Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 3819 - 3834, 2005

MAKING CITIES MORE COMPACT BY IMPROVING TRANSPORT AND AMENITY AND REDUCING HAZARD RISK

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Abstract: Population aging and population decline, coupled with a saturation of the Japanese economy and declining revenue for infrastructure maintenance, pose particular problems in outer suburban areas. A new planning philosophy based on planned-retreat and planned re-concentration is described. To evaluate and identify those areas suitable to apply this planning system a decision support system is being constructed. This paper introduces the theory underpinning this research and development into the social value of residential locations. It explains the optimization model structure based on the quality adjusted life years concept and its associated components of accessibility to land uses, residential amenity and risk of hazardous factors such as earthquakes, floods and road traffic noise and emissions (livability). Economic, equity and global environmental constraints are factored into the model. An approximate model for practical applications is formulated and its data requirements relevant to the urban planning process are outlined.

Key Words: Social value, Chance of livability, Planned urban retreat and re-concentration

1. INTRODUCTION

The 21st Century offers Japanese urban planners unique challenges that are in marked contrast to the urbanization experience of rapid economic expansion and suburbanization of the second half of the 20th Century. An aging and declining population, and associated reductions in the revenue base for local government authorities to maintain urban services and infrastructure, will require new approaches to planning and new decision support techniques. Concepts are emerging about the need for the spatial re-organization of the Japanese city that involves planned retreat from some outer suburban areas, or other areas experiencing environmental stress, and the planned re-concentration of land-use activities into areas where there is surplus infrastructure and service capacity. In an open and transparent, consultative, planning regime it is essential to have a decision support system for planners that will evaluate and identify locations where both planned retreat and planned re-concentration are desirable, and will be able to communicate to the general public in a graphical format the key results of such an objective and independent analysis.

Land is a fundamental resource to the Japanese people, and any land-use zoning change impinges on the property rights of individuals and organizations. The theoretical research reported here is the development of a mathematical model that calculates the social value of different locations (based on accessibility, amenity and proneness to natural hazards or road transport induced environmental externalities) subject to constraints, and makes assessments of where planned retreat might occur and where planned re-concentration should occur.

In chapter 2, the problem and the context in which this research is undertaken is explained: the urban issues in local cities of Japan; the current situation with urban sprawl; the relationship between urban sprawl and local government finances; and the meaning of planned retreat and planned re-concentration. Chapter 3 explains the new concepts that underpin the proposed model. Drawing from the medical literature on quality of life adjusted years, the model uses a related concept to evaluate locations and their “chance of livability”. The livability maximization approach is explained. Chapter 4 represents the core of this theoretical paper where the equations embedded in the model, together with the constraint equations, are presented. For practical planning applications some modifications to the model are required and these directions are outlined in section 4.3. The data requirements of the model, and how the model may assist practical policy making, are outlined in chapter 5.

2. RESEARCH PROBLEM

The research problem addressed is in response to emerging issues in all Japanese urbanized areas. The areas of local cities have expanded at a faster rate than population growth and population densities have declined from the mid-1960s. Urban sprawl is now imposing serious problems of sustainability. A proposed solution is planned retreat and planned re-concentration.

2.1 Urban Issues and Current Situation of Urban Sprawl

The change of the population density in Densely Inhabited Districts (DID) of each prefecture in Japan is shown in Figure 1. Both the area of DIDs and the population of each prefecture have increased. However, population density in local areas is less than the areas that include city centers, such as Tokyo and Osaka. This means that the increasing rate of DID area is more than the increasing rate of

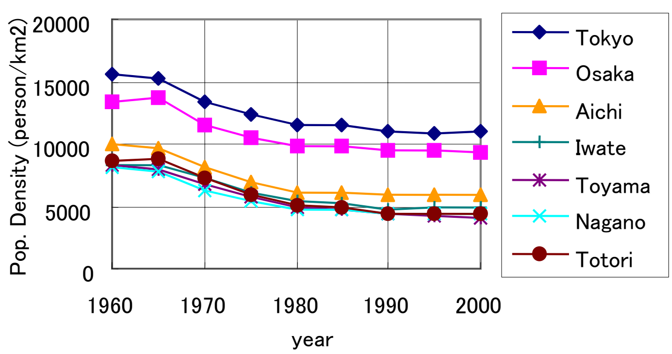

Figure 1. Change of Population Density in DID

population in local cities. Urban growth in local cities has been expanding in suburban areas.

2.2 Urban Sprawl and Its Problem

In Japan, rapid economic growth, motorization and increases in population have caused expansions of urban areas toward areas into previously rural lands. As a result, it has caused waste of land, and increased infrastructure maintenance cost, which supports the expansion of urban area, but also increases natural disaster risk. On the other hand, the urban planning system, which is responsible for control of these problems, has not been successful because land-use zoning restrictions are relatively loose and the zoning division system was revised to extend urbanization promotion areas.

Table 1. Readjustments of Urban Sprawl Problems

●Objective Function: Improving Quality of Life
■Decline of Accessibility to Commercial and Public Facilities **■Decline of Amenity in Residential Areas** **■Extension of Residential Areas to Disaster Hazardous Areas**
●Constraint Conditions: Criterion to be achieved
■ Pressure on Local Government Finance by Increase of Infrastructure Maintenance Costs (economic) **■Regional Gap of Infrastructure Provision (equity)** **■Decrease of Global Environmental Load Arising from Car-Usage Dependent Life Style (global env.)**

The expansion of urban areas does not impact local government finance during economic growth, or when population increase grows. However, the expansion of an urban area does impact local government finance when economic growth is saturated and population decreases. Thus, restructuring the current urban form will be needed because it is difficult to sustain quality of life through sustaining expanding and sprawling urban areas. Under these conditions a new planning system is needed - not one based on land-use zoning division, which cannot control urban sprawl - but one based on regulation and derivation of places to live considering the characteristics of each area.

This study defines ‘planned retreat’ as restricting the supply of houses and infrastructure in new urban developments. ‘Re-concentration’ is defined as the guided migration of population to those districts with existing surplus infrastructure. This study proposes the idea of ‘Social Value’ as an index for identifying areas for ‘planned retreat’ and ‘re-concentration’, and develops a methodology for identifying ‘planned retreat ’and ’re-concentration’ areas. The basic concept is land-use distribution as a goal for restructuring urban form using the existing infrastructure for improving quality of life. Suburbanization of residences and commercial facilities and the hollowing out of city centers have caused problems that include: decrease of accessibility and amenity; increase in natural disaster risk; increase of infrastructure maintenance cost; decrease in equity among each residential area; and greater environmental loads caused by automobile-dependent life styles.

These problems can be formulated into an objective function relevant to quality of life and some constraints relevant to some criteria that are shown in Table 1. The desirable urban form is formulated as a problem that maximizes quality of life subject to economic, equity, and global environmental constraints.

3. CONCEPT FOR EVALUATING LAND USE IN URBAN AREA: LIVABILITY MAXIMIZING APPROACH

In order to make judgments about what land uses to abandon, and where additional increments should be re-concentrated, resort is made to a theoretical proposition called the Livability Maximizing Approach. It is based on a concept borrowed from the medical literature called "quality of adjusted life years."

3.1 Quality Adjusted Life Year (QALY) Index in the Medical Field

The QALY index was developed to improve health-care resource allocation by accounting for both the quality and the duration of survival in assessing the outcome of health-care interventions (Perou and Renton, 1993). By assessing numerical values to various illness states, QALYs can account for both morbidity and mortality. The usual approach is to calculate the health gain provided by medical treatment as follows:

$$QALY_{gain} = \left(l_e\right) \times \left(q\right) \tag{3.1}$$

where, (l_e) = life expectancy and (q) = health-related quality of life.

Although expensive and problematic, (l_e) can be determined by a follow-up qualitative survey of patients who received a medical intervention and a control group who did not have this intervention (e.g., standard life-table methods). Determination of the (q) function (0 = death, +1 = full and healthy life) is more difficult, as the construction of an index that combines morbidity and mortality necessarily requires value judgments about quality of life. Limitations to the use of QALY include inadequate information, ethical problems, and methodological problems.

The resulting formula for calculating the number of QALY for an individual p is expressed in the following function:

$$QALY\left(p\right) = \int_a^{a+T} w\left(p;t\right) Ct \exp\left(-\beta t\right) \exp\left\{-r\left(t-a\right)\right\} dt \tag{3.2}$$

where, a is age of onset, T is life expectancy. The first term $w(p;t)$ represents the weight by means of health-related quality of life (0 = death, +1 = full and healthy life) for an individual p at time t. The second term, Ct exp (- βt) represents an age-weighting. In this term, C is age-weighted correction constant and β is parameter from the age-weighting function. A differentiated function $C(1-\beta t)\exp(-\beta t)$, which is local maximal value when $t=1/\beta$, can be derived from differentiating this term with respect to t. The third term $\exp\{-r(t-a)\}$ represents a time discount rate. This equation can be solved as:

$$QALY(p) = -\int_a^{a+T} w(p;t)dt \left\{ \frac{C\exp(-\beta a)}{(\beta+r)^2} \right\} \times \left[\exp\{-(\beta+r)T\}\{1+(\beta+r)(T+a)\} - \{1+(\beta+r)a\} \right] \quad (3.3)$$

[The explanation about QALY is quoted from Nelson (2003)]

3.2 Modified Quality Adjusted Life Year (QALY) Index for Evaluating Land Use, Urban Form

The QALY index has been modified to create the quality-adjusted life years used in our research (Figure 2). This can evaluate land use and urban form, and evaluate urban planning, land use, urban form from a perspective of individual quality of life. In particular, the first term $w(p; t)$, which represents the weight by means of health-related quality of life, in the formula of QALY was changed to “Livability”, which means quality of life derived from the “Chance of Livability” (or “Life Prospects”) and individual preference.

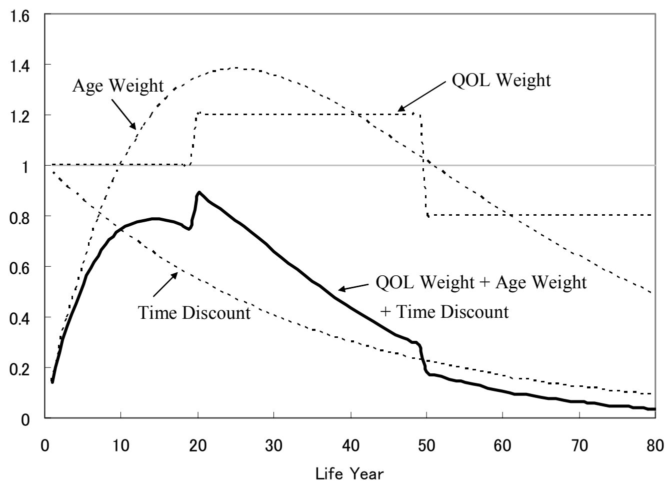

Figure 2. General Concept of Modified QALY

Livability depends on location attributes. Livability should be different when a person lives in a different location. For example, livability should be different between case 1 where a person has lived for fifty years in the area where accessibility to commercial and public facilities is high, and case 2 where accessibility is low. Another positive location attribute includes living in the surrounds of an attractive townscape area. A negative attribute of a location is living in an earthquake-prone area. Livability depends on individual preferences. Although location attributes are the same, livability should also be different according to each individual preference – the importance, or weights, to which an individual places on accessibility, amenity and hazards.

Therefore, Livability should be divided to two factors: “Chance of Livability” - land availability that provides something relevant to the quality of life; and individual preference. “Chance of Livability” is the supply side characteristic which expresses the ‘what and how land is supplied’, and individual preference is the demand-side characteristic that expresses ‘what and how individual wants are desired'. The resulting formula for calculating the number of modified QALY for an individual h, who lives in zone l, is expressed in the following function:

$$QALY(h,l) = \int_{a}^{a+T} L(h,l;t)\, Ct \exp(-\beta t) \exp\{-r(t-a)\}\, dt \tag{3.4}$$

where, a is age of onset, T is life expectancy. The first term $L(h.l;t)$ represents the weight by means of "Livability" for an individual h, who lives in zone l at time t. The second term, $Ct\exp(-\beta t)$, represents age-weighting. The third term $\exp\{-r(t-a)\}$ represents the time discount rate. The modified term $L(h.l;t)$, can be derived from "Chance of Livability" and individual preference, and is expressed in the following function:

$$\begin{aligned} L(h,l;t) &= \langle COL(l;t), P(h:t)\rangle \\ &= \left\langle COL\begin{bmatrix} AC(l;t) \\ AM(l;t) \\ H(l;t) \end{bmatrix}, P\begin{bmatrix} w_{AC}(h;t) \\ w_{AM}(h;t) \\ w_{H}(h;t) \end{bmatrix} \right\rangle \\ &= w_{AC}(h;t)\, AC(l;t) + w_{AM}(h;t)\, AM(l;t) + w_{H}(h;t)\, H(l;t) \end{aligned} \tag{3.5}$$

where, $COL(l;t)$ represents "Chance of Livability" in zone l at time t, $AC(l;t)$ is accessibility in zone l at time t, $AM(l;t)$ is amenity in zone l at time t, $H(l;t)$ is the hazard in zone l at time t. $P(h;t)$ represents the individual preference of individual h at time t. $w_{AC}(h;t)$ is the accessibility weight of individual h at time t, $w_{AM}(h;t)$ is the amenity weight of individual h at time t, $w_H(h;t)$ is the hazard weight of individual h at time t. (<,> means the inner product.)

The "Livability" index is divided to two components: "Chance of Livability"; and individual preference. These are interpreted as follows. "Chance of Livability" expresses the situation of a residential area, and includes accessibility, amenity, and hazard. This term can express the change of the situation (accessibility, amenity, and hazard)over time caused by implementing urban planning or through market mechanisms of urban development.

First, accessibility relates to the role of the land use and transportation system, i.e. giving residents the opportunity to participate in activities in different locations. Thus, accessibility is used here to refer the extent to which the land use and transportation system enables groups of individuals or goods to reach activities or destinations by means of a transport mode.

Secondly, amenity is a component depending on the situation of each zone, and is not affected by the situation of other zones, as is the case with accessibility. It includes: natural environmental features that exist in the target zone; living comfort (which mainly depends on the condition of each house); townscape in the target zone; environmental noise and air pollution (which are mainly caused by road transport in the target zone).

Thirdly, zonal hazard is also unaffected by the situation in other zones. It includes the risk of an earthquake, flood, crime, traffic accidents. These are expressed by their damage and probability. In particular, the risk of earthquake and flood depends on the geotechnical conditions and the

properties of each building.
Individual preference is expressed by weights of three "Chance of Livability" components. This term expresses the change of individual preference of individual *h*.

3.3 Livability Maximizing Approach

The QALY index is divided to the two parts, which are life expectancy and livability. The livability is divided to the two parts, which are "Chance Of Livability (COL)" and individual preference. The former part is more relevant to land use and transportation because its components, which are accessibility, amenity, and hazard, depends on the attributes of land use and transport. The latter part is very important for examining land use and transportation, although individual preferences are very difficult to control or influence. Therefore, it is very important to control land use and transportation to maximize livability. This approach for controlling land use and transportation is named the "Livability Maximizing Approach".

4. FRAMEWORK FOR IDENTIFING THE PLANNED RETREAT AND THE RE-CONCENTRATION AREAS

Figure 3 summarizes the evaluation process and the identification of zones for re-concentration.

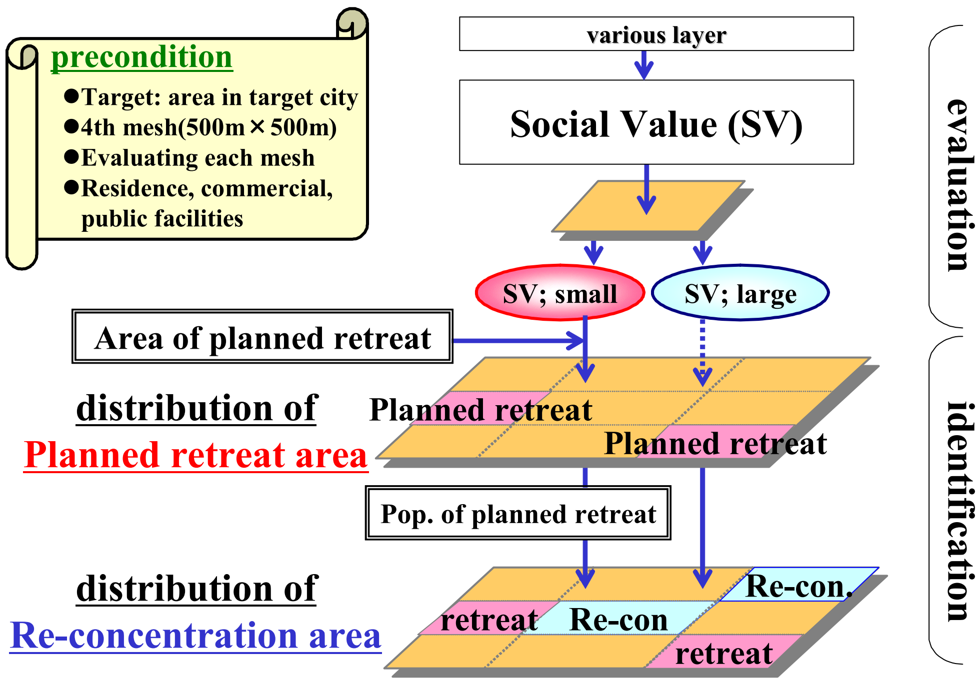

Figure 3. Framework for Identifying Planned Retreat and Re-concentration Areas

Based on the manipulations explained in chapter 2, different parts of the city are evaluated as to whether they contain relatively large "social value", or relatively small social value. GIS maps can display such spatial information. The layers shown in Figure 3 are a conceptual means to identify areas of low social value – targets for planned retreat – and areas of high social value – target zones for planned re-concentration. The identification of both types of area is important in the process of community consultation.

Figure 4 shows the Framework for Target Oriented Modeling for Restructuring Urban Form based on Livability Maximizing Approach. The basic concept is land-use distribution as a goal for restructuring urban form using the existing infrastructures for improving the quality of life. Quality Adjusted Life Years (QALY) mentioned in chapter 3 is used as an index for quality of life. The desirable urban form (distribution of land use) is formulated as a problem that maximizes QALY according to some components, under some constraint conditions. Three types of components of the QALY and three types of constraint conditions re considered in the model as follows: The three types components of the QALY are Accessibility, Amenity, and Hazard The three types of constraint conditions are Economic, Equity, and Global environment

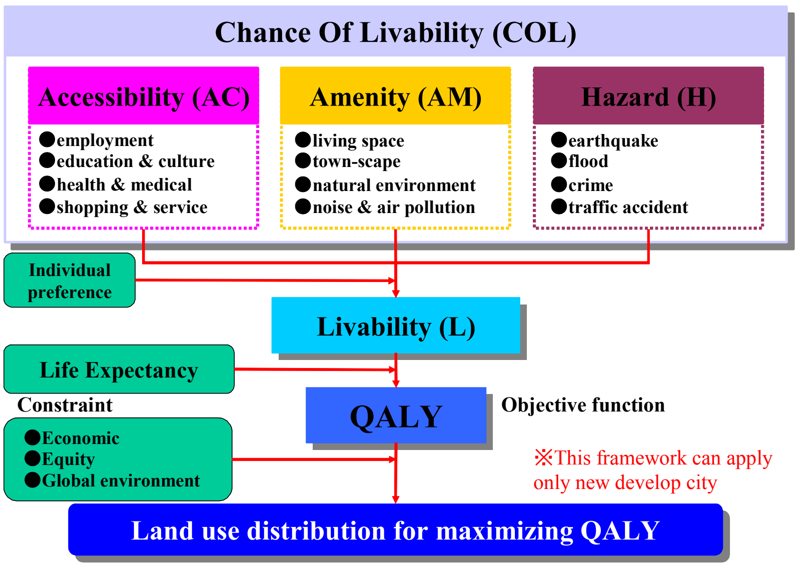

Figure 4. Framework for Target Oriented Modeling for Restructuring Urban Form based on Livability Maximizing Approach

4.1 Objective Function

The objective function can be expressed in the following function.

$$\max\left[QALYs = \sum_{l=1}^{n} \sum_{h=1}^{m(l)} QALY(h,l) \right] \tag{4.1}$$

where, $QALY(h,l)$ denotes level of quality adjusted life year of the population cohort h based on age of people who live in the zone l. Then, $QALY(h,l)$ can be expressed by equation (3.4) above and the modified term $L(h.l;t)$, can be derived from "Chance of Livability" and individual preference, expressed in equation (3.5).

4.1.1 Accessibility

Accessibility can be derived from attractiveness of the zone's target facilities and generalized cost. It is expressed by the following function.

$$AC(l;t)=\sum_{m=1}^{2}\sum_{\substack{j=1\\j\neq l}}^{n}\sum_{k=1}^{K} w_m w_k A\left(k,j;t\right)\alpha\exp\left\{-\beta C^{\gamma}\left(m,l,j;t\right)\right\} \tag{4.2}$$

where, $AC(l;t)$ denotes level of accessibility in zone l at time t. $A(k,j;t)$ is attractiveness of facility k in zone j at time t, $C(l,j;t)$ is the generalized cost between l and j at time t, and F($\beta C^{\gamma}(m,l,j;t)$ is the impedance function. w_k is weight of facility k, w_m is weight of transport mode m, α, β, γ are parameters.

4.1.2 Amenity

Amenity can be derived from natural environment, living space, townscape, noise and pollution. It is expressed by the following function. These depend on location attributes.

$$AM(l;t)=w_{NE}\left(h;t\right)NE(l;t)+w_{LS}\left(h;t\right)LS(l;t)+w_{TS}\left(h;t\right)TS(l;t)+w_{LP}\left(h;t\right)LP(l;t) \tag{4.3}$$

where, $AM(l;t)$ denotes level of the amenity in zone l at time t, $NE(l;t)$ is the natural environment in zone l at time t, $LS(l;t)$ is the comfort of living space in zone l at time t, $TS(l;t)$ is the townscape in zone l at time t, $LP(l;t)$ is the local pollution in zone l at time t. $w_{NE}(h;t)$ is the natural environment weight of individual h at time t, $w_{LS}(h;t)$ is 'the comfort of living space weight' of individual h at time t, $w_{TS}(h;t)$ is the townscape weight of individual h at time t, $w_{LP}(h;t)$ is the local pollution weight of individual h at time t.

The natural environment in zone l is expressed in the following function.

$$NE(l;t)=NE\left\{A_{gs}(l;t),N(l;t)\right\} \tag{4.4}$$

where $NE(l;t)$ denotes level of the natural environment in zone l at time t. $A_{gs}(t)$ is green space in zone l at time t, $N(l;t)$ is the population in zone l at time t.

The comfort of living space in zone l is expressed in the following function.

$$LS=LS\left\{A_{bs}\left(l,i;t\right),AT_b\left(l,i;t\right),N\left(l;t\right)\right\} \tag{4.5}$$

where $LS(l;t)$ denotes living space in zone l at time t. $A_{bs}(l,i;t)$ is building space of building i in zone l at time t. $AT_b(l,i;t)$ is other attributes of building i in zone l at time t. $N(l;t)$ is the population in zone l at time t.

The townscape in zone l is expressed in the following function.

$$TS(l;t) = TS\{AT(l,i;t)\} \tag{4.6}$$

where $TS(l;t)$ denotes townscape in zone l at time t. $AT(l,i;t)$ is attribute i in zone l at time t.

The local pollution in zone l is expressed in the following function.

$$LP(l;t) = LP\{NISE(l;t), AP(l;t)\} \tag{4.7}$$

where, $LP(l;t)$ denotes the level of local pollution in zone l at time t. $NISE(l;t)$ is noise in zone l at time t. $AP(l;t)$ is air pollution in zone l at time t

4.1.3 Hazard

Hazard can be derived from risk of earthquake, risk of flood, risk of crime, and risk of traffic accident.

$$H(l;t) = w_s(h;t)R_s(l;t) + w_f(h;t)R_f(l;t) + w_c(h;t)R_c(l;t) + w_t(h;t)R_t(l;t) \tag{4.8}$$

where, $H(l;t)$ denotes the level of the hazard in zone l at time t, $R_s(l;t)$ is the risk of an earthquake in zone l at time t, $R_f(l;t)$ is the risk of a flood in zone l at time t, $R_c(l;t)$ is the risk of crime in zone l at time t, $R_t(l;t)$ is the risk of a traffic accident in zone l at time t. $w_s(h;t)$ is the earthquake risk weight of individual h at time t, $w_f(h;t)$ is the flood risk weight of individual h at time t, $w_c(h;t)$ is the crime risk weight of individual h at time t, and $w_t(h;t)$ is the traffic accident risk weight of individual h at time t.

The risk of an earthquake, which can be derived from a probability density function and damage, is expressed in the following function.

$$R_s(l;t) = \int_a^{a+T} P_s(t)dt \times D_s(l) \tag{4.9}$$

where, a is age of onset, T is life expectancy. $R_s(l;t)$ denotes the level of the risk of an earthquake. $P_s(t)$ is a probability density function which represents the event probability of an earthquake at time t , $D_s(l)$ is the damage in zone l when an earthquake happens.

The risk of a flood, which can be derived from a probability density function and damage, is expressed in the following function.

$$R_f(l;t) = \int_a^{a+T} P_f(t)dt \times D_f(l) \tag{4.10}$$

where, a is age of onset, T is life expectancy. $R_f(l;t)$ denotes the level of the risk of a flood. $P_f(t)$ is a probability density function which represents the event probability of a flood at time t , $D_f(l)$ is the damage in zone l when a flood happens.

The risk of a crime, which can be derived from a probability density function and damage, is expressed in the following function.

$$R_c(l;t) = \int_a^{a+T} P_c(t)dt \times D_c(l) \tag{4.11}$$

where, a is age of onset, T is life expectancy. $R_c(l;t)$ denotes the level of the risk of a crime. $P_c(t)$ is a probability density function which represents the event probability of a crime at time t , $D_c(l)$ is the damage in zone l when a crime happens.

The risk of a traffic accident, which can be derived from a probability density function and damage, is expressed in the following function.

$$R_t(l;t) = \int_a^{a+T} P_t(t)dt \times D_t(l) \tag{4.12}$$

where, a is age of onset, T is life expectancy. $R_t(l;t)$ denotes the level of the risk of a traffic accident. $P_t(t)$ is a probability density function which represents the event probability of a traffic accident at time t , $D_t(l)$ is the damage in zone l when a traffic accident happens.

4.2 Constraints

There are three constraint conditions, which includes economic, equity, and global environment. The brief explanation about them is given in the following sub-sections.

4.2.1 Economic Constraint

The first constraint condition is economic constraint, which means total cost including 'maintenance cost for accessibility, amenity' and 'control cost for hazard' is less than a par of total income, is expressed in the following function.

$$\int_a^{a+T} \sum_{l=1}^{n} \sum_{i=1}^{I(l;t)} C(l,i;t)dt \le \alpha \int_a^{a+T} \sum_{l=1}^{n} \sum_{h=1}^{m(l;t)} N(h,l;t) IN(h;t)dt \tag{4.13}$$

where, a is age of onset, T is life expectancy. $C(l,i;t)$ denotes the cost for infrastructure i in zone l at time t. $I(l;t)$ is number of the type of infrastructure in zone at time t. $N(h,l;t)$ is the population of the cohort h based on age in zone l at time t. $IN(h;t)$ is income of individual h in zone l at time t. The term α is the rate of total income for infrastructure maintenance. $m(l;t)$ is the population in zone l at time t.

4.2.2 Equity Constraint

The second constraint condition is the equity constraint, which means equity relevant to accessibility, amenity, and hazard, and is expressed, in the following function.

$$G\{AC(l;t), N(h,l;t)\} \le \bar{G}_{AC} \tag{4.14}$$

$$G\{AM(l;t), N(h,l;t)\} \le \bar{G}_{AM} \tag{4.15}$$

$$G\left\{H(l;t), N(h,l;t)\right\} \le \bar{G}_H \tag{4.16}$$

where, $G(\ )$ denotes the Gini coefficient of the zonal (spatial) distribution, $N(h,l;t)$ is the population of the cohort h based on age in zone l at time t, and $\bar{G}_{AC,AM,H}$ is a specified criterion given as planning input to the model.

4.2.3 Global Environmental Constraint

The third constraint condition is a global environmental load constraint, which means global environment load arising from accessibility, amenity, and hazard is less than a specified upper capacity level, and is expressed in the following function.

$$EL\left\{AC(l;t), AM(l;t), H(l;t), N(h,l;t)\right\} \le \overline{EL} \tag{4.17}$$

where, $EL(\ )$ denotes the global environmental load. $N(h,l;t)$ is the population of the cohort h based on age in zone l at time t, and $\overline{EL}$ is a specified criterion.

4.3 Approximate Model

The model specified above is difficult to apply to a real city because it is an optimization model for exploring the best distribution of land use and all data required to make this model operational are unlikely to be available. Figure 5 shows the structure of an approximate model that we have designed, where QALY is calculated from equation(3.4). Data are addressed in chapter 5.

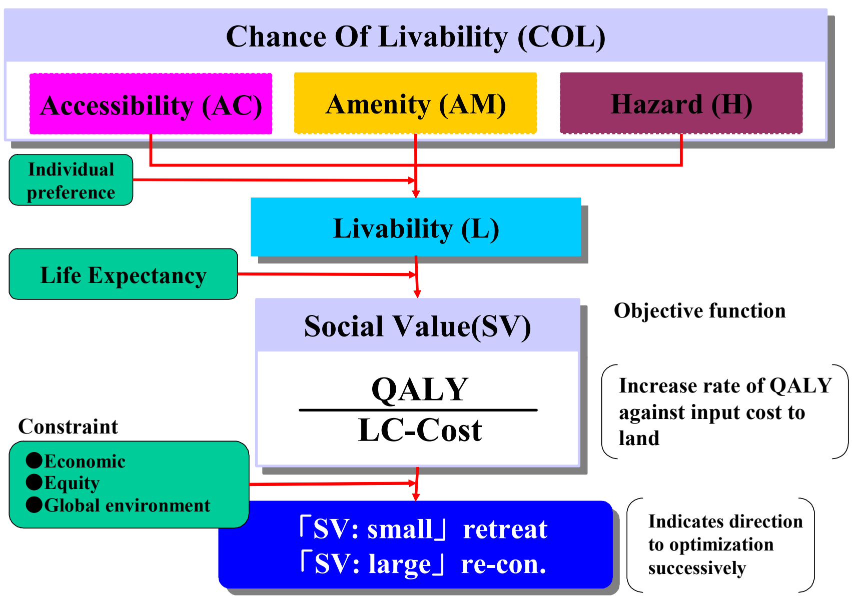

Figure 5. Approximate Model for QALY Maximizing

In this model, the indicator named Social Value makes it possible to explore the areas where higher QALY can be gained by means of capital investment. Social Value, which will be applied as an indicator for identifying the planned retreat and the re-concentration areas, is expressed in the following function:

$$SV(l) = \frac{\sum_{h=1}^{m(l)} QALY(h,l)}{LCC(l)} \tag{4.18}$$

where, $SV(l)$ denotes the level of Social Value in zone l and $m(l;t)$ is the population in zone l at time t. The life cycle cost is $LCC(l)$, which is expressed in the following function.

$$LCC(l) = \int_{a}^{a+T} \sum_{l=1}^{n} \sum_{i=1}^{I(l;t)} C(l,i;t)dt \tag{4.19}$$

where, a is age of onset, T is life expectancy. $C(l,i;t)$ denotes the cost for infrastructure i in zone l at time t. $I(l;t)$ is number of types of infrastructure in zone at time t.

The Social Value, which is the rate of total QALY against life cycle cost in each area, represents the efficiency of capital investment in each area. Therefore, the Social Value index can be applied to the identification of the planned retreat areas. The priorities of planned retreat areas are decided in ascending order of the calculated Social Value in each area. Social Value cannot directly be applied to identification of the re-concentration areas because the increase rate of QALY against additional cost accompanied with re-concentration is more important than the current social value. Therefore, the priorities of re-concentration areas are decided in descending order of the following index in each area.

$$\frac{\Delta \sum_{h=1}^{m(l)} QALY(h,l)}{\Delta LCC(l)} = \frac{\sum_{h=1}^{m(l)} QALY_{w}(h,l) - \sum_{h=1}^{m(l)} QALY_{w/o}(h,l)}{LCC_{w}(l) - LCC_{w/o}(l)} \tag{4.20}$$

where, w is the subscript representing that re-concentration is implemented, and w/o is the subscript representing that the re-concentration is not implemented.

5. APPLICATION OF APPROXIMATE MODEL

In section 4.3, an approximate model was introduced as an index for exploring where, in an urbanized area, should be appropriate for planned retreat or re-concentration. This is because the desired model in section 4.2 is difficult to directly apply so as to calculate optimized solutions. In this section, data collection, and the process of the application of the approximate model to an actual city, are illustrated. Figure 6 shows the data for the calculation of Social Value and its process. This data is divided to three types, which are: GIS data; questionnaire data about residents and their preferences; and statistical information.

Life expectancy according to the age brackets and genders is available from life table statistics, which is published by Ministry of Health, Labor and Welfare. Individual preference is obtained as the weights of each 'chance of livability' components by a questionnaire to the residents in a target city. Accessibility is calculated based on the attractiveness of urban facilities, such as gross floor space of shopping store and the distance from the residential area to urban facilities by using GIS. Amenity includes living space, townscape, natural environment, and noise and air pollution. For example, amenity relevant to living space is calculated as gross floor space per person. The gross floor space is calculated based on housing maps by using GIS. Hazard includes earthquake risk, flood risk, crime risk and traffic accident risk. Hazard relevant to earthquake risk is calculated as the multiplication of the probability of an earthquake and the number of deaths that ensue. The number of deaths is calculated based on the magnitude of the earthquake, foundation conditions, building characteristics and the population distribution by using GIS. Life cycle cost

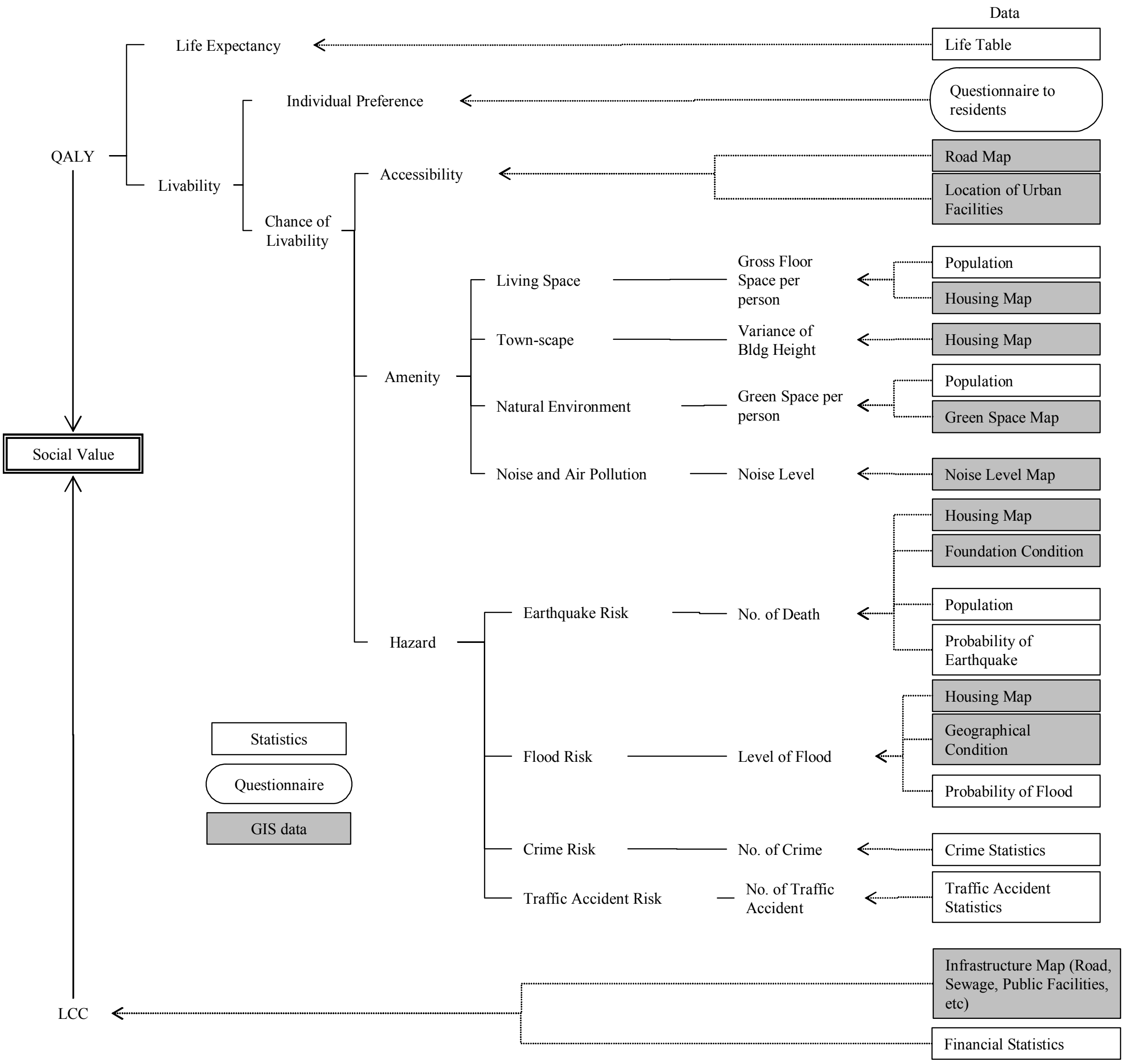

Figure 6. Data for the Calculation of Social Value

(LCC) is calculated based on an infrastructure map (road, sewerage, public facilities, etc) and financial statistics, which are published by each municipality, by using GIS.

The geographical distribution of Social Value can be calculated based on the distribution of QALY and LCC by using GIS, and it can be displayed graphically to the stakeholders. The output of the model is a map that indicates land in the case study city that is appropriate for planned retreat or re-concentration based on using this Social Value index. Under these conditions a new planning system is needed to implement the findings - not one based on land-use zoning division, which cannot control urban sprawl - but one based on regulation and derivation of places to live considering the characteristics of each area. We know that land-use development is a result of the activities of individuals and companies. Although local government is responsible for land-use zoning and development control, many decisions about land-use location depend on the decision making of individuals and companies. On the other hand, as the result of this strong commitment in decision making about land use by individuals and companies, local government finance and environmental load arising from unregulated land use is increasing. Consequently, the absence of control on individual and company behavior - those who have caused the current situation - has increased the risk of not achieving urban sustainability. Therefore, policy measures, which can play an active role in the location behavior of individuals and companies, are necessary for the urban sustainability in the future.

First, we suggest that the findings of our research are widely demonstrated to policy makers so that they can think about the financial implications of re-orientating policy to achieve more compact cities. As local governments are elected by its citizens then a parallel process of public education must be undertaken to interpret the findings of the model for the general public. The aim of this is to put pressure on governments to change their strategic directions. Thus, in a favorable political climate, specific policy instruments can be formulated to attract people back to areas identified as having positive Social Value, such as financial subsidies, marketing and promotion, and the highest quality of urban design to reflect principles of ecologically sustainable urban development.

6. CONCLUSIONS

In the 21st Century, urban areas of Japan face enormous challenges of structural adjustment because the current urban sprawl is not sustainable. The total population of the country will decline, the population will age, and, as a consequence, the financial revenue to maintain essential urban infrastructure and services will shrink. In response to this situation, we suggest that an appropriate policy response by local government is planned retreat and planned re-concentration. Given the complexity of the land market and the vested interest of land-owners, and other stakeholders in any matter related to land-use zoning and associated property rights, this research is directed towards designing a suitable decision support for planners that will enable them to evaluate and identify suitable locations for urban spatial re-adjustment.

Drawing on an analogy from the medical literature on quality adjusted life years, we define a composite index of livability that is composed of accessibility, amenity and hazard attributes of each location. In the optimization model, whose equations have been specified in section 4.1 and 4.2, zones of low livability (low Social Value) and high livability (high Social Value) are identified as a rational basis for determining suitable locations for planned retreat and planned re-concentration, respectively. In a practical planning situation, where data availability may act as a constraint, a modified model is required, and this has been presented in section 4.3 as an approximate model. The data requirements of this model were summarized in chapter 5. Research in progress aims to make the model operational and to make it of practical value in the land-use re-zoning process where the community and stakeholders must be consulted. To do this, a case study of the model application in the city of Iida, Nagano Prefecture, is proposed where the data requirements will be addressed and an integrated package of policy instruments proposed.

ACKNOWLEDGMENTS

The financial support of the Japan Society for the Promotion of Science (JSPS) with an Invitation Fellowship for Professor Black in 2003 – 2004 allowed this collaboration to take place and is gratefully acknowledged.

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