

## Development of new building systems using innovative structural materials Part2: Investigation of market trends and application model

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### Summary

In Japan, various value-set has been changing; the real estate is now viewed as the asset to use rather than to own and it is required to reduce the environmental load. Amid such mega social trend, the investment on new construction is less while the attention is given to the existing building stocks. Various approaches are taken to apply the existing legal framework and construction technologies to maintain and improve the functions of the existing stocks to the maximum extent.

This paper is to introduce “Buildings in New Structural System with Innovative Structural Materials” and its future visions, the model for urban infrastructure and architecture fitting to the sustainable society from the long-term perspective, which is in contrast to the ad-hoc approaches now taken as mentioned above. This model is the “Building in New Structural System” tapping the features of highly functional materials including the high-strength steel, aiming at the longer life span and the better maintainability in the higher level. Especially, the system design is free from damages to the plastic region even in case of mega earthquake (over 7 in JMA seismic intensity scale) enabling the partial replacement and reuse of members.

## 1. A Society Envisioned in New Building Systems

### 1.1 Trend towards a sustainable society

In Japan, buildings are generally considered to have a life span of 30 to 40 years. As a typical example, the regulations for calculating property tax set the depreciation period at 47 years for residential buildings and 50 years for commercial properties. It is projected that office buildings that are too aged to comply with the new quakeproof design will suffer a rapid surge in vacant room ratios in central parts of urban areas(See Table 1). The number of “Aged Apartments” that are 30 years old and older are expected to increase sharply in future. These residential houses cannot satisfy the current needs for dwelling. Prompt action is required (See Fig.1).

Table 1 results of vacant room ratio estimation for large office buildings  
in six wards in Central Tokyo by age

Building generation	ratio
Buildings compliant with the latest Law for Promotion of Seismic Retrofit (Completed in 1996 and later)	3.0%
Buildings compliant with the new quakeproof design (Completed in 1984-95)	5.0%
Old buildings non-compliant with the quakeproof design (Completed in 1983 and earlier)	10.0%

Solutions that are increasingly being adopted into these existing “building assets” include conversion and renovation. Conversion focuses on the potential of buildings to be used effectively for more appropriate purposes than conventional objectives. Renovation involves substantial expansion of the area and functions for continuing to make effective use.

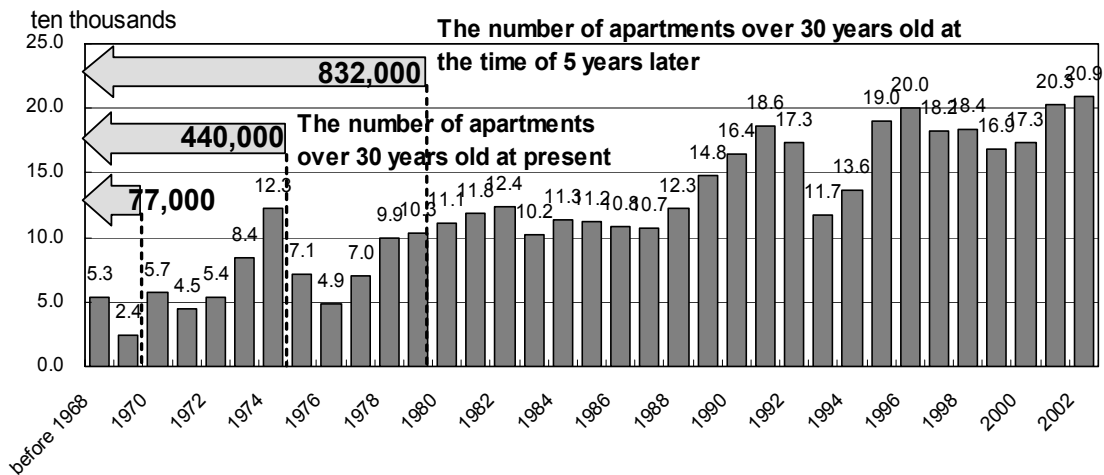


Figure 1 Trend in supply of housing units in apartment houses

These approaches are rather like stopgap measures for stock volumes with degraded competitiveness in the overall office or housing market. But when we conceive of a society that is sustainable for the future, there must be a need for a system that can lead the market in the long run and that ensures a continuous supply of facilities and spaces that have advanced functions and environmental features.

## 1.2 Position of architecture in new building systems

Densely-populated urban areas consist of central districts chaotically overcrowded with small residential houses and their surrounding areas that continuously sprawl outwards. Most such cities do not provide a safe and comfortable living environment and have unfavorable environmental impacts because of inefficient transport, energy consumption and thermal conditions. The concept of the "compact city," which suggests that efficiency should be improved by raising the height of buildings to a certain degree within the scope necessary to make more relaxed use land and to create green spaces elsewhere, will undoubtedly propose a solution to be followed by future cities.

Architecture in new building systems is structured to have multi-layer platforms, which are floors conceptually close to land. This structure may help make cities more three-dimensional and more compact and functions as an essential element of cities.

## 2. Outline of Architecture in New Building Systems and Model for Application

### 2.1 Basic requirements of architecture in new building systems

As discussed earlier, architecture in a new building system is built up by joining structural members made of innovative structural materials using mechanical joints. The building envisioned as the goal can withstand an earthquake with seismic intensity 7 within the range of elastic deformation. It is a mega-structure that constitutes a large-scale frame that is one-step up from individual buildings according to the existing concept. The "platform" is a universal system on which it is possible to build facilities for different purposes, including business, commercial and residential buildings, whether they are in the style of detached houses or apartment houses. It is a three-dimensional structure that does not merely provide structural support but is equipped with energy, water, sewerage, information and all other infrastructure. From the perspective of time, its durability far exceeds the time span of existing buildings.

Architecture in new building systems is a "framework of cities" as well as a building, and meets the following requirements.

#### (1) Variability

Changes in the social structure lead to changes in the style of the city and in what people want there. While lasting for a very long time as a framework, it must be flexible enough to be freely transformed by external impacts.

#### (2) Partial renewal and dismantling

For the purpose of successively introducing these new building systems into existing cities, blanket broad-area redevelopment in the scrap-and-build method is neither realistic nor efficient in terms of environmental impacts. It is necessary to use as many assets in the existing situation as possible and make gradual urban renewal as required to develop the cities. It requires a system that enables partial renewal and dismantling without allowing any part to be decisive to the whole.

### (3) Stability

Land is a natural object that is so stable that its properties do not suddenly change or vanish, and this stability is a significant element decisive to its social position. Providing the platform that takes over from the land, architecture in new building systems, as well as its infrastructure, must have very long-term stability and reliability. Physical stability is a key factor for lowering the risk involved in the very long-term project period, as discussed in a different section.

## 2.2 Application model – Renewal model in residential areas crowded with wooden buildings

This section examines a case study on the renewal model in residential areas crowded with wooden buildings with many problems peculiar to Japan as an example in which the proposed architecture in new building systems can be effectively applied.

### 2.2.1 Current situation and problems of residential areas crowded with wooden buildings

Many residential areas crowded with wooden buildings were intensively created during certain periods of several to a dozen years. Especially in Tokyo and other large cities, many of the areas that still remain as such were formed just after World War II or in the first half of the rapid economic growth period.

Overcrowded built-up areas are expected to suffer particularly huge damage in the event of a major earthquake. Throughout the country, such districts lie in Tokyo, Osaka and other large cities and add up to an approximate area of 25,000 hectares. The Ministry of Land, Infrastructure and Transport confirms that there were 400 such districts with an approximate total area of 8,000 hectares at the end of fiscal 2002 as involve an extremely high risk of fire spreading in the wake of an earthquake and as are likely to see fires escalating in different places at the same time. A majority of the areas lie in the prefectures of Tokyo and Osaka, with some 2,400 hectares each.

To identify the problems faced by these densely built-up zones, it is necessary to take into account the social aspects, such as stagnation of the communities, site fragmentation and difficulty in independent renewals. This section focuses on the disaster control problem, which is an issue concerning the performance of cities and buildings. Architecture in new building systems is expected to directly work it out.

The greatest challenge in terms of disaster prevention in residential areas crowded with wooden buildings is to improve the safety from earthquake disasters.

Given that many residential houses that stand in such zones are likely to collapse for structural reasons or as a result of aging degradation, the top priority is to ensure that these houses are resistant to tremors. Research conducted by Architectural Disaster Prevention Office of the Ministry of Land, Infrastructure and Transport in 2002 reached the following three conclusions, in which the anti-quake feature serves to enhance disaster prevention: (1) The percentage of non-collapsed residential houses that are damaged by fire is one-third that of collapsed houses, (2) A smaller number of casualties is expected to lead to fire extinguishing efforts by occupants at an initial stage, and (3) Non-collapsed houses obstruct no roads and so ensure smooth evacuation, fire extinguishing and rescue activities.\* (\* The investigative report on the Hyogoken Nambu Earthquake shows that collapsed houses blocked more than 50 percent of the roads with a width of four meters or less and no more than 15 percent of the roads with a width of six meters and more.)

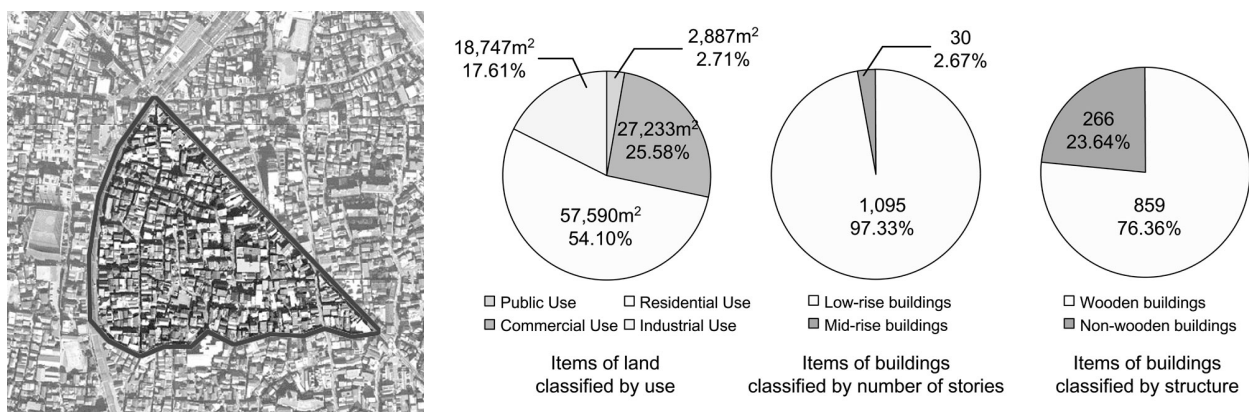


Figure 2 Air view of the sample district

Figure 3 Lot and building configuration in the sample district

### 2.2.2 Application model

The case study targets the district of Kanegafuchi in Sumida-ku, Tokyo, which is designated a priority district for improvement in the project to promote development of a disaster-resistant city carried out by the Tokyo Metropolitan Government. Figs. 2 and 3 portray the current state of the sample district.

The basic principle in the district layout planning is to define the belt along the main trunk roads, with advantages in transport and natural lighting, as an intensive land utilization zone that includes commercial tenants to improve the business feasibility in the entire district to be renewed. For the rest of the district, the layout plan envisions constructing an artificial ground to raise the overall ground level, rearranging narrow roads and reserving a sufficient outdoor space that is useful for forming the local community to create a human-scaled living environment. But given entangled ownership relations and geographical formation, it is considered difficult to implement the renewal in a blanket and integrated manner. Hence, expansion and renewal are to be implemented on as-needed basis in units of small sections. (See Fig.4)

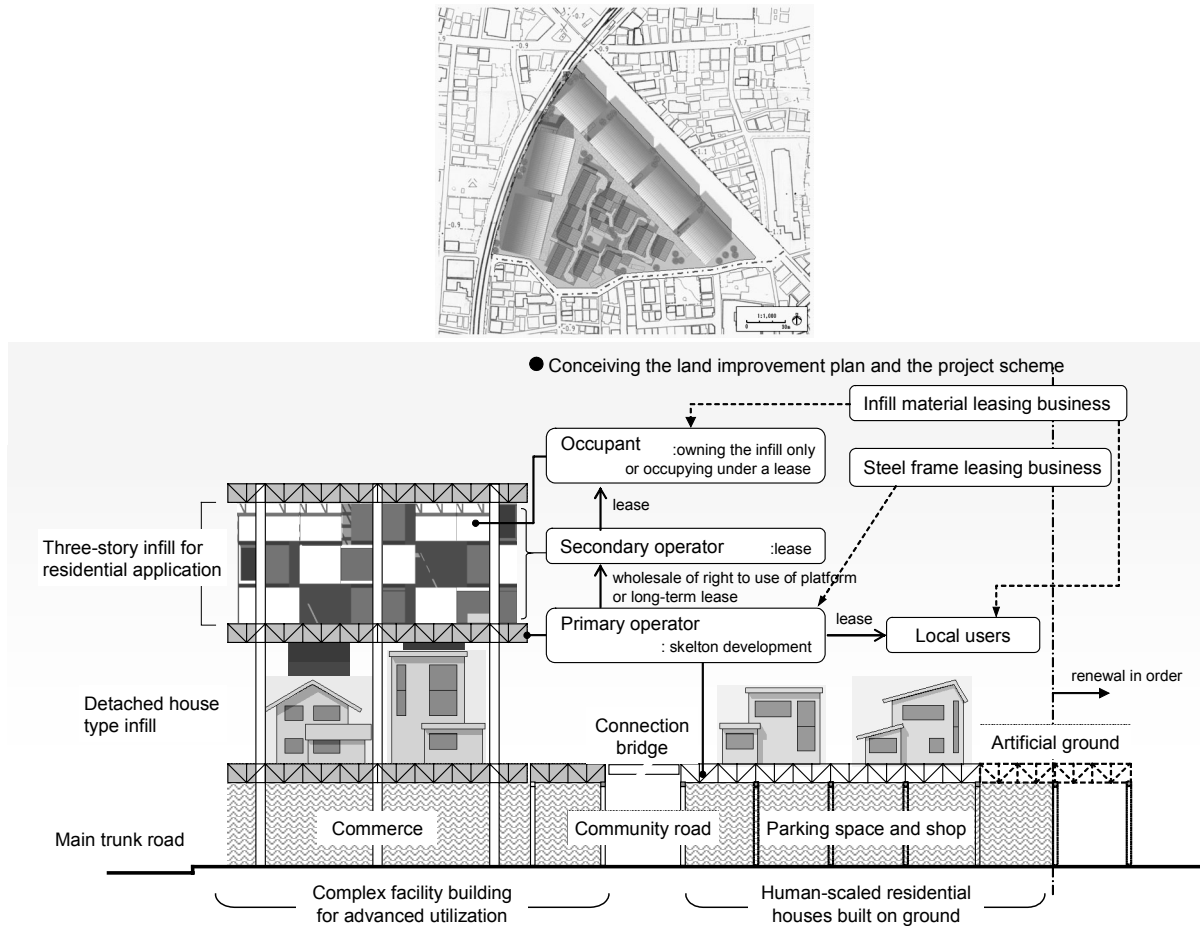


Figure 4 Outline of the renewal model (layout view / section view)

### 2.2.3 Conceiving the land improvement plan and the project scheme

Major obstacles to improvement projects for districts crowded with wooden residential buildings include the difficulty in achieve a consensus among local residents.

There are a number of possible reasons for the difficulty in achieving a consensus, including the hesitation of those living in detached houses to live in multi-dwelling buildings, the question of raising funds for reconstruction, concern about life and business during the rebuilding period and a lack of awareness of disaster prevention. It is unlikely that any consensus will be reached or that rebuilding will make any progress without any motivation to overcome the inhibition, such as a strong sense of crisis against possible disaster and financial assistance.

The new building systems proposed herein are characterized by flexibility in floor planning, addition and improvement, which is an alluring feature for residential buildings, as well as by technical approaches such as construction without evacuation, step-by-step improvement, retrofitting and partial renewal and adoption of leased materials. They are considered likely to be effective in eliminating the obstacles to advancement of the project.

## 3. Project model and related industries for architecture in new building systems

Large in scale and extremely long in duration, the project for architecture in new building systems necessitates the introduction of an unprecedented structure and concept regarding the investment in the main project and the costs to be borne by those who have the right to use it, as examined below in Section 3.1. It is also advisable to study supplementary businesses for ensuring the perpetuity of the main project

(Section 3.2) and other businesses created in the manner of using the architecture in new building systems itself or as a sub-product (Section 3.3) as well.

### 3.1 Construction project under new building systems for urban infrastructures

The project for architecture in new building systems is so large that relatively few operators are presumably able to participate in it at the initial stage. In the phase in which the systems are universally diffused, it is likely that many projects will introduce asset liquidation (development-type securitization) prior to development for fund raising in view of the necessity to spread the risk.

Urban infrastructure supported by the frame of the architecture in new building systems is of a highly public nature and have functions within the range of that which has been provided by the public sector. In Japan, many people perceive land and buildings as properties under private ownership, and Japanese society may not be willing to accept the style in which the cost of the frame is imposed on individual usufructuaries. It is not very practical and is indeed unfavorable in the sense of long-term maintenance of the entire project to sell the property in lots at a price to which the frame cost is added to transfer the ownership to sectional owners.

It is important to consider whether to define the ownership as belonging to the public domain or to the private domain during or after the project period. In either case, it is likely better to study an approach in which the project for the frame is separated and placed under a very long lease by a special purpose company in a private finance initiative (PFI).

### 3.2 Businesses supporting architecture in new building systems

Architecture in new building systems is by no means a natural object. It cannot be constructed and maintained as something that acts like the land without new businesses that support it and without a new response to existing related businesses. Table 3 is a list of businesses that are expected to be changed or newly created to support new building systems.

Among other things, the due diligence business and many different related research and evaluation businesses will inevitably grow. The construction risk of the main project is so high that highly accurate due diligence is indispensable to development-type securitization. For the purpose of building individual structures, more reliable evaluations will be needed given that it involves double or triple construction uncertainty that arises from purchasing the right to use the platform as a human-made structure and building another structure on it. Real estate dealers will have to carry on a new business concerned with circulation of rights to use.

The maintenance business to impede the physical degeneration of the human-made platform (disintegration or perishing) for an extraordinarily long period of time is likely to be of growing importance.

Table 3 Businesses that Support the Architecture in New Building Systems

Fields/Phase	Business Category	Business Contents/Change of Business
Evaluation/quality assurance	Performance evaluation organization	Performance evaluation/Evaluation of the eco-efficiency of architecture in new building systems and individual buildings (infill)
	Building component certification organization	Registration of building materials using the standardized codes/evaluation of soundness of the materials
	House inspectors	Inspections and evaluation of residences on a platform, primarily for individual purchasers
Control	Construction information control	Control of construction and historical information of architecture in new building systems
	Town Management	Three-dimensional control of efficient management of the whole town (Guidance of usage structure)
Circulation	Intermediary service	Circulation of second-hand residences (generate development profit from reselling of renovated residence)/circulation of rights to use
	Buyers agents	Collection of highly reliable information and advice to select the best property from the buyers' standpoint
	Sales and leasing of construction materials	Sales, purchase and leasing of the frame and infill materials

### 3.3 New businesses created by new building systems

A key factor to bolster motivation to invest in the construction of architecture in new building systems lies in the creation of appealing urban and living spaces on the platform as well as high profits. As seen from the relationship between infrastructure and content in the information business, attractive new services are a driving force for the entire industry.

Standing on a structurally robust platform, individual constructions enjoy enhanced structural freedom. It widens the gateway to the construction business and is likely to produce unprecedented space designs. It may also pave the way for a further advancement in the “proximity between home and workplace” and the “proximity between urban amenity and residence” and allow local residents to enjoy more sophisticated urban services in their daily lives.

Table 4 New businesses Created by New Building Systems

Fields/phase	Business Category	Business Contents/Change of Business
Construction	Infill specialty providers	Construction contract utilizing the environment and conditions on the platform
	Self-building support	Support for individuals who construct residence by utilizing the environment and conditions on the platform
	Multi-dwelling produce	Support for multi-dwelling building projects and reconstruction of multi-dwelling buildings on the platform initiated by purchasers
Aging society	Management of facilities for the elderly	Group home, general housing and care service-type housing for the elderly
	Provision of Reverse Mortgage	Provision of Reverse Mortgage that allow lifetime use or change of the residence for the elderly/ rationalization of final disposal of buildings and rights
Services	Life functioning outsourcing	Daily life services such as meals, cleaning, washing and childcare services/care services for the elderly/provision of the facilities such as libraries, public baths and accommodation
	Sharing	Car sharing/sharing of bicycles, equipment and space

### 3.4 Feasibility of industry and density

In the context of the consideration of three-dimensional cities, residential density is a major factor critical to the form of the architecture. Past initiatives to develop high-rise cities scrutinized in Japan were based on different awareness of problems and concerned with different project requirements significant to determination of the form. However, it should be noted that their envisioned residential density levels are eventually concentrated within a narrow range.

A good example is the “Tokyo Model” in a research project under the Research for the Future Program operated by the Japan Society for the Promotion of Science (JSPS), entitled “Development of a Sample High-Density Residential District with Reduced Environmental Impacts Adapted to a High-Temperature High-Humidity Climate.” In this model, a mega-structure made of steel materials has an abundance of empty spaces in which to install infill material. It sets the residential population density at 1,000 people per hectare (See Fig. 5).

For reference, a scheme for building a very elevated city with a height of 1,000 meters envisioned accommodating 132,500 people in the daytime and 35,000 people at night in a site with an approximate area of 100 hectares (See Fig. 6).

For architecture in new building systems aimed at achieving proximity between home and workplace and at reducing commuting distance, it will be sufficient to set the density as a basis for examining project viability and other factors at about “1,000 people per hectare” with limited fluctuations between the daytime population and the nighttime population.

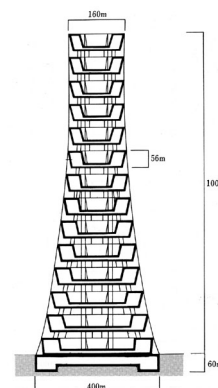


Figure 5 Development of a Sample High-Density Residential District with Reduced Environmental Impacts Adapted to a High-Temperature High-Humidity Climate

Figure 6 Plan of Vertical City ‘SKY CITY 1000’

## **4. Eco-efficiency of the architecture in new building systems**

### **4.1 Upgraded environmental quality and performance**

#### **(1) Proximity between residence and urban functions**

Even today, those who prefer living in the central part of a city tend to have diverse daily life functions served by conventional dwelling units in a compact size and to make active use of services such as laundry, house cleaning and child care services, and facilities (such as restaurants, libraries and relaxation spaces) outside their residence. As the population increasingly ages, different care services are likely to be in growing demand. Density at a certain level or higher generates this demand for services and creates a cycle in which it leads to an increase in services offering efficiency on the part of service providers, to improvement in business viability and then to an enhancement in the level of services provided.

All manner of people are more eager for urban amenities, including shopping and cultural entertainment facilities. Proximity between home and these functions means that they can enjoy them more often.

Ensuring that functions essential to lifestyle are shared to maintain the capacity to satisfy personal demand, the new building systems will serve to improve the quality of life of those living there.

#### **(2) Disaster prevention and safety**

If the conceived plan envisions forming a framework for the entire district with highly quake-proof frames and securing an adequate distance between buildings, it will serve to bolster the disaster prevention capacity and the safety of the entire district.

This does not merely enhance the safety of people and properties in the architecture in new building systems. It will also contribute to disaster control measures for the adjacent areas by setting a base for local disaster prevention inside a frame that boasts absolute safety.

#### **(3) Plantation for amenities**

There is often debate over the difficulty of creating green space closely linked with everyday life in the existing urban environment. Given that the architecture in new building systems enables green spaces to be installed freely on it and helps create greenery easily accessible to people, it is expected to upgrade the quality of the living environment.

### **4.2 Reduced environmental impact**

#### **(1) Reduction of materials introduced in construction and waste emission**

The architecture in new building systems designed to be free of damage after a major earthquake with seismic intensity 7 and to have 200-year durability is expected to require fewer materials committed to framework construction and to emit less waste than in the current situation where entire buildings are scrapped and rebuilt in a relatively short cycle, as described above. The difference is equivalent to the amount involved in a couple of projects.

Adopting fully-mechanized joints, the building could be upsized and downsized as needed. It is possible to further reduce material consumption by repeatedly diverting dismantled materials.

#### **(2) Reduction of operating energy consumption**

The shift from aged detached houses with poor thermal insulation efficiency to apartment houses with excellent thermal insulation capacity will result in reduced operating energy consumption. Moreover, a combination of residential with business and commercial facilities will help increase energy efficiency at the district level. It will entail effective use of surplus waste heat and level out energy consumption.

In addition, downsizing of the district will curtail the commuting distance to cut energy consumption for transport as well as gas emissions.

## **5. To make the scheme into reality**

### **5.1 Statutory coordination**

The existing legal system based on the conventional concept of land and buildings is inconsistent with and insufficient to realizing building systems based on an innovative notion of "land on an artificial object." Careful deliberation will be required for adapting the statute to them.

Major laws that likely need to be reviewed and points are listed in Table 4.

Particularly in terms of the Building Standard Law, the scope of architecture regarded as an entity is a key question. If the overall structure in new building systems is seen as an architectural unit, it is possible to regard it as "incomplete" for two hundred years. Under the existing legal system, it is possible to invoke the concept of partial completion, provisional use and application of the current regulations to old buildings at the time of renovation or expansion, but it is necessary to devise a new idea for evolving new building systems

into common building systems. In other words, it is important to establish a new style of building confirmation that ensures structural safety, fire safety and evacuation safety in a manner in which it is possible to separately treat individual sections and in which no problem with any one part affects the whole.

Table 4 Points Requiring Consideration in the Regulations

	Related regulations	Points Requiring Consideration
Regulations relating to buildings	Building Standard Law Fire Service Law	<ul style="list-style-type: none"> <li>• At which point in time is a building is considered to be “completed”</li> <li>• Whether to think that “a building is usable even when it is not entirely completed” or that “a completed building keeps evolving”</li> <li>• Whether to set “individual rules” that regulate secondary structures based on the design of the primary structures</li> </ul>
Regulations relating to real estates	Building Subdivision Act Leasing Act Act of Registration of Immovable Property	<ul style="list-style-type: none"> <li>• How to decide on the scope of the building to be registered (In case of primary structure = leased and secondary structure = in case of subdivided building, in particular)</li> <li>• How to handle the registry of exclusive and boundary shared buildings and buildings for undetermined purposes</li> </ul>

## 5.2 Incentive measures

As discussed above, the new building systems have an aspect of transferring the infrastructure functions from the public sector to the private sector or to individuals. And this project has a payback period that would be too long for an ordinary private project and involves great uncertainty.

While it is necessary to introduce private-sector activities in the form of PFI, it is advisable to consider additionally implementing incentive measures such as a certain level of deregulation and subsidies. Potential measures for study include not only conventional approaches such as an raise in the floor area ratio limit but also subsidization and tax relief in proportion to the achieved improvement in environmental performance and a system under which individuals can reap benefits commensurate with their cost burden.

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