

The Case for Automated-Guideway Transit

GEORGE J. PASTOR

Automated-guideway transit (AGT) is a class of transit systems characterized by fleets of driverless transit vehicles operating under computer control on exclusive rights-of-way above, at, or below ground level. AGT systems, in general, can perform all of the operating functions of conventional, fixed-guideway transit systems, ranging from simple shuttles through collection and distribution to urban and commuter line-haul systems, including complex networks. AGT transit systems represent a fundamental change in the operational capabilities of transit systems, resulting in significantly improved service levels with simultaneous improvements in productivity

when compared with conventional transit. Two of the most significant urban deployments of AGT are in North America and Europe: the SkyTrain system in Vancouver, British Columbia, Canada, and the VAL system in Lille, France. Their first years of operating performance are compared with those of other contemporary but conventional fixed-guideway systems. The conclusions drawn are that, in certain applications, AGT is more than competitive with conventional transit, and that, under certain conditions, AGT systems can return sufficient revenues to match and even exceed their total operating and maintenance costs at acceptable fare levels.

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FAI, Inc., 7927 Jones Branch Drive, Suite 400, McLean, Va. 22102.

A variety of AGT systems have been developed and deployed during the past 20 years, with most applications located at airports and activity centers built during the 1970s. But it was the 1980s that produced several successful installations of AGT systems in urban transit applications in Japan, France, Canada, Germany, and the United States. Today AGT systems increasingly are recognized and accepted as a proven, workable alternative within the repertoire of transit modes.

This increasing acceptance is justifiable, because AGT systems are a fundamental improvement to urban transit system design and technology and the major innovation for transit during the 20th century. What is less well understood and accepted is, indeed, the fundamental and profound improvement that AGT provides to transit, namely, a quantum jump in improved service levels at affordable low costs, or, put in another way, cost-effectiveness and productivity surpassing conventional transit. It is full automation of transit system operations and the impact of automation on the entire AGT system design that give AGT systems this unique capability. This is revealed by an examination of the needs of the passenger, the needs of the system owner and operator, and the needs of the communities in which transit operates.

NEEDS OF THE PASSENGER

For acceptable mobility, the urban transit passenger needs a high level of safety, an acceptable level of comfort, and, most important, good service. Good service means ready access, high frequency, and a high level of certainty that the time it takes to get from origin to destination will be short. The total travel time includes access time, waiting time, and trip time.

Considering trip time first, it has been well known for many decades that, in congested urban areas, acceptably short trip times can be achieved only by fixed-guideway transit with reserved rights-of-way. [Even busway and light rail transit (LRT) systems today are trying to minimize the shared, or nonexclusive, portions of their routes.]

It is in waiting time that conventional, fixed-guideway transit has a severe limitation, which, through the uncertainty of waiting time for the next train, discourages many potential patrons. Yet the economics of conventional fixed-guideway transit are such that only in the most highly traveled corridors and during peak rush hours can a few large metropolitan transit systems afford headways on the order of 1.5 to 3 min and off-peak headways of 5 to 15 min. In most other transit systems, typical peak-period headways are 5 to 6 min and off-peak headways range from 10 to 30 min.

AGT systems, in general, can provide access times that are as convenient and short as those of any conventional fixed-guideway systems, or better. In

addition, stations for AGT systems are smaller and less costly than those for conventional systems, as will be discussed later. Thus, more stations and more frequent stops to accommodate this convenient access are not a penalty. Nevertheless, LRT systems at grade and in mixed traffic can provide easier access with simple stops at the cost of lower overall speed and interference with vehicular traffic.

Today's AGT systems are the only ones that have demonstrated reliable and safe peak-period operations at 40 sec and, in general, 1- to 3-min rush-hour headways, and off-peak operations at 3- to 5-min headways. It is only in AGT systems, which provide economies of operation through automation, that the owners can afford this level of service. It is this unparalleled service level that captures the added ridership and creates the 3- to 4-hr noon rush by ensuring the AGT patron of negligible waiting time and a predictably fast trip time throughout the day and the night. This quantum jump in service level is one reason two automated line-haul AGT systems turned an operating profit over and above operation and maintenance costs during 1986 in Lille, France, and Vancouver, Canada—an unparalleled achievement in recent transit history. The other reason for such achievement by the early urban AGT operations is their affordably low costs.

NEEDS OF THE OWNER-OPERATOR

Essentially all fixed-guideway transit agencies in North America (and most around the world) operate at a deficit and therefore depend on subsidies from local, state, and federal sources. This fact "politicizes" the transit business. Nevertheless, each agency wants to provide the best possible service that it can afford, which, of course, depends on the following:

- The capital cost of a (new) transit system, and
- The operating and maintenance (O&M) costs.

The above two costs are frequently combined and expressed as the life-cycle cost (LCC) of a transit system. In the politically dominated transit business, the changing availability of capital and O&M cost subsidies frequently distorts the cost-effectiveness analyses among competing modes. Thus, for a politician with a 2- or 4-year horizon in office, the "cheapest" is often confused with the most cost-effective. AGT system design was undertaken to minimize all three costs—capital, O&M, and life-cycle costs—taking full advantage of automation in service to provide cost-effectiveness and productivity through careful system design.

In the following, the UTDC design of AGT is used for illustrative purposes, but the analysis holds true for most AGT systems. It will be shown that

AGT systems design is far more complicated than snapping an automatic train control (ATC) package on an existing conventional vehicle or pulling the operator off an existing subway train running under ATC.

Capital Cost Reductions

The characteristics of AGT systems permit capital costs to be trimmed as the following suggest:

- The passengers' need for frequent service could be easily satisfied by newly developed automation, proven initially abroad, not using the old block system, and providing safe headway control down to 40 sec (or even less).
- The short headways permit considerable, and respectably high, line-haul capacities (over 30,000 passengers per hour per day) with smaller and lighter vehicles than conventional heavy and light rail vehicles (750 versus 1,000 lb/ft).
- Smaller and lighter vehicles provide for significant cost reductions in elevated guideway construction (two-thirds of the width of a guideway required by most heavy or light rail cars and less depth) or significant diameter reduction in tunnel construction, if required.
- To achieve a given line-haul capacity, short trains are used at short headways, which allows the train station and platform lengths to be reduced to up to one-half of that required by conventional rail vehicles.
- Trains formed from small vehicles with improved turning ability permit tight turning radii in urban applications, thereby reducing right-of-way costs.

It is clear from the above that a very significant cost reduction in guideway and station (or tunnel and station) construction costs can be achieved through the interaction of automation and vehicle and train sizing. Obviously, the trade-off here is between guideway costs and more vehicle miles to satisfy a given capacity and frequent service. Thus, O&M costs must also be significantly reduced to balance the increased vehicle miles.

O&M Cost Reductions

The lighter weight of AGT vehicles in general reduces both the power requirements and the wear and tear of both vehicles and running surfaces in the wayside. In addition, the following system features were incorporated into the UTDC AGT design (others use different innovative features):

- Steerable trucks that provide tight turning radii and eliminate squeal in turns and that also reduce wheel flange and track wear, thus reducing

maintenance costs. (Initial operational problems with the steerable trucks have since been corrected.)

- Linear induction motors (LIMs) provide propulsion power without depending on traction between wheels and rail. This feature provides all-weather capability without heating the guideway, improved gradability, and an almost complete elimination of moving parts. The only moving parts are the cooling fans for the LIM, and the passive rolling axles and wheels in the trucks and the doors. There are no costly motor overhauls; no significant brake wear, because the LIMs act as electromagnetic brakes; and no gear-boxes to maintain. Most mechanical complexity is replaced by solid-state electronics, which is virtually maintenance free.

- The hierarchical structure of automation provides ample diagnostics and fault identification at a continually shrinking cost typical of the computer and semiconductor industries.

- Judicious use of redundancies provides both for high operational availability and minimized maintenance costs at predictable intervals.

Operational Flexibility

Another important feature for the owner-operator is operational flexibility to meet service demands. Essentially all AGT systems provide the ease of adding or withdrawing consists from operations by pushbutton control at a central control console without any other manual operations.

A particularly noteworthy example of operational flexibility occurred in Vancouver throughout Expo '86. Less than half a year after opening a new system, and throughout the six months of Expo '86, BC Transit operated 18 to 22 four-car consists in fully automated mode over the 13.5-mi line-haul route of SkyTrain, carrying up to 120,000 passengers daily at 2- to 4-min headways. Simultaneously, and superimposed on the downtown portion of the route, two dedicated four-car consists shuttled up to 40,000 Expo visitors between two shared, but secured, Expo stations separated by about 1.5 mi and three stations. The jam-packed shuttles essentially operated in a demand-responsive mode, interwoven with the regular line-haul trains, frequently operating at 40-sec headways. Each shuttle made the switchover for its short turnaround without any noticeable interference with the line-haul service, fully automatically—a magnificent example of operational flexibility through automation.

Cost-Effectiveness and Productivity

Capital costs of transit systems are perhaps the least meaningful measure for comparison because they vary so drastically based on location (by country,

geography, and geometry), time of construction, currency rates, system complexity, capacity, and service levels.

Nevertheless, capital cost is important to decision makers and politicians, so it must be identified. Vancouver's SkyTrain cost approximately \$615 million (1986 U.S. dollars) or approximately \$46 million/mi. Lille's VAL cost approximately \$328 million (early 1980 U.S. dollars) or approximately \$38 million/mi.

These capital costs per mile for AGT systems are generally higher than recently constructed LRT lines, which tend to range under \$20 million/mi (although the Long Beach-Los Angeles line currently under construction will exceed \$32 million/mi), but far lower than most heavy rail transit (HRT) lines, which range from \$58 million to well over \$100 million/mi. Yet, from a passenger-capacity point of view, these AGT lines are performing more like HRT than LRT.

Costs are, however, just one part of cost-effectiveness. Vancouver's SkyTrain carried 34 million passengers during 1986, its first year of operation. Lille's VAL carried 28 million passengers each during 1985 and 1986, its third and fourth years of operation. Hardly any North American LRT line approaches these ridership figures.

To provide a reasonable comparison among the capital costs of nine new-start rapid transit or light rail transit systems opened in North America during the last 10 years, the number of passengers carried (which is at least partially indicative of the quality of service) must be considered. Thus, the measure of capital cost per mile per weekday passenger is used in Table 1. All of the information in this table has been obtained by B.C. Transit, the Vancouver authority, from published documents or directly from the transit authority concerned. In addition, the data for the first VAL line in Lille, France, were provided by Matra Transport (1). All actual costs have been meticulously indexed to a common time period ending in 1986.

Thus, it is seen from Table 1 that the two AGT systems in Vancouver and Lille, together with the LRT systems in San Diego, Calgary, and Portland, are among the least expensive systems based on cost per mile per weekday passenger and, therefore, among the most cost-effective new-start systems. Both Vancouver and Lille produced an operating profit during the above-quoted years based on their total operating and maintenance costs. No other North American LRT or HRT line can make this claim.

An excellent performance measure for transit system operations is productivity, simply defined as annual passengers carried per operating and maintenance employee. Vancouver's productivity figure during Expo '86 ranged between 120,000 to 130,000 passengers per operating and maintenance employee. Lille's productivity figure is reported to exceed 140,000 passengers per employee. Among the LRT systems, Calgary, in its fifth year of

TABLE 1 CAPITAL COST PER MILE PER WEEKDAY PASSENGER

System	Length (mi)	Capital Cost [U.S. \$ millions (1986 equivalent)]	Year Opened	Weekday Passengers ^a	Capital Cost (U.S. \$) per Mile per Weekday Passenger
Vancouver, B.C.	13.4	615	1986	80,000	573
San Diego	15.9	149	1981	16,000	585
Calgary	7.8	196	1981	40,000	628
Portland	16.1	243	1986	22,000	686
Pittsburgh	10.6	529	1985-1986	35,000	1,425
Edmonton	6.4	215	1979-1982	20,000	1,679
Baltimore	8.1	833	1984	38,000	2,706
Miami	21.6	1,250	1984	20,000	2,893
Buffalo	6.4	516	1985-1986	18,000	4,479
Lille, France	8.2	387	1984-1985	58,000/ 78,000	813/ 605

^aNow or estimated for initial year.

operation, carried just under 100,000 passengers per employee; Edmonton, in its fourth year of operation, carried about 70,000 passengers per employee; and San Diego serves about 45,000 passengers per employee. It is premature to report on Portland. All of the data for the figures in this paragraph were obtained by the author during 1987 directly from the authorities mentioned.

The above information is illustrated in Figure 1. The data for the selected European systems are from Matra Transport (1), the data for Vancouver from that transit company (2), and, for the balance of North American systems, from unpublished data.

Another, perhaps more widely used, measure for operating productivity is the operating cost per passenger carried. Biehler, in a paper in this report, gives the following figures for recent LRT systems:

City	Operating Cost per Passenger (\$)
Buffalo	1.17
Pittsburgh	1.50
Portland	0.95
Sacramento	1.55
San Diego	0.89

The average is \$1.21 per weekday passenger. In contrast, the total operating costs per passenger for the AGT systems are as follows:

- Lille (1985 data @ 5FF = U.S. \$1): \$0.53,
- Vancouver (1987 data @ C\$1.28 = U.S. \$1): \$0.94.

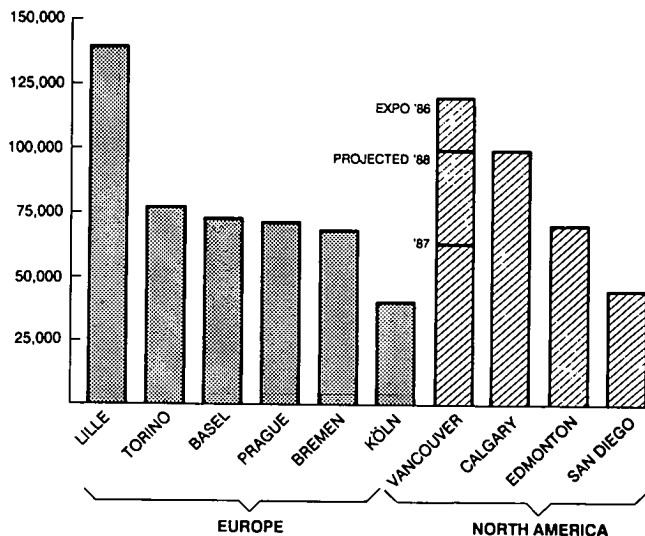


FIGURE 1 Productivity: annual passengers carried per operating company employee.

By both measures, the two AGT systems perform at higher productivities than the comparable conventional systems.

To preserve the accuracy of reporting, the Vancouver ridership figures must be clarified. Figure 2 gives the total monthly ridership history of the SkyTrain operations in 1986, 1987, and the first half of 1988 (2). While 1986,

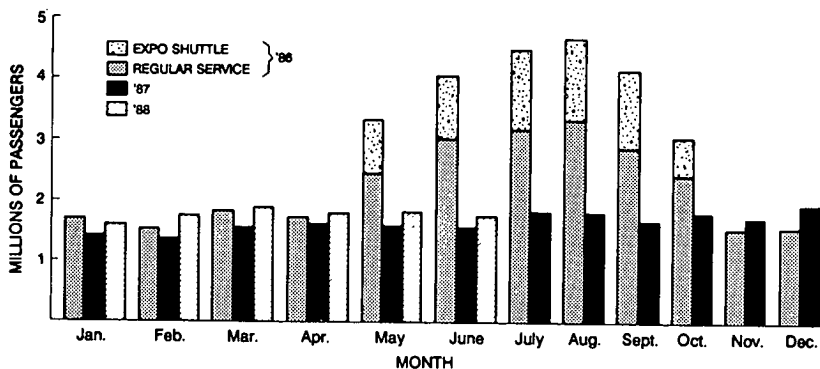


FIGURE 2 Vancouver ridership.

the opening year, was an extraordinary success with 34 million passengers carried during the year thanks to Expo '86, the weekday ridership was conservatively scaled back to 80,000 by B.C. Transit for the purposes of performance comparisons. The post-Expo '86 economic slowdown in Vancouver, however, reduced the SkyTrain weekday ridership to 60,000 or slightly below. Thus, an operating subsidy was required during 1987. Starting with November 1987, ridership began increasing again and this trend has been maintained throughout 1988, resulting in a current rate of 75,000 weekday passengers, which restores the credibility and significance of the above comparisons.

Simultaneously, the more mature Lille AGT system has shown an increasing weekday ridership from 58,000 in 1984 to 78,000 in 1986 and 1987, further reinforcing the validity of these comparisons. Thus, Vancouver's SkyTrain and Lille's VAL appear to be the least-cost, highest-productivity lines among the new-start transit systems surveyed.

THE NEEDS OF THE COMMUNITY

All fixed-guideway transit systems are designed to be "neighbor-friendly." So are AGT systems, with a few pluses, as follows:

- Reserved rights-of-way provide no street interference and no grade crossings;
- Smaller, lighter structures and stations provide a clean modern look, drawing no aesthetic objections;
- Noise levels are equal to or better than those of other transit modes, frequently less than the urban ambient;
- No pollutants are used;
- Safety (unsurpassed records over millions of passenger and train miles);
- Image (modern, high-tech, progressive); and
- Good developmental impact (captures the imagination of the private sector, stimulating mixed and joint development).

CONCLUSIONS

The advocates and developers of AGT technology have been promising a potential to recover operating and maintenance costs from farebox revenues. This promise has been fulfilled in Vancouver and in Lille with even a small operating profit. AGT systems' ability to reduce operating deficits has been proven. The ability of AGT systems to attract extraordinary, induced ridership, especially in off-peak hours through improved service, also has been

proven. Public acceptance of fully automated (driverless) trains is complete and highly enthusiastic. Thus, AGT systems are here to stay and the mode has become a prime candidate for implementation in new public transit initiatives.

REFERENCES

1. *Matra VAL in Lille: The 1983-87 Track Record*. Matra Transport, Vanves, France, Fall 1987.
2. BCRTC Corporate Plan and Monthly Management Reports. British Columbia Rapid Transit Company Ltd., Burnaby, B.C., Canada.