13. GIS-Based CO_2 Emission Assessment Caused by Suburbanized Activities Case Study in MUKO River Basin Region for Automobile Trips

GISによる流域圏での郊外化にともなうCO_2発生増加の算定

El-Lithy KHALED*, Tsuyoshi FUJITA**, Tohru MORIOKA*, Jun TOKUOKA*
カレード・エリシー，藤田 壮，盛岡 通，徳岡 潤

Abstract; This paper attempts to estimate CO2 emission generated by suburbanized urban activities growth. Taking MUKO River Basin Region, Hyogo, Japan as a case study for the emission caused by automobile trips to shopping areas in the region, site significant effects of economic growth and suburban activities growth were found. The analysis was carried out utilizing 1km grid GIS data, 1km statistics data for land use, population allocation, commercial activities, and other related data in this region focusing on the commercial areas where the CO2 emission by automobile trips is most serious. Comparative analysis for changes assessment between 1975s and 1995s two steps are done as follows; First step is to establish "sales regression model" to explain the correlation of the sales changes with several explanatory variables including population, retail floor space, trip distance and time length from residential area surrounding commercial areas. Second step is to calculate the CO2 emission amount which is regressed by parameters of the analysis and other statistical data. The results show significant impact of automobile trips generation to shopping areas oriented CO2 emission on the property value.

Keywords: *GIS, CO_2 Emission, Suburbanization, Environmental impacts, Basin Region*

1. INTRODUCTION

The rapid urbanization and the high diversified development of urban areas and urban facilities in Japan after the World War II has brought much social efficiency, and has led to occurrence of pollution in areas of large scale urban facilities[1]. The urbanization and economic growth in MUKO River Basin Region, Hyogo, Japan, starting from 1950s and 1960s, have caused several environmental impacts such as air pollution, water contamination and CO_2 Emissions. The commercial and suburbanized activities are experiencing dramatic growth in the region and resulting in considered environmental changes and related environmental impacts. The population, socio-economic activities data and their changes are analyzed by making effective use of the available data in the region integrating with GIS 1km Grid database and detailed digital maps. The urbanized area expansions of cities surrounding MUKO River Basin, and the current environmental changes affected by the suburbanization activities growth in this region are analyzed and related environmental emissions such as CO_2 are estimated.

2. MUKO RIVER BASIN REGION DATA SET PROCESSING

The population growth in MUKO River Basin Region, a west part of Kansai Metropolitan Region, from 1.5 million in 1975 to 1.7 in 1995[6] (Fig.1 shows population changes in the region), increasing of infrastructure and railway construction, as well as development of automobile expressways network have resulted in suburbanized urban activities growth which consequently caused a lot of global environmental emissions such as CO_2, local contaminations and other environmental impacts. GIS-based analysis is established to estimate CO_2 emission caused by development of urban facilities in the region based on a comparative analysis between 1975s and 1995s[2]. The emission of CO_2 brought by expansion of suburbanized urban areas and activities, and automobile access to shopping areas are identified utilizing 1km grid GIS data with their spatial patterns. The analysis was carried out based on considered data of population and commercial activities in the suburbanized areas of Nishinomiya, Takarazuka, Kita-Kobe, Sanda, and Ashia cities of MUKO River Basin Region. Fig.2 shows the boundaries of these cities and classification of their commercial activities patterns.

*Osaka University (2-1 Yamadaoka Suita City Osaka, 565-0871, Japan)
**Toyo University(2100 Kujirai Kawagoe City Saitama, 350-8585, Japan)

2.1 MUKO River Data Boundaries

An integrated GIS data base system for MUKO River Region utilizing 1km grid statistics data was established for time series change analysis. The system was obtained by various categories and types of regional statistical and spatial data such as land use, transportation network, automobile trips time distance, and population allocation[6]. Social activity data and other coverage data for the study area such as commercial sales and large scale stores allocation are also converted into 1km grid data as well as transportation accessibility of automobile ways in this Region. The data have been made for time-series comparative analysis between 1975s and 1995s for studying CO_2 emission changes and related factors. The commercial areas were classified into two major categories, large scale stores and arcades (the traditional shopping areas). These data of commercial allocation were converted also into GIS 1km grid data as shown in Fig. 2.

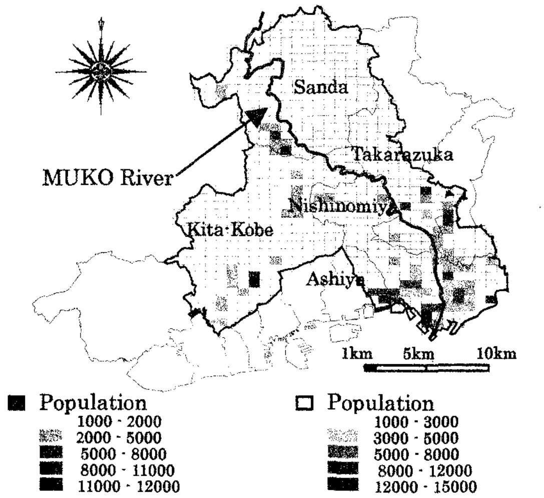

Fig.1 Population changes around MUKO River for time series between 1975s and 1995.

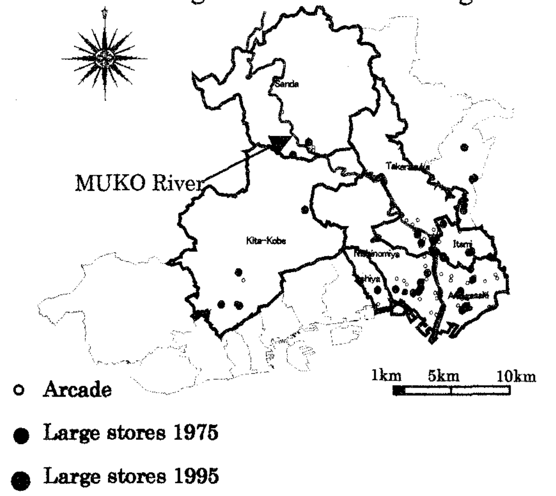

Fig.2 Boundaries of MUKO River Basin Region and commercial areas classification

2.2 Data Sources of CO_2 Assessment in MUKO River Basin Region

The data considered in the analysis included the following:

(A) 1km grid GIS spatial data for population, commercial, land use, etc (1975 to 1995).
(B) Statistical 1km grid data (1975 to 1995).
(C) Japan Statistical Yearbook Data, 2003.
(D) Road Traffic Census Data (1977, 1997).
(E) Other coverage data for the analysis.

3. ESTIMATION PROCESS AND ASSESSMENT OF CO_2 EMISSION

As various data are used for estimation and simulation, GIS-based simulation system is constructed for CO_2 emissions estimation. The system is composed of three modules, a) database establishing, b) models setting and simulation, and c) results displaying for the outputs of the system of data modeling and simulation, Fig.3. Environmental impact elements attributable to management policies are identified and suburbanized areas and activities changes in the region are analyzed in order to direct the future development polices, plans and processes to the environmental management[4].

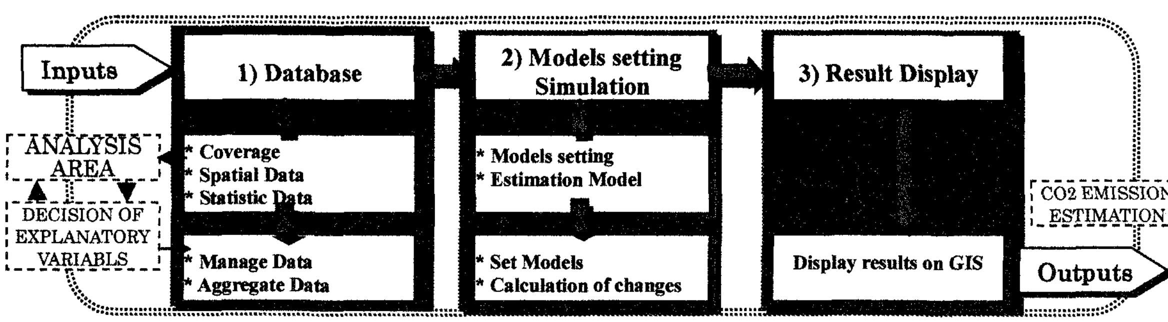

Fig.3 CO_2 Estimation and Simulation Process

3.1 GIS-based Assessment of CO_2 Emission in MUKO River Basin Region

GIS-based analysis of changes in suburbanized urban areas of MUKO River Basin Region was established in 1km grid data for suburbanization and commercial activities to be analyzed. Carbon dioxide emission and its changes for three decades are estimated by designing the calculation model for CO_2 emission depending on the results of the sales regression Model. The impacts of CO_2 emission were divided into three main factors namely; suburbanization increasing impacts, population increasing impacts, and shopping related impacts.

3.2 Analysis Methodology

The analysis process depends on studying the correlation of sales change and automobile trips generation to shopping areas depending on time distance changes and related changes of CO_2 emission rates. The analysis focuses on studying the grid areas, which include the commercial uses and the related CO_2 emission rates and their changes between 1975s and 1995s. The commercial areas were taken as destinations for automobile trips from suburbanized surrounding areas within buffer zone of 10km around shopping grids. These zones were built on the suitable accessibility time from 15-20 min. by automobile for shopping by surrounding residences. The grids of commercial use were selected as the influenced area for estimating CO_2 emission rates caused by residences shopping activities.

4. MODELS OF THE ANALYSIS

4.1 Sales Regression Model

Sales Regression Model was designed to explain the correlation coefficient of the sales changes with several explanatory variables including population, retail floor space, trip distance and time length from residential area surrounding commercial areas, Fig.4 shows sales changes between 1975s and 1995s in MUKO River Basin Region. The Model study the relation between sales changes on commercial areas and related explanatory variables, as shown in Table 1 and Eq. 1, 2, and 3 as inputs of calculation CO_2 emission caused by automobile trips to retail areas. Fig. 4 shows the sales activities changes (increasing / decreasing areas) around MUKO River Region between 1975 and 1995.

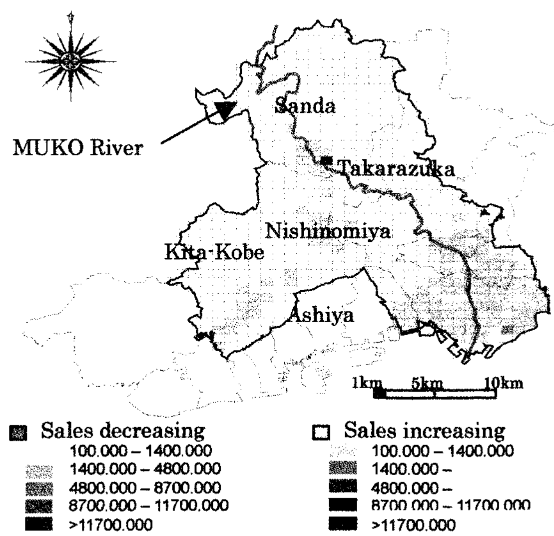

Fig.4 Sales changes around MUKO River for time series between 1975 and 1995

The correlation coefficient of sales with population and retails by time distance between the commercial areas and the origins was given for 10km buffering zone around retails centers for each city in the region.

$$S_i = \alpha_0 + \alpha_1 \left(\sum_{j=1}^{k} \frac{P_j R_i}{d_{ij}^2} \right) \quad (1)$$

where:

S: sales (10,000 Yen)

k: grids from 1 to k around retail grid

P_j: population in grid j (person)

R_i: retail floor space in grid I (m^2)

D_{ij}: time distance between i and j (min)

The sales in commercial areas of 1975 and 1995 were analyzed using the following regressions in Eq.(2), and (3). R & R^2 of the regression show the strong correlation of the sales with related explanatory variables.

$$S_i(t_0)_{1975} = \alpha_0 + \alpha_1 \left(\sum_{j=1}^{k} \frac{P_j R_i}{d_{ij}^2} \right) \quad (2)$$

$(R = 0.88, R^2 = 0.77)$

$$S_i(t)_{1995} = \alpha_0 + \alpha_1 \left(\sum_{j=1}^{k} \frac{P_j R_i}{d_{ij}^2} \right) \quad (3)$$

$(R = 0.86, R^2 = 0.74)$

The changes of sales from 1975 to 1995 were given by the following Eq. (4), which give indicator of increasing the sales amount in some areas of analysis related automobile trips for shopping to these areas:

$$\Delta S_i = S_{i}(t)_{1995} - S_{i}(t_0)_{1975} \quad (4)$$

where:

S_i: Sales in the grid (10,000 Yen) t_0: census time of 1975 t: census time of 1995

Table 2 Estimation results of statistics regression

Case	Coefficient estimate 1975	Coefficient estimate 1995	Case	Coefficient estimate 1975	Coefficient estimate 1995
Constant	252249.26	630877.3	Zone 19	1.0431	-1.0465
Zone 1	0.2533	-0.3330	Zone 20	1.0945	0.5026
Zone 2	0.6944	-1.1785	Zone 21	-0.3574	1.9318
Zone 3	1.6263	-0.0515	Zone 22	-0.7970	1.3430
Zone 4	-0.1747	-0.9389	Zone 23	-0.3675	1.9787
Zone 5	0.6181	-0.7438	Zone 24	-0.7807	1.1665
Zone 6	-0.0409	-0.8145	Zone 25	-0.7267	0.9168
Zone 7	-2.7983	-0.4524	Zone 26	-0.8131	-0.9478
Zone 8	0.3211	-1.1953	Zone 27	2.7361	1.4105
Zone 9	-0.7885	-0.0156	Zone 28	0.6323	0.7618
Zone 10	0.6406	-2.4153	Zone 29	-0.6149	0.9552
Zone 11	-0.5295	-0.5770	Zone 30	-0.8182	-1.1753
Zone 12	-0.6299	-0.1165	Zone 31	1.3611	-0.0192
Zone 13	-0.5869	0.1469	Zone 32	-0.1718	-0.9279
Zone 14	-0.0042	1.2328	Zone 33	-0.7347	0.8843
Zone 15	-0.9229	0.3790	R	0.8793	0.8598
Zone 16	-0.3869	0.3562	R2	0.7731	0.7393
Zone 17	1.8212	-0.5937	t	3.7306	5.4932
Zone 18	-0.2750	-0.7101			

4.2 CO_2 Calculation Model

The CO_2 emission in areas of shopping centers, which caused by automobile trips from areas around the commercial area was recognized as one of the most serious urban problems in the region as a result of suburbanization and economic growth. The automobile trips were calculated from surrounding areas to the areas of commercial uses within the considered buffering zones using the model shown by Eq. (5).

$$Y_{ij} = \left(S_i \times 10^4 \left(\frac{a \times \frac{P_j R_i}{d_{ij}^2}}{a \times \sum_{j=1}^{k} \left(\frac{P_j R_i}{d_{ij}^2} \right)} \right) \right) \times \left(\frac{1}{E} \right) \times A \times L_{ij} \times U \times \frac{1}{10^6} \quad (5)$$

where:

Y_{ij}: the amount of CO_2 exhausts (t-CO_2)

S_i: annual sales of grid i (10,000 Yen)

P_j: population of grid j (person)

R_i: retail floor space of grid i (m^2)

d_{ij}: time distance from grid I to grid j(min.)

k: grids No. from 1 to k around retail grid

L_{ij}: distance length from i to j (km)

E: living expenditure for one time shopping trip per person (Yen/person)

A: automobile rate from all transportation

U: CO2 exhaust unit (g-CO_2/person "km)

Changes of CO_2 emissions for time series between 1975s and 1995s were estimated using the Eq.(6):

$$Y_{ij}changes = Y_{ij}(t) - Y_{ij}(t0)$$

where:

$$Y_{ij}(t - t_0) = Y_{ij}(1995) - Y_{ij}(1975) \quad (6)$$

Y_{ji}: the amount of CO_2 exhausts (t-CO_2) t: time of estimation

5. RESULTS AND DISCUSSION

The regression model for sales changes analysis and CO_2 calculation Model estimated the CO_2 emission rates caused by automobile trips to shopping areas for 1975, and 1995.The results of analysis are displayed on GIS as shown in Figs. 5 and 6. Taking the rate of car using density from all traffic 28.7% for 1975, and 38.4% for 1995[8] (Road traffic census (1977, 1997). The car average speed on road accessibility to shopping areas in grid (i) from surrounding residential areas in grid (j), which used for time distance calculation (d_{ij}) from grid j to i, were divided into two major zones in this region as shown in Table (3).

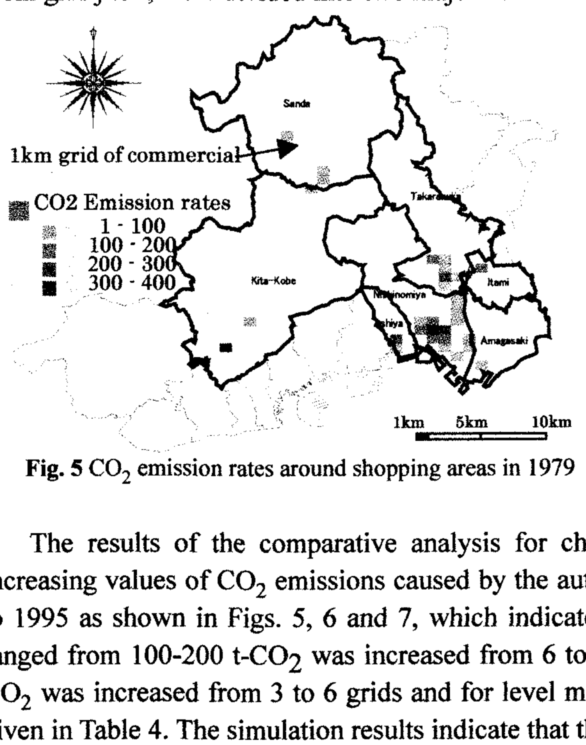

Fig. 5 CO_2 emission rates around shopping areas in 1979

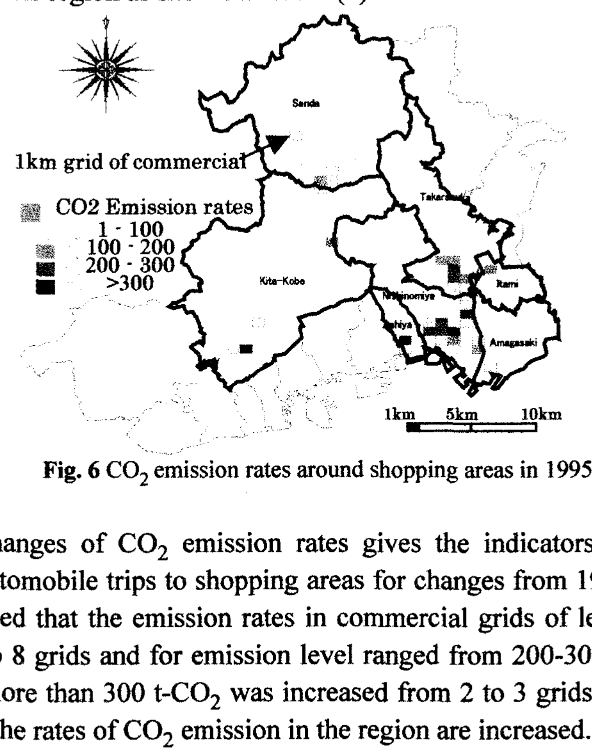

Fig. 6 CO_2 emission rates around shopping areas in 1995

The results of the comparative analysis for changes of CO_2 emission rates gives the indicators of increasing values of CO_2 emissions caused by the automobile trips to shopping areas for changes from 1975 to 1995 as shown in Figs. 5, 6 and 7, which indicated that the emission rates in commercial grids of level ranged from 100-200 t-CO_2 was increased from 6 to 8 grids and for emission level ranged from 200-300 t-CO_2 was increased from 3 to 6 grids and for level more than 300 t-CO_2 was increased from 2 to 3 grids, as given in Table 4. The simulation results indicate that the rates of CO_2 emission in the region are increased.

Table3. Average speed of cars in MUKO River Basin Region areas (km/h) *

Area zone	1977	1997
South-Hanshin area NISHINOMIYA, TAKARAZUKA	**29.3**	**22.9**
North-Hanshin Area (SANDA, KOBE-KITA,NORTH NISHINOMIYA)	**40.6**	**44.1**

*Road traffic census (1977, 1997)[8]

Table 4 Changes of CO_2 emission around commercial areas in MUKO River Basin from 1975s t0 1995s

CO2 emission level (t/km2)	Emission in 1979/1km grid		Emission in 1995/1km grid	
	No. of grids	%	No. of grids	%
1- 100	20	58.82	16	47.06
100 - 200	6	17.65	8	23.53
200 - 300	3	8.82	6	17.65
300 <	2	5.88	3	8.82
Total	31	100	33	100

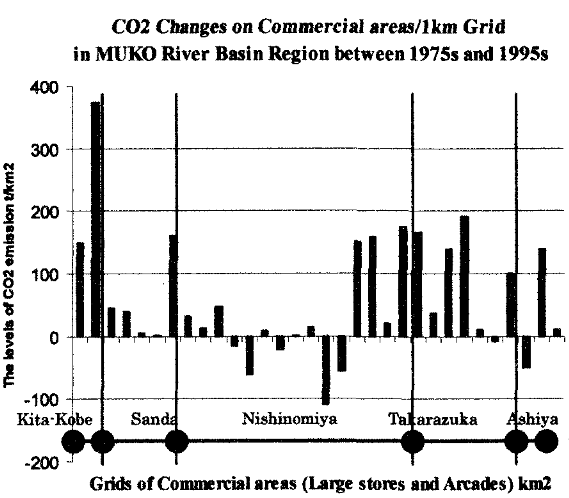

Fig. 11 CO_2 emission rates changes around shopping areas for time series between 1975s and 1995

The results of calculation Model and changes estimation give indicators that the places where the increase in CO_2 emissions is remarkable increasing in population and sales in the suburban area of Kita-Kobe City and Sanda City, also the southern Nishinomiya and southern Takarazuka. These results led to find out that CO_2 emissions are increasing in the whole commercial areas of MUKO River Basin Region.

Although sales in this commercial areas of MUKO River Basin Region are decreasing for the time series between 1975s and 1995s, the emission of CO_2 caused by automobile trips to shopping areas is still increasing, it is considered to be because of the increasing of consumption potential by the increasing of population in the suburbanization areas surrounding commercial areas in the Region.

6. CONCLUSION

The results of the changes time series comparative analysis between 1975s, 1995s and data simulation guide to know how much is the relation of CO_2 emission rates changes with automobile trips generation to shopping areas, population growth, and sales change. The results of the regression and data simulation guide to key factors for policy recommendations for future sustainable development planning, environmental and ecosystem management in the regional scale.

The simulation showed that the change of sales amount of retail areas results in change of CO_2 emission generated by car trips increasing for shopping activities. The retail area density distribution and the centralization of commercial areas and related increasing of CO_2 emission rates generated by automobile trips from the expansion of suburbanized urban areas in the region guides to plan for reducing the time distance from the residential areas to this commercial areas in order to reduce the generated emissions.

The urgency of the need to reduce CO_2 emission in urban areas may grant and guide to control the direction of the retail areas growth and urban areas growth in order to direct the development plans and strategies for growth management, urban control, and CO_2 reduction.

REFERENCES

Environment Agency, "Quality of the Environment in Japan", Ministry of Finance, Tokyo, Japan, March 1995.

MORIOKA, T. and FUJITA, T., "Integrated Planning and Evaluation System for Scenario-driven Policy Programs for Ecosystem for Ecosystem-friendly and Cycle-oriented Basin Management", *International symposium on sustainable basin management, Osaka Science & Technology Center*, Osaka, Japan, march 5th 2003.

HARI Srinivas," Japan Urban Observatory", UNCHS, E., http://www.gdrc.org/uem/observatory/index.html, April 2003.

KITANO, Y., KATO, H. and HAYASHI, Y., (2001), " A Life Cycle Estimation System of Various Environmental Loads in Urban Space Restructuring", *Spatial Planning and Environmental Policies, New Technology for a New Century, International Conference*, Seoul, Korea 6-11 May 2001.

Statistics Bureau, Statistical Research and Training Institute, "Japan Statistical Yearbook", Ministry of Public management, Home Affairs, Posts and Telecommunications, Japan, 2003.

HYOGO Prefecture, MUKO River Region, Japan, 1km Statistics Data, for Population, Commercial Census, and Transportation Road Network, (1975, 1995).

TRANSPORT ENERGY, Survey on Transportation, Hyogo Prefecture, Japan, (1997, 1982).

National Land Planning Office, "Road Traffic Census", Ministry of Land, Infrastructure and Transport, Japan,(1977, 1997).