MODELING OF URBAN INDUSTRIAL ECONOMY THROUGH UTILIZATION OF THERMAL BAND

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ABSTRACT:

Cities are formed and develop. They also go through periods of decline and growth. If correlations between data from remote sensing and social, economic, and human data can be derived, many additional useful studies will become possible.
This study was intended to build up urban industrial economic models utilizing surface temperatures. The study region is Daegu, a city with the fourth highest population density in Korea. The Landsat Band6 satellite was used to calculate surface temperatures during the period of 1997~2003 to build up temporal and spatial surface temperature models. The models were verified, based on the surveyed contents of the business types, and sales amounts of private businesses. Through the spatial models, the effects of the development of industrial complexes on surface temperatures, and differences in surface temperatures by business kind were elucidated. It was found that the distributions and changes of surface temperatures reflected economic crises and recoveries.

1. INTRODUCTION

As a result of the development of remote sensing, more information can now be obtained, and many studies are being conducted using this new data. Particularly, surface temperature measurement is being widely used in areas such as weather, environment, and forest and water resources.
It is being warned that urban surface temperatures have been increasing globally since the 19th century. Temperature distributions in cities are affected by changes in land-covers (Chen, 2006). Regarding this, there have been studies of correlations between NDVI, NDWI etc. (Weng, 2004; Lo, 1997). Voogt (2003) showed that the use of remote sensing could substitute temperature measurement in cities, and could be used in further understanding climates. There also have been studies comparing the surface temperatures calculated by Landsat and the values measured in the field (Lagios, 2007). Xian (2006) conducted a comparative study of correlations between the expansions of city shapes, the densities of development, and surface temperatures of Tampa bay and Las Vegas at two time points using the ISA (Impervious surface area) index.
Diverse studies are being conducted that not only extract remote sensing data, but also interpret causal relationships with related factors, as well as utilizing the results. The aspect of social utilization is also being highlighted. Methods to measure population densities using remote sensing are being presented (Li, 2005; Mubareka, 2008).
This study was intended to construct urban industrial economic models utilizing surface temperatures. The study region, Taegu, is a city where industries have been developed, it thus has a large population, and it is economically prosperous. Furthermore, this can be said to be a representative region in how it is affected by the national economy. The spatial distributions and time serial changes of surface temperatures were concretized and analyzed.

2. STUDY SCOPE

Daegu has an area of 884.15 km^2 where 2,512,604 people (5.4% of the population of Korea) are residing (Statistics as of December 31, 2008). Daegu has led the industrial economy of Korea since the 1970s. There are large textile, machine, equipment, and car component industries. There are six industrial complexes in total, and approximately 97,000 people engage in manufacturing.

Y/M/D	Landsat	Path Low	Atm. Temp (℃)	Sun Azimuth	Sun Elv.
19970517	5 TM	114 35	21.4	118.0	61.0
19980520	5 TM	114 35	22.8	120.0	63.0
19990507	5 TM	114 35	22.3	124.0	60.0
20000508	7 ETM	115 35	20.4	128.2	62.8
20010418	7 ETM	114 35	19.4	134.3	57.1
20020523	7 ETM	114 35	23.0	121.5	64.6
20030510	7 ETM	114 35	16.3	126.4	62.5

Table 1. List of images used in this study.

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Korea requested a relief loan from the IMF in November 1997. Conditions of many businesses had deteriorated, and many people had lost their jobs. The GDP growth rate in 1998 dropped to -6.9%, but businesses have since recovered, and the growth rate was recorded as 7% in 2002. In Daegu, which is an industrial city, the unemployment rate in May 1997 was 3.5%, but this was recorded as 8.0% in 1998 and 7.6% in 1999. This time period has thus shown clear industrial recessions and recoveries.

Band 6 of Landsat TM5 and ETM7 were used. Images from April and May were used. The data were adjusted based on the conditions at the times of image captures in an attempt to minimize error ranges.

3. METHOD

The images were geometrically corrected using 1:5000 digital maps. The GCP errors were made to be less than 0.2. When Landsat Band6 is used(Nasa, 1998; Chander, 2003), spectral radiance values are calculated for individual DNs (1), and then surface temperatures are extracted (2).

$$L_\lambda = \frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX} QCAL + LMIN_\lambda \quad (1)$$

where L_λ = Spectral radiance in W/(m^2· ster·㎛)
QCAL = Calibrated and quantized scaled radiance in units of DN
LMAX = Spectral radiance at *QCAL* =0
LMIN = Spectral radiance at *QCAL* = *QCALMAX*
QCALMAX = Range rescaled radiance in DN

$$T = \frac{K_2}{\ln(\frac{K_1}{L_\lambda} + 1)} \quad (2)$$

where T = Effective at-Satellite temperature in Kelvin
K_2 = Calibration Constant 2 in Kelvin
K_1 = Calibration Constant 1 in W/(m^2· ster·㎛)

TM5 was rearranged to 60X60. Using administrative district maps, 1:5000 digital maps and factory layouts, temperatures of Daegu, and six industrial complexes were extracted and converted into data(Figure 1).

Daegu is a basin surrounded by mountainous regions at least 300m above sea level on the north and south. Vegetated areas have low surface temperatures. Downtown areas have relatively high surface temperatures. The surface temperatures of the six industrial complexes are generally at least 30°C.

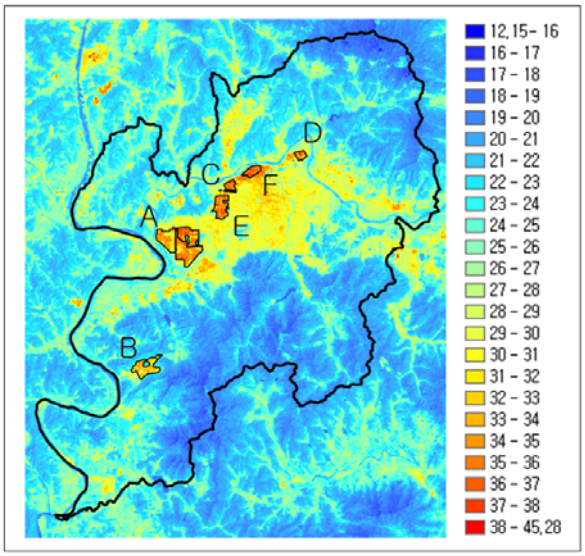

Figure 1. Temperature distribution diagram (°C) and factory arrangements. (2002.5.23)

Industrial complexes A and B have large-scale production. Industrial complex C is characterized by the fact that it comprises textile industries only. Industrial complexes D, E, and F have many small businesses, and are relatively superannuated. At least 70% of factories in these complexes have steel roofs. Some of the factories have slate or concrete roofs. The majority are two stories high(Figure 2), and their roofs are flat or slightly sloped. They are suitable for preparing heat distribution diagrams. Although factories are densely situated in the industrial complex, roads or trees lining the streets might affect surface temperatures.

Figure 2. An photograph of the factory region.

To compare images from different time points, criteria for measuring increases and decreases of surface temperatures are necessary (Xian, 2006). Daegu has a high population density and many buildings. Therefore, 50 playgrounds were selected, since they are flat and have uniform sand. Values with large error ranges were removed through cluster analyses. T_p values of individual images were defined(Table 2), and T_n values were calculated (3).

Images	1997	1998	1999	2000	2001	2002	2003
T_p (℃)	27.429	26.807	25.752	27.180	27.389	28.383	23.842

Table 2. T_p values of individual images, 50 playgrounds.

$$T_{n,y} = T_y - T_{p,y} \quad (3)$$

where $T_{n,y}$= Nomalized surface temperature values of individual pixels (˚C)
T_y = temperatures of individual pixels calculated in the thermal band (˚C)

Spatial industrial economic models are compared with statistical values. Through business surveys, information on the sales amounts, production quantities, the numbers of operating businesses of individual complexes were collected. Of the national income statistics of the Bank of Korea, quarterly manufacturing businesses' GDPs were used as verification. The GDPs were prepared for both business kind and quarter.

4. RESULT OF SPATIAL ANALYSES

4.1 State of development of Seong-Seo industrial complex

Seong-seo industrial complex was developed over time. This is the complex corresponding to Figure 1-A, which is the largest industrial complex in Daegu. The 1st complex (1984~1988, 2.42 km^2), the 2nd complex (1988~1992, 3.87 km^2), and the 3rd complex (1994~2000, 2.86 km^2) were constructed one after another(Table 3).

	The number of businesses		Sales amount (1000,000Won)
	ALL	Closed or Lease	
1997, 2/4	1134	74	340739
1998, 2/4	1183	206	604631
1999, 2/4	1198	256	1126043
2000, 2/4	1232	171	1237330
2001, 2/4	1259	211	1423599
2002, 2/4	1318	254	1414573
2003, 2/4	1655	303	1636269

Table 3. The numbers of businesses as of the second quarter of each year in Seong-Seo industrial complex, the numbers of businesses closed or leased, and the sales amounts in the second quarter.

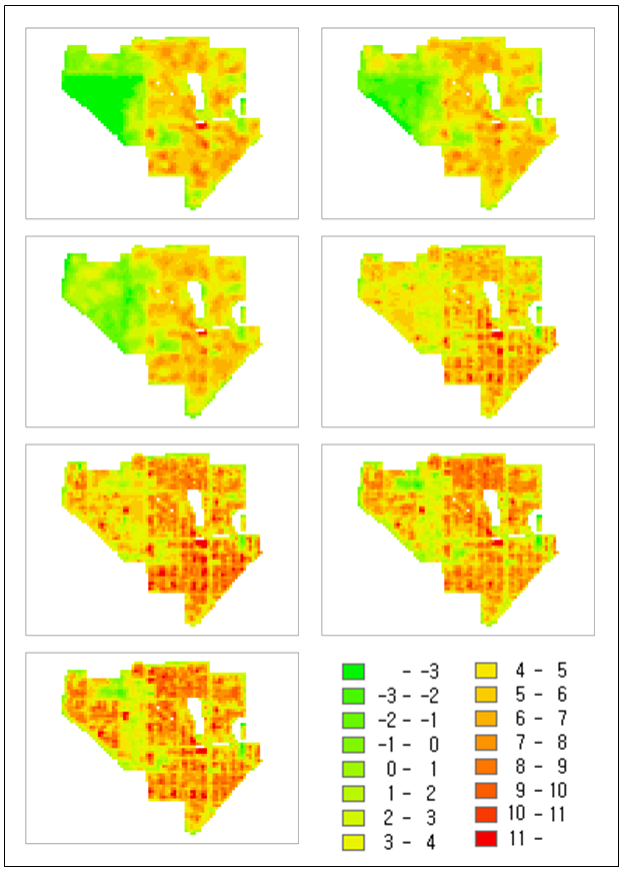

Figure 3. T_n (˚C) distribution diagram for Seong-Seo industrial complex in 1997~2003.

The yearly numbers of businesses has increased throughout the processes of development. There are many car component and general machine manufacturing factories, and there are some metal, textile, and food manufacturing factories.
The development of the 3rd complex in progress can be identified through the surface temperature distribution diagram (Figure 3). The surface temperatures of the 3rd complex gradually increased.

4.2 Differences between the kinds of businesses in Seong-Seo industrial complex

Since 1995, the number of businesses in the complex has been at least 1,000, and most of the businesses have been small-scale businesses. To monitor changes in the surface temperatures of factories, 60 factories were selected as samples. The flat area of the factories is at least 28,800m^2 and the factories are located in the 1st complex and the 2nd complex. The factories were classified under the Korean Standard Industrial Classification.
The surface temperatures of electronic equipment businesses and chemical industrial businesses are high, and those of food businesses and machine manufacturing businesses are relatively low.

Images	1997	1998	1999	2000	2001	2002	2003
All Sample factories	4.76	4.82	4.76	6.50	7.70	7.25	7.79
Food, beverages and tobacco	3.98	4.06	4.18	5.42	6.85	6.34	6.18
Textiles and leather	5.99	5.67	5.59	7.03	7.73	7.33	7.66
Petroleum, coal and chemicals	5.50	5.36	6.13	6.91	8.06	8.02	8.50
Metal, Fabricated metal products	4.52	5.31	4.85	6.41	8.09	7.65	8.49
Electrical and electronic equipment	6.14	5.56	6.36	9.64	11.28	9.42	10.29
Transport equipment	3.35	3.61	3.74	6.35	7.37	7.06	8.03

Table 4. Average temperatures(˚C) by kind of businesses.

5. RESULT OF TIME SERIES ANALYSES

5.1 Relationships with sales amounts of Seong-Seo industrial complex

The average temperatures of sample businesses in individual images were calculated. The range of the temperatures was approximately 4.76~7.79 °C. The relationships between these values and the quarterly sales amounts of Seong-Seo industrial complex were regression analyzed. There are positive correlations with the value R^2=0.7431(Figure 4).

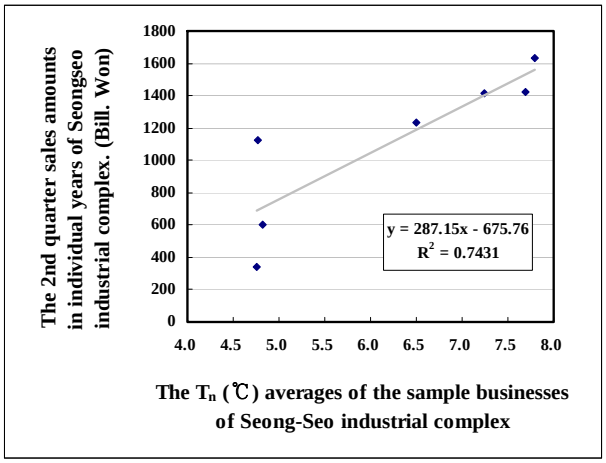

Figure 4. Relationship between the T_n average values of Seong-Seo industrial complex and sales amounts in the second quarter.

5.2 Correlations with GDPs by business type

Different temperature distributions are shown depending on the kinds of businesses of the factories (Table 4). It should be verified whether this is related with economic conditions for the different business types. The GDP values(Figure 5, Table 5) that show the trends of production activities in the domestic economy were presented by quarter(The bank of KOREA, 2005).

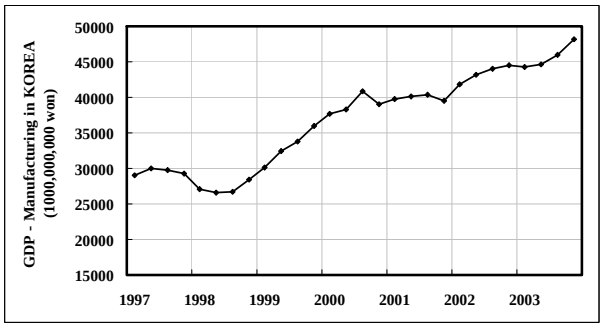

Figure 5. GDP by kind of economic activity. (at chained 2005-year prices, SA)

The second quarter GDP in individual years (Bill. Won)	1997	1998	1999	2000	2001	2002	2003
GDP - Manufactoring	29942	26528	32386	38335	40162	43168	44589
Food, beverages and tobacco	2593	2423	2539	2712	2806	2887	2800
Textiles and leather	2580	2158	2656	2985	3063	3383	2844
Petroleum, coal and chemicals	5887	5753	6393	7056	7871	8377	8276
Metal, Fabricated metal products	6046	5271	5883	6905	7057	7399	7631
Electrical and electronic equipment	2919	3298	4704	6466	6689	7723	8556
Transport equipment	4202	3230	4288	4623	5298	5312	5888

Table 5. GDP by kind of economic activity. (at chained 2005-year prices, SA)

Regression analyses were conducted by industry(Figure 6). The average value of the entire sample was correlated with the manufacturing businesses' GDP with the value R^2=0.8823. The correlations of petrochemical businesses, electric-electronic equipment businesses, and transport equipment businesses were quite strong(Table 6). It can be seen that the presented results from the temporal-spatial surface temperature model are reflecting economic trends by business type.

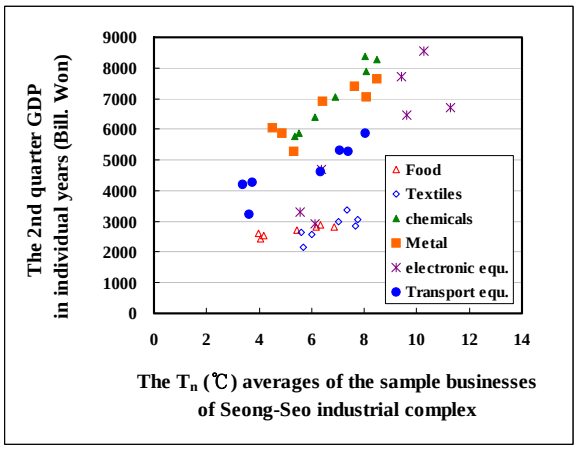

Figure 6. Results of regression analyses of the average values of T_n and GDP values.

Regression analyses with the manufacturing businesses' GDP	a	b	R^2
All Sample factories	4585.5	7898	0.8823
Food, beverages and tobacco	126.24	2012.6	0.8373
Textiles and leather	324.78	628.95	0.6031
Petroleum, coal and chemicals	846.6	1224.3	0.9752
Metal, Fabricated metal products	474.16	3528.3	0.7781
Electrical and electronic equipment	830.92	-1200.1	0.7753
Transport equipment	396.14	2455.5	0.8054

Table 6. Results of regression analyses of the average values of T_n and GDP values.
Y (GDP, bill.won) = a * X(T_n,°C) + b

6. CONCLUSION

This study was intended to develop urban industrial economic models utilizing surface temperatures. Daegu, an industrial city of Korea, was selected as the study region. Surface temperatures in 1997~2003 were calculated using the Landsat Band6 satellite. Temporal and spatial surface temperature models were constructed using survey data and GIS technologies.

The temperature distribution diagram for Seong-Seo industrial complex reflects increases in the number of businesses caused by the coinciding development. In addition, sample businesses were selected to prepare average values of the entire complex, and by business type. The average temperatures of the sample businesses showed positive correlations with the sales amounts of Seong-Seo industrial complex in the second quarter, and the GDP values of manufacturing businesses that showed the trend of domestic industries. Correlations were also obtained according to business type to verify the temporal and spatial industrial economic models. This can be said to have reflected the state of stagnation of industries and economy during the IMF assisted period and later recoveries.

The method to analyze the time series using surface temperatures of playgrounds may be applied to studies utilizing thermal bands. In addition, studies to compare results with field observations, and the elucidation of correlations with socioeconomic indexes are necessary.

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