Improving Urban Mobility through ITS

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Transportation has enabled the creation of the modern city, but the public's increasing need to travel and the difficulty of providing additional capacity to accommodate this travel has increased congestion and reduced mobility in many cities. Current technology for intelligent transportation systems (ITS) offers the potential to improve the operations and efficiency of travel by providing information that can help drivers make better use of existing facilities. But the pervasive congestion already apparent in many cities cannot entirely be overcome with current technology alone. This paper offers a vision of how future transportation technology can be used to improve mobility and the quality of life in cities.

Transportation and Growth

Both population and number of households have continued to increase in most urban areas, and the need to accommodate this growth is accepted. This growth can be accommodated in the urban infrastructure through rebuilding existing structures (e.g., often by increasing the density of housing units or increasing the concentration of workers), through infill development (e.g., building on available brown fields), or by extending the boundaries of the urban area by building upon the fringe. The utilization of fringe areas is often the most controversial, but inevitable response. As the urban areas expand, some expansion into the adjacent area can be expected. But simply building housing in formerly rural areas often provides relatively inexpensive housing units without the same transportation infrastructure (and service) that has been developed over an extended time in the rest of the area. This shortcoming in the infrastructure, coupled with the longer travel distances to existing work places and other services, causes major increases in automobile travel. This in turn burdens the rest of the urban area through saturation of already crowded roadways and through adverse environmental effects caused by the proportionally longer trips.

Transportation demand has typically greatly exceeded the population growth, and while most people would agree that the resulting problems must be solved, the choice of methods is controversial. The relationship between transportation services and the quality of life in an urban area suggests that transportation improvements will benefit the urban area if the improvements facilitate the movement toward an "ideal" structure of the urban area. An ideal structure is an abstract idea, however, and is not likely to be defined much less agreed upon or realized. For the purposes of this paper, the "ideal" urban structure will be assumed to offer a rich diversity of housing, employment, commercial, social, and cultural choices that can be accessed readily through an effective transportation system.

Our existing urban areas offer many prototypes for elements of an ideal" structure, although the limitations of current transportation technologies, and fundamental economic and societal factors that limit deployment of transportation services, have prevented any urban area from achieving an "ideal" structure by anyone's definition.

Transportation Improvement Goals

A premise of this paper is that diverse residential and commercial uses will be well served by socially and economically responsible transportation systems that meet both current mobility needs and those in the foreseeable future. The following general goals are proposed to guide the introduction of transportation improvements that can support an “ideal” urban structure: (1) provide balanced and effective transportation services; (2) protect and enhance the urban structure; (3) avoid congestion for all modes, and the resulting costs and other negative consequences; (4) encourage the use of sustainable modes; (5) encourage the use of more efficient automobiles and travel patterns; and (6) divert automobile trips to other modes, but preserve the availability of automobile travel.

Achievement of these goals implies that several improvements must be made to the transportation structure and services that are typically available throughout urban areas. First, transit service must be significantly improved and expanded to provide efficient and attractive alternative travel opportunities. Service must be extended so that the entire urban area, other than the fringe, is well served so that virtually all residents can commute to their workplace and fulfill other travel needs through transit. To be attractive, the transit service must be capable of providing competitive travel times and service as compared to automobile travel. Transit stations/stops and local activity centers must also be accessible by pedestrian/bicycle travel. Commercial vehicle movements must be accommodated more efficiently so that delays are avoided and environmental impacts diminished both for inter-city and intra-city travel. Automobile travel must be changed to achieve greater efficiency and fewer adverse environmental impacts by diverting travel (particularly longer trips) to other modes, by utilizing more efficient vehicles, and by avoiding congestion.

These changes to the current transportation system are not feasible without the introduction of innovative solutions such as the use of new transportation technology.

Transportation Technology

The technology that offers the most potential to address the structural problems in cities has been termed automated vehicle guidance. Automated vehicle guidance (AVG) is a technology that allows individual vehicles to move without physical control by a driver. Initial concepts for AVG were identified decades ago, and a project sponsored by the Federal Highway Administration demonstrated basic AVG concepts for automobiles and buses in San Diego, California, in 1997.

Although AVG technology has taken many forms, the most common elements include in-vehicle and roadway infrastructure components. The in-vehicle components might include: (1) a controller/processor; (2) sensors to detect the presence of other vehicles, the location of the roadway, and the placement of the vehicle on the roadway; (3) an interface with the in-vehicle communication bus to provide information such as current speed, acceleration rate, direction of movement, and status of steering, accelerator, and braking controls; (4) actuators by which the system can control the throttle, brakes, and steering; (5) a radio transceiver to communicate to and from other vehicles and the infrastructure; and (6) human interface displays and controls. The roadway infrastructure components might include: (1) the roadway itself, which may or may not be dedicated to AVG vehicle use; (2) roadway markings used to delineate the roadway to the vehicle; (3) traffic control devices such as signals that can regulate the flow of automated and manually driven vehicles at points of intersection; (4) access control facilities to restrict use of the facility and protect the automated vehicles from external threats such as animals or errant vehicles; (5) a traffic management system that can direct the flow and protect the safety of all vehicles; and (6) roadside transceivers to communicate with the automated vehicles.

AVG technology with similar components has been applied experimentally to control passenger cars, buses, and trucks. Initial concepts have typically assumed that AVG vehicles would operate on designated protected lanes or roads, primarily to simplify the control problems and to avoid external threats. Current ideas from Europe, however, envision relatively low speed AVG vehicles operating also in mixed pedestrian and vehicle traffic. Continuing advances in vision sensors and associated processors, in particular, suggest that AVG vehicles will eventually be capable of safe operation in a variety of currently challenging environments, including mixed traffic.

Previous AVG research has focused on the technical feasibility of safe automated travel. Demonstrations have shown that AVG concepts are technically feasible and affordable and that the public is willing to accept the notion of automated vehicles. Initial studies have suggested that managed traffic flow can be safer (as some driver errors can be avoided) and more efficient. Simulations of automated highway systems, performed under the previously referenced Federal Highway Administration research project, suggest that traffic flow rates on unrestricted freeway sections can increase by 100 percent or more. While these results encouraged engineers tasked with alleviating major traffic congestion problems, others were concerned about the possible consequences for the structure and quality of life in urban areas. Given the major impact of freeways, some were concerned that significant further increases in traffic volumes on automated freeways would increase traffic problems on adjacent surface streets, increase environmental problems, and encourage further “sprawl” of urban areas by allowing commuters to live even farther from their workplaces. These issues are serious challenges to the use of AVG to improve mobility, and must be fully addressed if the significant benefits offered by AVG can eventually be realized.

Application of AVG to Improve Transportation

The remainder of this paper will describe how AVG can improve transportation services that can in turn provide a better quality of life for residents of urban areas. Strategies for applying AVG technology might require: (1) improvement and an expansion of transit services; (2) shared use of designated AVG roadways by buses, trucks, and automobiles; (3) use of more efficient vehicles; and (4) leveraged private choices and investments by the public in AVG vehicles.

These ideas can be realized through changes and improvements to the structure of urban transportation services. Dedication of freeway lanes to AVG vehicles would provide major improvements in system capacity and performance. Dedication of lanes on arterial streets would provide capacity and performance improvements for these corridors, but would also help to efficiently distribute the major flows of AVG vehicles on and off the freeways. Automation of buses through AVG would significantly improve the reliability and performance of the buses. Provision of local community transit service, through the use of economical (and driver-less) AVG vehicles, would improve accessibility to transit and to local activity centers.

The potential application of AVG technologies to improve movement of buses, trucks, and automobiles will be separately discussed.

The objective for improving transit (bus and rail) is to offer a sufficiently high level of service so that automobile drivers will divert to transit, particularly for their longest trips. This would likely require that the end-to-end travel time for transit is reasonably comparable to the travel time for an automobile, that costs are perceived to be similar, and that access to the transit service is convenient.

Major transit corridors might be improved by extending the corridors to serve the entire urban area, by improving service with respect to travel time and reliability, by providing necessary bus stop or station parking, and by establishing effective feeder service. Some roles for AVG are to allow faster movement (and greater reliability) of buses through the corridor on designated lanes, to improve lane-keeping (and allow use of narrow lanes) along the route, and to better accommodate bus movements through signal preemption or priority at intersections.

Community transit service would allow residents, employees, or customers from low-density areas to effectively access the major transit corridor systems or other local activity centers. As noted above, this service might utilize small AVG vehicles that can serve a relatively limited low-density residential or commercial area. The resulting service to passengers would be very convenient, fast, reliable, and inexpensive, and would likely be cost-effective for the government (or a private company) to provide because the need for a driver would be eliminated by the nature of the service.

The objective for improving commercial truck travel is to offer faster travel, with greater reliability, and hence also lower operating costs.

Long-distance commercial trucks are particularly vulnerable to urban congestion since their delivery schedules do not necessarily permit avoidance of congested facilities during peak periods. AVG dedicated lanes, on freeways and on major arterials, could provide faster and more reliable service. The use of a scheduling/order process could add value by ensuring that the trucks will not overwhelm the capacity of even the AVG facility.

Special provisions for commercial trucks would also be needed to facilitate their movement to and from the dedicated AVG lanes and to allow high volumes of trucks to proceed to their destinations without encountering numerous stops or significant delays. Conventional measures such as dedicated truck lanes, generous roadway geometries that can readily accommodate the needs of large trucks, and traffic signal modifications to favor the major truck movement can be beneficial. The role of AVG might include the extension of the dedicated AVG lanes to the key ramps, terminal access streets, and major truck routes so that the speed and reliability offered to trucks by the major AVG facility will not be compromised immediately beyond the AVG facility.

The objective for improving automobile movement is to provide an attractive alternative to inefficient and environmentally costly travel patterns. While dramatically improved bus transit service likely represents the major opportunity to divert drivers, the provision of dedicated AVG facilities could complement bus transit and reduce the adverse societal impacts of automobile travel. The major incentive offered would be to ensure faster, more reliable, and safer travel for major trips provided that the consumer invests in an automobile that meets the government's functional specifications.

Government could restrict use of the AVG facilities to highly efficient automobiles. For example, the Virginia Department of Transportation currently allows "hybrid" gasoline/electric vehicles to use the High Occupancy Lane (HOV) facilities without the minimum number of passengers. Vehicles already available from some manufacturers offer 200 percent improvements of fuel economy and emissions compared to the larger passenger vehicles used by many commuters.

Facilities for AVG automobiles could be provided to support end-to-end service, at least as much as possible. AVG only lanes could be provided on all major freeways in the urban area, so drivers can reasonably expect to reliably travel at a predetermined speed. AVG lanes could also be provided on major arterials. Although the speed would not compare to the freeway portions of the AVG system, traffic signals could enable priority movements of platoons of AVG vehicles so that relatively few stops are encountered and relatively high speeds are achieved. The AVG management system could also adjust the speeds and arrival times of the platoons, in coordination with the traffic signal timing, so as to minimize disruption to other traffic at intersections. Infrastructure-based sensors and collision avoidance systems could protect the AVG vehicles, other vehicles, and pedestrians at intersections and would, if necessary, prevent a collision by inducing an emergency stop of the platoon of AVG vehicles.

Electronic gates at system entry points could control access to all AVG facilities. Entry gates might be located at freeway entrance ramps or at convenient points on or adjacent to arterial streets with dedicated AVG lanes. The system would recognize eligible vehicles automatically and would establish, through a communication protocol with the vehicle, that the driver is authorized (and trained in AVG operations), the vehicle is mechanically ready (using on-vehicle diagnostics), and the destination of the trip (as provided by the driver through an in-vehicle control). Tolls could readily be collected, if necessary. Exit from the AVG facilities could also be controlled. Exit gates would be automatically activated to allow smooth exist movements and special provisions for traffic signal timing on adjacent surface street intersections would be needed to distribute AVG vehicles with minimal disruption to other vehicles.

Special provisions might also be needed to support the parking of AVG vehicles. This is particularly important both to preserve a very high level of service for AVG motorists and to accommodate the unusually high volumes of vehicles that can be accommodated through AVG systems. These facilities might themselves have automated parking features that direct drivers to specific parking spaces, that take advantage of the AVG technology to move the vehicle to a specific parking space (possibly after the occupants leave the vehicle), or to use mechanical parking facilities (where the car can be mechanically stored once the occupants leave the vehicle).

Although this discussion has emphasized means of accommodating passenger cars, both transit buses and commercial trucks would be expected to share the specialized AVG facilities. Human factors issues associated with motorists' acceptance of mixed traffic, particularly when the flow is heavy and headways are short, must be considered and addressed.

In summary, this discussion has outlined a number of attributes of AVG applications for urban areas. Sensibly applied AVG systems can significantly improve transportation efficiency and safety by shifting automobile trips to more efficient transit, by shifting trips to more efficient AVG vehicles, and by allowing more vehicles to avoid congestion delays and inefficiencies through AVG applications. These improvements can complement corresponding facility improvements to encourage increased pedestrian and bicycle travel as well. These transportation improvements can stimulate constructive changes in the structure of the urban area and provide significant public benefits.