地域計画シナリオのコストと効果の自動推計
−静岡県裾野市の計画事例をもとに

馬玨*・小俣博司・渋谷遊野・関本義秀****

Automatic cost and effect estimation for regional planning scenarios
- Based on the Planning Cases in Susono, Shizuoka Prefecture

MA Jue*, OMATA Hiroshi, SHIBUYA Yuya**, SEKIMOTO Yoshihide**

This article introduced an extension function and improvement of evaluating the cost and effect automatically in the prototype application of a citizen-oriented digital design regional planning tool. The cost estimation consisted of the expenditure class including the land purchase cost, construction cost, compensation cost, and administrative cost, and revenue class including tax revenue, and land revenue. The living population, visitors, and traffic volume were incorporated in the effect estimation. The result can be used as a referential expectation for planning stakeholders during consulting and public participation phase, to support the decision-making. The pseudo people flow data and simulation model were installed for the evaluation of future visitors and traffic volume by time. Finally, the cost and effect generation were applied in two regional planning cases: the New Fukara Station project and New Hiramatsu Fukara Line project in Susono, Shizuoka Prefecture as case studies.

Keywords: コストと効果推計（Cost and Effect Estimation）, デジタルデザイン（Digital Design）, 地域計画（Regional Plan）

1. Introduction

1.1 Background

The rapid population decline and aging issues have been growing considerable problems in Japan for decades. Accordingly, the compact city policy was adopted by Japanese national government and local governments for a sustainable development of society (MLIT, 2015), which aims to gather residents to a compact area for ensuring their accessibility of infrastructure in the future. It does not only work for the daily conveniences but also a restriction of public service cost, owing to the fact that the higher the density of a residential area, the lower the public cost (Kimura, 2019).

Moreover, the urban development methods are also utilized to deal with those social issues. However, the time and economic costs in feasibility study phase are usually high for current urban development methods, such as land readjustment projects and urban redevelopment projects. The implementor need to do survey in target area and communicate with stakeholders for draft plan making and budget calculation to get the permission and support from national government (公益社団法人街づくり区画整理協会, 2019).

Meanwhile, public explanaroty meetings were required for conveying the proposal to stakeholders and getting reflection opinions from them. However, it is not easy for stakeholders to grasp the whole picture of cost and effect of a project. In order to provide a sense of ownership to the living space for stakeholders, it was belived to be helpful to have a regional plan simulation tool to simulate planning proposals, especially the ensuing cost and effect.

For the current regional plan simulation tools, the economic factors were involved in different ways. Anas and Liu (2007) developed the RELU-TRAN model, which combines the regional economy, land use, and transportation using dynamic general equilibrium method.

*　学生会員　東京大学工学系研究科（The University of Tokyo）
〒**153-8505**　東京都目黒区 4−6−1　E-mail：**majue@iis.u-tokyo.ac.jp**
**　正会員　東京大学空間情報科学研究センター（The University of Tokyo）

The individual salary and real estate price was modeled in UrbanSim by hedonic regression method (Waddell, 2002). Hasegawa, et al. developed a web-based urban communication tool to forecast future urban factors with & without compact city policy (Hasegawa et al., 2019), including the administrative cost. However, most of them considered the holistic economic indication in large scale, rather than focusing on a specific project and each stakeholder.

1.2 Research Objective and workflow

Figure 1 indicated the framework of the automatic cost and effect simulation working within the regional planning tool system. In our previous research, a prototype of the regional plan simulation tool was developed as a web application (Ma et al., 2021), and a GIS database for supporting the implementation of the tool was further equipped (Ma et al., 2021).

In this study, the cost and effect estimation of the reginal plan simulation tool was further improved and automated as an extension function. The cost estimation consisted of expenditure and revenue. The expenditure included the land purchase cost, construction cost, compensation cost, and administrative cost. While the revenue contained tax revenue, and land revenue. On the other hand, the change of living population, visitors and traffic volume were incorporated in the effect estimation.

The pseudo people flow data and simulation model were installed for the evaluation of visitors change and traffic volume by time. The result can be used as a referential expectation for planning stakeholders during consulting and public participation phase, to support the decision-making. Finally, the estimation model was applied in two regional planning cases: the New Fukara Station project and New Hiramatsu Fukara Line project in Susono, Shizuoka Prefecture as case studies. The result exhibited the project budget and indicated a positive effect for regional development with an increasing of vitality.

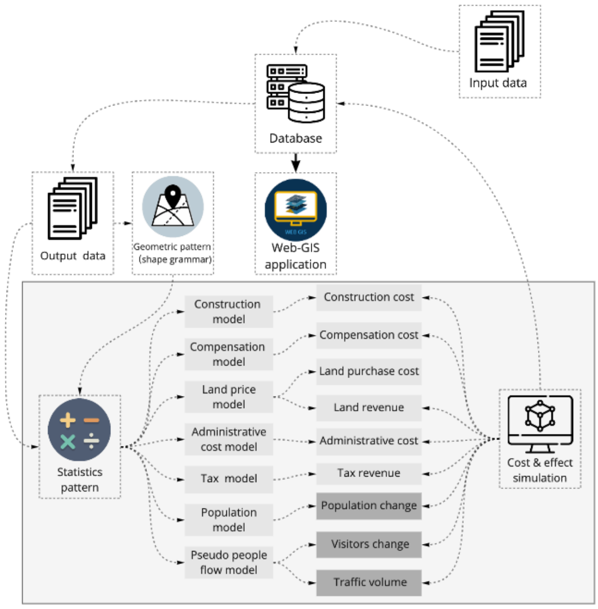

Figure 1 Framework of the cost & effect simulation

2. Cost and benefit estimation model

The cost and effect estimation model was explained from three classes in this section: expenditure, revenue, and effect. Each class was consisted of several division calculation modules (Table 1).

The basic estimation models and data source of indicators for calculating the expenditure and revenue were explained in previous study (Ma et al., 2021), including the construction cost model, land price model, and future population model. In this section, only the newly added modules were introduced. It has to be noted that not all of items were calculated for every case. The applied ones were selected based on the nature of the project.

Table 1 List of cost and effect estimation items

Class	Division	Section
Expenditure	Construction cost	Road
		Public building
	Land purchase cost	Public use land
	Compensation cost	Land
		Building
	Administrative cost	Before
		After
Revenue	Tax revenue	Realty tax
		City planning tax
	Land revenue	Before
		After
Effect	Living population	Before
		After
	Visitors change	Before
		After
	Traffic Volume	Before
		After

Table 2 Public expenditure in Susono (2015) and main influencing factors

Items	Cost (Yen)	Constant	Main influencing factors
Council	219,392,000	True	
General affairs	2,176,191,000	True	
Public welfare	5,461,661,000	False	Population of elderly
Sanitation	3,259,418,000	False	Area of built-up area
Labor	760,572,000	False	Total population
Agriculture	378,453,000	True	
Commerce and industry	227,523,000	True	
Infrastructure	3,370,669,000	False	Area of built-up area
Fire service	1,051,276,000	False	Area of built-up area
Education	3,150349,000	False	Number of school facilities
Emergency restoration	0	False	Area of built-up area
Public bond	1,714,696,000	True	
Contingency funds	352,758,000	True	

2.1 Administrative cost model

The administrative cost per citizen was estimated based on the public expenditure data from local governments. Table 2 shows the annual administrative cost of Susono city in 2015. The method referred to the research from Hasegawa et al. (2015). Each item of administrative cost was supposed to be either constant or not constant. And the main influencing factors to those not constant were listed. The sum of public expenditure within the case area was calculated along with the change of main influencing factors and divided with the estimated living population.

2.2 Pseudo people flow model

Pseudo-people-flow model was developed to acquire a nationwide synthetic open dataset for people movement based on limited travel survey and open statistical data (Kashiyama et al., 2022). The outcome dataset is the typical weekday movements of people rather than a representation of actual travel movements. It represents the seamless movement of people throughout Japan, without restrictions on coverage, and covering the entire population of approximately 130 million people.

There are four processing steps to generate the pseudo people flow by this method. At first, a high-resolution population data was generated using a household estimation method proposed by Kajiwara et al. (2022). Each person produced here was located in a specific house building as the home location and first origin point. Based on the initial population data, each person was assigned a role, including worker, non-worker, and student.

Then, the activity chain was generated for each person separately in each group. The activity duration and purpose were equipped with the output in this step. The time-inhomogeneous Markov chain model was adopted to decide the activity schedule and purpose.

Thirdly, the person trip dataset was created with the origin coordination, destination coordination, and transportation mode. The destination location of activity was firstly chosen at the boundary level, such as city, grid, and school district, based on the MNL model and multiple factors such as the number of employees. And it was finally chosen at the building level within the selected boundary based on factors such as area of building, and facilities related to the trip purpose. In addition, each trip was assigned with transportation mode based on mapping a transportation characteristics survey data. For trips with rail, each trip was split in three sub-trips: origin-station-station-destination. The access and egress trips were also assigned to separated mode.

Finally, a trajectory dataset was transformed with the input of railway and road network data. The trajectories were shown as points indicating individuals passing through every node of the road network.

On account of the generally applicability and high-resolution, the pseudo-people-flow model was employed for evaluating the visitors and traffic volume in effect estimation of this study. The number of visitors was defined as the counting of trips which the destination locates inside the case area. And the traffic volume was defined as the counting of trajectory points for each road segment during the sample daytime of pseudo-people-flow model.

However, the input data and parameters for each step were adapted for different case scenarios (Figure 2). The move-in & out population and buildings estimated during the previous model for each regional plan project case were added into the initial population data. The new station and other planning facilities from user's input setting were added into the input datasets.

After that, the new activity, trip, and trajectory were created through the model, which indicate the future situation based on the planning scenarios.

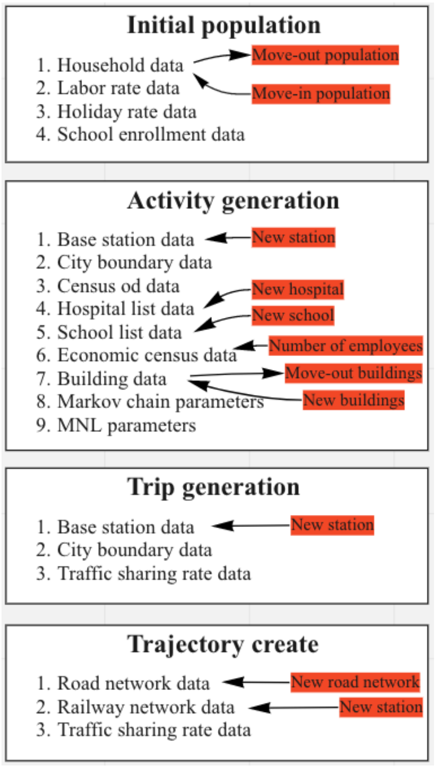

Figure 2 The adjustment of input data for pseudo-people-flow simulation

3. Implementation of evaluation model in Case Study

In this study, the automatic cost and effect simulation model has been applied to two real project cases in Susono city. Susono is a local city with nearly 51 thousand population (2020) in Shizuoka prefecture, Japan, which is now suffering from the problem of depopulation and aging. Figure 3 shows the situation of three estimation scenarios in central area of Susono city: (1) Baseline (up), (2) New road project (mid), and (3) New station project (down).

3.1 Case 1: New Fukara Station Project

The new urban area regional plan in the Fukara region of Susono has been continuously proposed with the submission of a petition for the establishment of a new Fukara station to the city council in 2005. The regional master plan and zoning have been proposed based on the previous workshop with citizens.

After the setting of (1) zone type, (2) ratio of different land use, and (3) land regulation, the future urban form was automatically generated as well as the result of cost & effect calculation (Figure 4, down).

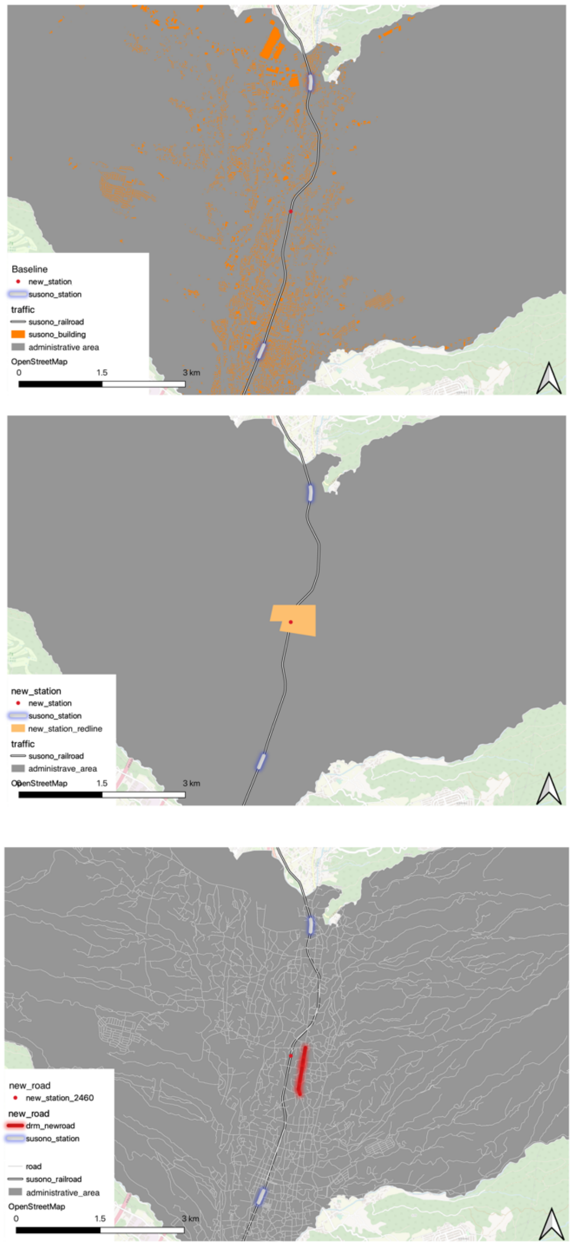

Figure 3 Three estimation scenarios: baseline (up), new station (mid), new road (down)

For new station case, since users only define the type of each zone area rather than the specific location of each facility, the location of new facilities were randomly chosen as one building within the related zones. The initial input setting was designed based on the information from the master plan and zoning (Figure 4, up).

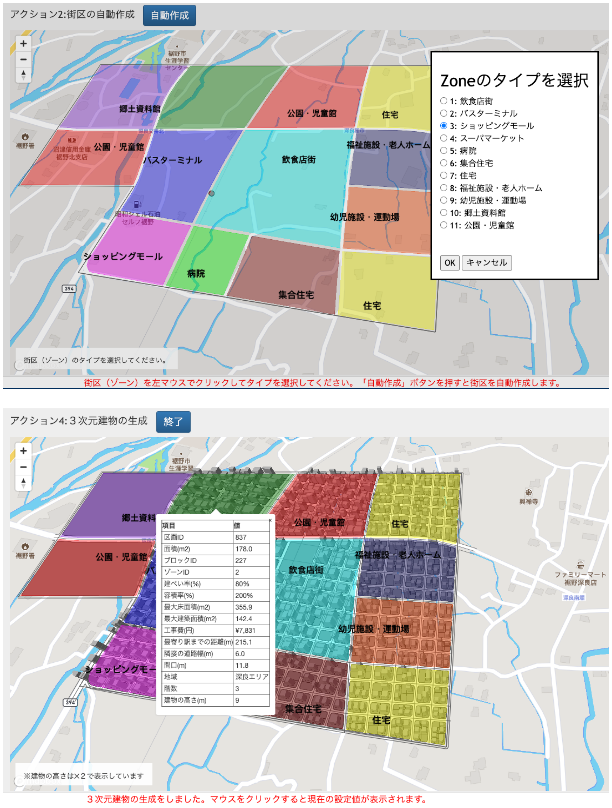

Figure 4 The interface of the web application prototype for new station case

For the location choice model, the former choice of boundary level was influenced by the facilities within each unit. However, the data of facilities was not applied directly. Instead, the influence of facilities was reflected by the number of employees, which was stored in the "Economic census data" (Figure 2). This dataset comes from the economic census survey open data provided by Ministry of Internal Affairs and Communications of Japan. Thus, the number of employees was changed in this case along with the planning new facilities. The standard of employee number for different facilities was estimated from the statistic data of "Number of private establishments by industry category" in economic census survey (Table 3).

Table 4 shows the result of cost and effect calculation newly created in this study for new station case. The result indicated the administrative cost (including the items list in Table 2) per citizen per year inside the case region was predicted to drop from 380,642 yen to 322,264 yen (-15%), whereas the actual administrative cost per citizen per year for the whole Susono city (2015) was 417,139 yen. This result was preliminarily considered to be in line with the expectation of the compact city policy. The tax revenue was estimated to grow by 696% (from 59,313,441 yen to 472,129,389 yen). And a 360% increase of living population with origin value of 527 and estimated future value of 2424. The number of visitors with trips moving to the case area was also estimated highly improved after the regional plan project (from 643 to 7564). Figure 5 shows the distribution of visitors before and after the new station project, from which a trend of compact for people's activity can be found. And the new Fukara region could be recognized to be a new active area in Susono city.

Table 3 Standard of employee number for Susono city

Facility	Average number of employees	Code
Hospital	115	T000917036 P 医療，福祉
School	28	T000917035 O 教育，学習支援業
Shopping mall	169 (Shizuoka Pref.)	T000917029　I 卸売業，小売業
Restaurant	6	T000917033 M 宿泊業，飲食サービス業
Supermarket	169 (Shizuoka Pref.)	T000917029　I 卸売業，小売業
Hotel	12	T000917033 M 宿泊業，飲食サービス業
Welfare	19	T000917036 P 医療，福祉

Table 4 Result of cost and effect calculation for new station case

Cost & effect (yen)	Before	After	Rate of change
Administrative cost	380,642	322,264	-15%
Tax revenue (10000)	5,931	47,213	696%
Living population (person)	527	2424	360%
Visitors change (person)	643	7564	1076%
Traffic Volume (person)	39718	68568	726%

The total traffic volume within the case area during the sample day was estimated to be 68568 while the original volume was 39718. Figure 6 shows a comparation of traffic volume within the whole project area during one sample daytime before (a) and after (b) the regional plan, whereas the result for each road segment was exhibited individually from the web application. It is obvious that the traffic volume during daytime (9:00–18:00) increased. The reason could be the increasement of facilities improve the probability of destination choice within the case area, which indicates a positive effect for regional development.

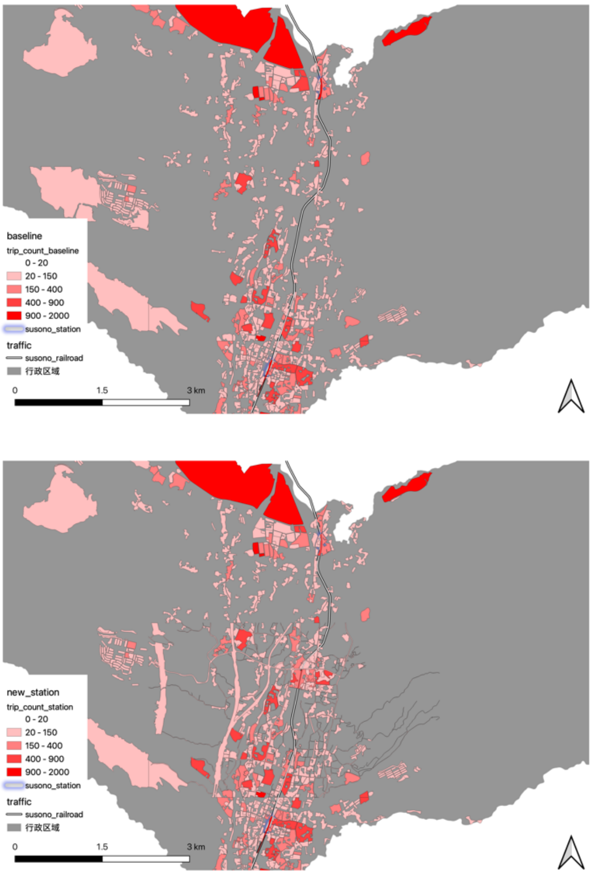

Figure 5 Visitors distribution before (up) and after (down) the new station case

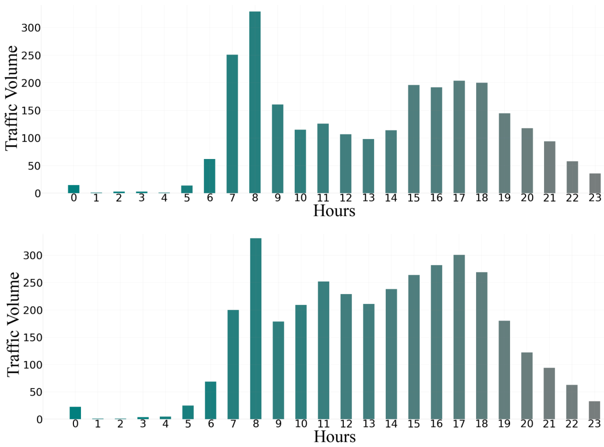

Figure 6 Traffic volume within the case area before (up) and after (down) the new station project

3.2 Case 2: New Hiramatsu Fukara Line Project

The new city plan road project has been proposed in Susono city since 2007 for a safe and comfortable urban development. In this project, the part of Hiramatsu Fukara Line in Fukara region was designed as a new road case. The road project in Japan usually develop in two methods (MLIT, 2008). One is the land purchase method, and another is land readjustment method. The differences of these two methods covering the project cost, land rights and urban morphology. In this study, the result of land purchase method was exhibited to examine the effectiveness of the estimation model.

For new road case, users can draw the mid-line of new road by the web application (Figure 7, up). After the setting of road level and road width, the land purchase plan will be provided (Figure 7, down). The calculation result of cost and effect was displayed in Table 5. The total traffic volume within case area improved by 266% (from 2296 to 8405). The temporal distribution of traffic volume was further analysis and compared between with (down) and without (up) the new road (Figure 8). However, the traffic volume of morning commuting period (7:00–8:00) was indicated particularly increased compared to other time. The reason was speculated to be the decrease of living household along with the construction of new road. Thus, the traffic mainly caused by the passing through for commute rather than daily activities.

Table 5 Result of cost and effect calculation for new road case

Cost (10000 yen)		Value	
Road construction cost		50,132	
Land purchase cost		15,023	
Compensation cost		37,703	
Effect (person)	**Before**	**After**	**Rate of change**
Living population	88	67	-24%
Visitors change	101	124	23%
Traffic Volume	2296	8405	266%

In addition, the city scale traffic volume for each road segment counting within the whole day after the project was compared with other scenarios in Figure 9. The change of traffic was established from the comparison. The new station case dispersed the traffic from the national highway to city plan road around the case region. On the other hand, the new construction segment of Hiramatsu Fukara line strengthened the impact of the whole Hiramatsu Fukara line. Both of the two cases were forecasted to create a positive effect to the vitality of the Fukara region.

Figure 7 The interface of the web application prototype for new station case

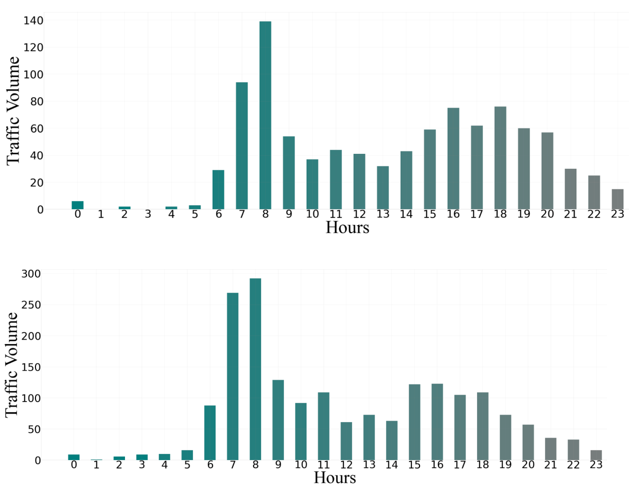

Figure 8 Traffic volume within the case area before (up) and after (down) the new road project

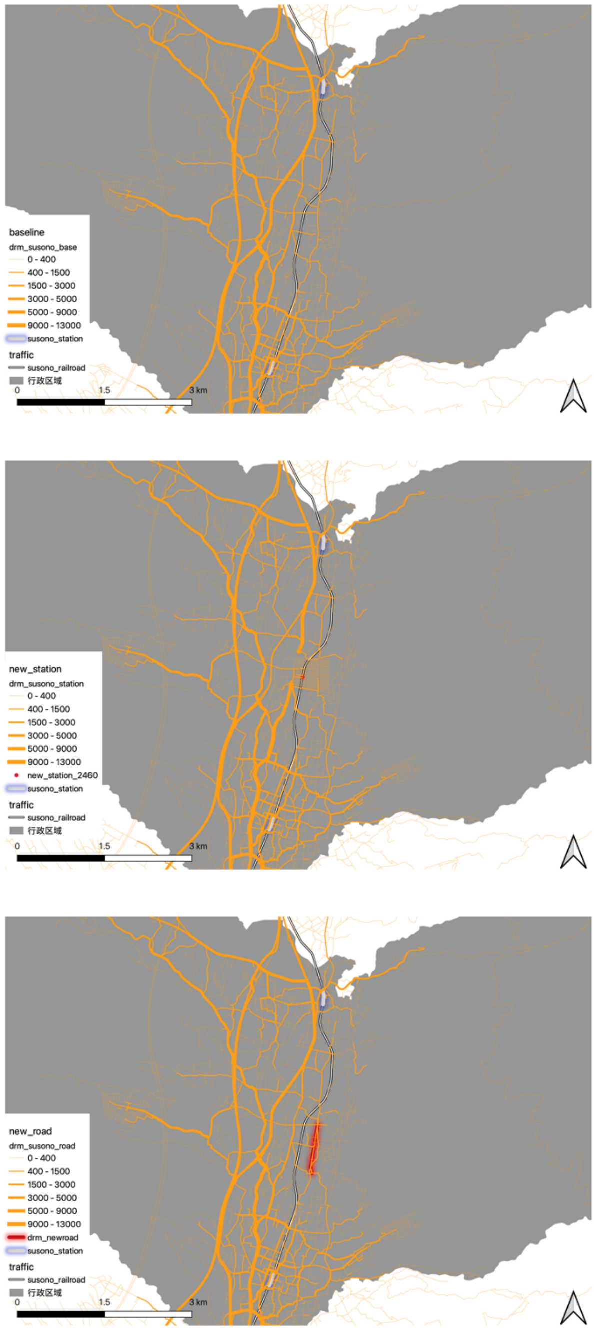

Figure 9 Traffic volume of Susono city in baseline (up), new station case (mid), and new road case (down)

4. Conclusion and Future Work

This study described the development of the automatic cost and effect estimation model as an extension part of a regional planning tool. The estimation models for different types of projects were loaded in a web-GIS application for a real-time accessing of the cost and project effect approximately. A rough evaluation of proposed regional plan can be produced without the field measurement and stakeholder. All of these works contribute to streamline the project preparation phase while spending less money and time.

However, the current model cannot accomplish the dynamic simulation. The interaction of land use, population, economy, and transportation could be added for a higher accuracy in future study. Besides, two cases studies were only simulated based on the initial settings. A optimization analysis could be done with iteration method for proposing a better plan.

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