A Study on Sustainable Urban Management Strategy in Japanese Local Cities: Through the Research on LRT Project in Toyama City

Masanori Muto
markun@sfc.keio.ac.jp

Graduate School of Media and Governance,
Keio University, Japan

Abstract

This study aims at finding out the effective method to achieve the sustainability of Japanese local cities from the viewpoint of urban form control. Being faced with the proceeding of hollowing-out phenomena of city center and mortalization with lower use of public transportation, many Japanese local autonomies have begun to take counter-measures called Compact City policy as the solution. In this regard, the exact impact assessment of urban form reform in terms of sustainability is urgently necessary. This study consists of three stages. 1st Stage: Fact-Finding. Problem finding of local autonomies and the evaluation of Compact City policies are done through comparative analysis. 2nd Stage: Case Study. Toyama City is typical Japanese local autonomy suffering from hollowing-out and mortalization. This study evaluates the effect of Light-Rail Transit (LRT) project of this city through analyzing the process of residents’ modal shift. 3rd Stage: Policy Simulation. Based on the outcome of 1st and 2nd stage, the future sustainability of Toyama City is simulated. By comparing some scenario simulation including LRT and Compact City, the most sustainable controlling method of urban form is calculated. In this paper, 1st Stage (Fact-Finding) and the overview of 2nd Stage (Case Study) are disserted as major issues.

Keywords: LRT, Modal Shift, Sustainable Urban Form, Compact City, Local City
1. Introduction

1.1. Background

Japanese local autonomies are thought to be faced with the problem of their sustainability in terms of environmental, economical, social, administrative and financial. Three main categorized upcoming phenomenon in Japanese local autonomies may endanger the sustainability; 1) **Demographic Change**: Depopulation combined with rapid aging and low-birthrate in Japan endangers the sustainability of entire Japan in terms of number of population as fundamental resources to support the nation power (especially decrease of people in productive-age). In November 2005, Japan finally turned into depopulation period, the demographic stage where crude natural decrease outweighs crude natural increase. As that trend continues (See Figure 1), it is expected that Japan will seriously suffer from labor shortage and economic decline. In addition to that, rapid expansion of aging population worsens the situation. Because demographic structure is the basis of all urban activities, how to deal with these new upcoming changes now has become the urgent issue for Japanese cities. 2) **Spatial Change**: Suburban sprawl in accordance with motorization endangers the environmental and social sustainability of Japanese cities. As density of cities becomes low, and modal shift to cars from public transport goes, with the decline of users, many public transport systems especially in local cities have become defunct. It not only imposes the environmental impact on cities, but also devastates the unique transit means for elders or teenagers who cannot use vehicles. Such socially unacceptable condition would continue if present spatial changes continue. 3) **Financial Change**: Followed by the depopulation and the reduction of allocation tax from the central government, most Japanese autonomies are faced with financial crisis (Fukuda, 2003). How to invest effectively with the limited budget is big issue in terms of administrative sustainability.

These three main issues are especially remarkable in Japanese local cities (See Figure 2. This shows the mechanism how the sustainability decline as I explained above). Hence in order to tackle them and to achieve the sustainability, many Japanese local autonomies have begun to take counter-measures called “Compact City” policy as the solution. In this regard, in order to examine and consolidate the theoretical basis of “Compact City” in Japanese local cities, the exact impact assessment of urban form reform in terms of sustainability is urgently necessary.
1.2. Objectives

This study aims to examine the impacts of Compact City policy and public transportation renovation project as methods to achieve the sustainability of Japanese local cities. 1) *Public Transportation Renovation Project*: Renovation of public transportation like construction of new station of improvement of service level et al. may contribute to the enhancement of sustainability by triggering the modal shift from vehicles to public transport or by activating the trips to city center. This study examines its impact on person trips or trip patterns (in this study, LRT project is the case), leading to the exact quantification of service improvement project in terms of sustainability.

2) *Compact City Policy*: Compactification of the city, making the city centralized dense form, may enhance the sustainability of local cities by shortening the trip distance or even leading to the modal shift to public transport or walking & bicycles. This study examines its costs and benefits in terms of sustainability. 3) *Public Transport & Compactification*: Combination of public transport renovation and compactification may maximize the enhancement of sustainability. This study simulates the impact of policy combination, revealing the most effective method to achieve the sustainability of Japanese local cities. (Figure 3. shows the model how Public Transport and Compactification raise the sustainability.)

The output of this study offers the theoretical background of sustainable urban form for local administrations that are discussing how to manage the cities to make them sustainable.

![Figure 1: Demographic Simulation of Japan to Year 2050 (Data: National Institute of Population and Social Security Research, 2002)](image-url)
Figure 2: Local Autonomy Sustainability Model

Figure 3: Public Transport & Compactification Model
2. Literature Review

2.1. Effect of High-Density

Previous compact city-related studies have found out that “moderate density” of city may maximize its sustainability. For instance, a study on density of world large cities shows that about 200-people/ha density maximizes the sustainability in terms of environment or quality of life (Hijioka, 2005). Figure 4. shows the correlation between density and the SO\textsubscript{x} and Co\textsubscript{2}. As the density approaches the 200-people/ha, the pollution level declines. In one hand, if the density goes to high over 200-people/ha, rather pollution level worsens. It seems from this study, moderately compact urban form is the most appropriate to maximize the sustainability. A similar study that features Japanese cities shows similar results, for example outlining the correlation between density and the use of gasoline for vehicles (Kaido, 2001). In this regard, the effect of density itself is verified to a certain level.

![Figure 4: Density - Pollution Correlation (Hijioka, 2005)](image)

2.2. Need for Revealing Compactification Dynamism

Although compact city itself is acknowledged as one of the ideal forms for sustainability, the dynamics of compactification, how and to what extent people’s behaviour change by movement, is still unrevealed. For example, a study on simulation of compactification in local cities indicates, a single action of compactification might not have significant effect on modal shift of residents who have been moved to the city center from suburban area (Shimaoka, 2005). Because previous suburban car users have continued to drive their own vehicles, whether they can change their behaviour simply by moving to center area is unknown. Because this dynamism of behaviour modification by compactification isn’t revealed, present compact city theory must rely on some assumption in this dynamism. However without inputting this dynamism into compactification mechanism, proper assessment of compact city policy is impossible. In this sense, analysis for this behaviour modification is necessary to properly quantify the impact of compactification.
Hence in order to achieve the sustainability of cities, further action to accelerate the modal shift or to induce the behaviour modification is considered to be necessary. However such compound action with compactification isn’t discussed or analyzed deeply in previous studies. These two points should be focused on as critical issues for further development of compact city theory (See Figure 5).

![Figure 5: Flow of Compactification Compound Policy Dynamism](image)

3. Research Methods

3.1. Target: Case Study on LRT Project in Toyama City

This study researches on Toyama City as one of the typical Japanese cities that is struggling with problems concerning sustainability (Located in Toyama Prefecture along Japan Sea, Hokuriku Region, northwestern part of Japan. See Figure 6 for the location.).

Toyama City adopts the concept of “Compact City” as the solution for difficulties threatening its sustainability (Toyama City, 2006). In this context, Toyama City has launched the project that renovates the existing train line to the new Light-Rail Transit (LRT) in order to expand the public transport users and to activate the trips to the city center (Further information is noted in the
4th Chapter.). Through the case study on this policy and project, potentials of these methods for achieving sustainability in Japanese local autonomies shall be examined.

3.2. Data Sampling & Analysis: Impact Assessment of LRT

In order to implement the impact assessment of LRT project, questionnaire regarding the behaviour modification of residents shall be done. Collected data from the questionnaire shall be analyzed on the PRO (previous rail line) / POST (LRT) basis. Because it is expected that renovation of public transport, improvement of service level, can enhance the attractiveness of public transport, the framework for this analysis shall be as follows;

\[
T = T(U) \quad (1)
\]
\[
U = U(S, C) \quad (2)
\]

where T: Trips by Public Transport
U: Utility for Public Transport
S: Service Level of Public Transport
C: Characteristic Attribute of People

Based on these models for the determination of trips, PRO/POST individual data shall be collected. These data shall be put into the next equation;

\[
\Delta T = T(\Delta U(\Delta S, C)) \quad (3)
\]

By comparing the residents’ trip behaviour changes in accordance with the improvement of service level, the process or determinants of behaviour modification shall be analyzed.
Main variables adopted in S and C functions are as follows;

\[ S = (F, D, SP, B, CF) \] \hspace{1cm} (4)

where:
- \( F \): Transportation Fee
- \( D \): Distance to the Station
- \( SP \): Speed of the Transport
- \( B \): Degree of Bareerfree
- \( CF \): Comfortability of Ride

\[ C = (A, O, E, V) \] \hspace{1cm} (5)

where:
- \( A \): Age
- \( O \): Occupation
- \( E \): Earnings
- \( V \): Ownership of Vehicles

Regarding S variables, data of PRO/POST are collected individually in the questionnaire.

3.3. Compactification Simulation

Simulation of the compactification in Toyama City is done by moving the residents to the city center from the suburban area. By compounding the assessed LRT impact in Toyama City, behaviour modification based on the service level improvement and characteristic attribute of residents shall be examined quantatively (Also see Figure 5). Four policy simulations shall be done in this study; 1) No Project (assuming even LRT project), 2) LRT Project Only (Status Quo), 3) Compactification Only, 4) LRT + Compactification. Each policy shall be simulated in terms of maximizing the sustainability;

\[ ST = ST (ES, ECS, SS, AS) \rightarrow \text{Maximize} \] \hspace{1cm} (6)

where:
- \( ST \): Sustainability (Total)
- \( ES \): Environmental Sustainability
- \( ECS \): Economical Sustainability
- \( SS \): Social Sustainability
- \( AS \): Administrative & Financial Sustainability

This sustainability index (ST) shall be used as determinant to clarify which policy would maximize the sustainability and therefore should be adopted.
4. Discussion of Findings

4.1. Analysis of Toyama City

Toyama City is the typical Japanese local city suffering from hollowing-out phenomina of the city center and the motorization. Figure 7 shows the accumulation and distribution of the population. Although residents in Toyama City are accumulated around train lines, much population is assumulated along the arterial roads in suburban area at the same time followed by motorization. Moreover when it comes to the trend of urban density, it has been observed lower density is sprawling to the suburban area (See Figure 8). In accordance with these sprawling phenomina, modal shift to cars (motorization) and the decline of public transportation users are obviously observed (See Figure 9). Under the condition of future depopulation of Toyama City (See Figure 10, if this trend continues, the sustainability of Toyama City is sure to decline (See also Figure 2: Local Autonomy Sustainability Model).
4.2. Identification of LRT Project

Toyama City has launched the project that renovates the existing JR train line (called “Toyama-Kou Line”) to the new LRT line (named “Portram”) in order to expand the public transport users and to activate the trips to the city center in the context of Compact City. The previous line “Toyama-Kou Line” became defunct on Feb.28.2006, and the new LRT line “Portram” has opened on Apr.29.2006 (See Figure 11).

Figure 11: Previous “Toyama-Kou Line” (Left) and New LRT Line “Portram” (Right)

<table>
<thead>
<tr>
<th>Services</th>
<th>Toyama-Kou Line</th>
<th>Portram (LRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Train Frequency</td>
<td>1 train/30-60min</td>
<td>1 train/15m in.</td>
</tr>
<tr>
<td>2 First / Last Train</td>
<td>5 am / 9 pm</td>
<td>5 am / 11 pm</td>
</tr>
<tr>
<td>3 Stations</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>4 Cars</td>
<td>Normal Train Cars</td>
<td>Low-Floor Cars</td>
</tr>
</tbody>
</table>

Table 2: Improvement of Service Level (Data: Toyama Light Rail Co., Ltd., 2006)

Unique characteristics of LRT have been being focused on as a tool for reactivating public transport and inner city; 1) High Quality: High-speed, silent, and breerfree train cars are considered to enhance its attractiveness. 2) Low Cost: Comparatively lower cost for construction and maintenance plays a role. Taking advantage of these characteristics, in case of “Portram”, many service levels have been improved than previous line (See Table 2). Especially construction of new stations (See Figure 12) and elder-friendly characteristics are considered to play significant role to expand the scope of targeted public transport users.

Figure 12: 4 New Stations and their 500m Domains
4.3. Impact Analysis

Because the questionnaire of this research is now going on, latter two studies are still need to be developed. Hence it isn’t enough to analyze the impact and to draw the conclusion from the present data, though, some implications are acknowledged so far; 1) Expansion of Users: Compared to the train users of previous “Toyama-Kou Line”, its users of “Portram” has become larger from about 3400 ppl/day to 5500 ppl/day (See Table 3). The increase of attractiveness like shortened distance by new stations and high train frequency et.al. are considered to have played a role to expand the scope of new users. 2) Effect of Elder-Friendliness: Within the expanded number of users, increase of elder users is significant. Breer-free service level (low-floor cars, bareer-free stations, or shortened distance to stations) of LRT is considered to have played the role. It means in equation (3), in the function of \[ T = T (U (S, C)), \]

service level variables D and B (in equation (4)) and a characteristics function variable A (in equation (5)) works remarkably in this case. On this point, a research on Toyama Light Rail even reported the significant rides of wheel-chair users (Toyama Prefecture Koutsu Seisaku Kenkyu Group, 2006). From these data and facts, certain service level variable uniquely works on the certain characteristics variables, leading to the different effect on different kind of people who have different attributes. By clarifying these different mechanisms, determinants of behaviour modification for each categorized people can be identified. (Figure 13 shows the Distance → Trips regressions re-categorized by Age Characteristics as an example.) More appropriate and exact assessment of projects could be possible by inputing these mechanism into the behaviour modification model.

### Table 3: PRO/POST Users Number Comparison (Data: Toyama Pref. & Toyama City)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Average Users per 1 day (people)</td>
<td>3400</td>
<td>5500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Station Impact</th>
<th>Elders</th>
</tr>
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<tbody>
<tr>
<td>distance change</td>
<td>[ y = -0.2877x - 26.506 ] [ R^2 = 0.6435 ]</td>
<td>[ y = -0.2754x - 36.612 ] [ R^2 = 0.7362 ]</td>
</tr>
</tbody>
</table>

**Figure 13:** Normal Regression (Left) and Categorized Regression (Right)
5. Conclusions

In this paper, I mainly disserted the Fact Finding of Local Cities (especially Toyama City) and the overview of the Case Study and Policy Simulations in terms of sustainability. Mainly outputs have been acknowledged in this paper.

1) The problems of sustainability in Japanese local cities are modeled out.
2) The significance of dynamic mechanism of behaviour change in the context of compactification is clarified.
3) Impact assessment of LRT project distinguished by each service level variables and each resident's attributes are shown.

Although complete analysis of LRT project and Policy Simulations haven’t been implemented yet in this paper, because the positive impact of LRT and the behaviour modification distinguished by each resident’s attributes have been acknowledged so far, as the present research goes, these outputs are surely applied to the next stages. Especially the unique impacts of LRT on elders acknowledged in this paper are expected to be highlighted in terms of social sustainability where every people can keep the equal right to travel.

As all the mechanism in accordance with the public transport renovation (LRT project) are revealed, by inputting the mechanisms into the behaviour modification model, this study are to implement the policy simulations of compactification and transport innovation as the final stage of the study, offering the optimum urban form in Japanese local cities in terms of sustainability.
References


