Reforming Urban Land use - Transport Systems to be Sustainable based on the Indicator of QOL Performance against CO_2 Emission

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Abstract: Population decline and the consequent maturity of economy are bringing more difficulties to maintain Quality of Life (QOL). Urban land use - transport development should not harm inhabitants' QOL, meanwhile, CO_2 emission should be reduced. This paper is aiming at establishing an evaluation system to assess QOL, further evaluate the QOL performance against CO_2 emission in the Nagoya Metropolitan Area, seeking for a planning approach to reform land-use transport systems to be sustainable in the stage of population decline and even more aged society. It is highlighted that QOL evaluated in this paper is composed of both objective and subjective approaches, which makes possible to measure and evaluate different preference on QOL factors for different age groups with their own attributes. The results of QOL vs. CO2 performance can give the information to achieve an environmentally more sustainable land use – transport system within the metropolitan area.

Keywords: Quality of Life; CO_2 emission; Ageing; Sustainable land use – transport system

1. INTRODUCTION

Most developed countries and regions are facing population decline and ageing, which are brought by the reduction in fertility (UN, 2012). As a result, there are concerns that the quality of life (QOL) of inhabitants, which consists of accessibility to various opportunities, amenity and hazard of the living place, may deteriorate in the near future. This is because it becomes increasingly difficult to maintain necessary public service facilities and the transport network linking them with residential areas in the face of lower population density while CO_2 emission increases, both due to continuous suburbanization under population decline. Furthermore, the financing capacity to meet expenditure requirements and the efficiency of infrastructure to protect from natural disasters will deteriorate as well. Thus the performance of QOL against CO_2 emission, which the authors call sufficiency, will decline.

Ageing and population decline means the lack of taxpayer support. This makes it impossible to provide a full range of government services in high-expenditure requirements and thus results in lowering of QOL in cities and regions. Furthermore, unless the environment is maintained in a stable manner, ecosystems and human society can come under threat. Therefore, those cities and regions with high QOL may spend excessive investments on urban maintenance as well as generate excessive environmental burdens, then become unsustainable.

The objectives of this research are 1) establishing an evaluation system to assess QOL, 2) further evaluate the QOL performance against CO_2 emission in the Nagoya Metropolitan Area, and 3) seek for a planning approach to reform land-use transport systems to be sustainable in the stage of population decline and the more aged society.

2. REVIEW OF RELATED RESEARCHES

There have been related researches existing as follows.

In conventional cost benefit analysis of transport network, the economic benefit by calculating the sum of saved travel time or cost GDP by transport users are measured. This method is not applicable to elderly people. However, in 2050 majority of the transport system will not be workers but may be elderly people which will dominate more than 40% in 2050 in Japan. Therefore we need a method to cover the benefit of also non-working generations.

Over the last ten years, special attentions have been given to the concept of QOL to evaluate the development of an area (Beukes, E., Colff, A.V., 1997) and to investigate the determining factors of QOL, and making proposals to enhance it (Lever, J.P., 2000). Although there is absence of an admitted single definition of QOL (Dissart, J.C., Deller, S.C., 2000, Zhang, J. Li, X., et al, 2009), it is widely accepted that a person's quality of life depends on both the exogenous (objective condition) facts and endogenous (subjective attitude) perception of these factors (Dissart, J.C., Deller, S.C., 2000).

Related to these concepts, several literatures have proposed alternative ways of QOL measurements. Subjective quality of life can be evaluated by investigating 'the degree to which the individual's life is perceived to match some implicit internal standard or referent' (Evans, 1994) or assessed by understanding urban residents' tendencies and geographical imagination using questionnaire survey or interview (Lofi, S., Koohsari, M.J., 2009), while objective quality of life usually applies quantitative indicators. Some researchers such as Lofi and Koohsari (2009) argue that the two measuring approaches are not always the same, while the others, like Szalai (1980) 'merged the two approaches and accepted social indicators as based on subjective measures as well (Dissart, J.C., Deller, S.C., 2000).

Hayashi and Sugiyama (2003) proposed an integrated QOL indicator system including economic, service opportunity, amenity, safety and security and environment burden to evaluate urban and transport development strategies. It is important that although it is a kind of multi-criteria analysis method but the estimated values have a dimension of quality of life which can be universally used.

Generally, the quality of life can be evaluated in both objective and subjective approaches by using quantitative and qualitative data. Since quality of life also has a geographical dimension as it relates to places, for subjective approach it is rational to collect data from the people residing in a particular place and evaluate independent control variables by analysing their responses to a specifically designed survey (details in later session). These control variables not only yields information as to which factors are more important in measuring QOL, but also can be used as parameter to each factor. For objective approach, the increasing availability of geocoded data, namely, the collection, handling, and analysis of spatial data have been much simplified by the implementation of GIS (Geography Information System) (Longley, P.A., Goodchild, M.F., et al., 1999), which further combine abundent social data, investigate patterns and anomalies, and develop interesting new hypotheses (Goodchild, M.F., Anselin, L., et al., 2000). The present research is one of the first studies to combine both approaches to measure QOL, assume that residents of vary characteristics have different perception levels (subjective preference) of different QOL factors (objective social indicators). According to Goodchild and Janelle (2003), the inter-relationship between human behaviour and urban space can be explored by the integration of social and spatial data using an effective mechanism. The analysis of social and spatial data can be partially attributed to the transformation of social space, with multi-degree of magnitude shifts in social science conceptualising and theorising (Goodchild, M.F., Anselin, L., et al., 2000).

The tool of Eco-efficiency was proposed by (Yadong, Y., 2013) arguing that the quality of urban development should be measured 'as the ratio between the (added) value of what has been produced (e.g. GDP) and the (added) environment impacts of the product or service (e.g. SO2 emissions).' It is further embodied by WBCSD(1992) that eco-efficiency is achieved through the delivery of 'competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life-cycle to a level at least in line with the Earth's estimated carrying capacity.' Although QOL is mentioned here, they focus only on economic activities because they always relate to cost and value. As criticized above, economic growth was not enough to measure people's quality of life.

Based on above, we can understand that the necessities of evaluating QOL performance particularly for the declining society lie in two conjectures:

1) the constructed infrastructures suitable for today's population would be somewhere/somewhat over supplied in the future, which will cost a lot in maintenance work;

2) the future productivity won't be keeping increasing due to the decreasing labor force, which means to pay additional maintenance fee is not economically efficient.

Not only these global views, but also more concrete reasons to adopt QOL performance. For a big amount of population who are now living in the places which are not their optimal choices because of the limited land area and their own tradeoff decisions between the high land prices and the households' budget constraints, it is a chance for them to change and to improve.

In this research, the concept of Eco-Sufficiency[1] was developed to evaluate the quality of urban development, which considers an overall indicator QOL (Quality of Life) as comprehensive 'added value' for happiness, instead of only GDP (economic growth). This concept is intended to set an integrate evaluation model to estimate the quality of urban development and to give some implications to urban planners and policy makers.

3. EVALUATION SYSTEM OF SUFFICIENT QUALITY OF LIFE

3.1 Fundamental Assumptions

This research is developing a methodology to measure geographical distributed QOL in a city based on questionnaire survey to local residents, social development statistics of the city, as well as geocoded spatial data. The method is based on the following fundamental assumptions:

- Each mesh block is supposed to have a certain objective value of each factor of QOL. To be specific, in the case of education opportunity, if no school exists in a mesh block, then the value of education in this mesh block is zero. Otherwise, this value will be represented by the number of students.

- The amount of value, saying utility, can also be regarded as attractiveness to the residents

[1] "Weizsaecker, E. U. v. et al., 2009. Factor five. London: Earthscan" uses the word sufficiency in a way that "question why it is so difficult to depart from material dreams towards sufficiency.

residing within the vicinity of the mesh block, but gradually decreases by the travel time/money cost to it, and assume that residents have equal opportunities to use the transport facilities (Joseph, A.E., Phillips, D.R., 1984, Pirie, G.H., 1979).

- The QOL of residents who live in a certain mesh block can be regarded as sum of all the available utilities of each factor, where the weight of each factor vary to diverse population groups with different social-economic attributes.

3.2 QOL Indicators

Current researches have rich reviews on the factors of QOL in the field of urban research. Due to the data availability, aims of the research, methodology used and the spatial disaggregation level examined, different factors were set, which can be grouped into six categories, namely natural environment, built environment, social-political environment, local economic environment, cultural and leisure environment, as well as public policy environment (Lambiri, D., Biagi, B., Royuela, V., 2006). In this research, three categories including 12 indicators composed the QOL indicator system (Table 1). In order to quantitatively evaluate the QOL of inhabitants, a model created in prior research is employed. In this model, the QOL value is comprised of three classifications: accessibility (AC), indicating ease of access to social capital and public/private facilities; amenity (AM), indicating habitability and favourability of scenery; and safety and security (SS), indicating safety from disasters and accidents/crimes.

Table 1 QOL Indicators

Categories	QOL Indicators for Residential Location
Accessibility (AC)	Commute time
	Access to Shop
	Access to School
	Access to Hospital
Amenity	House Size
	Landscape
	Green Area
	Noise
Safety and Security	Earthquake
	Flood Risk
	Crisis on Rd.
	Traffic Accident

3.3 Estimation Method for QOL

The QOL value is defined by the sum of products of physical quantities influencing the neighborhood environments, LPs, and weightings (w) representing the subjective perceptions of the inhabitants living there, and is formulated as in Equation (1). By establishing weightings (w) representing perceptions in each habitation and age group area, differences in perceptions of QOL based on attributes are included in the estimation.

$$\mathrm{QOL} = \sum_i w_i (LPs_i - LPs_{0i}) \tag{1}$$

LPs_{0i} represents the reference value for LPs. This means that the QOL value in areas where all LPs_i correspond to LPs_{0i} is 0. Quality Adjusted Life Year (QALY) values, used in fields of medical/environmental risk, are used as a measure of QOL. A QALY value is the number of years of life adjusted for QOL, and the units used are "years" or "days".

Accessibility to facilities in this study can be evaluated by following equations.

$$AC_i = \sum_k^m (\alpha_k AC_{ik}) \tag{2}$$

$$AC_{ik} = \sum_j^n \{S_{jk} exp(-\beta_k c_{ij})\} \tag{3}$$

$$S_{jk} = \sum_l^p \gamma_l \frac{A_{jkl}}{\sum_j^n A_{jkl}} \tag{4}$$

Where,

i : living district i,
j : neighbourhood district j,
k : QOL indicator k,
l : service facility l,
AC_i : accessibility to district i,
AC_{ik} : accessibility to district i for QOL indicator k,
S_{jk} : share of attractiveness of QOL indicator k in district j,
c_{ij} : travel cost from district i to j,
A_{jk} : attractiveness of QOL indicator k in district j,
α, β, γ : parameters.

Equation (3) represents accessibility in the form of gravity model, where negative exponential function represents diminishing along with travel cost. It takes the value from 0 (no service facility in the whole area) to 1 (the service facility is existing in the living district).

3.4 Questionnaire Survey for Population Group k's Weight W^{mk}

To estimate population group k's weight (W^{mk}), rank logit model in equation (5) and maximum likelihood function in equation (6) were applied.

$$U_{jk} = w^{mk} X_{jk} + \varepsilon_{jk} \tag{5}$$

$$P_p(1,2,\dots,J|w^{mk}) = \prod_{j=1}^{j-1} \frac{\exp(w^{mk} X_{jk})}{\sum_{i=j}^{J} \exp(w^{mk} X_{jk})} \tag{6}$$

Where

$P_p(1,2,\dots,J|w^{mk})$: probability of observing the given data as a function of P,
U_{jk} : utility of respondent k for item j,
X_{jk} : given observed value for respondent k choose item j,
ε_{jk} : random component, IID (Independent and Identically Distributed) and,
J : Sample size.

3.5 CO_2 emissions originating in passenger transportation

CO_2 emissions associated with passenger transportation activities are estimated using Equation (7).

$$E_t = \mathrm{N} \times x \times \sum_m (e_m \times l_m \times p_m) \tag{7}$$

Where,

N : population,
x : trip generation unit per capita per year,
p_m : modal split,
l_m : trip distance,
e_m : basic unit of emission.

x was adjusted using the results of the Chukyo Urban Area Person Trip Survey (2001). Additionally, in order to measure the CO_2 reduction effect from the modal shift, modal split p_m and distance l_m are established from the output results of the transportation model.

Table 2 Basic units of CO2 emission originating in passenger transportation

	kg-CO2/km/capita
Cars	0.172
Public transport	0.018

4. CASE STUDY IN NAGOYA METROPOLITAN AREA

4.1 Introduction of Case Study Area

The case study was conducted covering the municipalities included roughly within a 20 km radius centered on City of Nagoya, namely from Nagoya Station (31 municipalities as of February 2012). According to the 2005 National Census, the total population is 4.64 million, of which, the percentage of working-age people (15-64 years old) is 67% and the percentage of elderly people (65 years old or over) is 18%. Additionally, 74% of the working-age population is employed among which the percentage of people employed in agriculture, forestry, and fisheries industries is 1.3%. Spatial structure features of the study area include a flood hazard zone extending throughout the western part of the metropolitan area (at elevation 0 m or below), and large-scale new towns such as Tokadai and Kozoji located in the northeast. Table 3 also shows basic information on the elementary school districts in the study area and Table 4 shows the spatial distribution of the district classifications corresponding to the colored geographical zones in Figure 1.

Table 3. Basic information on the elementary school districts

Number of Elementary School District	571
Average Area	2.4 km2
Average Population	8,100
Average Population Density	5,612 people/km2

Table 4. Spatial distribution of the district classifications

District category	Location in metropolitan area	No. of school districts	Overview
1) Commercial	Central area inside Nagoya City	20	Although there is inflow of people in their 20s, there is a serious outflow of people in their 30s. There is a mixture of medium- and high-rise housing with commercial and industrial districts.
2) City Center Residential	Peripheral area inside Nagoya City	70	Inflow of people aged 15–24 is striking. There is population inflow from other regions for reasons such as universities being situated nearby.
3) Inner Suburban Residential I (declining trend)	Peripheral area of Nagoya City and central areas of core cities	40	There is no population inflow. There is a trend for population outflow centered on people in their early 20s.
4) Inner Suburban Residential II (recent development)	Areas along railroads situated outside city center residential district	95	Inflow of family households appears to have been occurring in 2005.
5) Outer Suburban Residential I (junior baby boomer)	Entire outer suburbs	56	The proportion accounted for by the junior baby boomer generation is large, and this type of district is considered to have become residential as a result of home buying by this generation.
6) Outer Suburban Residential II (baby boomer)	Entire outer suburbs	82	The proportion accounted for by the baby boomer generation is large, and this type of district is considered to have become residential as a result of home buying by this generation.
7) Agricultural	Entire outer suburbs centered on western side of metropolitan area	69	There is no population inflow. There is a trend for population outflow centered on people in their early 20s.
8) Mountain Forest	Far edge of eastern side of metropolitan area	54	This type of district exists in hilly and mountainous areas. Many districts were opened up as residential areas for the baby boomer generation, but there are also districts that have been developed in recent years.
9) Other	Northern and southern edges inside Nagoya City	59	District where large-scale public facilities, etc. are situated.
10) Industrial	Primarily close to the harbor	26	District where large-scale factories are situated.

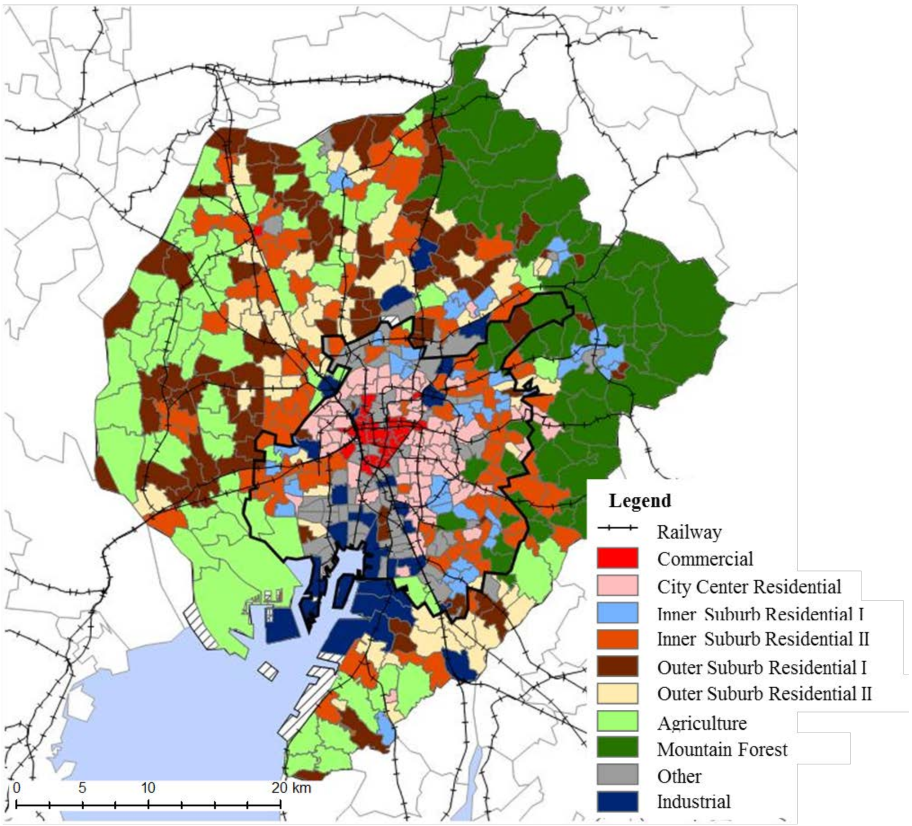

Figure 1 Spatial distribution of the district classifications in Nagoya Metropolitan Area

4.2 Questionnaire Survey Results

The questionnaire Survey was conducted online in Oct. 2010 in Nagoya Metropolitan Area and 400 respondents aged from 20s to 70s were collected. Based on equation (5) and (6), weights (represents people's interests) of QOL indicators for each population group various in age and residential area were calculated and shown in Table 5, which is also displayed in Figure 2.

Comparing the youth aged below 30s, those who live in inner city care more on commute, shopping, land scape and Noise pollution, while the same age group who live in suburb concern more on Safety and Security factors like earthquake, flood risk, crisis on road and traffic accidents. For middle aged group from 30s to 50s, both of living in inner city and suburbs follow the similar trend, only those who live in inner city are showing more interests on commute, housing price and shopping. In the case of aged over 50s, it is interesting that elders living in suburbs care a lot about green space, which may be the reason they choose to live out of the city center. However, for the elders living in inner city, they have been concerned a lot on flood risk, crisis on road, as well as shopping opportunities.

Thus we saw the difference lie in age and residential area leaded to people's different preference on living environment. If we add in gender difference, we will see more changes as shown in Figure 3. Comparing different population groups' weights of shopping interests by both age class and gender, we can interpret that female in their 20s shows the highest, that decreases in the 30s and 40s, further diminish in their 50s, 60s and 70s, while male recognizes shopping comparatively important in their 20s and 30s, but suddenly dropped in their 40s. However, their interest will again increase in their 50s and further in their 60s. In an aged society, which we'll face in 2050 and beyond, we could use the weight by the elderly people for planning the city and infrastructure.

Table 5. Different weights of QOL indicators for each population group

Age groups		Below 30s				40s – 50s				Over 60s			
Residential Area		Inner City	T value	Suburbs	T value	Inner City	T value	Suburbs	T value	Inner City	T value	Suburbs	T value
AC	Commute	1.41	7.718	0.77	7.596	1.54	5.227	0.62	4.105	0.94	1.014	0.90	1.013
	School	1.19	4.687	0.88	7.007	1.04	4.598	0.95	5.076	1.30	1.577	0.67	1.697
	Hospital	0.99	5.299	0.99	5.776	0.97	4.155	0.99	4.764	1.08	3.217	0.81	-0.74
	Shopping	1.48	8.156	0.72	7.319	1.12	6.468	0.90	7.145	1.41	3.444	0.56	3.205
AM	Housing Space	1.24	-12.108	0.81	-10.71	1.26	-9.326	0.77	-9.505	1.11	-4.016	0.93	-2.362
	Land Scape	1.39	-7.325	0.72	-6.09	0.88	-5.076	1.04	-5.973	1.07	-3.811	1.00	-1.496
	Green Space	1.25	-5.659	0.80	-5.713	0.94	-4.853	0.99	-5.321	0.71	-3.448	1.41	-1.476
	Noise	1.36	-9.057	0.73	-9.164	1.06	-7.781	0.92	-7.321	0.94	-2.772	1.13	-1.775
SS	Earthquake	0.62	-6.16	1.38	-5.466	0.97	-3.544	1.05	-4.322	0.90	-1.999	1.19	-1.502
	Flood Risk	0.60	-9.563	1.42	-9.073	1.09	-6.967	0.93	-7.988	1.67	-3.18	0.74	-1.502
	Crisis on Rd.	0.67	-8.648	1.27	-9.253	0.95	-7.7	1.05	-7.782	1.66	-2.84	0.75	-1.833
	Traffic Accident	0.61	-6.368	1.40	-7.196	0.83	-6.289	1.15	-6.499	0.94	-1.368	1.19	-0.933

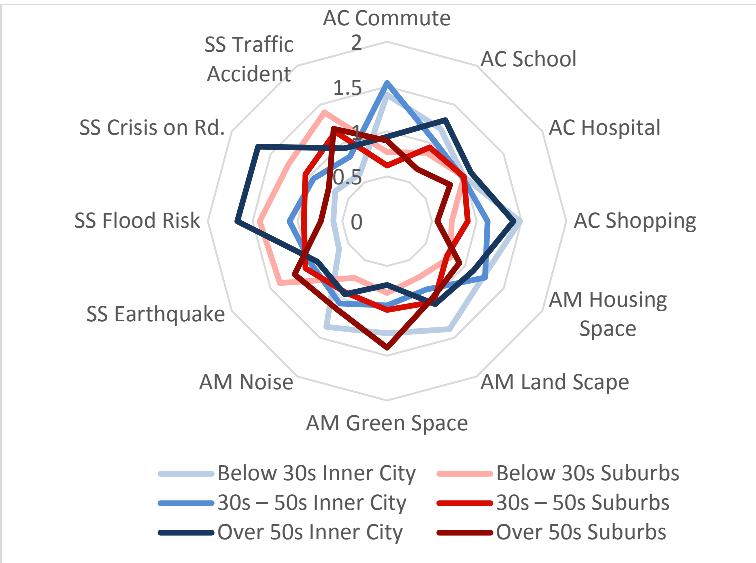

Figure 2 Different weights of QOL indicators for each population group

Based on the social context in Japan, it can be interpreted as follows. Females in their 20s have the strongest interest in shopping, which diminished with the growing of age, however, as housewives, they still have the obligatory to go shopping as you can see the peak in their 40s. For males, they would have more spare time after their 40s, when their career life is stabled. They would have even more spare time and money after being retired in their 60s. Our work shouldn’t stop at interpreting how these differences come out, but further to think about how a package of strategies can be made to meet different groups’ needs.

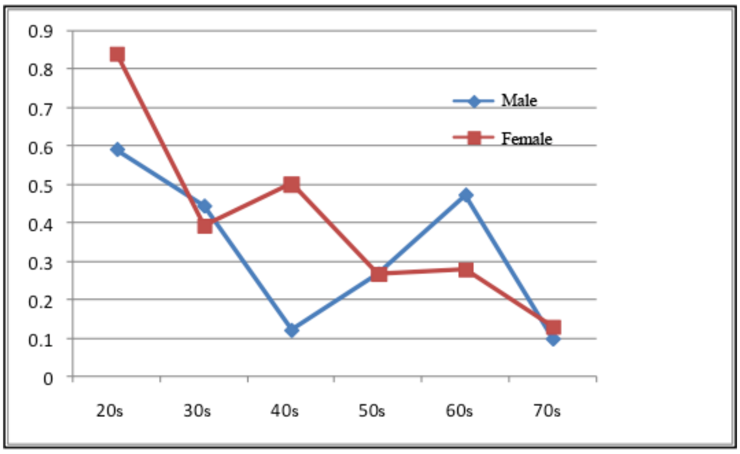

Figure 3 Age/Gender differed shopping interests

4.4. Spatial distribution of QOL in the Nagoya Metropolitan Area

With geocoded road network and locations of facilities, commercial facilities and medical care facilities in this study, it's easy to calculate accessibilities to all the districts. By overlaying 500×500 meter square grids, we can see how accessibility distribute in the metropolitan area. As shown below, Figure 4 and Figure 5 respectively display spatial difference of accessibility to medical care facilities (hospitals) and commercial facilities (Shops) in Nagoya Metropolitan Area.

About the accessibility to medical care facilities (Figure 4), a good amount of grids in red indicate that these inhabitancy areas can access a hospital within 7 minutes, while limited grids in dark blue represent those with worst accessibility to medical care facilities, requiring 26 to 39 minutes. Generally, most areas in the Nagoya Metropolitan Area have an accessibility to medical care facilities within 15 minutes, thought to be quite convenient. As to commercial facilities (Figure 5), only limited grids in city center could access a large scale shop within 15 minutes, while the majority areas need more than half hour.

Based on equation (1), the average QOL of around 4.7 million population, measured by Quality Adjusted Life Year, was calculated in Nagoya Metropolitan Area within 20km radials from the city center of Nagoya. According to the spatial distribution of QOL shown in Figure 6, it is obvious that the people living inside Nagoya city which has the highest density of rail and road transport services and agglomerates the majority of facilities gain the highest QOL, which is gradually diminishing with the distance to city center. Unlike the residents living in vicinities of railway stations in Nagoya city, those who live in suburban areas with no railway line covered gain the least QOL.

So we can make an easy conclusion that with necessity of a lot of car usage, these outskirts of the metropolitan region still require various efforts to improve their QOL, such as more constructions of rail network and facilities. However, as a matter of fact, having been a developed country for long, the maintenance of long existing infrastructures is also an inevitable challenge. Thus, it needs to be reconsidered if it is a feasible plan to more adding in these outskirt areas.

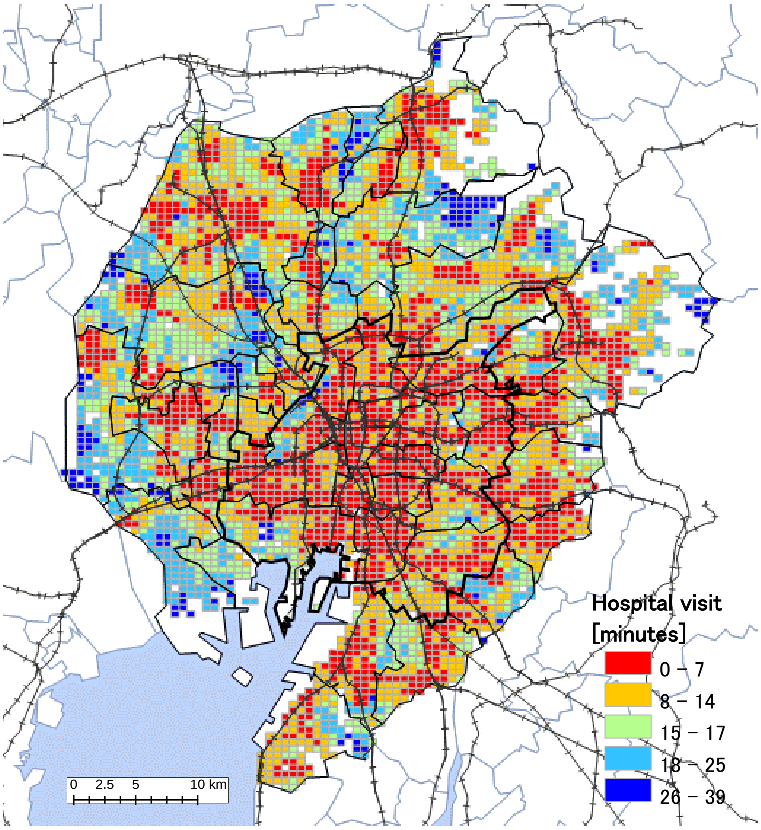

Figure 4 Accessibility to medical care facilities in Nagoya Metropolitan Area

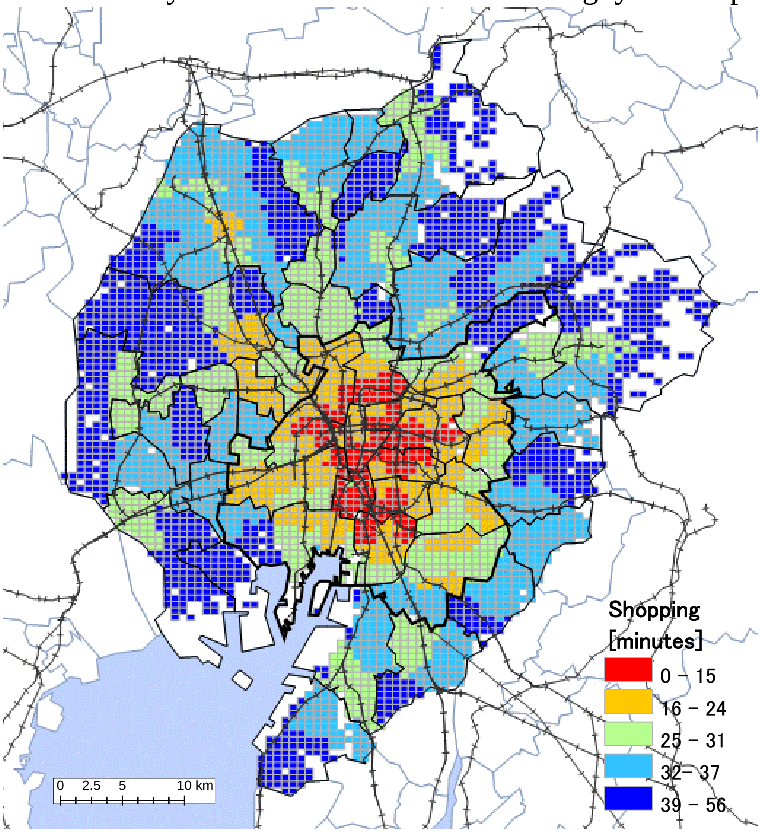

Figure 5 Accessibility to large scale commercial facilities in Nagoya Metropolitan Area

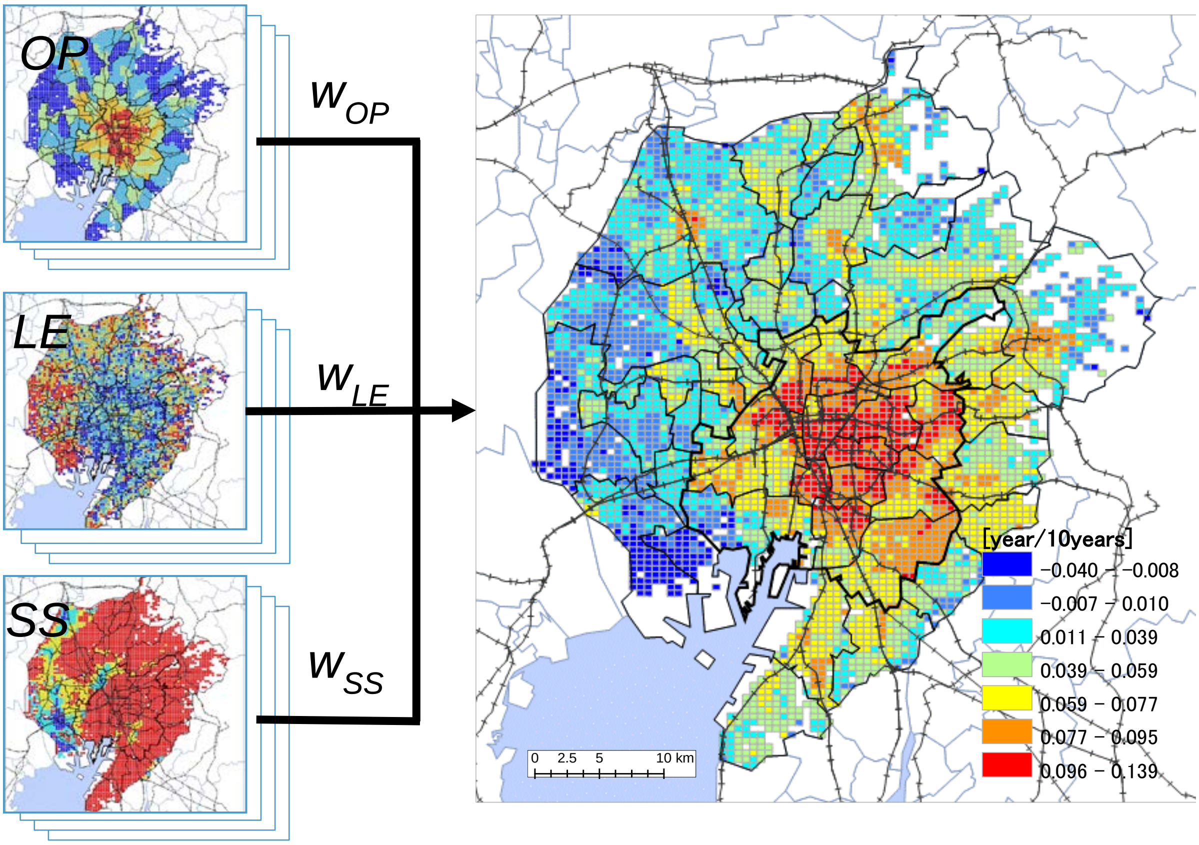

Figure 6 Spatial distribution of QOL in Nagoya Metropolitan Area

4.5 CO_2 emission in Study Area

Environmental loads have been considered as an important fact of sustainability. Only if the city is designed eco-sufficient, could it be sustainable.

It’s widely accepted that railway system creates least CO_2 emission, bus system next, while car usage creates the most. Figure 7 first compares different transport means’ accessibility per unit CO_2 emission in the grid of 500×500 meter squares. As is shown in this figure, each transport mode offers different accessibility distribution. The railway systems provide highest accessibility in the vicinities of railway stations, and also cover almost whole metropolitan area. Obviously, places where emit less CO_2 don't have railway passing by. According to Figure 7, only limited areas have very low accessibility because of the almost matured railway network. On the contrast, the bus system just provides highest accessibility in limited areas, where they serve as a complementary public transport system to railways. Complete bus lines have not yet covered almost half of the metropolitan region, especially in the suburban areas, where dramatically car transport provides the highest accessibility, with most CO_2 emission as well. It’s easy to understand in the way that the majority attractive opportunities locate in city center where many cars rush into, bringing the result of significantly dropped accessibility, while the suburban areas on the contrast can provide sufficient road space to drive. As a result, car usage proved to be very important to enhance both accessibility and accessibility in suburban areas. To achieve eco-sufficient accessibility in suburban areas should be the top priority.

Figure 7 also demonstrated that in outskirts of Nagoya Metropolitan Area, per capital CO_2 also emitted the most compared to the other areas, especially city center. Thus, in a population decline era, it is not a sufficient way to construct more infrastructures and facilities in such high emission area.

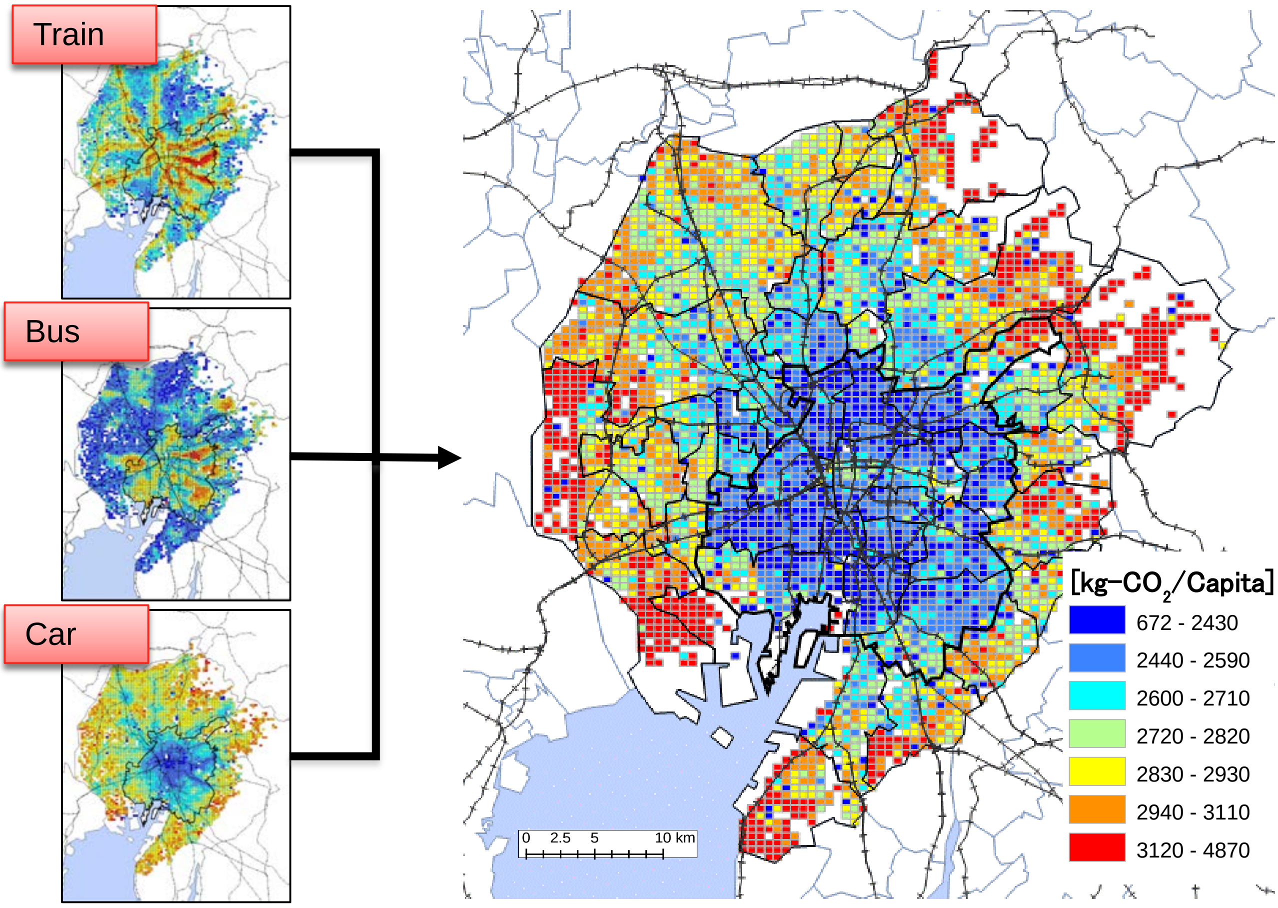

Figure 7 Spatial distribution of per capital CO_2 emission in Nagoya Metropolitan Area

5. SIMULTANEOUSLY ACHIVING HIGHER QOL AND LOWER CO_2 EMISSION

According to above spatial analysis on both QOL and per capital CO_2 emission in Nagoya Metropolitan Area, it is becoming clear that the grids with high QOL are limited, as well as low CO_2 emission. With the limitation of environment load and cost control, we need to seek for a way to improve both QOL and eco-sufficiency, namely CO_2 emission. Regarding the reality of population decline and economy stabilization, the basic idea is to shrink in space use, in a way we should abandon those grids where very low QOL and high CO_2 emission. Instead, residents should be persuaded to move from these areas to those where they can obtain higher QOL with less environmental load. This idea is further interpreted in Figure 8.

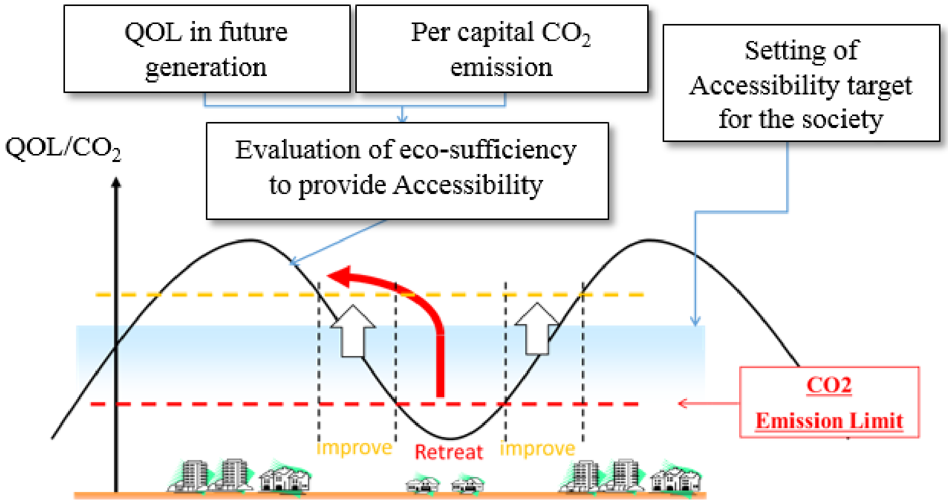

Figure 8 Proposal of Urban Shrink Design System Based on Sufficient QOL target

It is believed that removing residents from places with low accessibility and QOL to places with high accessibility and QOL can firstly improve entire accessibility and QOL, further reduce CO_2 emission, and even save future maintenance cost as well. By analyzing and comparing results shown in Figure 9, we can identify good areas to accommodate residential population, and that for retreat of population in Nagoya metropolitan region.

In the case of Nagoya metropolitan region, it is obvious that residential areas located in the outskirts of Nagoya city are with lower or even the lowest QOL (shown in Figure 6 above in section 4.4), less or the least public transportation and most car using which is not eco and economic efficiency (shown in Figure 7 above in section 4.5). In a shrinking city, our approach is to abandon those areas with lower accessibility and QOL, in which process it is also possible to reduce CO_2 emission.

With this basic idea, we selected retreat districts necessary for different CO_2 reduction targets. As is shown in Figure 9, we set 4 levels of reduction target, which are 5% reduction, 10% reduction, 15% reduction and 20% reduction

Referring to Figure 9, districts in blue colors (from dark blue to light blue) are about to retreat. With different reduction target, different scale of retreat district was chosen. As is shown in Figure 9, if retreat districts in dark blue are removed, first 5% CO_2 emission reduction target can be achieved. If the CO_2 emission reduction target is 10%, both of the dark blue and light blue districts should be retreated. Further 5% reduction target can be reached by removing the green districts, and 5% more can be achieved by removing the orange districts. The districts in red are all with higher Sufficiency.

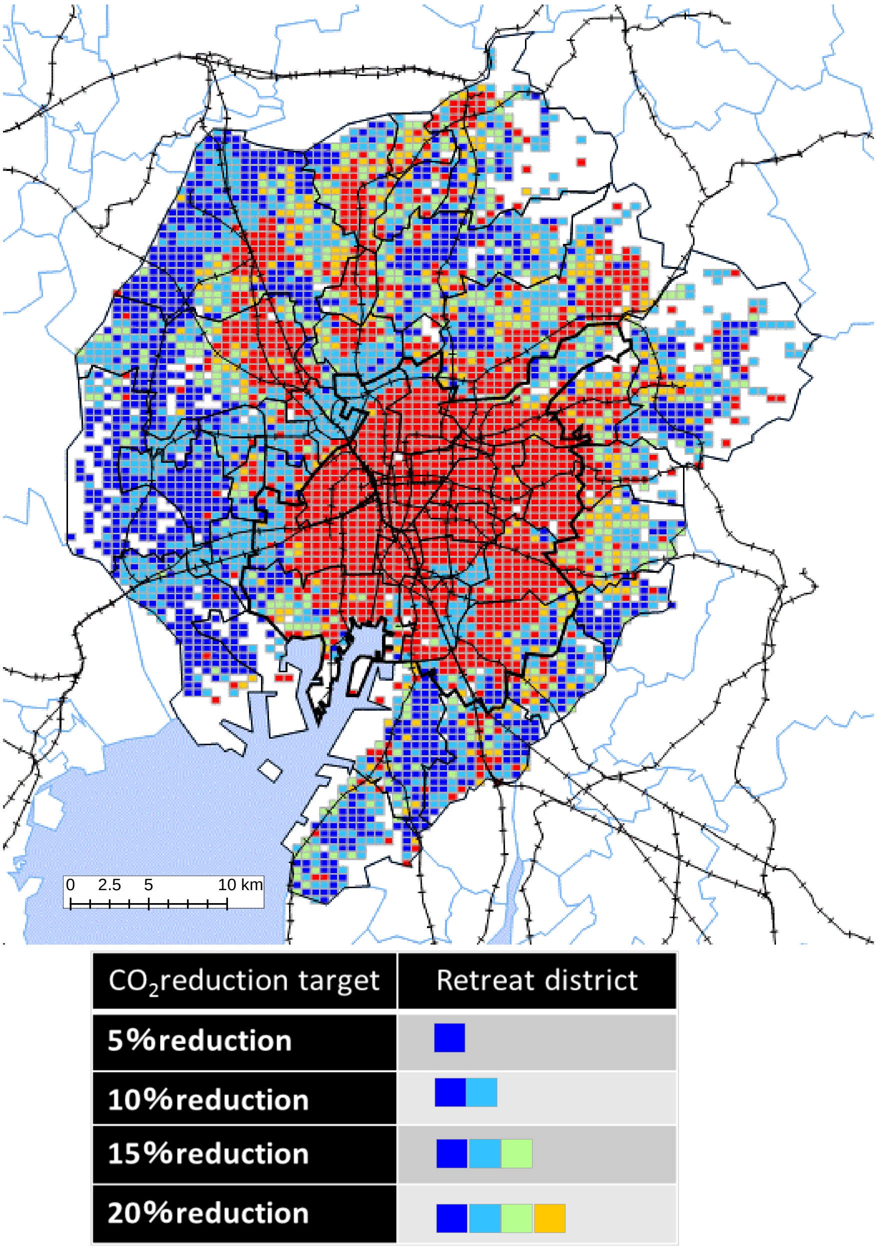

Figure 9 Selections of Retreat Districts in Nagoya Metropolitan Area

6. CONCLUSIONS AND DISCUSSION

This research has developed a method to evaluate whether a land use - transport system is sustainable or not, based on the indicator of QOL performance against CO_2 emission by 500m*500m grids. It guides a way for land use reform, especially special reform, within the metropolitan area or within the city, by identify which grids to maintain and which not.

This is a much higher special resolution compare to CGE models of which analysis unit is city or big region. Therefore, this method allows to be used for making plans and policies for compact city by identifying which grids should be reformed. As well as how the transport network should be reformed its aliment.

Moreover, this method can evaluate quantitatively by people's attribute group. Namely, by age group, gender, etc... It can be useful also for policy making or further, for reforming land use - transport system to be adaptive for a more aged society.

As aging is going on, not only in Japan, but also in East Asia and South East Asia, this method will be useful for these countries as well.

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