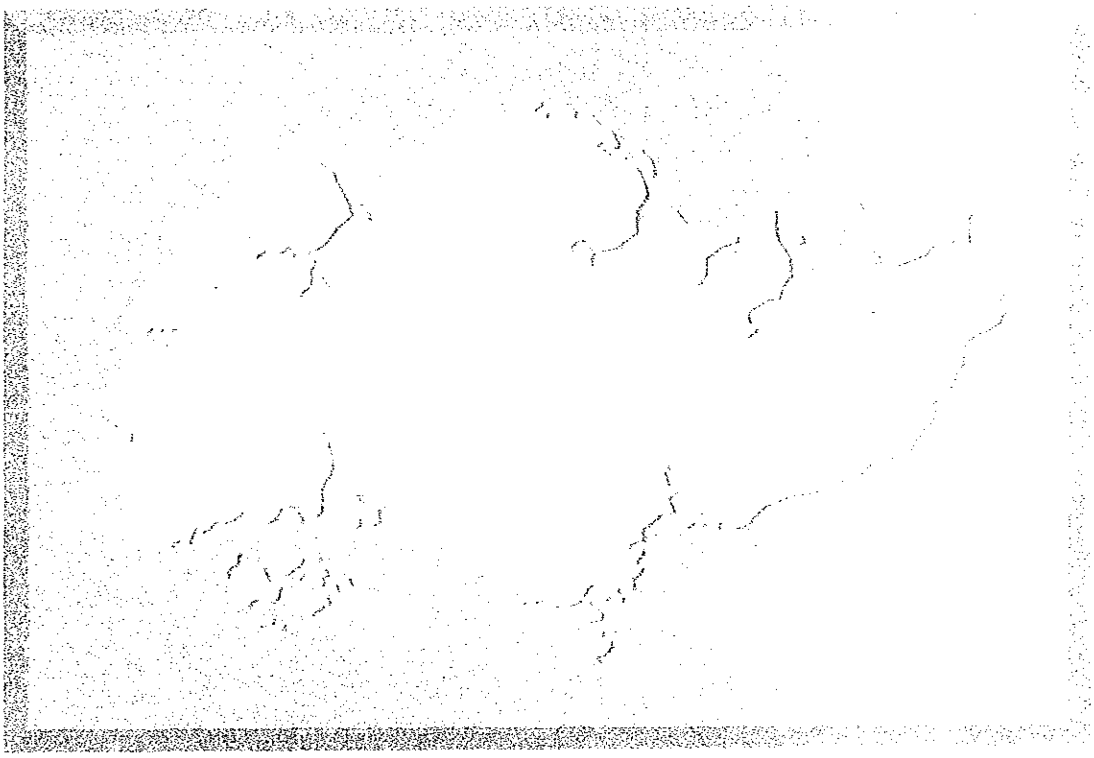
REPUBLIC OF SINGAPORE

SINGAPORE URBAN TRANSPORT IMPROVEMENT STUDY (SUTIS)

TECHNICAL REPORT No. 5

Comparison of Available New Transit Systems



NOVEMBER 1988

Japan International Cooperation Agency

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1. INTRODUCTION

At present, the term "new transport system" has not been specifically defined, and technologies of the varieties of the systems are at different stages of development. Although a number of countries have developed or been developing various systems, there are not enough examples for the government to consider in order to decide on a definite approach to the development of such systems.

This paper present primarily the characteristics of the new transport system which could possibly be introduced to the areas where feeder transport services should be improved.

2. OUTLINE OF NEW TRANSPORT SYSTEM

2.1 HISTORICAL BACKGROUND

The need for a "new transport system" was first discussed seriously in the 1960s in the USA. Rapid urbanization which took place from 1940 to 1960 had resulted in a sprawling of urban areas and deterioration in CBD areas. The US Department of Housing and Urban Development issued "Tomorrow's Transportation - New Systems for the Urban Future, 1968" wherein the foreword of the President states that "cities must be renewed to create employment opportunities, to promote health and to provide better education." This can only be realized by rehabilitating the transit systems. The following goals were set for the development of new transport systems:

a) To ensure the equality of mobility (for the handicapped, non-car owners, children, and the aged) within urban areas;

b) To improve the quality of transport services:

c) To relieve traffic congestion;

d) To achieve maximum/effective use of transport facilities;

e) To encourage efficient use of land;

f) To minimize adverse environmental impact;

g) To meet various transport demands due to varied urban development pattern in a flexible manner; and

h) To improve institutional aspects which are obstacles to the extension of new systems or technologies.

It is known that the conventional transit modes represented by subway/heavy railway and bus cannot necessarily cover the varied transport demands sufficiently, either because of their rigid hardware and inflexible operation system or their financial restriction.

There are three areas where conventional systems can not properly meet the demand and would, therefore, require new systems:

a) a transit system with intermediate capacity in between bus and heavy rail system,

b) a personal transit system with flexible operation which can compete with private cars,

c) short-haul mass transport system to cover around 500 to 1,000 meter distance.

Accelerated by the above movement initiated by the USA , many countries including Japan, West Germany, France, UK, Canada, etc. started to experiment and construct various systems especially in the 1970's. Although the activities have slowed down and diverted from the original concepts, both the government and the private sectors of said countries have been continuing their efforts towards these developments.

2.2 DEFINITION AND CLASSIFICATION OF NEW TRANSPORT SYSTEM

There is no proper definition for the so called "new transport system". However, for this study a "new transport system" means "unconventional transport system" and will include all possible transport systems other than those existing in Singapore.

Accordingly, various classification methods are used in different texts/publications. Table 2.1 shows the type of the systems classified by guidance method.

Table 2.1

Classification of New Transport System

Classification		Description & Examples of System
1. Guideway Transit System	Intermediate Capacity Transit System	The system with an intermediate carrying capacity (about a bus size) and automated operation on the guideway.
	Personal Transit System	Same as the above system but with a personal car unit capacity.
2. Continuous Transit System		The system such as moving pedestrian walkway, escalator, etc.
3. Non-Guideway Transit System		The system such as dial-a-bus
4. Dual Transit System		The system which can be operated both on guideway and road, such as dual mode bus.

A new transport system in the narrow sense is defined as automated "guideway transit system" in the above table. When this was first discussed in "Tomorrow's Transportation for the Urban Future," the system was classified as shown in Table 2.2.

Table 2.2

Classification of Guideway Transit System

Classification	Description
AGT: Automated Guideway Transit	General term for new transport system
SLT: Shuttle Loop Transit	AGT with simple route structure single line or loop line
GRT: Group Rapid Transit	AGT using bus-size cars, comprising a number of routes
PRT: Personal Rapid Transit	AGT using personal car unit and being operated on rail network according to passengers demand

Source: Tomorrow's Transportation - New System for the Urban Future, HUD, 1968

The other classification made more scientifically for the guided mode is shown in Table 2.3, which also indicates typical systems either existing or being experimented.

Table 2.3

Classification of Guided Modes with
R/W Category by Vehicle Size and Guideway Technology

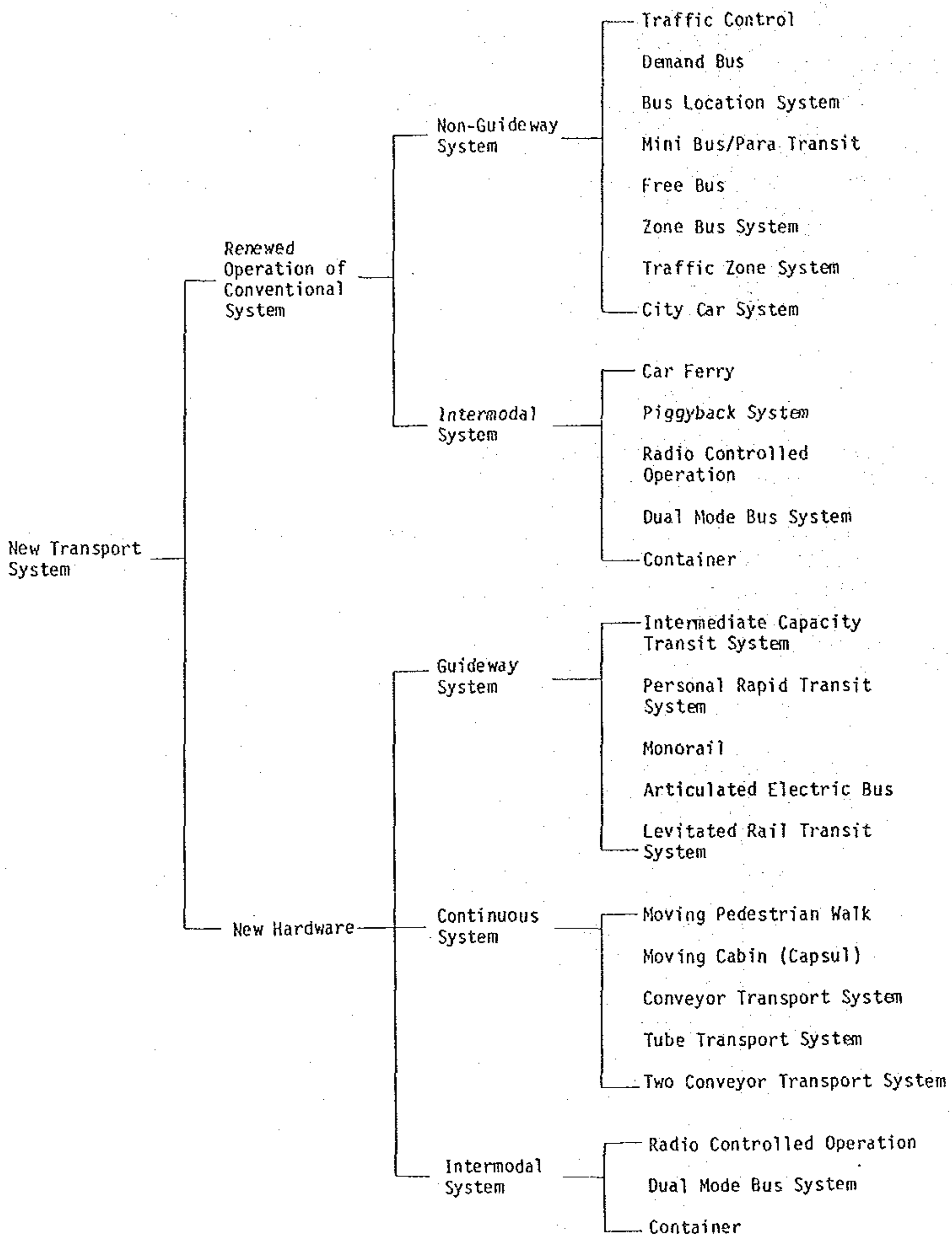
Guidance Technology \ Vehicle Size	Samall	Medium	Large
Rubber-tired	Rubber-tired Aramis, CVS CVS, Kabinen-taxi, Monocab)	GRT or people mover systems (Airtrans, Skybus, Trans-urban, VAL)	Monorails (Alweg, Safege) Rubber-tired RT (*Lyon*, Mexico, Montreal)
Rail	Rail PRT (Palomino, Minitram)	Light rail rapid transit	Rail rapid transit Regional rail
	Automated guided transit	Rapid transit	

Source: Urban Public Transportation by Vukan R. Vuchic

Taking into account of a new way of operating conventional systems, the "new transport system" can also be classified as shown in Figure 2.1.

Figure 2.1

Classification of New Transport System



Source: New Transport System by I. Ishii, 1970

2.3 CHARACTERISTICS OF THE SYSTEMS

A new transport system can be distinguished from other conventional systems particularly on the following aspects:

a) automated operation
b) demand oriented flexible operation
c) pollution free
d) intermediate capacity
e) transit system

In addition to the above, low cost is supposed to be one of the features. However, as many systems are still under development, there is little accurate information on the system cost. Table 2.4 presents some selected typical new transport systems.

Table 2.4
Outline of the Selected New Transport Systems

Particular \ System		Guideway Transit System					Continuous Transit System		Dual mode Transt System	Non-Guideway Transt System
		Intermediate Capacity Transit System	Monorail	Min-monorail	LRT:Light Rail Transit	PRT:Personal Rapid Transit (People Mover)	Moving walk	Capsul	Dual mode Bus	Demand Bus
Practical Range of Transport Capacity (No of Pass.hr/Direct)		5,000 - 20,000	10,000 - 40,000	2,000 - 10,000	3,000 - 10,000	- 1,000	- 5,000	- 3,000	- 5,000	- 5,000
Transt	Car size;LxW (m)	8 x 2.4	15 x 3	5 x 2	13 x 2.5	3 x 1.5	-	2 x 2	10 x 2.5	10 x 2.5
	Standard Passenger Capacity	75	100	20	100	2 - 6	-	2 - 6	80	80
Structure		grade separated	grade separated	grade separated	at grade	grade separated	at grade	grade separated	at grade	at grade.
Operation	Sched. Speed (kph)	25	25	20	25	30	6	12	12	12
	Min. Headway (min)	2	2	2	1	0.5	continuous	0.1	1	1
	Assumed Station Spacing (m)	500	500	300 - 500	300	300	-	300	300	300
	Automated Operation	automated	automated	automated	manual	automated	automated	automated	automated/ manual	manual
Approximate System cost	US$ million/km	60	70	30	6	70	45	70	40	3
	Ratio	(20)	(23)	(10)	(2)	(23)	(15)	(23)	(13)	(1.0)
Environmental Impact	Noise, Air Pollution	none	none	none	noise	none	none	none	noise & air pollution	noise & air pollution
Maturity of System/Technology		fairly extensively used	faily extensively used	a few development cases	extensively used	more on experimental stage	short distance only	experimental stage	a few development cases	a few development cases
Existing Systems/Cases		Kobe Osaka Lille others	Tokyo Kitakyuhsu Wuppertal others	Sydney Sentosa	Düsselforf Stockholm Toronto Hiroshima others	Morgan Town Miami	Osaka		Essen Adelaide Turin others	Osaka Tokyo

Source: various data and information
worked out by the study team base on

3. DEVELOPMENT OF NEW TRANSPORT SYSTEM IN SELECTED COUNTRIES

3.1 United States of America

With the strong support of the government on the development of new transport systems initiated by "Tomorrow's Transportation" in 1968, a number of development groups, both from private sectors and those organized by the government, had promoted research and experiment feverishly. The new transport system intends to overcome the problems caused by excessive car oriented transport systems, to provide transportation for the poor, to ensure accessibility to new town areas and to meet the needs for a pollution-free transport mode.

At that time the electronics industries were growing rapidly. Coach builders, electric and electronics companies and aircraft manufacturers participated in the development. In 1971, the government enacted the "Urban Mass Transit Promotion Act" to encourage the development of mass transit in urban areas. This law also enabled the demonstration of new transport systems. Transpo '72 held in Washington was also very successful under the above environment. It is said that there were more than 300 plans and ideas on new transport systems, submitted for government assessment for technical and economic merits. The following systems were considered favorably:

a) Dial-a-bus: A system whereby buses are operated according to passenger demand and request.

b) Personal Rapid Transit: Automated unmanned system operated on exclusive network.

c) Dual Mode Vehicle System; A system using a small vehicle which is operated on roads by driver mixed with other vehicles operated automatically on the guideway.

d) Automated Dual Mode Bus: A system described in (c) above but using bus.

e) Pallet or Ferry System: An alternative system to dual mode system transporting conventional vehicles using pallet or ferry on guideway but otherwise on their own tracks/roads.

f) Fast Inter-urban Transit Line; An inter-urban mass rapid transit system wherein unmanned medium size cars can be operated either individually or in articulated manner.

g) Major Activity Centre's System; A system for the circulation in CBD area such as moving pedestrian walk, capsul type transport system.

The history of new transport development in the USA is summarized as follows:

1) A 3 km long experimental line of Sky bus, an Automated Guideway Transit (AGT) by Westinghouse was opened in 1965 for demonstration in South Park of Pitsburg. The system was developed with Government subsidy.

2) In 1971, a Shuttle/Loop Rapid Transit (SLT) was constructed in Tampa Airport, Florida, with 2.2 track-kms., 8 stations, 8 cars and 4 shuttles. (See Table 3.5 for more details of Tampa).

3) In 1972, a SLT was developed for Houston Airport, Texas.

4) In 1972, Transpo '72 was held in Dallas Airport, Washington. With 17 million dollars assistance from the government, the following four systems were demonstrated:

   a) Cashbear: rubber-tired intermediate capacity system with a 31-passenger capacity by BENDICS.

   b) Act: rubber-tired system with a 24-passenger capacity by FORD.

   c) Mono-Cab; suspension-type monorail system with a 31-passenger capacity by ROAR.

   d) TTI: air-levitated linear-motor system with a 12-passenger capacity by OTIS.

5) AIR TRANS was opened in 1974 in Dallas-Fortworth Airport. The system intends to provide internal transportation of goods and passengers in huge airport with 73 sq kms. (See Table 3.5 for more details).

6) Morgan Town PRT was opened in 1975 to provide passenger transport services for the scattered facilities/buildings in the campus. (See Table 3.5 for more details).

7) In 1976, the government launched the Downtown People Mover (DPM) program in conjunction with the redevelopment of downtown areas. Eighty percent of the cost was funded by the Federal Government and 20% by Local Government. The SLT was intended to be introduced in 65 in the downtown area. Sixty-five cities applied but only five were selected for this program: Los Angeles, Saint Paul, Houston, Detroit and Miami. However, the Reagan Administration cut the budget from 50 million dollars to 19.5 million dollars in 1981 then to nil in 1982. In spite of the budget cut, the system in Miami was constructed. (Refer to Table 3.5 for more details of Metro Mover in Miami and People Mover in Detroit).

7) The other systemns constructed particulary for the airports are summarized in Table 3.1.

Table 3.1

New Transport Systems Constructed for Airports in USA

Airport	Year Completed	Cars	Stations	Track-km	Configuration
Tampa	1971	8	8	2.2	Four shuttles
Seattle-Tacoma	1973	12	8	2.8	Two loops
Miami	1979	6	2	0.8	One shuttle
Atlanta	1980	17	11	3.8	Doubles track
Orlando	1981	8	4	2.4	Two shuttles
Las Vegas	1984	2	2	0.7	One shuttle

Figure 3.1
Views of Selected New Transport System Developed in USA

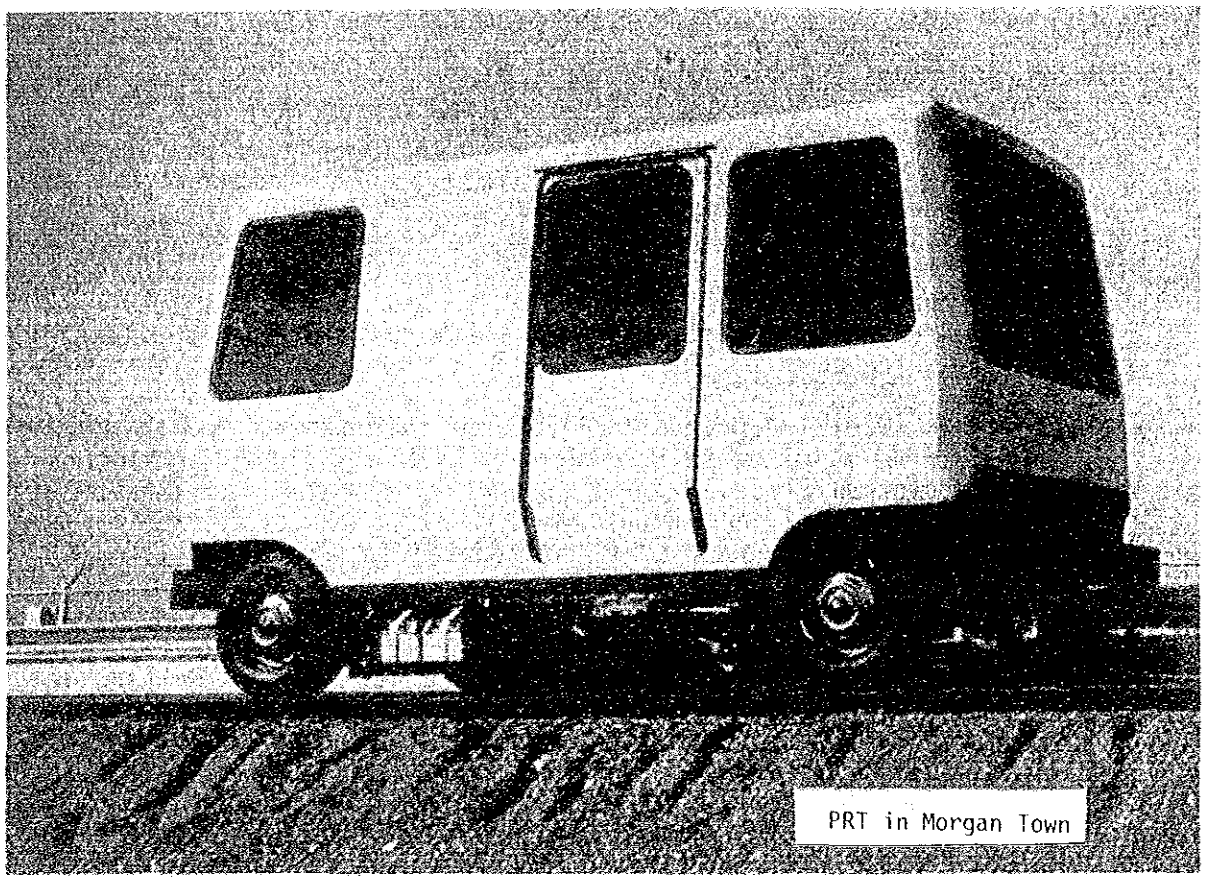
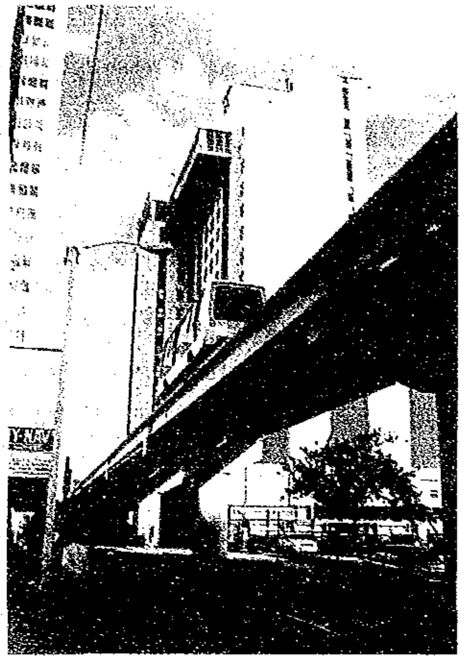
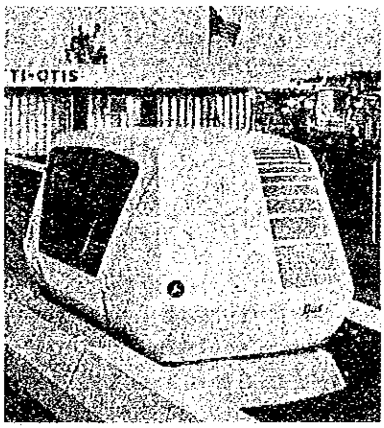

PRT in Morgan Town

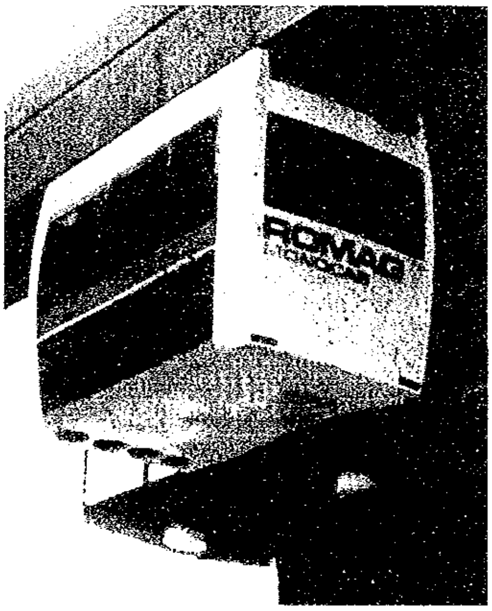
Figure 3.1 (continued)

Miami Metro Mover





TTI demonstlated
in 72", TRANSPO



Mono-Cab

3.2 JAPAN

The activities in Japan commenced in the 1970's. Both the Government and the private sectors were involved. The Government agencies contributed rarions reseach and expreimental work, while the Private Sectors developed various syatem, such as FAST,KCV,KRT,MAT,NTS,PARATRAN etc. (See Table 4.1). The history of the development is briefly described, as follows:

1) In 1971 the "Operation Technology Council" under the Ministry of Transport emphasized the need to develop new transport systems.

2) In 1972, the operation of VONA was started in Yatsu amusement park, a recreational facility.

3) In 1975 the following two systems were demonstrated in the EXPO held in Okinawa:

   a) EXPO-KRT; The system was computer controlled, had 3.7 track-kms, comprised 16 cars with capacity of 23 passengers/car. It carried 4 million passengers during the six-month period of the exhibition.

   b) EXPO-CVS; The system was computer controlled, had 1.6 track-kms, comprised 16 cars with capacity of 6 passengers/car. Of the 16 cars, 3 were dual mode cars and were able to run on ordinary roads as electric car. The system carried 0.8 million passengers during the same period.

4) In 1974, the Government legislated relevant laws and subsidy for the development of new transport systems. The Central Government shouldered 44.9% of the total construction cost as part of road construction by the Ministry of Construction or a part of port development by the Ministry of Transport.

5) A series of standards for the development of new transport systems were prepared by the government, as follows:

   a) Safety Standards in 1974
   b) Design Standards in 1975
   c) Development Standards of Guideway Bus System in 1975
   d) Structural Design Standards in 1976
   e) Operational Guidelines in 1977

6) Since the 1973 oil crisis, the development of new transport system in Japan has shifted to the development of systems which are more economically/financially feasible. Therefore development policies range from fine network service (i.e. increase in transport capabilities) to the introduction of larger articulated vehicle systems and those closer to the conventional rail system. Therefore, most of the systems developed in Japan are intermediate capacity transit systems with fairly large capacities.

a) Kobe Port Island Line in 1981
b) Osaka South Port Town Line in 1981
c) Yukarigaoka Line in 1982
d) Ina Line in 1983
e) Yamaguchi Line in 1985

The outline of these systems is summarized in Table 3.2. In addition, the following two lines are under construction:

a) Tokadai Line in Komaki City, Aichi Ken
b) Kanazawa Seaside Line in Yokohama City, Kanagawa Ken

7) In 1983, the Government prepared the following specifications for the new transport systems:

a) "Standardization and Specifications of New transport System", Ministry of Construction.

b) "Specifications of New Transport System (Intermediate Capacity Transit System)", Ministry of Construction.

8) In Japan, the monorail system in also fairly well developed as listed in Table 3.3.

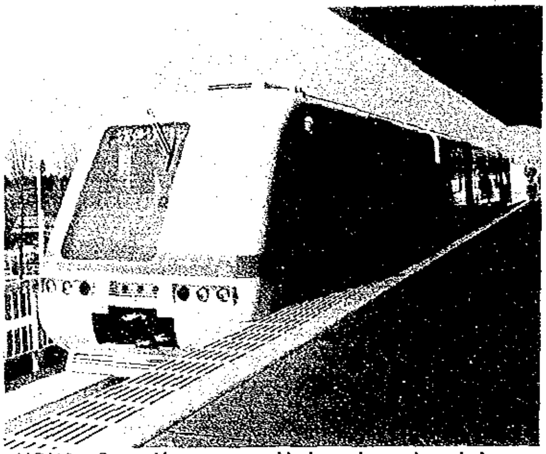
Table 3.2

Outline of the Selected Systems in Japan

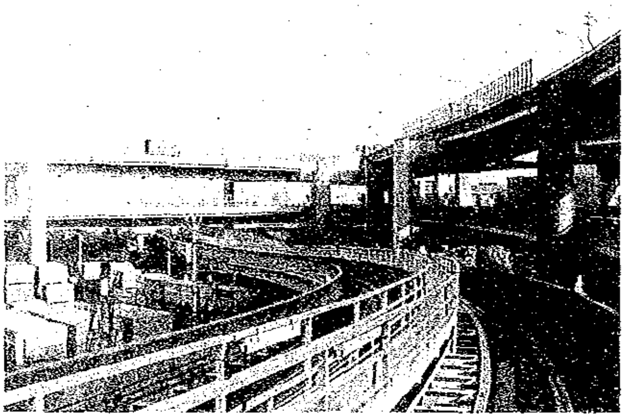
Name of System	K R T	I C T S	I C T S	I C T S	I C T S	I C T S
City/Location	EXPO in Okinawa EXPO Association	Kobe City Port Island Line Private Company	Osaka City South Harbour Osaka Govn't	Sakura City Yukarigaoka Private Company	Omiya City Ina Line Private Company	Tokorosawa City Yamaguti Line Private Company
Year Opened	July 1975	February 1981	March 1981	September 1983	December 1983	April 1985
Type of System	Rubber - tired Side - guided	Rubber - tired Side - guided	Rubber - tired Side - guided	Rubber - tired Side - guided	Rubber - tired Side - guided	Rubber - tired Side - guided
Route Length : kms	1.4	6.8	6.6	4.1	11.6	2.8
Track Type	double	single/double	double	single	single/double	single
No of Stations	3	9	8	6	12	3
No of Cars	16	72	52	9	40	12
Length of car : meters	4.7	8.0	7.6	8.8	8.0	8.5
Pass. Capacity/car	30	75	72/75	65/75	55/64	71/80
No of Cars/Train	1	6	4	3	4,6	4
Driving Method	Unmanned - Automated	Unmanned - Automated	Automated/driver assissted	One - man drive	One - man drive	One - man drive
Electric System	AC 3 phase 600V	AC 3 phase 600V	AC 3 phase 600V	DC 700V	AC 3 phase 600V	DC 700V
Scheduled Speed : kph	22	21	26	19	32	24
Min. Headway : min.	-	2.5(presently 5)	2.3(presently 2.3)	7.0	3.0(presently 6)	-
Transprot Capabilities: No of Pass./hour	- (22,000/day)	Max 10,7000 (42,000/day)	Max 12,000 (43,000/day)	1,200～2,600	(15,000/day)	(3,000/day)
Manufacturer	Kobe Steel	Kawasaki Ind.	Niigata Steel	Nihon Shoryo	Kawasaki/ Niigata Steel	Niigata Steel
Construction Cost : S$ million/km	-	97.1	87.1	7.1	35.7	20.0

Figure 3.2

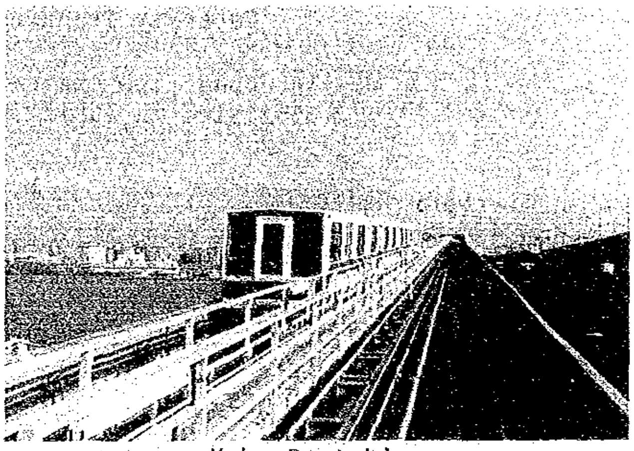
Views of Selected Systems Developed
in Jao Japan.



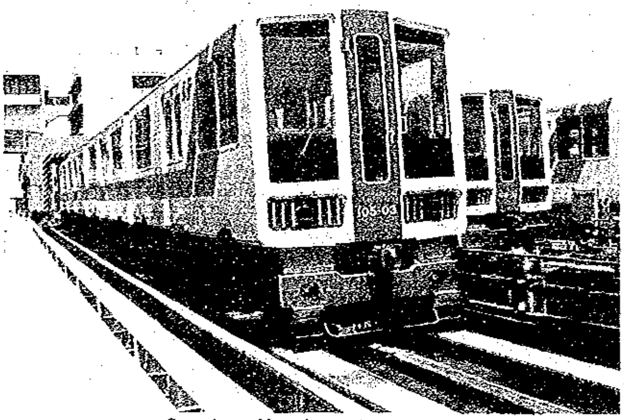
VONA for Yamaman Yukarigaoka Line



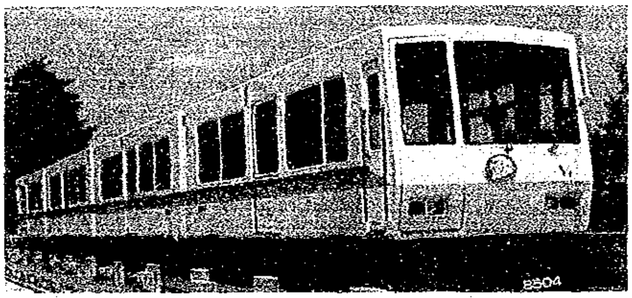
Kobe Port Liner



Kobe Port Liner



Osaka Nanko New Tram

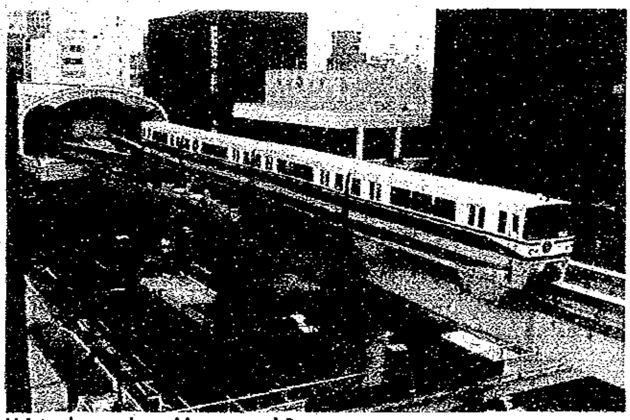


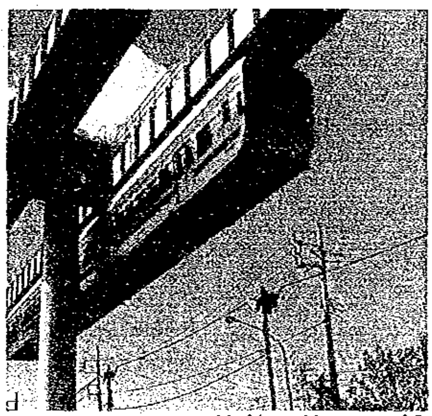
Yamaguchi Line

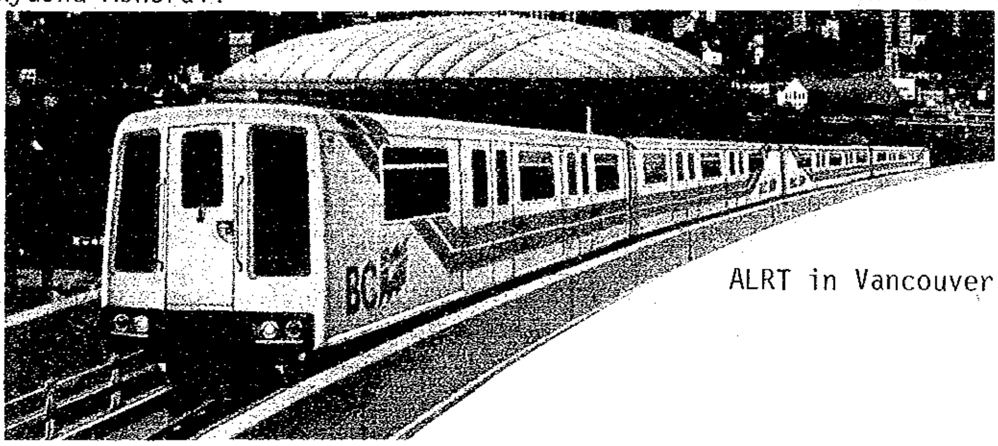
Table 3.3

List of Monorail Systems Developed in Japan

Developer	Location/Section	Length :Km	Type	Year Opened
1. Tokyo Metropolitan Government	Ueno Zoo	0.3	Suspension	Dec. 1957
2. Nagoya Rail Co., Ltd.	Inuyama Zoo	1.2	Straddle	March 1962
3. Tokyo Monorail Co., Ltd	Haneda Int'l. Airport	13.0	Straddle	Sept. 1964
4. Odakyu Rail Co., Ltd.	Mukogaoka Park	1.1	Straddle	April 1966
5. Shonan Monorail Co., Ltd.	Ofuna - Katase	6.9	Suspension	March 1970
6. Kitakyushu Rapid Rail Co., Ltd.	Kokura Station-Kikugaoka	8.4	Straddle	Jan. 1985
7. Chiba Urban Monorail Co., Ltd.	Chiba Station-Chishirodai	12.1	Suspension	1988 (under const'rn)
8. - ditto -	Central Port	3.4	Suspension	Planned
9. Osaka Rapid Rail Co., Ltd.	Osaka Int'l. Airport	13.7	Straddle	Planned


Kitakyushu Monorail


Chiba Monorail


ALRT in Vancouver

3.3 REST OF THE WORLD

Main countries developing new transport systems are West Germany, France, UK, Canada and Switzerland. The systems are different and have unique features.

3.3.1 West Germany

The development activities started around 1970. The government intended to develop a alternative system to the bus, with intermediate capacity. The government subsidizes approximately 50% for systems analysis and 80% for technical research.

The outline of the major systems is as follows:

1) CABINEN TAXI

Development of this system was started in 1970. The system comprises two subsystems: the straddle type and the suspended type using the same guideway. A car has a capacity for two adults and a child. The original system was modified to use a 12-passenger car and was contructed in Tugenhein Hospital for inter-building transport.

2) TRANS URBAN

Experiment of the system was started in 1973 in the compound of Krauss Maffei Ltd. with a 185-meter track using a 12-seater car. The system is magnetic levitated with linear motor propulsion.

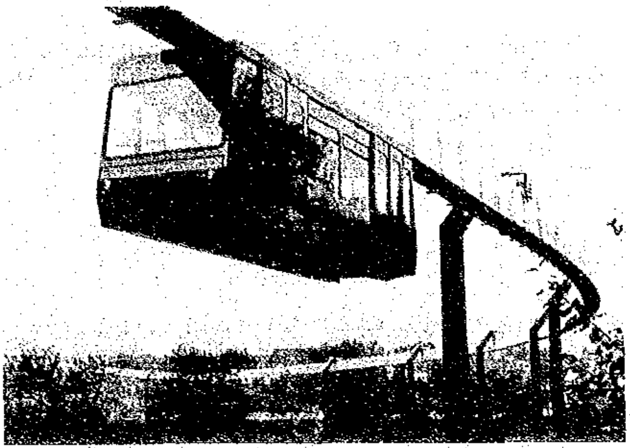
3) H-BAHN

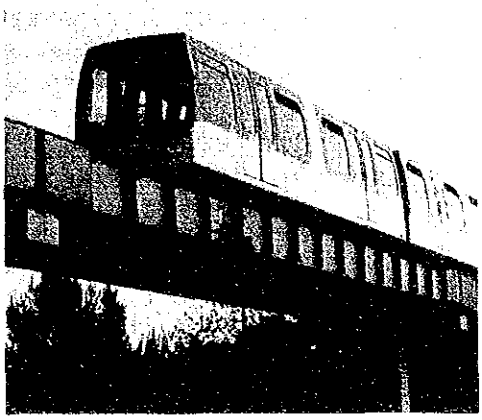
Development of the system was started in 1974 by Siemens and DenBerg Ltd. with subsidies from the government. The system is similar to suspended type mini-monorail. Automated unmanned operation enables the system to carry 1,000 passengers/hour/direction with 40 seconds headway. Capacity of a car is 42. The system has been operating between Dortmund University and Trunk Railway station since 1983.

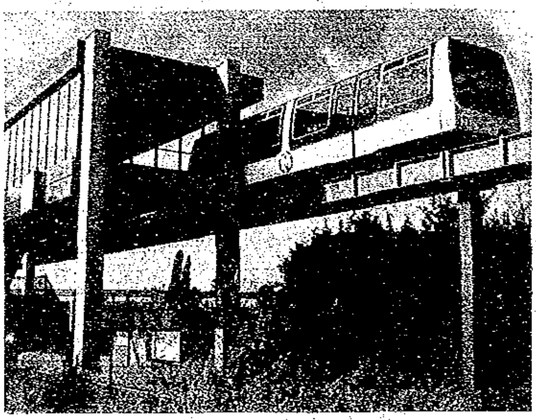
4) M-BAHN

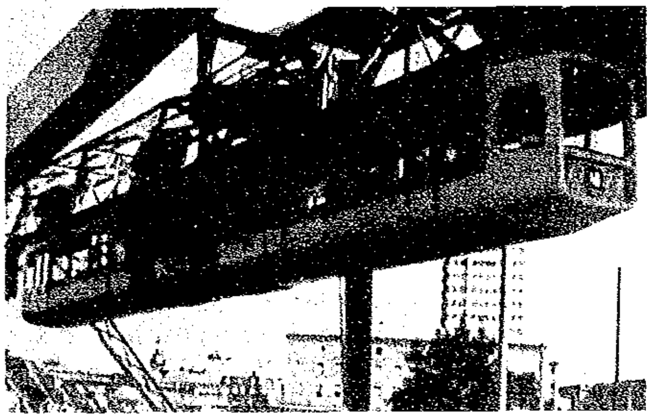
Development was started in 1973 by Magnetbahn Gmbh with technical assistance from Braunschweig Institute of Technology and financial assistance from the government. The system is supported by permanent magnet which shoulder 90% of the vehicle weight and driven by linear synchronous motor equipped on the ground to make cars and guideway light. Propulsion is not therefore equipped with a car.

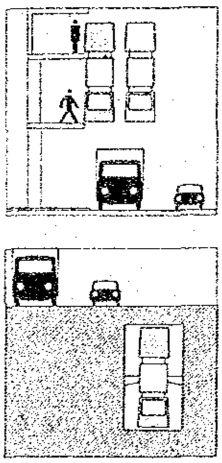
A 2.2-km experimental line was constructed between Komphel Platz and subway station. A car has normal capacity of 71 passengers or crash capacity of 132 passengers.

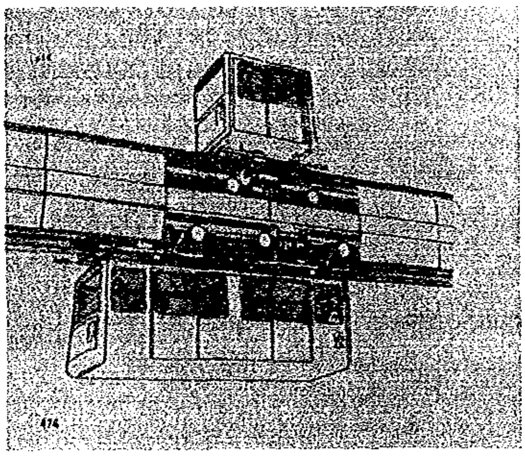

H-Bahn


M-Bahn


A Magle Pilot System


Wuppertal Monorail


Cabinen Taxi


Cabinen Taxi

3.3.2 FRANCE

The Land Transportation Bureau of the Ministry of Transport is in charge of the development of new transport systems. The objectives of the development are:

a) reduction of transport cost
b) assurance of transport safety
c) increase in service quality
d) reduction in manpower

Government assistance is provided for the following three stages of the development:

a) Theoretical research: more or less 100% subsidized

b) Technology research and development: 100% for substructure and 50% for vehicle and experimental research

c) Experimental operation until the commencement of commercial operation: In the case of Lille City, 2/3 by the Central Government, 1/3 by Lille City for the structures and 100% by Lille City for vehicles.

Major systems currently developed in France are as follows:

1) ARAMIS

The system is a 4-passenger capacity rubber-tired PRT driven by electronic motor. A train is composed of about 50 cars which are magnetically and electrically linked with about 30 cm spacing. The computer train will be disconnected automatically by computer to enter off-line when it approaches its destination. Transport capacity is about 6,000 to 15,000 passengers/hour/direction. Development has started in 1970; test track was constructed in Orlie Airport and experimentation is still underway using larger vehicles.

2) VAL

The system is a smaller version of rubber-tired subway of Paris. It intends to transport 8,000 to 10,000 passengers/hour/direction. An automated unmanned method was applied for the 12.6 km system constructed in Lille City in 1983. The system was expanded to 13.3 Km in 1984. (See Table 3.5 for more details of the system).

3) URBA

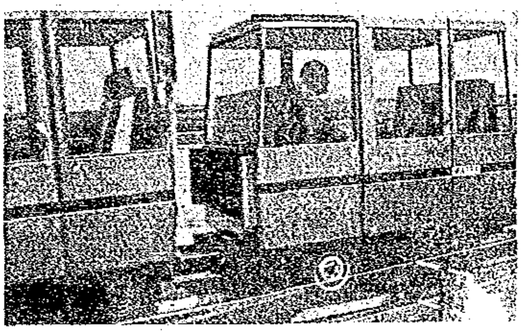
The system looks like the suspended type monorail. It is air-levitated with propulsion from on-board linear motor. Transport capacity is designed to be approximately 6,000 passengers/hour/direction.

4) AEROTRAIN TRIDIM

The system is air-levitated and driven by electric motor. Transport capacity is between 5,000 and 20,000 using cars with capacity of 4 to 100 passenger/car. The system is still under experiment.

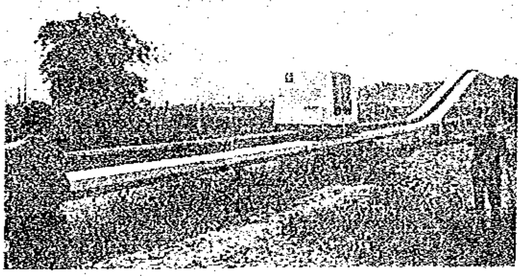
Figure 3.4
Views of the Systems Developed in France

VAL in Lille City



ARAMIS

URBA



AEROTRAIN TRIDUM

3.3.3 United Kingdom

The development of the PRT was started in late 1960's to improve the urban transit system of London, where traffic congestion became very serious due to the sharp increase in private car users. However, there was no such institution for the government to subsidize research and development of new transport systems. It was only in 1974 that the government constructed a 100-meter experimental track for a magnet-levitated system.

Major systems developed in the United Kingdom are as follows:

1) Various systems experimental in the early state of the development are shown in Table 3.4.

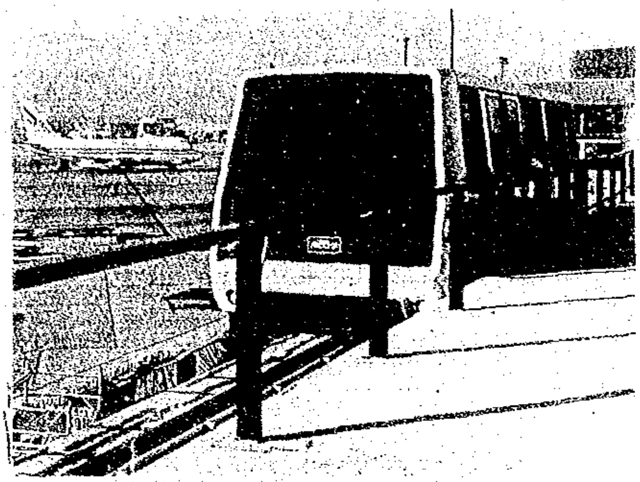
Table 3.4

Outline of the Systems Experimented in the United Kingdom

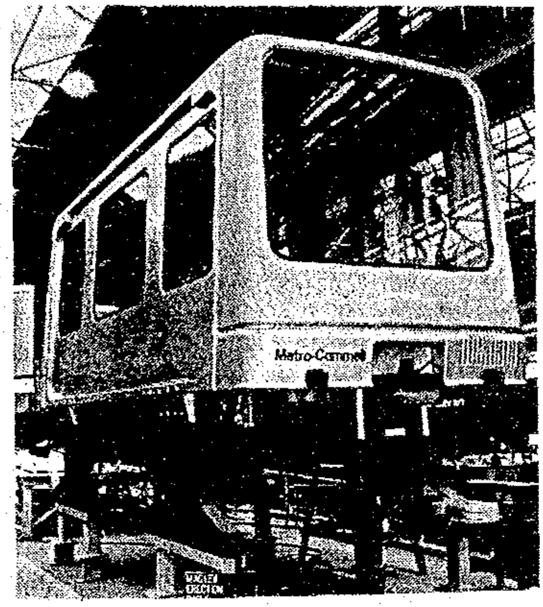
System Name	Type	Capacity of Car: No. of pass/car	Transport Capacity: No. of pass/car	Speed Kph
MINITRAM	Guideway	20	10,000 - 20,000	30-50
CABTRACK	Guideway	4	14,000	32
SPEEDWAY	Continuous System	-	10,000	15
HOVERTRAIN	Air Levitated, Guideway	80-100	5,000 - 6,000	200
UK AEROBUS	Cable, Guideway	25	500	60
DIAL-A-RIDE	Non Guideway	6 - 15	-	20-30

2) In 1984, a magnet-levitated LIM driven system was opened for commercial operation to link a 620-metre section between Birmingham Airport and the railway station. LIM is set on board. A train consists a few cars with capacity of 40 passengers/car to transport about 2,200 passengers/hour. (See Table 3.5 for more details of the system).

3) A similar magnetic-levitated system was introduced to Gatwich Airport in 1980 after the comparative analysis with a rubber-tired system.



System in Gatwick Airport



Magnet Levitated System

3.3.4 Others

In Switzerland, there is Habegger Ltd. which has been developing mini-monorail systems and demonstrated in various exposition in Lausanne, Montreal, Tsukuba. This system was also constructed in Sentosa and opened became operational in the CBD of Sydney in December 1987.

In Canada, UTDC has developed linear motor systems in Toronto and Vancouver as shown in Table 3.5.

Table 3.5

Outline of Selected Systems

Name of System	AIR TRANS	PRT	VAL	People Mover	Metro Mover
Country City/Location Population of the City	USA Dallas Forthwoth Airport (840,000)	USA Morgan Town (60,000)	France Lille City 180,000 Region : 1 million	UK Birmingham Airport (1,050,000)	USA Miami (350,000)
Year Opened Type of System	Jan. 1974 Rubber - tired Side - guided	Oct. 1975 Rubber - tired Side - guided	May 1983 Rubber - tired Side - guided	Aug. 1984 Magnet - levitated Linear motor	April 1986 Rubber - tired Side - guided
Route Length : kms	20.8(single)	14.0(single)	13.6	0.62	3.0
Track Type	single	single/double	double	double	double (loop)
No of Statios	55 (14 for pass)	5	18	2	9
No of Cars	68 (51 for pass)	73	76	3	12
Length of Car : meters	6.7	4.7	12.7	6.0	11.7
Pass.Capacity/Car	40 (16 seated)	20 (8 seated)	62 (34 seated)	40	100 (8 seated)
No of Cars/Train	1～2	1	2	1	1～3
Driving Method	Unmanned-Automated	Unmanned-Automated	Unmanned-Automated	Unmanned-Automated	Unmanned-Automated
Max. Speed : kph	27	48	80	40	48
Transport Capabilities :	9,000	3,300	120,000/day	2,200	1,700 85,000/day
Manufacturer	LTV	Boeing	MATRA	PGM	Waitinghouse
Remark	Min. headway : 18 seconds	Min. headway : 15 seconds	Min. headway : 60 seconds		OPM project

Name of System	LRT	Sky Train (ALRT)	People Mover	LRT	Shuttle
Country City/Location Population of the City	Canada Toronto (630,000)	Canada Van Coover (410,000)	USA Detoroit (1,290,000)	UK Dockland, London (7.38 million)	USA Tampa, Harbour Island (260,000)
Year Opened Type of System	March 1985 Rail Linear motor	Jan. 1986 Rail linear motor	July 1987 Rail Linear motor	July 1987 Rail Rotary motor	1985 Hover Rope tracted
Route Length : kms	6.6	21.4	4.7	12	0.8
Track Type	double	double	single (loop)	single/double	single
No of Statios	6	15	13	16	2
No of Cars	24	114	13	11	2
Length of Car : meters	12.7	12.7	12.7	14	-
Pass.Capacity/Car	85 (36 seated)	75 (40 seated)	76 (34 seated)	112 (42 seated)	100
No of Cars/Train	2	2,4,6	1～2	2 (articulated)	1
Driving Method	Unmanned-Automated/manual	Unmanned-Automated	Unmanned-Automated	Unmanned-Automated	Unmanned-Automated
Max. Speed : kph	80	80	48	-	40
Transport Capabilities :	3,600	10,050	5,500	-	-
Manufacturer	UPTD	UPTD	UPTD	General Electric	OTIS
Remark		Used for Transport EXPO	OPM project		

4. DESCRIPTION OF MAJOR SYSTEMS

4.1 GUIDEWAY SYSTEM

4.1.1 General

The new transport system, in a narrow sense, is considered as an automated guideway system which is a combination of railway and automobile technologies supported by computer controlled technology. In general, it is a system wherein specially designed buses, street cars or taxis operate on their own guideway in a fully automated manner without benefit of a driver. The system can practically be divided into two major categories:

a) Groupd Rapid Transit (GRT) System: wherein an intermediate size vehicle (about 20 to 60 passengers capacity/car) be operated individually or in articulated manner. Intermediate capacity transit system will fall into this category.

b) Personal Rapid Transit (PRT) System: wherein a much smaller capacity vehicle can be operated more in a flexible manner on the guideway network.

The overall characteristics of the guideway system are briefly described, as follows:

a) Transport capacity is flexible depending upon the demand, although there are areas considered more economical for the respective system.

b) Vehicles are operated automatically on exclusive guideway, so that unmanned operation is possible.

c) Minimum headway is normally 12 to 120 seconds depending on the blocking system, switching system and capabilities of the station (e.g. with or without off-line).

d) Both scheduled operation and demand operation are possible. The former for peak hours and the latter for off-peak hours can also be applied.

e) The guideway is normally a grade-separated structure, the cost of which can be reduced for smaller and lighter vehicle system.

f) Noise and air pollution are normally much less than the other conventional system.

Major system which fall into this category are explained in the fillowing secttions.

4.1.2 Intermediate Capacity Transit System (*GROUP RAPID TRANSIT*)

Many systems explained in Chapter 3 are of this category. Table 4.1 compares the selected systems developed in Japan, while Figure 4.1 shows the standard vehicle dimension of the selected systems. Figure 4.2 shows sketches of side views of systems in other countries.

Table 4.1

Outline of the New Transport Systems Developed in Japan

Name of System	CVS (Computer Controlled Vehicle System)	DMBS (Dual Mode Bus System)	FAST (Fuji Advanced Systems of Transportation)	KCV (Kawasaki Computer-Controlled Vehicle System)	KRT (Kobe Rapid Transit)	MAT (Mistubishi Automatic Transportation System)	NTS (Newtran System)	PARATRAN (Public and Automated Rapid Transportation System)	VONA (Vehicles of New Age)
Guidance	Central-guided	Side - guided	Side - guided	Side - guided	Side - guided	Central - guided	Side - guided	Side - guided	Central - guided
Pass.Capacity/Car	4 (all seated)	40~70	50 (16 seated) 75 (24 seated) 135 (40 seated)	30 (16 seated) 75 (24 seated)	75 (20 seated) 30 (8 seated)	32 (16 seated) 75 (24 seated)	75 (22 seated)	75 (24 seated)	40 (14 seated)
Car Size : m (L×W×H)	3.0×1.6×1.85	12×2.5×3.8	6.4×2.15×3.07 8.8×2.15×3.07 13.0×2.45×3.15	6.35×2.35×3.15 9.1×2.35×3.15	8.0×2.3×3.17 4.7×2.03×2.67	5.7×2.2×2.9 7.8×2.46×3.25	8.0×2.3×3.05	8.0×2.4×3.19×	5.3×2.0×3.1
Dead Load : ton	1.0	7.5	6.5 7.5 12.0	5.0 9.0	10.5 4.1	5.0 9.5	10.5	9.5	4.5
Max. Speed : kph	60	60	60	70	60 50	60	60	60	60
Min. Curvature : m	5	35 *(guideway)* 12 or less(road)	23	20	15 9.14	15	20	25 (when articulated)	20
Max. Gradient : %	10	10	10	10	9 10	10	9	10	7
Electric System	AC single phase	DC 430V	AC 3 phase 440/400V	AC 3 phase 440/400V	AC 3 phase 550V	AC 3 phase 550V	AC 3 phase 600V	AC 3 phase 440/400V	DC 500V
Switching System	On-board Selection	On-board Selection	Vertical Diverting	Vertical Diverting	Swing Arm (On-board Selection)	180° Rotation	Movable Guidance Brade	Movable Guidance Brade	Turn Table
Operation Control	Moving Target System	Speed Instructed	Central Computer Control	Central Computer Control	Central Computer Control	Central Computer Control	Central Computer Control	Central Computer Control	Central computer Control
Min. Headway : second	1	10	90	90	90 15	90	90	90	90
Max. Transport *Capabilities : pass/h*	15,000	15,000	12,000	3,000~18,000	1,600~18,000 7,200	4,000~12,000	3,000~20,000	5,000~15,000	3,000~19,000

Figure 4.1

Dimension of Standard Cars of Selected Systems
in Japan

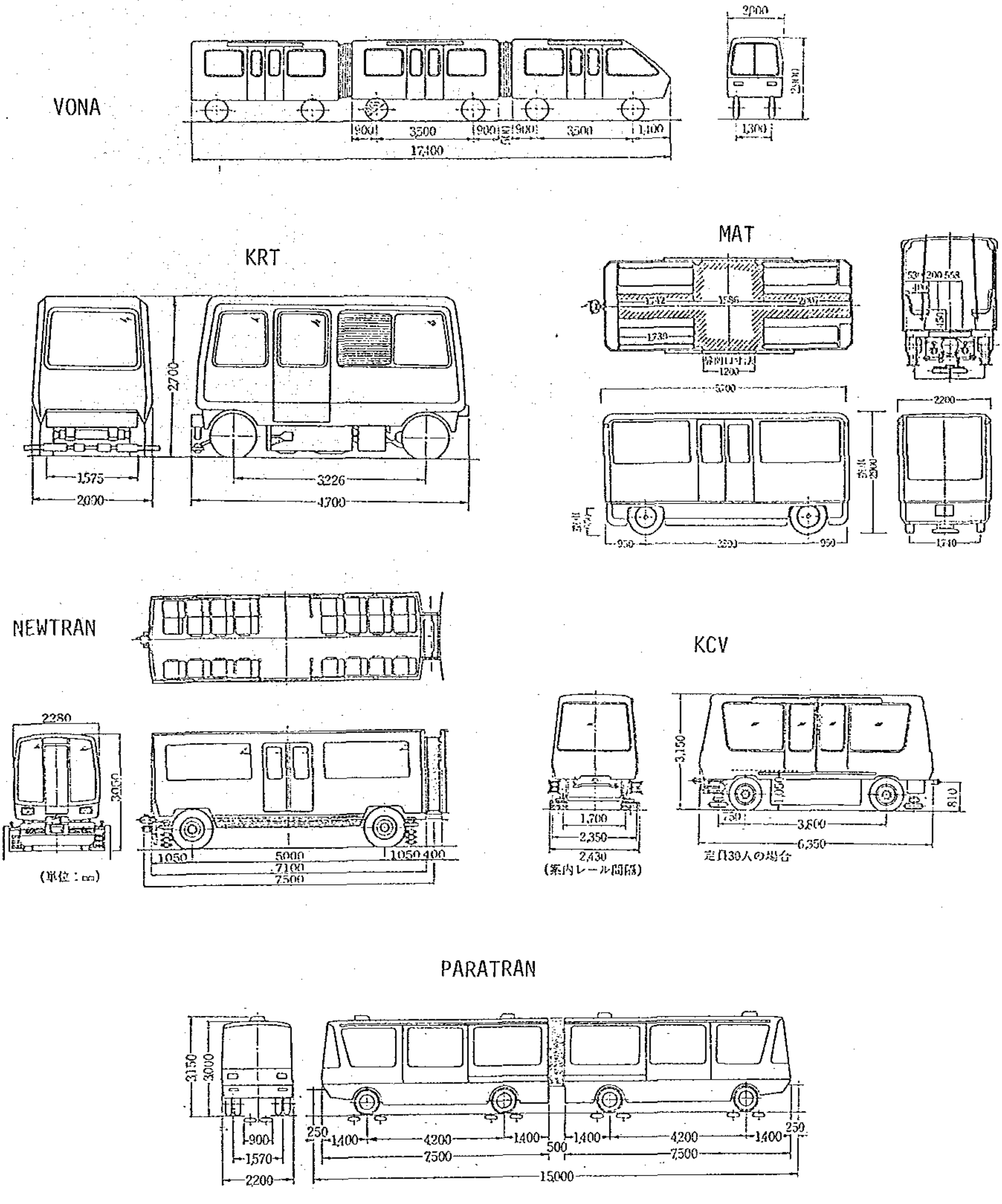


Figure 4.2

A View of Various Systems Existing in Countries
Other than Japan

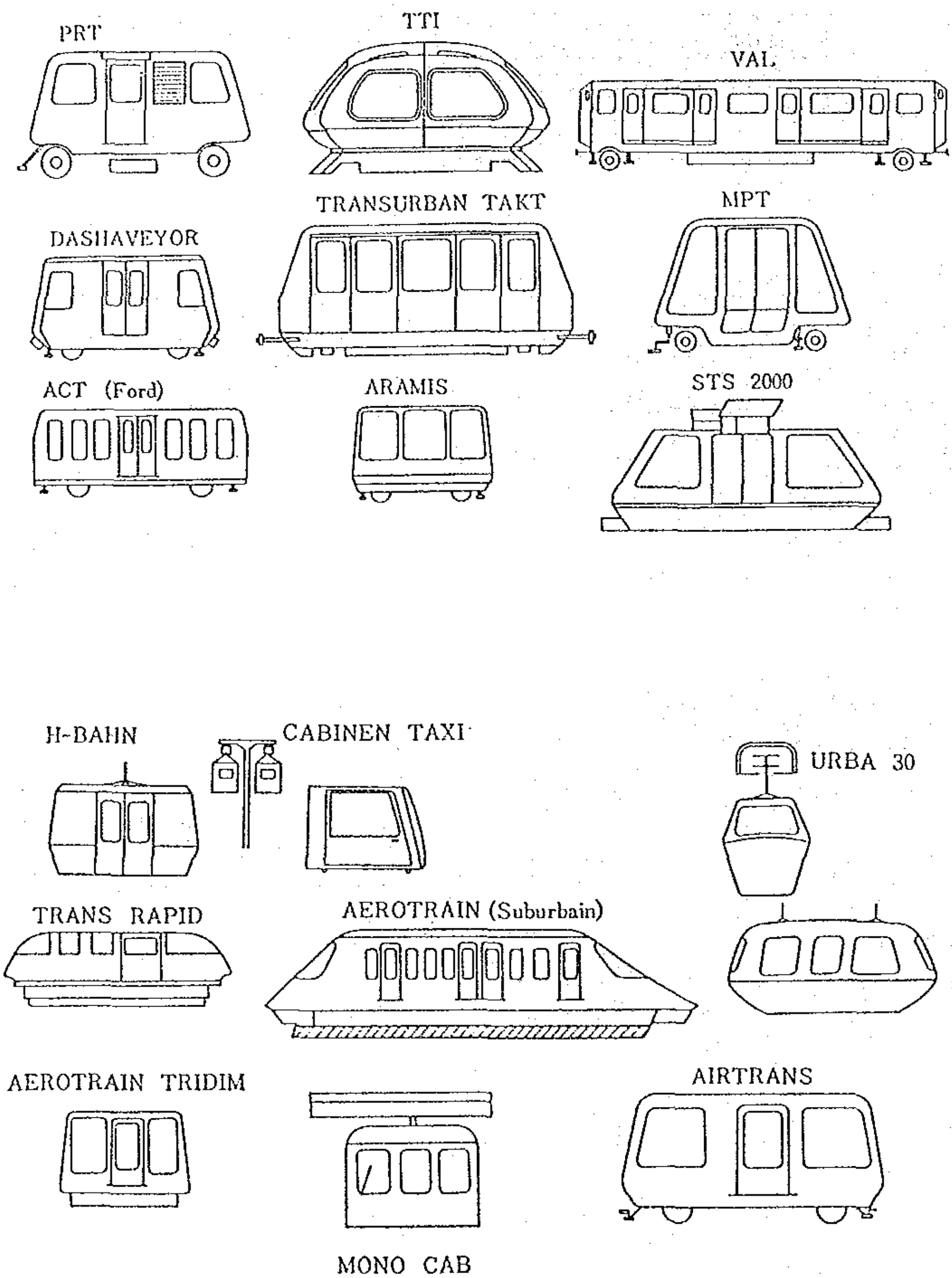


Figure 4.3

Dimension of the Structures of Selected Systems in Japan

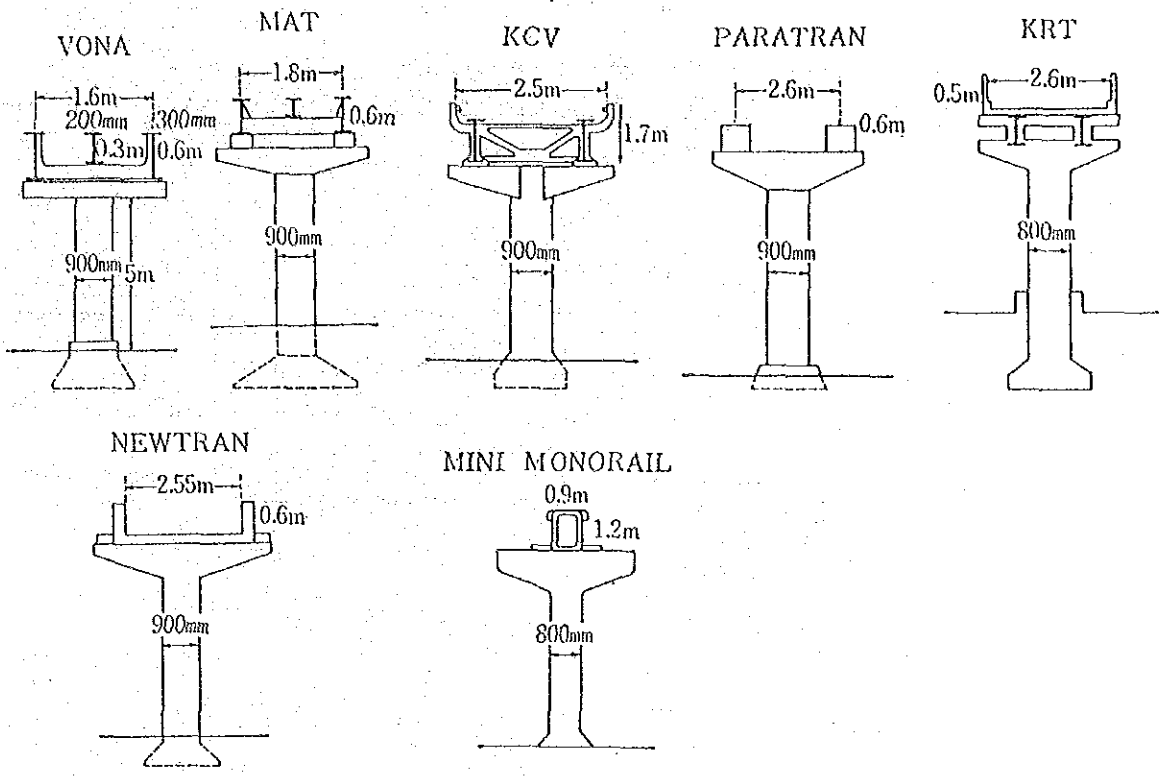


Figure 4.4

Guidance Methods of Selected Systems (Japan)

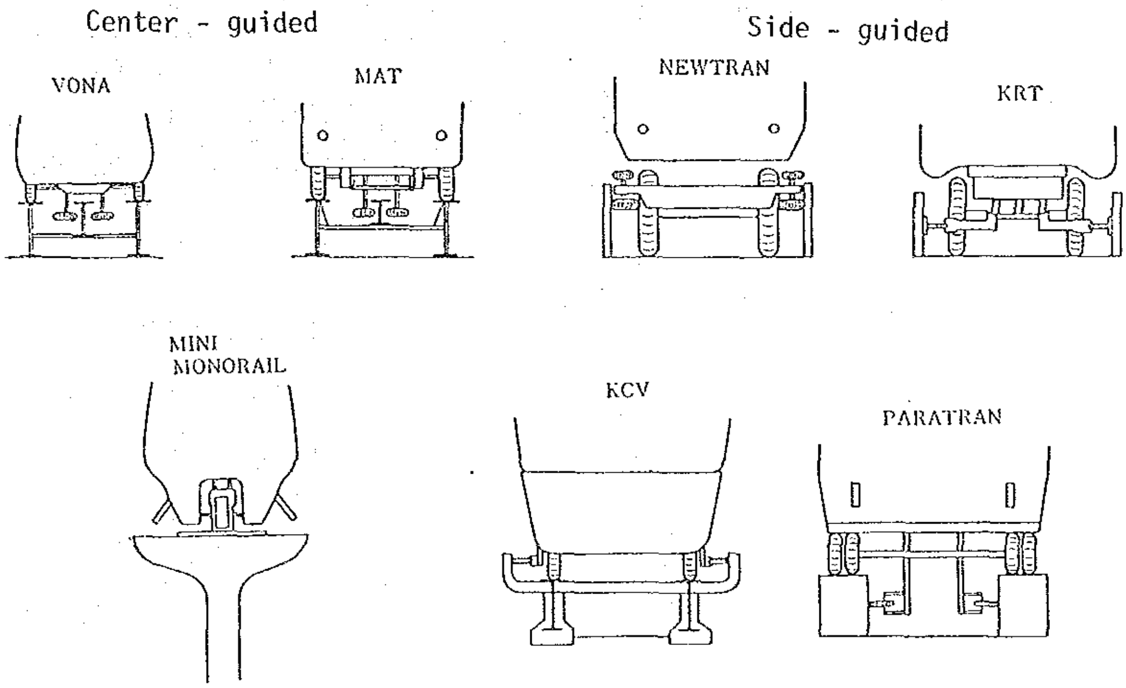
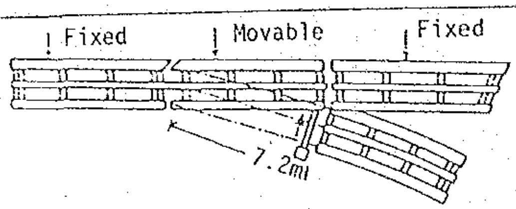
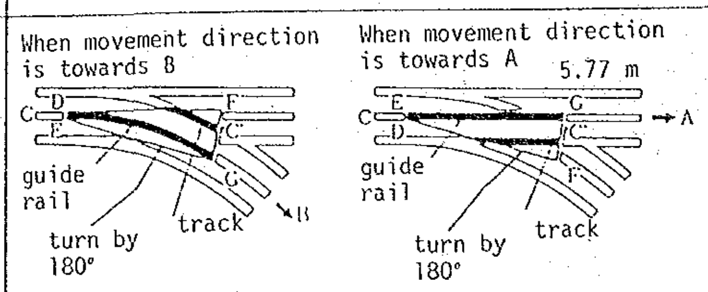
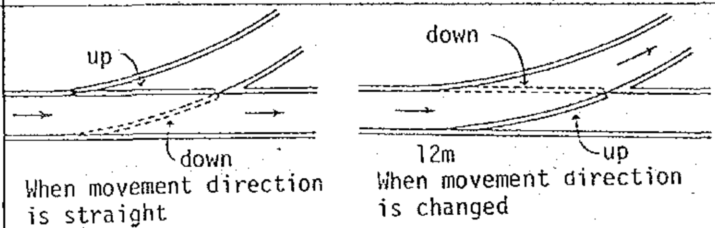
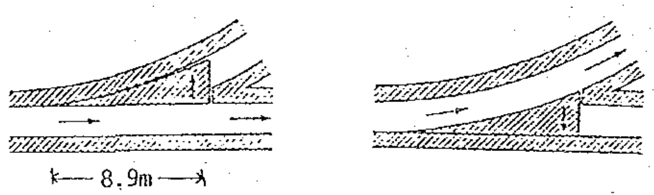
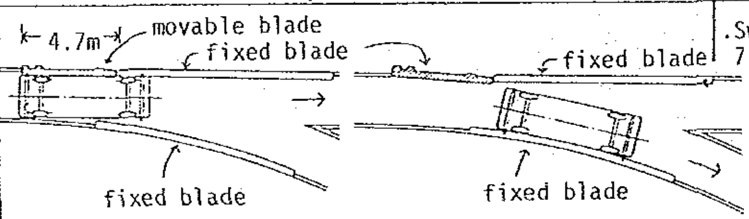
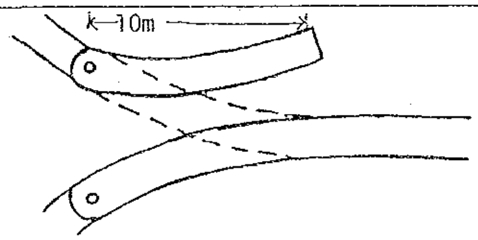


Figure 4.5

Outline of the Switching System

Type	Operation Method/Dimensions	Remarks
Rail Switch Type : VONA		.Switching time: 6 sec .Vertical vibration at joints affects riding comfort
Rail Turn Type : MAT		.Switching time: 6 sec . same as above
Sidewall Exchange Type : KCV		.Switching time: 3 sec.
Sidewall Exchange Type : PARATRAN		.Switching time: 6 sec. .Horizontal vibration affects riding comfort.
Sidewall Exchange Type : NEW TRAN		.Switching time: 7 sec.
Rail Switch Type : Monorail		.Switching time: 8 sec. .Movable portion is large

Source : New Transport System, I. Ishii, Kazing Printing 1975

4.1.3 Monorail

A monorail is a system with considerably large transport capabilities compared to other intermediate capacity systems. As shown in Table 4.2, the system can carry 15,000 to nearly 50,000 passengers per hour per direction.

Table 4.2

Transport Capabilities of the Monorail

Train Composition	Train Capacity: No. of pass	No. of pass/hr direction by headway		
		2 min	2.5 min	4 min
2 car	520	15,600	10,400	7,800
4 car	1,040	31,200	20,800	15,600
6 car	1,560	46,800	31,200	23,400

The first monorail was built in 1901 in Wuppenterl in West Germany and it is still being commercially operated while it was only in the 1950's that the subsequent systems were developed in the world. In addition to the monorails developed in Japan, shown in Table 3.3, there are others developed in several countries, as shown in Table 4.3.

Table 4.3

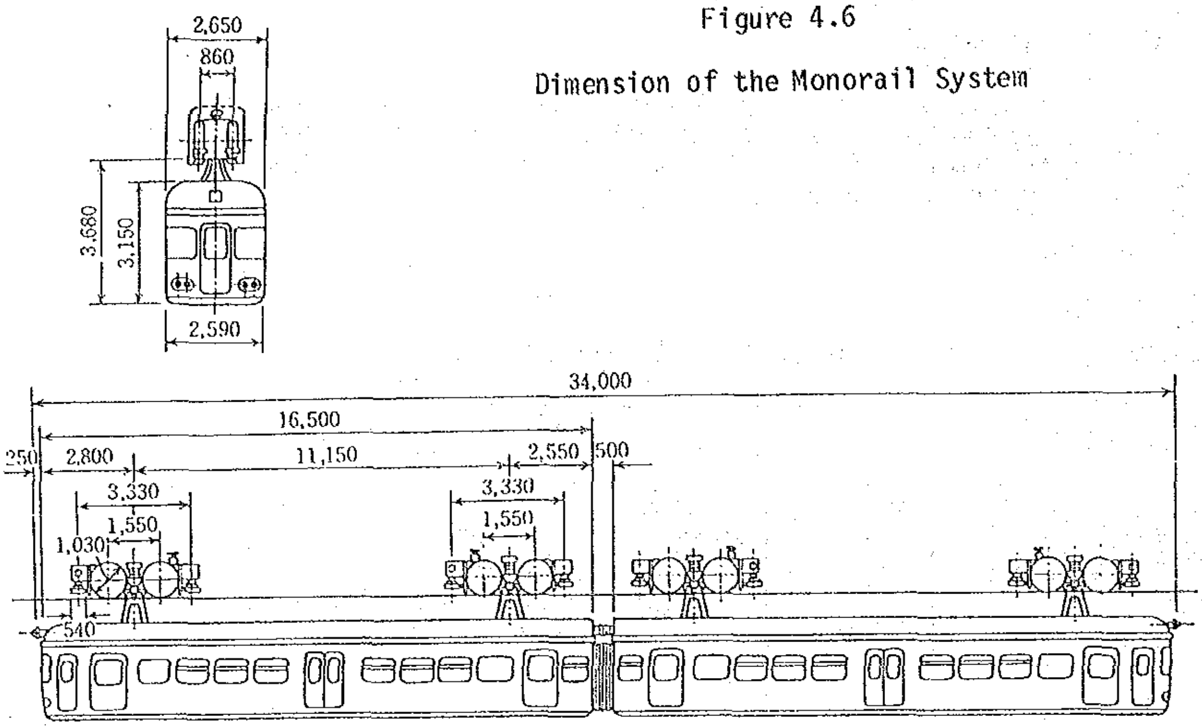
Development of Monorails

Location	Route Length:Kms	Type	Year Operation Started
Wuppental (W. Germany)	13.2	Savege	1901
Furlingen (W. Germany)	1.8	Straddle	1957
Houston (USA)	0.4	Savege	1958
Disneyland (USA)	3.7	Straddle	1959
Torino (Italy)	1.2	Straddle	1961
Seattle (USA)	1.9	Straddle	1962
Japan	See Table 3.3		

One of the disadvantages of the monorail is that the switching system becomes complicated. Savege (suspension) type normally requires a higher cost compared with the straddle type because the former needs higher column.

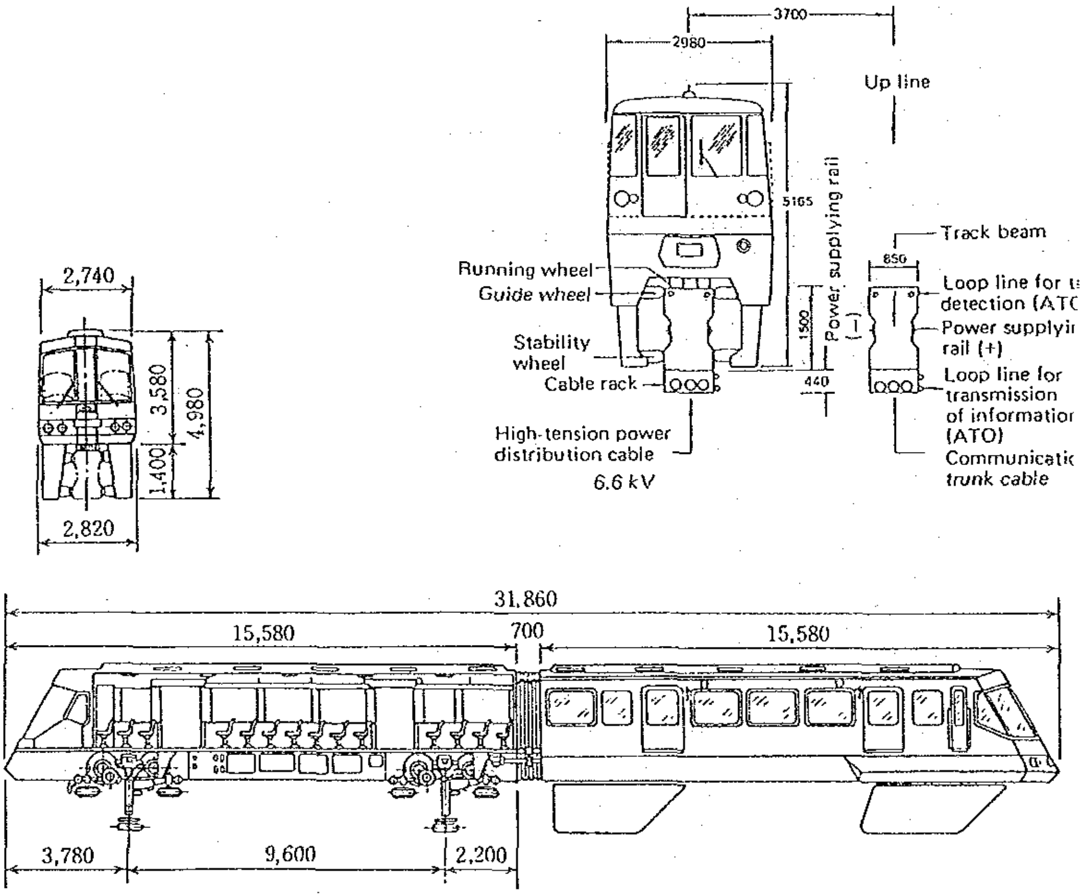
Figure 4.6

Dimension of the Monorail System



Suspension Type

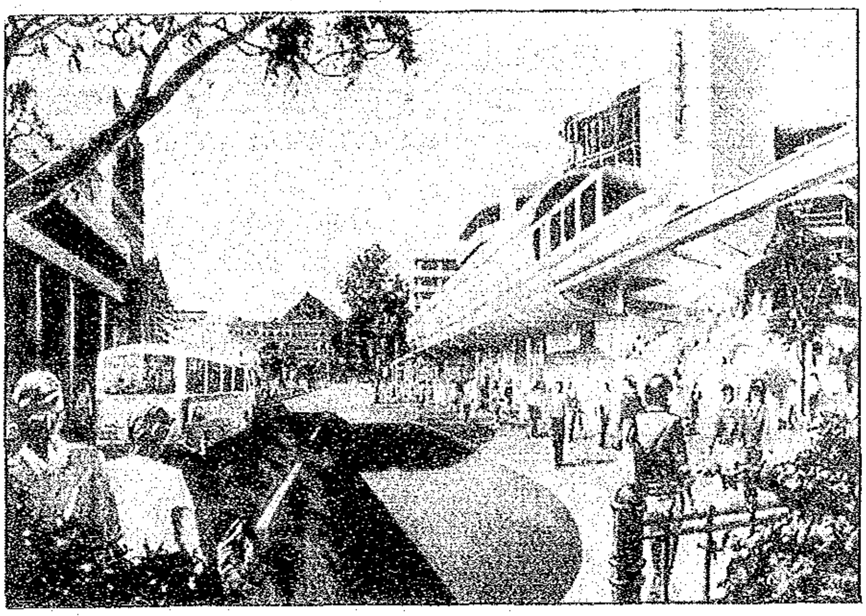
Straddle Type



4.1.4 Mini-Monorail

The mini-monorail is a system which needs further investigation since it may provide more opportunities for application with regard to feeder transport improvement than the standard monorail. In terms of transport capabilities, the system can be categorized as intermediate capacity transit system. By introducing smaller vehicles, costs may be minimized since structures are smaller and there is a more aesthetic appeal. The system is usually of straddle type.

The most popular application of the mini-monorail is a single-track loop in the CBD or exhibition areas.



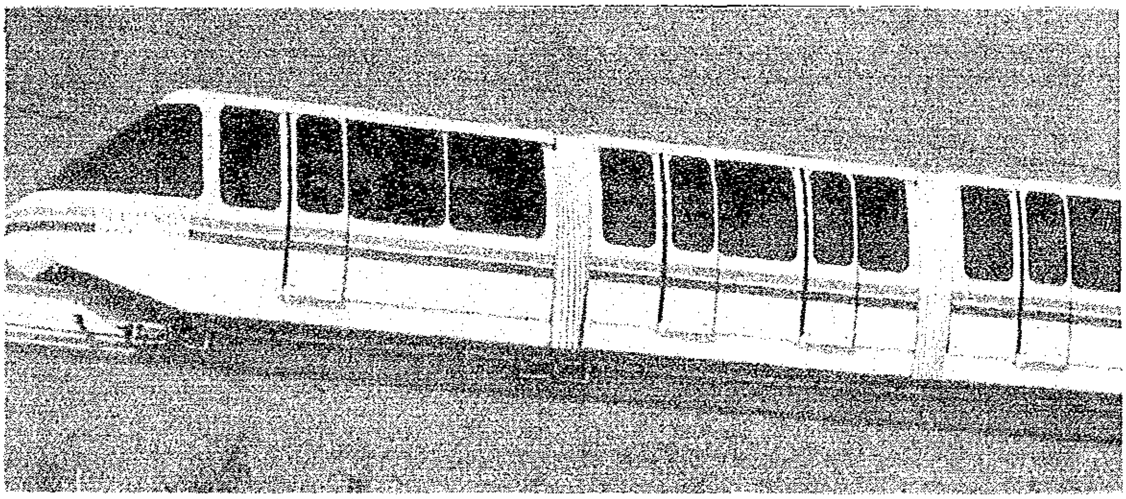
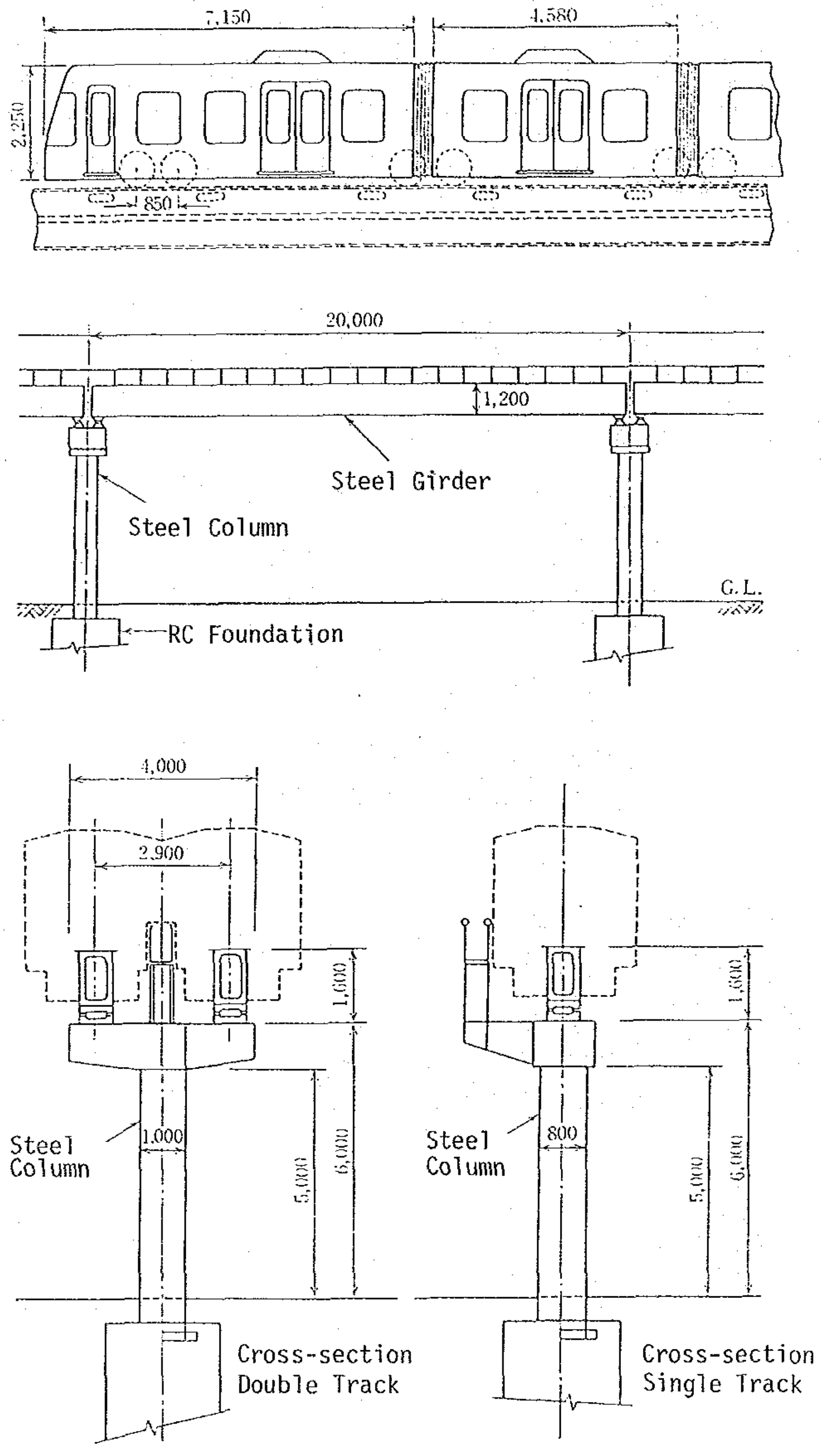


Figure 4.7

Dimension of the Mini-monorail System



4.1.5 Personal Rapid Transit System (PRT)

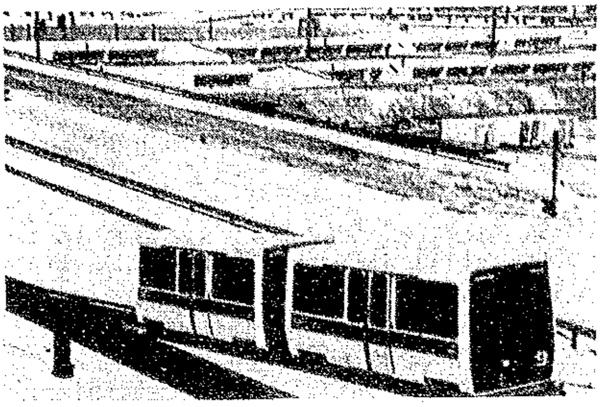
The PRT intends to meet more flexible and personal traffic demands to replace the services provided by passenger cars. Therefore, its vehicle is small and is operated on densely configurated network according to the demands of passengers. The system is fully computerized and automated.

Although this is one of the main targeted transport systems in urban areas, at present, it will still take some time before the system be realized due to the curently existing restrictive factors such as transport capacity, technological maturity and, in particular, the urban structure which has not been designed for this type of system. It is, however, anticipated that this system will become a major concern in the future, particularly in CBDs or equivalent activity areas.

Figure 4.8

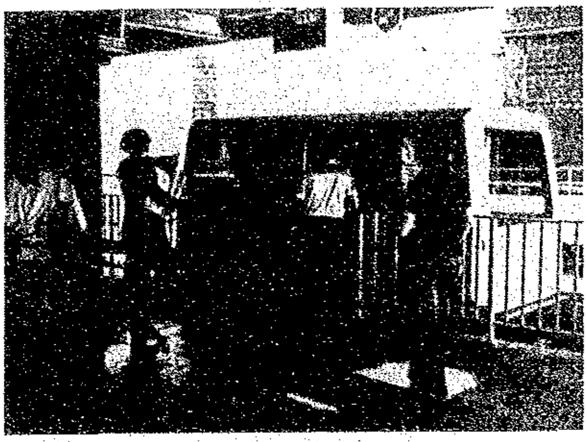
Outline of Selected PRTs

Table 4.8 (continued)

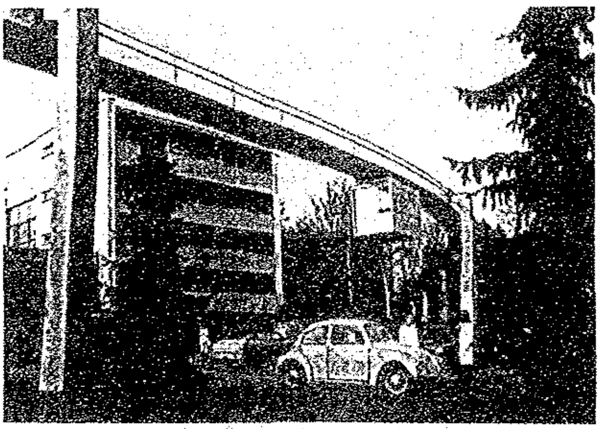


PRT in Dallas-Fort Worth Airport, USA

PRT in Morgan Town, USA



PRT in Morgan Town. USA



PRT in Ziegenhain District
Hospital, W.Germany

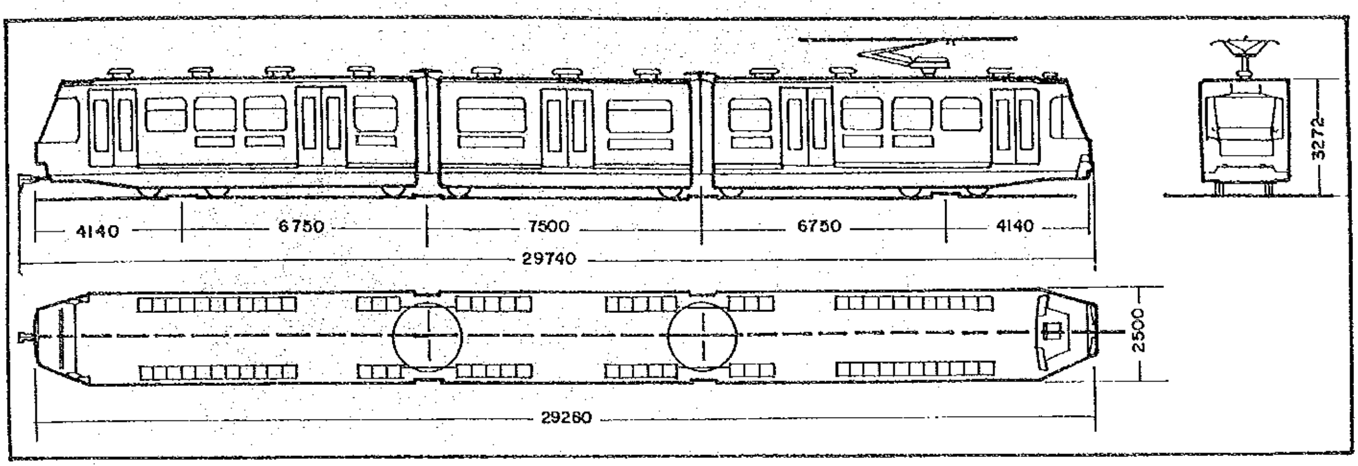
PRT in Ziegenhain District
Hospital, W.Germany

4.1.6 Light Rail Transit System (LRT)

The LRT has a long history of development and has been introduced in many cities, particularly in European countries. The system is being constantly improved and the modern version can be considered as a new transport system.

Figure 4.9

Dimension of the LRT



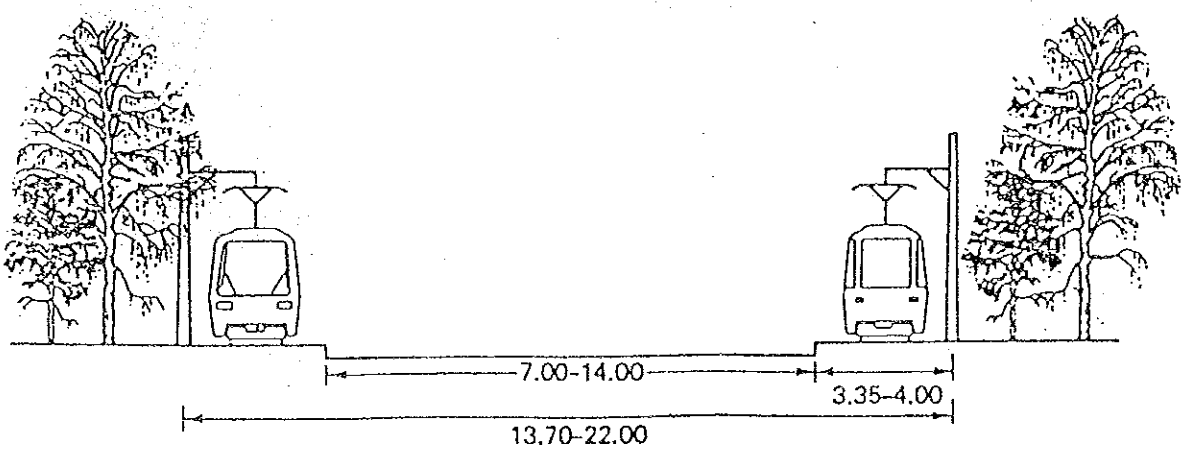


Figure 4.9 (Continued)

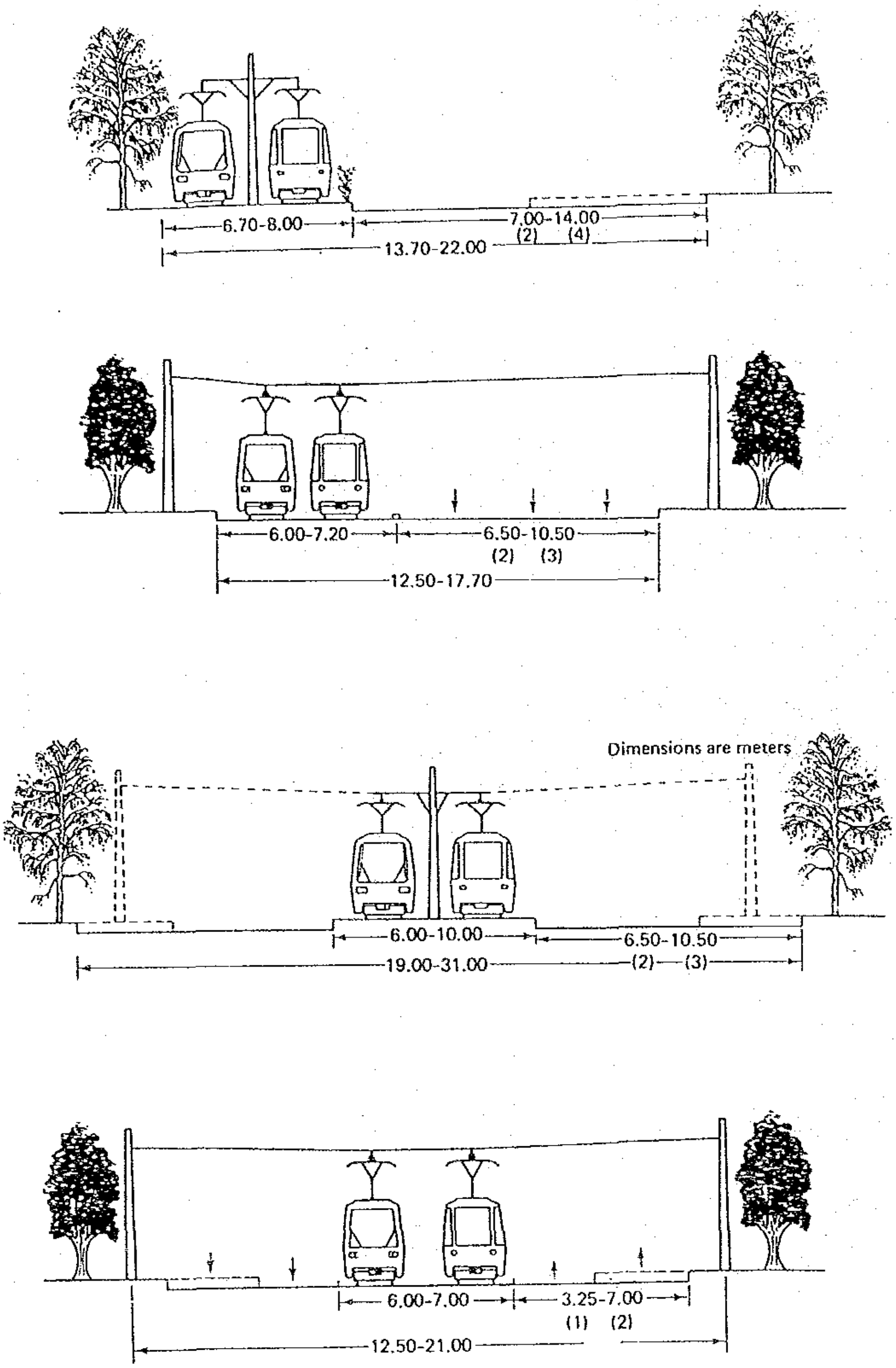
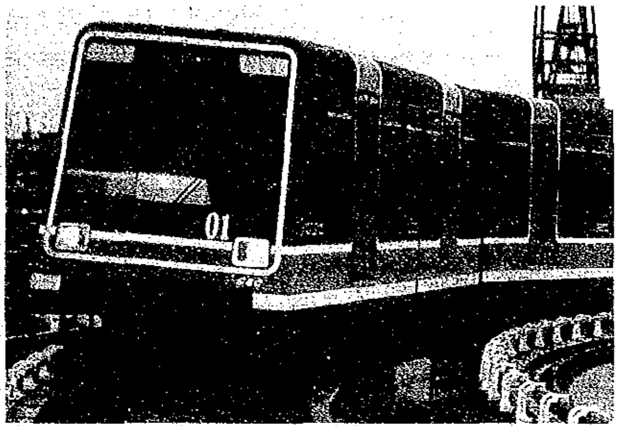


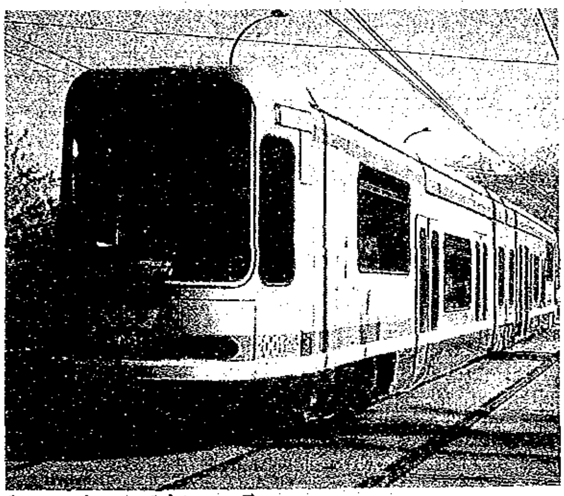
Figure 4.10

A View of the LRT in Different Cities of the World

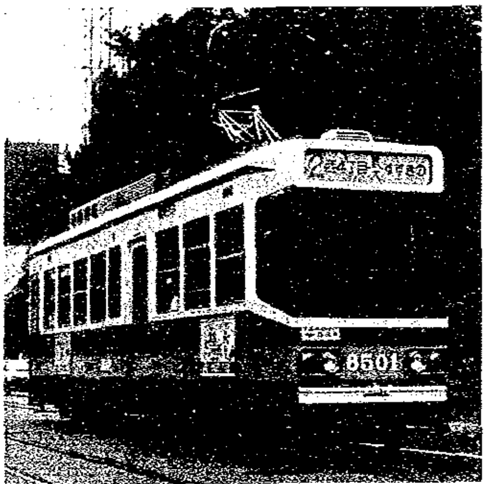


Dock Land, London UK

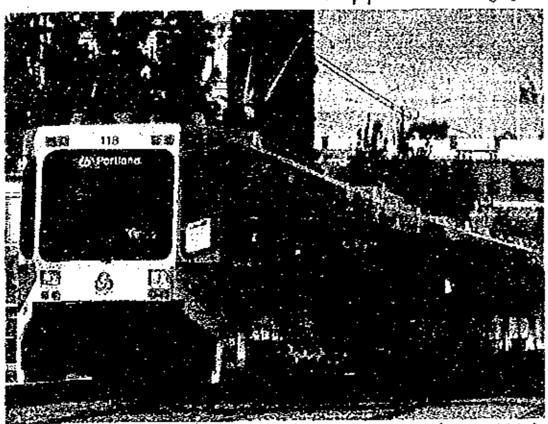
Melbourne City, Australia



Grenobre City, France



Sapporo City, Japan



Portland City USA

Table 4.4

Outline of the LRT Introduced in Different Cities of the World

Town	Number of Lines	Route Length km	% in Underground or Viaduct	Number of Trains	Traffic (in million trips/year)	Year Constructed
Bonn	3	45	15	48	13	1975
Breme	6	42	2.1	279	-	-
Cologne	-	35	-	54	-	1978
Cologne /Bonn	1	23	-	18	14	1978 interurban
Dusseldorf	9	146	1.4	824	168	mixed with streetcar
Hanovre	6	60	25	190	134	1975
Ludwigshafen	11	32	14	62	22	1973
Mulheim	1	5	80	5	5	1977
Stuttgart	10	115	9	372	98	1983
Total West Germany	-	503	-	1,852	-	-
Goteborg	9	77	-	50	-	Included in Streetcar network
Helouan	1	17	-	27	-	
Linz	2	14	-	64	30	1984
Manila	1	15	100	20	152	
Rotterdam	2	12	-	78	-	Feeder to subway
Tunis	1	8	10	27	16	1985
Utrecht	1	17	-	-	7	1983

	Date of Construction	No. of Lines	Length of Net-work (km)	Track Gauge	Current VCC	No. of Trains 1/	Daily Traffic 2/
A. USA							
1. Old Network							
Boston	1897	2	52.4	N	600	230	70,000
Cleveland	1920	2	21.7	N	600	48	17,500
New York	1935	1	6.9		ind	26	12,000
New Orleans	1893	1	10.6		ind	35	21,000
Philadelphia	1892	15	149.5	L	600	236	127,000
Pittsburg	1891		36.2	L	600	90	20,000
San Francisco	1897	5	33.3	N	600	141	133,000
2. Special Network							
Detroit	1976	1	3.2	90cm	600	7	500
Fort Worth	1962	1	1.6		ind	8	6,500
Seattle	1982	1	3.5			4	2,000
3. New Network							
Buffalo	1985	1	10.3	N	650	27	21,000
Portland	1986	1	24.3	N	750	26	15,000
Sacramento	1987	1	29.4	N	750	26	21,000
San Diego	1981	1	32.0	N	600	30	23,000
San Jose	1987	1	32.2	N	750	50	40,000
B. CANADA							
1. Old Network							
Toronto	1892	10	73.4	N	600	284	334,000
2. New Network							
Calgary	1981	2	22.2	N	600	78	36,000
Edmonton	1978	1	10.3	N	600	37	25,000

Source:

1/ In number of trains either in single or articulated
2/ In number of passengers

Legend: N : normal (1.435m)
L : large (1.500m)
ind : unspecified

4.2 CONTINUOUS TRANSPORT SYSTEM

4.2.1 General

This is a system which transports passengers continuously like the "Moving Walk" and "Moving Cabin/Capsul". This system is considered particularly suitable where there is a large demand for short distance travel.

The advantage of the system are:

a) Transport capacity is large

b) Passengers do not have to wait

c) Free from pollution such as noise, air pollution

d) Easy for passengers using baby carriage, push cart, wheelchair

e) Structure of the system is simple

f) Not much space is required

The disadvantages of the system are:

a) Speed is slow

b) Transport capacity is fixed and can not be adjusted according to demand

c) Maintenance has to be done on site

d) Economy will be lost when the system becomes long

4.2.2 Moving Walk

This system also has a long history. Moving platform was constructed in Columbia Exhibition held in Chicago in 1893. This was later used in 1900 during the Paris Exhibition. In 1953, a belt-type moving walk was invented and introduced in various places. The first system actually used in Japan was the 3.5-km long system constructed for EXPO '70 that was held in Osaka. That was the longest system in the world then, but the speed was very slow -- only 36 meters/min or 22 kph.

The system has various types of structure as shown in Figure 4.11. Table 4.5 indicates the transport capabilities of the system.

Table 4.5

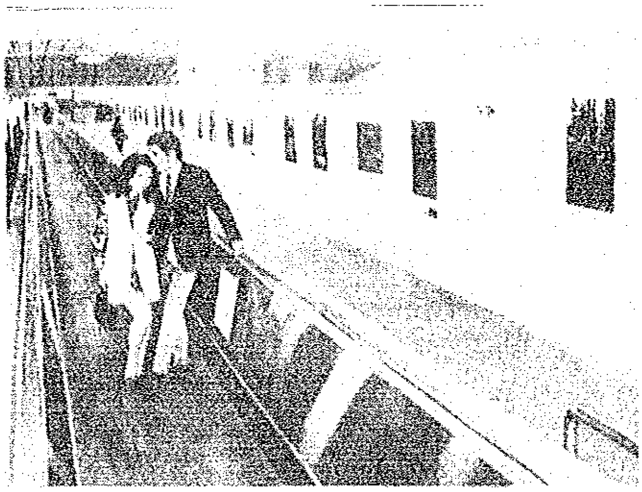
Transport Capabilities of Moving Walk

Speed: kph (m/min.)	Catalogue Capacity: No. of pass/hour		Maximum Capacity: No. of pass/hour	
	Width: 1 person1/	Width: 2 person1/	Width: 1 person1/	Width: 2 person1/
1.8 (30.0)	3,000	6,000	3,600	7,200
2.4 (40.0)	4,000	8,000	4,800	9,600
3.0 (50.0)	5,000	10,000	6,000	12,000

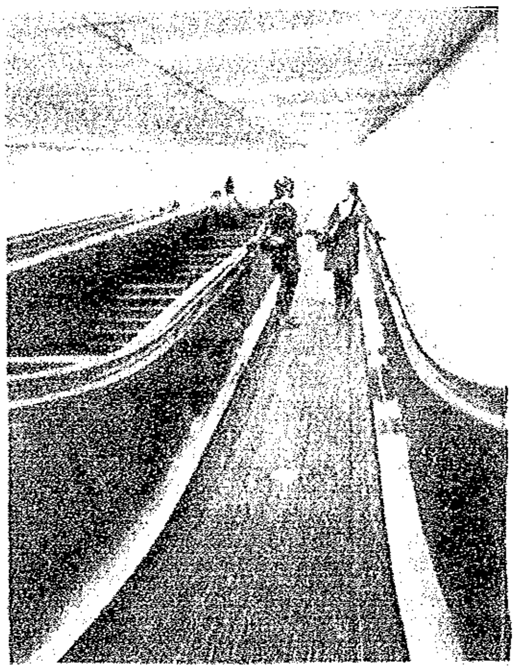
1/ required width for 1 person and 2 persons are 600 mm and 980 mm, respectively.

2/ average spacing required between two persons is assumed to be 50 cm.

In order to increase the system's speed, various ideas have been developed and experimented. Figure 4.12 shows the integrator and the turn table systems. The integrator has a parallelogram shaped pallets that accelerate to enter the main system and decelerate after exit. The turn table system has the person transferred from one turn table to another with a higher speed till he or she joins the mainstream. The center is an access point and the speed of turn table becomes faster for the outer one.



Pallet Type



Belt Type

Figure 4.11

Structures of Moving Walk by Type

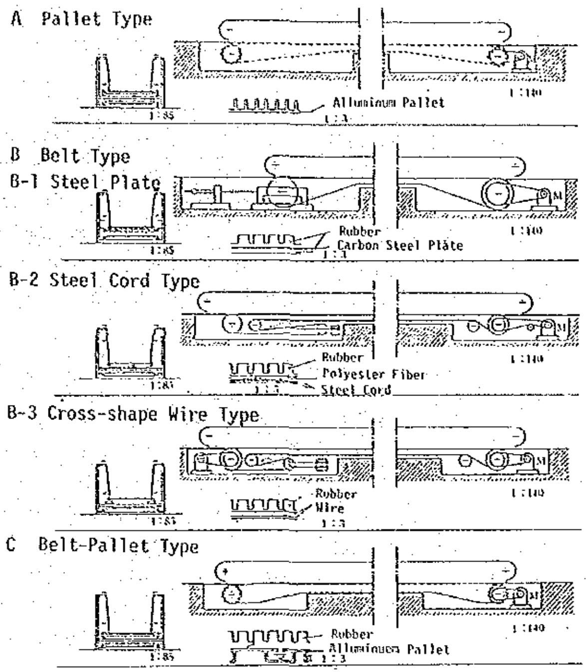
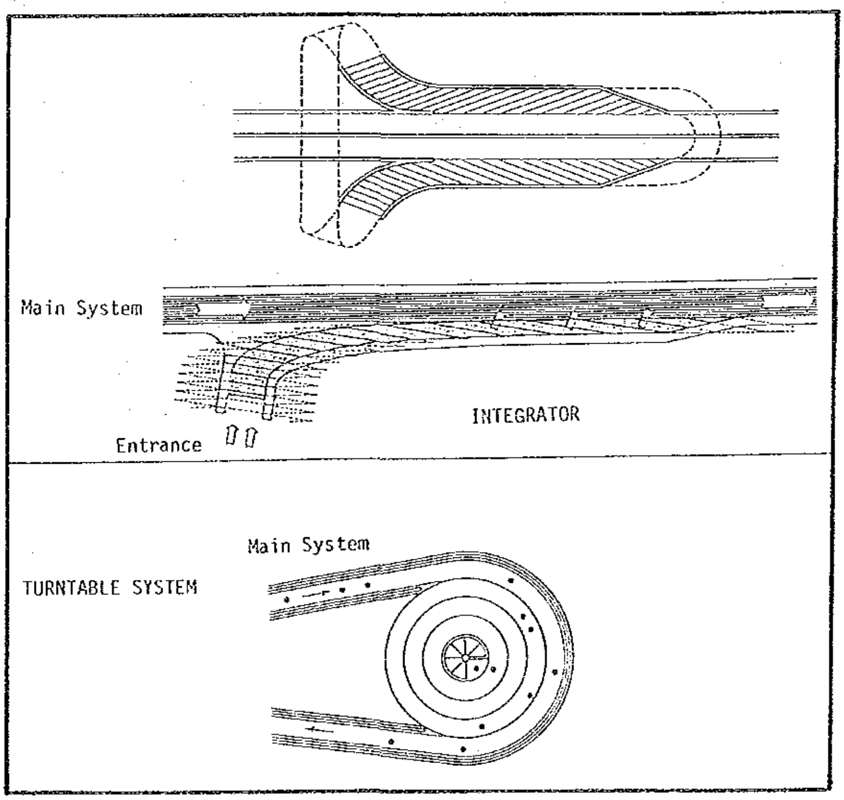


Figure 4.12

Concept of Integrator and Turn Table System



4.2.3 Moving Cabin/Capsul

The system is a "moving walk" equipped with cabin/capsul on it, to facilitate passengers to move while seated. There are many cases of development, the major ones are as follows:

1) Telecanabe

The system was exhibited in 1964 EXPO held in Switzerland. A "moving walk" equiped with capsuls with a capacity of 12 passengers/capsul and moves at 12.8 kph between stations, and at 6.4 Kph at the stations. It is a turn table system with the passenger and the turn table moving at the same speed. Transport capacity was around 8,000 passengers/hr.

2) Carveyor

The system was developed by Goodyear Co., Ltd., USA. Capsuls on the conveyor belt move at 24 kph but slow down at 2.4 kph near the stations where the spacing between capsuls is reduced. The station platform moves at the same speed with the capsuls. The system cannot change directions by switching but can move along curve of 27 meter diameter. Capacity of a capsul is 6 passengers, while that of the system is about 6,800 passengers/hour.

3) Transdick

The system was developed by Battele Memorial Institute, Switzerland, and travels at 22 kph with transport capacity of 7,200 passengers/hour.

4) Sky Lane

The system was developed by Toshiba Co., Ltd., Japan. It travels at 24 kph on the route and at 2.4 kph at the stations. Transport capacity is around 20,000 passengers/hour.

5) VEC

The system was developed by Cyec Development Co., Ltd., France in Paris in 1974 to link the shopping center of Menparnasse District with the underground parking. A capsul can accommodate two adults, a child and hand carried luggages. Capsuls travel at 14.4 Kph and at 1.36 Kph off the conveyor around the station. The capsul is stopped when passengers step the foot on the capsul. Empty capsuls are transferred to the conveyor using the turn table. Transport capacity is between 1,000 and 3,000 passengers/hour.

6) POMA 2000

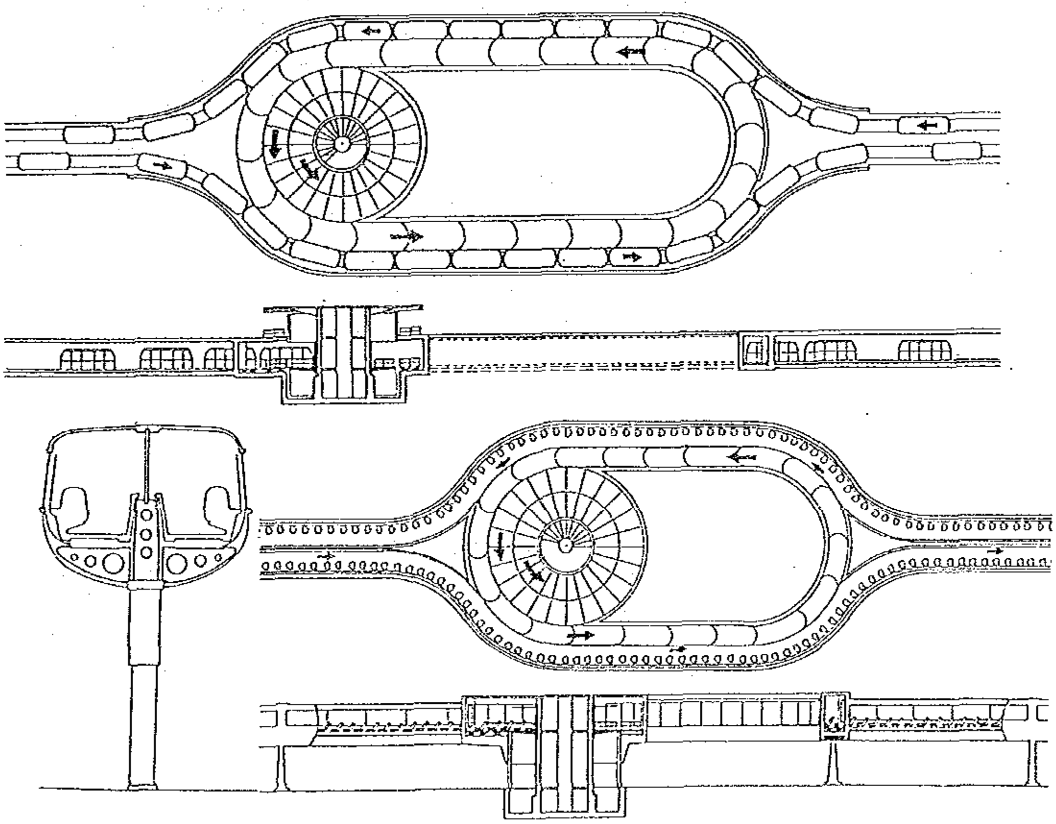
The system was jointly developed by Pomagalski Co., Ltd. and Cruesot Co., Ltd., France. The capsul is equipped with rubber tires but without propulsion and is tracted by cable; travel speed on the steel track is constant between 18 and 25 Kph. On the loop at the station, capsuls will be off the main route and decelerated to 0.9 Kph. Headway can be reduced to 15 seconds. Transport capacity is about 4,000 to 10,000 passengers/hour.

7) Trans Urban

The system was developed by Kraus Maffei Co., Ltd., West Germany. Magnet levitated capsuls with linear motor propulsion move continuously, while three turning pallets with different speeds facilitate passengers boarding and alighting at the stations. Transport capacity vary from 3,000 to 28,000 depending upon the speed. The operating speed is between 20 and 60 kph but can reach up to 100 Kph. The system with chairs in replacement of capsuls has also been developed. (See Figure 4.13)

Figure 4.13

Outline of TRANS URBAN System



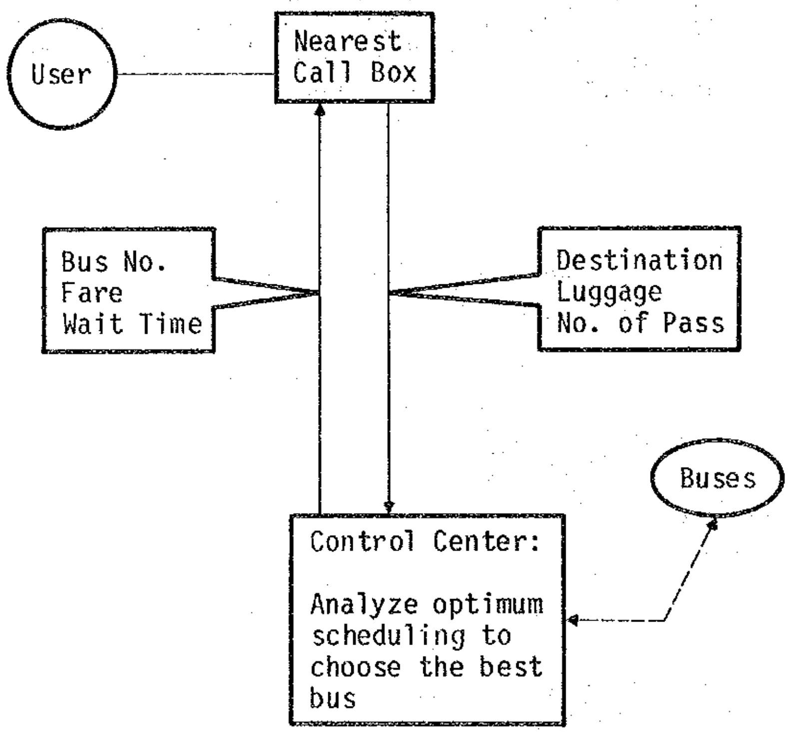
4.3 OTHER SYSTEMS

4.3.1 Demand Bus

The conventional bus is operated on fixed route and scheduled time table. When the demand is low, frequencies and routes can be adjusted. This system operate buses according to the demand of users who call control center from the nearest call box. The center analyze the optimum scheduling of buses and inform the users of the dispatch of a bus.

Figure 4.14

Information System of Demand Bus



4.3.2 Bus Location System

One of the critical factors why people do not appreciate the bus system is because the arrival time of the bus is very uncertain especially in urban areas. The system intends to inform users constantly of the exact location of the bus and at the same time to maintain headways of buses properly.

Figure 4.15

Example of Bus Location System

4.3.3 Dual Mode Bus

This system aims at achieving efficient transport (high capacity) along the line haul and flexible operation in the feeder service areas. Therefore, the line haul will be automated and segregated from the other traffic, while the vehicles will be operated in conventional manner off the route. The concept of application is schematically shown in Figure 4.16. The same guideway can be used with the one for intermediate capacity transit system.

1) Dual Mode Bus in Essen, West Germany

The first test run was undertaken in 1980 and the experimental operation using street car track was started in 1984. The following advantages are expected:

a) reduction in travel time to/from CBD
b) easy transfer between street car
c) operation schedule becomes accurate
d) reduction in traffic congestion on roads
e) increase in operational efficiency

Figure 4.16

Concept of Dual Mode Bus Application

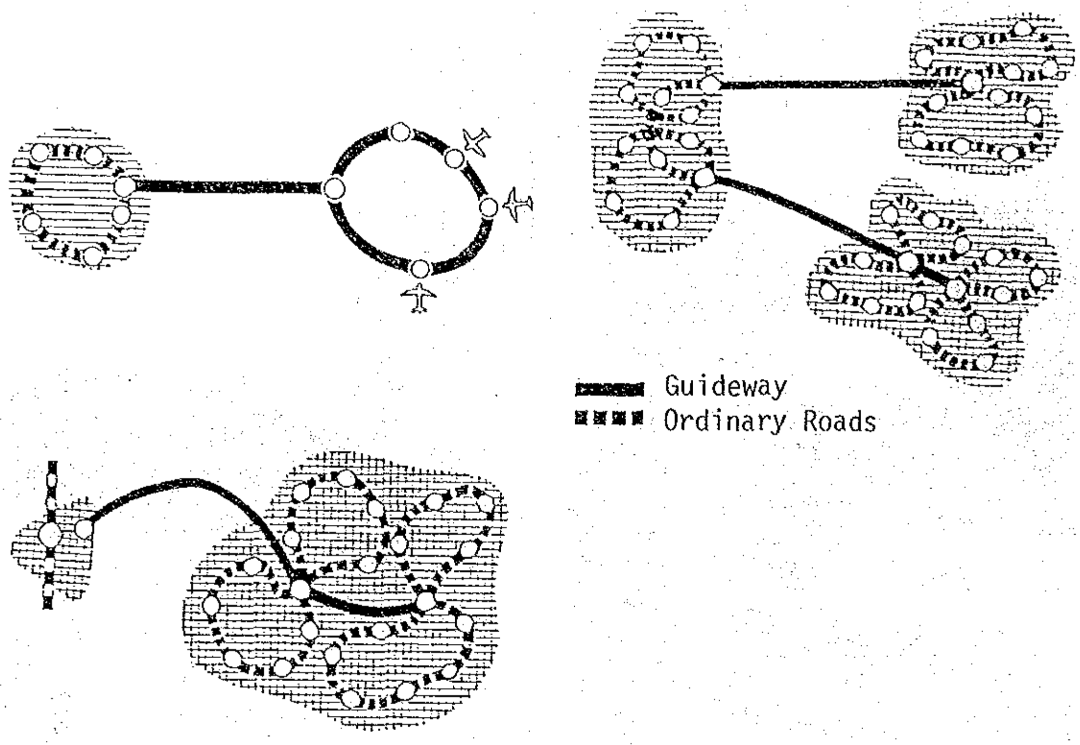
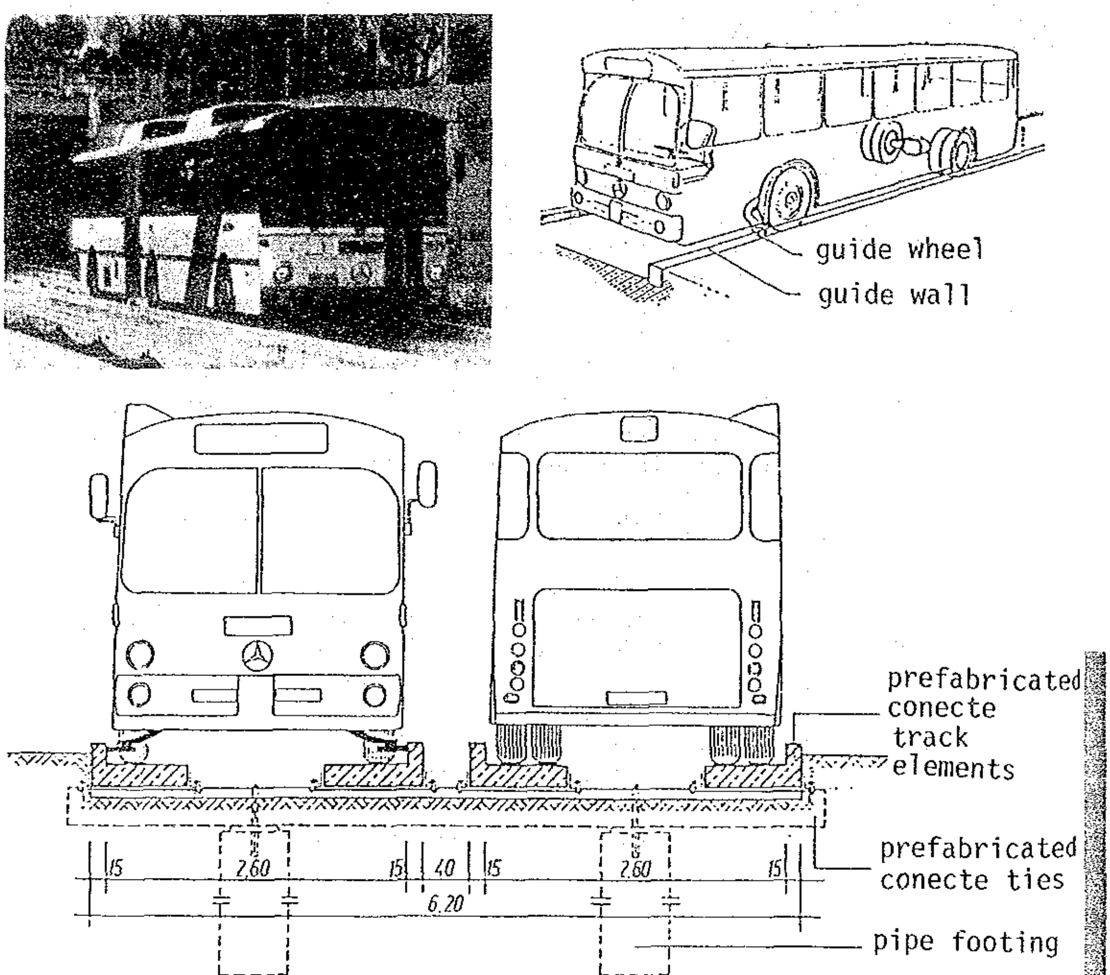


Figure 4.17

Structure of Dual Mode Bus



5. TECHNICAL ASPECTS OF THE NEW TRANSPORT SYSTEM

This chapter is a preliminary review of certain issues of new transport system. Figures quoted here for comparative purposes with other systems are not necessarily final partly because the new transport system itself is not technologically matured yet, and partly because they are still being studied by the team. The items selected preliminarily are as follows:

1) Energy Efficiency

Some factors relating to the energy efficiency for different systems are compared in Table 5.1. Weight per passenger will affect the structure, while electricity consumption gives a direct indication. The systems using rubber tire consumes more electricity than those using steel wheels. Weight of vehicles in terms of per passenger for intermediate capacity transit system (ICTS) and bus is relatively smaller than other systems. However, when the calculations of passenger capacity is adjusted using the same basis of 0.35 sqm per passenger, those figures of ICTS and bus will increase to 0.27 and 0.21 tons per passengers, respectively. These are in the same range as the other systems.

Table 5.1

Comparison of Energy at Different Systems

Systems	Weight (tons)	Capacity (No. of pass)	Weight Per Passenger	Electricity Consumption kwh/ton-km	Remarks
1. MRT (Subway)	334.0	1,424	0.23	68.9	
2. Monorail	176.0	478	0.37	70.4	
3. Intermediate Capacity Transit System (ICTS)	63.6	444	0.14 (0.27)1/	254.7	
4. LRT	18.0	100	0.18	116.7	
5. Bus	9.1	82	0.11 (0.21)1/	-	

Source: Worked out by the Study Team based on various information.

1/ adjusted based on space requirement of 0.35 sqm per passenger

2) Rubber Tire vs. Steel Wheel

Rubber tire has become popular mainly because it produces less noise compared to steel wheel vehicles. However, vehicles using rubber tires require guidance because the rubber tire do not have flanges. Therefore, rubber tired system has to be equipped with guide wheel. A comparison is given in Table 5.2.

Table 5.2

Comparison of Rubber Tire and Steel Wheel

Item	Rubber Tire Wheel	Steel Wheel	Remarks
a. Adhesive Characteristics (U)	high	low	
b. Influence of weather	1/ affected	hardly	1/ rain, snow freezing
c. Life	2/ short	long	2/ varies by weight, surface condition
d. Unit Cost	high	low	
e. Noise (running) level	low	3/ Normally high	3/ can be lower than rubber-tired wheel
f. Paneture measure	required	not needed	

3) Automated Operation vs. Manual Operation

Repetitive jobs which require reiterative action with high accuracy, like maintaining order/sequence etc. can be more efficiently and effectively handled by using automated equipment. Automated operation will also contribute to reduction in manpower, prevention of problems caused by human errors. However, it is to be noted that the automated operation normally require sizeable initial investments and maintenance of the hardware and software.

Unmanned operation is not technically difficult. The issue is rather on how to respond to anxiety of passengers against vandalism or crime and other emergencies.

4) Wheel-Driven vs. Levitated

Magnetic levitated system is getting more attention because of the various advantages. No wearing of wheels, reduction in running resistance and noise level can be expected.

5) Linear Motor vs. Rotary Motor

Linear motor allows the use of electrical power to propel or brake without using friction between wheel and rail. The advantages of linear motor are as follows:

a. A vehicle can be operated along section with steep gradient

b. There is no skid when braking

c. Due to the flat and thin shape of the motor, floor height of vehicle can be reduced

d. Unlike rotary motor, transmission equipment is not required which makes the maintenance cost low

When linear motor is combined with levitated method, the mechanism of a vehicle can be altered significantly. Linear motor, however, is still considered to be technologically immature yet.

6) Materials for Cars

Normally cars are made of steel. However, they require anti-rust painting and further reduction in weight is hardly possible when viewed technologically. Therefore, there are more cases where alluminum alloy body which is lighter than steel by 3.7 times are used. The price of alluminum is high but technological progress has made it possible to reduce it considerably. At the same time, stainless steel is getting more popular as the material cost reduces and processing technology improves. With these, car bodies will not require painting and will become lighter. Some features of the different materials are compared in Table 5.3.

Table 5.3

Commparison of Car Bodies Made of Different Materials

	Weight by Composite Material								
	Ordinary Steel		Atmosphere Corrosion Resisting Steel		Stain less Steel		Total Body Weight		
	ton	(%)	ton	(%)	ton	(%)	ton	(%)	Index
1. Steel Car	8.2	(8.2)	1.8	(1.8)	0	(0)	10.0	(100.0)	100
2. Skin-Stainless Car	8.2	(84.5)	0.7	(7.2)	0.8	(8.3)	9.7	(100.0)	97
3. Conventional All-Stainless Car	2.9	(36.2)	0	(0)	5.1	(63.8)	8.0	(100.0)	80
4. Light Stainless Car	0.7	(11.1)	1.2	(19.1)	4.4	(69.8)	6.3	(100.0)	63
5. Light Alloy Metal Car	-	-	-	-	4.7	(100.0)	4.7	(100.0)	47

Table 5.4

Comparative Characteristics of Light Alloy Metal and Stainless

Item	Light Alloy Metal	Stainless
weight	very light	light
processing	easy	difficult
anti-corrosion	good	better
painting	not required	not required
welding	difficult	easy
price	high	high
reuse	possible at low cost	-