Cost–Benefit Analysis of Developing a Light Rail Transit and Feeder Bus System in Utsunomiya City Considering the Change in Population Distribution

Tetsuji SATO a, Takuya SASAKI b, Mika CHIKUMA c

a Department of Civil and Environmental Engineering, Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino-shi, Chiba, 275-0016, Japan
b Tokyo Metropolitan Government, 2-1-8 Kuramae, Taito-ku, Tokyo, 111-0051, Japan
c
E-mail: tetsuji.sato@it-chiba.ac.jp
E-mail: Takuya_1_Sasaki@member.metro.tokyo.jp
E-mail: s1224216XE@s.chibakoudai.jp

Abstract: Utsunomiya City in Japan is planning a new light rail transit (LRT) system between the downtown area and Haga Town which is located just outside Utsunomiya. It will be open to the public in 2019. Development of the LRT may have a large impact on the population distribution in the city in the future. In this paper, a model that can evaluate the impact of developing an LRT and the feeder bus system (FBS) on population distribution in the city is developed. With the model, estimations of population distribution from 2015 to 2040 in the cases with and without LRT and FBS and the cost benefit analysis are conducted. As a result, it is indicated that developing an LRT and FBS will increase the population in the areas along the LRT and FBS lines, and developing feeder buses in addition to LRT increases the cost–benefit ratio compared to developing only LRT.

Keywords: Light Rail Transit, Feeder bus, Population Distribution, Location Equilibrium, Cost–Benefit Analysis

1. INTRODUCTION

In the 1990s, light rail transit (LRT) systems were introduced in many cities of Europe, USA, and Asia with the aim of reducing the environmental burden imposed by cars. In Japan, these systems were first introduced in Kumamoto City in 1997 and in Hiroshima City in 1999 using the existing tram tracks, and were later extended to other cities with pre-existing tramways. In Toyama, a city with a population of about 420,000, the development of LRT is a key part of development centered on public transport and pedestrian access. In 2006, a route connecting the north exit of Toyama station with Toyama Port (Iwasehama Beach) in the north part of the city was opened. Moreover, in 2009, a circular route running from the south exit of Toyama station to the city center was opened. These routes are expected to be linked by 2020. The city of Utsunomiya in Tochigi Prefecture, which has a population of approximately 510,000, plans to open a new LRT line with a length of approximately 15 km in 2019. This line will run from JR (Japan Railways) Utsunomiya station to Haga-Takanezawa Industrial Park in Haga Town, which is located on the east side of Utsunomiya City. Moreover, there is a plan to extend this line to Tobu Utsunomiya station in the downtown area. On the other hand, many cities in the world have opted to develop a bus rapid transit (BRT) system, which has lower maintenance...
costs than an LRT system and enables easier route changes. Within Japan, such systems have been introduced in Hitachi City, Ibaraki Prefecture, which deemed its railway system as unprofitable, and in Kesennuma City and Rikuzentakata City, which use the introduction of BRT as a provisional arrangement to compensate for the damage caused to the railways by the Great East Japan Earthquake in 2011. In Tokyo, a BRT system is being planned to connect the venue of the 2020 Tokyo Olympics at the coastal sub-center with the downtown area.

Previous studies on the development of LRT include Doi et al. (2011); Mizokami et al. (2007); and Mochizuki et al. (2007). Doi et al. conducted a questionnaire-based survey and compared the visitors to the center of Toyama City who had used the newly established LRT and those who had arrived by automobile. Their results suggested that over a long duration, the expense of downtown visitors via LRT was greater than that of visitors via automobile. Mizokami et al. conducted a cost–benefit analysis for the conversion of Kumamoto Electric Railway into an LRT system and demonstrated the profitability of the project. Mochizuki et al. surveyed the residents of Toyama before and after the development of Toyama Light Rail using a user origin–destination (OD) survey. In particular, they investigated the impact of the development of Toyama Light Rail on the increase in the number of trips made by vulnerable people such as the elderly. However, none of these studies analyzed the impact of LRT systems on the long-term population distribution, and no cost–benefit analyses have been performed taking this particular factor into account. Papers which analyze actual changes in population trends or population distribution in a city before and after introduction of new LRT lines include Sakamoto et al. (2015) and Javier (2010). Sakamoto et al. examined change in urban population before and after introduction of LRT in 27 cities in Europe. They also analyzed change in the population of areas along the LRT line in detail for four cities in France and Spain. Javier analyzed the impacts of development of LRT in Manila on land price, land use, and population along the line.

To analyze the change in urban population distribution over time because of transport improvements, land-use microsimulation models have been developed that are more accurate than conventional land-use/traffic models. UrbanSim (2002), a typical microsimulation model, is used by many city authorities to evaluate the impact of transportation measures on land use. However, it has been pointed out that such land-use microsimulation models fail to take into consideration the behavior of land suppliers or the equilibrium in the land market.

The computable urban economic (CUE) model is an equilibrium model of the land market; however, it is a static model that cannot analyze the time-series impact of urban measurements. It is considered that consideration of the time-series impact is very important in evaluating the development of public transport, because the introduction of public transport such as LRT will derive gradual residential land development and migration, which affect the benefit in each year. In addition, none of the existing CUE models take into account the segmentation of the housing market. Because it is apparent that each type of housing (detached house, rental apartment with one bedroom, rental apartment with three bedrooms, etc.) has a different market, it is necessary to consider the segmentation of the housing market to calculate the accurate benefit of urban transport development.

In this study, we developed a method for estimating the impact of urban transport developments, e.g., LRT systems, on the future population distribution in a city and the cost–benefit analysis based on the results. We used the developed method to estimate the population distribution from 2020 to 2040 in Utsunomiya City, Tochigi Prefecture, Japan, and performed a cost–benefit analysis of the LRT system and additional feeder bus network. Three development scenarios are investigated: new LRT without feeder buses, new LRT with feeder buses, and no LRT or feeder buses.
2. DEVELOPMENT OF POPULATION DISTRIBUTION ESTIMATION MODEL

2.1 Outline of the Model

The model estimates the population of each zone in five-year periods based on the cohort method, taking into account natural variation, population inflows to the target city, outward migration from the target city, and movement within the city. Population movement within the city is assumed to be determined by the demand for residential property for each type of residence, selection of household-movement destination areas, the supply of residential land (or residential floor) by absentee landlord, and supply and demand equilibrium (price adjustment). The model proposed in this study is therefore an extension of the general CUE model considering the time-series change of the market and housing type. The general CUE model covers both the residential area market and the business area market; however, because it is considered that the influence of LRT development on the business market is relatively weak, the model in this study deals only with the residential market.

Figure 1 shows the flow chart of the population distribution estimation model.

Figure 1. Flow chart of the population distribution estimation model

2.2 Relocation and Residential Land / Floor Demand Behavior of Household

It is assumed that households can be roughly classified into two categories: households with the intention of moving and those without. Households with the intention of moving to each housing type will select the area to move to depending on the utility level, which is affected by the convenience of using the transport system, etc.

The probability of choosing the destination area by each household can be expressed as
a logit model and is derived using Equation (3) after solving the maximization problem using Equations (1) and (2):

\[
E^t_i = \max_{\theta_k} \sum_i \left( P^t_{ik} U^t_{ik} - \frac{1}{\theta_k} P^t_{ik} \ln P^t_{ik} \right)
\]

\[
\text{s.t. } \sum_i P^t_{ik} = 1
\]

\[
P^t_{ik} = \frac{\exp(\theta_k \cdot U^t_{ik})}{\sum \exp(\theta_k \cdot U^t_{ik})}
\]

where, 
\(E\): expected maximum utility level of household in choosing the area, and 
\(P^t_{ik}\): choice probability of zone \(i\) of the household with the intention of moving to housing type \(k\) in year \(t\).

The utility level is expressed by Equations (4) and (5):

\[
U^t_{ik} = V^t_{ik} + \tau_k,
\]

\[
V^t_{ik} = a_k \cdot \ln(ZA^t_{ik}) + b_k \cdot \ln(ZB^t_{ik}) + c_k \cdot \ln(ZC^t_{ik})
\]

\[
+ d_k \cdot \ln(ZD^t_{ik}) + e_k \cdot \ln(r^t_{ik})
\]

where, 
\(U\): utility of household, 
\(V\): partial utility, 
\(\tau\): other factors of utility, 
\(ZA\): required time from home to the nearest railway / LRT station or bus stop, 
\(ZB\): required time from the nearest railway / LRT station or bus stop to the central station, 
\(ZC, ZD\): other factors which indicate living environment, and 
\(r\): land rent or room rent.

The area demand for residential land (or residential floor in the case of multifamily housing) per household is expressed by Equation (6), which is the same as the equation in the general CUE model. The residential demand in each zone is determined by multiplying the number of households moving into a zone by the area demand for land (or floor) per household; it is given by Equations (6)–(8):

\[
L^t_{ik} = \frac{h_k}{r^t_{ik}} \cdot y_i^t
\]

\[
N^t_{ik} = P^t_{ik} \cdot N^t_{ik}
\]

\[
D^t_{ik} = L^t_{ik} \cdot N^t_{ik}
\]

where, 
\(L\): area demand for residential land or floor per household, 
\(y\): household income, 
\(N_i\): the number of households moving into zone \(i\), 
\(N_T\): total number of households intending to move, and
2.3 Residential Land / Floor Supply Behavior of Absentee Landlords

The supply behavior of absentee landlords is given by Equation (11), which solves the profit maximization problem defined in Equations (9) and (10). Equation (11) expresses the increase in supply as rents increase:

\[
\pi'_t = \max_{S'_t} \left[ r'_t S'_t - C(S'_t) \right] \\
\text{s.t. } C(S'_t) = -\frac{\sigma_t}{r'_t} S'_t \ln \left( 1 - \frac{S'_t}{S'_t} \right) \\
S'_t = \left( 1 - \frac{\sigma_t}{r'_t} \right) \bar{S}'_t 
\]

where,
- \( \pi \): profit of absentee landlord,
- \( C \): supply cost of housing land or floor,
- \( S \): supply area of housing land or floor,
- \( r \): land rent or room rent, and
- \( \bar{S} \): available area for housing land or floor.

2.4 Supply and Demand Equilibrium of Residential Land / Floor

The supply and demand equilibrium of residential land (or floor) by housing type in each zone is expressed by Equation (12):

\[
D'_t(r) = S'_t(r). 
\]

3. ANALYSIS OF IMPACT OF DEVELOPMENT OF LRT IN UTSUNOMIYA CITY

3.1 Target Area and Unit Area

The target cities are Utsunomiya and Haga Town in Tochigi Prefecture, where a new LRT system is to be opened in 2019. The analyzed section of the LRT system is a 15-km route from JR Utsunomiya station to Haga-Takanezawa Industrial Park (Haga Town), which is the development priority. The target areas are regions of the urbanization promotion area in Utsunomiya City and Haga Town in which the available area and the number of households were not zero in 2010. The target area is divided into zones of 500m x 500m using the world geodetic system, with a total of 456 meshes constituting the target area.

Figure 2 shows the target area and unit area (zone division) of the analysis.
3.2 Questionnaire Surveys for the Residents

Two questionnaire surveys for the residents in the target area are conducted to determine the explanatory variables \((Z_C, Z_D)\) and estimate the parameters by housing type in Equation (5), in addition to being aware of the intent of the inhabitants to move (proportion of inhabitants willing to move). In the case of owned detached houses, the “\(r\)” in Equation (5) represents the rental value. However, because the respondents found it difficult to predict the rent and because land price is defined to be equal to the rent divided by the interest rate, the land prices are used as proxy variables for rents in the questionnaires and in Equation (5).

In the first-stage survey (the pre-questionnaire survey), the respondents were asked to answer using the Likert scale (very important, important, neither, not very important, unimportant) about how much emphasis they place on factors such as accessibility to the workplace or the nearest railway station from home in choosing relocation region, and the permissible level for each factor, in addition to personal attributes and desired housing type. Table 1 shows the components of the survey. Fieldwork was conducted on September 29, 2015 by the postal survey and distribution at JR Utsunomiya station. A total of 1000 questionnaires were distributed, out of which 188 were completed (a response rate of 18.8%).

Figure 3 shows the results for the current housing type and the housing type desired at the new address. Approximately 60% of respondents currently occupied an owned detached house, and about 50% were seeking an owned detached house in the new area; the percentage of people seeking a rental apartment increased.

The aggregated results for the degree of importance given to each factor are shown in Figure 4. In more than 80% of the responses, “the accessibility to grocery stores” received the highest “very important” and “important” rating. “Low risk of damage from river flooding” and “low risk of damage from landslides” were also rated as important, suggesting a strong interest in disaster avoidance. The correlation between these two latter results was very high (0.96). From the result, \(Z_C, Z_D\) in Equation (5) are determined to “the required time to the nearest grocery store from home” which represents “the accessibility to grocery stores”, “estimated maximum flood depth” which expresses “low risk of damage from river flooding”, respectively.
Table 1. Components of the pre-questionnaire survey

1) Personal attributes
- Age / Sex / Occupation / Number of household members
- Frequency of use of private car / bus / train
- Required time and mode of transportation from home to
  the nearest railway station, the nearest bus stop, the commuting destination
- Housing type / Duration of residence
- Living expenses per month

2) Desired housing type after relocation
- Housing type
- Land area / Floor area

3) Importance in choosing relocation region and the permissible level
- Accessibility to
  the workplace, the nearest railway station / bus stop,
  JR Utsunomiya station / Tobu Utsunomiya station, the local government,
  the nearest interchange / national highway / grocery store / convenience store
  / shopping mall / banking facility / general hospital / park,
  school for children, the doctor in practice, the house of parents / relatives
- Activity of the local community
- Low risk of damage from landslides / river flooding
- Cheapness of land price / rent

![Current housing type and desired housing type after relocation](image)

In the second-stage survey (the profile questionnaire survey), we first asked the respondents about their intention to move within Utsunomiya City in 1–5 years. To estimate the parameters of Equation (5), we combined the levels of each explanatory variable and repeated the question about the most desirable of the three conditions using profiles four times. Profiles were created by limiting the housing type to owned detached houses and rental apartments (30 m², 50 m², 70 m², or 90 m²) because these housing types accounted for approximately 80% of the desired housing type as shown in Figure 3. Three levels of each factor were created based on the results of the pre-survey, and these levels were assigned to an orthogonal table of type L12 (35). An example profile is shown in Figure 5.
Figure 4. Answer ratio regarding importance of for each item

<table>
<thead>
<tr>
<th>Item</th>
<th>a)</th>
<th>b)</th>
<th>c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The commuting destination</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest railway station</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest bus stop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The JR Utsunomiya station</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest interchange</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest national highway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest grocery store</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest convenience store</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest shopping mall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The local government office</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The doctor in practice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest general hospital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest hospital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nearest park</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The house of parents / relatives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity of the local community</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low risk from landslides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low risk from river flooding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheapness of land price / rent</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Example of profile questionnaire (owned detached house)
The questionnaires were posted to areas to the east, west, north, and south that could be reached within 10, 20, and 30 min from JR Utsunomiya station via automobile. The questionnaires were distributed on November 19, 2015 and September 29, 2016. We distributed 2400 questionnaires during the first survey and 1200 during the second (a total of 3600 questionnaires). A total of 289 questionnaires were returned in the first wave and 77 in the second, resulting in an overall response rate of 10.2%.

The rate of respondents with the intention of moving in five years is shown in Figure 6. Approximately 16% of the respondents in the 20s/30s age group were considering moving within Utsunomiya in five years; this figure was about 6% in the 40s/50s age group and zero in the 60s and above age group. All the respondents intending to move were currently living in rental apartments, and approximately 60% wished to move to owned detached houses.

<table>
<thead>
<tr>
<th>Age</th>
<th>Rate of respondents with the intention of moving in five years</th>
</tr>
</thead>
<tbody>
<tr>
<td>20s / 30s</td>
<td>16.28%</td>
</tr>
<tr>
<td>40s / 50s</td>
<td>5.88%</td>
</tr>
<tr>
<td>60s / over 60s</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Current housing type</th>
<th>Desired housing type after relocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20s / 30s</td>
<td>Owned detached house</td>
</tr>
<tr>
<td>20s / 30s</td>
<td>Owned detached house</td>
<td>0.00%</td>
</tr>
<tr>
<td>40s / 50s</td>
<td>Owned detached house</td>
<td>0.00%</td>
</tr>
<tr>
<td>60s / over 60s</td>
<td>Owned detached house</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Figure 6. Rate of respondents with the intention of moving in five years

3.3 Parameter Setting

The parameters of Equation (5) are estimated with the maximum likelihood method by two age groups (20s/30s and 40s/50s) using the individual data derived from the profile questionnaire survey. The parameter estimation results of the utility function are shown in Table 2. Regarding the rental apartments, due to the limited number of samples, we used all the data between 30 and 90 m² for the estimation.

<table>
<thead>
<tr>
<th>Age</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>Log-likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned</td>
<td>20s / 30s</td>
<td>−0.164 (−0.52)</td>
<td>−0.628 (−1.52*)</td>
<td>−1.250 (−3.65**)</td>
<td>−1.581 (−7.78**)</td>
<td>−1.469 (−2.66**)</td>
</tr>
<tr>
<td>detached</td>
<td>40s / 50s</td>
<td>−0.174 (−0.81)</td>
<td>−1.434 (−12.15**)</td>
<td>−1.444 (−4.14**)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>house</td>
<td>20s / 30s</td>
<td>−0.165 (−0.71)</td>
<td>−0.426 (−1.12)</td>
<td>−0.446 (−1.70*)</td>
<td>−0.897 (−6.18**)</td>
<td>−1.856 (−4.30**)</td>
</tr>
<tr>
<td>Rental</td>
<td>40s / 50s</td>
<td>−0.006 (−0.02)</td>
<td>−0.300 (−0.64)</td>
<td>−0.515 (−1.37*)</td>
<td>−0.933 (−3.31**)</td>
<td>−3.467 (−4.30**)</td>
</tr>
<tr>
<td>apartment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The figures in parentheses indicate the t value.

** indicates significance at 1% level and * indicates significance at 10% level.
The residential land (floor) demand function parameter $h$ in Equation (6) is set such that the mean residential land (floor) demand for 2010 and the mean residential land (floor) area are equal. In addition, the logit parameter $\theta$ of Equation (3) is set to one. Table 3 shows the parameters other than those included in Equation (5).

<table>
<thead>
<tr>
<th>Table 3. Parameter setting of Equations (6) and (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>$h$</td>
</tr>
<tr>
<td>$\theta$</td>
</tr>
</tbody>
</table>

### 3.4 Setting of Basic Data in Each Zone

To estimate the future population distribution using the developed model, it is necessary to set the initial year data (2010) such as land price, rent, the time required for reaching each facility, and estimated maximum flood depth for each zone. As for the land price, we estimate the land price function shown as Equation (13) using the published land price data by the Ministry of Land, Infrastructure, Transport and Tourism, and calculate the land price of each zone with the estimated function. The estimation results of the land price function are shown in Table 4:

$$ r = \alpha + \beta Z_1 + \gamma Z_2 + \delta Z_3 $$

where,

- $Z_1$: dummy variable for the nearest railway station,
- $Z_2$: road distance to the nearest railway station, and
- $Z_3$: floor-area ratio.

<table>
<thead>
<tr>
<th>Table 4. Parameter estimation results of the land price function</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>29,253.04</td>
</tr>
<tr>
<td>(4.11**)</td>
</tr>
</tbody>
</table>

Note: The figures in parentheses indicate the t value.

** indicates significance at 1% level.

The rent (per floor area) is calculated by dividing the mean rent (per floor area) of Utsunomiya City by the mean land price and multiplying it with the land price of each mesh. The mean rent is calculated with SUMO (http://suumo.jp/), and the mean land price is obtained from the published land price data in 2015.

The time required for $ZA$ and $ZC$ in Equation (5) is calculated by dividing the distance on the road by 80 (m/min) assuming travel time by foot. The distance on the road is obtained by multiplying the direct distance from the center of each mesh by 1.1666. The time required from the nearest railway station to JR Utsunomiya station is calculated with NAVITIME (https://www.navitime.co.jp/). The time required from the nearest bus stop to JR Utsunomiya station is calculated through the timetable search of Kanto Transportation, Inc. and “Utsunomiya.guide” (https://utsunomiya.guide/). The estimated maximum flood depth is set for four segments (0, 0.5, 1.0, and 2.0 m) based on the Utsunomiya City flood hazard map.
For the income in Equation (6), the municipality data from the municipal taxation (Ministry of Internal Affairs and Communications) are used.

The residential land (floor) supply area in Equation (11) is calculated by multiplying the residential land (floor) demand per household with the number of households. The available area is set to the sum of agricultural lands and building sites (multiplied with the vacancy rate 16.3%) which can be turned into residential land for owned detached houses. For rental apartments, the floor-area ratio for each use zoning is multiplied with this value.

3.5 Estimation of Population Distribution in the Future

Using the parameters of each function and the basic data for each zone in Equations (3)–(8), (11), and (12), the future time-series population distribution can be estimated. The ratio of households with the intention of moving in five years is 4.2% based on the profile survey. The estimated population distribution in 2020 and 2040 is shown in Figure 7. Overall, the population is expected to be slightly higher in 2020 compared to 2010; it is expected to decrease by 2040.

3.6 Impact of Developing LRT and Feeder Buses on Population Distribution in the Future

Herein, assuming that the LRT system will be completed in 2020, we estimate the future population distribution. The LRT stations to be built are determined based on the Utsunomiya City official website. The required time from each LRT station to JR Utsunomiya station is calculated based on the time from the beginning to the end points, the ratio between the distance from the beginning to the end points, and the distance from the JR Utsunomiya station to each LRT station. The establishment of new LRT stations reduces the time required to reach the JR Utsunomiya station in 14 meshes. However, this is a small travel-time reduction compared to the time required at present by taking a bus. Therefore, in this study,
we estimate the future population distribution in three cases: new LRT without feeder buses, new LRT with feeder buses which connect the LRT stations to nearby meshes, and no LRT or feeder buses.

Figure 8 shows the rate of population change comparing cases with and without new LRT in 2030 and 2040. Figure 9 shows the rate of change when there are new LRT and feeder buses. The rate of change is calculated by “(population with development minus population without development) / population without development”. These figures confirm that with only new LRT, the population increases only around some stations along the LRT line such as Haga and eastern Utsunomiya City. On the other hand, if feeder buses are added, some population increase will take place along the route of the feeder buses as well.
3.7 Cost Benefit Analysis

We perform a cost–benefit analysis for developing LRT and feeder buses. The benefit for each household for each year can be obtained for each zone with the utility function, Equation (14), according to the definition of EV (equivalent variation):

\[ EV_{ik}^t = \frac{V_{ik,with}^t - V_{ik,out}^t}{V_{ik,out}^t} N_i^t \]  

(14)

where,

- \( EV \): equivalent variation (benefit per household),
- \( with \): with development, and
- \( out \): without development.

The benefit for each zone for each year is obtained by multiplying the benefit for each household with the number of households. The benefit for the whole target area is the summation of the benefit for each zone. In addition, the user’s benefit except for the benefit in using LRT or feeder buses from home to JR Utsunomiya station, the supplier’s benefit, the traffic safety benefit, and the environmental benefit published by Utsunomiya City Government are taken into account. For the cost for each year, we take into consideration the expense for constructing LRT, the expense for building bus stops for feeder buses, and the operational cost for LRT and feeder buses. For the construction cost of LRT, we use the published values by Utsunomiya City Government. The expense for building bus stops and the operational costs of LRT and feeder buses are set based on the route distance and the cost per km designed by the Ministry of Land, Infrastructure, Transport and Tourism. The time frame for developing LRT and feeder buses is assumed to be three years, from 2017 to 2019, and the expense is evenly divided for each year.

The cost–benefit analysis is implemented using 2016 as the base year with a discount rate of 4% (rate of time preference per year) and the analysis period of 40 years from the opening of LRT (until 2059). The analytical results are shown in Table 5.

**Table 5. Results of cost benefit analysis of development of LRT and feeder buses**

<table>
<thead>
<tr>
<th></th>
<th>Benefit (million yen)</th>
<th>Cost (million yen)</th>
<th>Net Present Value (million yen)</th>
<th>Cost–Benefit Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of LRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>without feeder buses</td>
<td>60,719.7</td>
<td>59,615.6</td>
<td>1,104.1</td>
<td>1.0185</td>
</tr>
<tr>
<td>Development of LRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with feeder buses</td>
<td>69,440.0</td>
<td>63,617.6</td>
<td>5,822.4</td>
<td>1.0915</td>
</tr>
</tbody>
</table>

4. CONCLUSION

In this study, we build a model for estimating the impact of developing public transportation in a city on the future population distribution. For Utsunomiya and Haga (Tochigi), where LRT is being developed, we analyze the impact of developing only LRT and LRT plus feeder
buses on the future population distribution. Furthermore, we perform a cost–benefit analysis of the LRT development plan and the LRT plus feeder buses plan based on the estimated future population distribution. The results of the analysis show that the installation of LRT and feeder buses in Utsunomiya City increases the population along the LRT and feeder bus lines, and developing feeder buses in addition to LRT increases the cost–benefit ratio compared to developing only LRT.

The future challenge includes the effect analysis of a measure in accordance with “the network-type compact city” as noted in the Utsunomiya City master plan. The network-type compact city is a sustainable developing city concept which is realized by formulating a compact city center and some compact area centers and constructing the public transportation network and the road networks connecting these centers.

REFERENCES


