-second headways in mixed traffic and an uncontrolled environment in good weather, let alone inclement weather.

Since drivers will resist being tailgated, manufacturer motivation will likely be low and difficulty high, sub-second headways seem unlikely prior to 100% of the fleet being automated, and potentially for long afterwards.

The one area where automation could increase capacity quite soon, is in truck traffic. To the extent that trucks can platoon together at very short headways, they are likely to reduce congestion. However such platooning may be problematic on busy streets and freeways because it would hamper lane changes by other vehicles.

Vehicle miles traveled. This is another fairly complex issue with uncertain results. Numerous benefits could potentially derive from driverless cars, but many of these could increase vehicle miles traveled (VMT) and thus congestion. If a person can sleep/read/work during their commute, they might choose to live further away from work and might not care so much if they commute during the peak periods. If a car can park itself, people might send their cars some distance to find cheaper parking – perhaps even all the way home – essentially doubling the cars' daily miles travelled. People may have little, or no, reluctance to sending their cars home during peak periods – adding even more to congestion.

On the other hand ridesharing could reduce VMT. This concept, which has struggled to produce results for decades, is now gaining some traction with the proliferation of cell phones. However, only to the point that the decline in carpooling from 1980 to 2010 appears to have been arrested (American Association of State Highway Transportation Officials (AASHTO), *Commuting in America, 2013*). Some believe a more significant increase might be possible if driverless cars were to behave like taxis. However, driven taxis do not seem to presently involve much ridesharing, even though they are undoubtedly more expensive than driverless taxis will be. Furthermore, there is a possibility of automated taxis being more strictly regulated than driverless cars. If regulated like automated transit, headways in the order of 3 – 5 seconds are likely and these vehicle then may not be practical on the open road.

Driverless Transit Scenario

Since the driverless transit scenario involves new transit infrastructure, it will immediately begin to reduce road congestion as soon as it is deployed. The extent of congestion relief will largely be proportional to the mode share the new form of transit attracts. As shown in Figure 1, different studies from around the world, using different methodologies, all indicate that adding ATN to the existing transit mix will dramatically alter mode share.

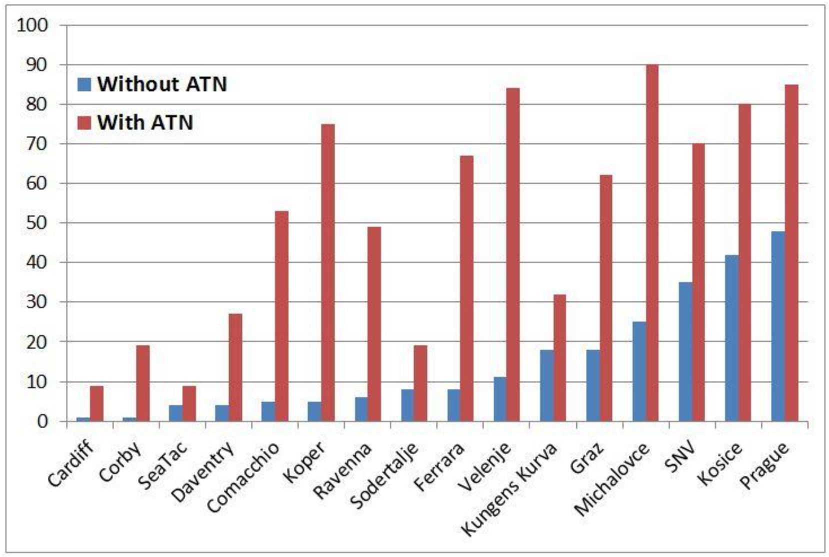

Figure 1. Transit mode share with & without ATN (driverless transit)

Source: Studies in named cities

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Driverless transit scenario

Infrastructure

Driverless Car Scenario

In this scenario the present types of infrastructure remain in use in approximately the same proportions. Heavy trucks continue to form a significant proportion of the traffic and to have access to most road surfaces that have to be built to withstand these loads. According to AASHTO, a single 80,000 pound truck applies the equivalent pavement stress as 7,000 to 19,000 4,000 pound automobiles. To the extent that driverless cars do not reduce or add to congestion, new infrastructure must be added to keep pace with population growth.

Driverless Transit Scenario

In this scenario a significant portion (50% or so, according to Figure 1) of urban travel shifts to small automated vehicles on elevated guideways. Despite supporting much lighter loads, these guideways probably cost more to construct per lane mile than roads because they are elevated. However, due to ridesharing and efficient vehicle spacing, they also have greater capacity per lane mile by a factor of at least two (the Vectus PRT system in operation in Suncheon, Korea has a theoretical line capacity of 7,200 passengers per hour). Indications from ATN systems that are in service are that there is a high tendency to rideshare, with vehicle occupancies doubling during peak periods.

New elevated transit systems are likely to be introduced in areas with high congestion. Thus the new guideway infrastructure is likely to replace additional surface roadways that would otherwise be needed.

In this scenario heavy truck traffic is expected to be much reduced with a significant amount of freight and goods being transported on the ATN system. This reduces the lane miles needed for heavy vehicles as well as the need for distribution centers and the additional VMT associated with them.

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Draw

Severance

Severance refers to communities divided by transportation infrastructure such as roads and railroads that are difficult to cross.

Driverless car scenario

Even if driverless cars do reduce congestion, the best that can reasonably be expected is that the need for wider roads is diminished in the future. Thus, severance will remain an issue. The only slight improvement may be that fewer surface parking lots are needed allowing facilities to be more closely spaced.

Driverless Transit Scenario

Since, in this scenario, a significant portion of traffic is moved to overhead guideways, some existing roads could possibly be narrowed and the need for roads in new developments could be significantly reduced.

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Driverless Transit Scenario

Energy use

Driverless Car Scenario

With this scenario, the movement of people and goods is expected to continue much in the same fashion as at present. While building solar collectors into road surfaces may be possible, the frequent resurfacing required for roads seems to indicate that it may not be cost-effective. Thus the only changes in energy use will come about from improvements in energy efficiency of the propulsion and heating/cooling of the vehicles involved.

Driverless Transit Scenario

In the driverless transit scenario, there is a significant move towards smaller vehicles enabling better matching of supply to demand, unlike trains or buses where large vehicles run mostly empty in off-peak periods. Existing ATN systems use less energy per passenger mile than cars or transit. ATN systems that use hard wheels on rails tend to be more energy efficient.

Furthermore, people have been observed to naturally share rides when using driverless transit systems at Heathrow Airport and in Masdar City, just like they do when using elevators. Since driverless transit systems operate from station to station, it is much more feasible to promote ridesharing than it is with taxis. When it comes to shipping of goods, it is clear that it is easier to dispatch the exact number of small vehicles needed than to ensure each large truck is full. Also the need for redistribution from sorting facilities will be reduced.

With their elevated guideways, driverless transit systems offer new infrastructure upon which solar panels can be mounted. In this way they could generate most, or all, of their own energy from a renewable source.

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Driverless Transit Scenario

Cost

Based on the previous discussion, infrastructure capital cost can be assumed to be a draw. However surface pavements tend to have a design life around 20 years compared to 50 for elevated structures, so maintenance costs should be lower for driverless transit infrastructure. Energy costs can be assumed to be lower with the driverless transit scenario due to lighter vehicle weights, less empty vehicle movement and greater ability to use renewable energy (including self-generated electricity from guideway-mounted solar panels).

Other costs include the capital costs of vehicles and associated control systems, and the operating and maintenance costs of the driverless transportation systems. As previously discussed, the driverless transit scenario is expected to result in more ridesharing and less empty vehicle movement. This should lower the capital costs of vehicles, as should mass production. Furthermore, the driverless transit systems will operate in a more exclusive environment (on separated guideways) leading to simpler, less expensive control systems and much lighter vehicles with lower requirements to be robust (ability to withstand potholes and accidents). Maintaining lighter, simpler vehicles constrained to operate on fixed guideways will also be less expensive.

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Driverless Transit Scenario

Greenhouse Gases

With lower energy use, use of electricity instead of fossil or agricultural vehicle fuels, and increased opportunity for renewable energy production, it follows that the driverless transit solution will produce far less greenhouse gases.

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Driverless Transit Scenario

Walkability and Use of Low-Power Vehicles

Reduced severance and surface traffic will undoubtedly lead to increased walkability in the driverless transit scenario, enhanced by devotion of land areas below ATN systems to sidewalks or development of low-power vehicle pathways. The driverless transit scenario will allow much greater density in urban development or redevelopment without the concern that density creates too much auto traffic in existing neighborhoods.

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Driverless Transit Scenario

Real Estate

Many studies have shown that close proximity to fixed guideway transit such as trolley or light rail stations, increases real estate values. ATN stations should be no different. Furthermore, it is anticipated that car-free communities can be developed that have higher property values, yet cost less to construct.

Winner

Driverless Transit Scenario

Making the Choice

The above discussion seems to point to the driverless transit scenario being quite significantly more desirable. However, the analysis is not detailed and we readily admit favoring driverless transit, having previously come to this general conclusion after studying this issue for many years. The point is that this conclusion may be game changing and preferred by most people, as indicated by limited feedback from a number of public workshops.

The choice we face is that of either continuing to let market forces and weak central planning dictate the future scenario that evolves, or verifying the preferred alternative and taking the steps necessary to see that it develops. While the driverless transit scenario is potentially much more cost-effective, it requires new thinking and new infrastructure in order to gain a foothold. Assuming we choose to foster driverless transit, four primary actions we could take are addressed below. The Advanced Transit Association is prepared to play a significant role in all of the processes outlined.

Develop and analyze future scenarios

This paper has taken an initial stab at doing this. However far more work is needed in order to be able to present the public with a stronger analysis of the probable outcomes of different scenarios.

Obtain Public Input

It is entirely insufficient to just ask the public what they want. As Henry Ford is reputed to have said, "If I had asked my customers what they wanted, they would have said, "a faster horse."". A more informative, iterative scenario development process based on public feedback is needed. A rough outline of such a process is presented here.

Public workshop process

The process starts with workshops, held around the country, seeking feedback on what the characteristics are that people prefer in transportation systems. These facilitated workshops help participants determine which characteristics should be used to measure potential scenarios. They might come up with characteristics such as reliability, trip time and costs. The facilitator might encourage consideration to be given to a more detailed breakdown of trip time into waiting and travel time and costs into fare costs and public subsidies. Once the characteristics to be measured are agreed upon, the participants should vote on their importance and each characteristic should be weighted accordingly.

Next, professionals involved in the development and analysis of future scenarios should present two or more scenarios and explain how they would work. The participants would then rank the scenarios in terms of how well each one would meet the previously-determined characteristics. The professionals would assist this process by providing relevant data from their scenario analyses. Finally, each scenario would be scored based on the weighted sum of the rankings for each characteristic. In previous applications of this process clear winners and losers have always emerged.

Facilitate the development of the preferred scenario(s)

An action plan needs to be developed to help the preferred scenario(s) come about, since it may well not be the one that is favored by market forces. This plan needs to address barriers to entry and seek to overcome them. It should address regulatory, political, economic, social and technical issues and develop budgets and actions necessary to steer development towards the desired future.

Iterate

The losing scenario(s) should be discarded and the winning scenario(s) should be further developed and analyzed based on the known public preferences. The action plan should be fine-tuned. This should be a continuous iterative process whereby new and better scenarios are developed, analyzed, publicly rated and implementation plans adjusted, all at suitable intervals of, say, five years.

Leveling the Playing Field

Regardless of what future scenario proves to be the most viable, there is a strong present need to level the playing field. Market forces and weak central planning presently combine to favor solutions, such as the driverless car scenario, that operate on existing infrastructure and can be implemented and acquired by the private sector with minimal government effort. Market forces include disparities in subsidies and incorrect perceptions, which lead to individual choices that are not reflective of true costs – the perceived cost per mile of an automobile trip is typically the cost of gasoline (10 ¢ to 20 ¢), whereas the societal cost has been estimated as high as $1.40.

Solutions, such as the driverless transit scenario, that depend largely on new infrastructure and procurement by public agencies, are presently at a major disadvantage. By continuing on our present course we are effectively choosing the scenario judged to be less desirable in the discussion above. Even if this judgment is found to be incorrect, it would seem to make sense to level the playing field and attempt to remove the considerable barriers to entry facing the driverless transit scenario. This effort should commence immediately in order, at a minimum, to allow transit to keep pace with the probable rapid development of new capabilities in the automobile sector. Some suggested actions follow.

Remove Biases from Technology Selection

Present rules, regulations, standards and guidance documents should be reviewed to remove references and requirements that are prescriptive as opposed to end-result based. An example is references to "corridors" which favor corridor-based systems over network-based systems. It is suggested that an alternative, more neutral, term that can be used is "service area". A second example is the requirement for so-called "brick wall stop" headways to avoid collisions. A recommended solution would be to require that the collision rate be kept below a specified amount by approved (but not prescribed) means. For example, European rail transit is required to have less than 0.15 fatalities per billion passenger kilometers.

Encourage Foreign Transit Technology Deployment in the U.S.

Driverless advanced transit systems are in public operation in six countries and commercially-available from four different suppliers, of which none are U.S. based. These foreign suppliers perceive the U.S. market as having formidable barriers to entry.

Furthermore, U.S. transit agencies often refuse to consider technology that is not in public service in this country. American-based developers of advanced driverless transit systems are struggling to raise capital since there is presently no local market for their systems. Encouraging the deployment of foreign systems will improve transit in the U.S. and help local developers by creating a market here. Therefore, incentives are needed to, at a minimum, require transportation planning agencies to fully consider advanced driverless transit systems as an alternative (perhaps a default alternative) in all future planning.

Some steps that could be taken include:

- Clarify and publish a summary of Federal and state-by-state regulations and requirements for automated transit systems including those related to:
  - Procurement
  - Labor
  - Safety
  - Local/disadvantaged businesses

- Require Federally-funded projects to consider advanced driverless transit options, where appropriate, based on current information of all applicable systems, regardless of country of origin/operation
  - Clarify Buy America requirements and, if necessary, modify to exclude advanced driverless transit systems when three or less similar suitable U.S. manufactured systems are in public operation.

Encourage Transit Professionals to Consider Advanced Driverless Transit

Transit professionals are not currently well informed about driverless transit – even those who are aware of it tend not to have the tools necessary to seriously consider it. Some actions that could be taken include:

- Mount a campaign to inform transit professionals of the existence and basic characteristics of modern driverless transit systems.
- Prepare guidance for considering advanced driverless transit options in Federal Transit Administration and National Environmental Policy Administration alternatives analyses processes.
- Require Federally-funded projects to consider advanced driverless transit options, where appropriate, based on current information of all applicable systems, regardless of country of origin/operation
  - Clarify Buy America requirements and, if necessary, modify to exclude advanced driverless transit systems when three or less suitable U.S. manufactured systems are in public operation.

Implement Demonstration Programs

Demonstration programs should be focused first on demonstrating the capabilities, upside potential and limitations of existing technologies, whether U.S. based or not. Once this is accomplished, demonstration programs to help develop and demonstrate emerging U.S.-based systems can be considered. The goals of demonstration programs should be:

1. Demonstrate the capabilities of existing commercially-available technology including:
    a. Speed
    b. Capacity
    c. Mode split
    d. Reliability
    e. Costs
    f. Scalability
2. Develop and demonstrate the capabilities of emerging U.S.-based technology

Conclusions

Beyond Traffic suggests present trends are leading us towards a troubled transportation future and it seeks public input to help reverse these trends. This is a much-needed worthy effort that will hopefully help avoid the worst. However, we should be striving to achieve the best, not just avoid the worst. If reasonable Federal transportation funding is reinstated and market forces continue to dominate, we will likely move towards a driverless car-centric future that is much safer than our present situation but only marginally improves the quality of life.

This paper suggests that a driverless transit-centric future may be more desirable for most people. The effort that would be required to investigate the two proposed different future scenarios, as well as many others, is miniscule in comparison to the major quality of life differences that could result. Steering future transportation development towards a preferred scenario will undoubtedly be more difficult but probably no more so than was committing to the interstate highway system.

We owe it to our children to seek out the best future transportation scenario and strive to bring it about.