Journal of Heat Island Institute International Vol.7-2 (2012)

The Mitigation of UHI Intensity through an Improved Land-Use Plan in the Urban Central Area: Application to Osaka City, Japan

Masakazu Moriyama*[1] Takahiro Tanaka*[2]

*[1] Kobe University, Kobe, Japan
*[2] Hiroshima University, Hiroshima, Japan

Corresponding author email: moriyama@kobe-u.ac.jp

ABSTRACT

Osaka City is the central city of the Osaka region. The authors and other researchers have promoted urban climate research projects in Osaka with the local government. Based on the results of such studies undertaken using observations and simulations, we outline ways to mitigate urban heat island (UHI) effects and solve other related environmental problems. Specifically, we propose the Compact Eco-City model for Osaka City. At present, Osaka City has less than 10% green space; this model would increase that to 30% green space. The model also includes a green-space arrangement that improves ventilation. The outline for a Compact Eco-City is described in this paper.

Introduction

Table 1 illustrates the concept of countermeasures to the urban heat island (UHI). The actions proposed as UHI countermeasures are as follows:

1. Change the land cover/surface properties
2. Reduce anthropogenic heat
3. Make use of the wind caused by local wind circulation; sea breeze

In essence, the UHI phenomenon refers to the air-temperature boundary layer over a city. It is important to consider the scale of the horizontal space over a city when designing countermeasures for UHIs. Generally, UHI intensity depends on city size. As shown in Figure 1, the following four methods can reduce the intensity of the boundary layer over the city:

Table 1. Concept of countermeasures to UHIs (1)

measures / viewpoint based on scale	Change of Land Cover (Especially, Green)	Reduction of Anthropogenic Heat (Buildings, Cars)	Wind Flow - Good Ventilation (Urban Form)
Urban Temp. Boundary Layer Regional scale 1:25000	・Green Area, Roof Garden, Cool Roof (High Reflection), Keeping Water Pave., etc. ・Introduce Large Green Area, Green Belt for Dividing	・Energy Saving ・Transportation ・District Heating and Cooling System Using Natural Energy	・Reduction of UBL by Local Wind such as Sea Breeze, Cold Air Drainage ・Air Exchange between Upper Air and Earth Surface
Environmental Design of Outside Space District scale 1:2500	・Visual and Thermal Design for Health, Comfort ・Prevention of Thermal Storage by Road Surface…	・Heat Release Method from Buildings (latent heat) and Cars, and its Location and Place	・Ventilation and Air Exchange by Form of Town, Arrangement of Buildings, Water Front, Open Spaces, Direction of Streets..

1. Reduction of UHI intensity by means of creating green spaces, cool roofs, and cool pavements
2. Division of the UHI boundary layer by means of green belts or water surfaces (e.g., rivers, lakes)
3. Elimination of the UHI phenomenon through a combination of high-rise buildings and the natural earth surface at ground level
4. Reduction of the UHI phenomenon by means of the wind caused by the local wind circulation system

On the urban scale, the countermeasure plan should be derived in accordance with the urban structural elements. The purpose of this study is to propose a compact eco-city plan in Osaka, which can be achieved integrally through an improved land-use plan and the resolution of current major urban problems.

Present Condition and Necessity for Change in Osaka City

The population of Osaka city is 2.65 million and the city area is 222.3 km^2. The population density is very high. As shown in Figures 1 and 2, the Osaka area is among the hottest areas of Japan. Local governments are striving to mitigate UHI effects. For example, Osaka's prefecture government produced the *Osaka Prefecture Heat Island Measures Promotion Plan* (2004);

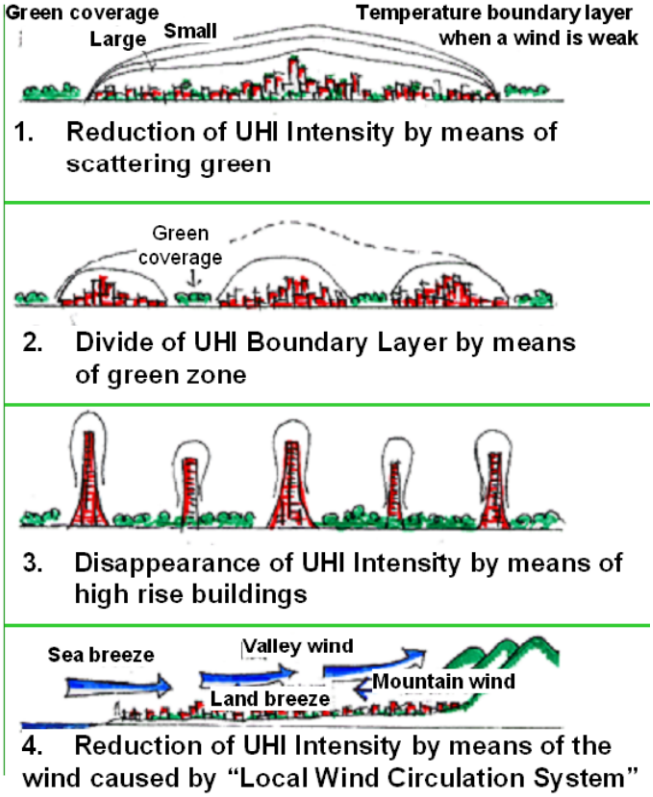

Figure 1. Concept of countermeasures to UHIs (2)

Figure 2. Location of Osaka City in Japan

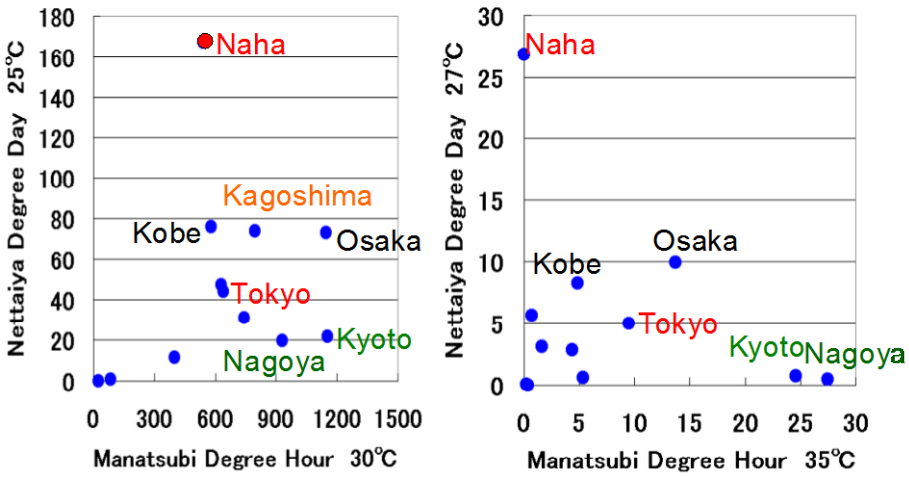

Figure 3. Comparison of summer heat severity in Japan's large cities (analysis period: 2000–2004, 5-year average)
Nettaiya Degree Day is the severity index for minimum temperature. It is the integrated value of the difference between the minimum and reference temperatures.
Manatsubi Degree Hour is the severity index of maximum temperature. It is the integrated value of the difference between the hourly temperature and the reference temperature.

the *Thermal Environment Map* (2006); and the *Heat Island Measures Guideline* (2007), which was based on *Thermal Environment Map*.

New Principles for Land-Use Planning

The new land-use planning principles aim to resolve the current urban problems in Japanese cities. These principles have three important goals for Osaka City:

1. Reproduce/increase green space and restore waterfront spaces within the central city area for climate control and amenity. This is important not only for UHI countermeasures, but also for the physical and mental health of the population.
2. Develop public transportation systems. Osaka City already has a good subway system. New transportation systems (e.g., light-rail trains) and greater space and comfort for pedestrians are needed.
3. Prepare the urban infrastructure (e.g., energy, water, and waste management) to better conserve resources and to protect the environment from pollution. This is one reason cities have to be compact. Consequently, high-density areas are built. Coordination and joint usage of some services is recommended to decrease environmental loads.

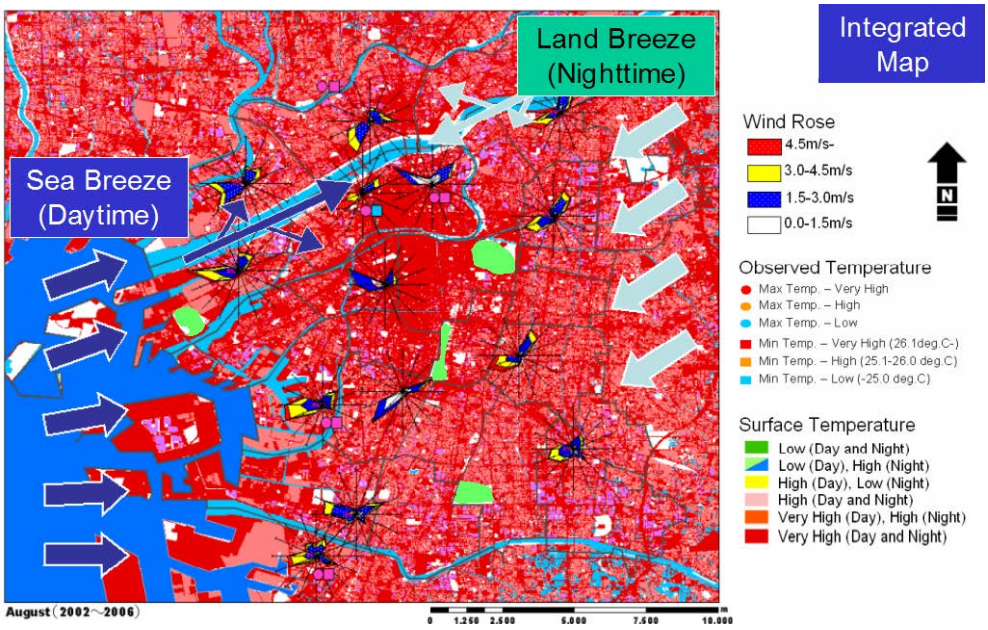

Figure 4. Climate analysis map of Osaka City

Climate Analysis Map for Planning

As described above, in the Osaka region, the urban climate is an important issue for urban design and planning from the perspectives of UHI mitigation and air-pollution reduction. Therefore, we conducted a climate analysis map for planning (Figure 2). This map represents the existing climate condition of the discussed area (Tanaka and Moriyama 2004). Based on this map, we propose a plan for Osaka's central area.

Figure 5 shows the *Kaze-no-Michi* ventilation lane in Osaka's central area, caused by the typical sea-breeze flow. However, the roads are not in good condition to help with the air quality and the thermal environment. Figure 6 shows an example of surface temperatures on Nagahori Street. The north lane of the street has a very high surface temperature because the road is wide and has no street trees. There are no shade spaces.

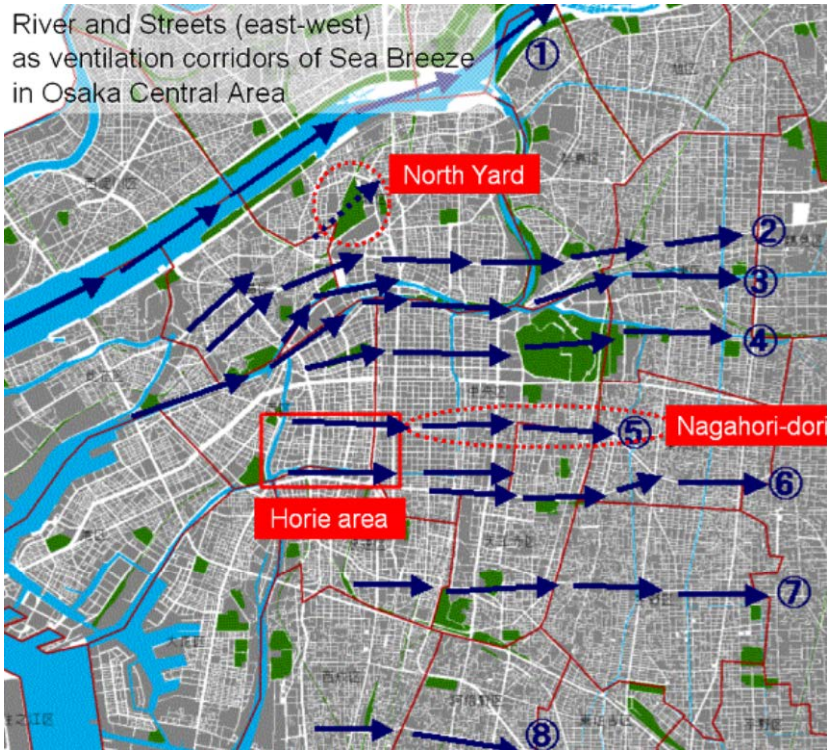

Figure 5. Proposal for a *Kaze-no-Michi* (ventilation lane) in Osaka's central area

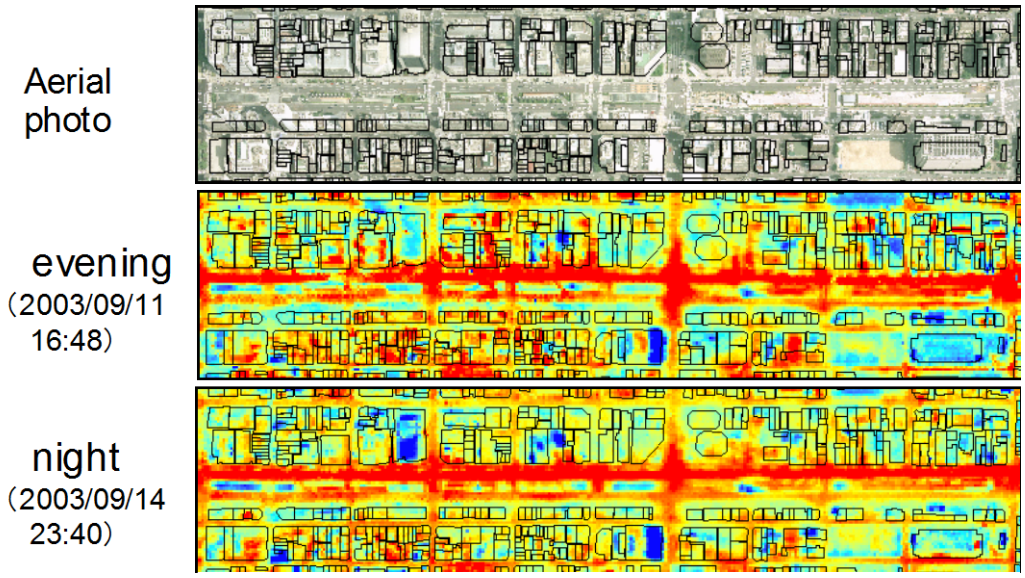

Figure 6. Surface temperature of Nagahori Street (provided by Pasco)

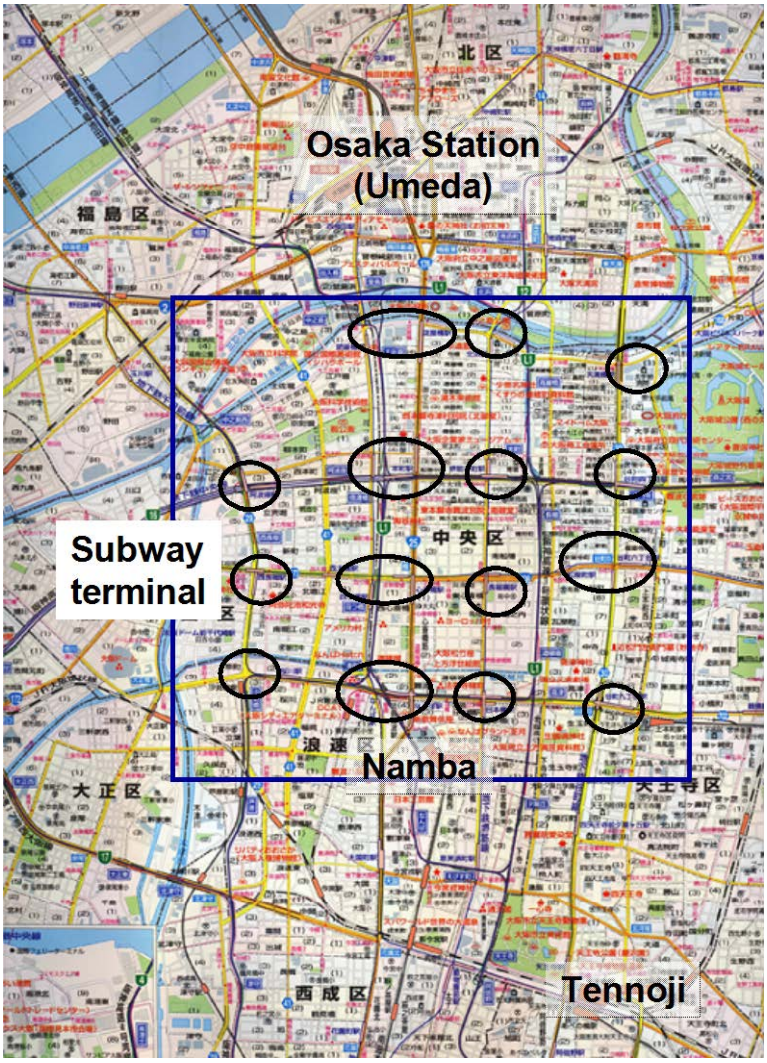

Figure 7. Principles for Osaka's grid model

Image of a New Land-Use Plan for Compact Eco-City

The roads in Osaka's central area consist of 86 m grids. The subway lines are located at approximately 1 km intervals, as shown in Figure 7. Therefore, the stations for changing trains (junctions) are located regularly.

The principles for a new land-use plan in Osaka's central area are as follows.

1. Create an urban core (high-rise areas) around the existing subway stations
2. Divide all focus areas into three types, based on land use
   (1) High-rise area for offices, commercial buildings, and public buildings
   (2) Low-rise area for houses, residences, and life activitites
   (3) Green areas (10%, 30%) for recreation, ecosystem conservation
3. Install green belts between subway stations; green zones should be constructed in the blocks between stations

Image of Three Zones

Core zone: The core zone consists of a high-rise area for offices, commercial buildings, and public buildings. It is located about 250 m to 300 m near a subway station. For the viewpoint of wind flow, high-rise buildings in the central area would be more desirable than the type of courtyard design that is popular in Europe.

Residential zone: The residential zone is a low-rise area for residential houses. The residential houses are located around the core zone and have plentiful greenery.

Green zone: The blocks located between the subway stations are the green zone. Historical buildings should be conserved, especially in the green zone. In some cases, these can be converted to restaurants, museums, and other similar structures.

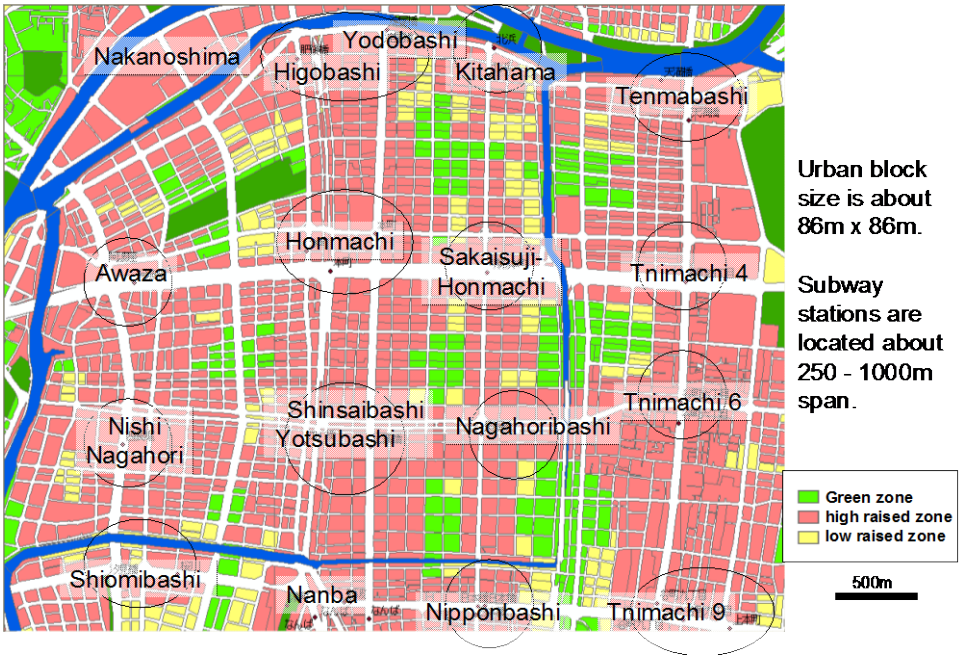

Figure 8. Osaka grid model (green area: 10% case)

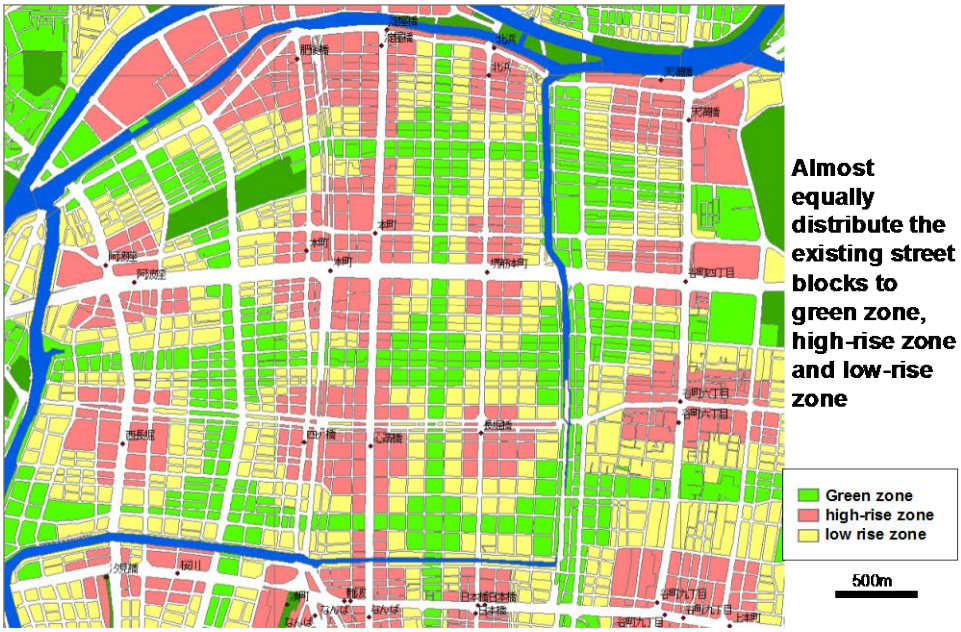

Figure 9. Osaka grid model (green area: 30% case)

Figure 10. Image of core zones (example of Osaka Business Park)

Conclusion

Based on the current problems in Japanese cities, the proposed plan is threefold:

1. Increase green space and restore waterfront spaces within the central city area for amenity and climate control. Design green spaces for 30% of the city area.
2. Prepare the infrastructure (e.g., water, energy, and waste management) to better conserve resources and to prevent environmental pollution, partly through coordination of mechanical services and promotion of joint usage to decrease environmental loads.
3. Develop a good public transportation system using the existing subway system and build a new transportation system that features greater comfort and more space for pedestrians.

Detailed quantitative evaluations of UHI mitigation and other related issues are needed. Countermeasures at the district level are important for urban areas. The method of achieving these measures is also important. One possible method is the land-readjustment program for creating green blocks. A redevelopment plan should be used for this program. These issues will be addressed through future research.

Acknowledgments

This research was partially supported by the Kobe University 21st Century COE program Design Strategy towards Safety and Symbiosis of Urban Space.

Reference

Tanaka, T. and Moriyama, M., 2004, Application of GIS to make 'Urban Environmental Climate Map' for Urban Planning, Proc. 5th Conference on Urban Environment (CD-ROM).

(Received Feb 9, 2012, Accepted Oct 10, 2012)