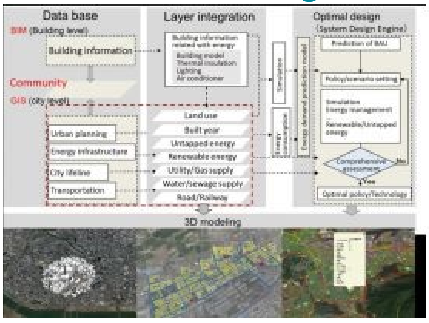
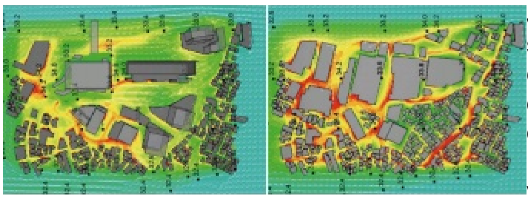
COMMUNITY-SCALE ASSESSMENT OF ENERGY PERFORMANCE

Combining BIM and GIS for a Sustainable Society



Nikken Sekkei Research Institute in Tokyo, Japan, has developed a vision for cities to help them choose an energy optimization strategy for neighbourhoods comprising a variety of building types. The optimization of energy consumption is approached from an area-wide standpoint. The added value of the method for city renewal programmes has been demonstrated based on a central district in the Japanese capital.



Japan has low energy resources and a high population density. That provides extra stimulation to develop ecofriendly urban planning. City and environmental designs use low carbon footprint solutions as their starting point, and planners, urban designers, architects, engineers and landscape specialists work together to provide integrated solutions. Urban energy supply and demand is an important item in this context of smart city management. It is a far more complex system than a single building since there are synergies between various elements like transport and the city infrastructure. Especially in Japan's largest cities, that infrastructure is becoming more and more compact.

Transit-oriented Development

According to the latest forecasts, more than a quarter of Japan's citizens will be aged over 65 in 2055. By then, the population will also have shrunk from the current 127 million to 90 million. In Tokyo (13 million people), one in four elderly citizens live alone with no family to take care of them. The predicted population growth in the 65-and-over group is one of the reasons that, for the past two decades, city planning has been based on compact, multifunctional neighbourhoods concentrated around the public transport system. Japan has no choice but to invest in developing such infrastructure rather than controlling road traffic.

Figure 1, Tokyo opted for the transit-oriented development concept. Most people live no more than 1,000 metres from a train station. Every circle is a fully functional community in which everything is within walking distance: shops, offices, public facilities, parks and green spaces, and of course transport.

Tokyo Metropolitan City is huge, but the scale has remained human in its neighbourhoods since Tokyo opted for the transit-oriented development (TOD) concept. Most people live no more than 1,000 metres from a train station. In these communities, everything is within walking distance: shops, offices, public facilities, parks and green spaces, and of course transport. "It helps people of all ages to live independently in their own homes and communities. It also saves emissions by vehicles and contributes to mitigating the production of greenhouse gases," elucidates Mr Shinji Yamamura, executive officer at the Nikken Sekkei Research Institute. Reducing CO_2 is very important for Tokyo. The city is a typical example of an urban heat island; the annual mean temperature has increased by about 3ºC (5.4ºF) over the past century. The municipality wants to reduce greenhouse gas emissions by 25% by 2020 compared with the level in 2000. Therefore, the city has not only created a thousand hectares of new green space over the last decade, but there is also a pressing need to reduce energy consumption, both in transport and in buildings.

Low-energy Buildings

Tokyo's urban infrastructure evolved during the city's period of rapid economic growth, and now requires renewal. Of course, energy saving is part of the plan. Mr Yamamura explains: "New buildings will be recommended, but net zero-energy buildings (ZEB) are not always possible. That is especially so in renovation. Much larger investments are needed than when one aims at the more common level of low-energy buildings. And even for that level, owners of very large commercially exploited buildings can perhaps generate enough budget, but it is still very difficult for the owners of small to medium-sized buildings.” Nevertheless, it is necessary. In 2014, the average annual energy consumption in Japan’s commercial buildings was around 2,140 to 2,450MJ/m^2, in office buildings it was 1,457MJ/m^2, in hospitals it was 2,952MJ/m^2 and in residential buildings it was 778MJ/m^2.

Figure 2, Structure of the energy assessment tool.

These elements – community infrastructure, renovation needs, energy reduction policies – inspired the researchers to develop a flexible strategy to renovate all the buildings in a neighbourhood as energy-efficiently and as pragmatically as possible, instead of each building on its own. It is the overall result for Tokyo that counts. Minimising the range of the infrastructure to be renewed would also reduce the initial costs.

The researchers developed three variations of pragmatic renovation policies and studied the effects of them in different areas of Tokyo. “In this process, BIM-GIS integration is essential to combine data in an efficient and holistic, user-friendly way,” states Shinji Yamamura. Building information modelling (BIM) is essential for the energy consultants and urban planners to prepare the building-related data, which can be combined with simulation software to predict the effect of every measure within or amongst buildings. The urban infrastructure data for this energy simulation comes from the local geographic information system (GIS) databases. The result is returned to the 3D city model on the GIS platform to check its effect at city or community level. The platform developed by Yamamura and his colleagues enables energy management operators or local government staff to visualize the energy consumption of the city, district or building. After inputting the location of a target area for city renewal, the planner obtains not only the urban plan information and the community features, but also the energy technology package that is likely to be most effective and needs further simulation and analysis.

Three Package Variations

Along one train line (East Japan Railway Company) in Tokyo, the researchers picked 12 communities which each have a train station at their centre. The GIS analysis combined with BIM databases from the urban planning department showed that there are a total of 150,000 buildings in those communities, 72% of which are small to medium-sized buildings. Only one community is made up of approximately 50% large buildings (over 50,000m^2). In three of the 12 communities, buildings are in use for commercial or business purposes; the other nine are more residential areas.

The first option is to check whether the community has buildings with more than 50,000m^2 of floor space. The owners of these large buildings would be in a better position to raise the budget for low-energy renovation work than the owners of small and medium-sized buildings. Rigorously renovating the large buildings only in such a way that they consume over 60% less energy and leaving the small and medium-sized buildings as they are would produce around 18% energy savings across the whole community, concluded Nikken Sekkei Research Institute. “By using advanced technologies such as ZEB-ready methodologies, the large buildings can achieve that 60% reduction,” claims Yamamura. But it is expensive.

As the second alternative, the government should still stimulate renovation of all the large buildings, but more simply. The aim is for them to use 20% less energy. That is feasible with today’s more common technologies to reduce energy consumption in the field of isolation, lighting, cooling and heating. Simultaneously, all the small and medium- sized buildings should implement rather small and easy measures to reduce their energy consumption by only 10%: change to LED lighting, use slightly more efficient air-conditioning systems, etc. In this case, the community achieves 20% energy savings overall.

The third option is that half of the large buildings implement measures to save 20% and all the small and medium-sized buildings likewise save 20%. In that case, energy consumption is reduced by more than 27% for the whole area. To reach that goal, the same reduction steps as in the second renovation policy have to be taken and an area energy management system also has to be implemented. Using the cluster of computer-aided tools, the electricity grid operator optimises the performance of the energy generation and transmission systems.

Looking to the near future, Shinji Yamamura reveals: “The software platform we developed suggests the best-performing strategy, depending on the input from the BIM and GIS databases. Artificial intelligence (AI) can automatically design the optimized energy consumption communities; I am now developing such an AI-oriented tool.”

Figure 3, Osaki Station West Exit Area, Tokyo â€“ microclimate plans with thermal environment simulation support the municipality in creating breeze corridors.

Heat Island

BIM-GIS integration is useful in all kind of 3D simulations; Yamamura also uses it a lot for 3D-environment thermal simulations. Although only the energy-oriented issues are highlighted for the purpose of this article, this energy management technology can be part of a comprehensive system that includes the transportation system and urban design measures for heat island mitigation. Yamamura explains his vision: “It is part of a smart city concept with the aim to develop solutions simultaneously and widely at different levels. I believe that prevention of global warming and pursuit of comfortable living conditions are both realizable at the same time.”

When a government decides to invest in BIM-GIS integration, it has a multipurpose functionality in environmentally friendly design. Yamamura, who is also an expert on urban thermal environment planning, has advised on many‘cool city’ design projects that mitigate heat island phenomena in Japan and elsewhere in Asia. Microclimate plans with thermal environment simulations support municipalities in creating breeze corridors in city centres to alleviate the heat problem. The starting point is the same as with area energy management: neighbourhoods or districts must be seen as part of the whole system to achieve success at city level.

Shinji Yamamura and Nikken

Shinji Yamamura is executive officer and principal consultant with Nikken Sekkei Research Institute in Tokyo. He has a PhD in engineering and is a registered building mechanical and electrical engineer. Nikken Sekkei Research Institute was founded in 2006 and is one of the companies in the Nikken Sekkei Group (1950), providing a large variety of city planning, design and redevelopment services (2,600 employees). Its award-winning urban services can be seen throughout Japan, Russia, Asia and the Middle East.