Comprehensive Urban Studies No.71 2000

"Formulae" for Energy-conscious Urban Planning

Takashi Kawanaka*

Abstract

This paper discusses the results of a study on energy-conscious urban planning from the viewpoints of the shape and spread of built-up areas and networks, transportation facilities, infrastructure for energy supply, greenery and vegetation, construction work and so on. The author proposes a set of 31 "formulae" for energy-conscious urban planning. "Formulae" are classified into two main groups: a) formulae for basic urban planning, and b) formulae for plan making and improvement of urban areas.

The current Japanese legislative urban planning system is reviewed from the viewpoint of applications of "formulae," mainly in zoning and master plan methods. It is considered that the combination of housing and work space, the mass transit facilities linking them, the mixture of different building uses, and the compactness of built-up areas are crucial to make our cities energy conscious.

This study was conducted as a part of "Research and Development of New Technologies in Building and Planning Field for Sustainable Society" (initiated by the Ministry of Construction, Japan, FY1991 to 95) by the Research Group of Urban Structure and Energy.

1. Objectives

The Ministry of Construction initiated the "Research and Development of New Technologies in Building and Planning Field for Sustainable Society" project from FY1991 until FY1995. The Building Research Institute shared some sub-themes, and analyzed energy and resource consumption by building construction and in urban development, and conducted life cycle analysis (LCA) of buildings, assessment of impact on urban climates and so forth. This paper considers energy-conscious urban planning as part of the above research.

The author was in charge of this sub-theme research through the entire period. The research project was carried out by the Research Group of Urban Structure and Energy, chaired by Prof. Koshizuka of the University of Tsukuba. The objective was to propose basic approaches to the cre-

*Department of Housing and Building Economy, Building Research Institute, Ministry of Construction, Japan

ation of energy- and resource-conscious cities under given conditions.

In the Japanese board games of *shohgi* （将棋） and *go* （碁）, there exists the concept of *johseki* （定石・定跡）. A set of *johseki*, or the established tactics set moves and so on, illustrates the best strategy for two competing players. We would like to show these tactics by quantitative analysis under a premise that they be as simple as possible, for energy-conscious urban planning. Naturally, *johseki* should only be used where appropriate; one cannot always win by *johseki* alone. In this paper the word "formula," or the key concepts in a report entitled "Guidelines for Energy and Resource Conscious Urban Planning" (Kawanaka (ed. 1997b)) will be used instead of *johseki*.

The background research of this paper sought ways to mitigate the global environmental burden through systems of urban planning. We would like to discuss this mitigation in mainly in terms of the application of energy-conscious methods. This paper does not consider the issues of waste or water circulation, different sub-themes in the research program, due to limitations in the scope of the research group.

2. "Formulae" for Basic Urban Planning

2.1 "Formulae" for Horizontal Development and Improvement in Urban Areas

Formula 1: The total area of small, useless vacant space increases as the density of buildings increases.

We can express w, which is the total area of small, useless vacant space in a built-up area, supposing that r is the total area of vacant space as follows:

$$w \approx 4 r \sqrt{C \rho}$$

Where C: building coverage ratio

ρ : density of buildings

(Refer to Koshizuka et al. (1989).)

Formula 2: The length of the supply network depends on both the quantity of building units and the area of network coverage.

We can express Λ, which is a length of a supply network on an urban plane, supposing that S is the area of network coverage, and n is the number of buildings supplied by the network, as follows:

$$\Lambda \approx \alpha \sqrt{nS}$$

α is a coefficient which varies according to the type of network and its pattern.

(Refer to Koshizuka (1994a).)

Formula 3: Congestion of a central area surrounded by a radial and loop road pattern is heavier than that surrounded by a grid pattern.

Congestion in a central area surrounded by a radial and loop road pattern is worse than that surrounded by a grid road pattern, even if both the distribution of origins and destinations of the traffic are identical.

(Refer to Koshizuka et al. (1994).)

Formula 4: There exists a certain road density that may minimize required transportation time.

If the total length of roads is fixed, road density increases in a smaller area but decreases in a larger area. There exists a road density that may minimize required driving time over areas of various sizes.
(Refer to Koshizuka (1994b).)

Formula 5: There exists a certain road density that may minimize required transportation energy.

If the total length of roads is fixed, road density increases in a smaller area but decreases in a larger area. There exists a road density that may minimize required driving energy over areas of various sizes.
(Refer to Koshizuka (1994b).)

2.2 "Formulae" for Energy Saving in Transportation for Commuting and Business Purposes

Formula 6: We should promote a modal shift to mass transit that may reduce energy consumption.

The proportion of energy consumed by car traffic is very large in urban transportation. In an area where the share of car traffic is large and there is heavy traffic congestion, it is better to promote a modal shift to mass transit, such as railways, that has smaller unit energy consumption. It is important to speed up mass transit, to improve comfort, to improve route-changing or inter-modal facilities, and to improve terminal-to-destination access.
(Refer to Tagashira et al. (1994).)

Formula 7: We should promote energy saving in commuting by encouraging people to live near their place of work.

Vitalization of the housing market is an effective means to encourage people to move, so as to shorten the distance between their residence and place of work. This is especially important if we are to promote decentralization.
(Refer to Suzuki (1994b) and Merriman et al. (1995).)

Formula 8: We should encourage offices to locate according to the traffic they generate.

It is desirable to create compact business areas located near well-developed railway networks to reduce total energy consumed by commuting and business transportation, in businesses where face-to-face communication is required and frequent trips to and from the office are necessary. Conversely, it is desirable to decentralize business areas that a) do not have this requirement, or b) are convertible into a business style supported by telecommunication. It is also desirable to promote a policy of encouraging people to live near their place of work.
(Refer to Suzuki et al. (1996).)

Formula 9: We should develop mass transit within a commuting area of each business core to construct multi-centric business districts.

Business cores should become independent, and we should improve mass transit facilities between them. We also should improve mass (or middle) transit facilities within the commuting zone of each business area and encourage houses to be sited near each railway station to offset the trend of commuting by car. These policies must be carried out simultaneously to promote the creation of multi-centric business districts through reduction of energy consumption by commuting and business transportation.
(Refer to Tagashira (1994) and Suzuki et al. (1996).)

2.3 "Formulae" for High-rise Buildings for the Development/Improvement in Urban Areas

Formula 10: There exists a base-to-height ratio, for a model of a city as three dimensional space, that may minimize transportation time.

There exists a ratio $h / \sqrt{S}$ (a ratio of the height by the base) that might minimize total travel time for trips between all of origins and destinations wherever they may be, assuming a simplified city, as in Fig. 1.

There also exists a similar proportion whether the target sphere is a square as in Fig.1 or an irregular shape. In this case, we adopt the root of the area of the target sphere as the base.
(Refer to Koshizuka (1993).)

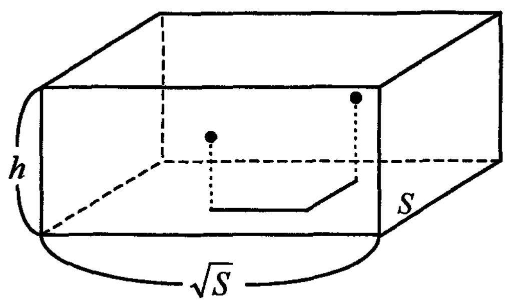

Fig.1 A Simplified Model of a City

Formula 11: There exists a base-to-height ratio, for a model of a city as three dimensional space, that may minimize transportation energy.

There exists a ratio $h / \sqrt{S}$ (a ratio of the height by the base) that might minimize total energy consumption of travels at trips between all of origins and destinations, assuming a simplified city, as in Fig. 1.

There also exists a similar proportion whether the target sphere is a square as in Fig.1 or an irregular shape. In this case, we adopt the root of the area of the target sphere as the base.
(Refer to Koshizuka (1995).)

Formula 12: We should restrain the urban sprawl and utilize unused land and promote multistoried buildings to guide the effective use of land and urban growth.

If a city is compact, both as a plane and a solid, energy consumption and environmental burden caused by traffic may be refrained over the entire urban area. By changing horizontal trips, increased by urban growth on a plane, into vertical ones, we can shorten the distance of travel. This is possible in a metropolitan area where growth is horizontal: promote the utilization of unused land and suitable multistoried buildings in the central area to create a compact city and to prevent urban sprawl. The height of buildings should suit the area of each district. We should avoid excessively tall buildings.
(Refer to Suzuki (1994a).)

Formula 13: We should utilize aerial and underground space in areas with high land use potential to reduce long-distance transportation demand.

Elevated streets, walkways, pedestrian decks and underground malls that enable multi-layered transportation systems should promote the compactness of an entire city. We can save energy by utilizing both aerial and underground space in areas with high land use potential, to mitigate congestion on the ground and to reduce long-distance transportation demand in urban areas.
(Refer to Suzuki (1993b).)

3. "Formulae" for Plan Making and Improvement of Urban Areas

3.1 "Formulae" for the Construction of a District Heating and Cooling System

Formula 14: We should consider the scale of investment in district heating and cooling systems to achieve energy-efficient, economically viable operation.

A district heating and cooling system requires considerable investment. It is important that the demand for heat energy is balanced with the initial investment. For example, if we plan to simply match heat output with final demand in a large-scale development that requires step-by-step construction over a long period, mistakes will be made. We will likely over-invest in a system with respect to the load requirements, which will result in profitless management and inefficient low load operation of the system. Because this tendency is common in areas that have a high heat load density, we should carefully consider the scale of a system and its merit in the area of development.

Formula 15: We should consider the area of the district, the floor area ratio and layout of blocks to determine the optimum coverage of district heating and cooling systems.

There are roughly two types of energy consumption by operation of a district heating and cooling system: a) energy for heat generation, and b) energy required for distributing the generated heat to consumers. Energy for heat generation per supply unit decreases by scale merit as the total heat supply increases, in other words, as the scale of the system increases. Energy required for distribution increases as the total length of piping increases and as the total supply decreases (i.e. the diameter of a pipe decreases) because of a piping friction loss and thermal loss. We should select the most effective system considering the combination of these factors.

Formula 16: Heat storage tanks enhance the efficiency of district heating and cooling systems.

A heat demand changes according to the time of day. When a consumer installs a heat storage tank, a supplier can level work loads thereby can reduce the size of their plant and the diameter of distribution. On the other hand, the consumer has to secure a place to install the storage tank and bear the cost of building and maintaining it. Measures to help installing it, relaxing of FAR and subsidies, for example, will be needed.

3.2 "Formulae" for the Construction of a Co-generation System

Formula 17: We can save energy and stabilize its supply by introduction of co-generation systems in built-up areas.

A co-generation is built and used by the consumer. In built-up areas, co-generation systems

can save energy, reduce local power demand peaks, and ensuring backup energy sources in times of civil disaster. The closer the match between co-generation system operation and heat consumption demand, the better the energy saving effect. It is desirable to operate co-generation systems in cooperation with conventional electric power systems and reverse-supply electricity generation systems.
(Refer to Ichikawa et al. (1992).)

Formula 18: We can save energy and promote economical operation of co-generation systems by planning them to supply energy to buildings that have different energy consumption patterns.

The effectiveness of introducing a co-generation system is higher in the case of mixed use of buildings than the case of single use, especially a mixture of both office/commercial use and residential/hotel use. This is because the heat/electricity demand ratio differs greatly between business/commercial facilities (uses more electricity) and residential/hotel facilities (uses more heat for boiling water). Introducing a co-generation system to a group of buildings or a block unit instead of to a single building can meet the mixed-use requirement described above. When the same system supplies both commercial users who consume energy in the daytime, and residential users who consume it at nighttime, the system works longer hours and is more economic and saves more energy.
(Refer to Sadohara et al. (1995) and Watanabe et al. (1997).)

3.3 "Formulae" for Utilization of Untapped Energy Sources

Formula 19: There are various temperature levels of untapped energy, therefore we should consider their use method according to each temperature level.

Untapped, wasted energy sources include heat from incineration, heat of sewerage, heat of river water and heat of seawater. The temperatures of these sources range from hundreds of degrees centigrade to about 10 degrees centigrade; therefore, we should select the method of use of this energy befitting the temperature level and quality. In the case of low-temperature energy sources, the effectiveness of energy saving is closely related to the heat load; it is better to use these energy sources when the load ratio is high. In the case of high temperature energy, the more we use it, the greater the energy saving.
(Refer to New Energy Foundation (1992).)

Formula 20: When utilizing untapped energy, the distance between the heat source and end user should be as short as possible.

When promoting energy saving and utilizing wasted natural heat energy it is important to minimize the distance between the source site and a consumption site. Since the energy needed to transport the heat is the weak point in the utilization of untapped energy, the larger the demand at the energy consumption site, the longer the distance of heat energy transportation can be. The area of a heat demand site should be a compact as possible to minimize the amount of energy required for transportation within the area.

Formula 21: We should utilize untapped energy from water in sewerage and rivers but with conditions attached.

There are some restrictions to the utilization of untapped thermal energy in water. General consumers cannot use the thermal energy from publicly-administered sewerage systems easily. We should consider public interests when we plan to utilize the untapped energy of rivers.

3.4 "Formulae" for Urban Vegetation

Formula 22: We should have a network of green spaces in urban areas.

Urban green spaces suppress the rise of urban air temperature in summer through transpiration of water vapor. This effect indirectly reduces the need for air conditioning. When utilizing green spaces for saving energy, it is important to increase the total volume of green spaces in urban areas. Nevertheless, the bigger the green space, the greater the restriction to land use—so a balance is needed. The distribution of green space should be optimized for maximum efficiency. In terms of effective utilization and esthetic beauty, it is better to have a few big open spaces that are networked and strategically located, than a scattering of many small green spaces.

(Refer to Honjo et al. (1991).)

Formula 23: We should promote the planting of tall trees in each lot.

When we enlarge the areas covered with greenery, it is not enough simply to promote the development of public parks and planting roadside trees. Trees can control temperature increase in summer and can thus save energy for air-conditioning. We need to plant tall trees that are higher than the roof of a building in an individual lot.

(Refer to McPherson et al. (1988).)

Formula 24: We should promote roof planting.

When the land use becomes more intensive, it becomes difficult to secure enough land for greenery. Rooftop planing is one way of increasing evaporation and reducing energy consumption for air conditioning on the highest story of a building to offset the rise of urban air temperatures in summer. Heat exhaust at night in urban areas can be reduced because the heat emissions from roofs decline.

(Refer to Nojima et al. (1995).)

Formula 25: We should promote the covering of building walls with vegetation.

In the urban areas where the land use is intensive, covering the walls of each building with vegetation can mitigate the heat island phenomenon, and decrease energy needed for air conditioning in summer.

We can mitigate the rise of wall temperatures during daytime in summer, by covering the walls with vegetation, ivy for example. This decreases electricity consumption for air conditioning during daytime and has the indirect effect of reducing high air temperatures by lowering emissions of heat stored in the building during the daytime.

(Refer to Nojima et al. (1993).)

3.5 "Formulae" for Construction in Urban Areas

Formula 26: We should utilize the advantages of accumulation in urban areas.

Growth in urban population is linked to the profitability of public service works. Existence of demand over and above a certain level and density ensures profitability and lessens the recovery risk of long-term fixed-capital investment. Utilizing the merits of accumulation should be a basic policy for the following reasons: a) to make cities more effective in terms of energy and resource consumption; b) to reduce emission of carbon dioxide (CO_2) and; c) to make cities a convenient place to live while saving both energy and resource.

Formula 27: Larger buildings save more energy.

The larger a building or group of buildings, the better the conditions for the introduction of energy- and resource-conscious methods. Nevertheless, super high-rise buildings tend to consume more energy for their conveying systems due to a reduction in effective floor ratio. The life cycle CO_2 emissions ($LCCO_2$) of a building need to be considered during the planning stages.

Formula 28: We should consume less cement and steel.

Most induced CO_2 emissions in construction come from building material production, especially cement and steel. To reduce CO_2 emissions, we should devise construction methods that require less cement and steel.

(Refer to Kawanaka (1994).)

Formula 29: We should maximize the service life of buildings.

We can reduce life cycle CO_2 by using buildings as long as possible. We should plan long-term use of buildings, particularly their structural members of columns and beams which require much cement and steel.

Formula 30: We should assess life cycle CO_2.

When we plan a building, we should assess its life cycle CO_2 emissions, including those generated in the building's operation and maintenance. It is also important to assess chloro-fluorocarbon (CFC) emissions since CFC-containing materials are often used in construction.

(Refer to Ikaga et al. (1996).)

Formula 31: We should recover and dispose chloro-fluorocarbons (CFCs) at a steady rate.

Refrigerants and thermal insulating materials in buildings, especially an office building, contain CFCs. These are ozone-depleting substances that contribute to global warming. When we demolish a building, we have to recover and dispose these refrigerants and insulation.

Formula 1 to Formula 31 are listed and classified in Table 1.

4. Urban Planning Systems and their Implementation Based on "Formulae"

There are a lot of land use control systems in Japanese urban planning. We shall have a quick look at the current urban planning systems from a viewpoint of energy conscious implementation of urban planning by considering "formulae."

4.1 Zoning Methods

There are some of methods that designate land use zones on a large scale, to control both the formation and scale of cities in Japanese urban planning systems. One is the designation of urban planning areas under the Urban Planning Act. The other is designation (delineation or subdivision called "senbiki") of urbanization promotion areas and urbanization control areas in many urban planning areas.

It is necessary to implement both types of definitive designation: an urbanization promotion

Table 1 Thirty-one "Formulae" for Energy-conscious Urban Planning

I. "Formulae" for Basic Urban Planning	
A. Formulae for horizontal development and improvement in urban areas	
1.	The total area of small, useless vacant space increases as the density of buildings increases.
2.	The length of the supply network depends on both the quantity of building units and the area of network coverage.
3.	Congestion of a central area surrounded by a radial and loop road pattern is heavier than that surrounded by a grid pattern.
4.	There exists a certain road density that may *minimize* required transportation time.
5.	There exists a certain road density that may minimize required transportation energy.
B. Formulae for energy saving in transportation for commuting and business purposes	
6.	Promote a modal shift to mass transit that may reduce energy consumption.
7.	Promote energy saving in commuting by encouraging people to live near their place of work.
8.	Encourage offices to locate according to the traffic they generate.
9.	Develop mass transit within a commuting area of each business core to construct multi-centric business districts.
C. Formulae for high-rise buildings for the development /improvement in urban areas	
10.	There exists a base-to-height ratio, for a model of a city as three dimensional space, that may *minimize transportation* time
11.	There exists a base-to-height ratio, for a model of a city as three dimensional space, that may minimize transportation energy.
12.	Restrain the urban sprawl and utilize unused land and promote multistoried buildings to guide the effective use of land and urban growth.
13.	Utilize aerial and underground space in areas with high land use potential to reduce long-distance transportation demand.
II. "Formulae" for Plan Making and Improvement of Urban Areas	
A. "Formulae" for the construction of a district heating and cooling system	
14.	Consider the scale of investment in district heating and cooling systems to achieve energy-efficient, economically viable operation.
15.	Consider the area of the district, the floor area ratio and layout of blocks to determine the optimum coverage of district heating and cooling systems.
16.	Heat storage tanks enhance the efficiency of district heating and cooling systems.
B. "Formulae" for the construction of a co-generation system	
17.	Save energy and stabilize its supply by introduction of co-generation systems in built-up areas.
18.	Save energy and promote economical operation of co-generation systems by planning them to supply energy to buildings that have different energy consumption patterns.
C. "Formulae" for utilization of untapped energy sources	
19.	There are various temperature levels of untapped energy, therefore consider their use method according to each temperature level.
20.	When utilizing untapped energy, the distance between the heat source and end user should be as short as possible.
21.	Utilize untapped energy from water in sewerage and rivers but with conditions attached.
D. "Formulae" for urban vegetation	
22.	A network of green spaces in urban areas.
23.	Promote the planting of tall trees in each lot.
24.	Promote roof planting.
25.	Promote the covering of building walls with vegetation.
E. "Formulae" for construction in urban areas	
26.	Utilize the advantages of accumulation in urban areas.
27.	Larger buildings save more energy.
28.	Consume less cement and steel.
29.	Maximize the service life of buildings.
30.	Assess life cycle CO_2.
31.	Recover and dispose chloro-fluorocarbons (CFCs) at a steady rate.

area to limit the scope of urbanization, and an urbanization control area to control and restrict urban development. Development in urbanization control areas, which is supposed to be controlled (prohibited in principle), is often permitted through special permits and variances. These permits however, should be kept to a minimum to reduce the urban sprawl and reduce the environmental burden (refer to "Formula 12").

Within the hierarchy of Japanese urban planning systems, there are several upper-tier planning systems. The first is the National Land Utilization Plan (national-level); the second is the National Capital Region Development Plan (metropolitan-level). These are planned and implemented through different acts. It should be noted that these plans are conceptual and have little connection with actual urban planning. They are not effective tools to challenge global environmental problems either.

The Japanese urban planning system has a zoning system that designates 12 use zones mainly in urbanization promotion areas. The system prescribes permitted building uses, upper limits of floor area ratios, and so on, in each use zone. Many kinds of use zones allow mixed land use, without limitation of building use. A variety of use zones allow mixed building use except in some zoning categories. On the other hand, the use zoning system can induce the inner structure of the city to change according to the method of zoning system implementation. It is possible to allow dense land use to some degree at a site with great economic potential for building, according to the combination of floor area ratio arranged for each use zone category. In short, there is room for mixing or approximating commercial-business use and residential use in use zoning, based on "Formula 17" and "Formula 18." We consider that the well-designed implementation of the zoning system—in coordination with energy infrastructure construction and transportation infrastructure construction—in the near future should save energy. We believe that the current zoning system is effective enough to guide both building use and density represented by floor area ratios.

4.2 Master Planning Methods

The Japanese legislative urban planning system can be interpreted as having two kinds of master plans at the "upper level" that describes basic guidelines and directions of urban planning.

The first kind of master plans is guidelines for improvement, development or conservation at urbanization promotion areas and urbanization control areas (GIDC). GIDC sets a 10-year goal. Several energy conscious methods (i.e. mitigation of environmental load indicated from "Formula 1" to "Formula 21" in this paper are included as items of GIDC. Examples include land use policy, urban development and renewal policies and a traffic system improvement policy. Other GIDC items concerned with the introduction of energy conscious technologies in urban areas are policies for sewage and river systems, and the construction of public facilities.

It is possible to provide an urban renewal policy and to deal with it as a part of GIDC when we choose urban renewal at a densely built-up area suitable for the introduction of energy conscious technologies. Policies for conservation of the natural environment and public open space are parts of GIDC that are related to Formula 22. "The basic green plan" (the former "green master plan" as a part of GIDC) is a part of the Japanese urban planning system. There are some planning systems called "sectional master plans" that are not based on statute. We may consider them as a part of

GIDC. "The urban environment plan" could be interpreted as one of them.

The second group of legislative master plan is "the basic policy for urban planning at municipalities," which is sometimes called "the municipality's master plan" or "the urban (or city) master plan." This plan reflects the originality of a municipality setting a goal 20 years later. Its expected roles are to indicate: basic policies for planning; the city's future image; programs or procedures; the arrangement of measures; coping with new tasks; the rationale and proper place for control and project; and creating opportunities for participation by residents. Environment conscious planning, especially energy conscious planning, should be included.

The municipality's master plan should include both an overall concept and local concept on a spatial scale in one municipality. The city structure of density and scales or locations of public traffic facilities that are conscious of environmental burden might be presented in the total concept. The local concept should present a policy for designation of use zones mentioned above, and each future image of a city, as a premise of planning. It also should include a policy for district planning that we will discuss in 4.3.

There are discussions of the double standards and redundancy of GIDC and the municipality's master plan. The author thinks that we should view countermeasures against global environmental problems as a fundamental direction of all administrative implementations in the future, not only as a part of sectional master plans in urban planning. To consider that countermeasures might work better on a larger scale and the energy conscious methods might be effective in built-up areas and suburbs of large and middle scale cities, the following points will be important. Firstly, it is necessary to encourage the mitigation of environmental burden by GIDC prescribed by the prefectural governor. Secondly, it is desirable to show a program of concrete, individual and detailed environmental mitigation measures in the municipality's master plan, created by the participation of local residents.

There were 537 municipality master plans as of June 1999. As far as the author knows, a few master plans devote entire policy sections to global environmental issues, but do not connect them with individual or local items in master plans. Because a municipality's master plan respects the "locality" of each city, it is hard to give shape to countermeasures against global environmental problems within a local city's tools for urban planning. Nevertheless, we hope that new types of master plans that consider the global environment will appear.

4.3 District Planning Methods

The Japanese statutory urban planning system has a district planning system that can prescribe controls for detailed building use, floor area ratio limits and so on. On the other hand, the use zoning system permits the selection from a fixed menu of control nationwide. The district planning system, introduced in 1980, has now a variety of 'menus' though we have no pages to describe details of each of them.

It is desirable to utilize a district plan to implement the "formulae" for energy conscious urban planning methods described in this paper within a limited area (few to dozens of hectares). It is possible to induce highly dense land use, to save green open spaces, to construct local co-generation plants and so on.

One case of urban renewal district plan which is a kind of district plan, has treated the construction of a district heating and cooling system as a bonus incentive factor for a floor area ratio. In district planning systems, it is desirable to realize an incentive or obligation mechanism for a project that can be evaluated by the GIDC (as an upper level plan) and the municipality's master plan as a promotion area for the introduction of energy conscious methods.

5. Conclusions

We have discussed the ability and position within current urban planning systems to realize methods for mitigation of environmental burden and promotion of energy conscious measures, by referring to an outline of urban planning in Japan. There are some planning systems, "the basic environment plan" or "the urban environment plan" for example, related to the conservation and creation of urban environment. The aim of each planning system is different, and each has an identified reason to exist.

As clarified in this paper there are indeed many useful methods of implementation, and it is desirable to introduce them within current urban planning system. It is especially so as the world as a whole is becoming more environmentally conscious.

When we implement environment conscious measures, joint implementation of tax exemptions, public aid for interest payment, and public subsidies to ensure the profitability and stability of a program will be needed—adding to its obligation in urban planning. This paper did not consider a detailed investigation of those problems.

There is a conceptual relationship between environment conscious urban planning in this paper and urban growth management. For instance Harashina (1996) states that growth management does not necessarily restrain growth, but also has two main aims: Firstly, to retain the level of public service level and; secondly, to conserve ecosystems and mitigate the environmental burden. Environmental measures must be related to urban planning to respect these aims. The "formulae" proposed in this paper can be tools for growth management policies in urban planning. Above all, they have the potential of changing the way of thinking of urban planners, both in public and private sectors, to help them to be more environmentally conscious.

Acknowledgments

Chapters 1 to 3 of this paper are a revision of Kawanaka (1997a). A full report was released as Kawanaka (ed. 1997b) and a summary of a series of research was published as Koshizuka et al. (1997), both in Japanese.

Contributions of the members of the Research Group of Urban Structure and Energy and the former staffs of the Building Research Institute formed the body of this paper and some referred papers. The author appreciates the efforts of all concerned with this research.

References

Harashina, S., "Density Control for Good Living at Tokyo," Nihon Keizai Shimbun, August 27, 1996 (in Japanese).

Honjo, T., Takakura, T., "Simulation of Thermal Effects of Urban Green Areas on Their Surrounding Areas," *Energy and Building*, Vol.15-16, pp.443-446, 1991.

Ichikawa, T., Ojima, T., "A Theoretical Study on Primary Energy Conservation with a Co-generation System for Building," *Journal of Architecture, Planning and Environmental Engineering*, No.433, pp.21-29, 1992 (in Japanese).

Ikaga, T., Tonooka, Y., Ishifuku, A., "Development of Data Base for Life Cycle Assessment of Buildings," *The Second International Conference on EcoBalance*, Tukuba, Japan, 1996.

Kawanaka, T., "A Research on CO_2 Emission in Urban Development and the Control Technologies," *Global Environmental Research of Japan (Final Reports for Projects Completed in 1993)*, Research & Information Office, Global Environment Department, Environment Agency, pp.74-77, 1994.

Kawanaka, T., "'Formulae' for Energy Conscious Urban Planning," *Second International Symposium on Urban Planning and Environment: Strategies and Methods for Improving Environmental Quality in Compact Cities*, March 11-14, Groningen, the Netherlands, 1997a.

Kawanaka, T. (ed.), "Guidelines for Energy and Resource Conscious Urban Planning," Building Research Institute, Ministry of Construction and Japan Institute of Construction Engineering, 1997b (in Japanese).

Koshizuka, T., Kotoh, H., "Estimation of Effective Vacant Areas by Building Densities," *Papers on City Planning*, No.24, pp.337-342, 1989 (in Japanese).

Koshizuka, T., "What is a Compact City?," *The 1993 Fall National Conference of the Operations Research Society of Japan*, pp.142-143, 1993 (in Japanese).

Koshizuka, T., Nishino, Y., "Patterns of Travel on Roads and Congestion Phenomenon," *The 1994 Spring National Conference of the Operations Research Society of Japan*, pp.37-38, 1994 (in Japanese).

Koshizuka, T., "On a Length of Supply Network in an Urban Area," *The 1994 Fall National Conference of the Operations Research Society of Japan*, pp.146-147, 1994a (in Japanese).

Koshizuka, T., "Road Densities which bring a Minimum Car Travel Time and a Minimum Gas Consumption," *Papers on City Planning*, No.29, pp.319-324, 1994b (in Japanese).

Koshizuka, T., "Compact Proportion of a City with Respect to Travel Time," *Papers on City Planning*, No.30, pp.499-504, 1995 (in Japanese).

Koshizuka, T. et al., "Special Edition: Urban Structure and Energy Saving," *Communications of the Operations Research Society of Japan*, Vol.42, No.1, pp.6-32, 1997 (in Japanese).

McPherson, G., Herrington, L., Heisler, G., "Impacts of Vegetation on Residential Heating and Cooling," *Energy and Building*, No.12, pp.41-51, 1988.

Merriman, D., Ohkawara, T., Suzuki, T., "Excess Commuting in the Tokyo Metropolitan Area: Measurement and Policy Simulations," *Urban Studies*, Vol.32, No.1, pp.69-85, 1995.

New Energy Foundation, "*Manual for Utilization of Untapped Energy*," Ohm Co., 1992 (in Japanese).

Nojima, Y. et al., "Practical Study on the Effect of the Plants on the Wall of a Building to Suppress the Increase of Wall Temperature," *Journal of the Japanese Institute of Landscape Architecture*, Vol.56, No.5, 1993 (in Japanese).

Nojima, Y. et al., "Practical Study on the Effect of the Plants on the Roof of a Building to Reduce the Heat Absorption of the Building and the Urban Area," *Journal of the Japanese Society of Revegetation Technology*, Vol.20, No.3, 1995 (in Japanese).

Sadohara, S., Shibata, O., Ichikawa, T., Ojima, T., "A Study on Selecting the Promotion Areas for District Cogeneration in Tokyo 23 Wards," *Journal of Architecture, Planning and Environmental Engineering*, No.468, pp.47-54, 1995 (in Japanese).

Suzuki, T., "3-dimensional Shape of a City and Load by Transportation," *The 1993 Fall National Conference of the Operations Research Society of Japan*, pp.140-141, 1993a (in Japanese).

Suzuki, T., "A Study on Optimal 3D Urban Form from a Viewpoint of Compactness," *Papers on City Planning*, No.28, pp.415-420, 1993b (in Japanese).

Suzuki, T., "Optimal Multi-level Space Use in Buildings, Measured by Accessibility and Energy Consumption," *Proceedings of the First International Conference Building and the Environment*, Building Research Establishment, UK, 1994a.

Suzuki, T., "A Theoretical Approach to the Relationship between Urban Structure and Commuting Distance," *Papers on City Planning*, No.29, pp.505-510, 1994b (in Japanese).

Suzuki, T., Tagashira, T., "A Model Analysis of Relationship between Business Use Location and Energy Consumption by Urban Traffic," *Papers on 12th Energy, System, and Economy Conference*, pp.177-182, 1996 (in Japanese).

Tagashira, N., "Location Patterns of Firms Minimizing the Total Distance of Commuting and Business Trips," *Papers on City Planning*, No.29, pp.511-516, 1994 (in Japanese).

Tagashira, N., Suzuki, T., "Analysis of Energy Consumption Effect by Modal Shift in Passenger Transportation," *Papers on 10th Energy, System, and Economy Conference*, pp.99-104, 1994 (in Japanese).

Watanabe, K., Kawanaka, T., "A Methodological Study on the Introduction of Co-generation Systems (CGS) in Tokyo Metropolitan Region for Energy-saving," *Proceedings of International Symposium on City Planning: New Paradigm in City Planning*, Nagoya, Japan, pp.139-148, 1997.

Key Words（キー・ワード）

Urban Planning（都市計画），Compact City（コンパクトシティー），Saving Energy（省エネルギー），Co-generation（コージェネレーション），Transportation Energy（輸送エネルギー）

省エネルギー型都市計画のための「定石集」の提案について

河中　俊

建設省建築研究所第一研究部
総合都市研究　第71号　2000　p.131-145

本論文は、既成市街地とネットワークの形状と規模、交通施設、エネルギー供給基盤施設、緑地と緑化、建設工事等の観点による省エネルギー型都市計画についての研究成果を述べるものである。本稿では可能な限り単純な前提条件下における定量的傾向に基づく省エネルギー型都市計画のための31の「定石集」を提案した。「定石群」は主にA.市街地の基本計画策定に即した定石群とB.市街地の整備計画策定に即した定石群の2つのグループに分類される。日本における現行の法定都市計画制度を「定石集」適用の観点から、主に地域制（ゾーニング）と基本計画（マスタープラン）の手法について検討した。上記の議論の結果より、住宅と職場の組合せ、それらを結ぶ大量輸送機関、用途の異なる建物の複合と混合、コンパクトな既成市街地が省エネルギー型都市形成のために重要であると考えられる。

本研究は建設省総合技術開発プロジェクト「省資源・省エネルギー型国土建設技術の開発」(1991-95年度)の一部として都市構造とエネルギー研究会により実施されたものである。なお、都市の微気候と熱環境に関する研究や建築物の日常的利用に関する省エネルギー性の研究は別の研究グループが担当しており、生態学、廃棄物や水循環の分野での検討は研究会メンバーの専門領域が限られていたため、共に本稿の対象外とした。