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A SPECIAL INTERNATIONAL ISSUE

The Status, Market Perspectives and Financing Approaches for Medium Capacity Automated Transit Systems

Prepared by
A. M. Yen
Advanced Transit Association

Acknowledgements

We would like to thank the WCTR for extending an invitation for ATRA to present a special session on the subject of medium capacity automated systems. The World Conference is convened once every three years and we are honored to have the opportunity.

Our gratitude to SNV for technical assistance provided us at Hamburg. Also, we thank the German television Deutsche Welle for interviewing and distributing this ATRA discussion for international viewing.

Acknowledgement to the speakers from various countries for taking their time to contribute to the session. Participation by Volvo and London Transport personnel in the panel discussion is also appreciated.

Special thanks to W. Heckelmann of Hamburg and A. Chambliss of MITRE for assisting with editing of the manuscript, and to the Institute for Transportation of Duke University, USA, in bringing about this special issue.

Preface

Two special sessions of the 1983 World Conference on Transport Research (WCTR) were devoted to a relatively new class of medium capacity transit systems (MCTS) referred to as Automated Guideway Transit (AGT). The primary focus of the presentation and ensuing discussions was on new applications of these technologies in Asia, Europe, and the United States. This special edition of the ATRA Journal presents condensed versions of the presentations made at the 1983 WCTR. The 1983 WCTR was held in Hamburg, Federal Republic of Germany from April 26 to 29.

Introduction

New Applications and Financing of Advanced Transit Systems

The special sessions addressed the renewed interest in lightweight, advanced technology, fully-automated, fixed guideway transit systems. They specifically focused on the recent demand from the developed countries, and the methods of financing being used or considered in those countries. The sessions were sponsored by the Advanced Transit Association following a request by the WCTR.

Six speakers from major manufacturers of AGT systems described their recent installations and their future market expectations. The six speakers were, in the order of their presentations:

G. J. Pastor, President UTDC (USA), Inc.	U.S.A.
S. Shimoura, Senior Manager Rolling Stock Division Kawasaki Heavy Industries	Japan
L. Saunders, General Manager OTIS/TTD	U.S.A.
F. Tremong, Project Manager VAL MATRA Industries	France
S. Müller, Manager H-Bahn System Siemens AG	W. Germany
H. Weinberger, Project Manager Magnetbahn GMBH	W. Germany

Two special speakers addressed management aspects of advanced systems applications and financing methods. They were:

U. Meyer, Director Advanced Systems BMFT	W. Germany
F. Ystehede, Director Urban Transport Norconsult A.S.	Norway

The special sessions were jointly chaired by Dr. A. M. Yen of the U.S.A. and Dr. K. Heinrich of West Germany.

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New Applications on Financing AGT Systems

Dr. A. M. Yen

Professor Barron, Prof. Kassak, Dr. Sandhäger, distinguished guests, ladies and gentlemen. As you know, our session is a special one in which we will be discussing the current and future status of Automated Guideway Transit (AGT) systems, also known as Medium Capacity Transit System (MCTS) in developing countries.

The best way to describe this type of system is via a story of my very recent experience. Last night, while taking passage here from Helsinki, a fellow traveler on the plane asked me the purpose of my trip. I told him about the conference and the subject of AGT, or MCTS. He became confused. So I tried to explain to him that they are a new form of transit system technology: fully automated and driverless, electrically powered vehicles operating on an exclusive guideway. He stared at me and said after considerable consideration, "Well, I guess you better refer to that simply as AGT, or MCTS for convenience."

Today, we shall speak on these subjects. For after more than a decade or two of development work, and somewhat scattered deployment, AGT is now facing opportunities for more applications in the coming decade. The timing is right to examine where we are and what do we expect in the near future.

First, what is the reason for this renewed interest in AGT systems? More precisely, why has it now become a market interest? Why is the timing for this type of system right, and where will the market be?

The first "how" question can be easily answered. For, the technical requirements for this type of system have now been fulfilled, particularly those pertaining to reliability and automation. More importantly, it has been proven that they are acceptable to the users, as is evident from applications in the U.S., Japan, W. Germany and France.

For the second question, the "why," there is also a good answer. The world transit market has changed rapidly since the '60s. By now, most

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major cities who can afford a subway system have already acquired one, even though there may be a few cities left without it. The next generation of major transit additions will be as a feeder or a secondary system to an existing subway infrastructure or as an independent, line haul system serving the needs of a medium sized city. For both of these applications, the MCTS system is the logical choice.

This brings us to the last question of "where." Where will the market be? We believe the real surge of this demand will be coming from the developing countries, who have not yet invested in subways and would like to purchase the most advanced technology at the lowest price. Now, the logical question to ask is how these systems can be financed, and what financial arrangements can be made to construct them. The financial arrangements will, of necessity, be quite different from what we had experienced with the building of heavy rail systems in the past. The new market, taking current difficult global economic conditions into account, will require more innovative financing than the traditional government grants or bonds.

We would like to examine the question of financing in relationship to different engineering stages of the system because every construction stage may have to be tied to a new phase of the financing package. Engineers and financiers can together find innovative financing methods practical and attractive for the buyers.

We would like to devote Thursday's session to the above topics and would like very much for all of you to participate in our discussion and share with us your opinions.

In closing, I would like to thank all who have participated in the development of AGT systems. Your dedication and the belief that such technologies can be successfully deployed in an urban environment have resulted in the hope of a new generation of mass transit technologies.

Now that I have taken more time than I promised, thank you very much, and I am pleased to be in Hamburg again.

Journal of Advanced Transportation 19:1, pp 3-14.

North American Application Strategy

G. J. Pastor

A discussion on the social, political, and technical developments of new systems is provided. Special emphasis is given to the Urban Transportation Development Corporations Intermediate Capacity Transit System technical development and its application in Vancouver, Detroit, and Toronto. A review is made of future applications of medium capacity transit, given current funding and economic condition.

Introduction

The need for public transport to assure the efficient functioning of metropolitan areas in our industrialized and developing societies is almost universally accepted. Even the most die-hard North American suburbanite will concede that public transportation service is an essential function to be provided by "somebody" for the "other guy" (so that he can keep driving his automobile more freely). New fixed guideway transit systems, or significant extensions of existing systems, are being constructed in the U.S. and Canada since 1970 in the following cities:

Atlanta, GA	Houston, TX	Sacramento, CA
Baltimore, MD	Los Angeles, CA	San Diego, CA
Boston, MA	Miami, FL	San Francisco, CA
Buffalo, NY	Montreal, Quebec	San Jose, CA
Calgary, Alberta	New York, NY	Toronto, Ontario
Chicago, IL	Philadelphia, PA	Vancouver, BC
Detroit, MI	Pittsburgh, PA	Washington, DC
Edmonton, Alberta	Portland, OR	

These include virtually all major cities in North America (with a few notable exceptions, such as Dallas and Denver). Essentially all of these were government financed undertakings (Federal and State in the U.S.,

MR. G. J. PASTOR *is President of UTDC (USA) Inc.*

Provincial and Municipal in Canada). The vast majority of the new transit systems utilize conventional fixed guideway technology such as heavy rail (HRT), light rail (LRT) and commuter rail, incorporating many evolutionary, technological improvements, but no radical departures from the proven approaches of the early 20th century.

Background to New Systems

If we define "New Systems" as fixed guideway systems using significant departures from conventional transit (as it is believed the organizers of this session intended), there is no such universal acceptance for their need among the decision-makers of transit planning, financing and project implementation as yet. If significant departure from conventional transit, i.e., "new systems," means Automated Guideway Transit (AGT, people movers or PRT) or Monorail or Maglev, there are only three examples of AGT deployment in North America among the 23 cities listed above, namely Detroit, Vancouver and Miami. (Toronto, the fourth one is a pseudo-AGT application, to be explained later.)

Considering the hundred of millions of dollars invested in new systems R&D over the past 15 years some may view this as a discouragingly poor showing; conversely, those of us familiar with the obstacles to introduction of major innovations, particularly in the public sector, can take some pride in having "cracked the doors open." The obstacles to introduction of innovative, automated guideway transit in North America, as elsewhere include the following:

- Some of the highly publicized failures of new, high technologies in the early 70's.
- The resultant distrust of any new, unproven technology by a conservative, professional transit establishment, ridden by increasing costs and decreasing ridership, under constant scrutiny of the press and revolting taxpayers.
- The frequent, competitive criticism among the proponents of the variety of innovative transit alternatives, creating distrust among laymen for all.
- The lack of profit incentive.
- The cumbersome and frequently inconsistent decision making and planning process involving all layers of government (Federal, state or Provincial, regional, municipal), and the multitude of involved or interested public interest groups. Somebody observed that, "the one who finances transit does not buy it, the one who buys and operates it does not pay for it, the ones who pay for it do not use it, and the ones who use it do not select, buy, or pay for it."
- The existence of a traditionally long cycle from transit project conception to completion, spreading over decades instead of just a few years.

Considering the enormity of obstacles, we have done quite well in North America in Detroit, Vancouver and Miami, just like our French colleagues in Lille and our Japanese colleagues in Osaka, Kobe City, etc.

Government Role in Transit Financing

If "the past is prologue—" it is worth reviewing, with some perspective, how we have reached where we are.

In North America, under the conditions of the past decade, there would not be any urban installation of a new (AGT) system without the strong, forceful initiative taken by governments; the Federal Government in the U.S., and the Provincial Governments in Canada (with some Federal support). While several cities in the U.S. flirted with the idea of introducing innovative AGT in their locale, it was the Federal Government's determined initiative, announced in April, 1976 for the Downtown People Mover (DPM) program which resulted in the existing two projects under construction in Detroit and Miami; the systems will open for public service in 1985, a decade later. Without an aggressive Federal policy, supported by the U.S. Congress consistently since 1975, and funds set aside for this specific purpose, there would not be two urban deployments of AGT in the U.S. today. It was the acceptance of the idea within government, that if government funds the R&D in the public interest, then government must also fund the initial deployments of the promising results of R&D for everyone to see (market test) the results before the new systems could be competitively selected.

It was the promising results from the small, private deployments and the Federal "carrot" that produced the successful construction projects of AGT in Detroit and Miami. (These two projects survived the proposed cancellation by the current administration through strong local commitment and Congressional support.)

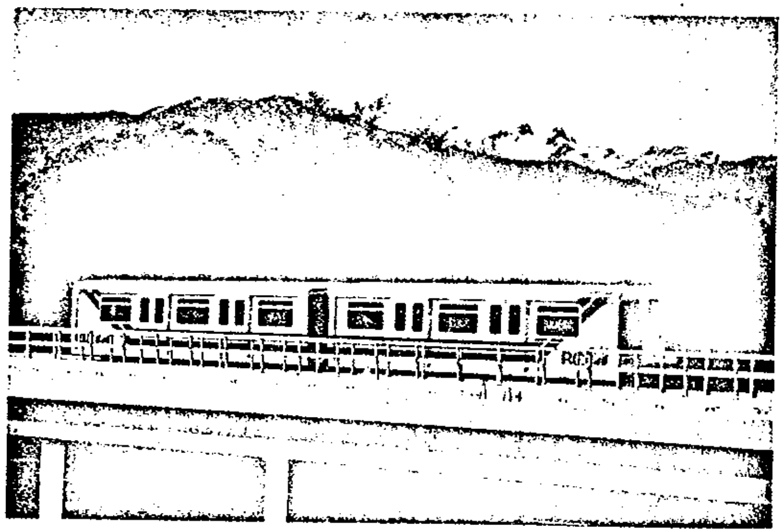

Figure 1. Vancouver Advanced Light Rapid Transit Vehicle

It was an identical recognition of government responsibility and role which sparked the initial AGT deployments in Canada, except they reflect a different inter-governmental relationship between Federal and Provincial Governments than those between Washington and the States in the U.S. In addition the Canadians boldly recognized the need for innovative and imaginative industry-to-government relations to remain competitive with similar trends in the international market place.

The support of urban transportation is a Provincial responsibility in Canada, thus the highly industrialized Province of Ontario, which contains the cities of Toronto, Ottawa, Hamilton among others, traditionally financed urban transit among its metropolitan centers. The Ontario Government established its Provincially owned "Crown Corporation," the Urban Transportation Development Corporation (UTDC) Ltd. in 1973 for the purposes of:

- Sharing the financial risk in the development of modern, innovative technology for use in Ontario and other cities,
- Assisting in maintaining a modern, competitive industry base,
- Promoting development of exportable products.

UTDC Ltd., the Crown Corporation, acts totally as a commercial entity;

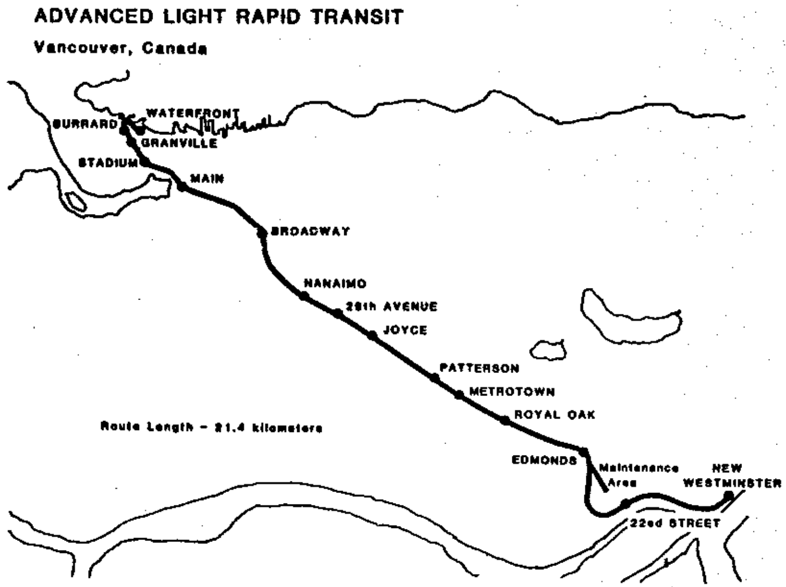

Figure 2. Advanced Light Rapid Transit System Route

it is governed by a board of directors, all from the private sector, and pays a royalty to its single shareholder, the Province of Ontario.

UTDC Ltd. between 1974 and 1980 successfully developed its Intermediate Capacity Transit System (ICTS), an AGT System which is the ingenious combination of proven rail technology with innovative and proven subsystems in the utilization of:

- Small, light-weight, welded aluminum vehicles for elevated operation,
- Steerable trucks for low noise and low maintenance operations,
- Linear-induction-motors for all-weather propulsion and braking without dependence on traction or moving parts, thus for low maintenance operations, and
- Proven reliable vehicle-follower automated control and communications subsystem.

The ICTS is known in Vancouver, B. C. as the Advanced Light Rapid Transit (ALRT) system (Figure 1) and in Detroit, the Central Automated Transit System (CATS) (Figure 4.).

The system design and product development showed its competitive strengths when it was selected in a fierce four-way international competition for the Los Angeles DPM in 1980 (later the project became a victim of Reaganomics) and for the Detroit DPM (now renamed to Central Automated Transit System, CATS) in 1981. While these successes were made possible by the U.S. DPM program, UTDC and Detroit clearly benefit from the Ontario government investment in the system development. Even more importantly, the financially most significant project, and the one that makes the UTDC system technology the most real and viable candidate in urban transit anywhere in the world, is the $700 million (Canadian) Vancouver project awarded in March, 1981 as the largest AGT project under construction in the world. Clearly the commitment and the backing of the two Provincial Governments, those of British Columbia and Ontario, and the catalytic endorsement and support of the Canadian Federal Government for the Vancouver Expo '86 made that project possible.

Similarly, the Ontario Government, which contributes most of the capital funding of the Toronto transit system, was contributing to the selection of the same ICTS technology for the elevated Scarborough extension of Toronto's East-West subway line (under construction today and to open for revenue service in the fall of 1984). For the purist, the Scarborough line, while it uses the same ICTS technology, is not a full AGT deployment. The Toronto Transit Commission (TTC), because of tradition and union rules, intends to operate the system with operators on-board the trains. A summary of the characteristics of the three UTDC systems under construction is given in Figure 6.

The four deployments of AGT in North America show that the roles of the U.S. and Canadian Governments were decisive in opening up the market place for AGT to prove its service and economic benefits, and therefore, to become a viable alternative for future selection by urban planners and transit operators.

Government performed its role as the introducer of innovation; hereafter it is just fair to expect that the AGT systems should compete based on their merits for their share in the urban market place.

The Present Outlook

During the past two and a half years, the worldwide recession in combination with the announced policy of President Reagan to shut-off (at

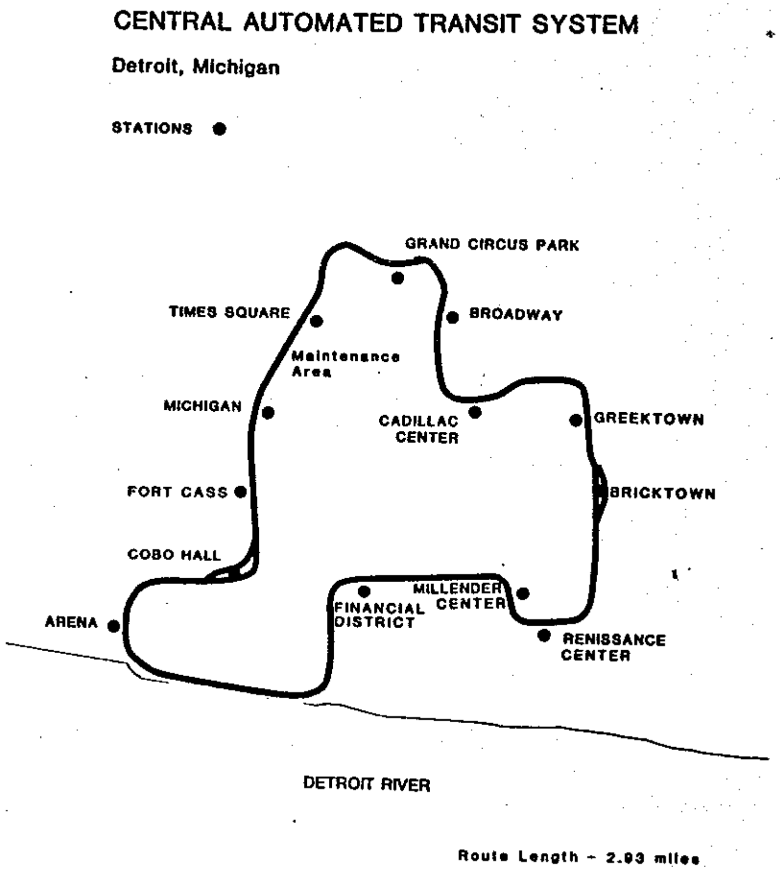

Figure 3. Central Automated Transit System Route Alignment

least temporarily) all Federal support to all new starts for fixed guideway systems, put a heavy damper on construction of all new systems, conventional or AGT, in the U.S. We, at UTDC, were indeed fortunate that the Canadian Provincial Governments did not subscribe to Reaganomics, and that the U.S. Congress did not allow the cancellation of the ongoing DPM projects. Thus, UTDC during the past two years, with the three contracts signed, became the world's foremost supplier of AGT systems with a backlog of orders approaching one billion dollars. We have 151 vehicles sold and in production, approximately 39 lane-miles of guideway and 33 stations in design and construction for our three customers. Our one kilometer demonstration "pre-build" segment in Vancouver will go into public operation with our first production vehicles in June of this year.

Simultaneously, we are negotiating with the Ontario Ministry of Transport for a major expansion of the Toronto commuter rail network, known as GO-Transit (for Government of Ontario), utilizing an adaptation of our ICTS technology.

We have recently announced the formation of a new company, 80% owned by UTDC Ltd. and 20% owned by Hawker Siddeley of Canada Inc. (HSCI). The new company includes UTDC's own production subsidiary, Venturetrans and its facilities in Kingston, Ontario, as well as HSCI's railcar division and Thunderbay, Ontario facilities. Thus, we now have a full transit product line—ICTS, light rail, heavy rail and commuter rail. Obviously, we believe in the viability of the urban transit market.

Reaganomics in the U.S. attempts to reduce the Federal Government's responsibility and financial participation in urban public transit assistance and to transfer much of that responsibility to the States (as in Canada and the F.R.G. the Provinces and Lander, respectively) and to the local, or even private sectors. This policy has the following consequences affecting the U.S. new systems transit market:

- Congress is moderating the cut-backs, and earmarks specific projects for continuation, i.e., the market becomes even more heavily politicized than before.
- Some of the States (or Regions) are willing to pick up the financial responsibility for new transit, (N.Y., Florida, California and Texas), while the others are incapable to do so.
- Many of the planned new transit projects are either delayed, or are banking on any of the following:
  - — Congressional earmarking
  - — A reversal of Federal policy after the 1984 elections
  - — State, or regional funding (tax) sources
  - — Private financing as a result of joint public/private ventures, shared development, tax write-offs or incentives

The resultant confusion and delays are a blessing in disguise for new (AGT) systems. Within the U.S. transit establishment there remains a strong skepticism of any "new, untried, unproven technology" as long as there is no documented, verifiable, operational history and experience in the real, urban transit environment. It will be between 1983 and 1986 that the Detroit, Vancouver, and Miami installations will accumulate convinc-

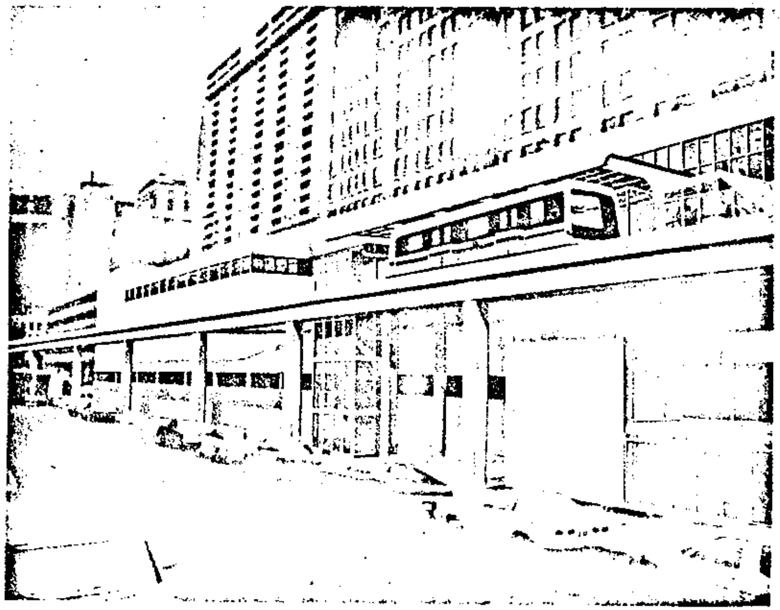

Figure 4. Detroit Central Automated Transit Systems Vehicle

ing availability, reliability, economic performance and public acceptability data, which will then "fully qualify" AGT in the minds of the transit community. Thus, from an AGT systems point of view, the more projects are delayed, the larger the potential market will be for urban deployment of AGT.

There are already some promising signs as more and more local communities, municipal planning organizations in the U.S. are including AGT as an option in their alternative analysis and planning process either because of their conviction of the merits of AGT or in anticipation of their successful operational deployment. Similarly, in Canada, both Vancouver and Toronto are actively engaged in planning the extensions of their initial ICTS installations.

Reaganomics gives added emphasis to a latent, natural inclination of the American private sector to exercise the imagination, vigor and initiative of its free enterprise system to any and all opportunities.

While, admittedly, it is difficult to see the recovery of investment with reasonable returns on the typical urban fixed guideway line haul installa-

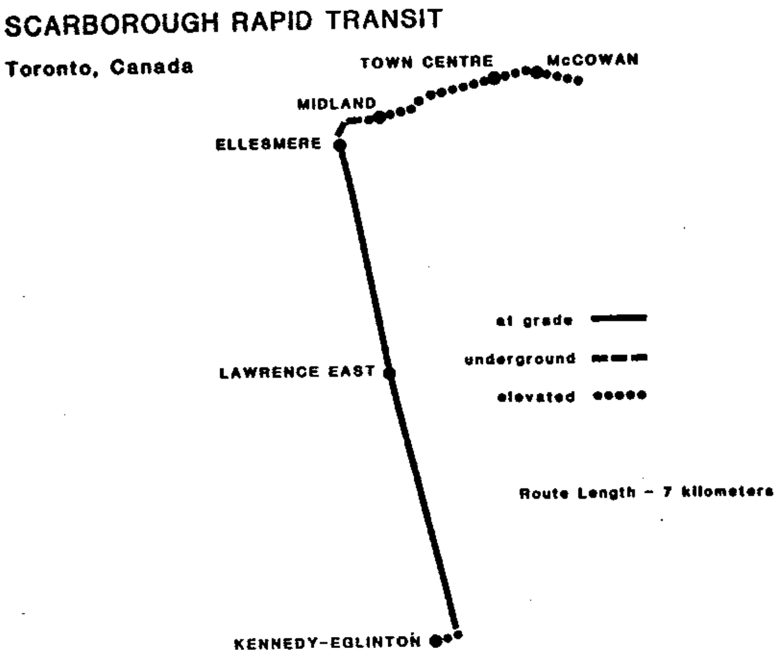

Figure 5. Scarborough Rapid Transit System Route

tions, there are some city-size, private real estate developments which incorporate the planning of integral AGT systems for the viability and profitable operation of those developments. Similarly, there is increasing interest in the shared, joint developments of portions of the transit infrastructure. Several of the unsuccessful former DPM cities and others are still pursuing AGT collection distribution systems for either revitalizing or maintaining the vitality of their central business districts (CBD's). Furthermore, the proven airport market for AGT is offering several opportunities in the near term, with Chicago's O'Hare Airport promising to be the largest.

Conclusion

In our mind, it is clear that our Intermediate Capacity Transit System (ICTS), as AGT in general, is not a toy, or an amusement park ride, or a shuttle to go back and forth between two adjacent buildings, but a new

UTDC
ICTS Systems
Under Construction

	Detroit CATS	Vancouver ALRT	Toronto Scarborough RT
Customer	SEMTA	B.C. Transit	Toronto TTC
Transit Application	CBD Collection & distribution	line haul & downtown collection	line haul extension of existing line
Start of Project	Aug. '82	May, '81	May, '82
Revenue Service	Jan. '86	Jan, '86	Mar, '85
Pre-build, Demo.	---	July '83	---
Length of System	2.92 miles	21.4 km (13.4 mi.)	7 km (4.37 mi.)
	Single lane	Double lane	Double lane
elevated	2.92 miles	13 km	2.4 km
at grade	----	6 km	4.5 km
underground	----	2 km	.11 kms
No. of Vehicles	13 (A/C)	114 (initially)	24
Vehicle Speed Operating	30 miles/hr.	72 Km/hr.	70 Km/hr.
No. of Stations	13	15	5
elevated	13	8	3
at grade	--	5	2
underground	--	2	-
Total System Costs (fully escalated US dollars)	$112 million	$697 million	$149 million
Cost per system-lane-mile (US dollars)	$38.3 million	$26.0 million	$17.0 million

Figure 6. UTDC ICTS Systems Under Construction

generation of sophisticated yet practical transit alternative which can perform most fixed guideway transit functions, (line haul, collection, distribution) better, more efficiently and at less cost than the existing, conventional alternatives.

While the road to the first urban deployments was long and tortuous, we have now reached that point of accomplishment. If our products, the AGT Systems, are as good as we know they are, they will sell themselves as long as there will be a need for public transit.

Governments which sponsored the R&D, which assured the initial deployments, cannot be asked to do any more—other than to maintain public policies which continue the support of the well-being, viability and vibrancy of our great urban centers throughout our industrialized societies.

While the jury may be still out on the full potential of AGT, it is a great beginning.

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New Medium Capacity Transit Systems In Japan

Shozo Shimoura

Japan has developed medium capacity transit systems and made several deployments. This paper discusses the reasons for this development and types of technology employed. Unmanned operation and its implementation in the Japanese context is addressed. A detailed description of the various aspects of the medium capacity transit system is provided. Topics include basic design, track, coaches, switching, electrical equipment, command and control. The paper concludes with a review of the first medium capacity system in operation in Japan at Kobe.

Development

Medium capacity transit systems in Japan were developed to provide efficient transit service under the following conditions:

- Japan already has a highly efficient public system composed of trains and buses.
- Ever expanding urban development has brought with it increased demand on the access routes to the cities.
- In terms of numbers of passengers, this access demand is too small to require railway facilities, yet too large to be accommodated by buses alone. There is also the problem of commercial profit potential, due to the large fluctuations in passenger traffic during peak versus non-peak hours.
- Spiraling railway construction costs have created the need for medium capacity transit service at a reasonable cost.

Some of the factors responsible for the development of new transit systems are presented in Figure 1. The relative standing of new transit systems with respect to other means of transportation are shown from the standpoint of transit service in Figure 2.

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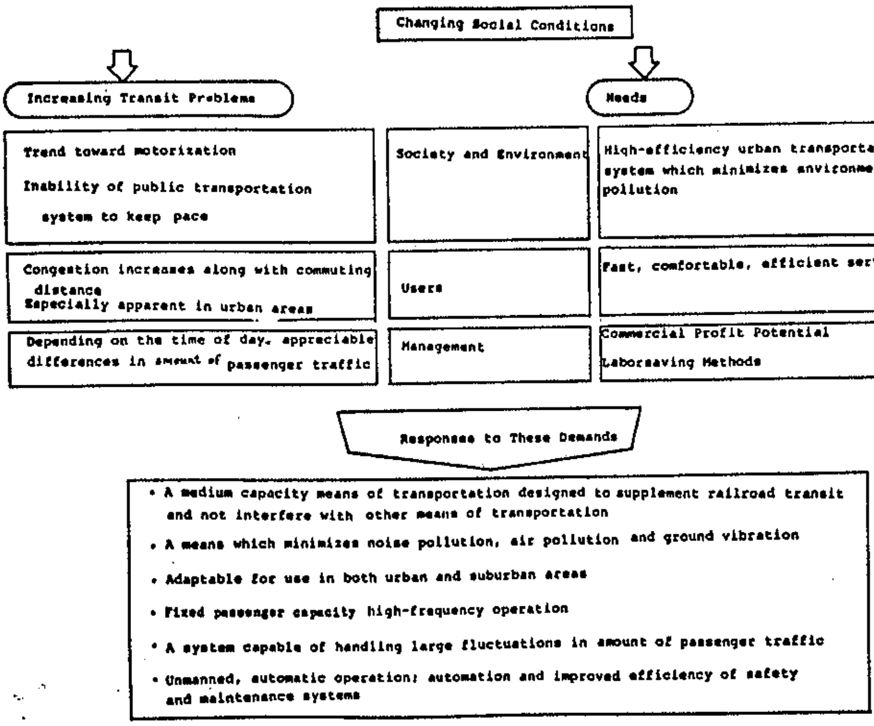

Figure 1. New Transit System Development

A. Item	B. Suburbs · Subways	C. New Transit Systems	D. Buses · Taxis
System Organization	General-use systems which are designed for use with existing systems for mutual extension of services between or within districts	Since system planning is limited to within district precincts, conventional restrictions do not apply, and therefore completely new design is possible. Such a specialized system is free to adopt the track shape, coach type and control system best suited to its particular needs.	Despite severely limited range, this general use system is the national common denominator in terms of vehicles (hardware) and operation (software)
Form of Transit	Line transit (long distance) Can accommodate a variety of train service (passenger, freight, express, ordinary, etc.)	Line transit (approximately 10 km) Limited to passenger transit via coaches of uniform construction	Surface transit (local) One of many means of road transportation
Operation Mode	Manual (engineer) with partial automation (CTC)	Automatic (unmanned) Centrally controlled by computer	Manual (driver)
Possibilities for Sophistication of System Functions	Possible on a gradual basis	Already equipped with the optimum in sophisticated system functions	Impracticable on a wide scale
Method of Operation (Method of Passenger Use)	Scheduled runs according to timetable	Scheduled runs Non-scheduled runs Service on demand	Scheduled runs according to timetable (buses) Rolling (taxis) on the street
Carrying Capacity (T passengers/hr)	Large units · high capacity	Medium units · medium capacity	Small units · low capacity

Medium Capacity Transit System

Figure 2. Standing of New Transit Systems

Unmanned Operation

Medium capacity transit systems were designed with the objective of creating a commercially profitable transit system by reducing both construction and operating costs. The main points necessary to achieve this objective are as follows:

- Lower construction costs. The plan calls for abandoning high-cost subway construction in favor of elevated track construction.
- Reduce coach weight, in order to reduce superstructure costs, which account for over half of total construction costs.
- Reduce coach size, for easy adaptability and use in existing urban areas.
- Offer high-frequency, connected-coach operation, in order to compensate for the decrease in carrying capacity resulting from the reduction in coach size.
- Equip the system with a Central and Protection Device, in order to offer this high-frequency service at a higher level of safety than subways.
- Eliminate the necessity of trained personnel, in order to keep operating costs down.
- Eliminate the necessity of station personnel.

In conclusion, we can say that the reduction of coach size resulted from the necessity of lowering construction costs, and unmanned vehicle and station operation from that of lowering of operating costs. Figure 3 shows the trend toward automation in public transit systems by presenting a comparison of the duties and functions of trained crew members and ground personnel for streetcars, railways, recent subways systems, America's latest subway system and the fully automated new transit systems.

Implementing Unmanned Operation

In addition to the social considerations involved in building a transit system with fully automated train service and unmanned station operation, it is necessary to automate the functions currently performed by human labor in conventional systems, and regulate those which cannot be automated by means of central operators. Duties performed by driver and conductor in even the largest subway systems have been largely automated in new transit systems, with the central operators functioning in a supervisory capacity.

	Attendant		Ground personal			Main function									Unusual case			
	Driver, Conductor (2 persons)	Attendant (1 person)	Signal staff	Station staff	Central operator	Route supervision	Dep/Arr Supervision	Door supervision	Start control	Speed control	Stop control	Ticket vending	Watching in vehicle	Guidance of destination	Collision avoidance	Judge from circumstances	Guidance	Manual interruption
Street car	○		○			○	○	○	○	○	○	○	○	○	○	○	○	○
Railway	○		○	○		○	○	○	○	○	○		○	○	○	○	○	○
Recent subway	○			○	○	○	○	○	○						○	○	○	○
Latest subway in USA		○			○	○	○									○	○	○
New urban transit system					○											○	○	○

Figure 3. Transition of New Vehicle Automatization

The most serious problems resulting from the elimination of train crew members and station personnel concern ensuring the safety of both passengers and trains, especially in times of emergency. In order to achieve fully automated transit service, it is necessary not only for the automatic train equipment to perform starting, stopping and speed control on instructions from the central traffic and train control computer, but also for the system as a whole to deal with operational procedures such as (1) route supervision, (2) passenger and train safety, (3) detection of malfunctions and emergency remedial measures, by either designing a system which is capable of eliminating them, automating them, or developing their regulation to central operators.

Implementing such a plan calls for a system control network which includes an automated traffic and train control system to monitor and regulate operation, and automatic train operation devices in coaches to carry out instructions from this system, along with another system for transmitting data on individual coach operating conditions to the central control room. In turn, such an information link between computer and automatic train operation equipment in coaches requires a network of information transmission devices set up along the entire length of the track.

Finally, in the interests of safe operations, it is necessary to establish a safety network independent of the automatic train operation system. These system control networks are shown in Figure 4.

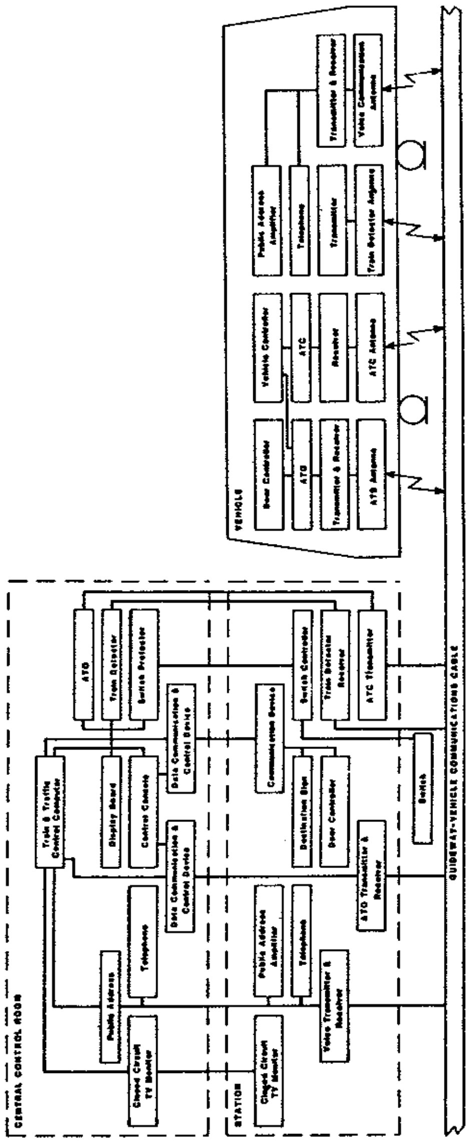

Figure 4. Traffic Control Functional Block Diagram

New Transit System Technology

Basic Design. The new transit systems use a compact rubber-tired, four-wheel electric coach which is designed to run on a track with a guidance rail as their principle piece of hardware. The reasons for adopting this type of coach are as follows:

- Operational noise is greatly reduced and ground vibrations are held to a minimum.
- The high-adhesion rubber tires allow a higher track gradient, and consequently, more freedom in determining route layout.
- High acceleration and deceleration allow significant reductions in braking distance and headway.
- Electric drive delivers high performance along with freedom from air and noise pollution.
- Track maintenance costs are reduced thanks to strong slab construction to accommodate the rubber tires.
- Passengers may be easily evacuated from coaches in emergencies.

On the other hand, some of the drawbacks of these special rubber-tired coaches are as follows:

- They require a separate lateral guidance/steering mechanism.
- Rubber-tired coaches necessitate load limitation and a quick method for puncture detection.
- The train detection method employed in today's railroads cannot be adapted for use in these systems.
- The running rail cannot be utilized as a return line for electric power.
- The use of rubber tires against a slab track increases the amount of running resistance.

Thanks to the efforts of system engineers, these problems have been effectively solved, allowing the above advantages to be utilized to the fullest. In fact, in recent years Japan has seen a spate of unveilings of monorail and rubber tire subways, featuring advantages unobtainable with conventional railway facilities.

Track. Tracks used in most new transit systems are of the elevated variety found on normal roads. Since there are limitations imposed on track height and width, numerical values for turn radius, gradient, etc., differ significantly from those found in conventional railroads. In addition,

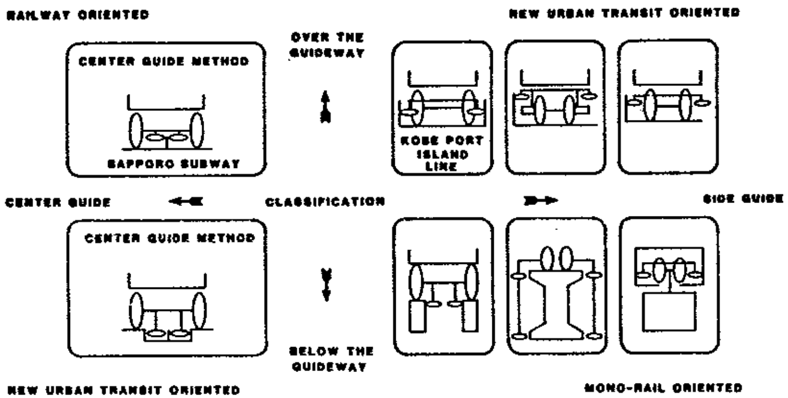

Figure 5. Classification of Vehicle Guidance

closed-floor track construction is normally employed within city limits to prevent the danger of objects falling from the track and to avoid induction interference. Such systems currently in use employ a minimum turn radius of 30 meters, a maximum gradient of six percent, and a width of approximately 7.5 meters for double tracks and 4.25 meters for single tracks.

Coaches and Switches. Coaches used in new transit systems are about the size of a large bus. They are both smaller and lighter than conventional railway coaches in order to reduce loads on the track. It required sophisticated design technology to give new transit systems automatic operation and rideability superior to anything conventional railways can offer. One of the pioneering efforts of Japanese train tire technology, and one which allowed it to take a great step forward, was the installation of the Sapporo subway systems in 1971. There have also been significant studies made in rubber tire tracks, especially in the areas of coach vibration (rideability), maintenance, installation and materials.

Such advances have also contributed to the development of small size coaches with rubber tires and several guidance system approaches. The guidance method is closely related to the switching method, and consequently the choice of switching devices. The various types of coach guidance systems are presented in Figure 5.

Electrical Equipment. Most new transit systems are employing 3-phase alternating current to power their trains. Some of the reasons for this are listed below:

- 3-phase alternating current may be used as an auxiliary source of electricity, thus eliminating the necessity for MGs or inverters in coaches.
- Automatic operation and electrical regenerative control are facilitated, since the thyristor Leonard control method, which is equivalent to the chopper control method, can be employed in coaches.
- Inductive interference is smaller than with single-phase alternating current.

Over and against these, the advantages of direct current are as follows:

- Simpler power rail and power collectors
- Smaller impedance
- Unnecessary to control power factor connection, etc.
- The guide rail may be used as a return line for electrical power.

Since direct current brings with it advantages such as these, it is well suited for use in connected coach trains. In the final analysis however, the choice of electrical format depends on the size and type of the particular system.

Train Safety Equipment. Train safety equipment used in new transit systems represent improvements over established equipment. Many use automatic train control equipment along with detectors placed over the entire length of the track. Signals are IR closely coupling high-frequency signals, and the ground train detector loop is also used for automatic train control transmissions.

In addition to an anti-power-failure system and a signal transmission checking capability in each coach, check signals are fed into ground level loops to check coach locations, as well as broken or damaged wiring.

Communication Equipment. New transit systems are equipped with a variety of communication devices for the purpose of relaying information under normal circumstances or in times of emergency. All trains are equipped with wireless telephones which can transmit two-way messages between them and the central control room. They are conveniently set up in each coach for easy passenger use. In addition, messages can be broadcast from the central control room to an individual train or all trains simultaneously.

In emergencies, the flow of electricity to affected sections may be stopped automatically by an emergency bulletin sent from any train or station.

Station information, as well, is usually broadcast automatically under normal operating conditions. However, in times of emergency, instructions or broadcasts regarding passenger safety are made by the control room operators. Interphones connected to the central control room are also provided at all ticket exits, from which any necessary passenger service can be conducted.

Information Transmission Channel. With unmanned operation as a goal of the new transit systems, the Information Transmission Channel assumes the role of an indispensible lifeline linking individual coaches with the central control rooms. In many systems, information transmission is performed by track-installed loops or LCXs, which exchange messages with coach antenna by means of radio waves. The IR loop operates via closely coupled waves within a carrier frequency range of 10-200 KHZ. This method has met with widespread success in conventional railroad applications, and contains the advantage of lenient legal restrictions. In the minus department, however, there are limitations on the number of signals this system can transmit per carrier wave, and the noise level is relatively high.

The LCX method employs space wave transmission with carrier waves in either VHF or UHF bands. This method maintains high stability with respect to external noise, and technically allows transmission of large amounts of information, such as voice and video messages, on a single carrier wave. However, there are at present restrictions imposed by the Wireless Telegraphy Act which must be resolved before this type of transmission can become available for widespread use.

Coach Depot. The coach depot houses coaches when they are not in service. Operations such as inspections, maintenance and repairs, and storage are also performed here, necessitating the establishment of inspection stations, maintenance bays and coach storage space on the premises. New transit systems have adopted a fully automated method of coach marshaling within the depot, including entry and exit. Marshaling is centrally regulated from the depot control room.

Station Equipment. Stations naturally contain equipment for the sale and collecting of tickets, as well as for providing passenger information. This equipment is supervised and controlled from the central control room

which also contains equipment to collect, monitor and control data on ticket sales, passenger counts, etc.

Comprehensive Control System. The task of the Comprehensive Control System is to assume the efficient functioning of all system components. Computers are employed to provide automated control, with the exception of areas requiring human decision making. Incorporating the functions of group control, remote control, and monitoring and correction, this control system is designed to guarantee system safety along with quick, correct functioning. It also contains the flexibility for responding to emergency situations according to the decisions of the central operators.

System control can be divided into the two general categories of centralized and localized control. Since factors such as numbers of component devices, response, reliability and maintainability differ with the type of control, the final choice must be based on system size (number of control objects) and operating conditions.

New Transit System: A Working Model

Japan's first new transit system (medium capacity transit system) is Kobe's Port Island line (KNT System) which links downtown Sannomiya Station and Port Island (Figure 6). It was opened to the public on February 5, 1981. Employing elevated track construction throughout, this system consists of double track as far as the island entrance, from which a single track loops throughout the island interior (a total of 9.3 km of track). It was designed to accommodate approximately 70,000 passengers per day, and approximately 10,000 passengers per hour during peak hours. Soon after completion, this system demonstrated its ability to respond to heavy commuter traffic demands by shuttling a record number of over 250,000 passengers in one day during the Port-Island Exposition: "PORTOPIA '81."

The coaches use four urethane filled rubber tires and a light metal alloy body. System operation is highly automated, with a Comprehensive Control System which handles automated electrical control, coach depot control, station control, accident prevention control and data processing in addition to traffic and train control. Coach marshaling inside the depot is also performed automatically by the coach depot control system. And, as

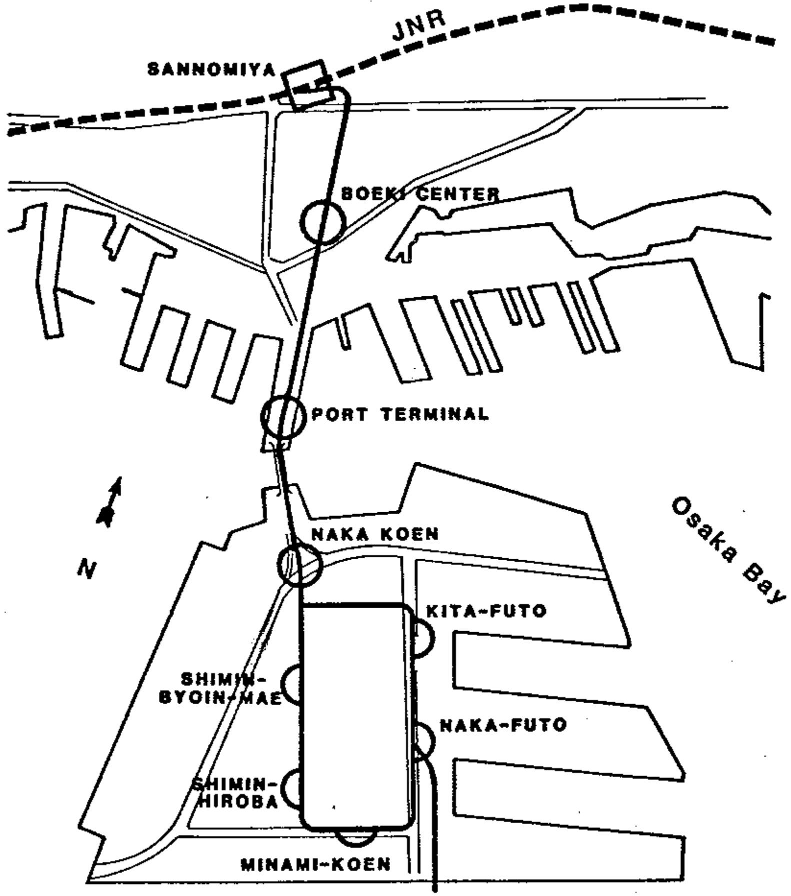

Figure 6. Route Map of Kobe New Transit Port-Island Line

a safety precaution to compensate for the absence of station personnel, platform doors are provided with glass partitions to keep passengers off the track, as well as platform doors which are synchronized with those on the coaches.

Vital statistics for the KNT System are as follows:

- Track length: 6.4 km (2.9 km double track; 3.5 km single track)
- Number of Stations: 9

- Minimum Turn Radius: 30 m
- Maximum Gradient: Main line—5.0%, Side line—6.0%
- Capacity: Peak hour—approximately 10,000 pass./hr.; One day—70,000 pass./day
- Minimum Headway: 2.5 minimum
- Coach Dimensions: Length—Approximately 8.0 m; Width—Approximately 2.4 m; Height—Approximately 3.2 m;
- Coaches per Train: 6
- Seating Capacity: 450 pass./train
- Maximum Speed: 60 km/hr.
- Electrical System: 3-phase alternating current 600 V, 60 HZ
- Train Operation: Unmanned drive via automatic train operation
- Train Safety: Automatic train control
- Guidance System: Both side rail guidance
- Switching System: Up-down type (2.5 seconds operation time)
- Coach Depot: Automatic marshaling

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The Future of Automated Guideway Transit In The Multi-Modal Mix Of Transit

Lawrence L. Saunders

Transportation has evolved and expanded over the centuries with each evolution as a result of the introduction of new technology. The potential role of automated guideway transit as a new technology for urban areas is the basis of the paper. Several methods to finance automated guideway transit in the urban areas are proposed.

- Cut Back
- Reduce Support
- Lower Ridership
- High Cost of Labor and New Equipment
- Fares Not Commensurate With Cost of Service
- Service Not Compatible With Ridership Needs
- No One Entity Responsible for Transit
- Flexibility of Systems Versus Changing Demands
- Subsidy from Federal, State and Local Governments Being Curtailed

All of these phases represent knee jerk reactions to age old problems experienced by transit in the United States and I fear for many countries around the world; namely, no consistent long term planning, financing or single business entity responsible for transit. If we can learn anything from history, it might be that a process or system used in the past, may, in fact, have some use in our current complex world. Transit is by no means an exception to this point, in that we have always been a society of multi-modal transit from the first human who used beasts of burden, then water-borne craft, land based conveyances, trains, the personal automobile and ultimately, aircraft. Much as the elevator changed the complexion of cities, I believe that Automated Guideway Transit (AGT) should be considered a reasonable alternative/solution in the multi-modal mix required to solve

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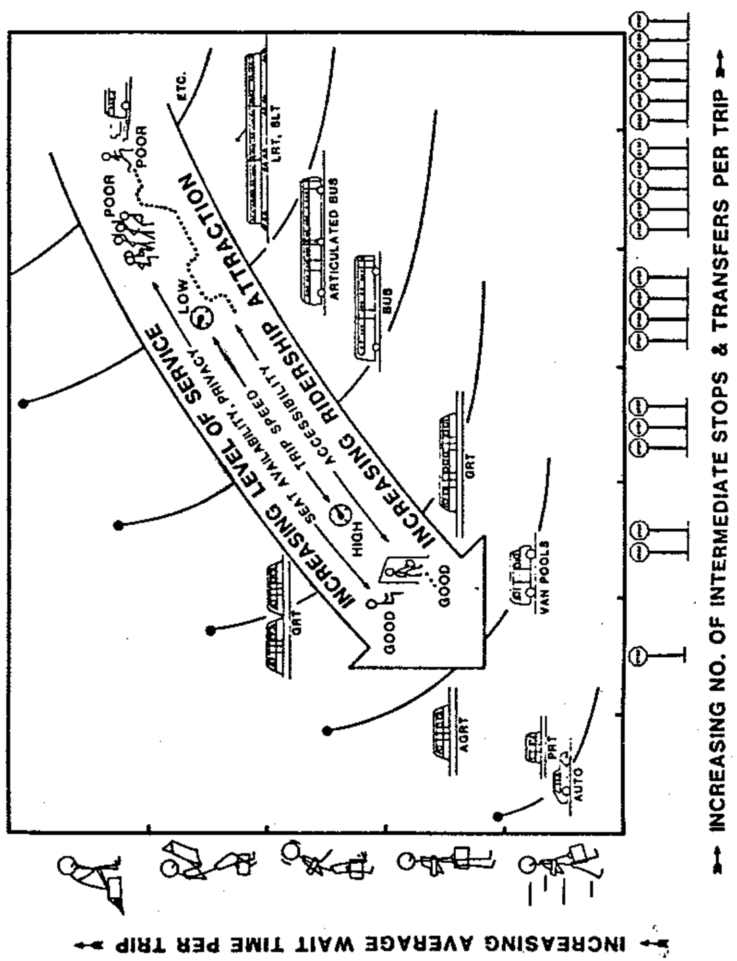

Figure 1. Transportation System Relationships

the very complex transit problems of today. Figure 1 is a graphic representation of the applicability domains for some transit modes used in such a multi-modal mix; within the broad range of technologies represented, the AGT category includes Group Rapid Transit GRT, Advanced Group Rapid Transit AGRT, and Personal Rapid Transit PRT versus other modes of transit. Just as the broad range of technical solutions must be used to satisfy a particular transit need, so must the varied approaches to financing the capital and operational costs of the system. So where do we go from here to create the interest and follow through to transit service that meets the perceived need in a cost-effective manner? First, it must be acknowledged that two basic factors prevent appreciable interest or investment in making the major changes necessary for positive transit customer response to AGT. The first is a continuous increase in automobile ownership and usage; the second, is the continuously increasing direct labor costs for all existing public transportation systems. These two factors have resulted in a continuing upward spiral of transportation subsidies while public transit patronage is on the decline.

Public transportation and urban development are being carried out more and more as separate functions. While there has been some limited coordination, each activity has funded, operated and planned new facilities with an "arms length" attitude. As direct subsidies increased, private development protected itself by making certain the public transportation function was performed separately. It is now evident that the investments in our cities require a new look at strategies to cause a more continuous and profitable growth process now that the subsidies are being radically reduced by all sectors of government. In the United States, urban centers comprise one of the nation's largest investments in facilities. The growth, operation, and maintenance of these facilities are now under severe pressure in many of our cities. Unless these facilities can be made more productive, they will decay and in some instances, die. There is no doubt in my mind that urban centers have the capacity for serving many more people and providing more activities than are currently being carried out. Yet, the recent trend in most large urban centers clearly indicates a reduction in population and activity in terms of the number of functions and the hours of utilization each day. Both the quality and quantity of mobility provided for people and goods is decaying, this in face of the fact that the nation's 75 largest metropolitan areas contain more than half of the U.S. population and account for 54% of the total national employment.

A specific example of the decay is the low productivity of the horizontal public people mover modes which are currently inhibiting full utilization of our urban centers. The public transit system—bus and rapid transit—does not consistently attract a large enough portion of the market (i.e., share of the total trips potentially generated), nor do they adequately participate in (or precipitate) the market growth in the urban centers. The automobile is the largest people mover market, but even its use is being limited by adverse downtown traffic conditions, inadequate parking capacity, and parking distribution which reduces parking "performance." Note: I am speaking of the horizontal people moving modes in contrast to the vertical movement so successfully used in high-rise offices, apartments and other commercial buildings.

The highways and freeways joining our urban centers are some of the finest in the world. However, when an automobile approaches or travels in our city centers, the energy consumption, cost and travel time are very poor; for some, unacceptable, but still they choose the automobile over public transit.

There is a dire need for reversing this trend and to begin showing improvement in economic and social conditions in these vital central areas of our cities. Government, at all levels, has attempted to bolster and hold up conventional public transit as a solution to urban center transportation problems. The problem areas of the urban transit situation are very well summarized by the U.S. Census Bureau which states that mass transit ridership dropped from 9% in 1970 to 6% in 1980.

This problem area resembles a troubled manufacturing plant producing a complex product requiring a great deal of labor. As inflation and rising labor costs continue, the product becomes less competitive, loses market participation, and this results in further increases in internal costs. Manufacturers who successfully cope with these situations do so by becoming more competitive (lower costs) and at the same time, improving the product over what was supplied at the high costs.

Automation has been one of the critical factors in solving the manufacturing plant problem. It now appears the same will be true for horizontal urban people moving—*the method of employing automation will determine its success, not how clever or sophisticated the technology of the automation.*

The time has come for the introduction of new concepts and methods if our urban centers are to become cost effective and continue their growth. The new concepts must fully utilize and interact with all modes of transportation, especially the automobile, while eliminating congestion and pollution. In other words, just like the manufacturing plant, our transportation "product" must not only be lower in cost per passenger, but higher in quality. It must become a joy once more "to get around downtown".

Two of our nation's greatest transportation successes in urban growth have been the highway system and the high-rise building system. AGT systems offer the opportunity of joining together the free flowing transportation systems of the highway including automobile and bus with the free flowing transporation systems of the vertical building using both of them for a new greater environmentally desirable and more exciting growth.

The greatest pitfall in applying AGT in the urban environment lies in the continuing use of single function or single agency implementation. That is to say, the highway department, the transit agency, the parking authority, etc. do their own thing quite independent of the other—only obtaining verbal cooperation. Just imagine if we had independent agencies for different parts of a high-rise building, what it would end up looking like. The degree to which the "development" or "business approach" is accomplished is a factor that will influence the success of AGT.

What is meant by bringing together a single "development" or "business approach" (enterprise) for people moving systems is the joining of all the elements involved in the planning, designing, marketing, financing, operating and maintaining a total system. These elements are not complicated but they appear to be very illusive in the horizontal people moving marketplace. Or to describe it another way, the elements are difficult to bring together as a financial and business package. The vertical building, even building complexes, can be readily brought together in one business enterprise by a single owner usually on one piece of land. The catalyst to growth in the high-rise building market has been the constant and continual improvement in the cost effectiveness of the rental space as a result of the proper application of the vertical automated elevator. There is now available in the marketplace, AGT hardware as illustrated on Figures 2 and 3 which can cause a greater revolution in our horizontal urban growth process. However, unless the objective is packaged as a continuously improving productive business addressing the following issues, we will not see AGT implemented to its full potential.

- A truly forward looking planning process taking into account the significant benefits of all modes of transit whether they be bus, automobile, AGT, light rail or heavy rail.
- Service available from intercept point to multiple destinations in the urban center meeting the equivalent criteria of the vertical elevator.
- Interceptions and parking for a continuously increasing number of

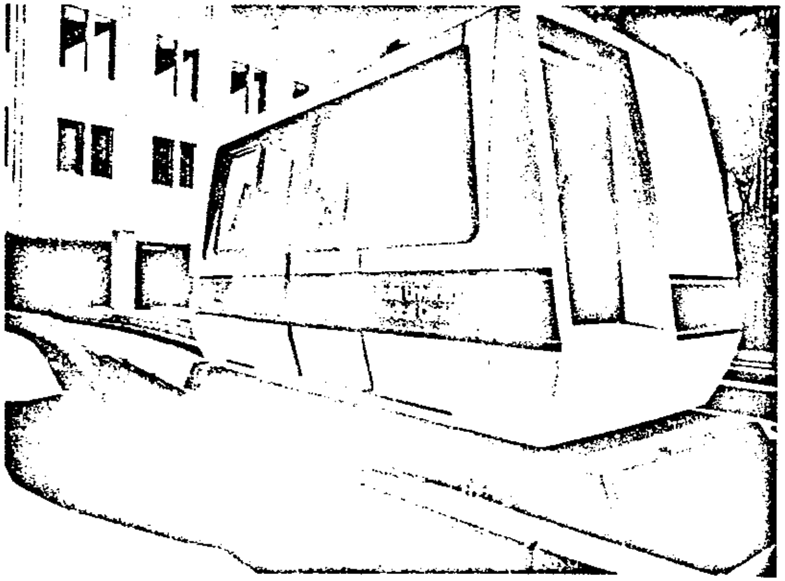

Figure 2. Otis 29 Passenger Vehicle System

customers, primarily from the automobile, but also from other modes of public transit.

- Developed intersection areas to provide built-in security making collection of fares automatic in parking or as a rental functions and new market situations at each stopping place (stations).
- Operation and activities designed and developed to more fully utilize facilities up to their full potential of 24 hours a day, 7 days a week, 52 weeks a year.

In order to have a successful development or business enterprise, it is absolutely essential that appropriate and timely financing be available. Transit in the United States has seen a radical change in its source of funds as the result of a significant change of policy by the current federal administration. Although traditional methods of financing still exist, the opportunity for a transit district, locality or business enterprise to avail itself of funds from "safe harbour" leasing, block grants and/or subsidies from federal, state and local governments is shrinking very fast; we must, therefore, pursue alternative sources to finance transit in the future. To this end, one largely untapped source of funds for transit, beyond the fare

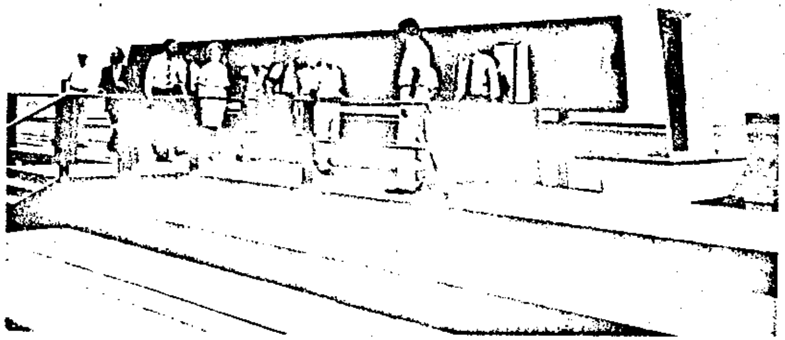

Figure 3. Otis 100 Passenger Vehicle System

box and generally accepted revenue sources, consists of innovative financing, so-called because it tends not to have been employed in any significant way to pay for transit. Some of the more promising methods of innovative financing are:

Approaches/Techniques Involving Land Use Regulation Incentive Zoning:

Transit or development entity benefits from incentives that encourage desirable land use and associated improvements at a particular location (e.g., a density bonus in the form of extra floor space for new buildings in exchange for developments which are directly connected to transit).

Special District Zoning: Transit or development entity benefits from detailed public planning and special zoning for areas adjacent to transit (e.g., developer provides pedestrian amenities or contributes to a transit improvement fund as a condition for zoning approval).

Dedications and Exactions: Transit or development entity receives from private developers a mandatory provision of land or public facilities (dedication) or cash (exaction) as a condition for subdivision approval, rezoning or other development requests.

Official Map: A transit or development entity benefits from an official map, which typically precludes building permits for land assigned to future public uses such as transit, highways, or other major public facilities.

Taxes, Special Assessments and Service Charges

Dedicated Property Tax: Transit or development entity levies (or receives per agreement) a tax on the assessed value of land and/or improvements within designated district served by the transit system.

Tax Increment Financing: Transit or development entity levies (or receives per agreement) all or part of property tax increases beyond a "frozen base" within a specified area served by transit.

Special Benefit Assessment: Transit or development entity levies (or receives per agreement) a charge against property in a specified district (e.g., within a specified radius of a transit stop).

Service Charges: Transit or development entity levies (or receives per agreement) a one-time or continuous charge in return for connection of an adjoining property to transit (e.g., fee for direct tie-in to transit facility).

Public Land Acquisition

Lease or Sell Air Rights: Transit or development entity acquires air rights as part of approved transportation right-of-way, then leases or sells space above or below the transit improvement.

Lease or Sell Supplemental Property: Transit or development entity acquires supplemental property (i.e., more than actually required to build the transit improvement) then leases or sells the land or related development rights.

Develop Air Rights/Supplemental Property: Transit or development entity acquires air rights and/or supplemental property, then develops and subsequently holds or sells the resulting real estate project(s).

Participate in Property Development: Transit or development entity contributes equity (e.g., land) or extends loans or loan guarantees as a part of project financing thus assuming a share of the risk as well as a share of the return.

Of particular note in the area of innovative sources of financing, are the areas of incentive zoning, dedicated property tax, tax increment financing, special benefit assessment, and lease or sale of air rights. Each of these

areas has to some degree seen use with respect to transit in the past. It has not, however, been the practice or an accepted approach to utilize these funding techniques for a singular enterprise responsible for a total transit system.

In summary, for there to be a future for AGT, government agencies representatives, looking out for the good of all, must join with suppliers, marketers, and transit operators to aggressively push for long term transit planning and commitment, and the evolution of a business enterprise encompassing all aspects of transportation. And finally, we must use innovative financial techniques as the time of unlimited subsidy support has come to an abrupt halt at least in the United States.