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## Quantitative Evaluation of the Past Recycling-oriented Society in Japan: An Analysis of the Edo System in the Late 19th Century

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## **Quantitative Evaluation of the Past Recycling-oriented Society in Japan: An Analysis of the Edo System in the Late 19th Century**

**Katsuhiko Sakurai<sup>\*</sup>, Tetsuya Takahashi<sup>\*\*</sup>, Shintaro Kobayashi<sup>\*\*\*</sup>  
and Yoshiro Higano<sup>\*\*\*\*</sup>**

### **Abstract**

This study focused on the Edo city and the basin of the Tokyo bay in the late 19th century. Edo is the former name of Tokyo, Japan, and was the central political city in the Edo period, which was from 1603 to 1868. In 1603 the Shogunate Government of Edo was formed, and the Edo period was ruled through a feudal system for all of its 265 years. Edo had over one million populations and high levels of consumption at the end of the Edo period, however, it is thought that the water environment of the city area and the Tokyo bay basin was unpolluted, and various and abundant marine resources had existed at that time. The reason is that the sustainable society was realized by means of the human wastes recycling system in the Edo society. In this study, we try to make a quantitative analysis of the “Edo system” from the viewpoint of the socio-economic and environmental aspects.

### **1. Introduction**

It is said that the Tokyo Bay was an ideal marine environment under the ecosystem that there were various fish species and a lot of fishing, and an excellent water quality maintained in Edo period through the 17-19th century. Edo is an old name of Tokyo, and the Edo period was from 1603 to 1868. In 1603, the Shogunate Government of Edo was opened, and this era was ruled by the feudality during 264 years. At the time, Edo was one of largest city in the world, the population of Edo city was about one million people (London had 900,000 and Paris had 600,000 people). And Edo had a character of consumption city, because it was a heartland of politics and there were a lot of samurais which were non-laboring class. It is called that the water environment in European cities had become aggravated by water pollutant emission from human activities at the same period of Edo era, for example, the Seine River was polluted by socio-economic activities in the land area. On the other hand, Tokyo Bay of Edo period was in an ideal situation though Edo city had a lot of population than London and Paris. However, actual condition of water environment of Tokyo Bay and its basin were not clarified in Edo era, and the social system and marine environment in that period had not been quantitatively researched.

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In this study, it is tried to analyze the social system of Edo city, which has waste and sanitation recycling system, and to estimate environmental impacts into the Tokyo Bay in Edo period from viewpoint of quantitative analysis.

## **2. Purpose and method**

First, the Edo city area will be spatially defined by the digital map from old data and materials such as the old picture map. Second, a model of the social system of Edo city will be constructed to analyze the material flow balance of the Edo city area, and the collected social quantitative data of Edo, which consists of the habitancy, the socio-economic activities, and the land use will be applied. And the environmental impacts from social activities in the land area of Edo city into Tokyo Bay will be estimated by unit value method. To make an analysis of Edo system, practical information will be obtained as a concrete guide to the policy-making for water environment in the near future.

The procedure of analysis in this study is as follows:

(1) Spatial data collection

To define the Edo city area, and to estimate the land use pattern<sup>1</sup>

(2) Social data collection, for example, population, industries, etc.

To estimate the economic activity in the Edo city

(3) Modeling of the material flow

To make an analysis of social activity in Edo city and environmental dynamics

(4) Environmental data estimation

To calculate the environmental impact for Tokyo Bay by unit value method

## **3. Target area and target period**

In this study, the target area is the Edo city in the 19th century as the catchment area of a part of Tokyo bay. The target period of this research is the end of Edo era, because the Edo city seemed to have the most unpolluted water environment in the world at that time, and the data availability. Edo period is from 1603 to 1867, Edo Shogunate reigned for 264 years.

First, it is focused on delimitation of the Edo city area on the basis of the official announcement by government of Edo in 1818, and estimating social and economic activities in the Edo city area.

### **(1) Tokyo bay**

Figure 1 shows the location and the area of Tokyo bay of our own time. Tokyo bay is situated in Kanto region of Japan. Tokyo bay is one of the largest enclosed coastal sea areas in Japan.

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<sup>1</sup> GIS data including

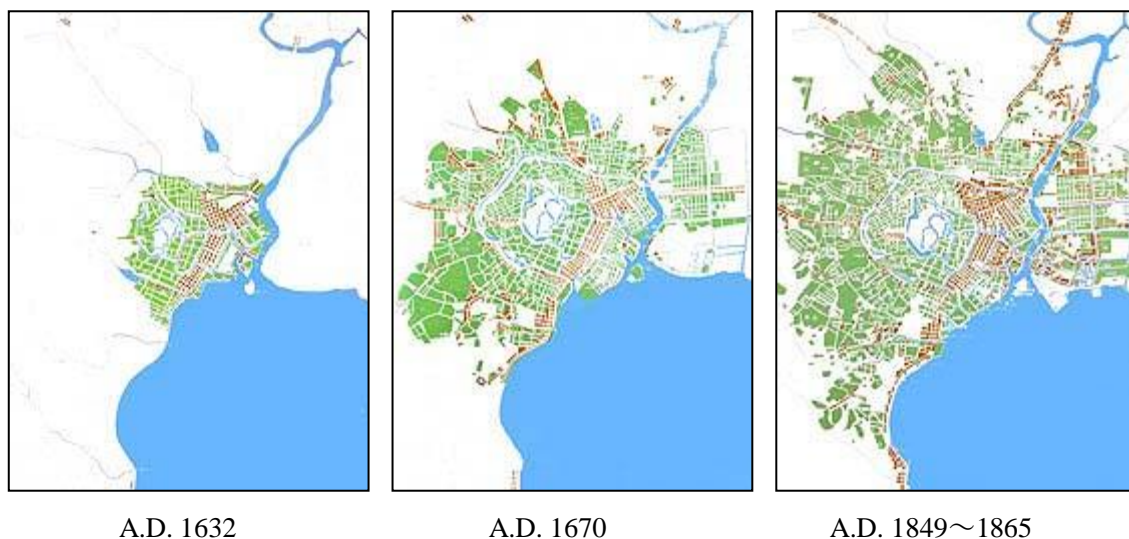


**Figure 1 Tokyo bay area**

## **(2) Edo city**

Edo city is the old name of Tokyo, and the city area of Edo is a part of present Tokyo metropolitan area. The city area of Edo has developed as a political city of Japan through the Edo era. Figure 2 shows the spatial growth of the Edo city during 200 years. The location of the Edo city is shown by yellow box in Figure 1.

The Edo city area called “Shubiki” was spatially defined by the conference chamber of Edo government in 1818. The left drawing in Figure 3 is the published picture map by the conference chamber of Edo government in 1818. The area of the Edo city is unclear from this map, because the Edo government had no scientific survey at the time.



**Figure 2 Urbanization of Edo city during the 17th-19th century**

(<http://park5.wakwak.com/~toshkish/hikesi01/hikesi01.html>)





**Figure 3 Edo city area (Shubiki) published by the Edo government in 1818**

## 4. Digital mapping of Edo city

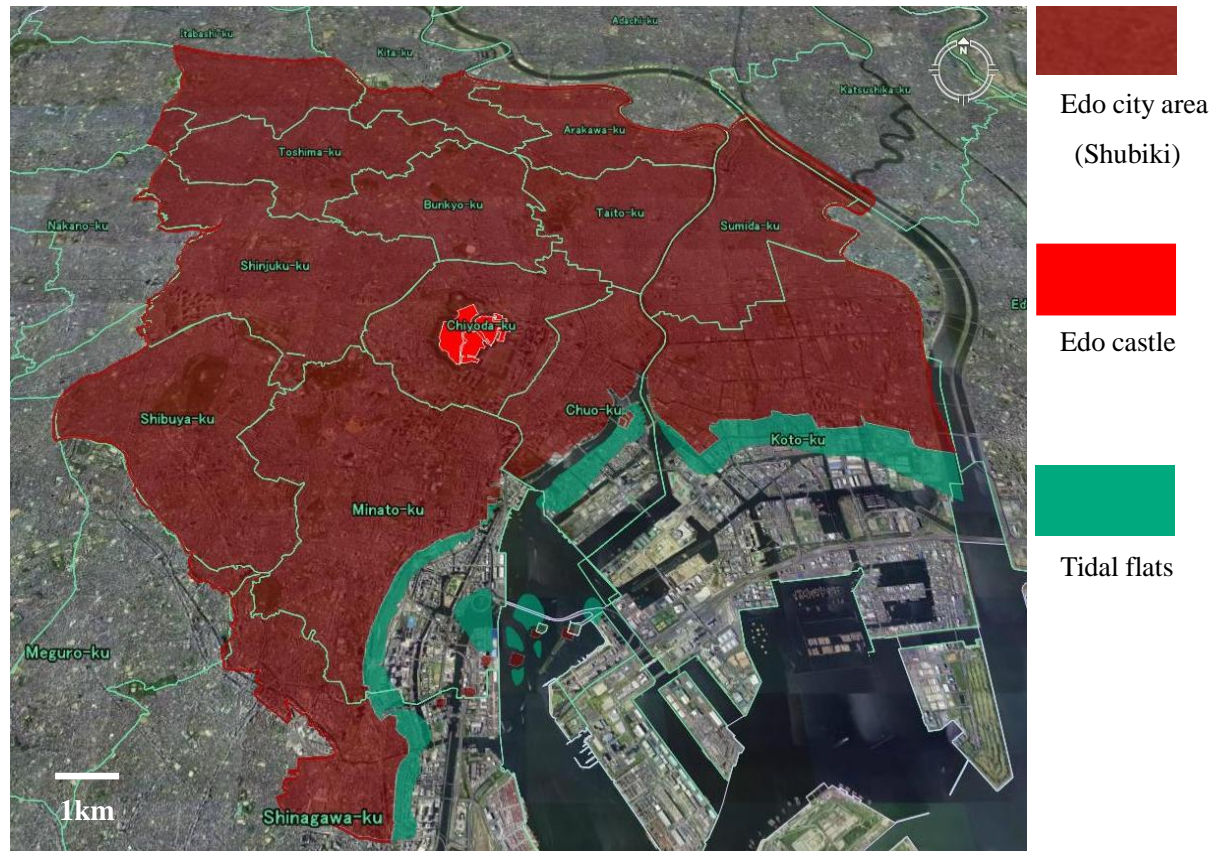
### (1) Edo city area

One of the important subjects of this study is to build a refined electronic map of the Edo city. In this section, the spatial area of the Edo city will be delimited by digital mapping using GIS.

Formerly, we have some maps built by the Meiji government using the Tokyo Datum in Meiji period (1868-1912, after Edo period). The Meiji map is the first cartograph on a scientific system in Japan, now we have no digital map of the Edo city area.

In Japan, the geographic coordinate system has been used by the Tokyo Datum from 1918 (Taisho period; 1912-1926, after Meiji period) to 2002, which is based on Bessel ellipsoid to make a measurement of the datum point. However, the WGS84 (World Geodetic System 1984) is now used as a world standard system after April 1st, 2002. The Tokyo Datum caused about 450 meters of distance error as compared the WGS84, because the datum point is both deferent.

Figure 4 shows the digital map that defines a boundary of the Edo city using GIS. This digital map is based on the new geographic coordinate system called WGS84.



**Figure 4 Digital map of Edo city area (Shubiki)**

## (2) Land use pattern of Edo city area

In this section, the land use pattern of the Edo city area (Shubiki) is classified into 11 categories shown in Table1. The data of land use is obtained from some materials such as the Edo cartograph by Masai (2000), Department of the Army General Staff (1880-1886), etc.

Figure 5 is the digital map digitized geographic information of land-use in the Edo city area on GIS.

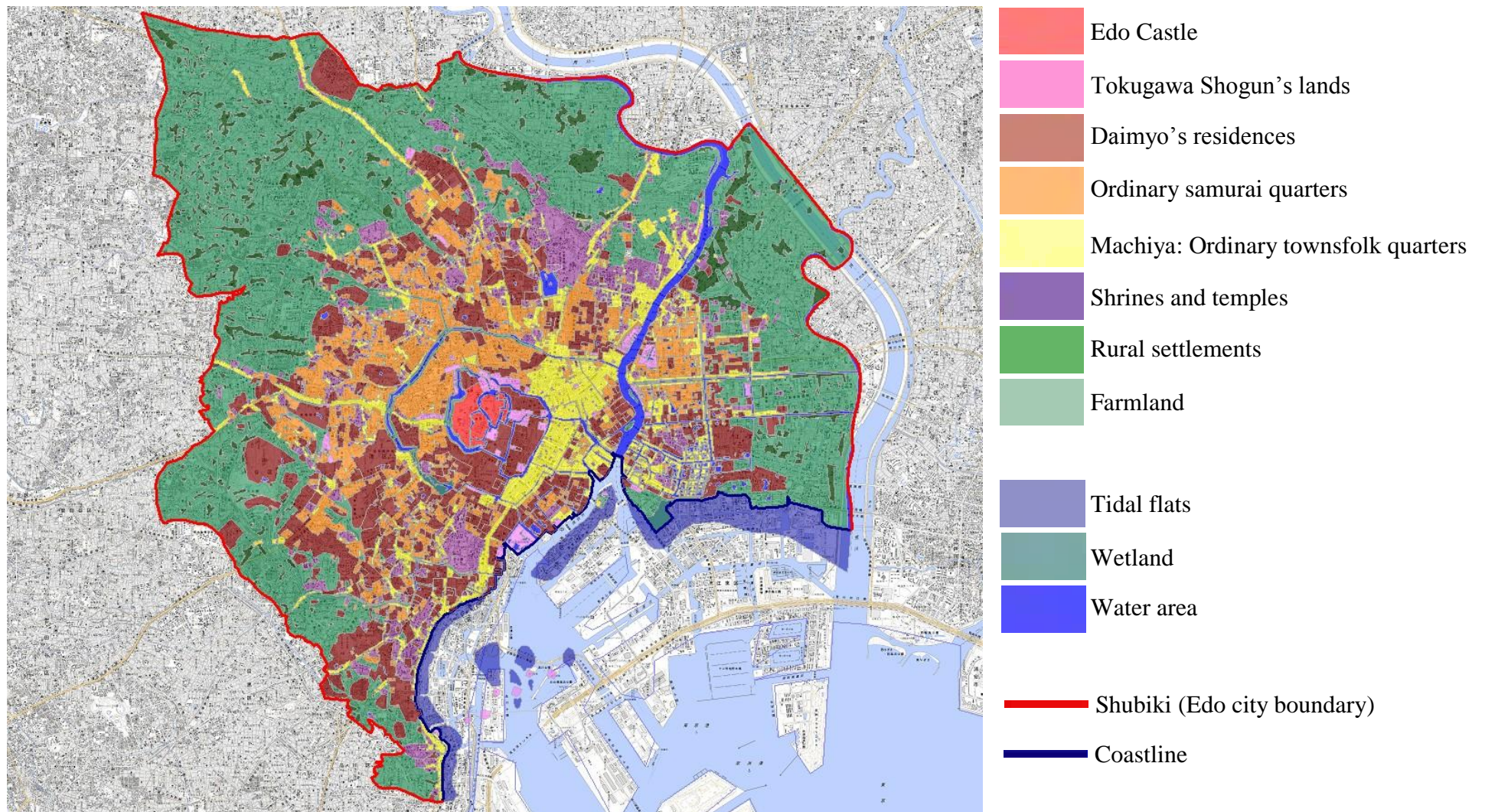
**Table 1 Classification of land use**

Index	Land-use classification	Index	Land-use classification
1	Edo Castle	7	Shrines and temples
2	Tokugawa Shogun's lands	8	Farmland
3	Daimyo <sup>2</sup> 's residences	9	Tidal land
4	Ordinary samurai <sup>3</sup> quarters	10	Wetland
5	Machiya: Ordinary townsfolk quarters	11	Water area
6	Rural settlements		

<sup>2</sup> feudal lord

<sup>3</sup> bladesman





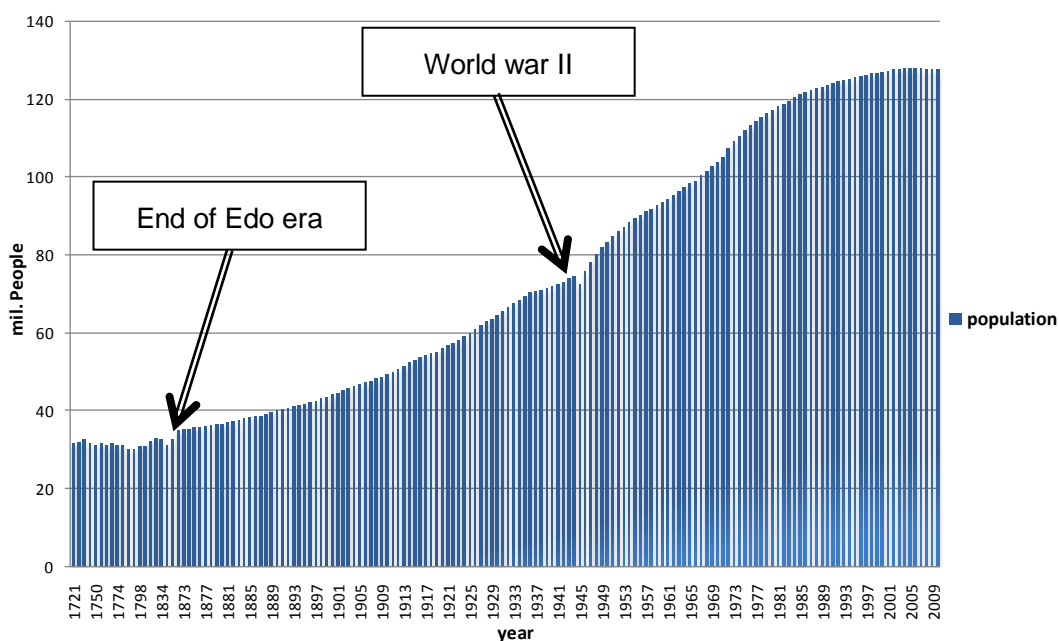
**Figure 5** Land-use pattern of Edo city on present map of Tokyo by GIS

## 5. Estimation of social and economic activities

### (1) Population of Edo city

Figure 6 shows the population of Japan from 1721 to 2009. The population in Edo period shows stable or a slight increase, though the population has been sharply increasing from the end of Edo period to 2000's.

The population of the Edo city in 1843 is estimated 1.1 million people from the survey of Edo government that is the oldest population data in Japan. Table 2 shows the total estimated population of Edo city and the collected data of Townsfolk (Cho-nin) by the population survey at that time.



**Figure 6 Population change of Japan from 1721 to 2009**

**Table 2 Population data of Edo city (1843)**

Index	Status	Population
1	Townsfolk (Cho-nin)	587,458
2	Samurai (Buke)	} more or less the same number of Townsfolk
3	Court noble (Kuge)	
4	Others	
Total estimate		1,100,000

(Townsfolk data: Edo Government (1843))

### (2) Economic activity of Edo city

Table 3 shows the production and economic data in 1874 (the early of Meiji period). The data is the oldest one using a statistical method in Japan. We have no quantitative economic data before the Meiji period. Hence, we selected and use the data of the main industries, which affect the water environment in



that time from the material based on the survey by the Ministry of the People's Affairs (Minbu-sho) (1875).

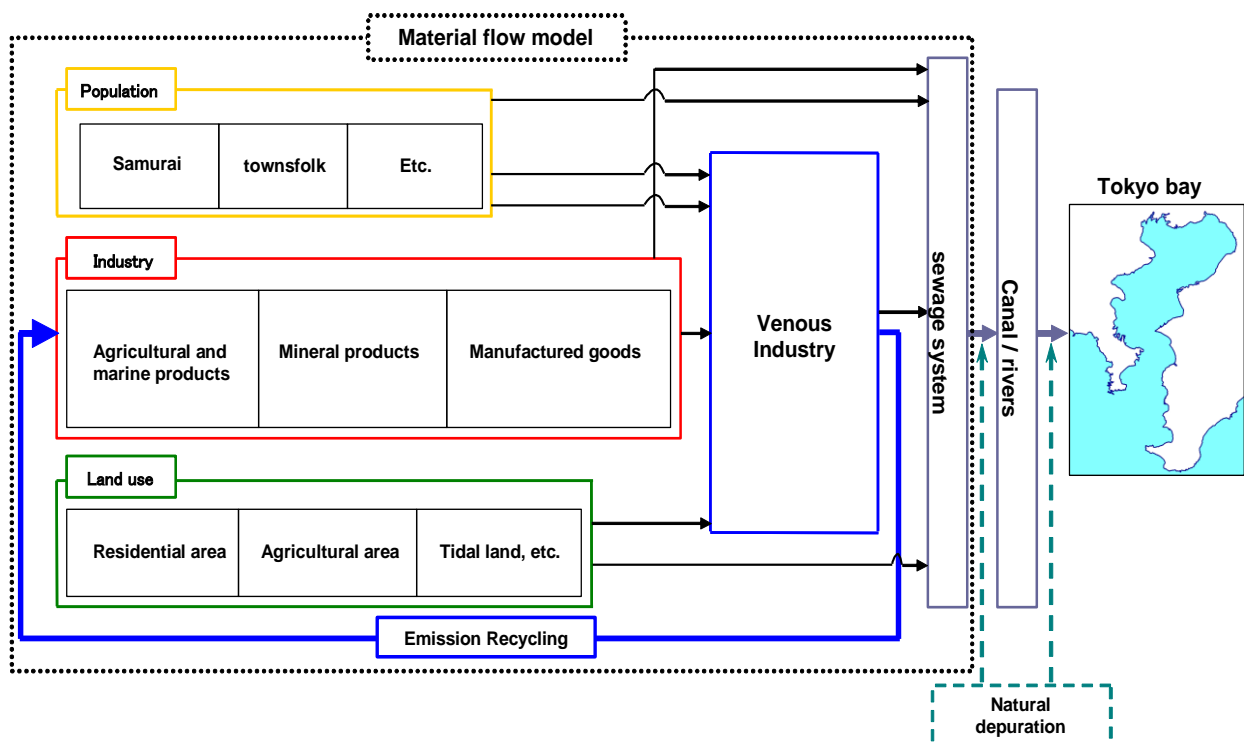
**Table 3 Economic data in Edo city (1874)**

Product	Yen
Agricultural and marine products	2,118,760
Mineral products	225,383
Manufactured goods	1,906,941
Total	4,251,084

## 6. Material flow model of Edo city

In this study, it is tried to make a quantitative analysis of environmental impact by human activity and the land use in the land area of Edo city using material flow model. The framework of the material flow model of Edo city is shown in Figure 7.

In this model, it is assumed that the human activity that means the population and the industry section, and land use make an impact on the environment. The venous industry means that the farmers in or near the Edo city recycled the human wastes as an organic fertilizer. The environmental load will flow into the Tokyo bay via sewage system in the city and canals/rivers taking account of natural depuration.



**Figure 7 Framework of material flow model of Edo system**

## 7. Estimation model of the impacts on water environment

In this study, we assume that the impacts on the water environment from the land area of Tokyo bay basin is the amount of water pollutant inflow into the Tokyo bay from the Edo city area. The model will estimate the total amount of environmental indices such as T-N (Total Nitrogen), T-P (Total Phosphorus), and COD (Chemical Oxygen Demand).

In this model, the water pollutant source from the land area of the Edo city is classified into three kinds of categories, which are the household sector, the non-point source, and the industrial sector. The water pollutant emission of household is estimated by population of Edo city, and the water pollutant emission of industrial sector is estimated by livestock industry and other industries. The water pollutant emission of non-point source means that of the land use area of Edo city.

### (1) Amount of the water pollutant emission from the source of household sector

The household waste water is generated from human activity in the land area of the Edo city, and the amount of the water pollutant emission is estimated by the population of the Edo city.

The coefficient of pollutant emission by population and the natural depuration ratio are quoted from the report of Council for Science and Technology Policy (2005). The estimated population, its water pollutant emission coefficient, and the recycling ratio of human waste are shown in Table 4.

The amount of the water pollutant emission from population of Edo city is calculated as follows:

$$WP_H^j = E_H^j \cdot Pop \cdot (1 - R_H) \cdot (1 - Nd) \cdot 10^{-3} \cdot 365 \quad (1)$$

in which,

$WP_H^j$  : Amount of water pollutant emission  $j$  by household sector (kg/year)

$E_H^j$  : Coefficient of water pollutant emission  $j$  by population (g/person/day)

$Pop$  : Population of Edo city (person)

$R_H$  : Recycling ratio of human waste

$Nd$  : Natural depuration ratio of water pollutant

$j = 1 \dots 3$  (1=T-N, 2=T-P, and 3=COD)

### (2) Amount of the water pollutant emission from the source of industrial sector

#### a) Total amount of industrial sector

Total amount of the water pollutant emission from industrial sector is summation of 5 industries, which are livestock industry, wood products, feeding stuff, food, and paper & products, shown in Table 5 and Table 6.

Total amount of water pollutant emission by industrial sector is calculated as follows:

$$WP_I^j = WP_L^j + \sum_{i=1}^4 WP_i^j \quad (2)$$

in which,

$WP_I^j$  : Total amount of water pollutant emission  $j$  by industrial sector (kg/year)

$WP_{LI}^j$  : Amount of water pollutant emission  $j$  by livestock industry (kg/year)

$WP_i^j$  : Amount of water pollutant emission  $j$  by industry  $i$  (kg/year)

$i = 1 \dots 4$  (See Table 6)

#### b) Livestock industry

The activity of the livestock industry and the livestock waste causes influencing water pollution in the basin. Table 5 shows that 1,002 cows were bred in Edo city area in 1874. It is assumed that the recycling ratio of water pollutant emission by the livestock industry and the natural depuration ratio are as same as the case of human waste.

Total amount of water pollutant emission by the livestock industry is calculated as follows:

$$WP_{LI}^j = E_{LI}^j \cdot Cow \cdot (1 - R_{LI}) \cdot (1 - Nd) \cdot 10^{-3} \cdot 365 \quad (3)$$

in which,

$E_{LI}^j$  : Coefficient of water pollutant emission  $j$  by livestock industry (g/cow/day)

$Cow$  : Number of cows (cow)

$R_{LI}$  : Recycling ratio of livestock waste

$Nd$  : Natural depuration ratio

#### c) Other industries

Other industries mean 4 industries, which are wood products, feeding stuff, food, and paper & products shown in Table 6.

The water pollutant emission by the activities of these industries is calculated as follows:

$$WP_i^j = V_i \cdot PI_i \cdot E_i^j \cdot (1 - Nd) \cdot 365 \quad (4)$$

in which,

$V_i$  : Value of production of industry  $i$  (100 million yen)

$PI_i$  : Price index of industry  $i$

$E_i^j$  : Coefficient of water pollutant emission  $j$  by industry  $i$  (kg/day/100 million yen)

### (3) Amount of the water pollutant emission from the non-point source

The water pollutant emission from the non-point source is estimated by the land use area of the Edo city. The land use pattern and its each emission coefficient are shown in Table 7. The land area of each land use is measured by digital map of Edo city shown in Figure 5.

The coefficient of pollutant emission by land use is quoted from the Japan Sewage Works Association (2001), and the natural depuration ratio is quoted from the report of Council for Science and Technology



Policy (2005) .

The amount of the water pollutant emission from the non-point source is calculated as follows:

$$WP_N^j = E_N^j \cdot L_k \cdot (1 - R) \cdot (1 - Nd) \quad (5)$$

in which,

$WP_N^j$  : Amount of water pollutant emission  $j$  by non-point generation source (kg/year)

$E_N^j$  : Emission coefficient of water pollutant  $j$  by non-point generation source (kg/ha/year)

$L_k$  : Area of land use  $k$  (ha)

$k = 1 \dots 11$  ( See Table 7)

#### (4) Total amount of the water pollutant inflow from Edo city into Tokyo bay

The total amount of water pollutant inflow from Edo city area into Tokyo bay is derived by summation of water pollutant from household sector, industrial sector, and non-point source as follows:

$$TWP^j = WP_H^j + WP_I^j + WP_N^j \quad (6)$$

in which,

$TWP^j$  : Total amount of water pollutant inflow from Edo city into Tokyo bay (kg/year)

**Table 4 Household sector**

Population (1843)	Coefficient of water pollutant emission $j$ (g/capita/day)			Recycling ratio
	T-N	T-P	COD	
1,100,000	11.2	1.32	27.5	80%

**Table 5 Livestock industry**

Cow (1874)	Coefficient of water pollutant emission $j$ (g/cow/day)			Recycling ratio
	T-N	T-P	COD	
1,002	290	50	530	80%

**Table 6 Industrial sector (except livestock)**

Index $i$	Industry (1874)	Product (Yen, in 1874)	Present value (Yen, in 2000)	Coefficient of water pollutant emission $j$ (kg/day/100million yen)		
				T-N	T-P	COD
1	Wood Products	3,018	23,320,780	0.01	0.00	0.32
2	Feeding stuff	108	837,618	0.52	0.11	3.53
3	Food	9,098	70,301,638	0.74	0.24	16.85
4	Paper & Products	78,753	608,532,104	10.23	0.96	93.50

**Table 7 Non-point source**

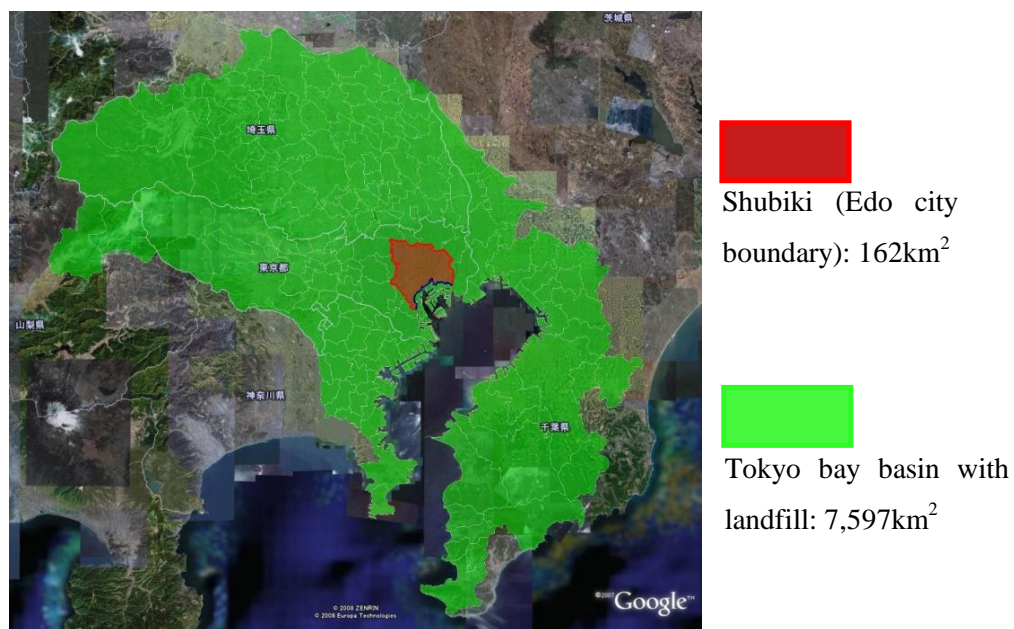
Index <i>k</i>	Land use (1860's)	Area (ha)	Coefficient of water pollutant emission (kg/ha/year)		
			T-N	T-P	COD
1	Edo Castle	8,468	16.5	2.2	115
2	Tokugawa Shogun's lands		16.5	2.2	115
3	Daimyo's residences		16.5	2.2	115
4	Ordinary samurai quarters		16.5	2.2	115
5	Machiya: Ordinary townsfolk quarters		16.5	2.2	115
6	Shrines and temples		16.5	2.2	115
7	Rural settlements		16.5	2.2	115
8	Farmland	7,071	29.3	0.9	54.4
9	Tidal land	676	0	0	0
10	Wetland	37	0	0	0
11	Water area	671	0	0	0
Total		16,924			

## 8. Results and concluding remarks

Table 8 shows the estimated total amount of three kinds of water pollutant inflow into the Tokyo bay from the household sector, the industrial sector, and the non-point source of land area of the Tokyo bay basin and the Edo city area. To compare the amount of water pollutant inflow between the Edo period (in 1843) and present (in 2000), we make an analysis of two cases of the target area in 1843. The first case is set up the target area as the Edo city area called "Shubiki," and the second is the case of the Tokyo bay basin as almost same as of present area shown in Figure 8. However, the area of Tokyo bay basin in 1843 did not contains the landfill area, which is about 250 km<sup>2</sup>, after the end of Edo period (1868).

In Table 8, household sector and industrial sector have each 540 tons and 26 tons of T-N emission with recycling the human and the livestock waste for farming. It is estimated 208 tons of T-N emission from non-point source. Table 8 also shows the total amount of water pollutant emission from the Tokyo bay basin in 2000 estimated by the same calculating method in case of the Edo period. The total amount of T-N emission of Tokyo bay area in 2000 is about 87,000 tons, which is 36 times as much as that of the same area in the Edo period. The reason why that the water pollutant emission of the Tokyo bay basin had been increasing during the last 150 years is clear that the impacts of household sector and industrial sector had

been expanded. To decrease the impacts on the water environment, we have to consider countermeasures for such sectors without declining the economic prosperity and the standard of living in the Tokyo bay basin.



**Figure 8 Target area**

**Table 8 Estimated total amount of water pollutant inflow into the Tokyo bay (tons/year)**

Year	Land area	Water pollutant	Source			Total inflow
			Household	Industry	Non-point	
1843	Shubiki (Edo city boundary): 162km <sup>2</sup>	T-N	540	26	208	774
		T-P	64	3.5	15	82
		COD	1,325	150	815	2,291
	Tokyo bay basin: 7,347km <sup>2</sup>	T-N	540	26	1,868	2,434
		T-P	64	3.5	146	213
		COD	1,325	150	11,909	13,385
2000	Tokyo bay basin with landfill: 7,597km <sup>2</sup>	T-N	59,939	20,833	6,446	87,219
		T-P	5,531	2,977	772	9,280
		COD	64,798	31,554	44,972	141,324



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