A LIFE CYCLE ESTIMATION SYSTEM OF VARIOUS ENVIRONMENTAL LOADS IN URBAN SPACE RESTRUCTUREING

Yasuo KITANO, Dr. Hirokazu KATO, and Professor Yoshitsugu HAYASHI, Japan

Key words: life cycle assessment (LCA), environmental impact, urban structure, and cohort model.

ABSTRACT

Cities are one of the major sources of environmental loads generated. To find effective measure to reduce the environmental loads from a city, it is necessary at first to estimate the environmental loads, then to evaluate the global and local impacts of the environmental loads. This paper presents a model system to estimate the major environmental loads from a city. The model treats most infrastructures and buildings comprising the study area. Ten kinds of environmental loads are estimated with the method of Life Cycle Assessment (LCA). The estimated values of environmental loads are evaluated by Environmental Friendliness Point (EFP). The model also estimates the environmental impacts of additional buildings and infrastructures. Finally, the effectiveness of the model is clarified by applying various house-building measures and urban spatial structural changes.

1. INTRODUCTION

Urban area has been a place where a lot of materials and energies are used, and enormous garbage and wastes are generated in a trend of mass consumption and disposal. As a result, enormous environmental loads have deteriorated the natural and built environment in local and global scale. In terms of sustainability of mankind and ecological system, it is one of the urgent issues to reduce the environmental loads from cities.

There are several proposals for the shapes of the cities that emit less environmental loads. Dantzig (Dantzig et al. 1973) proposes Compact City, which is 8-story 2,650m diameter circle building that can be resided by two million people. Ojima (Ojima et al. 1992) proposes 1,000m height rectangular parallelepiped building and claims that the population and the businesses in Tokyo can be accommodated in several buildings. Town and Country Planning Association (A. Blowers 1993) recommends measures to reduce the environmental loads for each size of the city or region, namely Social City Region.

These proposals mainly discuss the amount of environmental loads from the operation of the cities but the environmental loads generated from construction and demolishment of existing facilities in the cities are almost entirely ignored. Considering the fact that the structures and the components of the proposed cities are totally different from the existing cities, changing existing cities dramatically or developing the virgin land, it can be said that it is necessary to estimate the amount of environmental loads considering the process of change of the cities.

There is also other problem, which is the existence of the tradeoff between environmental loads. If one environmental load is reduced by a measure, other environmental loads could increase instead. Also normally in terms of the estimation of environmental load, carbon dioxide is mainly focused on with the concern of global warming, but it is also necessary to estimate and evaluate other environmental loads.

Considering the problems of existing research conducted, this paper presents a GIS-based simulation system to estimate ten kinds of environmental loads from a city. As a method of the estimation of environmental loads, Life Cycle Assessment (LCA) is applied for each facility. The merit of the introduction of LCA is that it is possible to estimate direct and indirect environmental loads from all stage of the facilities. To evaluate the environmental loads, Environmental Friendliness Point (EPA) is used as an integrated indicator. Also to describe the changing structure of the city, Building Cohort Model is applied.

2. APPLYING LCA TO URBAN SPACE RESTRUCTURING MEASURES

2.1 Definition of Life Cycle Environmental Load and Extended Life Cycle Environmental Load

Figure 1 shows the overall sources of environmental loads and their relationships with each other. There are three activities, landuse, transportation, and production and consumption. These are related with each other. For example, when landuse changes, the traffic pattern also changes. Then, this change causes the landuse change in the long run.

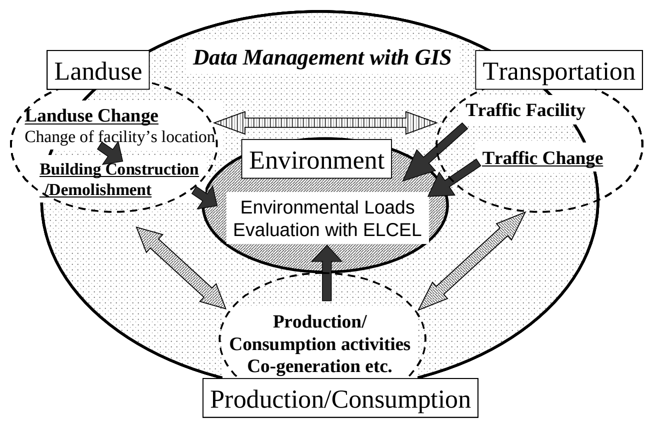


Figure 1: Activities and their relationship

These activities are conducted on the "urban stock", which is composite of facilities that relate to a city such as buildings and infrastructures. Existing researches about Infrastructure LCA (ILCA) have dealt with the Life Cycle Environmental Load (LCEL) from each facility. However, when treating a whole city, not only the urban stock itself generates environmental loads, but also the condition of urban stock changes the activities in a city and this also causes the change of the amount of environmental loads from a city. Kato (Kato 1998) defines the Extended Life Cycle Environmental Load (ELCEL) as environmental loads from urban stock (LCEL) and environmental loads from the activities that relate to a city. In this research, the concept of ELCEL is applied to estimate the environmental loads.

2.2 Existing Research

There are several researches estimating the environmental loads from a city or an area. One method is macro approach. This is appropriate to estimate the amount of environmental loads more correctly but it is difficult to test the effect of environmental load reduction measure. On the other hand, summing up approach, which estimates the environmental loads from each facility and activity and then piles up all of them, is appropriate to test the reduction measures. Existing researches estimating the environmental loads by summing up approach from a city or an area are summarized below:

1. HANAKI (Hanaki et al. 1996)

It focuses on the construction and operation stage of a New Town and analyzes how locational arrangement of each facility and the construction methods for it affect the amount of environmental load. This research is the first attempt to estimate the environmental load (carbon dioxide) from several facilities composing certain area with LCA. However, it does not consider the overall life cycle of each facility.

2. MORIOKA (Morioka et al. 1999)

It tries to estimate the amount of environmental loads with LCA from the existing facilities in the central business district (Nakanoshima District) of Osaka Japan, considering the life cycle of the facilities and the traffic generated from the district. It also estimates the amount of environmental loads by applying the several area-revitalizing measures. It is the first attempt to estimate the environmental loads from the existing city, by applying the concept of ELCEL. However, as this research uses disaggregate data of each facility, it is hard to widen the area of study because of the problem of data collection. Also it is hard to take accordance with the traffic or landuse analysis models that are mainly based on the zonal analysis, and this model linkage problem causes the problem of description of the structural change of the city.

3. KURODA (Kuroda et al. 1999)

This research estimates the amount of carbon dioxide from landuse and transportation of Kobe City in Japan with zonal analysis. A measure set for landuse and transportation that minimizes the carbon dioxide emission is decided considering the tradeoffs between them. However, as it doesn't consider LCEL of each facility, the amount of the environmental loads could be underestimated and the reduction rate of the measure set could be overestimated.

2.3 Characteristics of this Research

Considering the shortcomings of the existing researches, this research attempts to estimate the environmental loads with the concept of ELCEL. This research has five characteristics listed below:

- STUDY AREA

  Study area is Nagoya City, Japan. Its population is about two million and the administration area is 326.35km^2. Zonal analysis is conducted, although sometimes the characteristics of each zone are not considered well. However, LCA can be applied to a city easily with zonal analysis and the results can be taken accordance with the traffic and landuse model. The number of zone is 108.

- FACILITIES CONSIDERED

Table 1 shows the facilities considered, the Life Cycle Inventory (LCI) methods applied for each stage, and the durability of each facility. The development of green belt that fixes the carbon dioxide is dealt with. In terms of sewage and water supply works, the construction and demolishment stage is not mentioned. As these

Table 1: Facilities, LCI Method and Durability

Classification	Facility	Sub-class	LCI Method A*	LCI Method B*	LCI Method C*	Durability
House	Detached	Wood, Steel	‡ @	‡ @	‡ @	Survival Rate
	Apartment	RC,SRC	‡ @	‡ @	‡ @	Survival Rate
Other Building	Office, Hotel, Public, Commercial	RC,SRC	‡ @	‡ @	‡ @	50 years
Transportation	Road	Asphalt	‡ @	-	‡ @	15 years
	Subway		‡ A	‡ A	-	60 years
Incineration	Incineration Works		‡ @ A	‡ @	‡ @	15 years (machine) 50 years (building)
	Crusher Mill		‡ @ A	‡ @	‡ @	15 years (machine) 50 years (building)
Sawage	Sewage Works		-	‡ @	-	-
	Sludge Incinerator		-	‡ @	-	-
	Pipeline		‡ @	-	‡ @	50 years
Water	Water Works		-	‡ @	-	-
	Pileline		‡ @	-	‡ @	50 years
Park, Green Belt		City Park, Breen Belt	‡ @	-	‡ @	20 years

A: Construction, B:Meintenance, C:Demolishment
‡ @Convined Method, ‡ AApplication of I/O Analysis

facilities have been changed continuously, replacing some of the machines or widening reservoirs, construction and demolishment stage is included in the maintenance stage. The durability of each type of house is given by the survival rate of each age, which is mentioned in *BUILDING COHORT MODEL*.

– ENVIRONMENTAL LOADS ESTIMATED AND ENVIRONMENTAL LOAD EVALUATION INDICATOR

To cover almost all major pollutants from a city, ten kinds of environmental loads, CO_2, energy consumption, waste, water consumption, NO_x, SO_x, BOD, COD, T-N and T-P are estimated by using the Embodied Environmental Load Emission Unit (Tsurumaki et al. 1999).

To analyze the tradeoffs between various environmental loads, Environmental Friendliness Point (EFP) is introduced as environmental load evaluation indicator (Kato et al. 2000). EFP is defined by Distance-to-Target Method, which is based on the categorization and relative weight to each category. In this research, the number of category is six, Global Warming (CO_2), Acidification (NO_x and SO_x), Water Pollution (COD, T-N and T-P), Air Pollution (NO_x and SO_x), Energy Consumption, and Waste. The value of each environmental load is characterized by the physical characteristic within each category, and then it is changed to the value of environmental influence potential of each category. Then, the value of environmental influence potential within each category is weighed based on the natural resources' deposits, the environmental standards or acceptable amount of pollutants' emission.

Distance-to-Target Method is widely prevailing method in LCA studies and has the scientific objectivity compared with the questionnaire method. However, it is difficult to decide appropriately the environmental standards or acceptable amount of emission. Especially when considering the long-term description of the change of certain area, the weights between the categories can change. For example, the weight of waste can change in relation to the condition of the waste generated and the areas constructed for disposal in the future. Also in the future the environmental standards and the acceptable emission would become stricter, and then weights change. As these issues contain uncertainty, in this research the weight of each category is set constant. This means that the value of EFP might be under estimated.

– PREPCCUPATION OF THE ANALYSIS

Exogenous variables such as land price and household savings are set constant. On the other hand, variables, such as demographic forecast of each zone and average housing floor space, are assumed to change taking accordance with the demographic forecast from 1998 to 2020 by Nagoya City Hall.

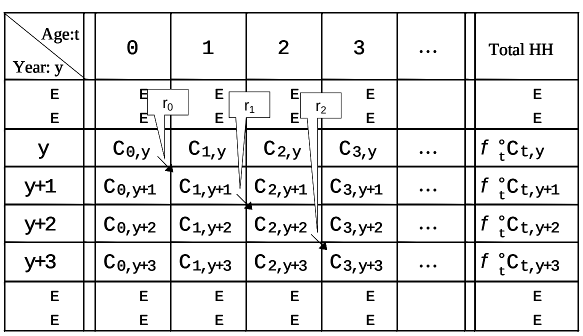
In terms of the relationship between landuse and transportation, the effects of the landuse change to the transportation activities are considered. However, the effects of the change of the transportation to the landuse, the industrial, and the commercial activities are not considered. To analyze these effects, landuse model must be introduced. The environmental loads from commercial and industrial sector are not considered because of data limitation.

3. BUILDING COHORT MODEL

To consider the transition of the structure of the city, by applying Building Cohort Model which is same as the cohort model used in demographic forecast, the estimation of environmental loads in time series can be conducted and several housing and city structure measures are tested.

Figure 2 shows the calculation method of building cohort model. By using $1\text{-}r_t$, which represents the demolishment rate of age t (r_t represents the survival rate of age t), total number of demolished houses in year y can be described as $\Sigma_t(1\text{-}r_t)C_{t,y}$. By inputting the number of new houses exogenously which is represented as $C_{0,y+1}$, total number of houses in year $y+1$ can be described as $\Sigma_{t+1}C_{t+1,y+1}$.

Figure 3 shows the structure of model constructed. It is applied to each zone and each type of houses in Nagoya. This model has two modules such as locational selection module, and structure selection and house type selection module. Through these modules, the effects of the measures can be analyzed.



*HH: Household

Figure 2: Calculation method of Cohort model

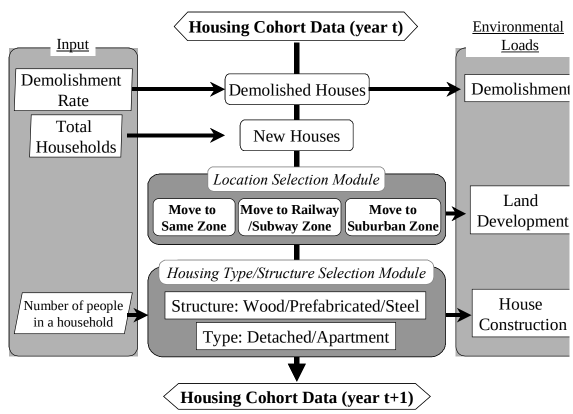


Figure 3: Building Cohort Model

The survival rate used is the result of Noshiro (Noshiro 1991). Building data used is Housing Statistics in Nagoya in 1992. The data can be gained in each ward and it is allocated to the 108 zones proportionate to the number of household in each zone. The house type is decided by multi regression analysis (variables: number of people in each household, land price i. e.). As the number of people in each household has tendency of decreasing, the ratio of apartment house increases and then the number of apartment houses increases. In terms of structure type, it also could change, but it is fixed to the ratio that is gained from the Housing Statistics in Nagoya, because of the data limitation.

4. ENVIRONMENTAL LOADS ESTIMATION METHODS AND GIS BASED SIMULATION SYSTEM

4.1 Life Cycle Inventory (LCI) Method Applied

Table 1 shows the facilities considered and LCI method applied to each stage. Considering the characteristics of the data, two types of LCI method, Combined Method and Application of Input/Output Analysis, are used. The application of these Methods to the environmental estimation is described below:

– COMBINED METHOD
  Data of materials and energies used in construction, maintenance, operation and demolishment of each facility is divided into the minimum unit with the adding-up materials of each facility and then the minimum unit data is classified into the categories of I/O Matrix. The classified materials and energies are multiplied by embodied environmental load emission unit, and then the environmental loads can be estimated. The merit of this method is that it can estimate environmental loads from the minor change of the materials or construction methods and it can estimate direct and indirect environmental loads by using Embodied Environmental Load Emission Unit.
  In this research, these data is stored in Material Matrix Database (91 categories) per unit (per square meter i.e.) in monetary term. The estimated amount is multiplied by Embodied Environmental Load Emission Unit (91 categories, Tsurumaki et al. 1999) and the scale of each facility, and then ten kinds of environmental loads can be estimated. As the price of each material and energy must be the price in 1990 to coordinate with the I/O Matrix but the prices of the adding-up materials are not always the price in 1990, so the amount of materials and energies are at first converted to the prices in 1999 and then they are modified to the prices in 1990 with the deflator of Statistics of Construction. As the values in I/O Matrix are the prices of producers, the prices must be converted to the producers’. And this can be done by reducing the added value of each material and energy from its price in 1999.

– APPLICATION OF INUT/OUTPUT ANALYSIS
  As some of the machines or facilities cannot be applied to Combined Method because they are too complex to apply the Combination Method, Application of Input/Output Analysis is applied. The prices of them in 1990 are converted to the prices of the producers and then they are multiplied by Embodied Environmental Load Emission Unit. This method is used for the machines that are used in sewage works, water supply mills and incinerating works.
  In addition to the environmental load, water demand, and sewage and garbage generated must be estimated in this research. In terms of the garbage from households in each zone, multiple regression analysis (variables: population and household savings) is conducted to forecast the amount of it. To estimate the amount of the environmental loads (CO_2, NO_x i.e.), transportation of the garbage to the incineration works is considered as well as the emission from incineration. Origin/Destination Matrix is made based on the amount of the garbage in each zone

and the locations of the incineration works. Then the environmental loads can be estimated by allocating OD Matrix to the road network. In terms of sewage and water demand, it is assumed from the existing research that they are proportionate to the floor space of a household.

In terms of the transportation activities, four-stage transport forecast method is applied to calculate the velocity and traffic volume of each type of vehicle of each road. By applying the velocity-CO_2 and velocity-NO_x curves for each type of vehicle, the amount of the CO_2 and NO_x can be estimated.

– GEOGRAPHIC INFORMATION SYSTEM BASED SIMULATION SYSTEM

As a lot of data is used for simulation for each scenario, GIS based simulation system is constructed to ease the data manipulation. The software used is Arc/Info (EWS version) and the programming language for customization is Arc Macro Language and C. With it, Graphic User Interface is constructed to ease the scenario setting and simulation.

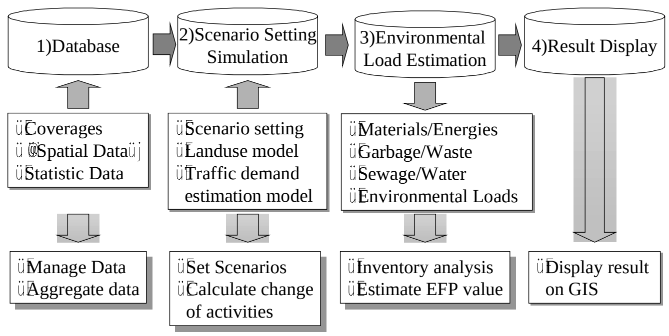


Figure 4: Simulation System

This system is composed of four modules, a)database, b)scenario setting and simulation, c)environmental load estimation, and d)result display. Database module manages the spatial and non-spatial data. Spatial data is managed as coverage and non-spatial data is maintained as normal database. By using the function of the database software through GUI, these data can be aggregated for each purpose. Scenario setting and simulation module is used for scenario setting through GUI. Then it is used for calculation of building cohort model, and traffic demand estimation and allocation. Environmental load estimation module calculates the amount of the environmental loads and EFP, using the result of the calculation by Scenario setting and simulation module. Display module displays the result of the calculation of each module.

5. MEASURES APPLIED

Table 2: Measures to be applied

Classificatio	Measure	Condition	Effects
BAU	1 BAU	Trend	\
Housing	2 Longer Durability	Double the durability	Decrease of the amount of waste from building demolishment Decrease of the newly constructed building
	3 Efficient Energy Use	30% off of energy use for air conditioning	Decrease of the energy use in operation of the building Increase the insulating materials
Structure of City	4 Concentration	Concentrating the HHs of demolished houses to around the major rail and subway stations	Increase of the modal share of the subway Decrease the total trip length of vehicle
	5 Green Belt	Greening the brown field	Fixing the carbon dioxide

The measures applied are listed in Table 2. The start year is 1991 and the final year is 2040. The calculation is conducted in every five years and the calculated values are five year total. BAU (Business As Usual) means that all facilities will change according to the trend change and the characteristics of the traffic such as modal share are constant. Measures for housing (2 and 3) and measures for structure of the city (4 and 5) are not only tested as a single measure, but also are tested to see the effective combination.

6. RESULTS

6.1 LCEL by the Measures for Housing Sector

Figure 5 shows the transitional change of the amount of LC-CO_2 of 1.BAU, 2.Longer Durability and 3.Efficient Energy Use from the housing sector.

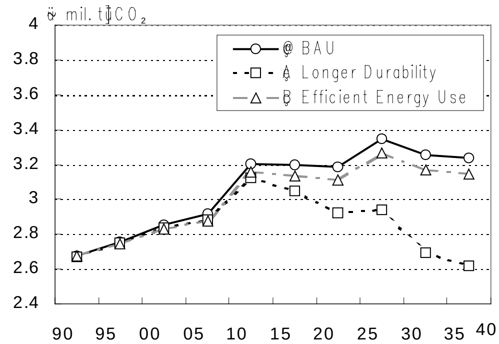


Figure 5: The Amount of CO_2 by Housing Measure

BAU shows that in the fifty years from 1991-95 to 2036-40 the amount of LC-CO_2 increases by 21.0%. Longer Durability Measure shows that until 2010 it increases almost same direction as BAU but after that it goes downward and finally decreases by 2.1% (compared with 1991-95 of BAU) and by 19.1% (compared with 2036-40 of BAU). In terms of Longer Durability measure, the amount of energy use increases by 2.9% (1991-95 BAU) and decreases by 15.4% (2036-40 BAU). The amount of NO_x decreases by 6.2% (1991-95 BAU) and decreases by 23.7% (2036-40 BAU). Also the waste from building demolishment increases 51.8% (1991-95 BAU) and decreases by 65.0% (2036-40 BAU). In the long run, Longer Duration measure is efficient to reduce the environmental loads.

On the other hand, in terms of Energy Efficient Measure, LC-CO_2 increases by 17.6% (1991-95 BAU) and decreases by 2.7% (2036-40 BAU). The share of the energy efficient house increases year by year and in 2036-40 the share of the energy efficient house dominates. But the effectiveness of this measure is slim, because of the additional insulating materials that cause the increase of the environmental loads in construction stage. LC-Energy increases by 16.3% (1991-95 BAU) and decreases by 2.0% (2036-40 BAU). LC-NO_x increases by 17.9% (1991-95 BAU) and decreases by 0.5% (2036-40 BAU). These results show that only with the Energy Efficient Measure it is hard to reduce the environmental loads to meet the COP3 criteria.

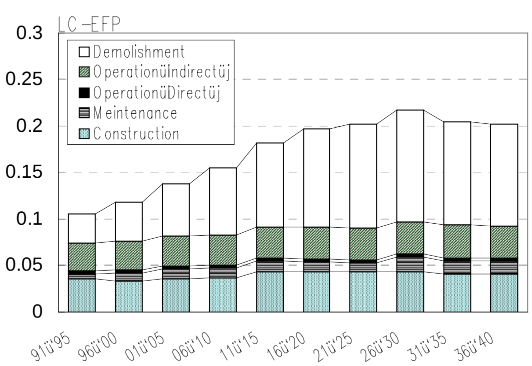


Figure 6: Life Cycle EFP of Housing Sector (BAU)

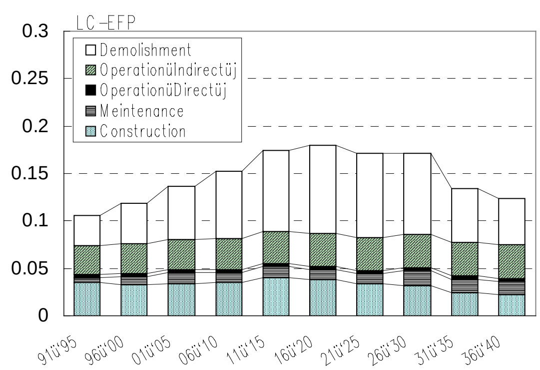


Figure 7: Life Cycle EFP from Housing Sector (Longer Durability Measure)

Figure 6 shows the result of the change of EFP from the housing sector from 1991-95 to 2036-40 in BAU. The value of EFP from the construction stage increases gradually. The average floor space of the detached house is about two times larger than that of the apartment house. However, the materials used in the apartment house are mainly steel

and concrete. This brings about more environmental loads compared with the Japanese typical wooden detached house. As the share of the detached house decreases and the share of the apartment house increases in 50 years, this causes the increase of the EFP of the construction of houses. The value of EFP of the waste increases dramatically by 300% and the share of the waste in the total value is 54.1% in 2036-40. Evaluating by EFP, the waste turns out to be a major source of environmental loads.
In Figure 7 shows the result of the Longer Durability Measure. In it, as the numbers of the new buildings and the demolished buildings decrease gradually, so the EFP decreases by 28.6% compared with the peak value in the 2016-20. From this result, the Longer Durability Measure is effective to decrease the EFP.

6.2 LCEL by the Measures for the City Structure

Figure 8 shows the transitional change of the LC-CO_2 and also Figure 9 shows LC-EFP from the all facilities considered. 4.Concentration Measure is that the households whose houses are demolished move to the zone where there are major railway or subway stations. 5.Green Belt Measure means that the brown fields, which are made by the movement of the households with 4.Concentration Measure, are changed into the green park. The CO_2 fixing rate of the green park is set to 30t-C/ha.year (Ichimura 1999).
In terms of BAU, LC-CO_2 increases by 21.6% in 2036-40 compared with the value in 1991-95. By the combination measure 2+3, LC-CO_2 increases until 2015 but after that it goes downward. Finally in 2036-40 it increases by 2.2% (1991-95 BAU) and decreases by 16.0% (2036-40 BAU). In terms of Measure 2+4, the similar change as Measure 2+3 occurs. With the combination measure of 2+4+5, LC-CO_2 decreases by 31.5% (BAU in 1991-95). And it decreases by 34.6%, when 3.Energy Efficiency is added. This is because the area of the green belt increases year by year and in 2036-40 the area of the green belt is 91km^2, which is about one fourth of the total administration area of Nagoya. This shows the effectiveness of Green Belt Measure when the large green belt is developed.

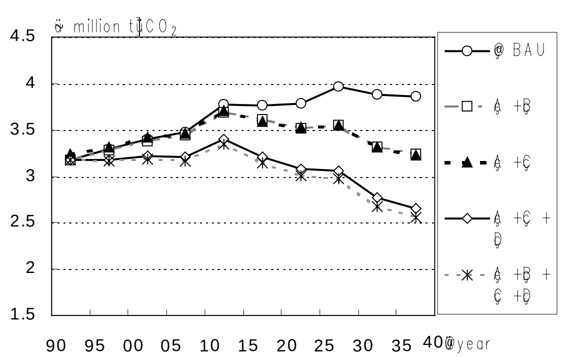


Figure 8: Life Cycle CO_2 Change By Each Measure Set

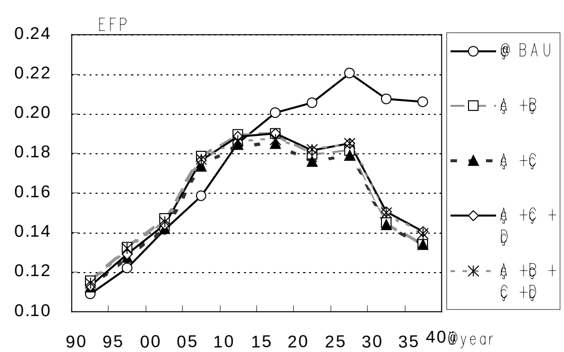


Figure 9: Life Cycle EFP Change by Each Measure Set

By BAU, LC-EFP increases by 89.0% in 2036-40 (BAU 1991-95). On the other hand, Measure 2-5 brings about relatively low increase by 21.2%. The reason why the result of the Each Measure set is almost similar is that each Measure set contains 2.Longer Durability, which dominate the value of LC-EFP.

6.3 ELCEL by the Measures for the City Structure

Figure 10 to 12 show the Extended Life Cycle (ELC) CO_2, NO_x and EFP respectively. In terms of ELC-NO_x, which causes the air pollution, the vehicle is the major source. In terms of ELC-EFP, housing sector is the major source. When applying the combination

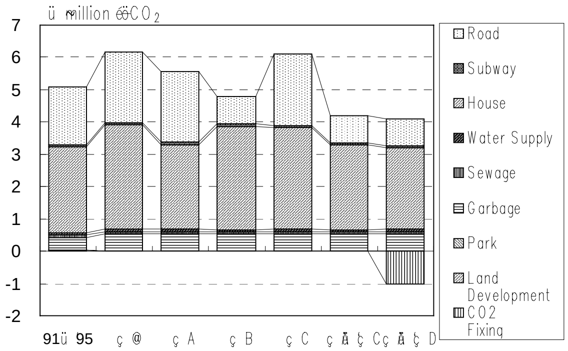


Figure 10: Extended Life Cycle CO_2 by Each Measure Set in 2036-40

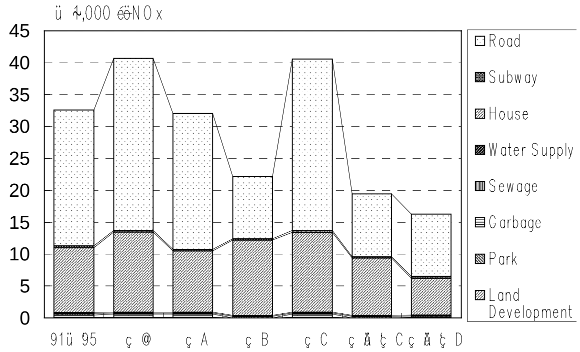


Figure 11: Extended Life Cycle NO_x by Each Measure Set in 2036-40

measure, 2 to 5, it can reduce ELC-CO_2 by 39.1%, ECL-NO_x by 51.9%, and ELC-EFP by 1.1% (BAU 1991-95). Also this measure reduces ELC-$CO_2$by 49.8%, ECL-NO_x by 61.4%, and ELC-EFP by 41.5% compared with the BAU in 2036-40.

From these results, it can be said that the majorities of ELCEL are vehicle and housing sector oriented and other sectors such as rail and sewage dominate little. To reduce the amount of ELCEL, it can be said that the measures for housing sector and landuse arrangement (concentration) is effective.

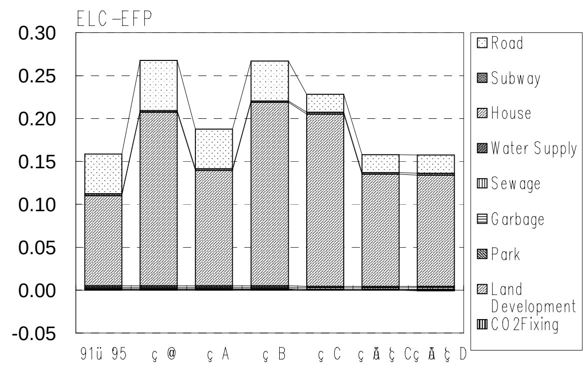


Figure 12: Extended Life Cycle EFP by Each Measure Set in 2036-40

7. CONCLUSION

In this research, a model system, which can evaluate the environmental loads from the implementation of the long-term city structure change, is developed. Zonal analysis is conducted to take accordance with the landuse and traffic simulation models. Applying the building cohort model, the long-term renewal process of the housing location is described. As the model system is developed on the GIS with GUI, it is possible to handle lots of special and non-spatial data easily.

Furthermore, ten kinds of environmental loads are estimated and evaluation of the environmental loads is conducted by EFP.

The knowledge gained from this study is summarized as:

– In BAU, the amount of LC-CO_2 from facilities in 50 years will increase by 21%. Also the amount of waste from housing demolishment in 2036-40 will be three times as much as that is in 1991-95. However, by applying combination measure, it is possible to reduce them,

– When evaluating by EFP, the waste from the housing demolishment dominates a lot. So Longer Durability Measure can contribute to reduce EFP,

– The amount of LCEL from the housing sector is much larger than that from sewage, water supply and land development. So the housing sector is important element to reduce the environmental loads,
– The Concentration Measure has a potential to reduce the environmental loads from the transportation sector. And the ratio of the reduction is almost equal to that of Measure for housing sector,
– And the Concentration Measure can contribute to reduce ELC-NO_x. Also together with the Green Belt Measure it can reduce ELC-CO_2.

8. THE FUTURE

In this research, co-generation system and district heating/cooling system whose introduction could contribute less emission are not considered. Heat-island effect, which would be changed by the landuse change and affect the energy use, is not considered. Considering them, the effective measures to reduce the environmental loads will be sought. And the environmental loads from commercial and industrial sector will be considered.

REFERENCES

Blowers A, 1993: Planning for a Sustainable Environment; A Report by the Town and Country Planning Association pp150-189, Earthscan

Dantzig G B et al., 1973: Compact City, A Plan for Livable Urban Environment, W.H. Freeman and Company

Hanaki K et al., 1996: Reduction of Carbon Dioxide Emission from Construction of NEW TOWNS, Environmental Systems Research vol.24 pp250-271, Committee of Environmental Systems, Japan Society of Civil Engineers

Ichimura K et al., November 1999: A Study of Atmospheric CO_2 Storage by Trees in Urban Parks, Papers on City Planning, City Planning Review Special Issue pp1-6, The City Planning Institute of Japan

Kato H, 1998: Life Cycle Assessment as a Environmental Impact Estimation Method for Transportation Planning, Traffic Engineering Vol.33 No.3 pp81-86, Japan Society of Traffic Engineers

Kato H et al. 2000: A LCA-Based Evaluation Model of Change in Environmental Load due to Improvement of Transport Systems, Proceedings of 28th Annual Meeting Environmental Systems Research pp131-138, Committee of Environmental Systems, Japan Society of Civil Engineers

Kuroda K et al. October 1999: A Synthetic and Quantitive Evaluation of Policies to Reduce Carbon Dioxide Emission in Urban Area, Proceedings of The Infrastructure Planning Committee, No.22 (1) pp655-666, Japan Society of Civil Engineers

Morioka T et al. 1999: Urban Environmental Management based upon Life Cycle Estimation of CO_2 from Central Urban Districts, Environmental Systems Research vol.27 pp355-364, Committee of Environmental Systems, Japan Society of Civil Engineers

Ojima T et al, 1992: Global Environmental Impact from Building Sector Eco City, The City Planning Institute of Japan

Statistics of Construction, 1997: Ministry of Construction Department of Construction

Economics, Construction Research Institute
Tsurumaki M et al.1999: Study on the Calculation Method of Many Kind of Environmental Load for Life Cycle Assessment, Environmental Systems Research vol.25 pp217-226, Committee of Environmental Systems, Japan Society of Civil Engineers

CONTACT

Yasuo Kitano, B.A., Dipl. of Town and Regional Planning, and M. Eng.
Tamano Consultants, Co. Ltd.
1-3-15 Aoi, Higashi-ku
Nagoya
JAPAN
Tel. + 81 52 931 5341
Fax + 81 52 931 5469
Email: kitano_yasuo@tamano.co.jp

BIOGRAPHICAL NOTE

Yasuo Kitano was born in 1973 and graduated from Department of Town and Regional Planning, University of Sheffield, UK (Diploma programme) in 1999 and Department of Geotechnical and Environmental Engineering, University of Nagoya, Japan (Master programme) in 2000. He is currently working in Geographic Information Department, Tamano Consultants Co. Ltd as a Geographic Information System designer for the local authorities. Tamano Consultants Co. Ltd. is one of the major consulting companies for landuse planning and civil engineering field in Japan. His current interest is Strategic Environmental Assessment (SEA) for landuse planning and GIS based supporting system for it. For this study he has researched with Prof. Y. Hayashi and Dr. H. Kato of University of Nagoya.