MASS RAPID TRANSIT SYSTEMS PLANNING IN TAIWAN METROPOLITAN AREAS

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abstract: The objective of this paper is to review the transit systems planned for the six metropolitan areas in Taiwan. The network planned for each of the six metropolitan areas was reviewed together with its socio-economic characteristics and transportation needs. Discussions were made on their economic, financial performances, as well as primary environmental concerns. Emphasis was placed on low financial and economic returns due to low transportation demand, and high cost of system standard and network configurations. Planning procedures and funding mechanisms currently used in Taiwan were compared with those in the U.S.. The effects of planning procedures and legal requirements on the cost-effectiveness of the system were explored. Suggestions were made as to how to establish a reasonable administrative environment for cost-effective transit investment in Taiwan.

1. INTRODUCTION

For the past decades, rapid economic growths have brought about heavy impacts to the living and transportation environments in the metropolitan areas. With large increase of personal income, private transportation modes such as passenger cars and motorcycles become far more affordable. However, the construction of roadway facilities, including roads and parking lots, are far behind the increase of motor vehicles. Thus, the urban streets are getting congested with degraded level of service.

Worldwide resurgence of environmental concerns have brought a slowdown, if not a complete halt, in highway construction. A high quality public transportation system becomes a requirement for all major cities in the world for their urban development as well as solving transportation problems. Mass Rapid Transit System (MRTS) are often selected to meet the passengers' demands in metropolitan areas for its safety, time-saving, comfort, high capacity and reliability.

The design and construction of RTS has also been undertaken in major cities of Taiwan in recently years to serve areas with higher transportation demand and to improve the current public transportation system. Planning and design of MRTS have been proceeded in six metropolitan areas in Taiwan. The first phase rapid transit network is actively under construction in Taipei. The first MRTS line (Mucha Line) has officially commenced its operation in March of 1996, and the second line, Tamshui Line, in March of 1997. Kaohsiung area MRTS is in the designing stage. The MRTS of four other cities, namely Taoyuan, Hsinchu, Taichung and Tainan, are in the planning stage.

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The objective of this paper is to review the MRTS plans of the 6 metropolitan areas. Socio-economic characteristics and the projected network performances are examined. Discussions are made for the probable reasons for their economic and financial ineffectiveness, and how they can be attributed to the planning and impleme ntation procedures in transit development. Suggestions are made as to how to establish a reasonable adminstrative environment for cost-effective transit investment in Taiwan.

2. SOCIO-ECONOMIC CHARACTERISTICS AND NETWORK PERFORMANCES

The socio-economic characteristics of the six metropolitan areas are shown in Table 1. Projected transportation demands and network characteristics are shown in Table 2.

TABLE 1 Socio-Economic Characteristics of the Six Metropolitan Areas

	Taipei	Taoyuan	Hsinchu	Taichung	Tainan	Kaohsiung
Base Year	1991	1991	1995	1994	1990	1990
Metropolitan Population in the Base Year (thousand persons)	5,760	1,380	870	3,460	1,400	2,770
Study Area (Hectare)	189,553	122,095	86,489	198,894	93,574	112,618
Average Population Density in the Base Year (person/hectare)	30.4	11.3	10.1	17.4	15.0	24.6
1996 Major City Population (thousand persons)	2,630	570	340	850	710	1,430

TABLE 2 Projected Demands and Network Characteristics of the Six Metropolitan Areas

	Taipei	Taoyuan	Hsinchu	Taichung	Tainan	Kaohsiung
Target Year	2021	2021	2021	2021	2020	2020
Metropolitan Population in the Target Year (1,000 persons)	7,610	2,430	1,510	4,820	2,580	4,210
Average Population Density in the Target Year (person/hectare)	40.1	19.9	17.4	24.2	27.6	37.4
Total Daily Trips in the Target Year (1,000 trips)	18,120	4,850	2,240	9,410	5,410	9,650
Daily Trips Generated per Person in the Target Year (boarding)	2.38	1.99	1.49	1.95	2.09	2.29
Daily Patronage in the Target Year (1,000 passengers)	3,380	450	173	461	517	620
% of Public Transportation Users on MRT System	52.8%	21.7%	40.4%	18.1%	52.6%	33.4%
Link Peak Loading in Peak Hours (1,000 Passengers)	51.4	9.3	6.8	13.3	15.2	30
Total Length of the Planned Network (kilometers)	158	47	26	69	63	43[a]
Selected Systems	MRT/ MCT	Small Section MRT	BUS/LRT	LRT	Small Section MRT	MRT
Construction Cost (US$, million)[b]	26,132	4,493	1,246	8,186	6,207	10,254
Average Cost (US$, million/km)[b]	165	96	48	119	99	238

Note: a - Total length for the Kaohsiung Metropolitan RTS is 77.7 kilometers. It refers to the length of the approved network here.
b - the exchange rate used here for US$ to NT$ is 1:28.

Economic and financial assessments of the MRTS in the six metropolitan areas are shown in Table 3. Even though most of the networks are economically feasible, but results from the financial evaluation is not satisfactory.

TABLE 3 Economic and Financial Assessment of the RTS in Six Metropolitan Areas

		Taipei	Taoyuan	Hsinchu	Taichung	Tainan	Kaohsiung
Economic Index	Internal Rate of Return (IRR)	15.00%*	8.15%	11.7%	10.18%	7.01%	7.65%
	Benefit/Cost (B/C) Ratio	1.60*	1.32	1.13	1.01	1.19	1.52
Financial Index	Internal Revenue Rate (IRR)	N.A.	-4.19%	2.20%	-5.21%	N.A.	-1.89%
	Self-Liquidating Rate (SLR)	N.A.	-11.62%	17.60%	-4.71%	0.31%	10.09%

*Note: *The preliminary rapid transit network (88 kilometers) index of Taipei RTS is applied here.*

3. REVIEW OF KEY ISSUES IN THE PLANNING PROCESS

Although the economic indices show acceptable rates of return for the six metropolitan areas in Taiwan, the financial performances are less than acceptable. This indicates that the transit systems cannot generate sufficient fare box revenue to pay for the operation expenses, not to mention paying back capital investments. While most transit systems in the world require some subsidies during the time when the networks are being developed, it would be a long term financial burden if the system is not projected to generate sufficient revenue to cover the operating expenses in the target year. These financial indices indicate insufficient ridership on networks that are probably over-sized. Since this is common to almost all transit systems being planned, some regulatory or structure factors may be attributable to the overall poor performances.

A. Lack of a Clear Transportation Policy and a Comprehensive Transportation Plan

The lack of a clear policy on the promotion of public transportation causes unnecessary competition between transportation modes. In Taichung metropolitan area, for example, many freeway and expressway facilities are at different stages of implementation in the corridor between Taichung and Nantou, including the Second Freeway and Chung-Tou Expressway. Transit services in this corridor can hardly compete with private automobiles which can be operated at an average speed of more than 50 kilometers per hour. And yet, the transit line was included in the first-phased network due to the consideration for serving the Provincial Capital of Nantou. With a comprehensive transportation plan, this competition may be avoided.

Another example lies in the need to clearly identify the functional roles of railway systems in regional transportation. Urban development in Taiwan was initiated from stations along the railway. Stripe along the railway was also the transportation corridor with the highest transportation demand, which highly overlaps with the MRTS corridor in a metropolitan area. Furthermore, the North-South High Speed Rail (HSR) is at implementation stage, and is expected to commence operation in 2003. It is important that the market served by the three systems be clearly segmented to avoid cut-throat competition and wasteful investment. If the railway is identified to serve short distance passengers, commuter's rail may be considered in some appropriate corridors to reduce redundant services provided by the transit networks.

B. Unclear Restriction by Law on System Selection

Article No.3 of the "Mass Rapid Transit Act" defines the MRTS to be a transit system operated in the exclusive right-of-way without being interfered by other transportation modes. For large metropolitan area, as Taipei, where transportation demands are high, a system on totally exclusive right-of-way is necessary for a transit system of acceptable service quality. As to middle-sized cities, such as Tainan and Taoyuan, it is questionable that an investment on transit systems of such high standard will be cost-effective. Considering the experiences in other parts of the world, LRT (Light Rail Transit) has been the most popular mass transportation mode in middle-sized cities both in Europe and in the United States, such as Los Angeles, San Jose, Dallas, etc. The LRT system in Tuen-Men of Hong Kong further becomes a successful model for new town development. Light rail transit has the advantage of being flexible in design. It can be on exclusive right-of-way in a tunnel, where the development is intensive, on viaducts where right-of-way permits. It can also be operated at-grade with full or partial interface with street traffic where degradation to service quality is not severe.

Taipei and Kaohsiung are the two largest metropolitan areas that are taking lead in the use of mass rapid transit systems in Taiwan. Since exclusive right-of-way is considered necessary, the definition of a "Mass Rapid Transit System" was never challenged. Taking a full exclusive right-of-way as the basic premise, the so-called "small section MRT" was selected in Tainan and Taoyuan, to reduce construction costs in underground tunneling. The light rail system was selected for the metropolitan area of Taichung. However, the rule of 100% exclusive right-of-way still applies, and the first phase network is mostly underground. Thus, the advantage of a light rail system has not been fully utilized, other than the probable future extensions. In the case of Hsinchu, the smallest city of the six, local government is more willing to consider more economic system in exchange for a higher priority for government funding. A staged development concept with busway/LRT was adopted. This is the reason why Hsinchu system has the most appealing economic and financial performances out of those of the six metropolitan areas.

From the result of detailed design of the Taichung system, the cost for 69 kilometers of transit lines is about US$8,186 million dollars, or US$119 millions per kilometer. Financial indices are very poor. For Hsinchu system, however, the total cost for 26 kilometers of transit line is about US$1,246 million, or an average cost per kilometer of about US$48 millions. The financial performances figures are significantly improved, although still on the low side.

Recognizing the advantage of having a full spectra for system selection, the Ministry of Communications and Transportation recently made an addendum for interpreting Article No.3 of the Mass Rapid Transit Act. As long as the transit line can be separated from street traffic both physically, and via traffic control measures, so that traffic interference can be avoided, it is considered applicable to the Transit Act. Thus, planners may, in the future, choose the most suitable system and alignment type in accordance with the local demand characteristics.

C. Over-sized Rapid Transit Network Relative to Demand

A comprehensive plan usually requires local participation to reflect its needs. However, the size of the rapid transit network tends to be overly expanded because the study area of the metropolitan areas are too large out of the citizens' strong request for extending the transit line.

In terms of the rapid transit network of Taichung metropolitan area, the originally suggested length at the system planning stage was 150 kilometers, which is equivalent to the length of the long-term network in Taipei metropolitan area. Since transportation demand is low outside the core of the rapid transit network, a cost-effective operation is therefore very difficult. The size of the network was recommended under strong pressure from the local communities. In the detailed planning stage, the rapid transit network is reduced to about 69 kilometers, but still fails to perform financial effectiveness. The reduction in network size causes strong opposition from the local communities in the extension areas, although other transportation modes, such as buses, are found to be sufficient and more cost-effective. Since the local governments are taking very limited financial responsibilities in the construction of the mass rapid transit system, it is always to the interest of the local communities to ask for the most expensive system.

Analysis of the local government's share of the construction cost is shown as Table 4 under various assumptions. If the central government subsidies 50% of the construction cost, local government are not be liable for more than 10% of the construction cost at the highest. The outlying Nantou County would pay less than 2% of the total construction cost. If subsidy from the central government is 80%, local government's share is lower than 4%, with Nantou County accounting for less than 1%.

Table 4 Taichung Metropolitan Area MRTS Funding Analysis

Central Government Share		Local Share (Provincial to Local is 2:1)			
		Provincial Government	Local Government		
			Taichung City	Taichung County	Nantou County
Assumption 1	50%	33.33%	9.40%	5.32%	1.95%
Assumption 2	80%	13.33%	3.76%	2.13%	0.78%

On the other hand, since all metropolitan areas have high expectations on the provision of MRTS by the central government, they tend to pressure the central government to subsidize and start the construction of RTS as soon as possible. It would be desirable, from the central government point of view, to establish a systematic method and procedure to implement the plan and its financial resources to be reasonably distributed among the six metropolitan areas.

D. Insufficient Decision-Making Points in the Transit Development Process

The planning and design of a mass rapid transit system should start from regional considerations to corridor, corridor to routes and points, a gradual process from macro to micro and detail design. The process can be divided into three stages,

(1) comprehensive transportation plan of the metropolitan area,
(2) RTS feasibility study, and
(3) corridor study and alternatives analysis.

Preliminary and detailed design then proceed. A decision-making point is provided after the completion of each phase, to determine whether it would be worthwhile to proceed into the next stage.

In Phase I, the main tasks are to forecast the metropolitan transportation demand and distribution in the target year and study the probable transportation transit modes and future developments for all the corridors.

In Phase II, the main focuses are on choosing a transit mode that will fit the transportation demands of all corridors. Preliminary analyses of the environmental impacts and economic effectiveness of the transit modes are made. The implementation sequence of the future RTS network of a metropolitan area is also studied.

In Phase III, ridership forecasts are examined in detail. Preliminary alignment, station planning, operation planning, and system selection are studied in depth, with detailed environmental impact assessments.

The current procedures do not provide sufficient decision-making points. Once a feasibility study, or system planning, confirms the need for a transit network, the whole network will be implemented without separating the priorities between various transit lines. There is a need to re-establish a reasonable planning procedure and identify the technical content of each step.

4. DISCUSSIONS ON A REASONABLE PLANNING PROCEDURE

Figure 1 shows the comparison of the MRTS planning procedure of the Federal Transit Administration (FTA) of the U.S., with that of Taiwan. Figure 2 is the suggested procedure for planning and approval.

RTS network planning and corridor planning should be differentiated in the planning process. Once the consensus for building an RTS has reached, the rapid transit network should be analyzed first and focuses on network configurations, system technology and engineering and financial feasibility. The purpose of this phase is to evaluate if the RTS is worth building.

Phase II emphasizes on "evaluation of the transit lines and alternatives," whose result is similar to the stipulation of the Article No.12 of the current RTS Act. It has to show on a 1/1,000 topography map for outlining the range of rezoning requirements. In additional to engineering and financing studies, environmental impacts are to be analyzed in details at this stage.

The aforementioned procedure focuses on examining funding subsidy at various stages, which helps to review repeatedly the priority and local coordination of an application of the

RTS. After considering the comprehensive needs, the local government submits the application of RTS plan. Provincial or Central Government can evaluate the application sequences by various performance indexes to screen out the ones with low economic and financial performances. To compete for subsidy, local government might cooperate himself with some more comprehensive plans to improve the performance for the submitted case. Such interaction shall be happening continuously in an interactive process and will help to evaluate priority and local participation interaction.

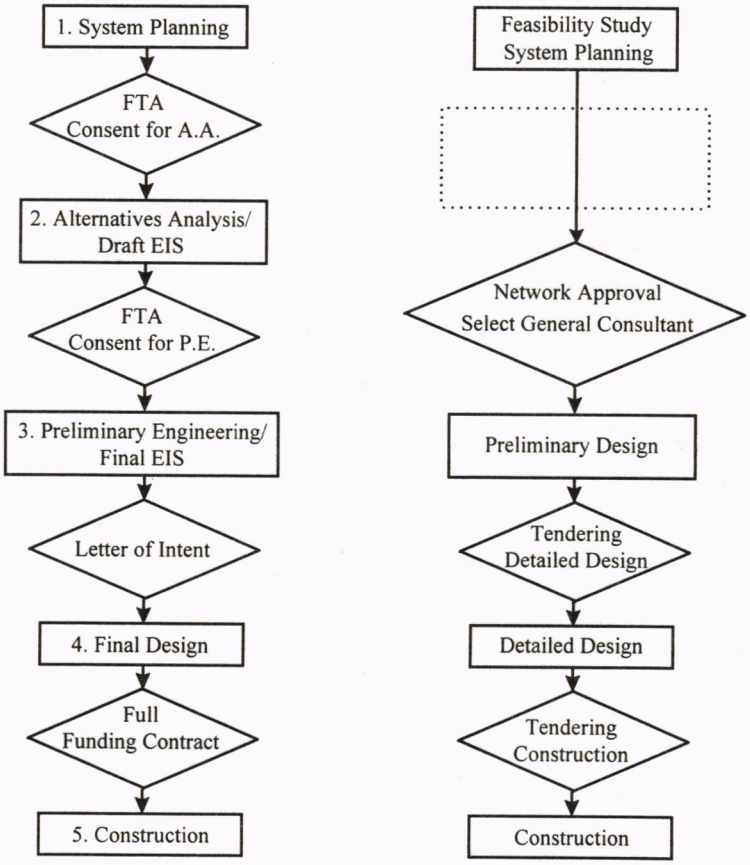

Figure 1 Design Procedure of the FTA and that of in Domestic

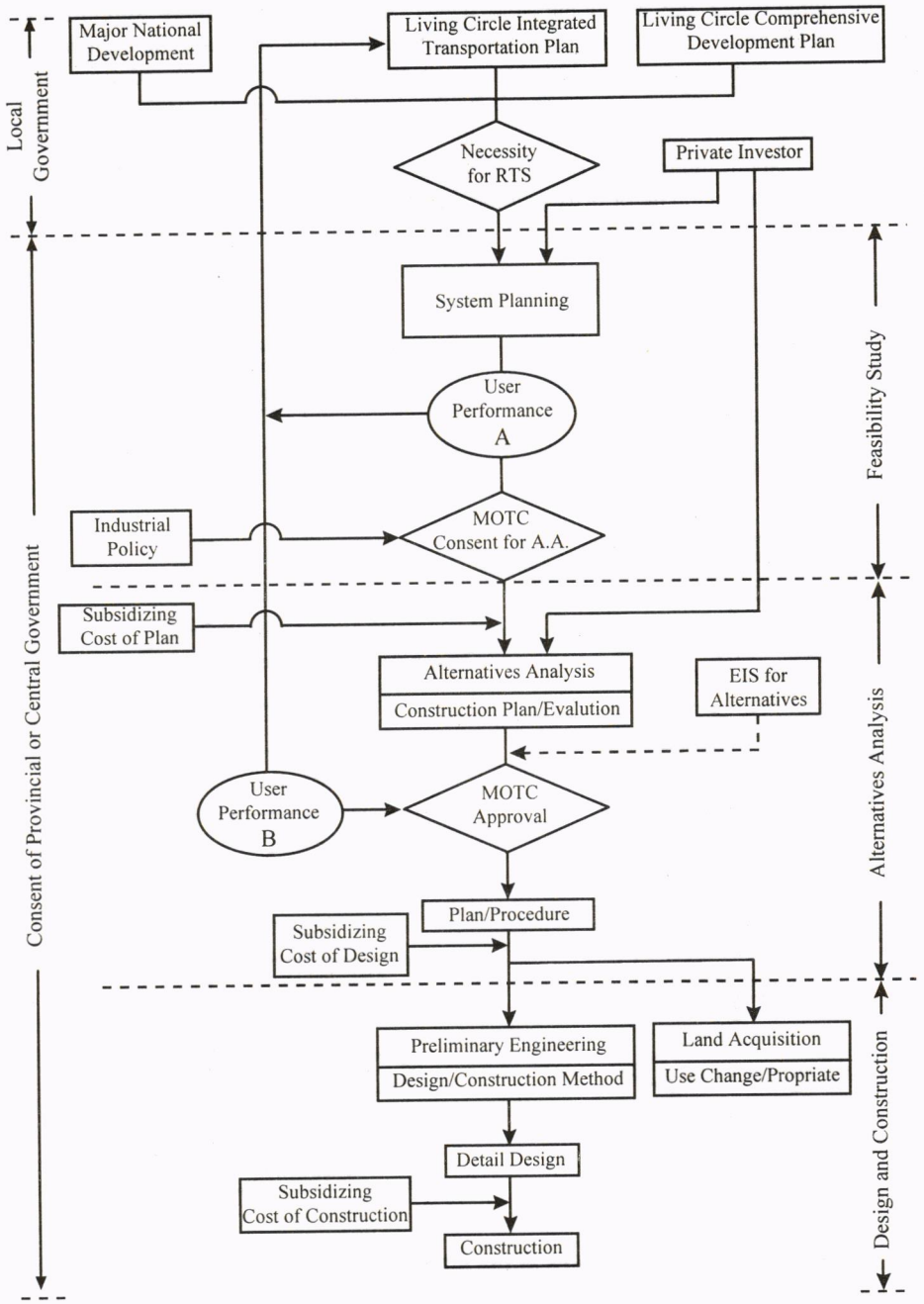

Figure 2 Suggested Procedures for RTS Planning and Examination

MRTS performance lies in a very complex ridership forecast. Its cost can hardly be estimated before the engineering design is completed to a certain extent. However, the current law combines the examination of such cost-benefit analysis and approved network together, many problems therefore emerge. The way of rectification should be applying the roughly estimated value as a threshold to make a quick judgment, then proceeds with the next examination step on the ones that pass the test. Descriptions of the test indices are as follows:

A. Threshold for User Performance A: Defined as additional transportation cost caused by each additional rider of the transit line(network).

- Estimation Formula

$$\frac{\text{Annualized Construction Cost + Annual Operation Cost}}{\text{Number of RTS Trips}}$$

- The U.S. FTA uses a figure of US$6/trip for screening. The lower the transportation cost per trip the worthier it is to be built.

B. Threshold for User Performance B: Defined as the user's benefit.

- Estimation Formula

$$\frac{\text{Annual Travel Time Saving - (Annualized Construction Cost + Annual Operation Cost)}}{\text{Number of RTS Trips}}$$

- The U.S. FTA uses a figure of US$8/trip for screening. The higher the user's benefit the worthier it is to be built.

5. CLOSING REMARKS

Rapid Transit System has not yet been widely operated in Taiwan. As a result, local communities might put too much expectations on its development and overestimate its capability to create urban wealth as well as underestimate its costs both for construction and long-term operation. Many citizen leaders enthusiastically competing for RTS construction fundings, which results in pressures on the governments. The content of the plan and the quality of the decision are therefore degraded. The objective of this paper is to evaluate the planning experiences so far. Preliminary suggestions on possible procedure and the relative meaning of threshold value are made.