BUS RAPID TRANSIT AND AUTOMATION: OPPORTUNITIES FOR SYNERGY

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SUMMARY

This paper identifies the opportunities for making significant improvements to bus transit operations by combining a variety of technical and service innovations that have heretofore been treated separately. Recently, increased attention has been devoted to “bus rapid transit” as an operational concept for enabling buses to provide a level of service closer to that normally only achievable in more expensive rail transit systems. When this concept is combined with APTS fleet management and passenger information systems, automated vehicle control technologies and innovative high-occupancy-vehicle (HOV) facility and operational improvements, there is a potential for larger improvements in service and economics, referred to here as Automated Bus Rapid Transit (ABRT). The components and deployment staging issues are identified here, and the longer-term implications for progress toward automated highway systems are also described.

INTRODUCTION

In recent years, public transportation systems have been implementing and studying a wide variety of technological and service innovations. Curiously enough, these innovations have generally been considered essentially independently of each other:

(a) information systems to enhance fleet management and passenger information, often under the general category of “Advanced Public Transportation Systems”, APTS;
(b) fully-automated guideway transit (AGT) systems, including automated metro operations;
(c) high-occupancy vehicle (HOV) lane operations on freeways, separating buses, vanpools and carpools from the more congested traffic on the general mixed-flow lanes;
(d) light-rail transit (LRT) deployments in smaller and less dense urban areas than have previously been considered candidates for rail transit services;

(e) bus rapid transit (BRT), which is generally seen as low-technology service enhancements to enable buses to provide service more comparable to traditional rail service, following the example set by Curitiba, Brazil (1).

There is a great potential for synergy among these separate innovations, if they can be combined in appropriate ways so that they can be mutually supportive. This paper explores the opportunities that could be opened by combining these transit innovations.

MOTIVATIONS

Public transit services in the prosperous, industrialized world face increasingly stiff service competition from the private automobile on the one hand, while they face increasingly high capital and operating costs on the other hand. These trends are particularly acute in the newer low-density cities of much of North America. Many of these cities have developed LRT systems at significant cost, in the hope that a permanent fixed-rail transit infrastructure will provide them with enhanced urban stature. However, these LRT systems have generally experienced low ridership because they can only provide accessibility for a very small fraction of the trips that people need to make, and their costly fixed infrastructure eliminates the flexibility needed to serve diverse origins and destinations. In higher density urban regions, however, LRT may still be able to serve a useful function.

BRT has been identified as a new service option, providing the enhanced line-haul service quality and capacity of LRT where needed, but integrated with the flexibility of buses to provide collection and distribution service for diverse trip ends (2). With provision of a separated right of way for the line-haul trip, the BRT buses can bypass the road congestion that tends to degrade the service quality of conventional bus operations. However, BRT could make use of more advanced information and control technologies to provide even higher service quality and line-haul capacity where needed, combined with reduced operating costs.

Combining the APTS information technologies with BRT service should be relatively straightforward because these are naturally complementary to each other and the risks are low. However, some more dramatic opportunities arise when combining BRT service with AGT-like automation technology and HOV lane operations. The transit industry has the advantage of having already developed a substantial body of design and operating experience with driverless automated vehicles operating on their own guideways in applications such as Vancouver's Skytrain, Lille's VAL Metro (3), London's Docklands Light Railway, Lyons' MAGGALY Metro (4) and Paris' Meteor Metro (5). Millions of passengers use these systems safely every week, and the technology for designing and verifying their safety has been developed over the past two decades (6). Combining that body of technology with the emerging and parallel developments in collision warning and avoidance systems for road vehicles provides the technological basis for automated BRT operations, as indicated in Figure 1.

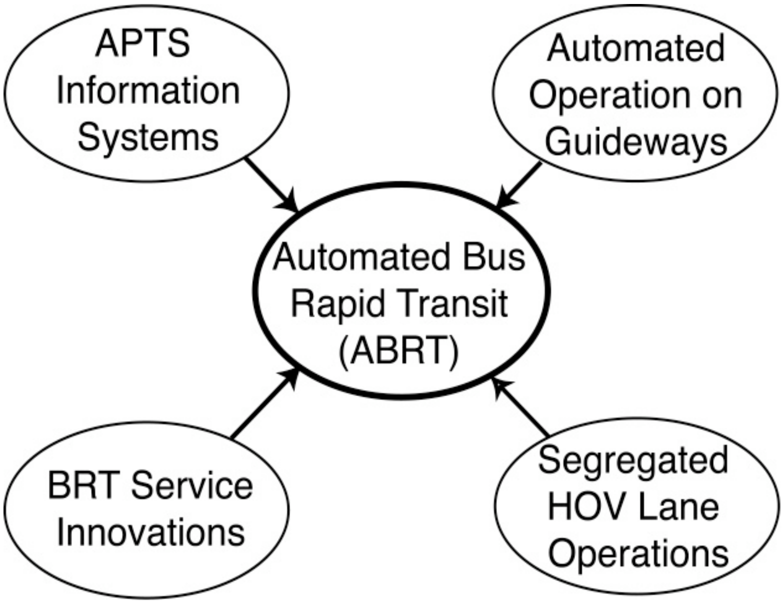

Figure 1 – Automated Bus Rapid Transit (ABRT) System Elements

NEW OPPORTUNITIES IN ABRT

Current research at PATH is exploring the opportunities for development of automated BRT (ABRT) service in suitable locations. This can provide direct economic and service benefits to the system operators and users, while also solidifying the technological foundations for much broader applications of automation in road transportation.

BENEFITS

The benefits that automation technology can provide, beyond those achievable with conventional, non-automated bus operations, include:

- permitting operations on narrower rights-of-way, thereby saving on land and physical infrastructure costs;
- permitting precision docking at bus stops, so that physically-impaired passengers can more easily gain access to and from the buses and speeding up the loading and unloading processes for all passengers;
- facilitating maintenance operations and saving labor ordinarily used to move buses through routine overnight maintenance and cleaning processes;
- smoother and safer travel for passengers, increasing passenger riding comfort and reducing crash costs for operators;

- significantly higher vehicle and passenger capacity per lane, by enabling buses to operate at shorter headway than under manual driver control;
- reduced fuel consumption and emissions for buses that can operate in automated platoons with small enough separations (half vehicle length or less) that aerodynamic drag can be reduced significantly;
- potentially reduced driver labor costs for the portion of the bus trip that operates on the automated lane.

ADDITIONAL COSTS

These benefits need to be considered in parallel with the incremental costs associated with use of the automation technologies. These costs are likely to be primarily in terms of additional electronic equipment installed on the vehicles and busways (together with their continuing maintenance), and some additional protection of the busways to prevent intrusion of pedestrians, animals, unauthorized vehicles and debris.

The additional vehicle equipment is likely to consist of:

1. electronically-controlled brake actuator (which may soon become standard equipment associated with anti-lock braking anyway)
2. electronically-controlled steering actuator
3. lateral-position sensing system
4. forward ranging sensor system (similar to commercially available sensors for adaptive cruise control systems)
5. collision warning sensor systems (which are already available for some vehicle applications and are under commercial development for others)
6. vehicle-vehicle data communications system
7. vehicle-roadside data communications system (which could build on existing and impending signal-priority system technologies)
8. onboard control computer (which needs to be no more powerful than standard home PCs).

It should be evident from this listing that there is no “exotic” technology involved here, and most of the elements are already close to being commercially available. The ones that are not yet that mature in development are also being developed for other vehicle automation applications (heavy trucks, snow removal vehicles), so their development costs can be shared with these other applications. The largest development costs are likely to be associated with the development of software, especially for the safety-critical parts of the application. These are being subsidized by publicly sponsored research and development programs in North America, Europe and the Asia/Pacific region. The net result is that the capital cost for an automated transit bus is unlikely to be more than 10% to 20% higher than the cost of the baseline conventional transit bus.

The roadway-based electronic equipment is likely to be much less significant, in all likelihood consisting of lateral position reference markers and transceivers for the vehicle-roadside communications. Initial, prototype, installations of the former have already been done for costs in the range of $10,000 to $20,000 per lane mile, which can certainly be reduced for production installations. The transceivers should essentially be those already being developed for dedicated short-range communications (DSRC), which should soon be in large-scale production for worldwide use. The physical protection of the roadway environment from intrusions does not involve high technology (barriers, fences), but costs are likely to be very site-dependent. Precedents for these costs can be found in the cost experience of providing analogous protection for existing automated guideway and Metro lines.

DEFINING DEPLOYMENT SEQUENCES

The ABRT operations can begin at limited scale, with applications such as precision docking for enhanced ease of access to and from buses at bus stops, and can then be extended to cruising along exclusive busways such as those that already exist in locations such as Essen, Germany and Adelaide, Australia (7). Subsequent stages of development could include integration with vanpools and carpools on HOV facilities, with careful consideration of the minimum complement of vehicle capabilities that would be needed to gain access to those facilities. These operational concepts enable buses to provide the reduced travel times and increased capacities normally only achievable with rail transit, while preserving the integrated collection/distribution capability of buses that can also operate in an entirely conventional mode on normal public streets.

The specific development and deployment sequence could vary from location to location, depending on local needs and constraints, so some locations will undoubtedly be able to make faster progress than others. However, a generic sequence can be defined, building on technologies that are already available or nearly available and then combining additional technologies and service elements in building-block fashion to achieve increasing levels of capability.

INITIAL STEPS – EXISTING TECHNOLOGIES

Begin with some existing and currently emerging technologies:

- forward collision warning
- lane-departure warning
- adaptive cruise control (ACC)
- elementary vehicle-roadside communication.

All of these are commercially available today in at least one major sector of the world (Europe, North America, or Asia/Pacific) for at least some classes of vehicles (commercial trucks in several cases) or for specialized applications (DSRC for electronic toll and traffic management or commercial vehicle regulatory and administrative processes). In some cases, they will need modifications to customize them for the greater complexity of urban transit bus operations. In the case of forward collision warning, for example, this transit adaptation is being performed for the San Mateo County Transit District (Samtrans) by the California PATH Program, under the sponsorship of the USDOT's Intelligent Vehicle Initiative (IVI).

NEAR-TERM AUTOMATION OPPORTUNITIES

Some special capabilities can be added to transit buses with moderate levels of development and deployment costs. These are expected to include:

- Vehicle-vehicle data communication for cooperative adaptive cruise control (CACC). It has been recognized that there are significant limits to what can be accomplished with purely autonomous vehicle collision warning and control systems. With the addition of vehicle-vehicle communication of limited amounts of data, these systems become cooperative rather than autonomous and their performance and safety can be improved significantly. Technological options for providing these cooperative capabilities are being explored under the “sensor-friendly vehicles and roadway” project of the IVI program (8).
- Low-speed precision docking of buses at bus stops. If the bus can be stopped with precisely controlled lateral position (tolerances of 1 or 2 cm), it becomes possible for buses to load and unload passengers as easily as rail transit vehicles, reducing the dwell times at bus stops and improving accessibility for mobility-impaired passengers (especially those bound to wheelchairs). It is difficult and stressful for bus drivers to try to achieve this kind of position accuracy, and if they try they often scuff their tires against the curb, creating maintenance and wear problems, as well as discomfort for their passengers. However, automatic steering control systems have been demonstrated to provide this kind of accuracy repeatably over several years of experiments by researchers at the California PATH Program. Since the precision docking maneuver is performed at very low speed, in well-defined locations, and under direct supervision of the bus driver, it is a form of vehicle automation that could be implemented relatively early and with a minimum of liability concerns.
- Automation of bus movements through maintenance facilities. Bus transit operators are concerned about the labor costs imposed by the need to manually drive their buses from step to step through their overnight maintenance procedures (fueling, cleaning exterior and interior, etc.). They see potential cost savings if the buses could be driven automatically through these routine processes. This is an application of vehicle automation that has strong analogies to factory-floor automation systems that are already in commercial use in the manufacturing world. There would be no passengers on board the vehicles and the automated activities would be confined to a well-defined and closely-supervised facility that would not be open to intruders, reducing the safety and liability concerns associated with possible malfunctions of the automation systems. Hence, this could represent a promising “building block” vehicle automation function, and an opportunity to verify the safety and effectiveness of the automation technologies before exposing them to the more complicated public environment and paying passengers.

PROTECTED-LANE OPPORTUNITIES

In locations where there are particularly strong needs for enhanced transit service and/or where the right of way can be made available, the operating agency can set aside a separated, protected lane for transit use. When such a lane is made available, it becomes possible to implement automatic steering control safely, permitting use of a narrower lane and relieving the driver of the steering responsibility. This is a key prerequisite for advancing to truly automated operations. The issues that would arise at this stage would be essentially the same as the issues for existing automated guideway transit and automated rail systems (3-6), so there are precedents that can be called upon to assist in decision making and reducing the perceived risks.

The initial ABRT operation would integrate a combination of the above elements in a very simple operational setting, perhaps a pure line-haul run with few if any intermediate stops. Passengers could be collected from their origin locations at normal local bus stops, where the bus would be driven manually (except for the assistance of automatic precision docking at the stops). At the entrance to the protected busway or bus lane, the driver would switch the bus to automated operation and it would continue to operate automatically until it reached the destination end of the busway. There could be intermediate stops along the automated busway, where the bus would operate exactly the way automated metros or automated guideway transit systems do today. At the end of the automated busway, the driver would resume manual control of the bus and could take the passengers to their preferred local bus stops. Through this kind of "dual mode" operation, the ABRT provides the collection and distribution flexibility of conventional buses and the line-haul efficiency and service speed of conventional rail transit, while saving the passengers the inconvenience and time associated with transfers. This is the great service advantage that ABRT can provide.

Over the longer term, with further advancements,

- access to the ABRT lane could be provided to suitably equipped vanpools and then carpools;
- the buses or vans could be coupled together more closely with their counterparts to form platoons, increasing capacity while reducing drag, to save fuel and emissions;
- the entry maneuvers could be automated with the addition of more sophisticated vehicle-roadside communication; and
- higher-level management functions could be implemented to serve a network of connected ABRT lanes.

These could indeed become the precursors to an automated highway network.

CONCLUSIONS

The integration of separate transit innovations in BRT service, AGT automation, APTS information systems and HOV lane operations provides the opportunity to gain benefits that substantially exceed the benefits achievable from these innovations applied separately. More research attention needs to be focused on this integration so that bus transit services can gain those benefits and progress can be advanced towards more widespread use of automation technology in the road transportation system as a whole.

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