A Study on the Optimum Size of a City

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Abstract

The overconcentration of population centered around metropolis areas and the outflow from small local cities and villages over recent years have been upsetting the balance of the living environment for man, causing various social problems. These are, destruction of the ecological balance, air pollution, health impairment, alienation of human relationships, increase of traffic accidents, and others.

This study, in analyzing the factors that influence a city, especially from the point of view of the population concentration, intends to discuss the optimum size, and environment of a city.

In forming the optimum size, the concept of urbanization index is applied. This index indicates comprehensively the degrees of the urban growth and development, and consists mainly of the functions and the environments of a city.

In this study, the method of the principal axis factor analysis is applied to the functions and the environments of 46 cities which are the local government seats of in Japan up to 1968, and as a result, it has become obvious that the following three factors are dominant in order to apply the urbanization index.

Primary factor:	agglomeration index
Secondary factor:	facility density index
Third factor:	industrial structure index

In the second place, 37 variables to be mentioned later, are classified into two groups with the method of the factor analysis: one group with 24 positive composite variables, and the other with 13 negative. The former indicates the agglomeration index, whereas the latter expresses the space index. Thus, assuming that the optimum urban environment may be defined as the junction point on which the above two groups of the composite variables come to meet at a well balanced co-existance, it may be deduced that the optical size is 400,000 in population, and 1,600 persons/km^2 in population density; the density is the mean of the resident district with the biggest density and the fringe urban areas.

It goes without saying that the apporopriate urban environment cannot be obtained by such quantities as size and density of population, and itself evident that the qualities and placements of urban facilities or the socialstructure are the decisive elements.

Therefore, this study is a mere tentative suggestion for the better understanding of the optimal size of a city.

1. Selection of the urbanization index

The urbanization index consists of the urban functions and the urban environments.

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The urban function consists of the following three items ; the population structure index which is the foundation element of a city, the information management index which controls the nerve and brain of a city, and the economic accumulation index that indicates the economic potentialities of a city.

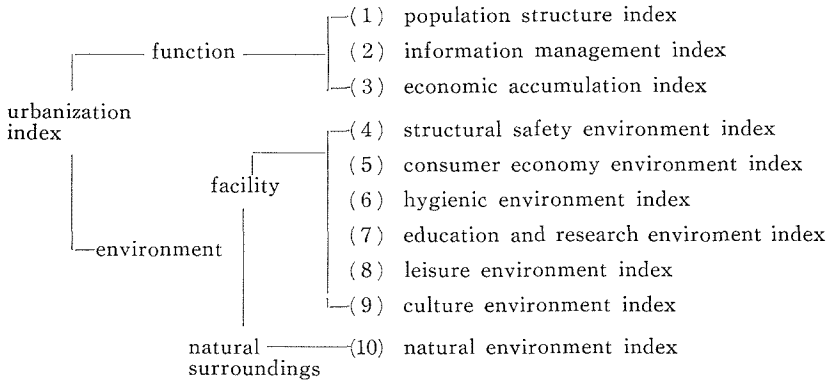

Fig. 1. Structure of the urbanization index.

Here, the urban environment is divided into seven items ; the structural safety environment index which indicates the degree of safety and facilities of transportation, the environmental indices of the consumer economy, hygiene, education and research, leisure, culture, and the natural surroundings. And five categories of each of the above ten items, with the exception of the natural surroundings into which four categories are introduced, become the basic variables.

In the first factor analysis, however, we have examined all 68 categories taken from the municipal year book of Japan, the statistical handbook of municipalities, and other statistical books available. As a result 49 categories are chosen for further analysis from a viewpoint of analytical results and some technical considerations.

Table 1. Basic variables in applications

(1) population structure index	1. population growth rate
	2. population density
	3. primary industry employee rate
	4. secondary industry employee rate
	5. tertiary industry employee rate
(2) information management index	6. government agencies
	7. head offices of businesses
	8. universities
	9. press and broadcasting corporations
	10. major publishers
(3) economic accumulation index	11. business establishments
	12. industrial sales
	13. sales volume
	14. computerization
	15. bank deposits
(4) structural safety environment index	16. commuter rate with less than 30 minutes-time-distance

	17. park rate
	18. municipal pavement rate
	19. fire disaster rate
	20. traffic accident rate
(5) consumer economy environment index	21. department store sales volume per capita
	22. number of tatami floor mats per capita
	23. land price of building site
	24. income/price rate
	25. telephone diffusion rate
(6) hygienic environment index	26. city water supply diffusion rate
	27. sewage disposal plant rate
	28. garbage disposal plant rate
	29. medical service per 10,000 residents rate
	30. public medical insurance rate
(7) education and research environment rate	31. kindergarten enrollment rate
	32. elementary school yard space rate
	33. university student enrollment rate
	34. library circulation rate
	35. research institutions
(8) leisure environment index	36. sports facility space per capita
	37. distance to seaside resorts
	38. distance to golf courses
	39. bowling alleys per capita
	40. botanical and zoological gardens
(9) culture environment index	41. public cultural assets
	42. places of historical interest and sight seeing spots
	43. major cultural organizations
	44. museums and aquariums
	45. art galleries
(10) natural surroundings index	46. temperature
	47. duration of sunshine
	48. distance to Tokyo
	49. location index

2. Factor analysis with 49 variables

The correlation matrix is calculated at first using 49 categories of 10 items, which were selected out of 68 variables. As the second step, the structures of composite variables were examined. Then those variables were arranged and divided into five groups in the order of their size. As a result the most influential variations of the urbanization indices, the primary, the secondary, and the third factors and so on were clearly shown.

(1) The primary factor (facility density)

The primary factor amounts to a considerable proportion of 39.19% of the total variations. It contains categories of government agencies, head offices of business, universities, business establishments, major publishers, sales volume, industrial sales, bank deposits, computerization, etc. These are primarily the indices of economic

accumulation and the information management, and even most of other categories in the primary factor are eventually related to agglomerative variables. Thus, the primary factor may be called the agglomeration index.

(2) **The secondary factor (facility density)**

Among the total variations, 9.37% is explained by the secondary factor. Taking the high structure values of the composite variables, these are the primary industry population rate, public medical insurance rate, library circulation rate, sports facility space rate, and others. Therefore, it is difficult to give a general name to the secondary factor. However, if we can refer to it as the urban facility density factor, this may be permissible because it has less correlation to the size of a city.

(3) **The third factor (industrial structure)**

The third factor indicates 6.5% of the total variation. Among the indices of the factor, the superior index of the positive structure is the secondary industry population rate, whereas the negative index is the tertiary industry population rate. It also has no correlation to the population or the daytime population. As a result, the third factor is assumed to be related to the industrial structure. A city with positive composite variables is considered to have more of the characteristics of the secondary industry; in contrast, that with the negative variable is closer to the tertiary industry.

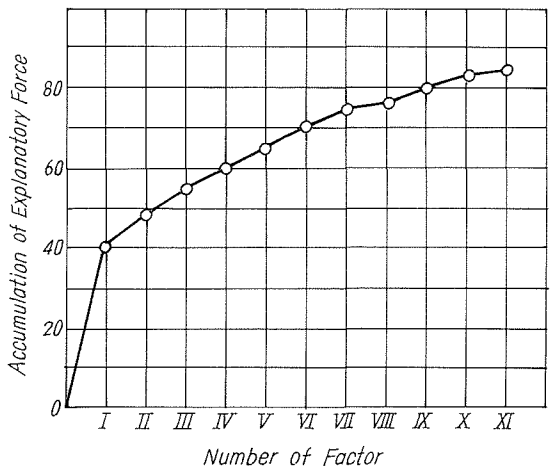

Fig. 2. Explanatory Force of Factors.

From the above mentioned considerations, we can understand the brief characteristics of the three factors, from the primary to the third. Although there still remains some doubt, we may refer to them as such, tentatively.

3. Factor analysis with 24 and 13 variables respectively

Out of the 49 variables analysed previously that express the urbanization function, 14 variables are excluded except for the population density, and two variables are newly added to the variables of the urban environment, in other words the expenditure and the rates of city tax. And these 37 variables were subjected to factor analysis. The results are shown in Table 2 which include 24 positive variables of the first composite variable structures, and 13 negative variables. Furthermore, factor analysis is again applied to both of the above two groups of variables respectively.

The above procedure is not for the selection of the factors nor is it for categorizing but it is rather for the calculation of the composite variables on the 46

Table 2. Structures of the compositive variables (37 variables: principal axes factor analysis)

		1st composite variable structure	2nd composite variable structure	3rd composite variable structure
1.	city expenditure per capita	△0.460	○−0.416	−0.057
3.	city tax per capita	◎0.856	0.060	0.103
3.	density of population	◎0.871	0.050	−0.038
4.	commuter rate with less than 30 minute-time-distance	○−0.667	0.228	−0.001
5.	municipal pavement rate	◎0.801	0.059	−0.129
6.	municipal park space rate	0.023	−0.223	◎0.590
7.	fire disaster rate	0.271	−0.273	○−0.340
8.	traffic accident rate	0.211	○−0.370	△0.464
9.	department store sales volume per capita	0.251	0.091	○−0.326
10.	number of tatami floor mats per capita	−0.267	△0.353	0.031
11.	land price of building site	◎0.915	0.094	0.028
12.	income/price ratio	◎0.862	0.172	0.131
13.	telephone diffusion rate	◎0.858	0.039	0.181
14.	city water supply diffusion rate	△0.467	○−0.330	−0.082
15.	sewage disposal facility rate	−0.042	△0.416	○−0.399
16.	garbage disposal facility rate	−0.217	−0.085	−0.189
17.	medical service per 10,000 residents rate	0.267	○−0.319	−0.044
18.	public medical insurance rate	−0.331	△0.389	0.267
19.	kindergarten enrollment rate	−0.029	0.003	◎0.890
20.	elementary school yard space rate	○−0.688	△0.316	0.142
21.	university student rate	◎0.586	0.170	0.087
22.	library circulation rate	○−0.514	△0.449	0.072
23.	research institutions	◎0.723	△0.485	−0.040
24.	sports facility space	○−0.505	◎0.509	0.188
25.	distance to seaside resorts	−0.192	○−0.582	0.108
26.	distance to golf courses	0.080	−0.230	−0.149
27.	bowling alley rate	−0.001	0.067	△0.461
28.	botanical and zoological gardens	◎0.694	0.051	−0.033
29.	public cultural assets	◎0.765	△0.442	0.130
30.	places of historical interest and sight seeing spots	◎0.504	0.265	0.171
31.	major cultural organizations	◎0.697	△0.483	−0.038
32.	museums and aquariums	△0.435	○−0.357	−0.051
33.	art galleries	◎0.811	△0.411	−0.054
34.	temperature	−0.259	△0.371	○−0.470
35.	duration of sunshine	0.122	○−0.304	△0.353
36.	distance from Tokyo	○−0.331	○−0.418	−0.163
37.	location index	◎0.729	−0.154	−0.128

◎ structure a $0.8 \leqq a \leqq 1$ ◎ structure a $0.5 \leqq a \leqq 0.8$
△ structure a $0.3 \leqq a \leqq 0.5$ ○ structure a $a < -0.3$

cities, by means of the agglomeration index and open space index which is a negative form of the agglomeration index.

4. Optimum size of a city

It is difficult to define or other wise ascertain the optimal size of a city because of the innumerable valiables and factors involved. Even though an answer may be derive, it may be complicated and diverse at the same time. Our discussion here is only one approach to the solution of such a problem, and it is by no means a complete accomplishment.

In attempt to deduce an answer to this question, we have calculated the optimum sizes of the population and the population density shown in Figure 3 and 4, by

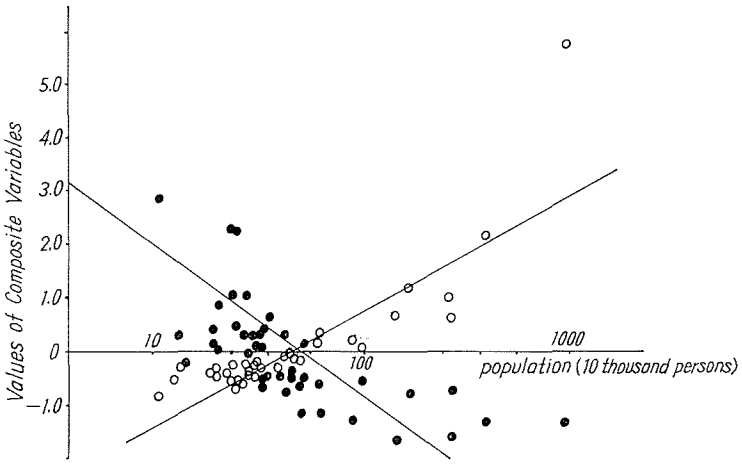

Fig. 3. Balancing Point of Population between Facility Agglomeration and Open Space.

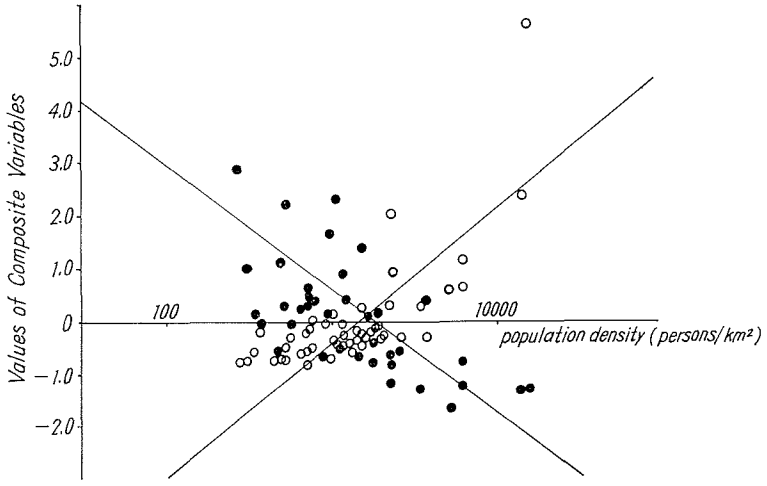

Fig. 4. Balancing Point of Population Density between Facility Agglomeration and Open Space.

dealing with the so-called agglomeration index and the open space index; the former has first composite variables of 37, or 24 variables respectively, and the index is considered to make efficiencies and varieties larger. And the latter indicates the first composite variables of 13 out of 37 environmental variables, which show a negative agglomeration in the primary factors. As a result of our present calculations, the optimum size of a city in Japan has a population of 400,000 with a population density of 1,600 persons/km^2.

Selecting such cities which meet the above conditions; we have Kanazawa, Wakayama, Okayama, Niigata, Gifu and Shizuoka which satisfy the size of population, and Okayama, Tzu, Maebashi, Wakayama meet the size of the density of population. Thus, Okayama and Wakayama meet both conditions.