ROAD NETWORK IMPROVEMENT AND REGIONAL COOPERATION EFFECTS

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Abstract: Regional interaction and cooperation is one of the main concepts of Japanese regional planning in the 21st century. However, the definitions of the two concepts have not been clear so far. We try to define the effects of them, which are produced by transportation system improvement and show the ways to measure them quantitatively in the framework of the public facility location problem. The regional interaction effect is related to time reduction effect and the regional cooperation effect to location adjustment effect in two kinds of facility location models, the p-median model and MCLP model. They are computationally examined for the expressway development in the Shikoku area. It is shown that the magnitude of the regional cooperation effect is gradually large measured by the MCLP model, while relatively small measured by the p-median model.

1. INTRODUCTION

The new nation's general development plan in Japan, titled the grand design of our country in the 21st century, was published by the National Land Agency in March of 1998(National Land Agency 1998). They proposed four main strategies to achieve the purpose of the plan. One of them is development of regional cooperation corridors. The nationwide high-speed transportation networks have been considerably improved over the last few decades. Even people living in less developed areas can enjoy benefits produced by expressway development. The National Land Agency encourages those people to attain a better quality of life with the idea of regional cooperation. It means that people living along expressways or high-speed train lines can visit more facilities in farther areas within a specific time. From the another point of view, one facility can have more users from areas farther away by travel time reduction due to transportation system development. Generally it seems that public facilities like hospitals, concert halls, or sports facilities have the effect of scale. That is, if a facility has more users it can offer more attractive services. Therefore, if some local governments located along expressways plan to build a joint public facility cooperatively and put it in a good location where most people in those areas can easily approach, a higher level of public facility services can be enjoyed with the same travel time as before.

The idea is understandable descriptively but the specification of the regional cooperation effect is not clear. There are many practical studies about development of the regional cooperation corridors so far (Chuugoku Regional Research Center 1997, Ministry of Construction 1998). They point out that the service areas of some cities are enlarged by transportation network development and describe some expectation of regional cooperation effects. But there are fewer studies that discuss the regional cooperation effect itself. Aoyama and Yamamoto(1988) tried to do and considered time reduction and the consequent service area enlargement by expressway development but they did not mention the spatial aspects of the regional cooperation effect. We think that spatial effects are very important to analyze the regional cooperation effect. Otherwise, it is impossible to distinguish the cooperation effect from the regional interaction effect that is also often mentioned in the nation's general development plan.

We study the regional cooperation effect quantitatively focusing on the spatial aspects of them in this paper. We try to define the regional interaction effect and the regional cooperation effect produced by transportation network development respectively with use of traditional public facility location models in Chapter 2. Computation studies to grasp these effects in the Shikoku area are shown in Chapter 3. We summarize our findings and discuss the future research in Chapter 4.

2. REGIONAL INTERATION AND COOPERATION EFFECTS BY ROAD NETWORK DEVELOPMENT

2.1 Illustration of the Two Effects

We discuss the effects produced by general high-speed transportation system development in this chapter but we use the term the *road network development* here because we deal with only expressway development in the Shikoku area in this paper. The exact definitions of the regional interaction and the regional cooperation effect are shown in the next chapter. Instead, the brief images are illustrated here. We explain two concepts in the framework of the public facility location problem.

Suppose there are some tracts in a region and people in each tract have an identical public service demand per head. The demand is generated in each tract but the service is supplied at the place where a public facility is located. Then they have to travel from their living tracts to the nearest facility location in the meaning of travel time. Given a facility location pattern, an efficiency index value of the public service supply is measured. For example, we apply the total amount of peoples' travel time from their tracts to the facility location in the region. This index value varies with the road network characteristics and the facility location pattern. As road network development usually reduces travel time among tracts it improves the index value even if the facility location pattern is fixed. On the other hand, road network development changes the road network characteristics, that is, the travel time matrix of tract pairs. Since evaluation of the facility location pattern depends on the road network characteristics a facility location pattern is evaluated differently on the different road network. Therefore, even if a facility location pattern is found optimal according to the index value measured on a road network before development it is no longer optimal on the road network after development. But we can improve the index value by adjusting the pattern to the optimal one on the road network after development. Thus, road network development improves the index value in two ways, one is travel time reduction under the fixed location pattern and another is location pattern adjustment to the optimal one on the road network after development. The former is referred to as a regional interaction effect and the latter as a regional cooperation effect in this paper.

Smaller dots in Figure 1 shows tracts where people are living and public facility service demand is generated; a triangle symbol shows the facility location and a double straight line, an expressway. A dotted circle shows the service area of the facility location where people in each tract can approach the facility within a specific time when the expressway is not developed. While a full line circle shows the same kind of service area with the identical specific time but the service area is drawn on the network where the expressway has developed. The range of the full line circle is wider than that of the dotted circle because expressway development reduces travel time among tracts. Figure 1 represents travel time reduction effect on a fixed facility location pattern and it is considered to be regional interaction effect by road network development. Two triangles in Figure 2(a) show a facility location pattern, which is decided on the road network before expressway development. But this figure represents the situation after expressway development. The full line circle shows the service area after expressway development. One circle line lies upon another circle. It suggests that the location pattern is not optimal on the network after expressway development. Two arrows indicate the direction to be adjusted. Figure 2(b) shows the adjusted location pattern. It is optimal on the network after expressway development. The efficiency index value of the public service supply in Figure 2(b) is better than that in Figure 2(a). And the difference of the index value between 2(b) and 2(a) is considered to be the regional cooperation effect by road network development. Here there are two cases for the location pattern in Figure 2(a). If the pattern is optimal on the road network before expressway development the effect is called the regional cooperation effect in a narrower meaning. If it is not optimal, the effect is called the regional cooperation effect in a broader meaning.

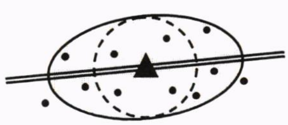
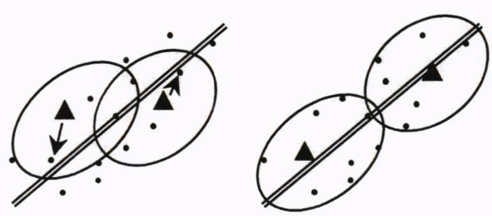


Figure 1. The Concept of
Regional Communication Effect



(a) (b)

Figure 2. The Concept of
Regional Combination Effect

2.2 Facility Location Models

2.2.1 Basic assumption

Generally the optimal location pattern depends on the property of the model adopted and the spatial character where facilities are located. Here we adopt very simple and classic models that were developed in 1960's. We do not solve a special facility location model of the real world in this study. Instead, we want to understand the general transport network development effects, particularly rhe network's potential ability. Then simpler models, p-median model and Maximal Covering Location Problem(MCLP) model are adopted. They are two of the three kinds of very popular classic discrete type models and are easily adopted on network spaces (Revell 1987, Hansen et. al. 1987). P-median model is more closely related to the distance or travel time between peoples' living tracts and facility locations while MCLP model is more loosely related.

Before introducing these models some basic assumptions should be stated. First, we do not consider any existing facilities. Second, people may want to use larger scale facilities because they are often more attractive but such scale or size effects are not considered in this study. On the contrary, people may want to use smaller facilities when the larger scale facilities are severely congested but such congestion effects are also not considered. This assumption means that capacities of facilities are not limited, in other words. Third, any costs to establish facilities including land acquisition cost are neglected. Fourth, a network space is assumed where tracts are presented as centroids of the network and arcs are characterized by travel time along them. Every centroid can be a candidate for the facility location. Fifth, people are assumed to use their nearest facility. The last assumption is that the population distribution pattern is identical even if the road network has improved.

2.2.2 P-median model

Locate p facilities on a network with discrete demand so that the average travel time of all users is a minimum. This problem can be stated as a zero-one programming problem as follows(Revell 1987):

$$\min Z = \sum_{i=1}^{n}\sum_{j=1}^{n} a_i d_{ij} x_{ij} \tag{1}$$

subject to

$$\sum_{j=1}^{n} x_{ij} = 1, \qquad i = 1,2,\ldots,n, \tag{2}$$

$$x_{ij} - x_{jj} \le 0, \qquad i,j = 1,2,\ldots,n,\ i \ne j, \tag{3}$$

$$\sum_{j=1}^{n} x_{jj} = p, \tag{4}$$

$$x_{ij} = (0,1), \qquad i,j = 1,2,\ldots,n, \tag{5}$$

where

a_i = relevant population at demand centroid i;

d_{ij} = shortest travel time, from i to j;

n = number of centroid;

p = number of facilities;

$$x_{ij} = \begin{cases} 1 \text{ if demand at } i \text{ assigns to a facility at } j, \\ 0 \text{ otherewise; and} \end{cases}$$

$$x_{jj} = \begin{cases} 1 \text{ if a facilitty opens at centroid } j, \\ 0 \text{ otherewise.} \end{cases}$$

The number of facilities p is exogenously given and d_{ij} travel time between demand point i and facility location j is also given according to the road network assumed. Then denoting road network T_l , the corresponding p-median problem is represented as (p,T_l) and the amount of objective function in the p-median model is represented as $Z(x_l^*,p,T_l)$, which is the solution of problem(p,T_l). Suppose a specific facility location pattern x^0 is given; that is, the value of x_{ij} is given. Then we assign x_{ij} the way that we obtain the minimum objective value satisfying those constraints. The objective function value obtained is shown as $Z(x^0,p,T_l)$

2.2.3 MCLP model

Allocate p facilities to positions on the network so that the greatest possible total population can be covered (service can be reached) within a stated time or distance standard S. In mathematical terms, the problem is (Revell 1987):

$$\max V = \sum_{i=1}^{n} a_i y_i \tag{6}$$

subject to

$$y_i = \sum_{j \in N_i} x_j, \qquad i = 1,2,\dots,n, \tag{7}$$

$$\sum_{j=1}^{n} x_j = p, \tag{8}$$

where

$x_j = 1$ if a facility opens at centroid j; 0 otherewise,

$y_j = 1$ if centroid i is covered within S; 0 otherewise,

$$N_i = \{ j | d_{ij} \le S \} \tag{9}$$

The number of p and S are exogenously given. The MCLP problem corresponding to a road network T_l is represented as problem(p,S,T_l) and the amount of objective function in the MCLP model is represented as $V(x_l^*,y_l^*,p,S,T_l)$, where the set(x_l^*, y_l^*) is the solution of the problem(p,S,T_l). When a specific facility location pattern x^0 is given the value of y_l is automatically calculated. The amount of objective function corresponding to the x^0 is shown $V(x^0,y^0,p,S,T_l)$.

2.2.4 The relationships of two models

The maximal covering location problem may be converted to a minimization problem by defining a new variable equal to the complement of y_i (Revell 1987):

$$\bar{y}_i = 1 - y_i = \begin{cases} 1 \text{ if demand } i \text{ is uncovered,} \\ 0 \text{ otherwise.} \end{cases} \tag{10}$$

When we replace y_i by $(1-\bar{y}_i)$, the problem becomes:

$$\min \sum_{i=1}^{n} a_i y_i \tag{11}$$

subject to

$$\sum_{j \in N_i} x_j + \bar{y}_i \ge 1, \qquad \forall i, \tag{12}$$

$$\sum_{j=1}^{n} x_j = p, \quad (13)$$

$$(x_j, y_i = 0,1), \qquad \forall i, j. \quad (14)$$

Comparing the objective functions in the converted MCLP model (11) with that in p-median model in (1), it is easily understood that as long as d_{ij} in (1) is less than S the travel time is evaluated as 1 in the objective function (11), while d_{ij} is larger than S the travel time is evaluated as 0 in (11). Then we compare travel time evaluation measures in the two models. Figure 3 shows the properties of the two models with relation to its travel time evaluation. It is suggested that the p-median model is more sensitive with travel time, that is, the optimal location pattern solved in the p-median model is more tightly related to densely populated areas. On the other hand, MCLP model is less sensitive with travel time, that is, the optimal location can be seen on tracts even if there are less population nearby.

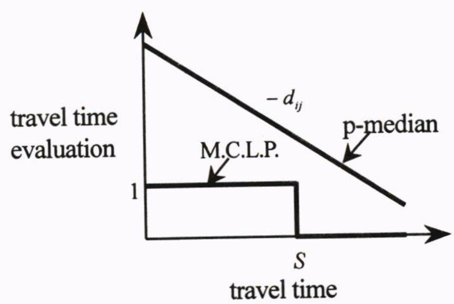


Figure 3. Travel Time Evaluation in p-median Model and MCLP Model

2.3 Definition of Interaction Effect and Cooperation Effect

The road networks before improvement and after improvement are denoted T_1 and T_2 respectively. It is not necessary to relate the concept of interaction effect to the optimal facility location. As for a given specified location pattern $\boldsymbol{x^0}$ the interaction effect by road network improvement is defined as follow:

p-median model,

$$Z(\boldsymbol{x^0},p,T_1) - Z(\boldsymbol{x^0},p,T_2), \quad (15)$$

MCLP model,

$$V(\boldsymbol{x^0},y^0,p,S,T_1) - V(\boldsymbol{x^0},y^0,p,S,T_2). \quad (16)$$

The effect can be called time reduction effect because the difference between the first term and the second term is generated by the time reduction caused by the road network improvement. Hereafter we use the term time reduction effect because it is more suitable for the above mathematical formulation.

The cooperation effect by road network improvement in the narrower meaning is defined as follows:

p-median model,

$Z(\mathbf{x}_1{}^*,p,T_2) - Z(\mathbf{x}_2{}^*,p,T_2)$, (17)

where, $\mathbf{x}_1{}^*$ is the optimal location pattern for p-median problem(p,T_1) and $\mathbf{x}_2{}^*$ is that for p-median problem(p,T_2),

MCLP model,

$V(\mathbf{x}_2{}^*,\mathbf{y}_2{}^*,p,S,T_2) - V(\mathbf{x}_1{}^*,\mathbf{y}_1{}^*,p,S,T_2)$, (18)

where, $(\mathbf{x}_1{}^*,\mathbf{y}_1{}^*)$ is the optimal location solution for MCLP problem (p,S,T_1) and $(\mathbf{x}_2{}^*,\mathbf{y}_2{}^*)$ is that for MCLP problem(p,S,T_2).

The effect can be called location adjustment effect because the difference between the first term and the second term is generated by the difference between two optimal location patterns and both terms are calculated using the value of travel time measured on the identical road network. Hereafter, we use the term location adjustment effect because it is more suitable for the above mathematical formulation.

The cooperation effect in the broader meaning is also defined as follow:

p-median model,

$Z(\mathbf{x}^0,p,T_1) - Z(\mathbf{x}_1{}^*,p,T_1)$, (19)

MCLP model,

$V(\mathbf{x}_1{}^*.\mathbf{y}_1{}^*,p,S,T_1) - V(\mathbf{x}^0,\mathbf{y}^0,p,S,T_1)$. (20)

3. A COMPUTATION STUDY IN SHIKOKU

3.1The Profile of Shikoku

Shikoku is one of the four main islands of the Japanese Islands and the location is shown in Figure 4. The area is 18,782 km^2 and the population was 4,195,000 in 1995. Most of the area is steeply mountainous and the rate of land covered by forest is 74.2%. Particularly, between 1,000 m and 2,000 m high mountains range from the east end to the west end in the central part. Then densely populated areas are spatially separated. Thus, population of the major metropolitan areas are Takamatsu metropolitan area 614,000; Matsuyama, 604,000; Tokushima, 568,000; Kochi, 458 ,000 and Toyo consolidated metropolitan area, 361,000. The total population of the five metropolitan areas is 2,605,000 and its share in Shikoku is 62.1%. They are all located along the coast and separately distributed. Each central city of the former four metropolitan areas is a prefectural capital.

3.2 Zoning

Zoning and ordinary road network in this study are specified according to the future road network improvement plan of Shikoku area planned by the Ministry of Construction of the central government. Shikoku Island, the main island part excluding its related small islands, is divided into 258 zones. These zones are divided along municipality boundaries in rural areas but larger cities are divided into several zones. Then the population at the maximum population

Figure 4. Location of Shikoku

zone is about 105 thousand while that of the largest city in Shikoku is 443 thousand. This zoning is suitable for facility location models. If the study area is divided only according to municipal boundaries the population distribution characteristics of a smaller number of densely populated cities affects the solution of the model. Figure 5 shows the distribution pattern of zones. They are densely distributed in major metropolitan areas and the populations in those zones are relatively larger.

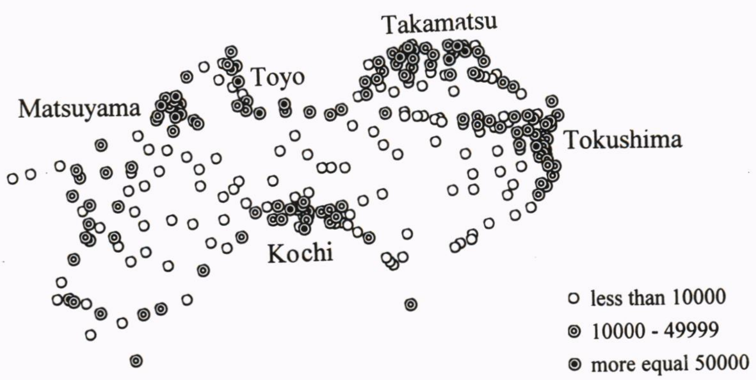


Figure 5. Demand Zone Distribution

3.3 Road Network

Figure 6 shows the ordinary road network in Shikoku. It is composed of national highways and some major prefectural roads. It has 697 nodes and 1,038 links and the total length of the network is 5,123 km. Actual road networks in metropolitan area are dense but they are simplified in Figure 6 to avoid a complicated figure. Figure 7 shows an expressway network. This is not the actual network at present but that in the near future as some sections are under construction. The total length of the combined network of the ordinary road network with expressways is 5,736 km and the number of nodes and links are 726 and 1,159 respectively. Hereafter we call it simply an expressway network. Actually, the road network in Shikoku has been connected with that of Honsyuu, the main land of Japan, since 1988. The second connecting bridges were completed in 1998 and the third in May 1999. However, the road network in our computation study is isolated from that of Honsyuu because of some conveniences of calculation.

The value of running speed on a link is specified to be identical to the one used in the plan by the Ministry of Construction. It changes from 30 km/h to 60 km/h on the link in the ordinary road network depending on the condition of the link. The running speed on an expressway link is generally specified 80 km/h.

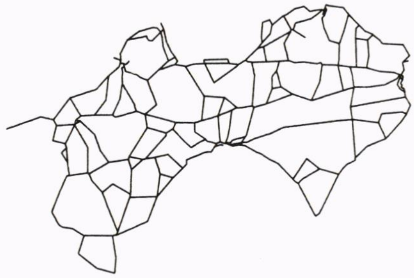


Figure 6. Ordinary Road Network

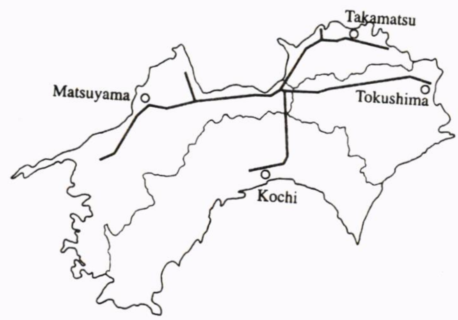


Figure 7. Expressway Network

3.4.Computation Results of p-median Model

Figure 8 shows the facility location patterns generated by p-median problems on the ordinary road and the expressway network. The optimal location of the facility with p=1 is on zone 63 in the ordinary road network. It means that the central point of population gravity of Shikoku measured on the ordinary road network is located there. But it is moved on zone 140 when we measure it on the expressway network. This is because that a junction of two expressway lines is located on the point very close to zone 140. The optimal facility locations with p=2 are seen on a north western zone and a central-eastern zone on both networks. It suggests that the central-eastern and western regional division is efficient when we have two facilities. The optimal facility locations with p=3 on the expressway network is different from that on the ordinary road network. Facilities are located on a north eastern zone, a north western zone and a south central zone on the ordinary road network but they are on an east end zone, a north central zone and the north western zone on the expressway network. The difference is generated by expressway network development. Before expressway development the range of steep mountains from east to west in Shikoku was a severe transport burden. Therefore, it is efficient that one facility should be located on a southern zone of the mountain border. However, the burden has been overcome by expressway development. The optimal location pattern with p=3 on the expressway network reflects just a topological character of Shikoku that the length of east-west axis is longer than that of south-north axis. Especially, the length along south-north axis is short in the central part of Shikoku. As for the optimal location pattern with p=4 they are almost identical on both networks and each location is in the prefecture capital city or zone close to the city.

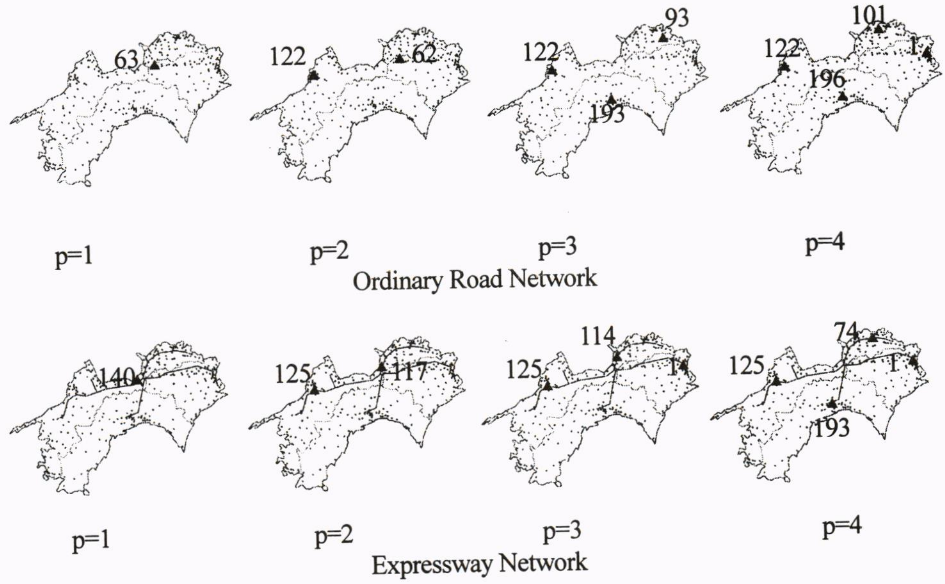


Figure 8. Facility Location Pattern Calculated by p-median Model

Table 1 shows the average travel time to reach a facility calculated by p-median model. Both the optimal location patterns on the ordinary road network and expressway network are calculated by solving corresponding p-median problems. This is calculated also when we fix facility locations on some specified zones. Such zones are chosen from the representative zones of the four prefectural capital cities because they are densely populated. When the number of p is four a location pattern composed of each representative zone of the four prefectural capital cities is used. When the number is 3 there are possible trios of three zones selected from the four cities. The prefectural capital city location pattern is the one, which gives the smallest objective function value among possible trios. The pattern inj the case of p=1 or 2 is obtained the same way. It is seen that the value of average travel time for the optimal location pattern is slightly smaller than that of the prefectural capital city pattern. This is because the optimal location pattern of p-median model is generated in a way to locate facilities on zones close to the densely populated areas. The difference of average travel time between the optimal and the prefectural capital city in the case of p=1 is larger and it reduces as p increases. It reflects the population distribution pattern in Shikoku that is concentrated on zones around prefecture capital cities and each prefecture capital city is separately located. A special average travel time to reach a facility is calculated to evaluate the location adjustment effect, that is, the regional cooperation effect with use of equation (17). In this way the location is fixed on the optimal zone on the ordinary road network but the travel time from each demand zone to the facility location is measured on the expressway network. This location pattern is called the old optimal hereafter.

Table 2 shows the value of time reduction effects and location adjustment effects calculated using equation (15), (17), (19). It is seen that the time reduction effect is much larger than the location adjustment effect in each p number case. The p-median solutions have the characteristics that facilities have to serve all zones and the objective function represents that they should be closely connected to the densely populated area.

Table.1 Average Travel Time to Reach a Facility in P-median Problem (minutes)

Number of Facilities	Location Pattern	Ordinary Road	Expressway
1	optimal	117.40	73.37
	the prefectural city	141.95	94.33
	old optimal		75.50
2	optimal	81.03	56.61
	the prefectural city	83.73	64.42
	old optimal		63.85
3	optimal	53.65	44.48
	the prefectural city	55.18	48.22
	old optimal		47.05
4	optimal	39.90	33.72
	the prefectural city	40.68	35.01
	old optimal		34.87

3.4.Computation Results of MCLP Model

The MCLP model has two kinds of parameters, p and S, maximal allowable travel time. It is generally considered that the values of S would be decided according to the kind of facilities which are considered in the problem. However, it does not make sense to specify the character of a facility because we are discussing general the meaning of transportation development effects. The former study suggests that a standard of 80% residents covered is suitable to examine the location patterns calculated by MCLP model in Shikoku(Kashiwadani et.al. 1998). We suppose three cases of p=1, 2 and 3 because the National Land Agency says that the regional cooperation effect helps us attain a better living standard with fewer but more attractive facilities. The corresponding S value to the number of p which guarantees 80% coverage is found to be 90, 70 and 60 minutes for each case of p=1, 2 and 3 respectively.

Table 2. Time Reduction and Location Adjustment Effects in p-median Model (minutes)

Number of Facility	Time Reduction	Location Adjustment		
		narrower	broader	
			before	after
1	41.90	2.13	24.55	20.96
2	17.18	7.24	2.70	7.81
3	6.60	2.57	1.53	3.74
4	5.03	1.15	0.78	1.29

Table 3 shows the amount of covered areas calculated by MCLP model. Figure 9 shows the optimal facility locations and their cover areas on the ordinary road network and the expressway network. The value of covered population rates on the ordinary road network are less than 70% for the three cases while those on the expressway network are more than 80%. The four prefectural capital metropolitan areas are covered in every case on the expressway network while Kochi, south central area of Shikoku, has never been covered in every case on the ordinary road network. It is easily understood that expressway development has greatly contributed to enlarge the range of covered areas, the location pattern on the expressway network is generally different from that on the ordinary road network for each case. Generally the location pattern on the expressway network moves in the western direction compared with that on the ordinary road network.

Table 3. Amount of Covered Areas in MCLP Problem (%)

Number of Facilities (Allowable Time Distance)	Location Pattern	Ordinary Road	Expressway
1 (90minutes)	optimal	43.33	80.70
	the prefectural city	33.46	44.98
	old optimal		66.15
2 (70minutes)	optimal	56.70	81.21
	the prefectural city	48.39	55.91
	old optimal		66.89
3 (60minutes)	optimal	68.83	82.58
	the prefectural city	60.25	68.71
	old optimal		69.64

Table 4 shows the time reduction effect and the location adjustment effect in the three cases. Generally speaking, considerable volumes of location adjustment effects are seen including both narrower and broader meaning terms. They are much larger than those calculated by p-median model which are seen in Table 2. The value of location adjustment effect in the narrower meaning is larger than that of time reduction effect for two cases of p=3, S=60 and p=2, S=70. On the contrary, the former is smaller than the latter for the case of p=1, S=90. Basically the size of the covered area of a facility becomes larger as the allowable travel time S increases. Then it is considered that time reduction effect becomes larger as the value of S increases. But the value of location adjustment effect remains a certain amount in the three cases. It means that the facility location pattern in the MCLP model can move more freely compared with that of the p-median model because its objective function does not involve directly the travel time between a demand zone to a facility location.

4.SUMMARY AND CONCLUSION

Regional interaction and regional cooperation are one of the major concepts of Japanese regional planning in the 21st century. However, the definitions of the concepts have not been clear. We tried to define these effects produced by transportation system improvement quantitatively using the public facility location model framework. The interaction effect is explained as the enlargement of the service area or accessibility improvement to reach a facility where the facility location pattern is fixed and the transportation system has changed. On the other hand, the cooperation effect is the one where the facility location pattern has changed while the transportation system is kept as before. Thus, the interaction effect is defined as

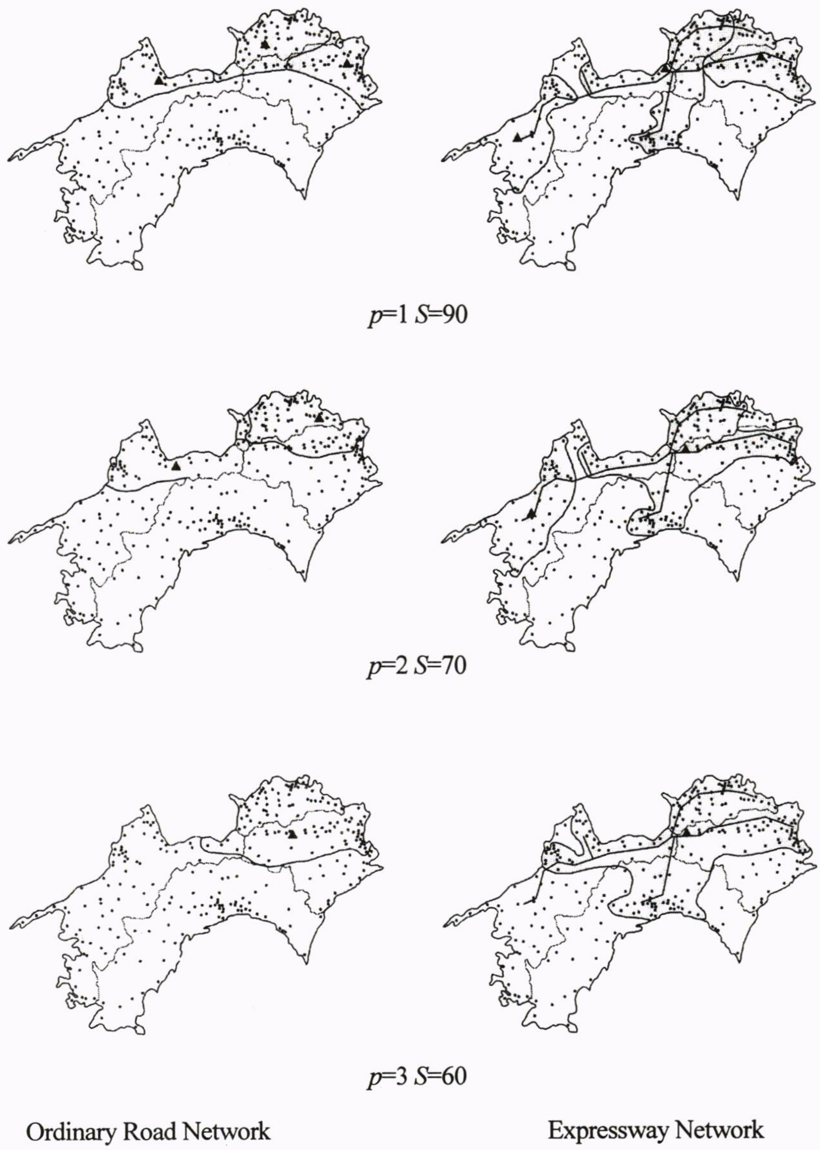


Figure 9. Location pattern and Covered Areas Calculated by MCLP model

Table 4. Time Reduction and Location Adjustment Effects in MCLP Model (%)

Number of Facilities (Allowable Time Distance)	Time Reduction	Location Adjustment		
		narrower	broader	
			before	after
1 (90minutes)	22.82	14.55	9.87	35.72
2 (70minutes)	10.19	14.12	8.31	25.30
3 (60minutes)	0.86	12.89	8.98	13.87

the time reduction effect and the cooperation effect as the location adjustment effect in the public facility location problems. They may seem to be slightly strict explanations because the facility location pattern usually changes when the travel time reduction of area scale has emerged after transportation system improvement. Therefore, the regional cooperation effects are often discussed including the interaction effects in practical regional planning works. But we believe the explicit division of the two kinds of effects helps us understand the transportation system development effects more systematically.

The regional interaction effect and the regional cooperation effect are computationally examined for the expressway development in Shikoku area. Two facility location models, p-median model and MCLP model are adopted to reflect people's different behavior against the travel time to a facility, more reluctant or less reluctant. It is shown that the magnitude of regional cooperation effect is generally smaller than that of regional interaction effect when we measure them using p-median model while it is gradually large and sometimes larger than that of regional interaction when we use MCLP model. This fact means that if the facility is characterized as one in which users are more sensitive to the travel time to a facility the regional cooperation effect would be small. But if the facility users are less sensitive to the travel time there would be the regional cooperation effect of a gradually larger scale. Thus, we can expect to a certain extent when we plan to locate a footloose type facility, for example, a large scale sport stadium, high-grade theater or high-grade hospital with special equipment, which users are not so sensitive to their travel time.

It should be noted that the computation results may not be general but related to the spatial characteristics of Shikoku, the spatial size of the area, population distribution patterns and the shape of the road network including expressways and so on. Therefore, the magnitude of the both effects would depend on the spatial characteristics of the study area. However, the definition and measurement method of the effects would be still effective in any study area.

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