A Study in Reconstruction Design of City Blocks by Low Carbon Performance Evaluation System

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Abstract

This study is intended to develop a system evaluation of low-carbon performance of “city blocks” as a spatial resolution level between a city and a single city block, and to examine practical designs of “city blocks” to be evaluated by the developed method. The system proposed this time is (1) to derive a carbon serviceability index and the cost efficiency of the city blocks to be evaluated, and (2) to propose spatial designs and combination of elemental technologies for improving those values as a regional feature. For that purpose, factors such as residential population, number of workers and CO_2 emission cap, which are determined after macroscopic examination of urban structures, are provided as requisites for the city blocks in order to derive a eco-efficiency index and the cost-efficiency, based on evaluation of LCA and city block service regarding architecture, energy and traffic.

Keywords: low carbon city, district planning, Quality of Life, Triple Bottom Line, dynamic update.

1. Introduction

As a method to realize a low-carbon society, rebuilding an aggregated-urban-structure is often insisted. However, how to design the aggregated area has not been fully discussed. For smooth remodeling to the aggregated-city structure, it is important to create a space-structure for steady realization of the low-carbon society while maintaining the quality of life of residents’.

On the other hand, although the elemental technologies to assist realization of a low-carbon society have been remarkably developed, the effects of those elementary technologies vary according to the circumstances. Accordingly, examination of possible combinations of circumstances to let each elementary technology perform fully is needed.

Under the above-mentioned circumstances, this study aims to develop a model to evaluate the amount and cost of CO_2 emissions from each activity and also to evaluate residents’ quality of life, in order to predict reconstructing a schedule of the existing buildings until 2050 by handling closely-related city-blocks as a unit of ‘city blocks’ as a spatial resolution level between ‘cities,’ for which an aggregated-urban-structure has been discussed , and ‘architecture’ or a ‘city block,’ into which each technology has been developed and introduced. In addition, using the developed model, we tried a case study on the center of Nagoya.

2. Review of existing evaluation system for performance of low-carbon

There are several representative methods to evaluate low-carbon performance in cities, such as CASBEE-urban development[1] of Japan, LEED for neighborhood development[2] of the USA and BREEAM[3] of the UK. However, as these methods, which were developed for planning or designing stages, are suitable for finding out indices of output such as introduction of individual technologies or consideration of designs, they are unsuitable for grasping the outcome of the development.

Accordingly, we need a system enabling us to evaluate the performance by outcome. In addition, chronological changes should be analyzed in remodeling in the existing urban area.

This study aims to develop a system enabling us to dynamically predict future requirements for building reconstruction, to present a renewal plan accordingly and to evaluate the plan in order to study steps for introducing policies or technologies chronologically according to step-by-step reconstruction of buildings.

3. Construction of evaluation system for low-carbon performance by TBL

3.1 Total structure of the evaluation system

The total structure of the evaluation system for low-carbon performance is shown in Fig. 1. The low carbon evaluation system developed by this study consists of two parts: (1) Chronological design model for city blocks necessary for us to predict future building reconstruction in chronological order, and (2) Triple-bottom-line (TBL) [4] evaluation system to evaluate the low carbon performance

Table 1: Outline of AM element

Evaluation element	Environmental element	Concept of evaluation	Mesurement indicator
About use of space	Personal space	Floor area for living	Total floor area per person
	Public space	Flexibility of street	ln(The number of store and restaurant)
About balance of the landscape	Public space	Consecutiveness of street	Area raito of the greatest numbers building type
About natural environment	Personal space	Green space in private site	Presence or absence of the gerden
	Public space	Exposure to the sun (street)	Rate of open space
About local environment	Personal space	Exposure to the sun (house)	Sunshine
	Public space	Pleasant air	Atmospheric temperature

of the city blocks individually in the three bottom lines, namely, (i) society, (ii) economy and (iii) ecology. On the assumption that the services provided by the city blocks derived from the above systems are considered to represent the quality of life (QOL) of the residents, eco-efficiency and cost-efficiency are defined as Formulas (1) and (2) respectively.

$$QOL / E_{CO_2} \quad (1)$$

$$QOL / Cost \quad (2)$$

Reference:

QOL : QOL value in the year of t,

E_{CO_2} : CO_2 emission per head in the year of t,

$Cost$: Maintenance cost for a city block per head in the year of t.

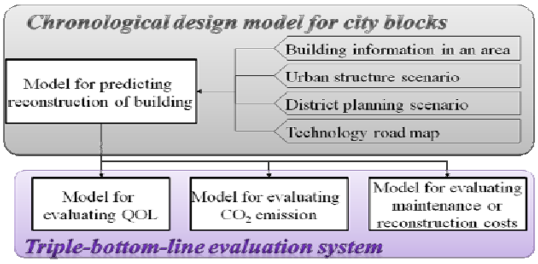

Fig.1: The total structure of the evaluation system for low-carbon performance

3.2 Model for predicting reconstruction of buildings

3.2.1 Prediction of reconstruction of existing buildings

Predicting the exact timing of reconstruction of existing individual buildings is so difficult that we applied the Monte Carlo Method to design a model instead. Specifically, using a function of residual ratio, $R_c(t,a)$, proposed by Komatsu and others [5] for calculating residual ratio for a building construction 'C' with an elapsed years of 'a' , as an explanatory variable, we calculated residual probability of a building 'i' in the year of 't' as $P_{i,c}(t,a)$ using Formula (3), and based on the results, we constructed a model for predicting the timing of reconstruction of buildings in a specified area by repeating the simulation year-by-year.

$$P_{i,c}(t+1,a+1) = R_c(t,a) \cdot P_{i,c}(t,a) \quad (3)$$

3.2.2 Assumption about introducing low-carbon technologies in the event of reconstruction

In this study, future performance of low carbon technologies is classified according to the existing plan made by the government and others [6] [7] [8], and we assumed that the latest technologies in performance are to be introduced when a new building is constructed.

3.2.3 Model for evaluating the quality of life (QOL)

In this study, dwelling service provided by city blocks is evaluated by Quality of Life (QOL). We assumed that QOL is decided by physical values of the residential environment as an environment and a sense of value by each resident and defined four components of QOL as Amenity (AM) in referring to ideas by Kachi and others 9) as shown in Table 1. In addition, we defined the QOL value as the amount that the AM is multiplied by a weight index that represents the sense of value of residents for QOL.

3.2.4 Model for evaluating CO_2 emission

In the ecological aspect, total CO_2 amount emitted by necessary activities for living in and maintaining or managing the city blocks for the whole life cycle is considered to be evaluated. Specifically, the total amount of CO_2 emitted at every stage from construction to disposal of infrastructure and buildings, CO_2 emission in household and business activities and the whole CO_2 amount emitted by traffic activities are determined as the targets of evaluation, and each factor is decided by using standard designs and statistics with one-unit for the base of each scale shown in Table-2 10) 11).

Table 2: Investigate Scale of Infrastructure・Building, Consumer and Traffic

Classification	Object	Scale
Infrastructure	Road	Paved road area (m^2)
	Water supply	Pipe line length(m)
	Sewer	Pipe line length (m)
Building	Wooden	Floor area(m^2)
	Nonwooden	Floor area(m^2)
Energy	Electric power	Electric consumption(kWh)
	Urban gas	Gas consumption(m^2)
Traffic		Trip length(km)

3.2.5 Model for evaluating maintenance or reconstruction costs of city blocks

In the economy, all costs incurred by the activities in the targeted city blocks during whole life cycle are considered to be evaluated. Like CO_2 emission, total costs incurred at every stage from construction to disposal of infrastructure and buildings and costs for household and business activities are determined as the targets of evaluation, and the whole cost is determined to be calculated according to each factor [12] [13] .

4. Case study on actual central city blocks

4.1 Constructing an analysis scenario

For analyzing, two scenarios are constructed: (1) "Business as usual (BAU) scenario, which means that the existing buildings will be freely reconstructed until 2050, and (2) "Collaborative reconstruction (CR) scenario", which means that buildings built in similar years will be collected to form a group for collaborative reconstruction in the city blocks and the reconstruction of the city blocks will be carried out under a fixed plan. The number of households and workers of 2050 will be estimated to increase to 1.8 times and 1.4 times of 2010 respectively, based on a target for an aggregated-urban-structure by 2050 in Nagoya.

4.2 Results of reconstruction simulation

Examples of forecast for reconstruction with intervals of ten years by each scenario are shown in Fig. 2. In the "BAU scenario", reconstruction will be continued for forty years on a step-by-step basis as buildings are reconstructed in the same place as before. Further, in the event of reconstruction, as wider floor space is generally needed in the same limited area where the prior building stood, the possibility of more uneven spatial structure in the city blocks may occur due to the volume of reconstructed buildings may vary in widely.

On the other hand, in the "Collaborative reconstruction scenario", as it may take a certain period to secure sizable land, it is forecast that demolishing old buildings will precede for the first ten years from 2020 and reconstruction of buildings will be concentrated in the next ten years.

4.3 Results of evaluation of low-carbon performance

4.3.1 Results of calculation of CO_2 emission

Calculated results of CO_2 emission per head (excluding service and construction sectors) in both scenarios is shown in Fig. 3. From the calculation, it is expected as a whole that CO_2 will be reduced by 60% in the "BAU scenario," and 65 % in the "Collaborative reconstruction scenario" respectively from 2010. In addition, in the "BAU scenario," CO_2 emission will be reduced gradually toward 2050, and in the "Collaborative reconstruction scenario," CO_2 emission will increase until 2020 according to the preceding demolishing of buildings, and then CO_2 emission will be decreased drastically. Accordingly, total emission of CO_2 for the forty years in the "BAU scenario" will be larger than that in the "Collaborative reconstruction scenario."

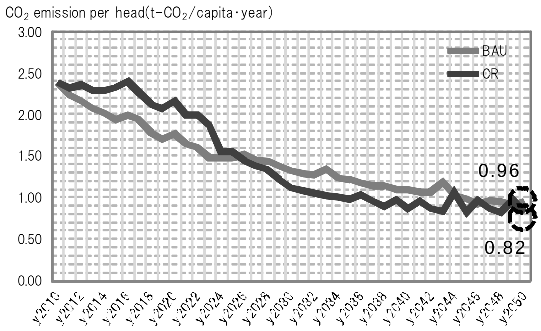

Fig.3: Calculated results of CO_2 emission per head

4.3.2 Results of calculation of eco-efficiency

Results of the calculation of eco-efficiency are shown in Fig. 4. The results show that eco-efficiency in the "BAU scenario" will be improved to 2.5 times of 2010 and that in the "Collaborative reconstruction scenario" to 3.8 times. This is caused by drastic reduction of CO_2 emission in the both scenario, however, the "Collaborative reconstruction scenario" will contribute further to improve QOL in addition to CO_2 reduction, which, it is considered, will enlarge the gap with "BAU scenario."

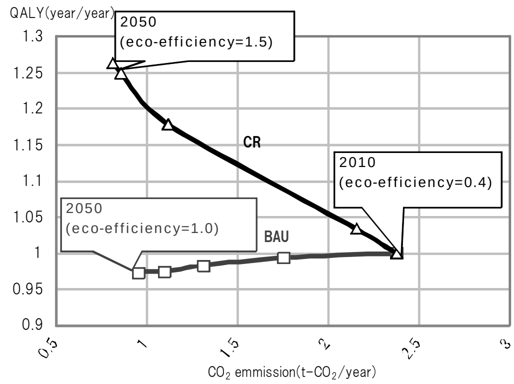

Fig.4: Results of the calculation of eco-efficiency

4.3.3 Results of calculation of cost-efficiency

Results of the calculation of cost-efficiency are shown in Fig. 5. Cost-efficiency is improved to 1.2 times of 2010 in the "BAU scenario" and to 1.7 times in the "Collaborative reconstruction scenario." The results of the cost-efficiency are similar to those of the eco-efficiency; however, in the "Collaborative reconstruction scenario," maintenance and reconstruction costs per head will increase in the first ten years from 2010 to 2020. This shows that the cost efficiency may be decreased temporarily in the "Collaborative scenario."

5. Conclusion

In this study, we constructed a model to evaluate the existing city blocks in consideration of TBL by predicting the reconstruction schedule of existing buildings yearly based on actual data such as constructed year. The study enables us to make a chronological design plan for changing the existing city blocks to a low-carbon society according to a fixed plan. In addition, the following points are revealed from the case-study.

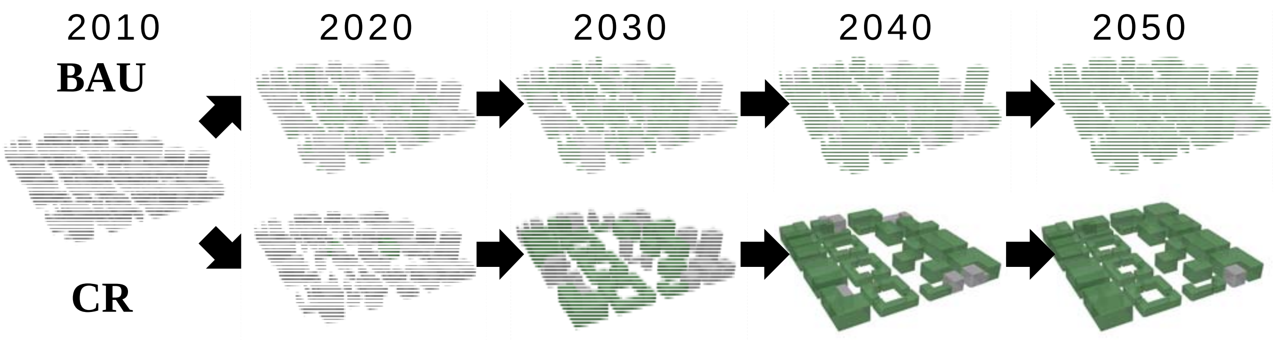

Fig.2: Results of reconstruction simulation (Decade by decade)

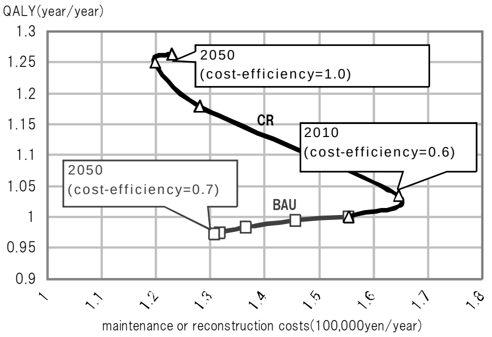

Fig.5: Results of the calculation of cost-efficiency

- In the efficiently used area, reconstruction by the unit of a total city block will contribute more to improving QOL of residents and to reduce CO_2 emission and costs than reconstruction by individual buildings.

- In the case of collaborative reconstruction, as a temporary increase of unoccupied area or a concentration of reconstruction can be easily expected, planning of the reconstruction process for the whole city block is considered important.

6. Acknowledgement

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