ANALYSIS SYSTEM FOR LOCAL STREETS NETWORK IN OLD DEVELOPMENT AREAS IN JAPAN

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INTRODUCTION

The aim of this study is to develop an analysis system of local streets networks in old developed residential areas, in order to assist planners in defining problems and preparing improvement plan of local streets.

In Japan, there are many residential areas which have disorderly street systems. Most of them are located in outskirts of the city and were sprawled carelessly after 1950s when controls on land development and buildings were loose. Some of them in inner city areas were developed under old planning schemes, for example, arable land's readjustment which was applied to land owners to subdivision after 1919.

The street network of these areas have many narrow roads and blind alleys. It is not only inconvenient for motorists and hazardous in case of fire and disaster prevention, but also limits the practical use of the land. To plan the improvement scheme for these areas, it is important to analyze the performance of the street networks.

First, in this paper, a geographic data base of street network and building lots is developed using Digital Town Maps recorded in CD-ROM. Second, the analysis methods of the street network are developed. By these methods, networks can be evaluated from different viewpoints, namely; vehicle accessibility from arterial streets, safety on streets, accessibility of fire engines and the value of land. By employing this system, improvement plans of street networks in old residential development area are analyzed. Comparing the alternative plans of different length of widening streets, the appropriate level of road space for the area is clarified.

1. DATA BASE OF LOCAL STREETS AND BUILDING LOTS

A data base system is useful and necessary for computational work of analysis. For this study, the data base is developed consisting of data listed in Table 1. As shown in the table, CD-ROM Town Maps (*Denshi Jutaku chizu*) are potential tools in making operational geographic data base in this study. They can be attained on the market for lower costs than custom made data bases. The software is also developed to define detailed street networks and estimate population from the data recorded in CD-ROM.

1.1. CD-ROM Town Maps

CD-ROM Town Maps are machine readable plans of urban areas consisting of building shapes and residents' names. two or three companies in Japan developed and are selling CD-ROM Town Maps, which are different in their coverage of cities. Stored data in the CD-ROM consists of streets lines, buildings shapes, map symbols and characters. Names of all residents and offices in multiple dwelling buildings are also stored in addition to the names of buildings and urban facilities (shown as Figure 1).

Table.2 shows the items of data stored in the CD-ROM Town Map. These are classified to 64 layers, which can be selected and overlaid. This CD-ROM Town Map is based on the 1:2500 scale plans, which are made by local authorities for their town planning

Table 1 Data base for Local Street Network Analysis System

Elements	Data	Data source
Street Network	Geographical data	CD-ROM Town Map
	Width Traffic restriction	CD-ROM Town Map
Building Lots	Boundary of lots	CD-ROM Town Map Land Use Census map
	Land use	Land Use Census data
Population	Zone boundary	Zone map of Census Zone map of Bussiness Place Census
	Residents' population Workers' population	Census Bussiness Place Census

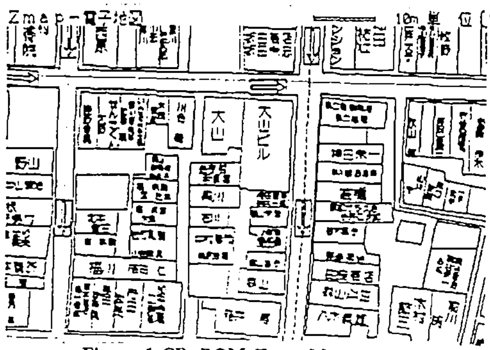

Figure 1 CD-ROM Town Map

Table 2 Stored data in CD-ROM Town Maps

Group	Layer	Data
Roads	Motoway, National higjway, Primary Distributor, Local street, Road under construction, Hidden roads.	LN
Railway	JR, Metro, Monorail, Private railway,Railway under construction, Cable-car	LN
Water	River, Coastline, Lake/pound, Stream	LN
Road Facility	Bridge, Tunnel-entrance, Sidewalk, Cyclic road	LN
Topography	Field boundary, Contour line, Topography shape	LN
Facility	Mine, Stairs, Water gate, Gate, Electric line	LN
Building	General buildings, Buildings for land-mark, Facility without wall, Hidden building	PG
Map Symbol	Building symbol, Field symbol	CD
Administrative Boundary	Prefectural boundary, City boundary, Town boundary, Zone boundary, Block boundary	LN
Address	Land number, Block number, Town name, Zone name	CD
Name	Land mark name, Building name, Facilities name	CD
Map sheet	Sheet boundary, Sheet number	LN,CD

Note: LN :line type data PG :polygon data CD :character codes and are based on ortho rectified aerial photographs. They have position data digitized at 0.1m accuracy. However, the positional accuracy of the database is not clarified. There are the following advantages in using the CD-ROM Town Map for the data base of town or street planning.

1) The cost of introduction and renewal data is lower than the custom made data base
2) The system is able to be employed on a small computer, and is user friendly.
3) The uniform format of the data base can be adopted for many cities where the CD-ROM Town Map is published. This improves the system portability.

1.2. Detailed Street Network

For the data on street networks in the CD-ROM database, outlines of roads and boundary lines of city blocks are stored (shown as Figure 2). It is necessary to redefine the detailed network from these data. Most of the outlines of city blocks are fitted to center lines of the streets, but they also include center lines of rivers and so on, and exclude center lines of some streets such as narrow alleys existing in the blocks.

The system offers methods of defining the street network shown in Figure 3. The first method uses a CAD procedure for supporting the change of block outlines to a street network. The system is developed to automatically cut links which are not street center lines by checking whether they cross street outlines or not. Additional links are entered on the screen using a pointing device (i.e. mouse or digitizer). Node matching procedure is to convert the links of streets, which when entered are only isolated vectors on the data structure level, to the network data

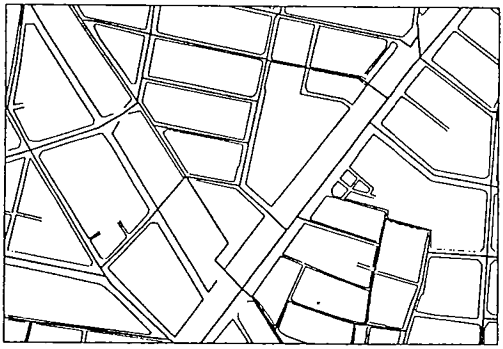

Figure 2 Data concerned with street network in CD-ROM Town Maps

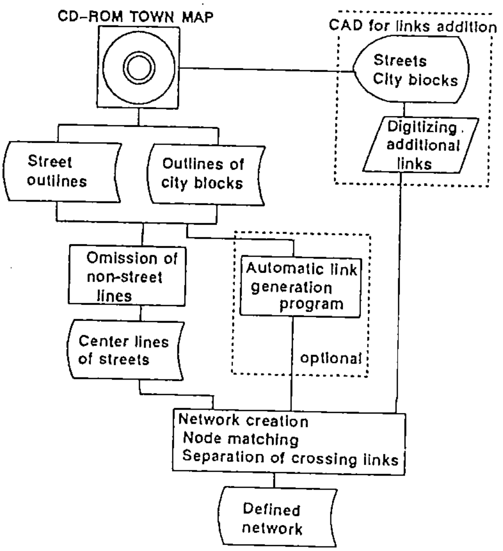

Figure 3 Process of network defining

structure. The second method is an automatic way to generate additional links for block outlines. Center lines of streets can be generated from the outlines of roads by the same method of "thinning" as in image processing. Street width and side-walk width can be also estimated for the attribute data of each street.

1.3. Building Lots

All lines of the polygon shape indicating the boundary of each building lot are also entered to the data base by editing the CD-ROM Town Map data. Land Use of these lots are classified to "detached dwelling", "apartment house", "shop","office","factory" and "farmland" by using the names of buildings or map symbols recorded in CD-ROM and map of land use survey.

1.4. Estimation of Population

The following models can be used to estimate the resident and day-time work population of small zones in the district, such as along a street section or in a city block. The models are estimated by the multi-regression method using statistical population data of each zone of towns which are administratively defined by address name. The explanation variables of this model are calculated from the values of the database of the CD-ROM concerning the number and building area of dwellings. These population models estimated in the case study area; Kami district, in Osaka city. Table 3 shows these results.

Table 3 Calibration results of population model

Model	Estimated value of parameters (t value)			R^2 (samples)
Residents'	a_1	a_2	a_3	0.9551 (51)
Population	3.603 (10.13)	2.353 (12.52)	1.154 (2.33)	
Workers'	b_1	b_2	b_3	0.9423 (20)
Population	0.2588 (3.44)	0.0347 (1.21)	0.0093 (6.02)	

$$Rp_i = a_1\ NDH_i + a_2\ NDA_i + a_3\ NFC_i$$

where

Rp_i :Estimated residential population in zone i

NDH_i :Total number of detached houses in zone i

NDA_i :Total number of dwellings in apartment houses in zone i

NFC_i :Total number of small factories in zone i

$a_{1,2,3}$:Parameters

$$Wp_i = b_1\ ABS_i + b_2\ ASH_i + b_3\ AFC_i$$

where

Rp_i :Estimated residential population in zone i

ABS_i :Total floor space of office buildings in zone i (m^2)
ASH_i :Total floor space of shops in zone i (m^2)
AFC_i :Total floor space of factories in zone i (m^2)
$b_{1,2,3}$:Parameters

2. ANALYSIS MODELS OF LOCAL STREET NETWORKS

The analysis methods of the street network are developed to evaluate them from different viewpoints, namely; vehicle accessibility from arterial streets, safety on streets, accessibility of fire engines and value of land.

2.1. Vehicle Accessibility

The evaluation model of vehicle accessibility is developed by discriminant analysis. By analyzing data from a survey in which the residents' sense of convenience for car access from the collector type street to their home was investigated, the following model was developed. By predicting minimum access time to their home from the nearest collector type street and employing this model, the ratio of people who are not satisfied with accessibility can be estimated. In this study the collector type street is defined as a street with for lanes.

$$Pa_i = \frac{f(Ya_i - 0.480)}{f(Ya_i + 0.450) + f(Ya_i - 0.480)}$$

$$Ya_i = 0.28\ AT_i - 1.60$$

where
Pa_i :The ratio of people living along street i who find it inconvenient to go home from the nearest collector street.
$f(x)$:Equivalent to $\exp(-x^2/2)$
Ya_i :Discriminant function score of street i
AT_i :Minimum access time to street i from the nearest collector street.

The minimum access time is predicted under the following condition.

1) Link time function : LTi(sec.)=length(m) 3.6/(1.5 width(m) + 9.0)
2) Loss time of turn at the intersection : 5 (sec.)

2.2. Safety on Streets

To evaluate the safety on streets in the district, the index of occupancy of moving vehicles(1) is adopted. The occupancy index represents the ratio of demand space of moving vehicles against total space of road, and can be calculated from average traffic volume, speed of vehicles and width of the road. By using this index, the relationship of road space and traffic demand can be considered in evaluating safety on streets. By analyzing the residents' sense of safety about their frontal streets and occupancy index of the streets, the following model is developed.

$$Si = c_0 + c_1\, QCi$$

$$= c_0 + c_1\, (1000\, ACi\, Qi) / (Wi\, VSi)$$

where

Si :Safety index on street i (ratio of people feeling unsafe by using the street)
QCi :Occupancy index of moving vehicles
ACi :Average road space occupied by one vehicle moving at speed of VSi (m^2)
Estimated value of AC = (0.84 VSi + 6) * 2.75
Qi :Traffic volume on street i (vehicles per hour)
Wi :Width of street i (m)
VSi :Average speed of vehicles (km per hour)
Estimated value of VSi = 1.117 Wi + 0.049 Li + 11.0
Li :Length between intersections on both ends of street i
c_0,c_1 :Parameters
Estimated values : $c_0 = -0.42$ $c_1 = 15.73$ R=0.856 Number of samples=21

To apply this model to the evaluation of street network plans, it is necessary to estimate traffic volume of all links in the area if we use estimated values of vehicle velocity. In this study, the step estimation methods (2) are applied for this purpose.

2.3. Accessibility of Fire engines

To evaluate the overall performance of fire engines in case of fire within the local street network, use the access time of fire engines to each street in the area from the nearest fire station. The access time is estimated by seeking the minimum time path under the following condition.

1) Time on streets : The average speed for fire engines to go through link isassumed to depend on the minimum roadway width. Figure 4 shows the velocity

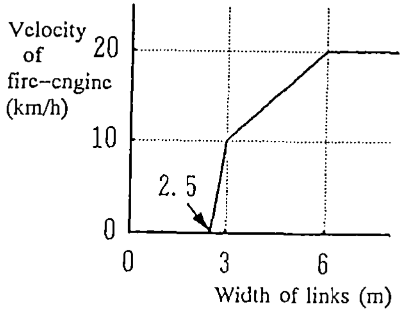

Figure 4 Velocity and width function of fire engines

function at each width, which is defined by the experimental data by Tokyo Metropolitan Fire Defence Board.

2) Lost time of turning at intersections : It is assumed that it takes 5 seconds to turn at intersections.

2.4. Value of land

To widen road space for network improvement, it is necessary to change the shape and decrease the area of building lots. On the other hand, the widening of the roads increases the value of land along them. To evaluate total increase of value of each lots, the following land evaluation method is applied, which is commonly used for land readjustment projects.

$$LVj = STIj\ Aj + VCLj + VTLj$$

where

LVj :Value index of the lot j

STIj :Street value indicator in front of the lot j ($/m^2$)

Aj :Area of the lot j (m^2)

VCLi :Vantage of corner lots (if j is not corner lot then =0)

VTLj :Vantage of through lots (if j is not through lot then =0)

The street value indicator function and vantage of lots are assumed as follows in the case study. They are defined according to the actual implementations of land value assessment under the readjustment projects in Osaka Metropolitan Area.

Street Value Indicator

$$STIj = Tj\ F(Wj) + AFj + LIj$$

where

Tj :Indicator of frontal street class assumed as follows:

District distributor	: = 2.0	Local distributor	: = 1.6
Access road	: = 1.2	Blind alley	: = 0.8

F(Wj) :Street coefficient : influence of the frontal street width of lot j ; Wj

$F(Wj) = (Wj-3.0) / Wj$: if $Wj >= 6.0$

$= Wj / 12$: if $Wj < 6.0$

AFj :Coefficient of accessibility : the influence of the accessibility to station

$AFj = 0.5\ (Smax - Sj)^2 / (Smax - Sc)^2$

Smax : Maximum distance of influence area (assumed 800m)

Sj : Distance between lot j and the nearest railway station

Sc : Distance of constant influence area (assumed 50m)

LIj :Land coefficient : the quality of land (assumed constant overall the district =1.4)

Vantage of lots' shape

VCLj = STI2j ID2 LF2j

VTLj = STIBj IDB LFBj

where

STI2j :Street value indicator of the second frontal street of corner lot j
ID2 :Influence depth of second frontal street (assumed to be 2.0 m)
LF2j :Length of frontage to the second frontal street of corner lot j (m)
STBj :Street value indicator of the back street of through lot j
IDB :Influence depth of back street (assumed to be 2.0 m)
LF2j :Length of frontage to the back street of corner lot j (m)

3. EVALUATION OF IMPROVEMENT PLANS OF LOCAL STREET NETWORK

By employing the analysis system, improvement plans of street network in an old residential development area are analyzed. Comparing the alternative plans of different length of widening street, appropriate level of road space for the area is clarified.

3.1. Study Area

Figure 5 shows the plan of street network and building lots of Kami district in Osaka city which is selected for the case study area. This area was developed under the readjustment project of arable land which started in 1923 and finished in 1939. When the project ended, the restriction of building frontage lines was introduced to cope with the future urbanization. This "building line" scheme was established under the Building Control Act of 1919 and requested that all land owners must provide land for road space gratuitously. However, the restriction became unclear after the Building Control Act of 1919 was substituted by the Building Standard Act. Many lots remain which are not set back and many streets remain too narrow for a residential area. In this study, considering the step improvement project, the priority of widening streets is studied.

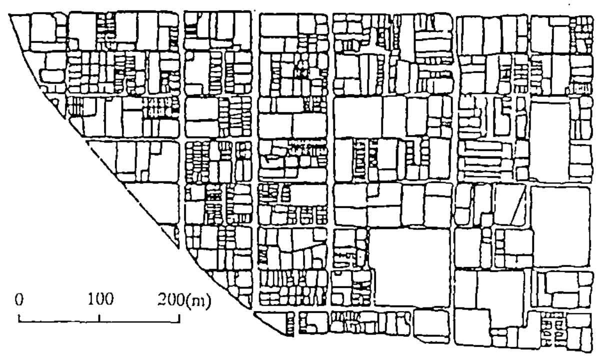

Figure 5 Kami District (Osaka city)

3.2. Alternative plans for street network improvement

Figure 6 shows the alternative plans for improvement of the street networks. Six phases of improvement of street space are shown. Improvement begins from the original conditions to the planed network under building line schemes.

1) Original condition : Situation when the land readjustment project was introduced

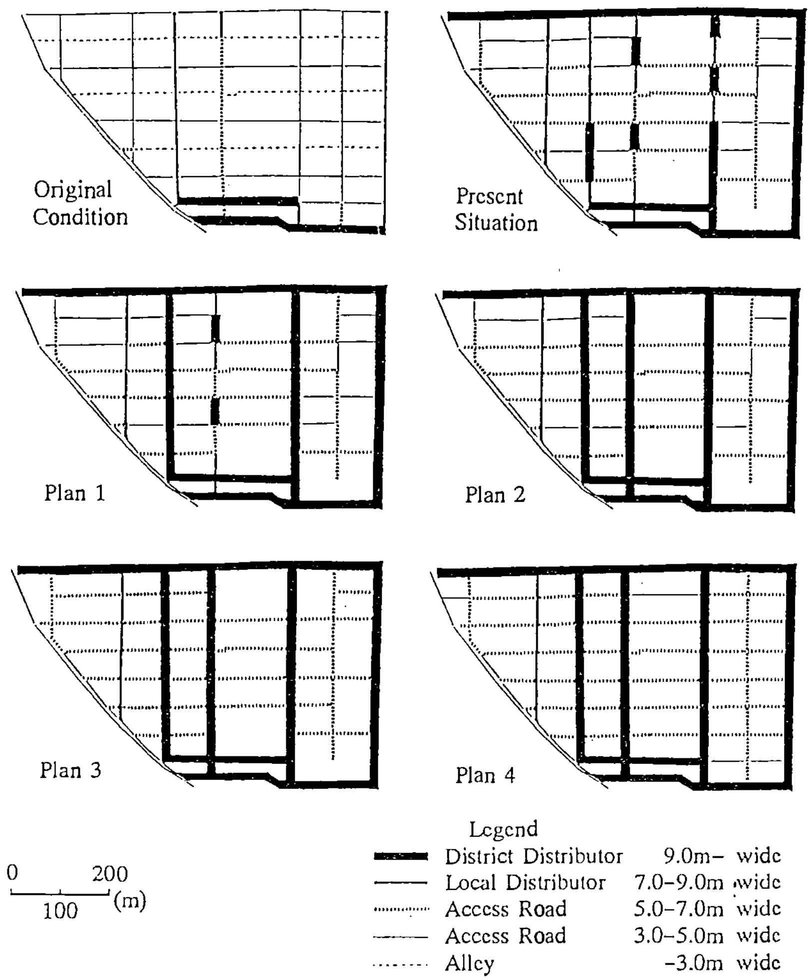

Figure 6 Alternative plans of street improvement

2) Present situation : About 52% of streets are formed by building line schemes.
3) Plan 1 : Two of north south streets are widened to over 9m wide.
4) Plan 2 : Additional one of north south streets is widened to over 9m wide and three of east west streets are widened to over 5m wide
5) Plan 3 : All of access roads are widened to over 5 m wide.
6) Plan 4 : All streets are widened and constructed under the building line scheme planed in 1923.

3.3. Results

Figure 7 shows the results of calculation of the indices by the analysis system. These indices indicated on the vertical axes show the average or the total of whole area and graduate so that the lower shows the better results. The horizontal axes show the

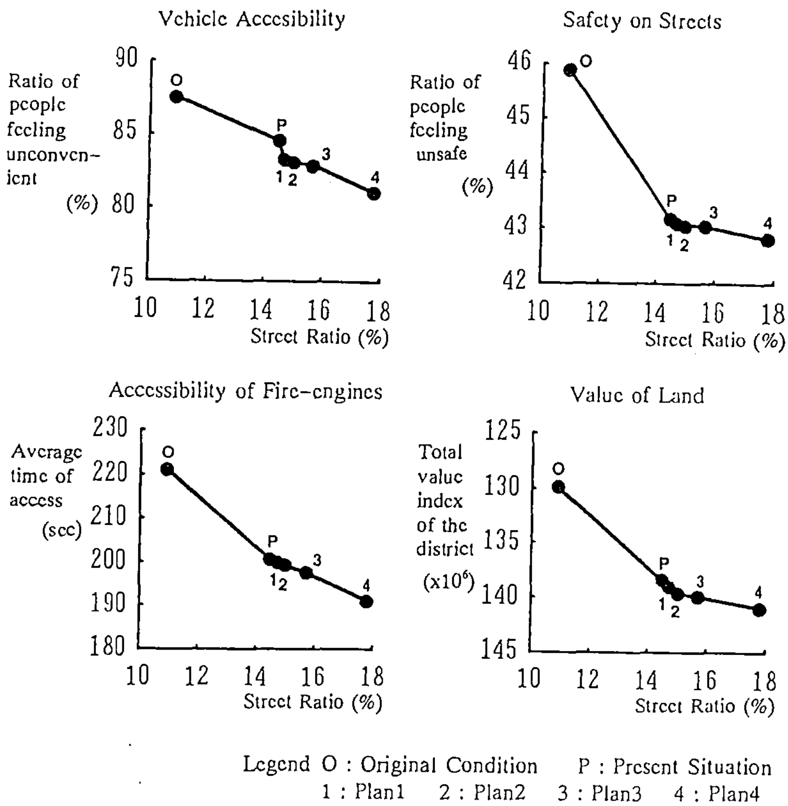

Figure 7 Results of evaluation of plans

street ratio ; the ratio of land occupied by streets of the alternative plans. By increasing the street ratio due to the street widening, all indices get better. Although the index of fire engine accessibility shows liner relationship with the street ratio, there is a gap between present situation and plan 1 at the index of vehicle accessibility. Indices of street safety and land value show successive diminution approximately from the street ratio of plan 2.

From these results, the appropriate level of street ratio of this area seems to be between 14% and 15%.

CONCLUSION

In this paper, it was shown that a compact and effective data base system can be provided by utilizing CD-ROM Town Map data base. Also models useful in evaluating local street networks from different viewpoints were shown. By employing this system, appropriate levels of local street improvement are clarified.

In further research, we hope to consider the following subjects. First the consideration of land price and speed of building-up in evaluating local street networks. Second the introduction of cost and benefit analysis in planning improvement schemes for local street networks in sprawling developments.

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