A VERIFICATION STUDY ON MULTI-OBJECTIVE PLANNING OF DEVELOPMENT PROJECTS CONSIDERING FINANCIAL MANAGEMENT PROBLEM AT LOCAL CITY*

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1. Background

In Japan, after long high speed development, especially in Tokyo area, the system fatigue of centralization in administration has caused a lot of problems. Shift from centralization and top-down to decentralization requires the re-assignment of the national and local roles, independent urban development with peculiarity and assurance of the public service level.

For local cities, they should enhance its ability to promote independent from the big central cities, which means a local city must perform the management itself and aiming at self-supporting and sustainable development.

In this case, effective and efficient infrastructure construction is to be carried out for the urban development with limited financial resources. And in this study, an attempt is made to develop the rational planning methodology of urban development considering the process of idea finding, planning and projects implementation, mainly from the economical and administrative viewpoint.

2. Literature Review

There have been some studies and surveys on the public investment problems. M. Haruna and M. Takebayashi developed the management system and multi-project mathematical model[1)] for the rational and feasible analysis for the construction projects implementation planning. T. Okumura[2)] of Ritsumeikan University did the study of evaluation of investment plan of urban development and construction by using financial simulation analysis based on the system approach. In his study, the financial structure of urban units has been concluded. In T. Moritshita's thesis[3)] about the verification study related to administrative system and financial system for the local city synthesis promotion planning, Kusatsu city was selected as the subject city to observe the influence effect from promotion projects. T. Watanabe[4)] advanced this research together with the optimization concept.

The hybrid model has been used for transportation planning by Dr. Koyichirou YAMADA[5)]. And in this research, the hybrid concept is applied to the optimization of the proposal from the time-related dynamic viewpoints.

3. Introduction of Kusatsu City

Kusatsu city locates at the central part of Japan, in Shiga prefecture, near the largest lake – Lake Biwa. It covers about 48.22 square meters and 12 kilometers in south-north direction and 9 kilometers in east-west direction, with Rito Chiou at east, Otsu City at south Moriyama City and Lake Biwa at north. National main transportation routes such as JR Main Tokaido line, Biwa Line, Shinkansen, Meishin Expressway and Route 1 and so on cross the Kusatsu Urban area.

Kusatsu City has a population of 113,796 until October 1, Heisei 14. It is becoming the city which plays a central role in Shiga.

For more details, please refer to the appendix. Here the city is briefly introduced from the seven aspects, which are also

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defined as seven objective indexes in the study.

- Population: representation of the vitality of the city; Kusatsu city is one of the few cities in Japan which has the increasing population.
- Employee persons: representation of the city employment power; There is a trend of increase of the employee persons in Kusatsu city.
- Average income: representation of the civic economical content; the average income of the city keeps waving under limited control.
- The production sum of 1st, 2nd, 3rd industry: representation of the activity of the industry; the agriculture of the city decays slowly; and the main industry is the 2nd industry. While the 3rd industry is developing in a high speed.
- Tax: representation of the strength of the independence of city finance. There is no obvious change about tax of the city in recent years.

And the city structure is changing toward the urban type. In the comprehensive development plan made by Kusatsu City in 1999, "Vision for Kusatsu City at 2010"[6], three objectives are made for the Kusatsu urban development:

a) To keep the population scale and develop the 2nd and 3rd industry;
b) To increase the tax for self-supporting;
c) To keep the level of the 1st industry though no rapid expansion is expected.

So, we arranged priority positions of the seven objective indexes according the situation mentioned above. They are listed in order of importance: population, the production sum of 2nd industry, the production sum of 3rd industry, the tax, the employee persons, the average income and the production sum of 1st industry.

In the literature, the financial simulation system has been already constructed, and complied into a program, named FSKLA (Financial System of Kusatsu City based on Local Act ivies).

4. Mathematical Formulation of Planning Model

The introduction above may be considered as the description of the scenario, from which we can find it is a multi-objective problem in financial distribution. Multi-objective problem is very common in regional planning. And many kinds of methods have been developed since early fifties.

The idea of stating min-max optimum and applying it to multi-criterion optimization problems was taken from game theory which deals with solving conflicting situations. The min-max approach to a linear model was proposed by Jutler (1967) and Solich (1969). It has been further developed by Osyczka (1978), (1982).

The min-max optimum compares relative deviations from the separately attainable minima. Now we describe the min-max optimization as follows. A point $\bar{x}^* \in S$ is min-max optimal, if for every $\bar{x} \in S$ the following recurrence formula is satisfied.

Step 1

$$v_1(\bar{x}^*) = \min_{x \in S} \left\{ \max_{i \in I} \left[z_i(\bar{x}) \right] \right\}$$

and then $I_1 = \{i_1\}$, where i_1 is the index for which the value of $z_i(\bar{x})$ is maximal. If there is a set of solutions $S_1 \subset S$ which satisfies Step 1, then

Step 2

$$v_2(\bar{x}^*) = \min_{x \in S} \left\{ \max_{\substack{i \in I \\ i \notin I_1}} \left[z_i(\bar{x}) \right] \right\}$$

and then $I_2 = \{i_1, i_2\}$, where i_2 is the index for which the value of $z_i(\bar{x})$ in this step is maximal.

If there is a set of solutions $S_{r-1} \subset S$ which satisfies step $r-1$ then

Step r

$$v_r(\bar{x}^*) = \min_{x \in S_{r-1}} \left\{ \max_{\substack{i \in I \\ i \notin I_{r-1}}} \left[z_i(\bar{x}) \right] \right\}$$

and then $I_r = \{I_{r-1}, i_r\}$, where i_r is the index for which the value of $z_i(\bar{x})$ in the r th step is maximal.

If there is a set of solution $S_{k-1} \subset S$ which satisfies Step k-1, then

Step k

$$v_k(\bar{x}^*) = \min_{x \in S_{k-1}} z_i(x)$$

where $v_1(\bar{x}^*), \ldots, v_k(\bar{x}^*)$ is the set of optimal values of fractional deviations ordered non-increasingly.

This optimum can be described as follow. Knowing the extremes of the objective functions which can be obtained by solving the optimization problems for each criterion separately, the desirable solution is the one which gives the smallest values of the relative increments of all the objective functions.

So, the next comes the application of min-max method in solving this practical multi-objective problem.

Objective Function:

$$\min_{I \in S} \left\{ \max_{j \in J} \left[w_j \frac{A_j^{\,U} - A_j(I)}{A_j^{\,U} - A_j^{\,L}} \right] \right\}$$

$A_j^{\,U}$ *is the upper bound value of jth item.*

$A_j^{\,L}$ *is the lower bound value of jth item.*

$$A_j^{\,L} = \min\{A_j, A_j'\}$$

Constraints:

$$A_p(I) = \alpha_{p1} I_l + \alpha_{p2} I_r + \alpha_{p3} I_c + \alpha_{p4} I_w + d_p$$
$$A_1(I) = \alpha_{11} I_l + \alpha_{12} I_r + \alpha_{13} I_c + \alpha_{14} I_w + d_1$$
$$A_2(I) = \alpha_{21} I_l + \alpha_{22} I_r + d_2$$
$$A_3(I) = \alpha_{31} I_l + \alpha_{32} I_r + \alpha_{33} I_c + d_3$$
$$A_w(I) = \alpha_{w1} I_l + \alpha_{w2} I_r + \alpha_{w3} I_c + d_w$$
$$A_{in}(I) = \alpha_{in1} I_l + \alpha_{in2} I_r + \alpha_{in3} I_c + d_p$$
$$A_{pi}(I) = \alpha_{pi1} I_l + \alpha_{pi2} I_r + \alpha_{pi3} I_c + d_p$$

$$\alpha_{p1} I_l + \alpha_{p2} I_r + \alpha_{p3} I_c + \alpha_{p4} I_w + d_p \ge A_p$$
$$\alpha_{11} I_l + \alpha_{12} I_r + \alpha_{13} I_c + \alpha_{14} I_w + d_1 \ge A_1$$
$$\alpha_{21} I_l + \alpha_{22} I_r + d_2 \ge A_2$$
$$\alpha_{31} I_l + \alpha_{32} I_r + \alpha_{33} I_c + d_3 \ge A_3$$
$$\alpha_{w1} I_l + \alpha_{w2} I_r + \alpha_{w3} I_c + d_w \ge A_w$$
$$\alpha_{in1} I_l + \alpha_{in2} I_r + \alpha_{in3} I_c + d_p \ge A_{in}$$
$$\alpha_{pi1} I_l + \alpha_{pi2} I_r + \alpha_{pi3} I_c + d_p \ge A_{pi}$$

A_p :Objective value of Population in t

A_1 : Objective value of the 1st industry in t

A_2 : Objective value of the 2nd industry in t

A_3 : Objective value of the 3rd industry in t

A_w :Objective value of employee persons in t

A_{in} :Objective value of the average income in t

A_{pi} Objective value of the tax in t

I_l : The living basis service investment

I_r : The traffic basis service investment

I_c : The culture, science basis service investment

I_w : The welfare basis service investment

$$I_l + I_r + I_c + I_w = I$$
$$I_l \ge I_l^{\,*}, I_r \ge I_r^{\,*}, I_c \ge I_c^{\,*}, I_w \ge I_w^{\,*}$$

The α used above is the coefficient of each investment item. And the d is the constant parameter of each function.

Since the simulation system operated in three separated phase, we concluded three set of the parameters and did the optimal search three times. Here we choose the data of second phase to compare the optimal pattern concluded by min-max method and goal programming, which is also a widely-used method in solving multi-objective problem.

Table 1 the Concluded Distribution Patterns

Investment Category	Distribution (%)	
	Min-max	Goal Programming
Investment to Living Basic	48.71	43.34
Investment to Transportation Basic	29.27	36.66
Investment to Science and Culture Basic	11.72	10.00
Investment to Welfare Basic	10.00	10.00

Table 2 Comparison of the Results

Objectives	Unit	Same Target	Result by Goal Programming	Improvement (%)	Result by Min-max	Improvement (%)
Population	Person	119,988	137,710	14.77	142155	18.47
1st Industry	K yen	3,682,629	4,343,162	17.94	4575043	24.23
2nd Industry	K yen	450,588,243	491,151,346	9.00	504044863	11.86
3rd Industry	K yen	396,819,498	438,032,177	10.39	437975450	10.37
Tax	K yen	22,243,234	26,584,598	19.52	27663212	24.37
Average Income	Yen	5,251,042	5,944,202	13.20	5923061	12.80
Employee Persons	Person	33,401	35,650	6.73	35635	6.69

The goal programming was used to solve the same problem in T. Watanabe's research. And it was concluded that there was an average about 6%, from the least 1.5% to the largest 14% improvement of the influence effect based on the practical patterns performed by Kusatsu Local government. However, in the same initial condition and the same simulation system, we compared the data as shown in Table 1 and 2. The result was advanced further: in items of population, 1st industry, 2nd industry and tax we got fairly large improvement, with a slight victim of other items.

5. Conclusion

In practical application, after comparison with goal programming (GP), this research demonstrated the efficiency and flexibility of min-max method in solving regional multi-objective problems. Beyond GP and other tradition ideas of weighted, min-max method can handle the adjustment much better in advancing the items with high priority. In this study, slight compromise in the three items contributes much larger rise in other four more important items. The adjustment of balance or fixed target level can be realized in the same way.

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