【土木計画学研究・講演集 No. 24(1) 2001年11月】

Evaluation Models for Public Facility Location-Allocation on Districts Merger*

市町村合併にかかわる公共施設配置の評価モデル

Fauzy AMMARI [1] *Keiichi OGAWA* [2] *and* *Toshihiko MIYAGI* [3]

1. INTRODUCTION

The issues of reduction energy in all aspects of human activities are strongly affected in all real urban and regional planning. Here, The role of district merger becomes increasingly important as the need for speed of reaction and correspondence real situation. The concepts of district merger are fall into two types, these are, incorporated merger and new-established merger. It brings us to study an evaluation procedure for an integrated using of existing public facilities in a system of district merger. Generally, in the context of public facilities, government and public agencies are continually faced with problem of selecting best locations for facilities. In most research of this area, the facility location problems have often been planned and evaluated in terms of location-allocation models. Therefore, we propose an interactive framework and mathematical model for evaluation and planning the public facility location-allocation for these mergers type of districts. The framework is proposed based on the application of seven principles of universal urban design. These principles contain efficiency, equity, flexibility, perceptibility, size and space, small and intuitive, and tolerance for error.

On the modeling side, for same type and same level of facilities in incorporated merger, we consider three patterns of facility location, these are, (1) the facility sites are same as before merger, (2) some facilities located in low demand will be evaluated to be closed, (3) establishing sub center (sub facility) in low demand node. In the case of new-established merger, for same type and same level of facilities, we consider four patterns of facility location, these are, (1) the facility sites are same as before merger, (2) closing the overlapping facilities in high demand or low demand, (3) search new best site, and close the inefficiency of existing facilities, (4) establishing center facility and sub center facility using online system that can be operated as a connection tool between low and high demand. These patterns guide the constraints in modeling. All of these formulations are based on fixed charge facility location model with applied a user-choice sub model.

2. FRAMEWORK and MODELS

The framework guides a fundamental modeling goal based on the scenario of efficiency and equity, as shown in figure 1. The efficiency is defined as low-cost sitting facility and or using lowest-cost of energy in operating facility. The equity is defined as finding the best total demand-weighted distance/travel cost in merger network. The advance scenarios as well as flexibility, perceptibility, size and space, small and intuitive, and tolerance for error, are framed on next step and considered as special evaluations. The objective of presented mathematical models in this paper minimizes total demand-weighted distance and total facility costs.

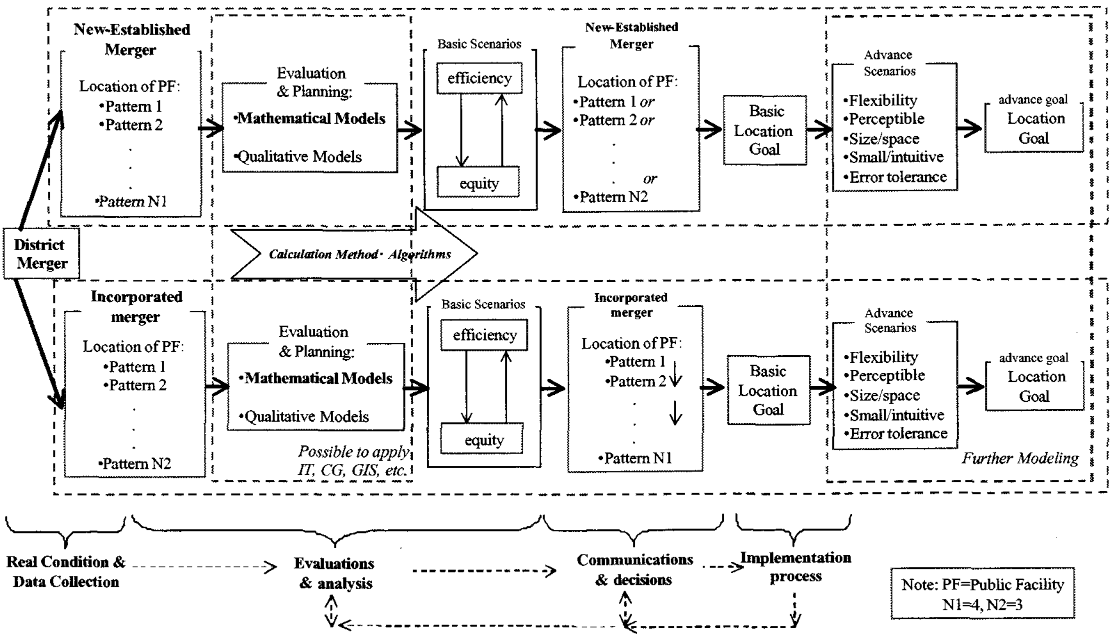

Figure 1. Framework for incorporated district merger and new-established district merger.

Based on present situation, the process of evaluation in incorporated-district mergers follows a priority sort procedure, that is, firstly the existing facilities configuration assumed to be sufficient to satisfy the existing demand. Therefore, after merger, the evaluation concentrates

* Keywords: district merger; public facility; location problem; regional planning; land use.
1 Dr. Eng., Dainichi Consultant Inc., 3 - 1 - 21 Yabuta Minami, Gifu 500-8384. Fax: 058-276-6417, EMail: F-Ammari@dainichi-consul.co.jp
2 Assistant Professor, Department of Civil Engineering., Faculty of Engineering, Gifu University.
3 Professor, Faculty of Regional Studies and Graduate School of Engineering, Gifu University.

on demand networks, if it does not satisfy the optimum criteria, the evaluation will continue to second location pattern evaluation. Secondly, it is assumed to reduce the number of same type of facilities based on evaluation results. Thirdly, the selected existing facilities are assumed as a center facility, then, sub center facilities can be established in low demand node. In the last evaluation step, in advantageous way, it could be dealing with the using of information technology, which sub center facility stand as the recently famous of ATM (automatic teller machine) or online service technology. In any cases, based on last result, it needs to be repeated the each step of evaluation till the optimum criteria reached. The outlined of the processes are described in figure 2.

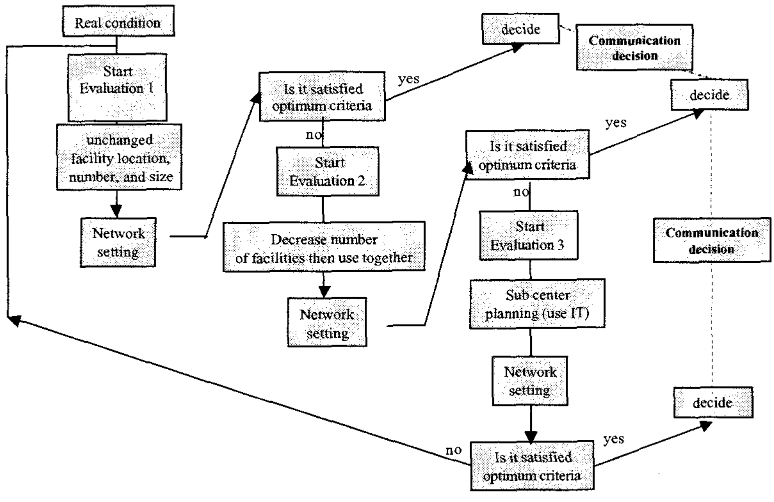

Figure 2. The process of public facility location-allocation evaluations for incorporated-district mergers.

In the new-established-district mergers, the process of evaluation simultaneously executed based on four location patterns. In first step, it is similar to the first evaluation of incorporated-district mergers, the configuration of existing facilities assumed to be sufficient to satisfy existing demand. Therefore, after merger, the evaluation only concentrates on demand networks. Secondly, the numbers of existing facilities are considered to be resetting, that is, to decrease the number of same type of facilities based on evaluation results. Thirdly, we consider the evaluation of relocation facility to some potential sites that could be correspondence to new demand network in merger area. The last evaluation here deals with the system of center and sub center facilities that can be worked under the application of information technology on network. The outlined of the processes are described in figure 3.

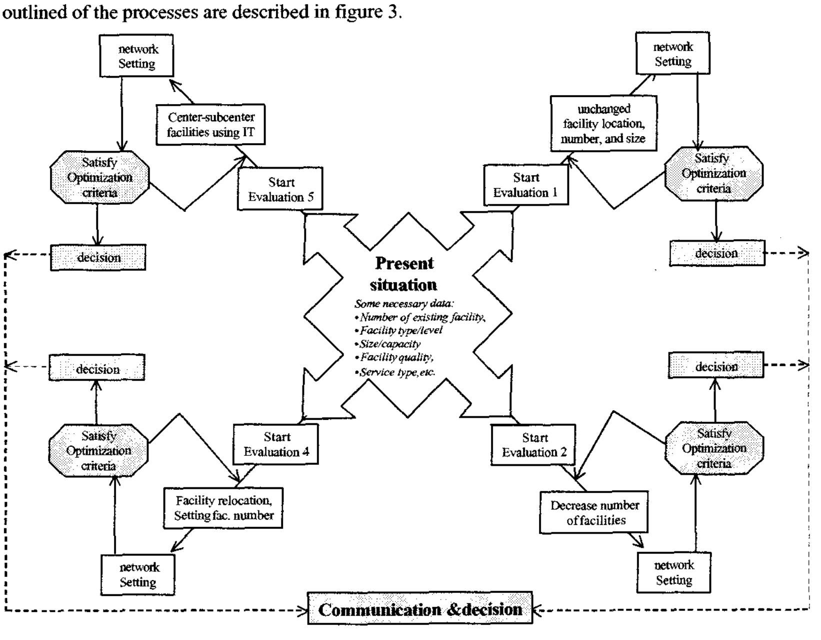

Figure 3. The process of public facility location-allocation evaluations for new-established-district mergers.

Before develop a formulation, the necessary of facility analysis is done based on data collection at present situation, that is, the analysis of fixed costs and operation costs. Fixed cost almost deals with a new open site or a relocation, it contains construction costs, land costs, and all rent contract costs (parking area, storehouse, etc.). Operation costs is consider as the salary of all staffs and the others activity cost. For example, electric expense, water expense, transportation fee, purchase articles, advertisement, etc.

In the formulation side, the objective functions and constraints are based on location allocation pattern. Basically, all the evaluation models have the objective function based on minimizing the total costs, which can be using to express the meaning of efficiency and equity. Briefly, in the formulation which using the present facility numbers (pattern 1), the model is executed on each old networks (before merger) and a new network (after merger). Thus, these results guide us to do a comparison. The objective function is written in equation (1). The constraints contain the linking between facility and demand site, using 0-1 location variables and aggregate demand of allocation variables.

$$Min \sum_{j\in J}(f_j^{F\cos t} + f_j^{O\cos t})y_j + \alpha\sum_{i\in I}\sum_{j\in J} d_{ij}x_{ij} \tag{1}$$

For location-allocation pattern 2, the model formulation is done similar to pattern 1 as mentioned above, the difference is only on the decreasing of facility numbers, where some trials could be done in determining the number of facilities. For location-allocation pattern 4, the formulation is also done similar to pattern 1, where some trials could be done in the process of resetting the facility numbers, that can be executed as a decreasing or an increasing.

$$Min \sum_{j\in J_{cent}}(f_j^{F\cos t} + f_j^{O\cos t})y_j + \sum_{k\in J_{subc}}(f_k^{F\cos t} + f_k^{O\cos t})y_k + \alpha^{cen}\sum_i\sum_j d_{ij}x_{ij} + \alpha^{subc}\sum_i\sum_k d_{ik}x_{ik} \tag{2}$$

$$x_{ij} \le x_{ij}y_j \quad \forall i,j, \quad x_{ik} \le x_{ik}y_k \quad \forall i,k \tag{3}$$

$$\sum_i x_{ij} \le c_j y_j \quad \forall j, \quad \sum_i x_{ik} \le c_k y_k \quad \forall k \tag{4}$$

$$\sum_j y_j = P^{cen}, \quad \sum_k y_k = P^{subcen}, \quad y_k \le \sum_j r_{kj}y_j \quad \forall k \tag{5}$$

$$y_j \in \{0,1\} \quad \forall j, \quad y_k \in \{0,1\} \quad \forall k, \quad x_{ij} \ge 0 \; \forall i,j, \quad x_{ik} \ge 0 \; \forall i,k \tag{6}$$

For location-allocation pattern 3 and 5, the objective function (2) minimizes the total fixed-operation cost and the total demand-weighted distance multiplied by the cost per unit distance per unit demand, for center facility and sub center facilities. Constraint (3) says that demands at node i cannot be assigned to a facility at candidate site j unless we locate a center facility at j, and analog to the sub center facilities. In constraints (4), we ensure that the demand of all nodes assigned to a center facility or sub center facility are within its capacity. Constraints (5) stipulate the setting number of center facility and sub center facility. Also constraints (5) states that sub center facility can be covered by more than one center facility based on critical coverage distance. Thus, we have been concerning not with facility placement disperse, but with the resulting coverage pattern of those placement. Constraints (6) are the integrality and non-negativity constraints, respectively.

As sub model, users choice model using in this evaluation based on accessibility-sensitive demand analysis and facility-congestion sensitive demand analysis. Such subsystem is formulated under a spatial interaction model, which contains space discount function, to represent user choice behavior. The space discount function is assumed as exponential as follows:

$$f_{ij} = \exp(\beta_1 u_{(1)j} + (-\beta_2)u_{(2)ij} + (-\beta_3)u_{(3)j} + \beta_4 u_{(4)j} + \beta_5 u_{(5)j}). \tag{7}$$

Thus, the user allocations based on logit model are as follows.

$$x_{ij} = G_i \frac{f_{ij}h_j y_j}{\sum_j f_{ij}h_j y_j} \qquad \forall i\in I, j\in J \tag{8}$$

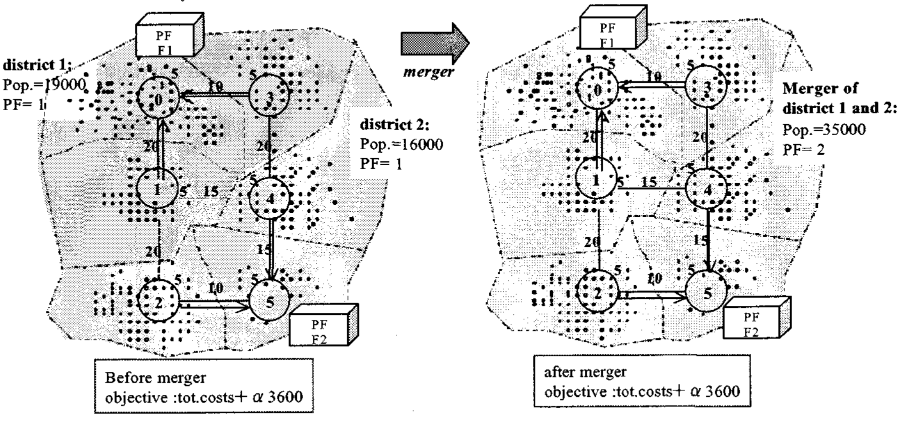

Figure 4. Facility sites are assumed same as before merger.

3. CALCULATION EXPERIENCE

We consider two districts and a simple network. These two districts are different in population size and assumed to be merger in incorporated-district merger type and new-established-district mergers. Both of district 1 and district 2 has one public sports center, respectively. The results presented in this paper are only preliminary calculations where it does not involve all aspects discussed in the model formulation. Generally, the purpose of calculation is pointed out on the demonstration of capability of the presented evaluation models for whole location-allocation patterns. The parameters can be calculated based on an estimation of curve analysis. Figure 4,5, and 6 show the performance of evaluations and the objective values.

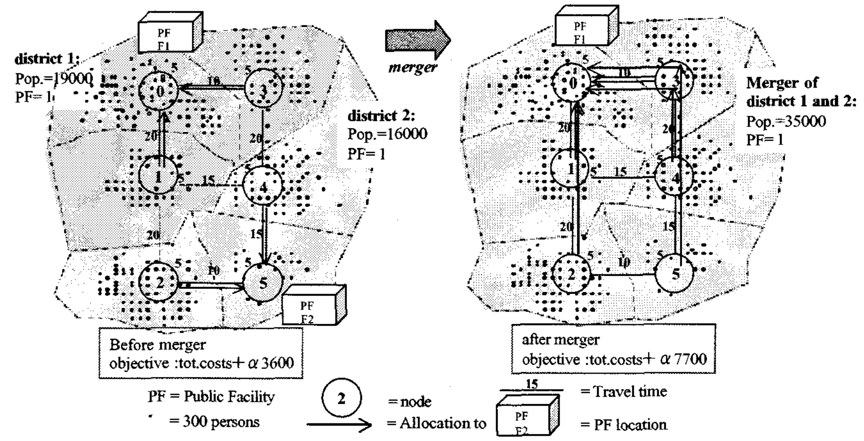

Figure 5. Facility located in low demand is assumed to be closed.

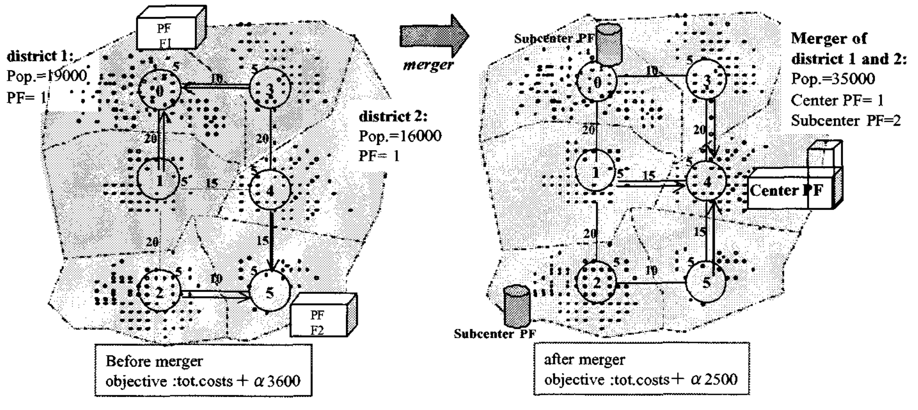

Figure 6. Center facility and sub center facility using online information technology.

4. CONCLUSION

The evaluation models presented in this paper describe the important of process and trials to reach a best decision for location of public facilities in districts merger. The calculation performances show the different evaluation results that can be used to assist decision maker based on financial ability. Theoretically, the application of users choice model could give the compromises between user and public agency decisions.

References

1.Ministry of Public Management, Japan, *Online Information Service* (2001), http://www.soumu.go.jp/.

2.Saitama Prefecture Office, District Merger Procedure (2001), appear in *Prefecture Online Information Service*. (In Japanese).

3.Gifu Prefecture Office, Important Points in District Merger support (2001), appear in *Prefecture Online Information Service*. (In Japanese)

4.Daskin, M.S. (1995), Network and Discrete Location, *John Willey & Sons*, Inc., New York.

5.Leonardi, G. (1981), A Unifying Framework for Public Facility Location Problems-Part 1: A Critical Overview and Some Unsolved Problems, *Environment and Planning A, Vol.13*, 1001-1028.

Notations:

$F_j^{F\,cost}$: *fixed costs*; $F_j^{O\,cost}$: *operation costs*; y_j : *location decision* $\{0,1\}$; α : *cost calibrator*; d_{ij} : *distance between i and j* :
x_{ij} : *allocation decision based on user choice model*; c_j : *facility capacity*; P : *number of facility*; r_{kj} : *coverage distance between center and subcenter*; f_{ij} : *space discount function*; β : *space discount parameter*; $u_{(1)j}$: *utility type* (1) *in facility site j*;
$u_{(2)ij}$: *utility type* (2), *transportation cost between i and j*; $u_{(3)j}$: *utility type* (3) *in facility site j*; $u_{(4)j}$: *utility type* (4) *in facility site j*; $u_{(5)j}$: *utility type* (5) *in facility site j*; G_i = *demand at node i*; h_j : *attractiveness facility j*.