Determining Sustainable Development Density using the Urban Carrying Capacity Assessment System

Kyushik Oh[*], Yeunwoo Jeong[**], Dongkun Lee[***], Wangkey Lee[****]

Abstract

Diverse urban problems in the capital region of Korea occur due to over-development and over-concentration which exceed the region's carrying capacity. Particularly, environmental problems such as air and water pollution have become more evident and become central issues for urban planners and decision-makers. In achieving sustainable environment through resolving such problems, practical approaches to incorporate the concept of environmental sustainability into managing urban development are needed.

This research aims at developing an integrated framework for assessing urban carrying capacity which can determine sustainable development density, and has yielded the following. First, seven determining factors for urban carrying capacity including energy, green areas, roads, subway systems, water supply, sewage treatment, and waste

should be utilized to provide opportuniti sustainable development indicators have been conducted. In 1996, the United Nations Commission on Sustainable Development (UNCSD) announced the formulation of a draft for sustainable development indicators to evaluate and compare the degree of sustainable development of each country. Since then, sustainable development indicators have been developed and applied in many countries in European Union (EU). International organizations such as the Organization for Economic Cooperation and Development (OECD) and the World Trade Organization (WTO) have also developed diverse indicator sets for assessing the results of their research.

The indicators developed in these countries and organizations generally include social, economic, environmental, and institutional dimensions. Among these, the environmental dimension is a primary concern in pursuing ESSD in Korea. Environmental indicators suggested by UNCSD, OECD, EU, the United States, and the United Kingdom have mainly focused on air, forest, ocean, fresh water, bio-diversity, etc. In this research, air and water quality among the environmental indicators are employed as strategic objectives which are of importance in urban planning and management in Seoul.

2.2. Carrying capacity

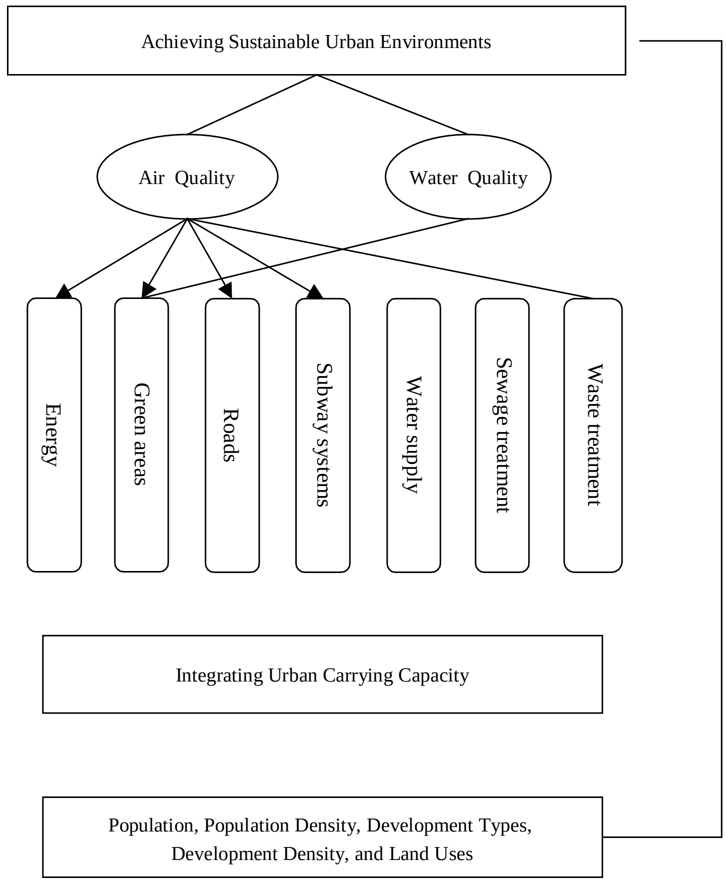
Ecologists generally consider carrying capacity to be the maximum number of individuals that can be supported in an environment without the area experiencing decreases in the ability to support future generations within that area (Chung, 1988). Planners usually define carrying capacity as the ability of the natural or artificial system that can absorb the population growth or physical development without considerable degradation or damage (Schneider et al., 1978). Carrying capacity is also said to be the ability of natural and man-made systems to support the demands of various uses, and subsequently it refers to inherent limits in the systems beyond which instability, degradation, or irreversible damage occurs (Godschalk and Parker, 1975). As a social science concept focusing on humans, carrying capacity can be defined as a scale of economy that the natural system of an area can sustain (Seoul Development Institute, 1999).

The urban carrying capacity concept in this research is defined as the maximum level of human activities—e.g. population growth, land use, physical development, etc.—which can be sustained by the urban environment without causing serious degradation and irreversible damage. This concept is based upon the assumption (Kozlowski, 1990) that there is certain environmental thresholds which when exceeded can cause serious and irreversible damage to the natural environment. This carrying capacity approach can be useful when the thresholds are identified ahead of time. The determination of the capacity of a system is fairly straightforward when managing such urban facilities as water supply, sewage treatment, and transportation (Oh, 1998).

2.3. Determining factors of urban carrying capacity

Urban carrying capacity types can be classified based upon the purpose of application and spatial setting to which the concept is applied. Previous studies identified different types of carrying capacity (Penfold et al., 1972; Godschalk and Parker, 1975; Godschalk and Axler; and Daily and Ehrlich, 1992). Despite some differences in classification, urban carrying capacity can be understood in relation to four dimensions; environmental and ecological; urban facilities, public perception, and institutional dimensions (Table 1).

Types	Definitions
Environmental and ecological	The degree of human activity that environments and ecosystems


Achieving Sustainable Urban Environments
Air Quality
Water Quality
Energy
Green areas
Roads
Subway systems
Water supply
Sewage treatment
Waste treatment
Integrating Urban Carrying Capacity
Population, Population Density, Development Types,
Development Density, and Land Uses

3.2. Carrying capacity assessment for determining factors

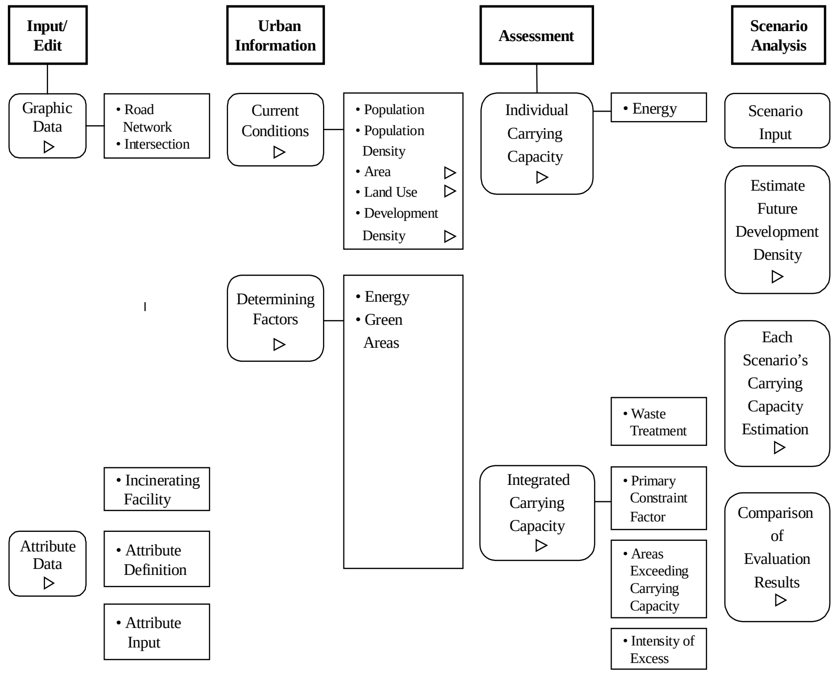
The carrying capacity assessment for seven determining factors can be further understood with the following three steps in mind (Figure 2). First, for the determining factors, environmental standards and targeting service levels for maintaining air and water quality are established (Table 2). Second, the energy consumption and the operational loads of urban facilities/infrastructure (green areas, roads, subway systems, water supply, sewage treatment, waste treatment) to provide the targeting levels of service for sustaining human activities are measured. Third, environmental impacts resulting from the energy consumption and operations of urban facilities are analyzed. The impacts are compared with environmental standards and allowable development density is then determined.

Determining factors	Environmental quality standards	Targeting service levels
Energy	NO_2 concentration: 0.04ppm/year	Level of energy consumption (substituted with air quality)
Green areas	-	Green area per capita: 6
Roads	NO_2 concentration: 0.14ppm/hour	Level of service: E
Subway systems	-	Crowding ratio: 150%
Water supply	-	Water supply per capita: 310ℓ
Sewage treatment	BOD concentration: 3 - 6 /ℓ	Sewage treatment ratio: 100%
Waste treatment	Dioxin concentration: 0.0006ng/	Waste treatment ratio: 100%

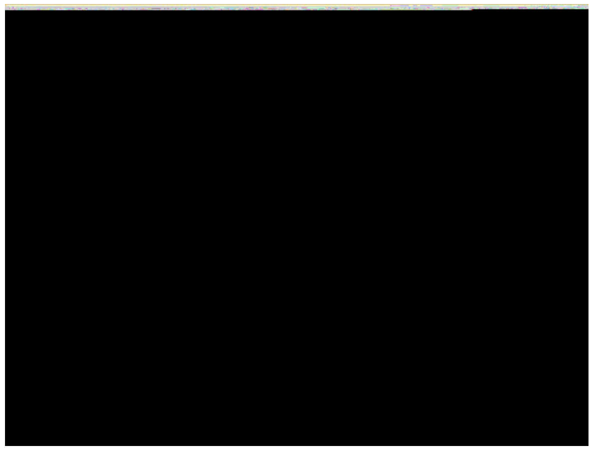
Table 2. Environmental quality standards and targeting service levels

3.3. Development of the Urban Carrying Capacity Assessment System (UCCAS)

The UCCAS includes five main functional modules: File, Input/Edit, Urban Information, Assessment, and Scenario Analysis (Figure 3). The Input/Edit module creates a new field, which is needed for creating and updating the database for determining factors' graphic and attribute data. The Urban Information module displays diverse thematic maps, graphs, tables, and texts for urban areas of interest. The Assessment module consists of carrying capacity assessment for each factor and integration of results from individual assessments. Finally, the Scenario Analysis module allows the performance of carrying capacity assessments under diverse scenarios.


Input/ Edit
Graphic Data
• Road Network
• Intersection
Attribute Data
• Incinerating Facility
• Attribute Definition
• Attribute Input
Urban Information
Current Conditions
• Population
• Population Density
• Area
• Land Use
• Development Density
Determining Factors
• Energy
• Green Areas
Assessment
Individual Carrying Capacity
• Energy
• Waste Treatment
Integrated Carrying Capacity
• Primary Constraint Factor
• Areas Exceeding Carrying Capacity
• Intensity of Excess
Scenario Analysis
Scenario Input
Estimate Future Development Density
Each Scenario's Carrying Capacity Estimation
Comparison of Evaluation Results

▼



identify

▼

Figure 4. Example of operating the UCCAS

4. Case Study: the application of the UCCAS

4.1. Case study area

The study area, the Gangnam District (Figure 5) is one of the most densely developed in Seoul. The area is about 39.55 and has 550,000 residents (in 2000). The total residential, commercial, and business areas combined is 27,873,327 ratio (FAR) of the study area is 152%. Figure 6 displays FAR of each *dong*[2]. Yeoksam-dong, a typical commercial area, and Daechi-dong, a representative residential pollution levels in Seoul.

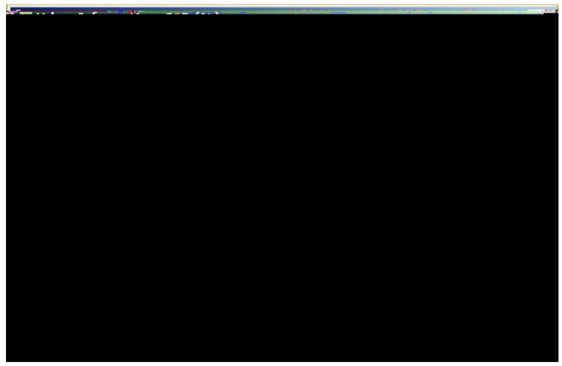


Figure 6. Current development density in the Gangnam District

Although the green areas in Seoul measure 155.85km^2 total and 15m^2 per capita (in 2001), green areas with which citizens can actually utilize on a daily level is quite insufficient because 78% of the areas compose forests in the outer ring of the city. In the Gangnam District, green area per capita is 8.8m^2, which is even lower than the average of the city.

Signaled intersections on major roads are total 63 places in the Gangnam District. Only two intersections show ‘D’ level of service (LOS), 13 intersections have ‘E’ LOS, and other 48 intersections show ‘F’ LOS where traffic jams usually occur during rush hour.

The water supply in the Gangnam District meets 100% of its demand. The capacity of the sewage treatment plant in the study area is 1,100,000tons/day. Currently the sewage treatment plant is operated by a standard activated sludge process

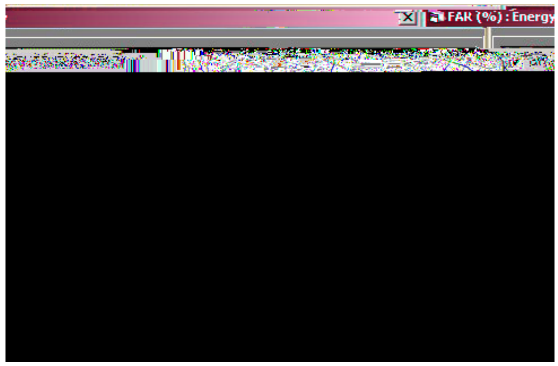


Figure 7. Carrying capacity for energy (FAR)

4.2.2. Green areas

Currently, it is suggested that 6 per capita be provided under urban planning guidelines in Korea. Green areas including urban parks, green open spaces, and urban forests are identified from satellite images of the city. The total area of green is then divided by the suggested level of provision, 6 per capita, and desirable development density in terms of green areas is determined.

Green areas in the Gangnam District is 3,994,200 . For supplying and

4.2.3. Roads

For assessing the carrying capacity for roads, a minimum LOS of roads should be determined. LOS ranges from A, the best condition of traffic flow, to F, the worst

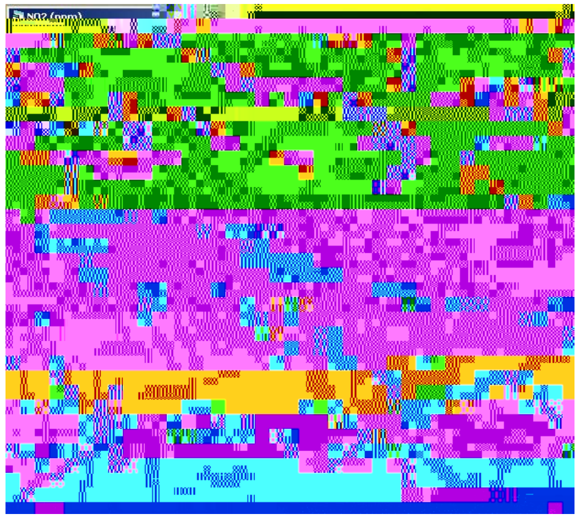

NO2 (ppm)

figure that has been adopted in many deve

4.2.5. Water supply

The minimum level of water supply to assess the carrying capacity is set at 310ℓ per capita per day, which was the average consumption level in Seoul in 2002. The amount of water produced by current water is identified under the capacity of current sewage facilities. Environmental impacts on water quality from treated sewage and untreated runoff are then assessed. In this

4.2.7. Waste treatment

The target level of waste treatment is 100%. The capacity of current waste treatment facilities includes landfill, waste incinerators, composting facilities, and recycling facilities. Dioxin produced by waste incinerators is particularly harmful. Dioxin concentration of 0.0006ng/ (Seoul Development Institute, 2000) is employed as the standard of air quality. If dioxin concentration by waste treatment does not satisfy the environmental standard, development density is calculated after adjusting the amount of waste for achieving the standard.

Currently there is a waste incinerator within the study area. With 100% waste treatment, the amount of waste processed by current incinerator was 1,181,300kg/day. On the other hand, the highest level of dioxin concentration at landing points caused by waste incineration was 0.000002ng/ (Figure 14). This level was below the environmental standard of 0.0006ng/ . The environmental impact of incineration was therefore, considered insignificant. The population accommodated by current waste facilities in the study area is 1,158,259 people, which can be converted into total floor area 29,487,257 . This equals to 169% FAR (Figure 15).

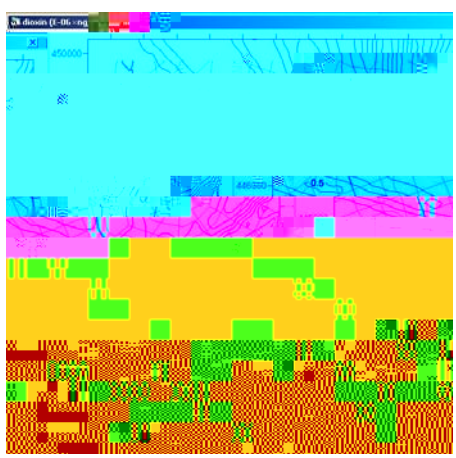


Figure 14. Air quality in the Gangnam District (dioxin)

Figure 15. Carrying capacity for waste treatment (FAR)

4.2.8. Integrated assessment

Based upon the results from analyses for the seven determining factors, it was revealed that urban carrying capacity of the study area was determined mainly by roads, water supply, green areas, sewage treatment, and energy factors. The sustainable development density for the entire study area as revealed by the primary determining factor of roads, was estimated as 15,571,770 of the floor area (89% FAR) (Figure 16) which was approximately 56% of those of the Gangnam District in 2000. It was also found that determining factors that could

Figure 18. Intensity of carrying capacity exceeded

5. Conclusion

If developments already exceed carrying capacity of an area, strategies for improving its capacity such as developing or adopting better technologies for environmental treatment and pollution prevention/control in conjunction with supplying additional public facilities should be considered. On the other hand, if the area is not yet overly developed and more facilities cannot be provided in the near future, it is vital to prepare ways to control possible future developments. Decision support with a GIS-based carrying capacity assessment system demonstrated in this research can play a pivotal role in planning and managing urban developments more effectively.

Such an approach is meaningful because it is integrated and proactive. Specifically, it is useful because it can identify which factor(s) is most influential for determining the carrying capacity of an area. Also, problematic area(s) can be