How will Compact City Affect Me? : Urban Planning Simulation for Citizens

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Abstract

Depopulation is a serious problem in local cities of Japan, where urban management plan is in the need of revision to reflect the concept of compact city. However, there still remain major questions, such as how the compact city can be induced and whether it can bring a higher quality of life for citizens. In this research, we have developed an urban simulation tool for citizens as a web application named 'My City Forecast', which provides information about the future of their city to enhance their awareness and communication with urban planners. Through interviews to urban planning department of local authorities of 4 cities, it has turned out that there are demands for simple and comprehensible urban simulation tools. However, it has also proved that the principle of urban management differs from one city to another, and the tool needs improvement to respond to various needs.

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1. Introduction

1.1. Urban management for depopulating Japan

The approaching era of population decline is a serious problem to be concerned by Japanese urban planners, especially in local cities of Japan. National Institute of Population and Social Security Research forecast that total population will fall from 128 million to 97 million during 2010-2050. Therefore, conserving current urban structure, which are mainly the results of postwar urban sprawling, will lead to additional burdens on citizens' economies and increase of highly depopulated regions.

The idea of compact city is thought to be a breakthrough idea to decrease the effect of this problem. It enables one to decrease the public burden such as high infrastructure expense by population concentration in the central areas of cities. In previous studies including OECD report (OECD 2012), various advantages of the compact city have been proven, especially from perspectives of environment and efficient supply of infrastructure. However, there still remain major questions, such as how the compact city can be induced and whether it can bring a higher quality of life for citizens.

Sophisticated urban simulation models can support understanding these questions by predicting the long-term effects of alternative policies. There are readily available models that are aimed to be used in the decision making process of urban policies, such as land use-transportation model. However, most of these models require technical knowledge of statistics, GIS and spatial data analysis. In order to avoid creating a gap in the ability of local urban planners and citizens to systematically assess urban planning policies, development of a model accompanied with user-friendly interface is needed. Moreover, simple and easily operable assessment tool will enhance interactions that engage both planners and citizens in the decision making process.

1.2 Development of tools to understand your city

On the other hand, the number of tools that encourage citizens to understand and consider about their city's management is increasing. One of the important factors of this is the forwarding of open data movement. The release of the Open Data Charter by the G8 in 2013 gave a boost to the movement. According Seto and Sekimoto (2014), by August 2014, 38 local governments have opened some kind of urban data source, and the number is rapidly increasing to today.

Another important factor is the rapid improvement in data utilization technology. This includes technologies such as application development technologies and data visualization technologies. All kinds of data are made more understandable and accessible to anyone through Internet. Combining these technologies to open data, web applications are launched all over the world. For example, ’City Dashboard London’ (http://citydashboard.org/london/) visualizes real-time information of the city of London on dashboard and map to give the user a sweeping glance of what is going on in the city (Fig.1). Another example ’Where does my money go?’ (http://spending.jp) is a web application to visualize information about public spending (Fig.2). This application is a part of the OpenSpending project launched in 2011, which is to develop a global community driven platform for financial information open database.

1.3 Aim of research

Considering the needs and technological backgrounds to support them, the aim of our research is to develop a tool for citizens that shows information about the future of their city to enhance their awareness and communication with urban planners. We have designed and developed an urban simulation system for local cities in Japan that enables the citizens to understand how their living environment is going to change in the future up to 2040. The system is distributed as a web application for open access. Both the results of urban transition simulation with and without the concept of compact city will be shown through our interface, clarifying the effect of the concept. Our simulation model includes estimation process of population, location of urban facilities and administrative costs. The indicators used to summarize the simulation results are mainly in common with household indicators, with which the users can compare directly with their actual living.

Showing the alpha-version of our web application, we interviewed urban planners of 4 different local authorities, and obtained feedbacks. We will clarify our improvement plan for our tool regarding their comments, and sort through the merits and future issues.

The remainder of this paper is structured as follows. Section 2 explains the urban simulation tool we have developed as a web application. Next, section 3 presents the result of interview to the urban planners of local authority in 4 cities in Japan. Finally, section 4 concludes this research with improvement plans.

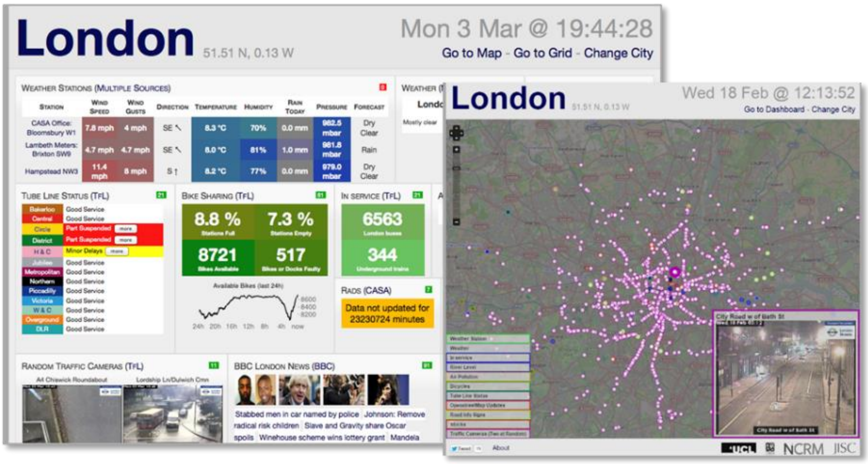

Fig.1 Real-time city information visualization: 'City Dashboard London' Interface

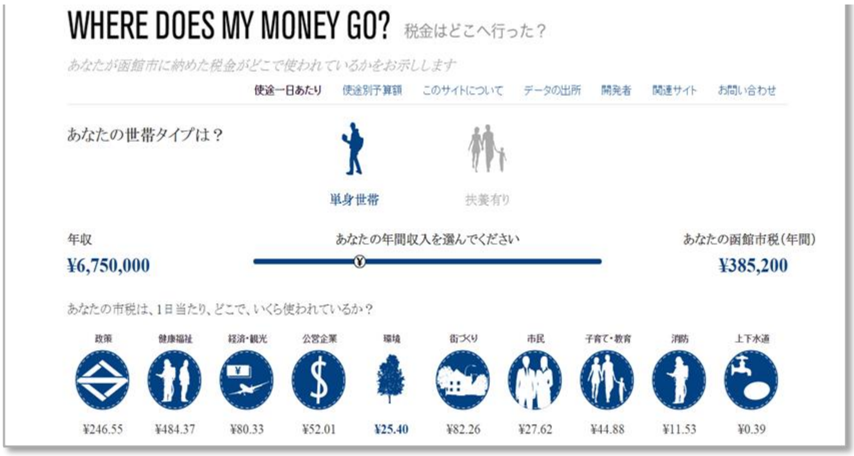

Fig.2 Public spending open data visualization: ' Where does my money go?'

2. Developing Web-App: 'My City Forecast'

We have developed the alpha-version of our urban simulation tool named 'My City Forecast'. In this section, the simulation system running in the background and the interface design of it is explained.

2.1 Simulation system

The output of this simulation system aims to show information of cities to citizens in intelligible manners. Generally, most of the citizens have low interest in the comprehensive plans for the whole area of their cities. What concerns them is the change in their living areas that could affect their quality of life (QOL), such as their neighboring facilities and environments.

For this reason, we decided to divide the whole city area into 1km2 squared small areas, and show the result of the simulation through 15 indicators shown in Table1 for each area. The indicators were selected referencing the research of living environment evaluation (Asami 2001) and QOL evaluation (Myers 1998), and can be categorized in 5 categories; basic population information, convenience of everyday life, green environment, safety and security, financial burden. Other indicators, such as hazard risk could be also important factor for living environment, but for this research, the indicators are limited to those that are likely to change within the change in social conditions.

Table 1. 15 indicators for urban simulation output

Category	Indicator
Basic population information	Total population of the area
	Elderly rate
	Youth rate
Convenience of everyday life (Access to daily-use facilities)	Access time to convenience stores
	Access time to supermarkets
	Access time to department stores / malls
	Access time to schools
	Access time to administrative facilities (libraries, city halls, community centers etc.)
	Access time to hospitals
	Access time to nursing institutes
	Access time to nursery schools
Green environment	Green covering ratio
	Access time to parks
Safety and security	Traffic accident risk
Financial burden	Administrative cost burden per person

The simulation flow for estimating these output indicators for every 5 years is shown in Fig.3. Both the urban transition simulation with and without the concept of compact city was done. The ‘without’ version will be referred to as ‘Business as usual’ (BAU) case in the following. Details of the conditions for each cases will be described in each model’s following explanation.

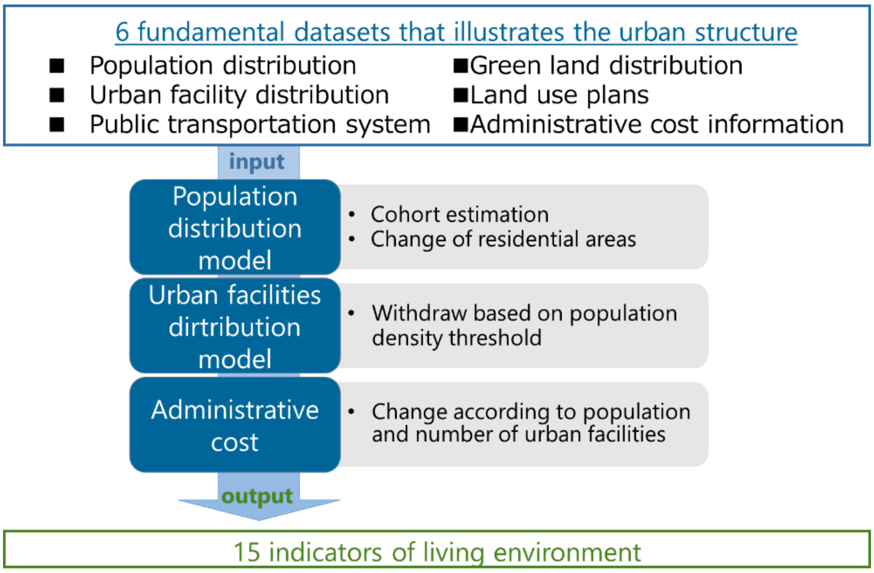

Fig.3 Flow of simulation

(1) Input data

As input data for this simulation, we have decided 6 fundamental datasets that well illustrates the urban structure of the city; population distribution, urban facility distribution, available public transportation system, green land distribution, land use plans, administrative cost information. The alpha-version was developed setting Mito-city, Ibaraki prefecture as a sample city, and the actual input datasets are listed in Table2. Datasets listed here are mainly datasets that are distributed by National organizations or private company, so that the tool can be adaptable to general cities in Japan.

(2) Population distribution model

The first step of the simulation is the population distribution estimation model. Here, from the population distribution of year t, we estimate that of year $t{+}5$ by applying cohort population estimation method and our hypothesis of change in people’s residential areas.

First, for each area i, cohort population P_i is estimated by the method developed by Nakanishi *et al.*(2011). Then, based on the household ratio to

Table 2. Input datasets for alpha-version sampling Mito city

Content	Name of dataset (year of publish)	Issuing organization
Population distribution	National population census (2005 & 2010)	Ministry of Internal Affairs and Communications
	Point data of buildings (2010)	ZENRIN CO. LTD.
Urban facility distribution	'Urban facilities' from Digital national land information (2008)	Ministry of Land, Infrastructure, Transport and Tourism
	Telepoint pack! (telephone book data)	ZENRIN CO. LTD.
Available public transportation system	'Railroads' from Digital national land information (2008)	Ministry of Land, Infrastructure, Transport and Tourism
Green land distribution	'Land use' from Digital national land information (2009)	Ministry of Land, Infrastructure, Transport and Tourism
Land use plans	'Land use' from Digital national land information (2009)	Ministry of Land, Infrastructure, Transport and Tourism
Administrative costs	Budget report (2015)	Mito city local authority

population α, we calculate the number of households, which could be interpreted as number of necessary housings in the area. Then, from the housing location point data with construction date information, we estimate the number of housings that do and do not require rebuilding. The remaining rate β of the households are decided from the approximate curve of remaining rate and construction date from Sakakibara *et al.* (2009). Among housings that require rebuilding, certain percentage γ of them are assumed to be renewed.

From the numbers of necessary, rebuilding and renewing housings, the number of additional housings can be calculated. For BAU case, all the renewing housing owners are assumed to stay in their present areas, and newly build housings will distribute all over the city area. The additional housing in area *i* of the year *t* will be obtained as $\Delta\mathrm{H}_{\mathrm{i}}^{t}$ from the equation below.

$$\Delta H_i^t = \alpha \cdot P_i^t - \beta \cdot H_i^t - \gamma \cdot U_t^i \quad (2.1)$$

H_i^t shows the present number of housings and U_t^i shows the number of rebuilding housings. On the other hand, for compact city concept case, with the assumption that citizens are cooperative to the plan of compactizing the residential area, the renewing owners and newly obtaining owners are to obtain their new housings in the urbanization promotion area. In this case, the additional housing will be calculated as

$$\Delta H_i^t = \alpha \cdot P_i^t - \beta \cdot H_i^t + \gamma \cdot U_t^i \quad (2.2)$$

and will be distributed among the areas that are included in the urbanization promotion area. In both cases, the additional housing demands were distributed to each areas to obtain the newly developed housings (NDC), based on Inohara (2014)'s approximate curve of building occupancy rate and its rate of increase.

Then, the population and number of housings in year $t+5$ are calculated as below.

$$\begin{aligned} &\text{BAU case: } H_i^{t+5} = NDC_i^t + \beta \cdot H_i^t + \gamma \cdot U_t^i \\ &\text{Compact city case: } H_i^{t+5} = NDC_i^t + \beta \cdot H_i^t \end{aligned} \quad (2.3)$$

$$POP_i^{t+5} = \frac{H_i^{t+5}}{H_i^t} POP_i^t \quad (2.4)$$

where NDC_i^t stands for newly developed housings and POP_i^t stands for total population in area *i* in year *t*. In order to maintain consistency with the population of the whole city, the total of each cohort population is adjusted to the estimation of National Institute of Population and Social Security Research.

At this point, basic population information and indicators that have high correlational relationship with population density, such as traffic accident risk, are calculated.

(3) Urban facilities distribution model

In this model, from the estimated distribution of population and facility distribution of the previous time step, we obtain the urban facility distribution. Each facilities in the previous time step is judged whether to be withdrawn or not according to the threshold of population density for each facility categories.

Most of the thresholds are obtained statistically from the population density around each facilities. For example, plot of the number of hospitals in an area and the average population density within 1.5km draws a quadratic curve as shown in Fig.4. As threshold for withdrawing of hospitals, the population density of where the number of hospitals becomes 0 is extracted.

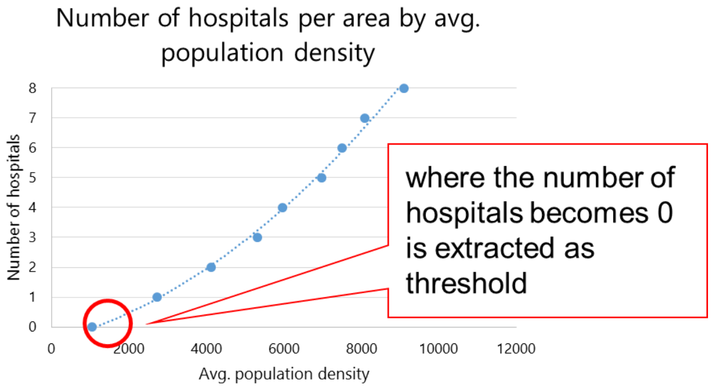

Fig.4 Example of obtaining threshold from the population density around hospitals

Between BAU case and compact city case, the target facility categories for withdraw is designated differently. The facility categories are divided into two groups, public facilities (schools, administrative facilities, hospitals, nursing institutes, nursery schools) and private facilities (convenience stores, super markets, department stores/malls). For BAU case, it is assumed that there will be no change in the public facilities, so only private facilities are the target of withdraw. For compact city case, it is assumed that public facilities are also withdrawn within the change of population density for urban management efficiency, and both groups of facilities are the target.

With the estimated facility distribution, accessing time for each facility from each area in the city is calculated. For simple processing, the accessing time is represented by the traveling time between the center point of target area and the closest area that the facility locates, by walk and by public transportation systems (for now, only trains).

(3) Administrative cost

Based on the local government's current open data of public spending for each areas in budget allocation, the administrative cost per citizen is estimated. The method of calculation is to suppose that some of the areas require more or less annual expenditure according to the social condition, such as population distribution and number of facilities. As shown for an example in Table3, we assign main influencing factors that will affect the expenditure cost to areas that are not likely to be constant. Assuming that expenditure cost for non-constant areas change within the rate of change in the main influencing factors, we calculate the sum of estimated costs and divide it with the total population.

Table 3. Example of public spending and assignment of main influencing factors

Areas	Cost (Yen)	Constant	Main influencing factors
Council	572778000	true	-
General affairs	7274040000	true	-
Public welfare	15914356000	false	Population of elderly
Sanitation	2046612000	false	Area of built-up areas
Labor	36329000	false	Total population
Agriculture	1792794000	true	-
Commerce and industry	857264000	true	-
Infrastructure	342299000	false	Area of built-up areas
Fire service	3682609000	false	Area of built-up areas
Education	985652000	false	Number of school facilities
Emergency restoration	1000	false	Area of built-up areas
Public bond	10808825000	true	-
Contingency funds	100000000	true	-

2.2 Interface design

Since all citizens are target users of this tool, the user interface must be simple and easily looked at so that the information it offers is comprehensible to many different age groups and properties. In order to enhance the effect on users to accept the information as things that are related to their own selves, the interface is designed to be interactive.

In addition, the tool has not only the role of providing information to citizens, but also the role of providing citizens the opportunity to voice their opinion about what they make much of urban planning. Therefore, the interface is designed to guide the users to questionnaire page that asks about their impression of their current and future living environment.

Based on the above, the interface design is as shown in Fig.5. User's operation procedure is as follows.

1. Select an area from **b.**
2. Select a year between 2015 - 2040 on **c**.
3. The estimated value for the 15 indicators at the designated condition bottom is shown in **d**. By clicking each price, the map layer shows the visualization map of the selected indicator on **b**, and by clicking again, the graph **e** that shows change along with time pops up.
4. Clicking the link in the bottom of the page, the users move on to the questionnaire page and answer to questions about their properties and opinions for their present and future living environment.

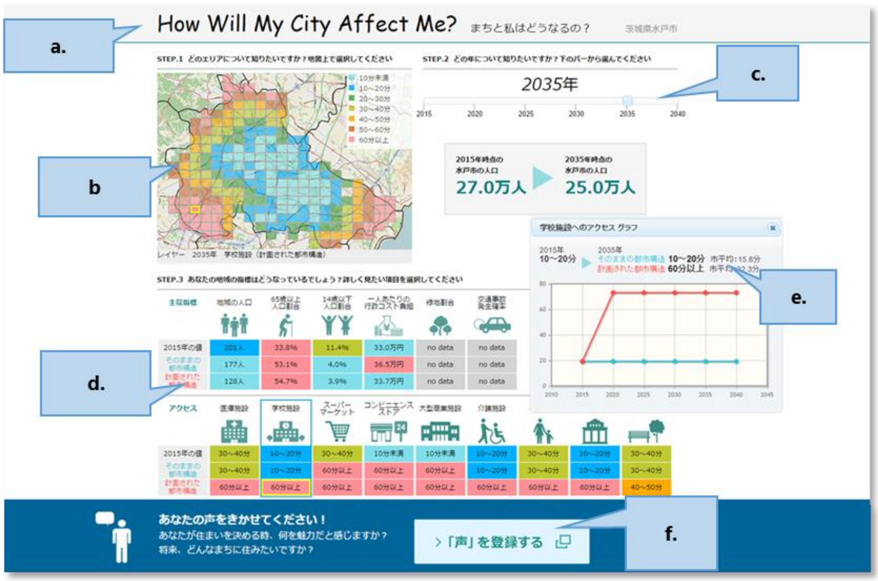

Fig.5 Interface design of ‘My City Forecast’
a: title b: city map for area selection and visualization c: sroll bar for year selection
d: Estimation result of 15 indicators, comparing current, BAU case, and compact city case   e: graph pop-up f: link to questionnaire page

3. Feedback from Local Planning Department

We interviewd urban planning department of 4 local atuhorities of cities in Japan and obtained feedbacks about our web application 'My City Forecast'. The 4 cities are Yokohama city, Sagamihara city (Kanagawa prefecture), Mito city (Ibaraki prefecture) and Muroran city (Hokkaido). To develop our tool to be more usable for general cities in Japan, the purpose of our interview was to obtain opinions from local government of cities with various city conditions. Following are the summary of opinions that were collected through interview about demand for this tool and functions they expect to be added.

Q1. Are there any demands for this urban simulation tool?
Summary of comments:
The city simulation tool that can be casually used by the local authorities is very limited, and the demand for urban simulation tool is high in the phase of planning, as well as the phase of explanation of the plans to citizens. In addition, since the local authorities owns and continues to organize data of various city factors, tools that can utilize those data could clarify the objective.
Other comments:
- Expect that neutral institutes stand between the local authorities and the citizens to offer this tool, regarding the too strong impact of numerical simulation results (Yokohama, Mito, Muroran)
- The increase of precision of the simulation by inputting actual data will be a motivation for open data movement (Mito).
- There are many datasets that the local authorities have prepared through town planning basic survey, taking large budget. Firstly, these data should be visualized for citizens to be aware of their city's situation and where they are heading. (Sagamihara)

Q2. What functions are expected to be added?
Summary of comments:
The function expected varies from one city to another, due to the difference in ways to induce compact city concept and also in the level of necessity for the concept. Also, the tool may let citizens experience city planning from the perspective of urban planners, which could lead to more positive understanding for future plans. It is desirable that the simulation can be flexible to various settings of parameters and data inputting.
Other comments:

- Expect function that enables anybody to set various substituting city plans to compare plans and search for the best on their own, along with simple interface for it. (Yokohama, Mito and Muroran)
  - Reflection of administrative district (Yokohama and Muroran)
- Higher resolution simulation that could reflect changes of facility distribution in inner-district (Yokohama and Muroran).
- Reflection of non-structural measures such as increasing number of buses. (Yokohama)
- Though change within the urban structure is little, the output indicators should include other major household indicators such as hazard risks and access to downtown, in order to understand which indicators do users make much of about their living environment. (Yokohama, Mito and Muroran)

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4. Conclusion

In this research, we have developed an urban simulation tool for citizens as a web application, which provides information about the future of their city to enhance their awareness and communication with urban planners. Through interviews to urban planning department of local authorities of 4 cities, it turned out that there are demands for simple urban simulation tools, for the purpose of rising awareness and enhancing commitment of the citizens as well as to utilize the datasets the local authorities have created paying high price for them. Moreover, it appeared that the principle of urban management differs from one city to another, including how they are going to induce compact city concept to their city conditions. The tool is expected to be flexible enough to correspond to various simulation setting demands.

Based on the feedbacks we have obtained, we will improve our tool for future study. One of the most important issue is to extend its function to be able to localize to every other cities. For the alpha-version, we have mainly used datasets that are available for all cities in Japan, however, these datasets are likely to have low precision compared to the datasets the local authorities possess based on their actual survey. With the enhancement of open data movement, it is assumed that more and more precise geo-spatial datasets will become available from local authorities, and our tool will be designed to be able to raise the precision of the simulation by inputting those data.

In addition, we are now planning to have actual citizens to examine the tool. The analysis of the questionnaire and log analysis will reveal what they make much of their living environment. It would also be an opportunity to test how the visualization give positive impressions about urban planning, compared to the document based explanation. Obtaining feedbacks again from citizens and local authorities, we will continue to improve the tool, and aim for holding an interactive workshop of citizens and local authorities to talk about the future of their cities through the usage of our tool.

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