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INTERDISCIPLINARY DISCUSSIONS ON SUSTAINABLE USE OF WOOD STRUCTURE AND FIRE RISK - SITUATIONS IN JAPAN AND AUSTRIA -

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ABSTRACT

Wood is globally expected to be used for construction material for urban buildings because of its low environmental impact. For sustainable use of wood, three aspects of sustainability – environment, society, and economy – should be fulfilled. Currently, wood is required strict legal restrictions due to fear of social fire risk increase, and individual building owners have to bear additional costs for the requirements.

Present building regulations deal with the worst fire scenario and require equivalent fire performance of wood to non-combustible materials. The probability of social fire risks and financial burden about the damage have not been discussed enough. That is one reason for strict legal restrictions on wood.

As legislative restrictions are decided by discussions among authorities of the area. Since each area has its traditional way of use on wood, the decisions tend to be influenced by their local "common sense". The probability of social risk and cost burden must be interdisciplinarily discussed to realize appropriate risk management for sustainable use of wood.

This paper deals with an international comparative study about legal and statistical tendencies concerning the responsibility of individual buildings about the use of wood in urban contexts.

INTRODUCTION

Wood is globally expected to be used for construction material for urban buildings because of its low environmental impact. For sustainable use of wood, three aspects of sustainability – environment, society, and economy – should be fulfilled. Currently, wood is required strict legal restrictions due to fear of social fire risk increase, and individual building owners have to bear additional costs for the requirements.

The overview of the complexity is illustrated in Figure 1, and each keyword in the figure are explained in the following sections.

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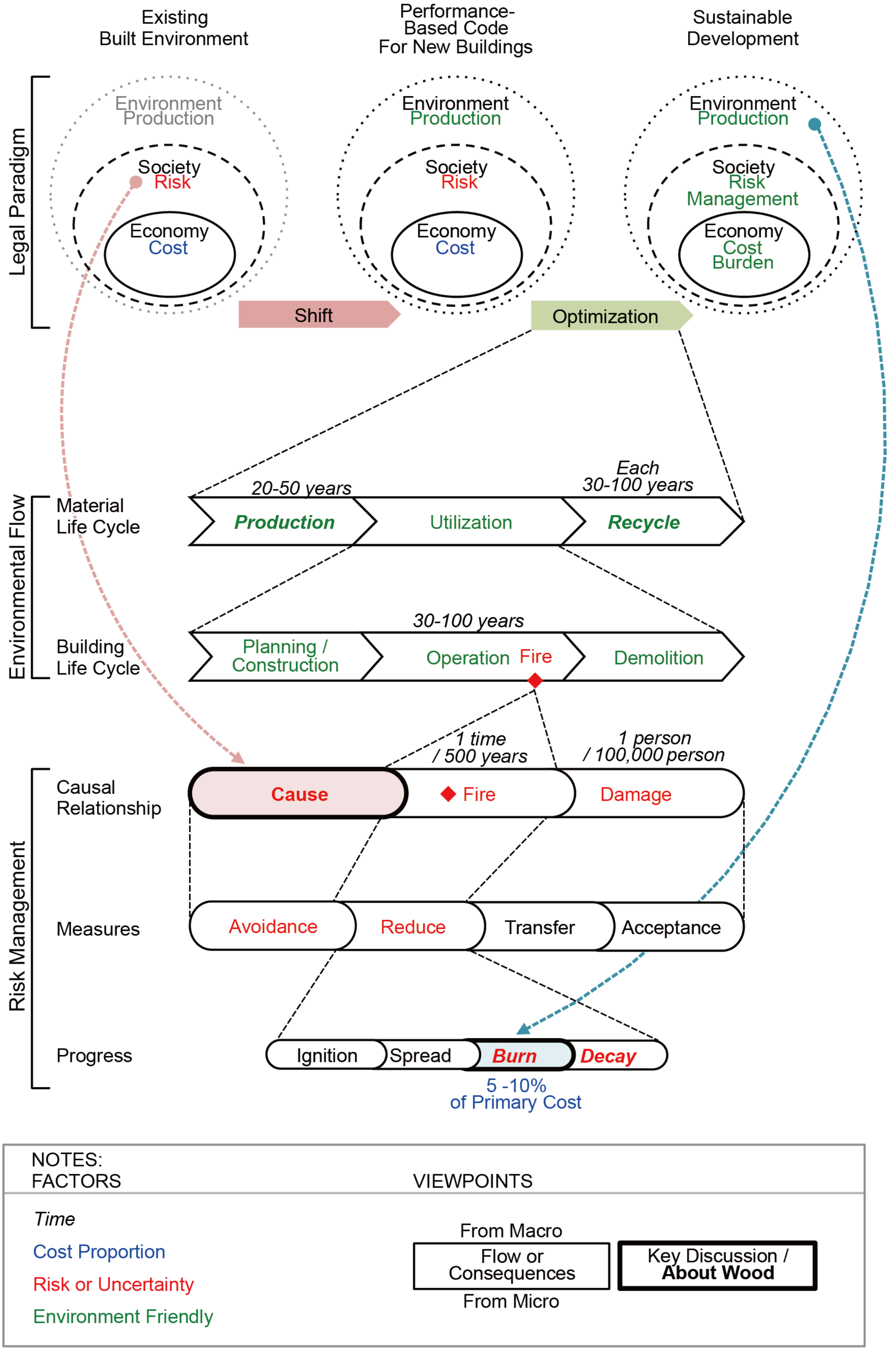


Figure 1: Sustainable Concept and Relative Issues

LEGAL PARADIGM SHIFT (FIGURE 1. UPEER)

Since the 1990s, building regulations have been shifted from prescriptive to performance-based codes. As legislative restrictions in national building regulations are decided by discussions among authorities of the area. Since each area has its traditional way of use on wood, the decisions on prescriptive regulations tended to be influenced by their local "common sense".

The Inter-jurisdictional Regulatory Collaboration Committee (IRCC) is consisted of 12 member countries, including Japan and Austria, and provides several documents about discussions on performance-based regulations. The key topics are: impact on material trade [Brassington, 2000], existing buildings by prescriptive regulation and new buildings by performance-based regulation [Bergeron, 2008], policy and experience in member countries [Meacham, 2010], sustainable system [Meacham, 2016], and socio-scientific aspect [Straalen, 2017].

In these documents, a confliction between environmental benefit and fire risk concerning the use of wood is pointed out that finding a suitable balance between sustainability and fire safety objectives can be particularly complex. Current paradigms of building regulations are optimized to non-combustible materials and the performance of fire-resistive wood-based structures is regulated as alternation of non-combustible materials.

Present building regulations deal with the worst fire scenario and require equivalent fire performance of wood to non-combustible materials. From the ecological viewpoint, wood is expected as sustainable material as it fixes CO2 while growing. As wood is combustible because of the carbon content in the material, it is recognized that social risk in its usage seems more serious than non-combustible material in the event of a fire. The scale of three sustainable aspects must be interdisciplinarily discussed to realize appropriate risk management for sustainable use of wood.

The overview of the conflict between environmental and social aspects of wood is illustrated in Figure 1. The red curved arrow on the left side of Figure 1 connects the cause of fires and the existing built environment. (See next section.) The blue curved arrow on the right side of Figure 1 connects environmental benefit and risk. (See the second next section.)

ENVIRONMENTAL FLOW (FIGURE 1. MIDDLE)

The combustibility of wood is recognized as a disadvantage of the material compared to non-combustible materials, such as steel or concrete. From the viewpoint of the material life cycle, advantages of wood are: the reproduction of material (25-50 years) can be controlled by manpower; scrap wood can be used for thermal recycle; it is biodegradable after landfill disposal. Non-combustible materials are burnt by fossil fuels during production processes, but wood can be fuel after its lifetime (30-100 years). Thus, it is not appropriate to compare materials only concerning combustibility.

From the viewpoint of building life cycle, the lightweight of wood can be beneficial for transportation with lower weight limit trucks, fast-clean construction, and reducing dead loads of buildings.

RISK MANAGEMENT (FIGURE 1. LOWER)

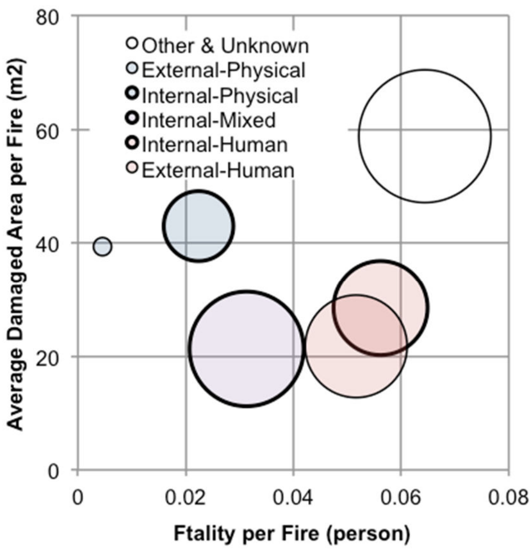
Fire regulation deals with technical issues about the reduction of damages about fire scenarios after the ignition of fire occasions among four countermeasures given in Figure 1. In this section, the frequency of fire and causal relationship of fire occasion are discussed.

In this paper, the causal relationships of fire factors are classified by place and type. (See Table 1.) Concerning the place of factor, internal factors (, which are related to the activity of users inside of buildings) are treated as responsible areas of buildings, and external factors should be discussed separately. About type of fire factor, human factor/damage separately from physical factor/damages of building fires. In this consequence: human factor/damage means issue related to human behavior and activities separate from shape/type of building; and that physical factor/damage means issue related to type/shape of buildings. Human damages should be reduced, and physical damages can be compensated for economical solutions.

From Japanese census fire statistics, the tendency of human/physical damages is analyzed by cause and building type/shape in Figure 2 and 3. Both X-axes indicate fatality rates per fire, and Y-axes indicate average damaged area per fire. Figure 2 shows that human factors of fire causes are related to fatality rate and physical factors are related to physical damages. Figure 3 shows that types of buildings (residential or non-residential) are related to fatality, and shapes of buildings (multi-story or open-space) are related to the damaged area.

Table 1: Factors of Fires

Factors		Concrete Cause	Characteristic
Place	Origin		
External (Outside of building)	Human	(Arson, war, etc.)	(Incident > other laws)
Internal (Inside of building)	Human	Tobacco, fire play, etc.	Incident by activity/habit
Internal (Inside of building)	Mixed	Heating- and cooking devices, etc.	Incident related to building equipment
Internal (Inside of building)	Physical	Electric- and Phone lines, etc.	Trouble related to things in building
External (Outside of building)	Physical	(Natural disasters, etc.)	(Accident > other laws)



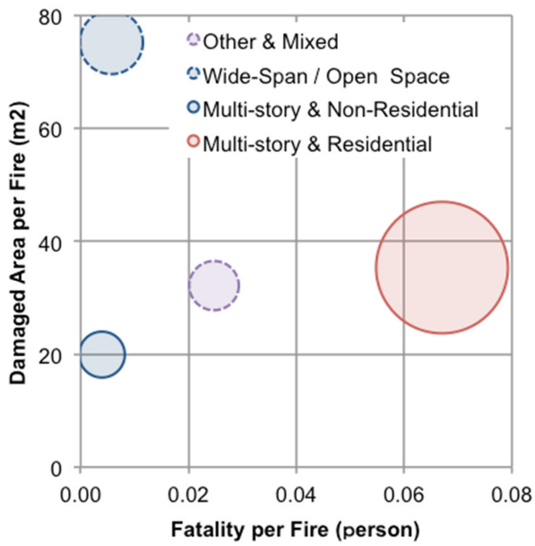


Figure 2: Average Fatality and Damaged Area per Fire by Cause (left)

Figure 3: Average Fatality and Damaged Area per Fire by Building Type/Shape (right)

Concerning the probability of damage on one building, incident rates of fire in averaged size office (ca. 1,500m^2) and housing (ca. 100m^2) are less than once per 500 years. In the case of earthquakes, these are classified by power and frequency of incident. An earthquake once per 500 years means rarely occurring during the lifespan of buildings. The fire fatality rate in one house is around one person per 100,000 years, and the fatality rate in one office is two digits less than in one house. The fatality rate from office fires is quite low compared to housing and can be negligible. The most critical discussion will be human-damages in housing. The two major causes of fire fatality in housings are tobacco and heating system. [TANI, 2015] [MLIT, 2010]

According to an analysis of tobacco fire (our human fire cause), structural material does not influence on fatality rate. [TANI, 2016] The average damaged area in wooden detached houses is wider than non-wooden housing due to the difference in building equipment. Building age of wooden houses are older tan non-wooden houses, and old houses with dangerous open fire heating system seem influence to the higher damage. [TANI, 2016]

SITUATION IN JAPAN AND AUSTRIA

Prescriptive to performance-based building regulation was enforced in 2000 in Japan and revised in 2015 and 2019. In Austria, enforcement of performance-based regulation was 2007 and was revised in 2011, 2015, and 2019. Requirements on fire resistance of wooden structural elements are similar in both regulations: it is tolerant of small or low-rise housings but strict to high-rise buildings. Even residential buildings are risky building types according to statistical tendency.

Both Japan and Austria invested a similar volume of budget to construction from 1980 to 2010, according to statistics on investment in construction works per Gross Domestic Production. [United Nations, 2012] In this period, 60% of Japanese and 20% of Austrian building stocks were newly constructed. [MLIT, 2010] [Statistik Austria , 2011] This means that Japan invested more for new constructions and Austria invested more for renovations of existing buildings. The penetration of the central heating system in Austria was 55% in 1981 and became 92% in 2011 [Statistik Austria, 2011], and in the same period, the Austrian fatality rate from burn becomes a half. [World Health Organization, 2016] Austrian investments for thermal conditions seem to reduce the probability of fire as a result.

CONCLUSIONS

This paper discussed on sustainable use of wood and fire risk related to wood-based structure. There is a key confliction between low environmental impact and social risk from the combustibility of wood.

According to statistical analysis on the frequency of fire occasion is quite low, e.g. less than 500 years in one average-sized building. About causal relation of fire risk: human damage (fatality) related to human activity; use of wood does not seem to increase; physical damage of fire seems to be related to the shape of building and type of building equipment.

Wood-base structures will be recycled as fuel for biomass energy after the lifespan. If we simply compare numbers, wood-based structures are used as fuels around 5-10 times more frequent than resist fire. Only from the viewpoint of ecological use of wood, combustible structural elements are reasonable.

If we intend to use wood as fuel, it is better to avoid some methods: inseparable combination with other non-combustible materials; or inflammable chemical treatment. It is possible to control the combustibility of wood by engineering effort. However, since current regulations require excessive performance on wood, and it increases costs substantially to fulfill the requirements.

In Austria, high thermal insulation and low energy consumption buildings are popular. The penetration of housing central heating seems the key reason for the reduction of the fire fatality rate. Sometimes, high thermal performance reduces fire resistance. If we intend to reduce the root of fire, it is better to give priority to thermal performance.

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