**The Transformation of Transportation**

For the last century the transportation industry has been focused on the supply of infrastructure to support the ever growing fleet of vehicles and the greater number of miles driven by each vehicle. Our focus has been planning, funding, designing, building and maintaining roadways. Politicians, engineers, planners, financial managers … all of us have had this focus. We have experienced demand growth since the first model T was launched from the factory. Congestion in urban areas, safety and the economic need to move people and goods and to compete in a global economy has driven our thinking. ***The ability to supply infrastructure has been the measure of transportation performance.***

Roadways and transit properties are public goods. They are generally built by government, maintained by government and funded by gasoline tax revenue, though tolling has grown in prominence because of the inadequacy of tax revenue to satisfy ever increasing demand. Transportation has been a public works effort administered by public agencies with a substantial institutional momentum that has kept the planning focus on supply. It is a highly regulated, standardized and lengthy process with enormous political, social and economic implications. In recent years, we have begun to use managed lanes in an attempt to meter demand and policy has been developed around the management of demand. In effect, the transportation community has begun to “operate” infrastructure through price controls based on occupancy and congestion levels. ***The introduction of practical autonomous vehicular travel may be the tipping point to transform transportation from the provision of large scale public goods to the private provision of vehicles that will modify the demand for highway capacity.***

The development of autonomous vehicular travel will modify the collective demand for transportation infrastructure in ways that have perhaps not been fully appreciated. The deployment of autonomous vehicle features will occur as a result of competitive business agendas rather than a public policy formulation approach. Perhaps we have not fully considered the potential ramifications on existing transportation plans nor the rapidity with which it might occur. The combined effect on the need to develop additional transportation infrastructure (supply) will be cumulative as the percentage of vehicles with autonomous features increases and as the features on any one vehicle increases (demand).

This is not the first time that changes in the vehicle fleet affected transportation development. The increase in fleet fuel efficiency affected the ability to fund transportation infrastructure over a period of several decades and yet there was surprise when development slowed as a result. The demand for infrastructure did not decrease just because vehicles could go further on less fuel, there was just less money to provide for the growth in demand and the accumulated deferral of maintenance. Fuel efficient vehicles, electric vehicles and vehicles operated on propane, hydrogen etc. all “demand” highway capacity to operate. Autonomous vehicles, trip matching and other converging technologies could change transportation paradigms to an even greater extent and reduce demand.

**Autonomous Vehicle History**

In 1999 the annual meeting of ITS America in San Diego was the venue for a demonstration of autonomous vehicular travel. The demonstration project was limited to a few miles of expressway. It was essentially the combination of adaptive cruise control, which maintained distances between vehicles and lane alignment maintained by sensors embedded in the pavement edges that communicated with the vehicle. While operating in a controlled environment, it was nevertheless an impressive demonstration. It was clear that vehicle autonomy would have many benefits, however the barriers to such technology were considerable. Potential litigation as a result of equipment failure was high on the list of barriers identified. The cost to equip the vehicle fleet with adaptive cruise control and roadways with necessary sensors was seen as enormously expensive and would likely take decades. The regulatory considerations seemed at first insurmountable and questions such as determining which roadways should allow autonomous vehicle operation, the human interface requirements and a myriad of other barriers led policymakers and the industry in general to consider the practical implementation of autonomous vehicles to be decades away and perhaps not possible at all. Public sector interest and focus moved away from autonomous vehicles.

**So what Changed?**

The private sector has continued to develop the facets and features of vehicle autonomy and began to deploy them as commercially available accessories. On a parallel but radically different track fully autonomous vehicles were developed using visual sensors and advanced software and were driven on public highways and streets in normal traffic where the highly unpredictable human operators create instantaneous and wildly varying circumstances. Simultaneously, trip matching using smartphone locator technology, online payment software and instantaneous driver/passenger communications began to be deployed.

While these technologies continued in refinement and business models developed around the technologies, vehicle manufacturers and software developers began to see the business potential of the convergence. Manufacturers of automobiles have begun to more fully envision autonomous travel and have set business strategies for introducing autonomous features for the automobile. The automotive business competition has quickened. Customers can now choose whether they want adaptive cruise control, lane alignment, crash avoidance etc. As further deployment of these technologies occurs, the competition amongst manufacturers will further increase. The deployment of autonomous vehicles is becoming more a factor of commercial competition and individual economic choice than policy development. Autonomous features as accessories will be the reason a particular vehicle is purchased or not. Remember the introduction of navigation systems and how that affected vehicle choice?

At the most recent ITS World Congress the CEOs of General Motors and Ford announced the production of highly advanced automated vehicles and new visions of what the vehicle of the future will be. A centerpiece of automotive business strategy is the development of the autonomous vehicle. The introduction of autonomous features on automobiles do not require a full scale retooling as might be necessary to introduce a new model of vehicle, rather autonomous features are accessories. Most importantly, they can be implemented with dispatch. Self-driving vehicles are already on the market and more advanced control systems are being integrated into the concept of the autonomous vehicle.

The collaborative business potential of automotive companies, fully autonomous software and trip matching is difficult to predict but the convergence is clearly beginning to occur. While regulation may slow the process it seems unlikely to be a stumbling block, safety goals and economic competitiveness are too nationally significant. After all, other automotive features that have saved lives have been the result of regulation (air bags, seat belts etc.) and increased fuel efficiency has been partially a result of CAFÉ standards and high fuel prices.

**The Fully Autonomous Vehicle and Transportation Planning**

The question is not when the fully autonomous vehicle will become a reality but how the cumulative introduction of autonomous features and converging technologies will effect transportation plans and the need for transportation infrastructure.

The difficulty in predicting the need for transportation infrastructure based on demand is the lack of an understanding of the connection between demand and price for transportation. As with many public goods, it is difficult to relate the choice to consume a transportation public good with the cost. This is especially true for transportation since so few consumers of transportation infrastructure have any idea what it costs to travel on a highway or use a transit service. The one exception is perhaps the tolled highway and thus the resistance to tolling. In this environment, under the current paradigm of delivery, greater supply of transportation infrastructure (Interstate era) creates a greater demand which has fed a growing economy.

How might increasing vehicle autonomy affect this model? There will likely be a greater number of persons in the average vehicle and there will be more vehicle capacity derived from the same transportation infrastructure.

The average number of persons per vehicle may change as a result of new businesses being created. Several businesses have been established that offer drivers and passengers the ability to be matched. There has been some institutional resistance as long held business models are challenged but the convenience and economic benefit that can be derived creating growth of these services. Freedom from the responsibility and cost of driving and the opportunity for the driver to share or fully fund driving costs could result in more passengers in one vehicle. Single occupant vehicular travel has been a predominant and holding pattern in transportation but it may at last begin to change as the convergence of technologies increases. Even a small percentage increase in vehicle occupancy will have a significant effect on the demand for transportation infrastructure. It may not be immediate but it is likely. It is important to note that Uber was formed three years ago and is now valued at over $20 billion dollars is reported to be the largest taxi company in the world with over 350,000 vehicles.

The number of vehicles that can safely occupy a travel lane will be impacted by the introduction of advanced vehicle controls. The average safe driver leaves “one car length per 10 miles per hour” between vehicles (at least we have been taught to do so). As a larger and larger percentage of the vehicle fleet becomes capable of safe travel in less space, the capacity of the roadway increases. The demand for highway infrastructure is predicated on human control of a safe traveling distance and traffic and revenue are predicted based on these assumptions. Highway capacity manual assumptions will be increasingly inadequate as autonomous features are introduced. A consideration is whether and to what extent vehicles with adaptive cruise control should be allowed to intermingle with normal traffic. Should there be restrictions on how close a vehicle should be allowed to travel behind another and how does one know whether the vehicle behind is operated on adaptive cruise control or by an overzealous human operator unsafely?

**A Tipping Point**

Individual choice of a mode of travel is based on convenience, safety, economics and freedom. The populace is sometimes slow to adopt new technologies but convenient, safe and economical travel is a large factor in the quality of life. As more people in the US become seniors, mobility is a major factor in their quality of life. The ability to drive is many times synonymous with whether someone can maintain a home without assisted living services or even moving to a rest home. The autonomous vehicle could change that.

The many thousands of lives that are lost each year to automobile accidents could potentially be eliminated. The cost of automobile insurance could be reduced significantly. If given the choice of buying an automobile with accident avoidance versus one without, which would you select and the greater the number of such vehicles in the fleet the greater the savings in lives, time and money.

Imagine a largely autonomous vehicular travel environment. Commuters no longer own vehicles, the services are ordered up on a smartphone or similar device by providing the desired time and place of origin and destination (the quicker the travel time for a given distance, the greater the price). The vehicle could be individually owned, it could be owned and operated by a transit property, a corporation or a charitable organization. Ownership becomes somewhat irrelevant and such an environment would create a freely competitive marketplace that will seek its own level of supply and demand at a competitive price. For the consumer, travel becomes more convenient, more cost effective, safer and quicker. No longer is he or she faced with buying a vehicle, insuring it and then risking bodily harm to driving it. There would be no need to park it, maintain it or worry about it being scratched or dented in the parking lot. There may not even be a need for a driver’s license.

Where will the tipping point occur? Perhaps we have already passed it. Where we are in autonomous vehicle development is probably not the issue. It is clear that it is happening and ***we should dedicate our energies to planning for mobility and operating the transportation infrastructure to get the most benefit from existing transportation infrastructure.***

**Regulation or PPPs**

Regulation could be a significant restraint to obtaining this futuristic, autonomous environment but control by regulation will be limited and temporary because of the economic forces that affect the public at large. When viewed without its barriers to introduction, autonomous travel is a disruptive technology that will affect the private sector and public sector. Regulation may be introduced to minimize this disruption and attempt to smooth the transition but the transformation will continue. The private sector and the public sector can compete or they may support each other through various public private partnerships that focus on mobility and demand rather than the supply of infrastructure. Great opportunities exist!