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An Empirical Analysis of Forecasting Light Rail Transit (LRT) Demand According to Realization of Land Development Projects for Residence in Korea

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***Abstract*:** *Recently, the discussions for construction of Light Rail Transit (LRT) have actively been discussed in Korea. But LRT construction requires a significant financial support, so cautious approach and review is needed. It has been observed that there are much difficulty in operating LRT. Many reports stated that over-demand forecasting is one of the biggest factors contributing to financial hardships. Future development plans and projects are uncertain, so there are a lot of changes, cancellations and delays in the course of promoting the construction projects. If development plans and projects are reflected without considering volatility of development projects, over-demand forecasting will be inevitable results in future.*

The purpose of this study is to confirm an empirical connection on LRT demand according to realization of land development projects for residence. The analysis of 4 cities cases was carried out to examine the before-and-after comparisons using trip generation model. The findings revealed that the actual results showed the percentage of trip generation low due to cancellations or changes the project, delays for moving new houses. This means that over-demand forecasting could affect estimation of railroad demand excessively in fact. In the future, it is necessary to revise guidelines concerning the feasibility of controversial big-budget projects such as LRT projects.

Keywords: *Light Rail Transit, Demand Forecasting, Trip Generation Model, Trip Generation, Feasibility*

1. Introduction

Recently, the construction of light-rail-transit(LRT) actively has been conducted in Korea due to the improvement of environmental problems and public transportation systems. As these projects take enormous cost, careful review is required. However, the side effect in promotion and management of LRT projects is showed because they have been promoted by the political engagement as the image enhancement and political interest in the Korean cities.

Many reports state that the over-demand forecasting is one of the big factors contributing to financial hardships. In LRT project, future increases to the population are reflected in demand forecasting. According to the national guideline about the transport demand forecasting, land-development-project (LDP) for residence after the approval of working plan is reflected to the future transport demand. Existing national validity-evaluations (VEs) and preliminary-feasibility-studies (PFSs) are applied with the counterproposal considering construction delay and occupation ratio. However, these are gone inconsistently.

The purpose of this paper is to analyze the demand forecasting according to the realization of LDPs for residence in driven LRT projects. In order to achieve the purpose, this paper reviews how much the original demand forecasting is realized actually, in case of 4 LRT project such as Yongin LRT.

In this paper, the basis of moment is in 2012, and the spacial range is set up with LDPs which are reflected to the forecasting transport demand of 4 LRT projects. First, this research grasps the land conditions of

development project reflected in the demand forecasting under the starting LRT planning and realizing these projects. Furthermore, the changes of demand are examined on the basis of both the land development planning at beginning LRT project and the land construction results at nowadays to confirm how these future development plans effect on the demand forecasting of LRT projects. Through this process, trip generation models applied in VEs of the LRT projects are equally adopted in order to reflect the recent LDPs.

2. Review of Related Literatures

2.1. Related Laws and Guidelines

In Korea, VE applies to the *Guidelines of Evaluating Public Transport Investment Project*, made along *National Transport System Efficiency Act*. Also, in PFSs, the selection criteria and research method are in the *Guidelines of Preliminary Feasibility Studies*.

The *Guidelines of Evaluating Public Transport Investment Project* presents that LDP after the completion of working plan must reflect in VE. However, the clear criteria about the potential of pre-sale and the consideration of occupation ratio are not stated. The *Guidelines of Preliminary Feasibility Studies* also shows that the reflection of LDP needs the discretion in the application of occupation ratio, net inflow ratio, and trip-generation-rate. The clear criteria about occupation ratio are not in the guideline, however.

2.2. Reviewing Reflection Method of LDP in PFSs

After 2007, 25 PFSs out of 28 PFSs about the transportation reflect the LDPs. Before 2009, most PFSs have 100 percent of designed population when LDP is completed, but now, the application of the occupation ratio or the review by scenario is being tried. However, the occupation ratio or scenario is reflected differently following analyst's decisions, rather than clear standard.

3. Case Analysis of Reflecting LDP used in LRT Demand Forecasting

3.1. Summary of 4 LRT Projects

Figure 1 shows site of LRT project reviewed in this paper. Yongin, Uijeongbu, and Gimhae LRT are promoted by private investment, and Daegu LRT is driven by public investment. Length of LRT line is 10.6~24.0km, and there are 15~30 stations in LRT. In 2012, Uijeongbu and Gimhae LRT are running, and Yongin LRT runs at 2013, and Daegu LRT will open at 2015.

TABLE I: Summary of LRT analyzed in this paper

Classification	Yongin LRT	Gimhae LRT	Uijeongbu LRT	Daegu LRT
Length of lines(km)	18.404	23.455	10.588	23.95
No. of station	16	21	15	30
Opening	Apr., 2013	Sep., 2011	Jul., 2012	May, 2015

Source: each LRT operation or construction agency

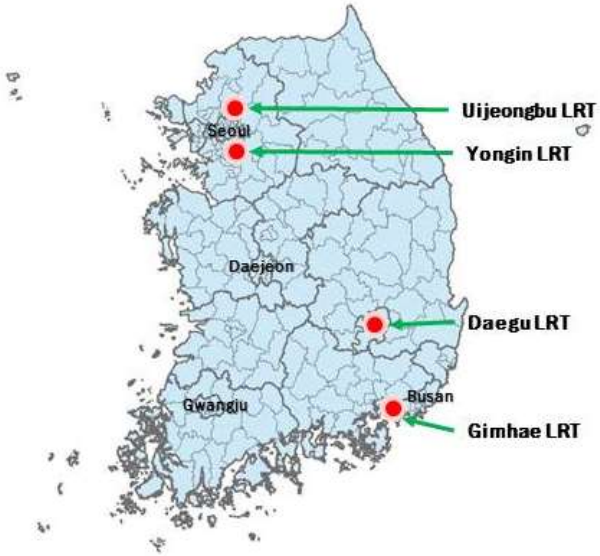

Fig. 1: Location of 4 LRTs

3.2. Present Conditions of LDP Around 4 LRT Projects

When 4 LRT projects are started, 5~12 LDPs are included in the transport demand forecasting. However, in 2012, most LDPs are delayed or do not begin yet or canceled. Therefore, the designed population of LDPs is changed lower than when LRT project is started. Occupation ratio of LDPs showed in LRT demand forecasting is also low about 42.43%~85.85%.

TABLE II: Comparison of completion year and designed population in each LDP included in LRT project

LRT project	No. of LDP	Changes of LDP		Year of completion[1)]		Max. period of moving (year)	Designed population[2)] (pop)			Occupation ratio[2)] (%)
		Canceled	Delayed	Planed	Actual		Starting LRT project	Current	Contrast by(%)	
Yongin	15	3	5	00~04	01~12	3	346,342	246,516	71.2	69.9
Gimhae	13	1	4	99~05	98~11	15	254,388	220,818	86.8	70.7
Uijeongbu	5	-	1	02~13	01~	8	92,850	103,591	111.6	85.9
Daegu	12	3	7	04~10	03~	4	61,802	50,458	71.2	42.4

Source: each regional government office including each LDP sites
Year of completion=In Oct. 2012
Designed population, Occupation ratio= In Dec. 2012

4. Empirical Analysis of LRT Demand Forecasting Result

4.1. Appling Method of Trip Generation Model by Each LRT Project

The purpose of this paper shows how the transport demand changes according to the reflection of LDP, thus trip generation model equally applies each PFS of LRT project. Moreover, trip generation flow is estimated by applying both the planning LRT project and current socio-economic indicators.

3 LRT projects including Yongin, Gimhae, and Uijeongbu estimate the trip generation flow by using the regression model.

In Yongin LRT project, the trip generation flow is calculated by trip purposes, and each model includes the number of population, students, and employees as the independent variables.

Eq. 1 shows the trip generation model applied in Yongin LRT project. In the equation, i means each trip purpose, and y is the trip generation flow. P is population, LS is living student, LE is living employee, ES is expropriated student, and EE denotes expropriated employee.

$$y_i = \alpha_i + \beta_{1i}P + \beta_{2i}LS + \beta_{3i}ES + \beta_{4i}LE + \beta_{5i}EE \quad (1)$$

In the Gimhae LRT project, the trip generation flow is estimated by Eq. 2. In the Eq. 2, parameters β_1 and β_2 are calculated separately by Busan-metropolitan-city and Gimhae-city, and final trip generation flow is revised by using corrected parameter (γ). In Eq.2, P is the number of population and the E is number of employees.

$$y = (\beta_1 P + \beta_2 E) \times \gamma \quad (2)$$

In Uijeongbu, the trip generation model is divided by commute and business purpose. Also, the separated commuting trip model is applied in residencial and residential-commercial mixed-use areas. The trip generation flow by purpose is estimated by using population and inhabitants more than elementary grade(Eq.3). P is population, SP means inhabitants more than elementary grade, and C_k denotes revising parameter of the trip generation flow in k district.

$$y_k = \beta_1 P \times C_k \quad \text{(Commute)}, \;\; y_k = \beta_2 SP \times C_k \quad \text{(Business)} \quad (3)$$

Parameters applied in 3 LRT project's trip generation model is below.

TABLE III: Parameters of each LRT project by variables

Yongin LRT		α	β_1	β_2	β_3	β_4	β_5
Trip purpose	School	-8.0203	-	0.9465	-	-	-
	Commute	-10.0462	-	-	-	0.8892	-
	Return home	-17.5652	-	-	0.9372	-	1.2346
	Business	-1.6893	-	-	-	-0.0327	0.1458
	Etc.	-14.9518	0.2555	-	-	-	-

Gimhae LRT			β_1	β_2	γ
Region	Gimhae city	City downtown	0.6789	3.0373	1.0345
		Rural	1.0819	0.6518	1.0556
	Busan metropolitan city		0.8810	2.4825	0.9638

Uijeongbu LRT			β_1	β_2
Trip purpose	Commute	Residential	0.1498	-
		Mixed	0.1802	-
	Business		-	0.4793

The trip generation model of Daegu LRT project is estimated by applying the trip-generation-rates of each LDP district (Eq. 4). The general function of trip generation model is below. y is trip generation flow, and a_i is trip-generation-rates of i LDP district.

$$y = a_i \times P \quad (4)$$

4.2. Estimation Result of Trip Generation Model

For the forecasting trip generation flow, socio-economic indicators are assumed from designed population, reflected in planning LRT project and adjusted in 2012. The trip generation flow of all LDPs by each LRT project is calculated by using Eq.1~4, applied each estimated socio-economic indicators. Estimated LDP's all socio-economic indicators and the trip generation flow by each LRT project are below. In most LRT projects, the estimated trip generation flow which is reflected by the 2012's socio-economic indicators is lower 13.4~28.8% than one reflected in planning LRT project.

TABLE IV: Estimation result of socio-economic indicators and trip generation flow by LRT project

LRT project	No. of LDP	Socio-economic indicators (No.)			Trip generation flow (trips)			
		Classification	Starting LRT project	Current	Purpose	Starting LRT project	Current	Contrast by(%)
Yongin	15	Population	346,642	246,516	School	56,446	40,160	71.1
		Living students	59,755	42,532	Commute	189,259	134,689	71.2
		Expropriated students	69,530	49,489	Return home	152,760	108,694	71.2
		Living employees	213,000	151,607	Business	3,396	2,414	71.1
		Expropriated employees	71,151	50,644	Etc.	88,281	62,805	71.1
					All purpose	490,142	348,762	71.2
Gimhae	13	Population	254,388	220,818	All purpose	384,575	332,950	86.6
		Employees	81,686	72,607				
Uijeongbu	5	Population	92,850	103,591	Commute	34,957	38,359	109.7
		Inhabitants (≥elementary grade)	82,382	91,910	Business	5,749	6,450	112.2
					All purpose	40,706	44,809	110.1
Daegu	12	Population	61,802	50,458	All purpose	87,758	71,546	81.8

4.3. Analysis of Trip Generation Flows Considering Occupation Ratio and Construction Delays

Considering actual completion year and occupation ratio by each LDP site, the trip generation flow is calculated below (Eq. 5), using the current estimated trip generation flow. Where i is each LDP site, T_b is the trip generation flow applying current estimated socio-economic indicators, T_a is the trip generation flow considering actual completion year and occupation ratio and OR is occupation ratio.

$$T_{ai} = T_{bi} \times OR \tag{5}$$

Considering actual completion year and occupation ratio, the result of trip generation flows using Eq. 5 is below. In all the LRT projects, the real occupation ratio is 69.9 %(Yongin), 70.7%(Gimhae), 85.6%(Uijeongbu), and 42.8%('Daegu'). Thus, through the occupation ratio, each actual trip generation flow rate is 68.7%(Yongin: 490,142trips→336,529trips), 69.6%(Gimhae: 384,575trips→267,666trips), 82.4%(Uijeongbu: 28,152trips→ 23,184trips), and 42.8%(Daegu: 87,758trips→37,570trips), compared with the LRT project of the starting year.

TABLE V: Estimation result of net trip generation flow by LRT project, considering actual completion year and occupation ratio

LRT project	No. of LDP	Changes of LDP		Max. period of moving (year)	Occupation ratio (%)	Net trip generation flow(trip)		Contrast by(%)
		Canceled	Delayed			Starting LRT project	Considering actual completion year and occupation ratio	
Yongin	15	3	5	3	69.9	490,142	336,529	68.7
Gimhae	13	1	4	15	70.7	384,575	267,666	69.6
Uijeongbu	5	-	1	8	85.9	28,152*	23,184	82.4
Daegu	12	3	7	4	42.4	87,758	37,570	42.8

* 2 LDPs are completed in 2013, thus net trip generation flow of 2 LDPs is excluded in this.

As we saw above, the occupation ratio is low and trip generation flow is also lower than estimated one when LRT project is started, because LDP's designed population is changed after starting LRT project, and some delays or cancellations are in LDP. As a result, the over-reflection of LDP is one of the large factors that LRT trip generation forecasting causes over-estimation.

5. Conclusions

3 LRTs out of 4 is opened recently, and problems of fiscal burden are embossed because of the over demand forecasting. One reason of that is perhaps due to the issue of reflection of LDP. Most LDPs are changed, delayed or canceled because of the project's uncertainty or lack of budget. If LDP is reflected without realistic attention, it is not surprising that over demand forecasting is showed.

This paper examined the change of transport demand on the basis of both the LDP reflected when LRT project is started and the result of LDP to inspect how LDP affects LRT demand. The designed indices of LDP is changed lower than started LRT project, and the delay of construction or occupancy is occurred, therefore, the occupation ratio is remained as 42.8~82.4%. Because of the lower occupation ratio, the transport demand when LRT project is started is also predicted two times higher than actuality.

In order to prevent this problem, the realistic reflection of LDP is necessary. Particularly, the related guidelines which need to apply the occupantion ratio or construction delay have to be revised so that the transport demand is not over-estimated.

This paper examined only some LDP reflected 4 LRT projects, but in the most LDP, there are various types of LDP depending on scale, form, and regional characteristics. Therefore, additional research is needed about the standard of LDP reflection in the transport demand forecasting.

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