

Study on Measures for Mitigating the Risk of Residential Fires and Fire Fatalities

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Abstract

In this paper, we have carried out an analysis of the trends in residential fires and the incidences of fatalities in fires in Japan using fire data from 1995 to 2001, and we have made a comparison of past and present trends in the incidence of fire fatalities. Applied to a statistical-analysis, we also examined the effectiveness of residential fire prevention measures through the use of fire extinguishers and fire alarm system.

1. Introduction

Every year in Japan, over 900 people lose their lives in residential fires accounting for approximately 90% of all fatalities in building fires. In addition, as is the case^[1] in the U.S.A. and the U.K., the fire death rates for the elderly population in Japan (per 100,000 population) are very high specially among the groups over 75 yrs in comparison to other age groups (**Figure 1**)^[2]. Also, our country is an aged society with the elderly over 65 yrs accounting for 18% of the total population. Furthermore, with the impact

of increasing life expectancy and a decreasing birth rate, our aging society is expected to progress further, with estimates that by 2015 more than one in four citizens will be aged over 65. Our aging rate is at a significantly higher level than the world average, and indeed higher when compared to other countries (**Figure2**)^[3]. Amidst all of this, there is a strong concern that there will be an increase in residential fire fatalities, and in particular an increase in the risk of residential fires involving the elderly. Thus, in regard to the objective to lower the number of fire deaths, saving vulnerable people such as the elderly from residential fires is becoming a most important issue in fire prevention.

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2. Purpose and Method of the Study

In this study, first we quantitatively analyze how much risk the vulnerable people such as the elderly have in regard to residential fires. On the basis of these analyses, we then examine the availability of various measures that would reduce residential fire fatalities in the high-risk groups. For this purpose, two main kinds of data were used in the analysis. The one is the national database of fire incident reports and fire fatality reports collected by the National Fire and Disaster Management Agency, the Ministry of General Affairs. The other is the census data of population parameters, which gives a detailed breakdown of population by age group, households by number of family members, dwellings by type of structure, and so forth.

Our research framework is shown in **Figure3**. In terms of measures to prevent residential fires, we believe it is necessary to analyze and clarify the relationship between three aspects: (1) Fire outbreak and subsequent escalation, (2) The causes of fire fatalities, and (3) Condition of the residence and family makeup where the fire occurred. In regards to number (1), the escalation or development of the fire, we can basically establish the features of the fire in terms of the source of the fire, the place where the fire began, the time of outbreak, items that caught fire, and the ultimate casualties. Number (2), the causes of fire fatalities, is an aspect which will establish the direct and indirect causes of death, including the age and physical condition of the deceased, physical relationship to the fire at outbreak, and physical state at outbreak (e.g. sleeping or in a heavily drunken state). Number (3), condition of the residence and family makeup, is an aspect which will give background to the outbreak of fire and the

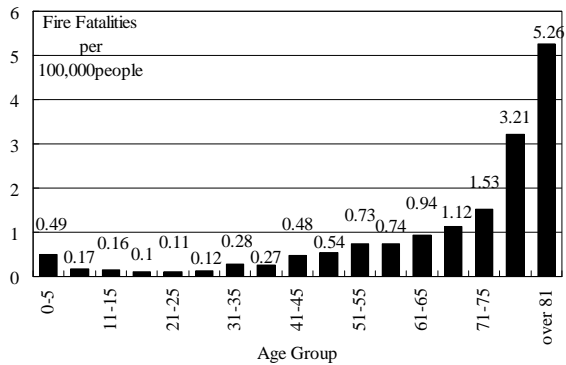


Figure 1. Residential fire death rate per 100,000 people by age group^[2].

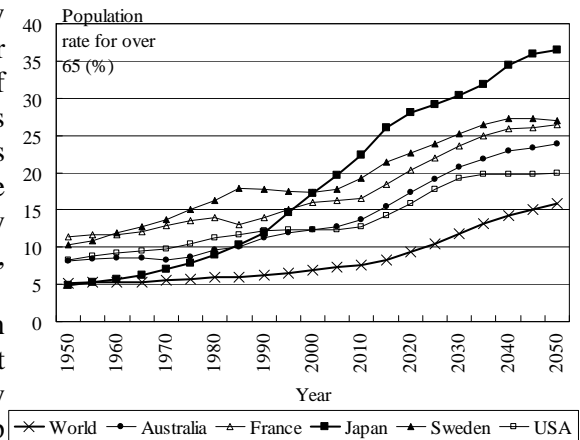


Figure 2. Population rate for over 65 by countries^[3].

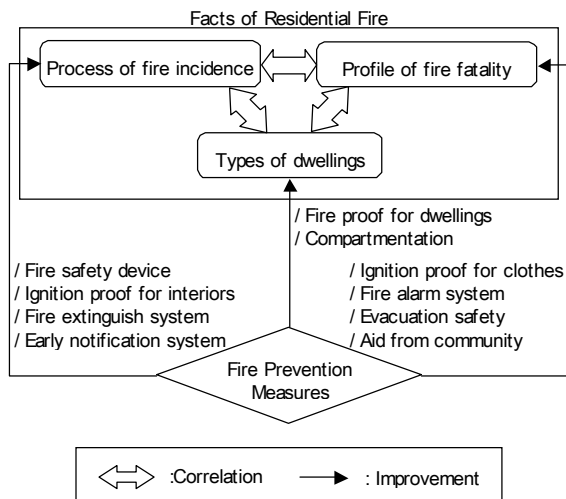


Figure 3. Framework of this study.

incidence of fatalities, including the type of dwelling (house or apartment), construction, age of the dwelling and household size. In light of this, we initially analyze the recent trends of the types of dwellings that vulnerable people are living in as well as any problem areas by analyzing housing survey data. In the meantime, there is the possibility that residential fire and fire fatality trends are changing in comparison to the past, due to changes in number of households, aging of residents, replacement of cooking appliances and heating equipment, and renovations. We will also analyze and examine this secular change.

Following this, by processing the data of fatal fires together with housing statistics, we can carry out an analysis of the fatal fire incidence by dwelling types, and then based on these results we can examine the effectiveness of residential fire protection measures in reducing fire deaths.

3. Results and Discussion

3.1 The trends in residential fire incidence and fatalities due to fires

In this section, we will analyze and examine the characteristics of the trends in residential fire incidence and fatalities due to fires in Japan, using seven years of fire data from 1995 to 2001. **Table 1-1** shows the breakdown of the fire data used in our analysis. Using data regarding total dwelling numbers and total inhabitants, we will calculate the rate of fire incidence and the fatality rate due to fires, and then make an analytical comparison according to dwelling type. We will use the results of the 1998 housing survey as the numerical value that will become our population parameter. A breakdown of the data is shown in **Table 1-2**.

Table 1-1. Breakdown of residential fire data 1995-2001^{**1}

Dwelling Type	Structure	Number of Fire Incidence	Number of Fire Fatalities			
			Under 14	15-64	Over 65	Total
Single	Wodden	74,557	267	1,596	2,938	4,801
	Fire-resistive	6,396	34	100	146	280
Apt.	Wodden	8,532	28	322	216	566
	Fire-resistive	17,016	93	309	201	603
Total		106,501	422	2,327	3,501	6,250

Table 1-2. Breakdown of residential census data 1995^{**1}

Dwelling Type	Structure	Number of Dwellings (10,000)	household membership (10,000 people)			
			Under 14	15-64	Over 65	Total
Single	Wodden	2,493	1,078	5,204	1,594	7,876
	Fire-resistive	217	117	483	106	705
Apt.	Wodden	324	65	385	43	494
	Fire-resistive	1,336	551	2,105	175	2,831
Total		4,370	1,811	8,177	1,918	11,906

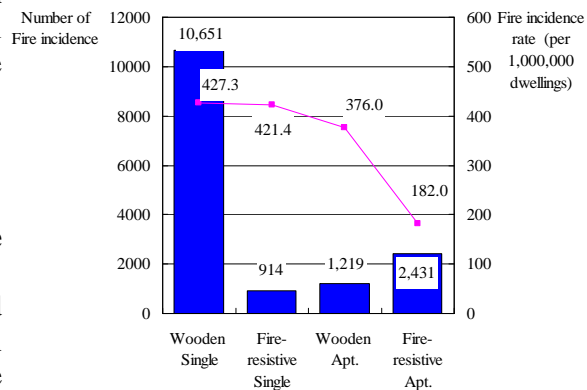


Figure 4. Number of fire incidence and fire incidence rate by type of dwelling^{**1, **2}.

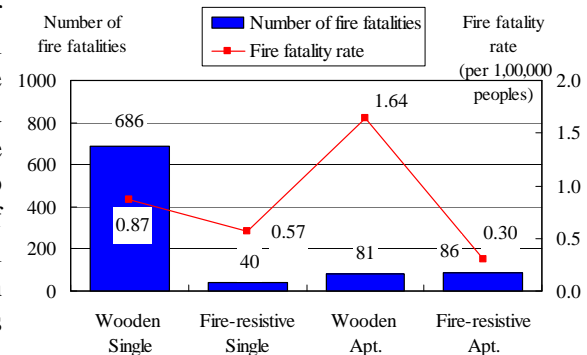


Figure 5. Number of Fire fatalities and Fire fatality rate by type of dwelling^{**1, **2}.

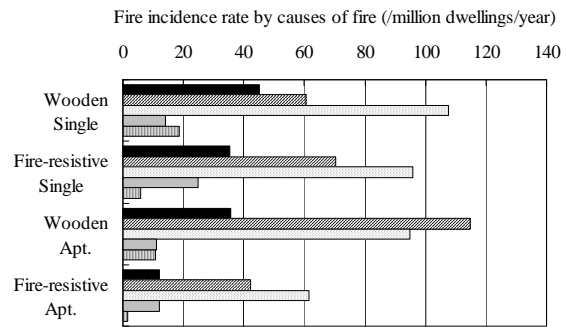
(1) Trends in fire incidence and fatalities due to fires according to dwelling type

As shown in **Figure 4**, for the average number of fires in one year (the bar graph) wooden houses account for approximately 70% of these fires, an extremely high amount. Meanwhile, if you look at the rate of fires (the line graph), the figure for fire-resistive apartments stands out as being very small – under half the rate of other dwelling types.

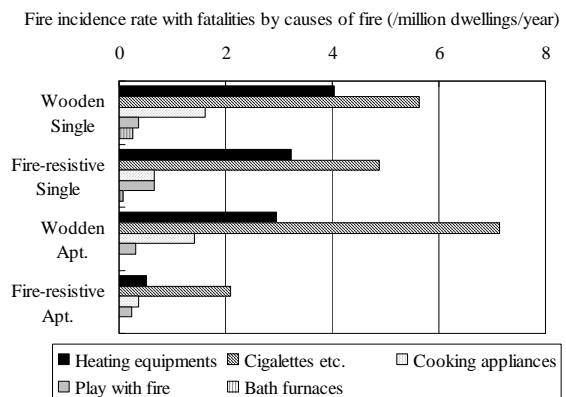
Next, if we look at fatalities due to fires according to dwelling type, as shown in **Figure 5**, the number of fatalities in wooden houses (the bar graph) is 686 persons. This number is the highest, accounting for approximately 77% of all fatalities. Looking at the rate of fatalities (the line graph), the figure for wooden apartments is extremely high, at 1.64 (persons per 100,000 per year). This rate is approximately double the rate of wooden houses.

If you look at both the total number of fires and number of fatalities as the number of incidence, the high incidence for wooden houses stands out, but if you look at the rate of fires and fatality rate in regard to the parameters, you begin to see characteristics that cannot be seen just by looking at the fire data, i.e. the low figures for fire-resistive apartments and the high fatality rate in wooden apartments. Fires and fatalities due to fires in wooden apartments do not quite reach 10% of the total, but by carrying out preventative measures in these kinds of dwellings, we can reduce the gap of fire incidence and fire fatality rates which exists between different dwelling types, which we believe is one of the most important objectives of residential fire prevention. In addition, the results in **Figure 5** indicate the possibility that we can further reduce fire fatalities by doing this.

To compare with the fire-resistive apartment, wooden apartment has quite



(1) All fire incidences



(2) Fires with fatalities

Figure 6. Fire incidence rate by dwelling type and major causes of fire^{**1}.

high fire incidence rate and also high fatal fire incident rate. There seems to be two reasons for this higher incidence of fires and fatal fires in wooden apartments. One is a higher potential of fire spread between units of dwelling because of weak fire separation. The other is that there are likely to be more single households in the wooden apartments, and so the delay in recognizing fire is easy to occur. On the other hand, the reason for the low incidence of fires and fires with fatalities in fire-resistive apartments is naturally its lower risk of fire spread. But, there is also another important reason such that fire-resistive apartments are relatively newer than wooden dwellings in Japan. This must be relating to new and safer devices for daily life used in fire-resistive

apartments, such as heating equipments and cooking appliances etc.

Figure6 is a graph showing the various causes of fire according to dwelling type. Looking at all fires, in most dwelling types cooking appliances make up the highest proportion (excluding unknown and other), followed by cigarettes, matches, lighters (hereafter referred to as Cigarettes etc.). However, in wooden apartments, “Cigarettes etc.” is higher than “Cooking appliances”. Meanwhile, if you look at the figures for the cause of fires with fatalities, it is notable that large numbers of fires were caused by “Cigarettes etc.” or “Heating equipment”, while fires caused by the use of cooking appliances is rather low. It could be said that fires caused by the use of cooking appliances do not usually lead to fatalities due to quick detection, appropriate countermeasures and plenty of time to escape. Thus, it is necessary to focus on the causes of fire where detection is delayed, which is one factor which can lead to the incidence of a fatal fire. At the same time, there is also a necessity to consider countermeasures in regard to the causes of fires where fatality rates were high according to dwelling type, such as fires caused by “Heating equipment” in wooden houses, and fires causes by “Cigarettes etc.” in wooden apartments. In terms of fatal fires, one reason for the high proportion of these fires caused by heating equipment in wooden houses is that older-style heating equipment such as kerosene heaters are still in use due to the age of these dwellings.

As shown in **Figure 7**, the most common sources of fire differ according to age. Compared with other age groups, the most common sources of fire are, in the group under 14 yrs, “Playing with fire”; in the group from 15 to 64 yrs, “Cigarettes etc.”, and in the group over 65 yrs, “Heating equipment”. Incidence rates

also differ according to age group even in fires with the same cause, and it is not uncommon to see such evidence as the risk of fatality being five times as much in the group over 65 yrs than the group under 65 yrs.

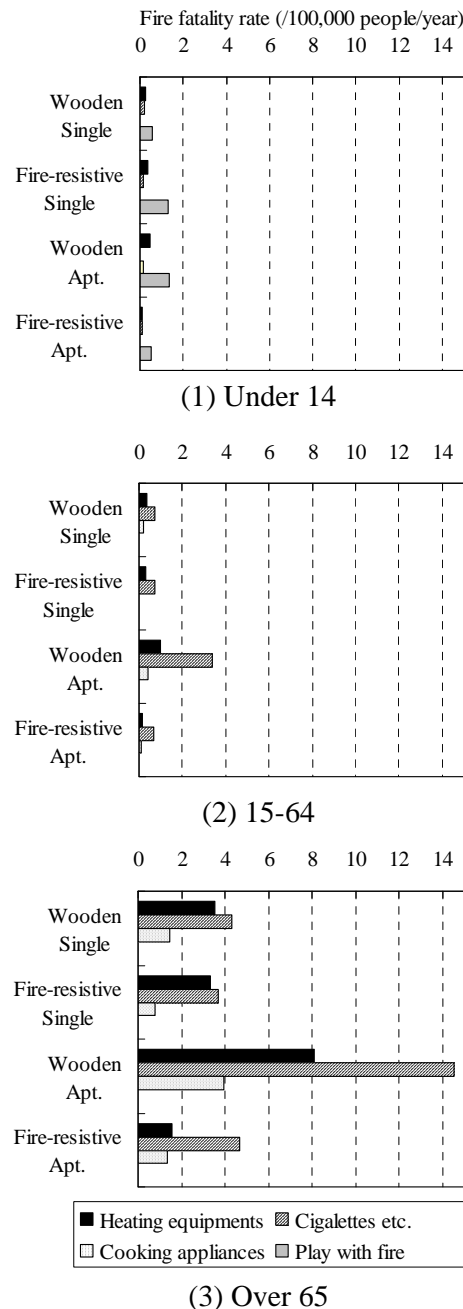


Figure 7. Fire fatality rate according to major causes of fire by age group and dwelling type**1.

It is thought that because those in the group over 65 yrs have a lower physical ability compared with the younger groups, even if the cause of the fire is the same, it is more likely that they will not be able to take the appropriate countermeasures, thus leading to death.

It was shown in **Figure 5** that the fire fatality rate in wooden apartments was higher than other dwelling types; and then in **Figure 7**, which additionally separates wooden apartment fatalities into age groups and causes of fires, it is again possible to see that this fatality rate is higher than other dwelling types in not just the older age groups but also in the group under 64 yrs. Because it is obvious that the influence of dwelling type is stronger than age, it can be said that in wooden apartments, it would be more effective to carry out fire prevention measures focusing on the actual dwelling rather than the age of the residents.

(2) Trends of the causes of fire death according to physical condition

Figure 8 shows the breakdown by causes of fire death for different fatality groups that are divided into by their physical conditions at a fire. In the categories of “Under 5yrs” and “Bedridden”, more than 50 to 80% of total causes of fire death fall into “Incapability of evacuation by oneself”. The sum ratio of “delay of detection” and “delay of evacuation” becomes larger as the group of physical condition of fatalities is shifting from harder physical conditions such as “Under 5yrs” and “Bedridden” to less hard conditions as “Normal in condition”. In the groups of “Disabled” and “Over 65yrs”, the cause of “Ignition on apparel” occupies 15 to 18% of the causes of fire death. These results demonstrate that appropriate fire protection measures should be considered according to the features of different types of high-risk groups.

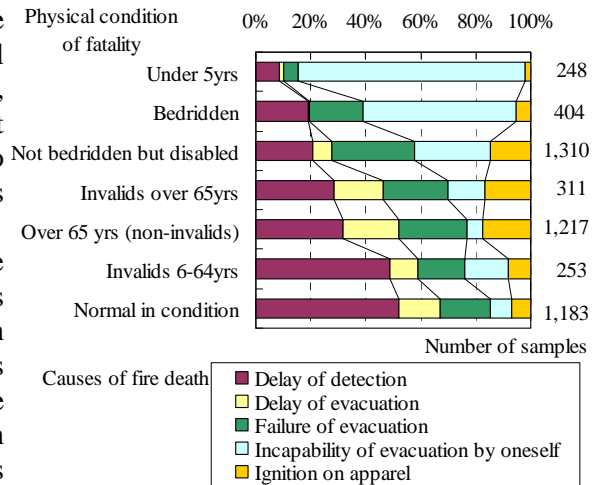


Figure 8. Causes of fire death by type of physical condition ^{**3}.

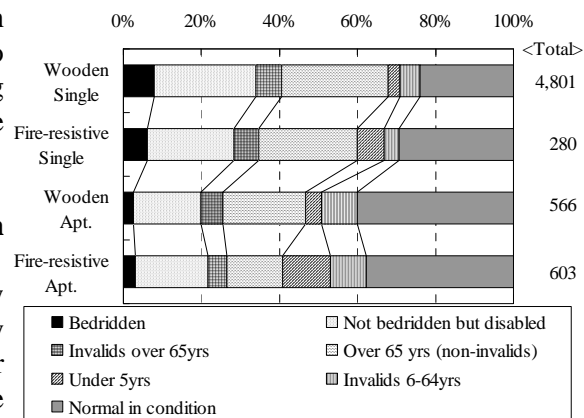


Figure 9. Breakdown of fire fatalities by dwelling type and physical conditions ^{**1}.

As shown in **Figure 9**, when looking at fire fatalities according to dwelling type, there was a higher proportion of elderly, disabled and bedridden in houses than in apartments. When considering fire prevention measures for houses in particular, it is necessary to have measures in place that will cater for these kinds of people. At the same time as having measures to prevent ignition of clothing and the actual fire from starting, it is also very important to have a support system in place, so that if a fire does break out,

family, neighbors, and firefighters can be notified promptly, an evacuation made, and the fire extinguished as quickly as possible.

3.2 Secular changes in the trends of fire fatalities

In this section, we will establish the characteristic trends in residential fire fatalities in recent years by comparing the analytical results of fire data from approx. 15 years ago, with the analytical results of data from the present day.

The data to be analyzed is the residential fire fatality data (nationwide) for the five years from 1997 to 2001, (hereafter referred to as “1999 data”, being the midpoint of the period) and the data from 1983 to 1987 (hereafter referred to as “1985 data”, being the midpoint of the period). The data to be used will be taken from all building fire fatalities, but with the place of the fire limited to residences (houses, apartments and multipurpose houses) where the fire was not caused by arson or suspected arson. The 1999 data includes 4,749 people, and the 1985 data includes 3629 people.

As shown in **Figure 10**, the proportion of heating equipment as a cause of fatal fires was 30.1% compared to 35.1% approx. 15 years ago, a significant decrease. As can be seen in the change in popularity of heating equipment shown in **Figure 11**, it is also thought that improved fire prevention has been achieved through the growing popularity of heating equipment such as heating/cooling air conditioners which are not likely to cause fire, as well as safety device fitted equipment, for example to prevent overheating.

Figure 12 shows fatalities due to fires divided into age groups of 10 years each, comparing the numbers of fatalities in the 1999 data with the fatalities in the 1985 data. There are more fatalities in the older age groups, and fatalities in the

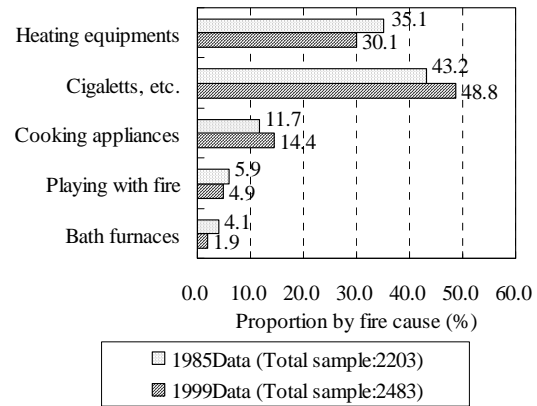


Figure 10. Comparison of causes of fire with fatalities^{**3}.

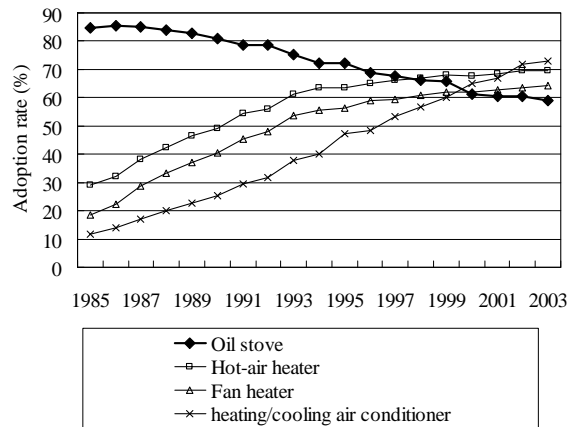


Figure 11. Trends of adoption rate for main heating equipments^[6].

groups over 60 yrs make up 63.2% of the whole. The proportion of fatalities in the groups over 60 yrs was higher in the 1999 data when compared with 53.0% in the 1985 data.

As shown in **Figure 13**, if you compare the numbers of fatalities per 100,000 persons (hereafter referred to as fatality rate per population) according to age, the fatality rate per population in the elderly is on the decrease. Note that the data in **Figure 13** was calculated by taking the average number of fatalities per year from the 1985 data and the 1999 data and dividing it by the population by age group (per 100,000 persons) from the respective National Censuses of 1985 and 2000. In

Figure 12, fire fatalities in the elderly seem to be increasing, whereas **Figure 13** shows that the fatality rate per population in the elderly is actually decreasing.

Figure 14 shows a comparison between the 1999 data and 1985 data of physical abilities according to seven types. Note that in this diagram, “infant” means children from 0-5 years old, and “elderly” means those over 65 years of age. It is notable that there is a marked decrease in the deceased who were bedridden in the 1999 data when compared to the 1985 data. This trend correlates with the decrease in the fatality rate per population in the elderly as shown in **Figure 13**.

The reasons for these results are thought to be improvements in living conditions, such as good housing and care for the elderly, improvements in the physical condition of elderly and a relative increase of those who are in good health; but there is still a necessity for more detailed analysis. In any case, these results hold a positive outlook for the future in view of the fact that our aging society does not necessarily mean that there will be a large increase in fire fatalities.

3.3 The effectiveness of fire protection equipment for residences to reduce fire fatalities

This section will investigate the popularity of fire protection equipment for the home such as fire alarm system and fire extinguishers, based on the residential fire data from 1995-2001, as well as presenting the results of the statistical analysis of the effectiveness of fire protection equipment to mitigate the risk of fire fatalities and casualties of fires in residential fires.

As shown in **Table 2-1**, the rate of fire extinguisher installation in all dwellings where there were fires was 21.8%, and fire extinguishers were actually used in approximately half of these cases (10.6%). However, if we separate this information

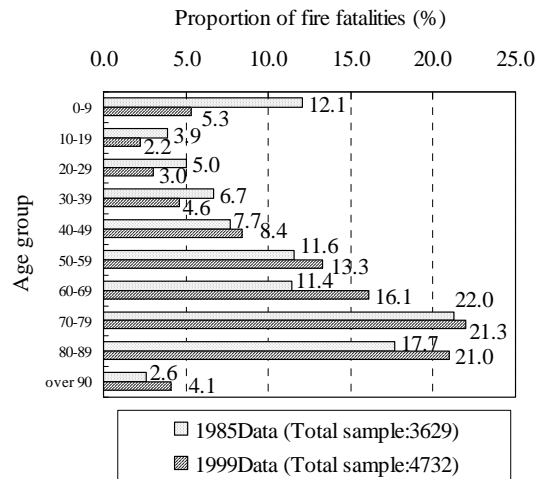


Figure 12. Comparison of age composition of fire fatalities.

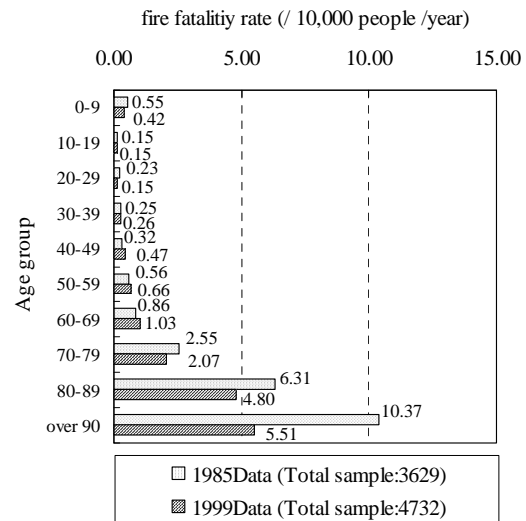


Figure 13. Comparison of fire fatality rate by age group.

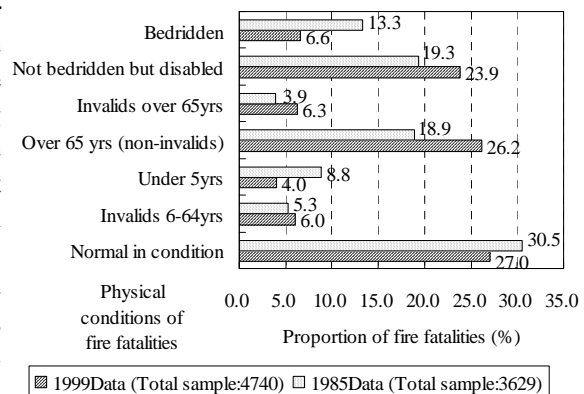


Figure 14. Comparison of proportion for physical condition of fire fatalities.

into dwelling type, significant differences can be seen. For example, in wooden houses, the installation rate is 7.8% (used in 4.6% of cases), which is very low, but in wooden apartments the installation rate is 49.5% (used in 21.3% of cases), which means about half of this dwelling type install fire extinguishers. In addition, the installation and activation rates in fire-resistive apartments are 64.2% and 28.7% respectively, which is approximately 30% higher than the rate for wooden apartments.

As is shown in the following table, **Table 2-2**, the installation rate of fire alarm systems in all dwellings where there were fires is about 1/3 of fire extinguishers at 7.2%, being activated in 4.1% of cases, which is, like the use of fire extinguishers, at about half. Again, the installation and activation rates of fire alarm systems in dwellings where there were fires differs greatly by dwelling type, in common with the fire extinguisher data. As an example, in wooden houses, the installation rate is very low at 0.7% (used in 0.1% of cases); while in fire-resistive apartments, the installation rate is comparatively high at 34.2% (used in 19.8% of cases). The installation and activation rates in wooden apartments are at about 1/3 of the rate of fire-resistive apartments.

If we look at the impact of the use of fire extinguishers on the fatal fire incidence rate in all dwellings, as shown in **Figure 15**, the rate is 5.9% for dwellings without fire extinguishers, versus 2.5% in dwellings with fire extinguishers installed and used; a fatal fire incidence rate of 0.43 times less. However, if we look at the type of dwellings where fires started, in other words, separated into wooden houses, wooden apartments and fire-resistive apartments; for fire-resistive apartments, a big difference cannot be seen in the fatal fire incidence rate in all three situations of installation and use of fire extinguishers. It is thought that in the case of fire-

resistive apartments this is due to the fire-resistive construction – the actual structure which reduces escalation of the fire, and thus contributing to a low fatality rate. Meanwhile, in wooden houses where fire extinguishers were installed and used, the fatal fire incidence rate is 0.28 times less than houses without fire extinguishers, so fire prevention as a result of having fire extinguishers can be said to contribute significantly to mitigate the risk of fire fatalities.

Table 2-1. Installation / usage rate of fire extinguisher in residential fires (%) **1.

	Wooden Single	Wooden Apt.	Fire-resistive Apt.	Average of All dwellings
Not Installed	92.2	50.5	35.8	78.2
Installed but not used	7.8	49.5	64.2	21.8
Installed and used	4.6	21.3	28.7	10.6

*Residential fire data 1995-2001 in Japan. Total sample: 99,502(excluding incendiary fire).

Table 2-2. Installation / activation rate of fire alarm system in residential fires (%) **1.

	Wooden Single	Wooden Apt.	Fire-resistive Apt.	Average of All dwellings
Not installed	99.3	88.6	65.8	92.8
Installed but not activated	0.7	11.4	34.2	7.2
Installed and Activated	0.1	7.6	19.8	4.1

*Residential fire data 1995-2001 in Japan. Total sample: 99,502(excluding incendiary fire).

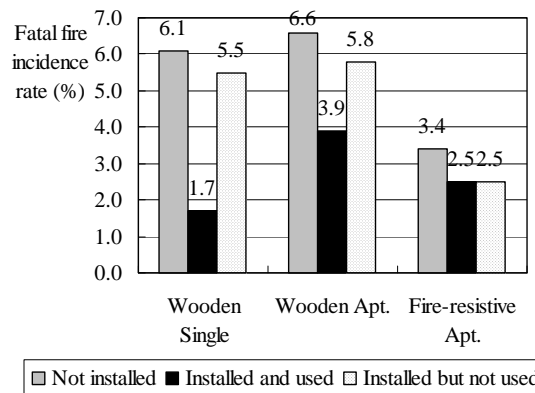


Figure 15. Fatal fire incidence rate according to installation/usage of fire extinguisher **1.

Among residential fire protection measures, fire alarm system is one of most popular equipment. Therefore, we examined the efficiency of fire alarm system on reducing the risk of fatal fire incidence by taking the factors of dwelling types and fire causes into consideration. As an example, **Figure 16** shows fatal fire incident rates by dwelling type and by conditions of installation/activation of fire alarm system at a fire. For fire-resistive apartments, in which the installation rate of fire alarms is the highest among the all dwelling types, the fatal fire incidence rate is 1.9% when fire alarm system was installed and activated at a fire, while the fatal fire incidence rate is 3.3% when fire alarm system was not installed. Thus, the reducing ratio of fatal fire incidence by fire alarm system for fire-resistive apartments can be estimated as 41% decrease to compare with the rate of homes with no presence of fire alarms. This decrease ratio of 41% is very close to 46% that is introduced as the reducing ratio of fatal fire incidence by fire alarm system in the U.S.A. [7], where the number of residential fire deaths has been declining drastically during these two decades due to the popularization of residential smoke detectors. Through the evidence of actual fire incidence data in Japan, we can also recognize the significance of promoting the universal installation of residential fire alarms for the purpose of reducing residential fire deaths as has been done in the U.S.A.

Figure 17 shows the results of an investigation of how the fatal fire incidence rate changes according to the installation and activation of fire alarm systems looking at the main causes of fires in apartments where fire alarm systems are quite common (including wooden and fire-resistive). In the case where matches/lighters and heaters were the cause, the fatal fire incidence rate was

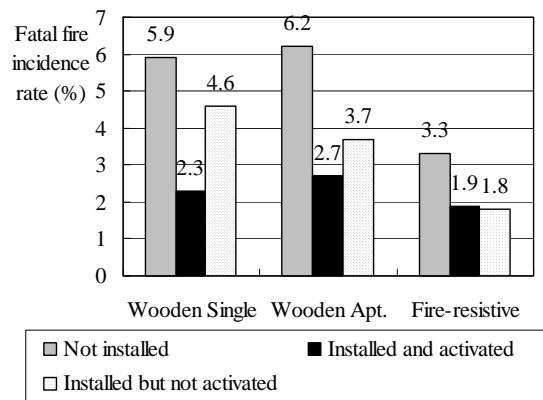
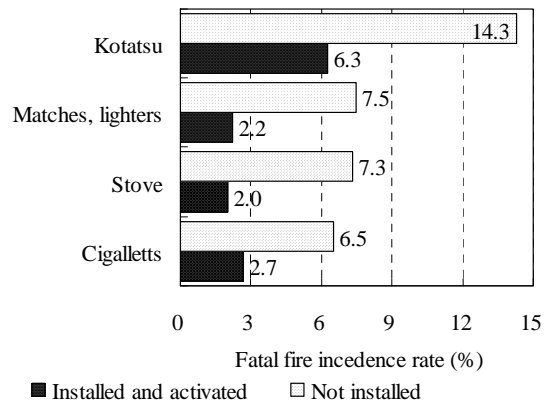
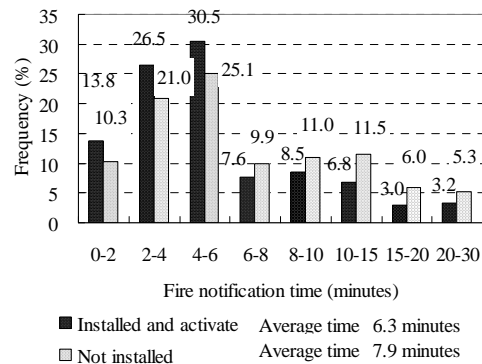


Figure 16. Fatal fire incidence rate according to installation/activation of fire alarm system^{**1}.



*Data: 1995-2001 residential fires in wooden and fire-resistive apartments.

Figure 17. Fatal fire incidence rate according to major causes of fire by installation/activation of fire alarm system.

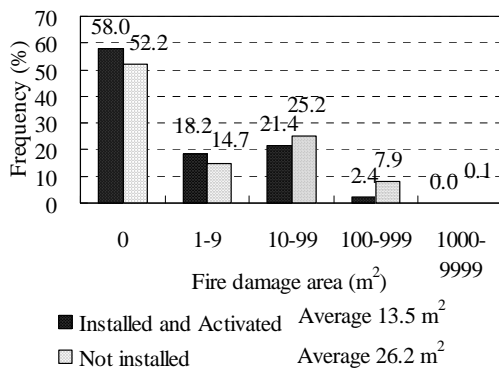


*Data: 1995-2001 residential fires that fire notification time is less than 30 minutes.

Figure 18. Histogram of fire notification time according to activation of fire alarm system.

approx. 0.3 times less when fire alarm systems were installed and activated than in the absence of a fire alarm system, and the same low rate (0.41-0.44 times) can be seen in kotatsu heated tables and cigarettes. As shown in **Figure 6**, kotatsu, heaters, cigarettes, matches and lighters are causes of fire where the risk of fatality is high, and since the activation of fire alarm systems is reducing the fatal fire incidence rate in relation to these causes, it can be said that the mitigating impact is significant.

Figure 18 is a frequency distribution of the time taken to discover a fire (the time from fire outbreak until alerting the fire department) according to installation and activation of fire alarm systems in all residential fires. This graph is based on fires where the time taken to discover the fire was within 30 minutes, accounting for approx. 90% of all fires. On the basis of this graph, it is around the 6-minute mark where the frequency relationship reverses between those cases with fire alarm systems installed and activated, and those cases without fire alarm systems. As a result, the expected reduction in the time taken to discover a fire could be as much as 1.6 minutes due to the installation and activation of fire alarm systems.



*Data: 1995-2001 residential fires in wooden apartments.

Figure 19. Histogram of fire damage area according to activation of fire alarm system.

Figure 19 shows the effect of fire alarm systems on the floor area damaged by fire. Fires with fire damage more than 10m² are 9.3% less than in the absence of a fire alarm, and even looking at the average floor area damaged by fire, it is at about half the area at 13.5m², versus 26.2m² in the absence of a fire alarm. In this way, we realized that the activation of fire alarm systems not only reduces the human toll, but also has a significant impact in terms of mitigating material loss.

4. Concluding Remarks

In this paper, we have carried out an analysis of the trends in residential fires and the incidences of fatalities in fires in Japan using fire data from 1995 to 2001, and we have made a comparison of past and present trends in the incidence of fire fatalities. From a statistical-analytical point of view, we also examined the effectiveness of residential fire prevention measures through the use of fire extinguishers and fire alarm system. The main results are as follows:

- 1) Fires and fatalities due to fires in wooden houses account for 70% of the fires and fatalities due to fires in all dwellings, and thus it is hoped that fire prevention measures can have the biggest impact in this area. Since the highest proportion of fatalities in this dwelling type are made up of the elderly and physically disabled, it is necessary to investigate not only general fire prevention measures, but also measures that will be suitable for these types of people.
- 2) In terms of fires and fatalities due to fires in wooden apartments, the incidence rate per residence and size of household is a lot higher than other dwelling types. The incidence rate is increasing in every age group – elderly, adults and children.

There is a need to consider fire prevention measures that are particularly suited to this dwelling type and to think of ways to promote them.

- 3) The incidence rate of fatalities due to fire per population for the elderly is on the decrease compared with 15 years ago. The proportion of bedridden which make up a part of the fatalities due to fire is also on the decrease. It can be said that these results show that the aging population will not necessarily directly lead to an increase in fatalities due to fire. In the future it will be necessary to consider the issue of risk in residential fires while looking in more detail at the improvement of living conditions and physical abilities of the elderly.
- 4) From an analysis of fire data, it has been confirmed that fire alarm systems are highly effective in curbing causes of fires with high fatality incidence rates such as heating equipment or cigarettes. It is also obvious that alarms have a significant impact in terms of mitigating material damage and shortening the time taken to discover a fire (time taken to alert the fire department).
- 5) In wooden houses, in cases where fire extinguishers were installed and used, the incidence rate of fatal fires was 0.28 times the rate when there was no extinguisher, and it can be said that the prevention effect of using fire extinguishers is a significant contributing factor in lowering the risk of fatalities due to fires.

In the future, we are hoping to continue our analysis and gain a more precise idea of the secular change of the fatality rate and fire incidence rate, the relationship of the position of the deceased to the fire origin, and the relationship between the cause of fire, ignition point of the fire and things that caught fire, all according to dwelling type. On the basis of these analytical results, we intend to construct a

model for future forecasts of incidences of residential fires and consequent fatalities, which will be a parameter for the rate of diffusion of residential fire prevention measures, in addition to examining the impact of the diffusion of these residential fire prevention measures.

Notes

- **1: The term of "Single" home stands for one-and-two family dwellings, and "Apt." stands for apartment.
- **2: Data: Average of 1995-2001 for residential fires.
- **3: Excluding Others/Unknown.

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