

System Dynamics Model of the Tokyo Subway System

Takahiro Kojima Senshu University

Yutaka Takahashi Gakushuin University

Kinya Machida Surugadai University

Teiichi Igarashi Teito Rapid Transit Authority

Abstract

Tokyo and the surrounding region support a huge population. The resulting large number of people who commute to the city centre has necessitated the ongoing construction and maintenance of a vast railway network. Currently transportation from terminal stations to the city centre is provided mainly by Japan Railways' Yamanote Line, the TRTA and the Tokyo Public Subway. Thirteen lines, including those in only partial operation, comprise the subway system in the downtown area. The TRTA forms the heart of the system, with nine lines, while the Tokyo Public Subway is relatively small in scale, with only four lines. The current research project provides the TRTA material for use in developing future management directions by data provided by the TRTA. This paper covers the first phase of this research.

Introduction

The Teito Rapid Transit Authority (TRTA) was established on July 4, 1941. Today, it is the largest subway operator in Tokyo, with a network of eight lines covering a distance of 162.2 km. It provides a fast, safe and convenient mode of transport for the six million people that travel on its lines everyday. This figure represents 80% of subway passengers.

Number of Employees: 10,772

Number of Stations: 148 (20 above ground)

Number of cars: 2,313

Ginza Line: 222

Marunouchi Line: 338

Hibiya Line: 336

Tozai Line: 480

Chiyoda Line: 369

Yurakucho Line: 360

Hanzomon Line: 176

Namboku Line: 32

Average passenger load per day : 5,920,000

Average ticket revenue per day : 647 million (yen)

Average distance traveled per passenger : 7.4 km

Parallel Program

The history of subways in Tokyo began back in 1927 when a 2.2 km stretch of line was opened from Asakusa to Ueno. This private company enterprise was not only the first subway in Japan, but in Asia. The entire line, now known as the Ginza Line, was completed in 1939, extending 14.3 km, from Asakusa to Shibuya.

In 1941, when TRTA was founded, the transportation system in Tokyo consisted of the Ginza line, the Japan National Railway's (JNR) Yamanote and Chuo lines, suburban trains operated by private companies and municipally run a streetcar network. As economic activity increased and the population grew, streetcars could no longer cope with the city's transportation needs. Buses and taxis began to crowd the roads, calling for a re-examination of urban transit operations.

As public demand for a coordinated transportation system increased, Reorganization of Land Transportation Undertakings Law was passed in 1938. As a result of this law, TRTA was established and assigned to construct subways in Tokyo and the surrounding area.

There are at currently two subway operators in the Tokyo area, the Teito Rapid Transit Authority (TRTA) and the Transportation Bureau of the Tokyo Metropolitan Government (TBTMG), TBTMG began operating lines in 1960 and has constructed four lines to date. Together these operators run an impressive 12-line mass transit network, that is receiving increasing recognition as one of the world's most developed subway systems.

Capital

In the early years, TRTA was financed by both the National and Local Government and private business. However, in 1952, TRTA eliminated its private capital to receive additional government funding. It has been financed by the National Government and the Tokyo Metropolitan Government ever since.

<As of March 1993>

Capital:	¥58.1 billion
National Government:	¥31 billion (53.4%)
Tokyo Metropolitan Government:	¥27.1 billion (46.6%)

Revenues and Expenditures

Year	1990	1991	1992	1993*
Revenues	254.1	273.0	286.7	338.5
Expenditures	249.0	269.7	286.5	341.9

*cf 1993 profit and Loss statement

Construction of New Lines

TRTA must apply to the Minister of Transportation for a license to construct new lines. The Minister then turns to the Transportation Policy Deliberation Council. This Council acts as an advisory organ to the Minister regarding the formulation of basic policies with the aim of establishing a comprehensive transportation system.

In July 1985, the Council submitted Transport Policy Report No.7. This report calls for the establishment of a 13-line rapid transit railway network in Tokyo by the year 2000. The railway network is characterized by its plan to efficiently connect the constantly growing suburban housing areas to the central business districts .

The flow chart below illustrates the procedure for authorizing rapid transit network plans based on the Metropolitan Plan Act.

Construction Methods

Of the eight subway lines operated by TRTA, seven were constructed by the Authority between 1951 and the present day. This period has seen remarkable progress in tunnel construction technology worldwide. Japan, in particular, has played a major role in the development of such in high-density areas. Construction methods employed by TRTA have been Cut-and-Over Method (1950 to 1985) and Shield Method (since 1985).

Through-Services

The subways were initially planned to replace the streetcar network, and passengers traveling into the center of Tokyo from the suburbs had to change trains at the terminal stations. However, as the number of passengers increased, these stations became more and more congested. An idea put forward to solve this problem was to create through-services with JNR and private railway lines.

The first subway line to provide through-services was the Hibiya line. This line was opened just before the Tokyo Olympic Games in August 1964 and operates through-services with the Tobu Isesaki line and the Tokyu Toyoko line. The Ginza and Marunouchi lines, the first of the twelve subway lines to be built, do not provide through-services due to differences in current collector methods and track gauges. However, seven lines have been connected to JNR and private suburban lines at twelve points. With the expansion of Tokyo's boundaries, the subways' through-service operation has increased in distance. They now extend to some 50 km from the city center.

RESULT :

1. From the standpoint of the passengers traveling into the city center from the suburbs,

Parallel Program

the inconvenience of changing trains was eliminated and service thereby improved.

2. Through-services provided the answer to the private railways efforts to gain access to central Tokyo.

3. Huge investments were required to build new subway lines in the city center. The through-services would guarantee a fairly large passenger demand for the subway from the very start.

Greater Tokyo

With more and more people squeezing into the suburbs, Tokyo continues to grow. According to the 1990 census, some 8 million people live within the city limits, a figure that has not significantly changed since 1960. However, in the same 30 years the population inside a 50 km radius from the city center has swelled from 15.5 million to 28.6 million.

According to a 1990 transportation census, the number of people in the Tokyo metropolitan area commuting to work and school by public transport was approximately 9.5 million a day. This is an increase of 1.4 million (17 %) when compared to the previous census (1985). As much as 30 % of this volume is concentrated in just one hour during the commuter peak period.

According to this census, the average distance traveled by commuters to work and school is 26 km and the average travel time is 68 minutes. Specially noteworthy is the huge daily inflow of passengers from Saitama and Chiba prefectures, numbering 960,000 and 810,000, respectively, a trend which is conspicuously increasing.

TRTA is dedicated to expanding and improving its network. Since 1955, the subway system in Tokyo has expanded more than 10 times in total track length and approximately 17 fold in passenger volume.

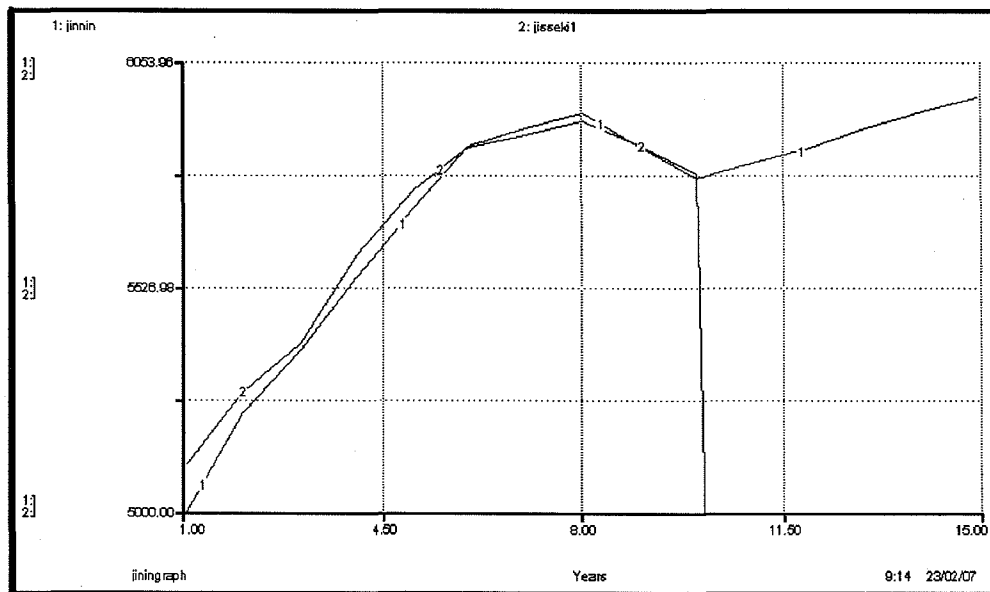
Conclusion

Our work on the model of the TRTA is currently in the early stage. At present, it predicts the change in passenger load resulting from various factors and accompanying change in TRTA revenues and the shift in passenger load and change in revenues resulting from the opening of new lines. Our first step in creating the model was to develop a sub model that would predict the passenger load.

In the past, we tried several times to reflect statistical data in the SD model. We were unsuccessful because the model was structurally dependent on the initial value. Recent advances in SD model development tools, however, have now made it possible to reflect statistical data.

Figure 1 displays data on past and predicted passenger load. The number 1 indicates the value predicted by SD model simulation. The number 2 indicates actual result data is from table function. The actual result data is from only the first 10 periods after the beginning of the simulation. Beyond that only predicted values are shown. There a good match between the predicted value and the actual value. The delay functions and smooth functions were used arrive at the predicted value. However, the table function, which directly reflects the prediction, was not used.

Figure 1.



References

- 1) Teito Rapid Transit Authority " '93 TRTA Hand Book"
- 2) Kameyama, S. Kojima, T. Uchino, A. Machida, K. " Accounting Measurement and Methodological Characteristics of Accounting Dynamics" Milling, P. M. Zahn, E. O. (Eds.) 1987 Spring-Verlag "Computer-Based Management of Complex Systems" pp. 111-118
- 3) Kameyama, S. Kojima, T. Uchino, A. Machida, K. " The Feedback of Accounting Dynamics " Saeed, K. Andersen, D. F. " Proceedings of the 1991 International conference of the System Dynamics Conference" pp. 738-743

Appendix

Profit and Loss Statement

(From April 1, 1993 to March 31, 1994) (Million yen)

Ordinary Profit and Loss

(Operating Revenues and Expenses)

I	Railway		
	Operating income	263,813	
	Operating expenses	218,776	
	Operating profit		45,037
II	Operating profit from related businesses		
	Operating income	3,221	
	Operating expenses	2,445	
	Operating profit from related businesses		776
	Operating profit from all businesses		45,813
	(Non-operating profit)		
III	Non-operating income		3,198
IV	Non-operating expenses		
	Interest expenses	53,059	
	Others	1,526	54,585
	Ordinary profit		-5,574
	Extraordinary profit and loss		
V	Special profit		
	Subsidies	62,874	
	Others	5,405	68,280
VI	Special loss		
	Loss due to reduced value of subsidiaries	60,954	
	Other	5,200	66,154
	Gross profit		-3,448
	Corporate tax refund		203
	Profit for the period		-3,651
	Surplus at the beginning of the period		0
	Undisposed profit for the period		3,651