BASIC CONDITIONS TO INTRODUCE LIGHT RAIL TRANSIT –COMPARISON OF EUROPEAN AND JAPANESE CITIES–

Tadashi Ito
Wakayama National Coll. of Tech., 77 Noshima, Nada, Gobo, Wakayama, 644-0023 Japan
tito@wakayama-nct.ac.jp

Abstract

Trams in Japan have declined these past 30 years because they were seen as an obstacle to car traffic. Recently, however, because of the success stories in Germany and France, a change in Japans transport policy is gradually taking place. Some development cases have been implemented. However, it will take more time and effort before the Japanese conventional trams are changed to Light Rail Transit systems. To examine the introduction of LRT in Japan, many success stories in Germany and France can be used as examples. However, recent success stories and certain case studies are only one aspect of trams and LRT. However, by looking only at these limited examples, there is the probability of overlooking other basic conditions needed for the introduction of LRT. This study aims to find basic conditions for introducing LRT through following three dimensions: Condition of all cities, situation of all tram/LRT operations and examples of recent developments of tram/LRT in Japan, Germany and France.

Keywords: Tram; Light rail transit (LRT); Urban public transportation system
Topic Area: B1 Public Transport and Intermodality

1 Introduction

Light Rail Transit (LRT) generally refers to the developed and improved conventional tram system. LRT was introduced to Strasbourg city in France in 1994. Sophisticated design of light rail vehicles, parking spaces for Park & Ride passengers, restraining of car traffic in the city center and so on have been introduced. As a result, Strasbourg has become a much more attractive city.

In 1960s and 1970s in Germany, underground and exclusive rail track for light rail vehicle were constructed. It is called “Stadtbahn” which means urban railway and it is the main urban transit system in many cities. Germany is also making a lot of effort towards the development of LRT systems. An example is the tram-train system where both tramway and railway vehicles can function on the system, hence enabling direct connection of the suburban area and city center.

Trams in Japan have declined these past 30 years because they were was seen as an obstacle to car traffic. Recently, however, because of the success stories in Germany and France, a change in Japans transport policy is gradually taking place. Some development cases have been implemented. However, it will take more time and effort before the Japanese conventional trams are changed to LRT systems.

To examine the introduction of LRT in Japan, many success stories in Germany and France can be used as examples. However, recent success stories and certain case studies are only one aspect of trams and LRT. But by looking only at these limited examples, there is the probability of overlooking other basic conditions needed for the introduction LRT.

In this study, chapter 2 examines the relationship between the transportation modes and attributes in all Japanese, German and French cities with a population of over 100 thousand. Differences among the cities which have introduced tram or LRT, cities abandoned tram/LRT, and cities reintroducing tram/LRT are taken into account. Then, the basicconditions for the introduction of LRT will be clarified.

Chapter 3 examines basic conditions to operate the tram/LRT systems. All tram/LRT operations in Japan, Germany and France are taken into account and operational conditions, management matters and transportation management measures are fully compared.

Finally in Chapter 4, recent examples of tram/LRT development in Japan, Germany and France are taken into account. Improvement of tracks, development of new transportation modes, reopening of tram/LRT lines and so on are reviewed and future trends of LRT development are discussed.

This study aims to find basic conditions for introducing LRT through following three dimensions: Condition of all cities, situation of all tram/LRT operations and almost all examples of recent developments of tram/LRT in Japan, Germany and France.

2 Differences in cities with/without Tram

2.1 Current situation in three countries: Japan, Germany and France

This chapter examines the difference of socio-economic attributes of cities with/without tram and compares three countries: Japan, Germany and France.

The aim of this analysis is to find the appropriate condition to introduce tram system to Japanese cities. Therefore, we will observe the relationship between the prevailing conditions of trams and the urban attributes in Germany and France. Many middle class Japanese cities which have a population of about 500 thousand lack main public transportation systems. A tram system could be suitable for theses Japanese cities.

From this point of view, Table 2.1 shows the condition of the tram system in cities which have a population of more than 100 thousand at present. It is noticeable that the definition of population is different among these countries. In Japan the area of a city is the boundary of the municipality. There are cases where it is difficult to differentiate between urbanized area and local area while some municipalities consist of one urbanized area. In Germany a city

area just includes the urbanized area. In France though one urbanized area consists of some municipality areas called “commun”. This study regards the population of one “commun” as equal to city population. In this study, the problem based on city area occur in Japan and France.

As shown in Table 1, about 20% of the 213 Japanese cities which have a population of 100 thousand or more have previously introduced tram systems, 19 cities continue to have them but there is no cases of tram reintroduction. About 80% of 83 German cities have at one time introduced trams and about 40% of them abandoned it. However, 3 cities have reintroduced trams at the moment. Though most French cities over 100 thousand population had tram systems, only 3 cities continued using it. However, 30% of the cities have reintroduced the tram system.

From this tendency, it is possible to elicit some information on how German cities have sustained the tram system and why in this decade, French cities have been reintroducing tram system in a succession.

Table 1: The Number of Cities which introduced Tram System
(Population more than 100 thousand)

	Total number of cities	No. of cities which have experience to introduce tram	No. of cities which have continued tram	No. of cities which reintroduced tram
Japan	213	47	19	0
Germany	8	69	42	3
France	33	32	3	10

2.2 Comparison of urban attributes

Rail system for urban public transportation in Japan is as follows: subway, automated guide-way transport (AGT), monorail and tram. Table 2 shows the situation of public transportation mode by city size in Japan. Most cities with a population of over 1 million have subway systems for main route transport and some of them have tram and AGT system for branch route transport. There is no underground line for light rail vehicles. Only 14 of 93 cities which have a population of 200 thousand to 1 million have a rail system for public transportation.

In German and French cities, there are light rail systems with underground tracks in the city center and with exclusive tracks in the suburban area. It is a relatively simplified system compared with the subway. The system is called “Stadtbahn” in German and “Pre-Metro” in Belgium. Moreover, in France, the AGT system called VAL and hybrid tram/bus system called TVR have been developed for medium sized mass transit. In Germany, one example of medium sized mass transit is the monorail in Wuppertal.

Table 2: City size and Public Transportation in Japan

Population	No. of cities	with Subway	with Tram		with other rail system
			Total No.	Underground track in the city center	
Over 1 million	12	10	5	0	6
From 500 thou. To 1 million	10	0	4	0	1
From 200 thou. To 500 thou.	83	0	9	0	0
From 100 thou. To 200 thou.	108	0	1	0	0

Table 3 shows the situation in Germany and Table 4 shows the situation in France. 27 of 37 German cities with a population from 200 thousand to 1 million and 5 of 9 French cities with a population from 200 thousand to 1 million have rail transport systems. These figure show that Japanese medium sized cities have less rail transport systems than German and French cities. However, differences in investment institutions and management must be considered for further comparison.

Table 3: City size and Public Transportation in Germany

Population	No. of cities	with Subway	with Tram		with other rail system
			Total No.	Underground track in the city center	
Over 1 million	3	3	2	0	0
From 500 thou. To 1 million	9	0	9	8	0
From 200 thou. To 500 thou.	28	1	18	6	1
From 100 thou. To 200 thou.	33	0	13	1	0

Table 4: City size and Public Transportation in France

Population	No. of cities	with Subway	with Tram		with other rail system
			Total No.	Underground track in the city center	
Over 1 million	1	1	1	0	1
From 500 thou. To 1 million	2	2	2	1	0
From 200 thou. To 500 thou.	7	0	3	1	2
From 100 thou. To 200 thou.	23	0	7	2	1

This section examines relationship between the city size and existence of trams in Japan and Germany. Figure 1 shows a considerable difference in population density distribution between two countries. Though one of reason is of course the difference in statistical definition, this is also the reason why German city planning controls population density suitably.

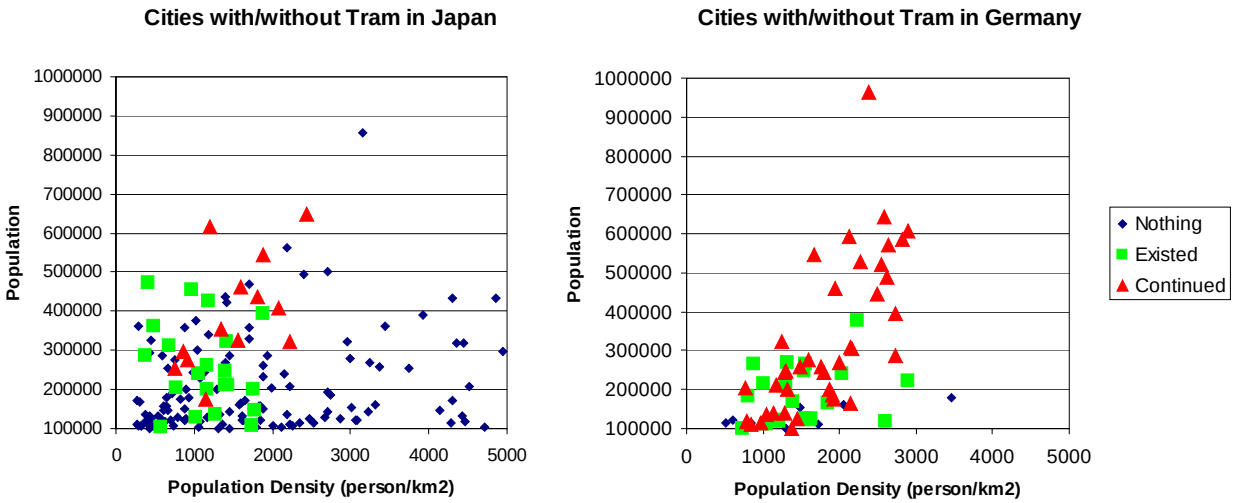

Figure 1: City size and existence of tram

(Under 1 million population ; Under 5000 person/km^2 density)

There are many Japanese cities whose population density is over 5000 person per square kilometer. Most of these cities are located around metropolitan areas and their main transportation mode is railway bound for metropolitan city centers. Tram systems do not have enough transport capacity for passengers.

Looking at the city size, cities over 1 million in both countries have previously introduce the tram system. However, as the city grows in size, the tram gets substituted with the subway system and now, most existing tram systems form the branch network.

Since cities with a population of over 1 million and a population density of over 5000 person per square kilometer exhibit the above peculiar situation. This analysis eliminates this condition. Figure 1 shows that population size and density of cities where the tram system once existed have a similar tendency in both countries. Though there is no significant difference between cities that abandoned tram and those that kept it, it appears that cities with a population under 500 thousand in Japan and under 400 thousand in Germany have abandoned the tram system.

Judging from population size and population density, cities with a population of over 1 million have tram system for their branch networks because the subway is too costly and has a high transport capacity. Cities with a population of under 1 million, and population density of from 1 to 3 thousand person per square kilometer are most suitable for introduction of the

tram system. Continuation or discontinuation of tram does not depend on population density, but the smaller the city size the higher the probability of abandoning the tram system.

Generally speaking, in Japan, the higher the population density, the lower the car ownership, the higher the modal split of public transportation is. Looking at the cities with a population of 200 thousand to 1 million which is considered the most appropriate city size for introducing the tram system, the presence or absence of trams in each city is contrasted in figure 2. There are cities in Japan which abandoned tram system though they have a population density of under 1,500 person per square kilometer and car ownership of over 400 cars per a thousand persons. However, some cities continued with the tram system under the same condition, therefore, there is a need for analysis using a different factor.

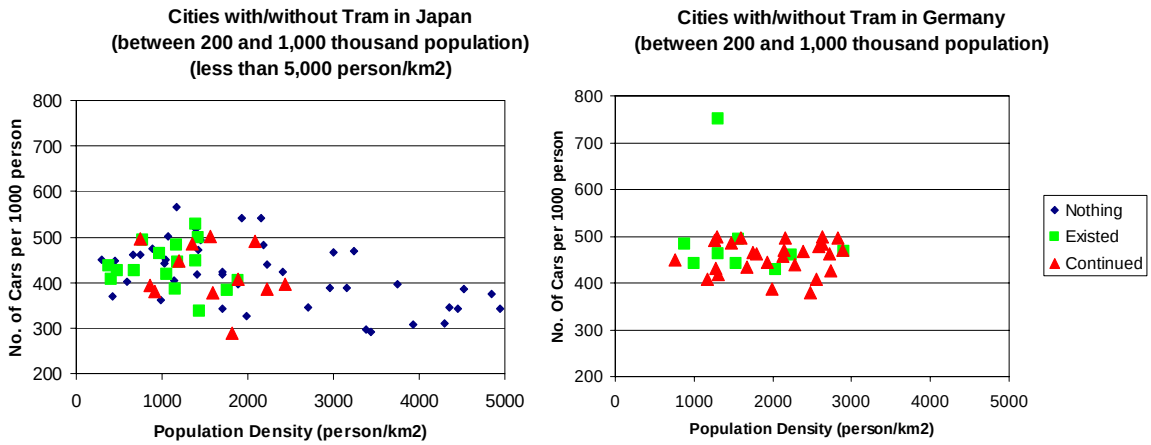

Figure 2: Car ownership and existence of tram
(Cities from 200 thousand to 1 million persons)

On the other hand, all German cities comparable to the above have previously had tram systems. However, as German cities have little difference in population density and car ownership, it is impossible to find factors that led to either the tram system being continued or discontinued. This means that car ownership is not dependent on the existence of tram systems, but that usage of cars may be another factor determining the introduction of tram systems.

From the above analysis, one determining factor of the existence of tram is the modal split of public transportation which is closely related with car usage. Since the modal split of each city is a substantial factor, scarce as it is, this section manages to collect various kinds of transportation investigation data.

In Japan there are 2 kinds of travel surveys. One is conducted in large cities and the other is simultaneously conducted in 80 cities using a relatively small sample. As a result, data of 33 cities has been collected. In Germany, Monheim et al. collected various kinds of modal split data of 50 cities. As this data does not have comparable precision for exact figures,

modal split figures are categorized into four ranges: under 10%, 10 to 20%, 20 to 30% and over 30%.

Figure 3 shows that some of the Japanese cities whose modal split of public transportation is under 20%, abandoned the tram system. Some German cities also abandoned it, when its modal split came under 20%. On the other hand, if the modal split of public transportation is over 20%, tram systems continued to exist.

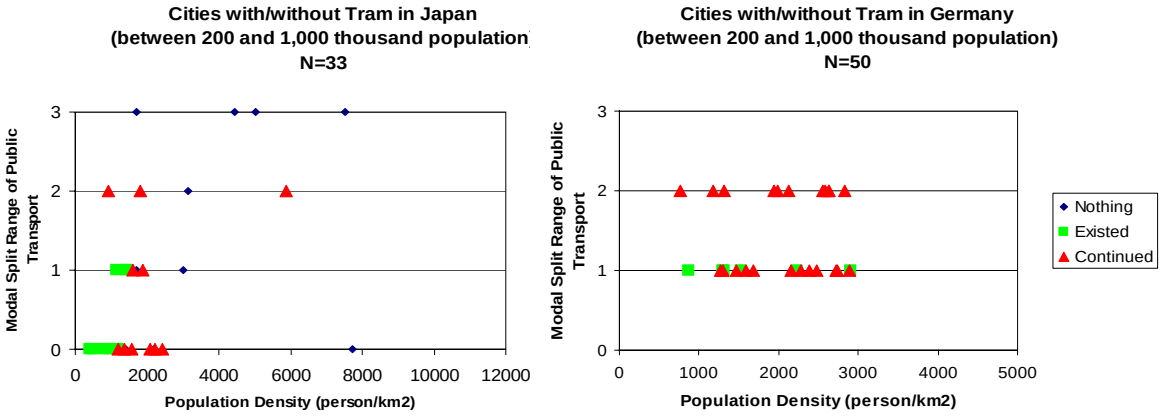

Figure 3: Modal split of public transportation and existence of tram

(Cities from 200 thousand to 1 million population)

All German cities whose population is over 200 thousand have a modal split of public transportation of over 10%. This reflects sufficient policy for public transportation. On the other hand, while some of Japanese cities have a modal split of public transportation of over 30%, there also exists cities whose modal split is under 10%. There is need to consider how these cities could increase the use of public transportation and manage to use private cars.

2.3 Summary

This chapter examined the relationship between transportation modes and attributes of cities with a population of 100 thousand people in Japan, Germany and France.

In Germany and France, most cities have at one time introduced a tram system and in many cities in Germany tram systems are the main transportation mode. In France, although most cities had abandoned the tram system, recently there is has been a tendency to reintroduce the tram/LRT. On the other hand, in Japan, because of rapid urban growth, only a quarter of the cities have introduced the tram system previously and half of these have abandoned it. As a result, the number of cities which have rail oriented transportation modes is much smaller than in European countries.

One reason is that population density of Japanese cities is very high and many cities are located in metropolitan areas. Thus, inter-urban railway becomes the main transportation in these cities. However, in cities which have tram system, basic conditions are similar: city size of 200 thousand to 1 million people and population density of 1000 to 3000 person/km^2.

The following conditions increase the possibility to abandoning tram systems : city size of less than 500,000 people, car ownership of over 400 cars per person in Japan, and a modal split of public transportation of under 10%.

Considering urban attributes, one important condition for the introduction of LRT is to induce the urban structure not to depend on cars and make it is easy to use public transport modes.

3 Comparison of operation of light rail transit and tram

3.1 Current situation of LRT and tram: Japan, Germany and France

Light Rail Transit (LRT) and tram are operated by different kinds of companies or organizations.

In Japanese cities, there are 5 operated by municipalities, 13 by private companies, and 1 by the third sector. In most German cities a public utility agency called “stadtwerke” , dealing with water, gas, electricity and so on (which is one of the functions of a municipality) operates public transport. The transport sector operates not only tram lines but also bus lines. In some German cities more than two transport companies operate tram lines in one city area. However, in this case, the transport association generally manages operation lines and the fare system of that area. Therefore, passengers do not have to care which company operates the lines. In French cities, the principle is that transportation in one whole metropolitan region is managed by only one transport company. This is because companies that want to run a public transport business take their proposals to a self-governing body and those that are accepted are left with the task of operating the public transport of that city.

Table 5 shows opening period of LRT/Tram line in each country. In Japan 14 of 19 cities were operating by 1925 and most of them until World War II. After the war, with only one exception, there has been no new tram introduction. In Germany 18 cities had trams by 1895 (when Japan had her first tram) and until 1910 most cities had tram system. Recently 3 cities have re-introduced the tram system again. In France 3 cities began the tram system from the first era of tram and have continued, and the other 10 cities re-introduced them recently.

Table 5: Opening Period of LRT and Tram

Period	Japan	Germany	France
1881 – 1895	0	18	3
1896 – 1910	3	32	0
1911 – 1925	11	3	0
1926 – 1935	4	1	0
1936 – 1984	1	0	0
1985 –	0	3	10
Total	19	57	13

Table 6 shows network size of LRT/Tram in each country. Japanese and French cities have small network sizes with a route length of within 30 km. Particularly in Japan there are

6 tram networks whose route length is within 10 km. This is not enough to cover the entire area of a city. Recent French tram systems have at least 15 km route length. This means that 15 km is the minimum route length required to cover the city area. In Germany, over a half of tram systems have a route length of over 30 km and 9 cities have over 100 km of tram systems. These systems provide a high density of tram networks.

Table 6: Network Size of LRT/Tram

(km)	Japan (n=19)	Germany (n=57)	France (n=13)
0 - 10	6	10	2
11 - 30	12	19	11
31 - 50	1	8	0
51 - 100	0	11	0
101 -	0	9	0

Considering the capacity of LRT/Tram, it is expected that the location of LRT/Tram; in a city of over 1 million is feeder lines in peripheral area and for a middle sized city is a line through the main corridor. Table 7 shows the present situation of LRT/Tram from this point of view.

Table 7: Location Characteristic of LRT and Tram

Population	Japan (n=19)		Germany (n=57)		France (n=13)	
	through center	feeder line	through center	feeder line	through center	feeder line
over 1 million	1	5	1	1	0	3
500 thousand – 1 million	3	0	8	1	0	1
200 thousand – 500 thousand	9	0	18	1	6	0
under 200 thousand	1	0	23	4	3	0

French cities show clear classification. In cities of over 500 thousand, LRT makes up the branch line because of the existence of subway. On the other hand in cities of under 500 thousand, LRT runs through the city center as the main mode of transport. 4 German cities which have subway (U-Bahn) also have LRT/Tram as the branch line and the other cities have it as the main mode of transport. However, as an exception, 4 cities with a population of under 200 thousand use it for the branch lines. As three of these cities are located near Berlin, the tram lines take the part of feeder lines connecting the Urban railway (S-Bahn). And the remaining one line is located in a natural park in Dresden, serving as a tourist line. In Japan, 5 lines serve as feeder lines located in metropolitan areas such as Tokyo, Osaka and Kyoto. Other lines run through the city center. In each country, LRT/Tram lines are located such that it plays an important role as a transport means in their cities.

3.2 Comparison of passenger transport situation and management of LRT and tram

Table 8 shows the passenger transport density index where the annual number of passenger is divided by the route length.

Table 8: Passenger Transport Density of LRT and Tram

(person/km/day)	Japan (n=19)	Germany (n=31)	France (n=8)
0-100	4	7	0
101-200	5	9	2
201-300	6	9	1
301-	4	6	5

In Japan there are 4 low density lines with less than 100 persons/km/day, even though there is no subsidy from municipality. There is need for measures to increase the passengers here. On the other hand, despite a vehicle length limit of 30 meters, there are 4 high density lines with over 300 persons/km/day. German cities also show a varied density transport. Low density lines can get a subsidy for their operation cost from the municipality. High density cities can transport with a maximum vehicle length of 75 meters. French cities have a well organized operation. There are no low-density areas and most areas have achieved a high density transport. This means that French new LRT lines are well planed and well operated.

A Tariff system can be regarded as an index of passengers' willingness to pay and level of revenue. Table 9 shows the total revenue from passengers' fare divided by the total passenger transport kilometers. That is average fare per kilometer. The Japanese data shows only the values of the tram lines while in Germany bus transport is included.

Average Fare is 0.38 Euro/km in Japan and 0.14 Euro/km in Germany. The Japanese fare level is about 3 times that of Germany. The average fare in most German cities is under 0.25 Euro/km. This makes it easy for people to use public transport. This is because of the operation cost subsidy. However, this analysis does not consider the payment of tax. It needs to be considered who should pay for the cost of public transportation.

Concerning the relationship between operating cost, fare revenue and subsidy, the situation in the three countries is examined.

Table 9: Average Fare of LRT and Tram

(EUR/person-km)	Japan (average=0.38) (n=19)	Germany[1)] (average=0.14) (n=54)
– 0.08	0	3
0.08 – 0.17	0	39
0.17 – 0.25	3	10
0.25 – 0.33	5	2
0.33 – 0.42	6	0
0.42 – 0.50	2	0
0.50 –	3	0

1) Some cities in Germany include bus fares.

In Japan there is no institute to subsidize operating costs and it is a regulation that operating costs are borne by the company through their own revenue. If operating costs are bigger than the fare revenue, the company has to compensate for this using the revenue from its other lines or other kinds of businesses.

In Germany, as it is hard to collect revenue and cost data from each company, aggregated data from VDV (Association of German Transport Undertakings) is examined. In 1999, the total operating cost for all companies belonging to VDV was about 21.1 billion DM and total fare revenue was about 11.5 billion DM. Fare revenue is about 54 % of operating cost. According to 1998 data, about 8.6 billion DM is used as subsidy for compensation of operating costs. On average, transportation companies in Germany receive around 45% of operating cost from subsidies.

Hass-Klau shows that most cities receive a 40 to 60 % of subsidy. Some cities show lower figures of around 20 %. For example in Erfurt, one of the subsidy sources is from revenue by public utility such as electricity and gas. However, even Strasbourg which is an LRT success story gets 43% subsidy for operating cost. The payer of operating cost is one significant political topic.

3.3 Comparison of tariff system

Japan has quite a different fare collection system from European countries. As management costs should be compensated for by the fare revenue, a tariff system is established by each company. Thus, even in the same city, if we use different companies, we have to pay a fare for each transportation company. On the other hand, a French city has only one transportation company covering the entire city area. Thus we can ride both a tram and a bus with one common ticket.

In Germany there are two cases. One, same as in French cities, an municipal organization manages public transportation in the entire city area. This case has common tariff systems in its area. The other is that more than two private companies mange public transportation in one city area like in Japan. However, in this case, the city or region has a transport association and transportation companies belong to this. Thus, the city or region has the same tariff system and passenger can ride any mode with one common ticket.

Table 10 shows typical examples of tariff system in each country. Hiroshima Railway in Japan, Rhein-Ruhr Transport Association in Germany and Lille region in France. Table 11 shows average price of tariff and the price structure.

Table 10: Examples of Tariff

Kind of Ticket	Japan (Hiroshima)		Germany (VRR : Rhein-Rhur Transit Association)		France (Lille)	
	Euro		Euro		Euro	
One-way ticket (1 Zone)	1.25		1.75		1.15	
One-way ticket (Short distance)	1.00		1.00		-	
Multiple return tickets (Price per 1 ride / No. of ticket)	1.04	16	1.40	4	1.00	10
One-day ticket (Price / No. of times with one-way ticket)	5.00	4	6.35	4	3.35	3
Week ticket (Price / No. of times with one-way ticket)	-	-	14.70	9	11.00	10
Month ticket (Price / No. of times with one-way ticket)	50.25	41	44.70	26	40.00	35

Table 11: Price structure of Term Ticket

Kind of Ticket		Japan		Germany		France	
		Price (Euro)	No. of sample	Price (Euro)	No. of sample	Price (Euro)	No. of sample
One-way ticket	Average price	1.36	19	1.52	55	1.18	
One-day ticket	Average price	4.89	16	4.16	55	3.42	12
	No. of times with one-way ticket	3.9		3.3		3.1	
Weekly ticket	Average price	-	0	12.35	41	10.06	8
	No. of times with one-way ticket	-		8.1		9.1	
Monthly ticket	Average price	55.82	19	37.02	55	36.94	11
	No. of times with one-way ticket	41.6		25.5		31.3	

Germany and France decide fare prices based on tariff zone. Tables show prices in the city center zone. In Japan there are two tariff systems. One depends on the zone, and the other depends on the distance.

In Germany, as the zone area is relatively large, there is a short distance ticket such as for inside a 2 kilometer trip. But the price of one-way ticket is relatively high. In Japan, there are 2 examples, Hiroshima and Okayama which have short distance ticket.

Each country has multiple return tickets for 4 or 10 trips and a passenger can ride with a 10% discount price. In Japan, there is multiple return tickets for holidays and day-time. This is a measure to increase passengers in off-peak hours.

One of the incentive tickets is the one-day ticket. In Japan price of a one-day ticket is based on 4 rides. However, in France 3 rides is enough and it is easy to use. In Germany the price is based on 3.3 rides. These figures include a one-day ticket for more than 2 persons. For example in Rhein-Ruhr region, 5 people can use a one-day ticket at the same time. Other cities have a one-day ticket for families, up to 2 adults and 2 to 4 children. This is an incentive for families or groups to using public transport.

Term tickets are contrasted by week or month tickets for commuters. Japan has no week ticket, but Germany and France have this type of ticket and its price is based on 10 rides. Monthly tickets in Japan are based on 40 rides, in France, 35 and in Germany is 30. There are high incentives in Germany.

Monthly tickets for commuters show the highest priced term ticket. There are discount tickets for elderly people or students in each country. Environmental tickets are one of the new type of discount tickets. This can be use for multiple people or a different person can use it with a small additional price.

3.4 Summary

This chapter examined basic conditions for tram/LRT operation. All tram/LRT operations in Japan, Germany and France were taken into account and operational conditions, managerial matters and usability measures were totally compared.

Although operational organization of tram/LRT is hard to compare among the countries because of the difference in institutional system, the basic operation condition were found to be as follows: network size of 10 to 30kilometers, line located through city center in cities with 200 thousand to 500 thousand people. It is generally said that LRT/tram introduction take the these forms: city center type, feeder line type, new city center type, new town type and so on. However, the present situation in Japan, Germany and France shows that major LRT lines run through the city center and that this type of LRT contributes to the revitalization of the city.

Concerning transport conditions, European countries are allowed to run long length vehicles, for instance 75m in Germany. Hence, many cities have attained high transport density in Germany and France whereas in Japan where vehicle length restriction 30 meters, it is hard to attain high transport capacity.

Concerning managerial matters, the fare level in Japan is higher than in Germany and France. Because Japan has the principle that cost must be compensated for from fare revenue while both German and French governments give subsidy to tram/LRT operators. However, there is no significant relationship between subsidy rate and transport density of passengers. It means that by good management operation of tram/LRT with low transportation density is possible.

4 Recent developments of LRT and tram

4.1 Combination of railway and tramway – Tram-Train System in Germany

Germany developed vehicle which can run on both railway and tramway. This Tram-Train System started in Karlsruhe in 1992 (Table 12).

In 1995, Kassel also started the Tram-Train System. The rail track for freight transport, KNE (Kassel-Naumburger Eisenbahn) was improved and electrified to accomodate tram vehicle. In 2001 another railway line was also improved and started tram vehicle operation. Kassel also plans to introduce “Karlsruhe System” in the near future and a 2 system vehicle “Regio-Tram”, which is the same type of vehicle as in Saarbrucken, and already runs on German railway track.

Saarbrucken adopted the same system as Karlsruhe in 1997. This vehicle runs 1 km into French Railway line. This is the only international tram in the world.

Zwickau started to operate a diesel vehicle in the city center in 1999, which has since been improved and now runs a tram in the same city. As Zwickau has a 1000mm gauge tramway which is different from the railway, a 3-rail track system was introduced.

In this way, Germany solved technical matter among same rail track with different operating systems. This succeeded in connecting the suburb and the city center with tramway thus directly increasing the passenger volume.

Table 12: Tram-Train System in Germany

City	Year	Outline
Karlsruhe	September, 1992	2-system vehicle, runs German Railway line and tramway line in the city center
Kassel	May, 1995	Railway line improved for tram vehicle. 2 lines under operation. Planning to connect German Railway line
Saarbrücken	October, 1997	Same system as Karlsruhe. 2-system vehicle runs reopened tramway in the city center, German Railway line and French Railway line.
Zwickau	May, 1999	Diesel vehicle for railway runs tramway in the city center

4.2 Combination of tram and bus – Trial in France

France has tried to develop a new transportation mode which have the same transportation capacity and comfort as tram and has flexibility of route operation, ease of introduction and affordable cost. In 1997, an experiment to test their feasibility was conducted in Paris and in the end of 2000 some of modes had been implemented (Table 13).

Table 13: New Tram and Bus in France

System	Adopted Cities	Outline
TVR (Tram Voie Réservé)	Nancy(2000) Cean(2002)	It runs with rubber tires and is guided by mono-rail. It can run without rail just like trolley bus and can run without trolley. Hybrid tram/bus. Bombardier developed.
Translohr	Clermont-Ferrand (2005)	It runs with rubber tires and is guided by mono-rail same as TVR. TVR is guided by one steel wheel, but this is by two steel wheel. Lohr Industry developed.
CIVIS	Clermont-Ferrand and Rouen (2000)	Optical tracking system, which identify painted line on the road, guides to run. It dose not need rail track and can run both with diesel engine and electric motor.
Agora		Conventional diesel engine bus with optical tracking system.

TVR, which began to operate in Nancy from 2000 and in Cean from 2002, runs with rubber tires and is guided by mono-rail. It can run without rail just like a trolley bus. However, it soon ran into trouble. When it runs without rail, the last vehicle of the three serial unit runs with a winding motion.

Another mono-rail guided tram system with rubber tires “Translohr” was also developed. Steel wheel makes it a little different from TVR. There are plans to introduce Translohr in Clermont-Ferrand in 2005.

Tram system without rail track has also been developed. This system is guided by painted markers on the road. “CIVIS” which can run with an electric motor and “Agora” which runs on a diesel engine have been developed. Guide marks are not painted all through the introduced line. They are mainly painted near bus stops or winding road parts. Therefore, the driver manipulates it the same way as a normal bus and drives without steering wheel help only on the marked parts.

Although new modes tend to have trouble and are under experiment, they have the possibility to be implemented the same way as existing trams and as a convenient mode.

4.3 Reintroducing tram/LRT in city

Cities of 200 to 500 thousand people can not provide enough transportation system without tram/LRT system. Bus transport is affected by car traffic congestion.

In France, since Nantes reintroduced tram in 1985, 7 similar sized cities have introduced tram or same performance mode (Table 14). This aims to revitalize the city center as new tram lines run through their city center. At the same time car traffic restraint measures such as park and ride change the car-oriented city into a human-oriented city.

Table 14: Cases of LRT reintroduction in 8 French Cities

City	Opening Year	Outline
Nantes	1985	Opened 1 line, 10.7km length. Now 3 lines, 35km length.
Grenoble	1987	Opened 1 line, 8.9km length. Now 2 lines, 28.5km length.
Strasbourg	1994	Opened 1 line, 9.8km length. Now 3 lines, 24.8km length.
Rouen	1994	Called “Metro-Bus” with underground track in the center. 2 lines, 16.5km.
Montpellie	July, 2000	Opened 1 line, 15.2km length
Orleans	October, 2000	Opened 1 line, 18.0km length.
Nancy	December, 2000	Opened 1 line, 11.0km length. TVR.
Cean	October, 2002	Opened 1 line, 15.5km length. TVR.

They have also been reintroduced in German cities (Table 15). Heilbronn introduced tram track in the city center and connects it to Karlsruhe center. Saarbrucken also adopted Tram-Train System and reintroduced a tram track in the city center. Oberhausen aims not only to access a new development area but also expects to have a network connecting it to the neighboring city, Mulheim.

Table 15: LRT Reintroduction cases in 3 German Cities

City	Opening Year	Outline
Oberhausen	June, 1996	1 line, 8.5km length. Elevated exclusive track between main station and Sterkrade station. Buses also run same track.
Saarbrücken	October, 1997	5.8km tram in the city. It runs 12km German Railway track and 1km French Railway track.
Heilbronn	July, 2001	1.6km tramway in the city. Connecting to Karlsruhe center via German Railway with 70km distance.

Many Japanese cities which once introduced trams face problems such as car traffic congestion and a decay of the city center. Considering the environment and the aging society, having a compact city is important. LRT is an effective option for the Japanese cities.

4.4 Summary

LRT is one device to revitalize the city. French cities made it successful. France is also making efforts to develop new transportation mode with same performance as trams but much more convenient than trams. Although there are still some problems with the new modes, they shall be adopted in more cities. German cities have made efforts to utilize existing railway and tramway infrastructure effectively.

Japan has only a few cases of redevelopments. Development processes of LRT, such as extension of line, reopening of tramway, implementation of Tram-Train System, will change the attractiveness of a city.

5 Conclusion

In this study, chapter 2 examined relationship between transportation modes and attributes of all Japanese, German and French cities which have a population of over 100

thousand. Basic conditions needed for LRT introduction are as follows: city size of over 200 thousand to 1 million people and population density of 1000 to 3000 person/km^2. The following conditions increase the possibility of abandoning a tram system: city size under 500 thousand people, car ownership of over 400 cars per person in Japan, and modal split under 10% public transportation. Considering urban attributes, one important step towards introduction of LRT is to induce urban structure not to depend on cars, and make it is easy to use public transportation modes.

Chapter 3 examined basic conditions needed to operate tram/LRT. All tram/LRT operations in Japan, Germany and France were taken into account and the operational situation, managerial matters and transportation management measures were fully compared. Basic conditions needed for operation are as follows: network size of 10 to 30 kilometers, line location through city center with cities of 200 thousand to 500 thousand people. The present situation in Japan, Germany and France shows that major LRT lines run through the city center and that this type of LRT contributes to the revitalization of the city.

Lastly, in recent years, examples of tram/LRT development in Germany and France were reviewed. Introduction of new types of vehicles, redevelopment of infrastructure, development of new transportation systems and modes and reopening of ram/LRT lines were important topics in examining future trends of tram/LRT. Germany and France have continued to invest in redevelopment and extension of infrastructure for a long time. France also continues to make efforts to develop new transportation modes with the same performance as trams but with much more convenience than tram. German cities continue to make efforts to effectively utilize existing railway and tramway infrastructure.

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