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Statistical assessment of fire safety in multi-residential buildings in Slovenia

Nearly a third of residential units in Slovenia are located in multi-residential buildings. The majority of such buildings were built after WW2, when the need for suitable accommodation buildings was at its peak. They were built using the construction possibilities and requirements of the time. Every year there are over 200 fires in these buildings, resulting in fatalities and vast material damage.
Due to the great efforts over the past centuries, which were all mainly aimed at replacing combustible construction materials with non-combustible ones, and with advancements in fire service equipment and techniques, the number of fires and their scope has decreased significantly but they were not entirely put out. New and greater advances in the field of fire safety of multi-residential buildings became obvious within the last few years, when stricter regulations regarding the construction of such objects came into force. Developments in science and within the industry itself brought about several new solutions in improving the situation in this field, which has been confirmed by experiences from abroad. Unfortunately in Slovenia, the establishment of safety principles still depends mainly on an occupants' perception, financial means, and at the same time, certain implementation procedures that are much more complicated due to new property ownership.
With the aid of the statistical results from the 2002 Census and contemporary fire safety requirements, this article attempts to show the present-day situation of the problem at both the state and municipality level and will propose solutions to improve this situation.
The authors established that not even one single older, multi-residential building meets complies with modern requirements. Fortunately, the situation is improved by the fact that most buildings in Slovenia are built from non-combustible materials (concrete, brick), which limit the spread of fire.

Keywords: fire, fire safety, multi-residential buildings, Slovenia

1 Introduction

In Slovenia, a large section of the population, especially an urban setting, live in multi-residential buildings. The results of the 2002 Census show that there were 18,005 multi-residential buildings in Slovenia at that time, which equalled only 3.9% of all residential buildings, however, they included 242,011 apartments or nearly one third of all apartments in the country (Statistical Office of the Republic of Slovenia, 2009).

These buildings are multi-residential houses, multi-storey apartment blocks and skyscrapers. The intensity of construction of multi-residential buildings has always been connected with population growth and immigration trends to certain areas. The quality and scope of construction corresponded with the wishes and abilities of investors and the construction industry, as well as the safety regulations in force at the time for the construction of such buildings (Kilar and Kušar, 2009; Slak and Kilar, 2005; Vidrih, 2008).

These buildings still serve their purpose however, today's requirements for comfort, usefulness and safety are more demanding than they were when these buildings were constructed. Therefore quite a few studies regarding multi-residential buildings have been carried out in Slovenia, which treat buildings in different areas. Assessment of earthquake safety of multi-residential and other buildings (Kilar, 2004; Orožen Adamič, 1995; Orožen Adamič and Perko, 1996) has shown that many older multi-residential buildings do not meet today's requirements and would very likely require remedial work. Analyses of heating systems and heat loss also confirm the need for heat-related remedial work on such buildings, as they do not meet modern requirements Šijanec-Zavrl, 1997; Tomšič, 2005).

Over 250 outbreaks of fire are recorded in multi-residential building in Slovenia every year. This number has not changed to any significant degree for a few years, while damage due to fire has increased in the last few years (Internet 1). Unfortunately, the problem of fires is unjustly overshadowed by other dangers: earthquakes, floods and lately, wind. The reason probably lies in the fact that fires are not very violent and do not cause as much immediate damage as other disasters, and so receive less media attention.

The problem of fires in multi-residential buildings around the world is dealt with in different ways. In the United States of America, this problem was dealt with by adopting measures for installing fire-fighting devices and systems for active fire protection (systems for fire detection and automatic fire-fighting). At the end of 1992, regulation on the measures for protection of multi-residential buildings against fire came into force, the *Fire Administration Authorization Act of 1992 (PL 102–522)* (Bukowski and Budnick, 1995). With this regulation the building stock of the country was classified into three categories:

- new constructions with 4 or more storeys;
- reconstruction of residential buildings with 4 or more storeys;
- other residential buildings with no more than 4 storeys.

Certain measures for ensuring an adequate level of fire safety were provided for each of these groups. For new constructions with 4 or more storeys fire detection devices (fire alarms) and automatic sprinkler systems are now required. Sprinklers requirements for the reconstruction of existing buildings are not as strict. However, the regulation demands that in all new and also in all existing residential buildings (single or multi-residential) a smoke detector must be installed. In doing so, also economic analyses on how reasonable it is to install automatic sprinkler systems in apartments and even individual houses were made (Brown, 2005; Butry et al., 2008; Internet 2). Similar solutions to the problem are proposed in some parts of Europe (Denmark, Sweden, Great Britain, certain German states), where the use of advanced fire detectors and alarms in existing apartments are advertised or even required (Ahačič, 2006; Internet 3).

An overview of the existing research shows that in ensuring fire safety, a greater emphasis is placed on construction measures in preventing the spreading of fire and evacuation procedures, and that a lot less attention is devoted to the analysis of the causes of fire and methods of prevention. Thus Zhao et al. (2004) presents a model of classification of criteria for the fire safety assessment of existing buildings in China, which is based on the method of analysing the hierarchy of processes. In doing so, he organises the basic criteria (construction material, the possibility of fire detection, warning and evacuation, intervention access, fire-fighting devices and installations and building management) into more detailed elements and determines the importance of each single element. On the basis of the data for the entire building, determined in relation to the importance of individual elements, it is possible to analyse and classify buildings. Similar methods for the assessment of existing buildings were also employed by Lo (1999), Lo et al. (2005), Watts and Kaplan (2001), and Wong and Lau (2007). The latter two analysed 122 older high-rise buildings in Hong Kong on the basis of 43 different forms of data. These data forms are combined into five groups: building characteristics, fire safety devices, management (which also includes door types, staircase lighting, fire safety signs, smoke stop door etc.), devices and installations for fire detection, alarm and fire extinction. The treatment of existing buildings is no doubt a complex issue, which is indicated by the fact that certain elements occur several times. A common feature of all these methods is the fact that they demand a lot of very specific informational input and are therefore useful only in assessing individual buildings or a small number of buildings.

A large number of studies deal with the performance of construction elements and materials in the event of fire. Interest in this field, especially in the performance of steel structures, grew considerably at the time of searching for reasons for the collapse of the WTC building in New York, after the terrorist attack in 2001 and after the report into the collapse was issued by the National Institute of Standards and Technology (2005), which researched the event in great detail. The aim of this research is to find different effective methods for the protection of such structures against collapse due to high temperatures during a fire (Goode, 2004).

Taking into account the rapid development of various new materials and technologies, which give architects more room for creativity and therefore opens new possibilities in the field of architectural development and at the same time increasingly stricter safety requirements and where new knowledge is also emerging in the field, regarding ensuring evacuation. Basic evacuation time calculations, based mainly on the movement speed of people, were later complemented by other parameters effecting evacuation speed and mainly form in the field of psychology (perception of danger, knowledge of the building etc.) (Kuligowski, 2008). On the basis of these findings, different programmes for evacuation modelling in different cases were made (Long et al., 2005). New materials and technologies also allow for the fire safe division of spaces by using transparent walls and doors as well as systems which automatically control evacuation doors and other escape route elements.

Many studies were conducted also in Slovenia (Hajduković, 1995; Rebec, 2006; Žarnič, 2005) in fields treating the performance of construction materials, elements and the building during a fire. Due to the increasing use of wood in the construction of multi-residential and other large buildings, different studies in the field of fire safety of wooden construction elements, such as wooden beams and wooden plates and walls, have been carried out in the recent years (Dujić, 2009; Žarnič, 2005). Their findings prove that wood is acceptable from a fire safety perspective, since a layer of charcoal is created when burning, which then protects the interior of the wood itself. Fewer studies have been made in the field of brick and partly reinforced concrete structures. These are in principle fire safe although this is not entirely true (Pajek, 2008).

Research into the fire risk in multi-residential buildings was conducted by Jug (2005), who focused on the processes occurring from the inception of a fire, its spread, evacuation, intervention, and calculation methods.

All these findings present a framework for protection against fire, which is regulated by the Fire Protection Act (OGRS, No. 3/2007). This framework defines certain activities for reducing fire risk and the alleviation of the consequences of fire. They include:

- fire prevention,
- fire detection and alarm,
- preventing the spread of fire,
- safe evacuation of people, animals and property, and
- fire-fighting intervention with fire extinguishment.

Knowledge gained through research and expert work, also transferred to legal regulations is used in the design, construction and reconstruction at the present time, whereas the treatment of the existing multi-residential stock from the viewpoint of fire safety is much more complex. In contrast to other authors who designed models for assessing individual buildings or their components, this article focuses on giving a general assessment of the entire multi-residential building stock in Slovenia built up to 2002.

The purpose of this research was to establish, to what extent older multi-residential stock meets contemporary fire protection requirements? Another purpose of this research was to complement the analysis with reference to the causes for outbreaks of fire with new information, and offer measures for reducing the number of fires.

The results are presented on a Slovenian level as a whole and also at the level of individual municipalities. Municipalities and residents will be able to use the results in planning fire protection measures. Even though this research is limited to Slovenia, its findings will also be useful elsewhere, where the circumstances are similar and there is a need for improvement (mainly the central European area).

This research was carried out within the scope of the research assignment entitled 'Introducing advanced technologies to increase safety in the architecture of modern residential buildings' at the Faculty of Architcture, Universty of Ljubljana.

2 Method

The basis for this research is the statistical data on multi-residential buildings from the 2002 Census. A part of the necessary data was obtained from the Internet site of the Statistical Office. Specific data, particularly the results of correlating the data, were prepared at the Statistical Office. Due to the obligatory disregard of small values, a principle employed by the Statistical Office; municipalities where the number is less than 5 are not to be shown. However, these data are included at the national level. Certain smaller municipalities, mainly in the eastern part of the country, rarely have more than 5 multi-residential buildings.

The 2002 Census collected data of interest to the client, i.e. the state. In the research, we used the following amongst the collected data: age of the building, material of load-bearing structures and the number of storeys. Unfortunately, certain data which would contribute to more accurate results for this research (circulation path positions, entrance door material, fire-fighting devices, façade structure etc.) were not included in the Census.

The second part of our investigation focuses on an analysis of fires in multi-residential buildings. The fire statistics were obtained on the basis of the information regarding the outbreak of fires in multi-residential buildings from the Internet pages of the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief. The analysis was conducted for 2005 and for the period from the 1st of October, 2006 to the 1st of January, 2009. This period was chosen because of the relevance of the data and a uniform classification of data on fires at the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief. We conducted analyses with specific reference to the number of fires, causes for fire outbreaks in multi-residential houses and spaces where fires are most likely to occur. The analysis included data at a municipality level as well as Slovenia as a whole.

The three years under analysis give accurate values for Slovenia and larger towns, whereas with smaller numbers of fires and buildings, the data is less representative. This is also the reason why municipalities that had less than 5 fires in the specified period are not shown, however, these fire are included in the statistics on the state level. The research on the municipality level included 154 or 64.3% of all Slovenian municipalities, which include as many as 17,785 or 98.8% of all multi-residential buildings in Slovenia.

These regulations, together with executive acts, present the legal framework of all fire prevention measures in multi-residential buildings:

- the Construction Act (OGRS, No. 110/2002, 126/2007),
- the Fire Protection Act (OGRS, No. 3/2007),
- the Protection Against Natural and Other Disasters Act (official consolidated text) (OGRS, No. 51/2006),
- the Regulation on Fire Safety in Buildings (OGRS, No. 31/2004, 10/2005, 83/2005 and 14/2007),
- the Regulation regarding the Minimal Technical Requirements for Construction of Residential Buildings and Apartments, OGRS, No. 125/2003).

The publication, *Technical guideline TSG-1-001: 2007 – Fire Safety in Buildings* (TSG) published by the Ministry of the Environment and Spatial Planning of the Republic of Slovenia, provides help in planning fire safety of buildings. It summarises the examples of good practice and the different foreign regulations on fire safety and also stresses the basic requirements for fire safe construction in a transparent and clear manner. The first publication came out in 2005, the second was amended in 2007, and a new, even more detailed one is being prepared. At the same time, legislation enables the provision of an adequate level of fire safety in relation to engineering methods, which are enabled by the advancement (computerized) in technology. Present fire safety guidelines can be summarised using the following key points (Ministry of the Environment and Spatial Planning of the Republic of Slovenia, 2007; Fire protection Act, OGRS, No. 3/2007):

- structural material of a building and separation elements between apartments should be non-combustible, and they should at the same time, stop the spreading of fire (fire, smoke, heat) from one apartment to another;
- circulation paths in a building should ensure safe evacuation, which means that these spaces should not become filled with smoke, they should be adequately short in distance and adequately lit;
- buildings should have suitable fire service access and adequately prepared surfaces for fire fighting intervention;
- buildings should be adequately equipped with fire-fighting devices (fire extinguishers and a suitable fire hydrant system);
- installations and devices in apartments should prevent the outbreak and the spread of fire;
- buildings should have a fire order, which describes procedures and actions to be taken in the event of fire.

3 Analysis of buildings and performance in the event of fire

This article deals with fire safety in multi-residential buildings. They are a specific type of building, intended to provide dwelling for a large number of people. Such buildings are most characteristic of towns, but also in industrial and mining settlements, where accommodation had to be provided for workers and their families. Multi-residential buildings can be categorized into urban multi-residential buildings, apartment blocks and skyscrapers (Figure 1). Each of the three types has certain characteristics, although we can say that multi-residential houses and apartment blocks are similar enough to claim that they are same type of building. A similar classification of multi-residential buildings is used by the Statistical Office in the 2002 Census, in which a multi-residential building is defined

Figure 1: 1 – multi-residential houses in Ljubljana; 2 – apartment block in Zreče; 3 – skyscraper in Ljubljana (photo: Domen Kušar).

as an apartment block, a skyscraper or an older, urban multi-residential building (e.g. buildings in town centres, which are built one next to another and do not look like modern multi-residential buildings on the outside) (Internet 4).

The oldest category of multi-residential buildings comprises of urban, multi-residential houses which, on the face of it are no different from other urban houses. Only their interior structure displays that they are divided into apartments. The mass emergence of apartment blocks began between the two world wars, but mainly after WW2. The first skyscrapers began to appear in Slovenia between the two world wars, and more predominantly after WW2. That was the time when apartment blocks and skyscrapers became the common buildings for accommodating a large number of residents in urbanised areas, where they formed the so-called apartment block settlements or neighbourhoods.

According to the Census in 2002, there were 18,005 multi-residential buildings in Slovenia, which equals 3.9% of all residential buildings. They contain 242,011 apartments, which equals as much as 31.1% of all apartments in Slovenia. The largest number of multi-residential buildings can be found in those municipalities with large urban settlements.

In Slovenia, there are 40 municipalities with 100 or more such buildings. They represent the biggest proportion in the municipalities in the Koroška region, in Zasavje, Jesenice, Tržič, Idrija and Velenje (Figure 2). This is a consequence of mass industrialization or mining during a certain period when apartments for workers had to be constructed. A high proportion of such buildings in the coastal municipalities (Koper, Izola and Piran) are partly a consequence of the historically conditioned construction method within the towns themselves and partly a consequence of industrialization and the development of different activities (port activities and tourism).

The majority of apartments were built in the period from 1971 to 1980. This period is followed by the previous decade (1961–1970) and thirdly in the decade between (1981–1990). In short, most apartments and multi-residential buildings in Slovenia were built between 1961 and 1991.

3.1 Shape and height

A typical **skyscraper** has a rectangular or even a square shape, with a ground floor and most commonly with 8 to 12 storeys. At the top, there is a flat roof and a lift machinery room. An **apartment block** is usually long in shape, and therefore it usually has more circulation centres. The usual height of an apartment block is the ground floor + 4 storeys.

The height of a single storey in older buildings is about 3metres, which complies with the older norms, written in the construction act of 1931, which required that rooms have a minimum height of 2.8metres. The height of each storey in more modern buildings is a little lower, as the required height of rooms today is at least 2.50metres (Regulation on Minimal Technical Requirements for Construction of Residential Buildings and Apartments (OGRS, No. 125/2003). Ground floor spaces are usually higher. Therefore the height of an older multi-residential building with a ground floor and four additional storeys is approximately 15 or 16metres, and the height of a skyscraper with 10 storeys is approximately 30metres.

From a fire safety perspective, lower buildings are usually safer, since evacuation and fire-fighting intervention is both easier and faster. This is precisely why modern requirements determined in the TSG for high-rise buildings regarding their actual structure, evacuation procedures and intervention are stricter than those for lower buildings. A high-rise building is any building where the height of the last storey is greater than 22metres, measured from the ground level upwards.

3.2 Construction materials

Multi-residential buildings in Slovenia have certain common characteristics, mainly with respect to the construction material used. Multi-residential buildings were most often bu-

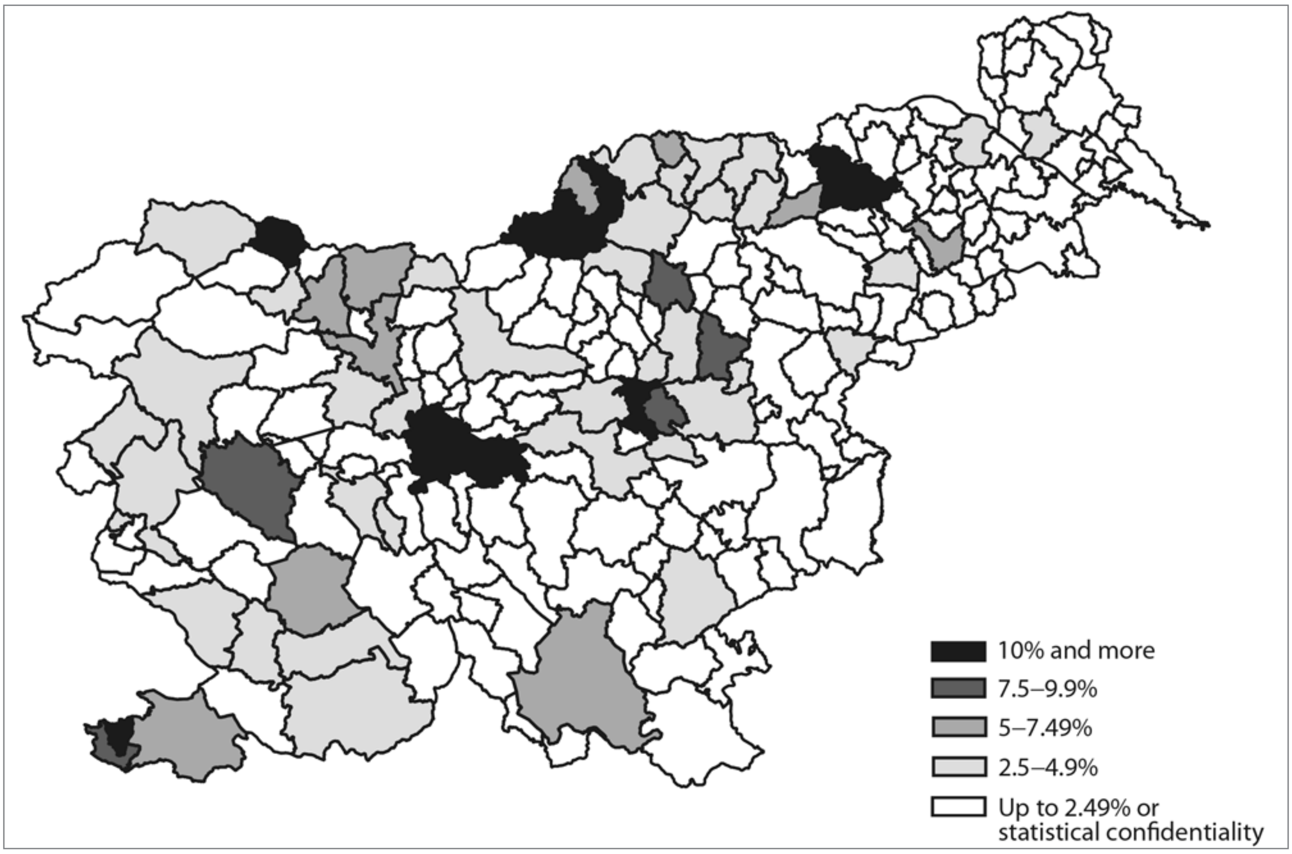

Figure 2: Proportion of multi-residential buildings in relation to the total number of buildings intended for dwelling purposes (source: Statistical Office of the Republic of Slovenia, 2009).

ilt from reinforced concrete and brick. Reinforced concrete is most prevalent in ceilings, staircases and bridge elements, while load-bearing walls are made of either brick, concrete or of prefabricated concrete elements. In older, multi-residential buildings, ceilings also include wooden beams, which had to be protected against fire under specific regulations. Walls of older, multi-residential buildings are made of brick, whereas after WW2 the use of reinforced concrete for the construction of walls began to gain ground. The popularity of concrete grew because it was both modern and useful and most importantly, there was plentiful supply of it. Wood as a construction material was used only for the roofing, where larger wooden, multi-residential buildings were not built in Slovenia. Steel skeleton construction also did not become widely used in our area. More noticeable changes in the use of materials are characteristic of the last few years.

In the event of fire, different construction materials have different characteristics (Table 1). The use of brick and concrete as the main construction materials is favourable from a fire safety point of view, since these materials prevent the spread of fire from one apartment to another and at the same time, they keep their integrity long enough and also prevent the collapse of the building. Steel does not have as many positive characteristics from the viewpoint of fire safety, since its elastic modulus quickly decreases with an increase in temperatures. Nevertheless, a steel structure can be adequately protected (coatings, coverings etc.). Wood is flammable, but when it burns a layer of charcoal is created which partly protects the interior of the wood itself. A wooden structure can be protected as well. TSG allows wooden buildings up to the height of the ground floor and first storey (G + 1), without special limitations. The installation of an automatic sprinkler system allows for construction up to a height of the ground floor and fifth storey (G + 5). There is not a similar height limitation for steel structures however, fire resistance is required.

3.3 Circulation paths and organisation of space

Most multi-residential buildings have an elevated ground floor at the point of entrance into the building, with a stairs leading to the entrance. Behind the entrance door, there is a hall with mailboxes. This space is usually separated from the main circulation path inside the building, which encompasses both the halls and staircases. In addition, skyscrapers also have two or three lifts. Unlike skyscrapers, where the circulation centre is usually at the centre of the building, certain apartment blocks have vertical circulation paths at the building's centre as well, but in such a way that one wall is located on the outside part

Table 1: Resistance of separation elements with regard to material type and thickness.

Material	Minimum thickness	Fire resistance
Brick	10 cm	60 min
Concrete	ca. 8 cm	60 min
Wood		Burning rate is ca. 0.6 mm/min (it depends on the type of wood and other factors)
Drywall structure ('gypsum')	3 cm	60 min
Wooden door		Up to 20 min

Source: Egan (1990).

of the building, so that natural lighting hits the staircase and is present during the day.

The design and construction of circulation paths in multi-residential buildings, where staircases and halls up to the entrances of the apartments are open from the basement to the roof are actually weak from a fire safety perspective. In the event of a fire, the communication path quickly becomes filled with smoke and disables the safe evacuation of any occupants who are trapped. The situation in this area is worsened by the fact that up until the 1990's wooden doors, which do not prevent the spread of smoke and fire, were still being installed. It is precisely at this point that the TSG guideline brought about changes, since it demands adequate construction of (protected) vertical circulation paths and entrance doors to apartments. This mainly concerns the separation of the staircase from the storey hallway, which prevents the spread of fire through the entire building.

3.4 Intended function of spaces

A characteristic of apartment blocks and skyscrapers is that the majority of them used to be intended solely for dwelling purposes. Thus every apartment (97.9%) has its own kitchen (Internet 5), which is a potential source of fire. Although modern cooking appliances are perfected and they themselves mostly do not cause fire, the presence or absence of the human factor in the heat treatment of food can cause food to ignite and start a fire.

Part of the basement area in multi-residential buildings was initially intended for the common need (multi-purpose room, bicycle room, boiler room etc.), and the remaining part for storage. Residents' storage spaces are usually separated with wooden walls or railings. According to fire-fighter experiences, basement areas are the most problematic in the event of fire. There is no supervision during the day as in other residential areas. In addition, basements store different substances, some flammable and may also include explosive materials or liquids. Therefore, fire-fighting in basements is dangerous, since fire-fighters never know what they will find there (Kejžar, 2008).

In recent years, a change in the (common) areas on the ground floors in multi-residential buildings was noticed: they have begun to be used for commercial purposes (especially for service activities). Changes regarding the intended function of certain spaces within multi-residential buildings are not problematic, if contemporary principles of fire safety are taken into consideration.

3.5 Emergency vehicular access

Lack of parking spaces next to multi-residential buildings, forces residents to park their vehicles everywhere and anywhere, blocking and hindering emergency vehicular access! This impedes or even makes effective fire-fighting intervention impossible. In Slovenia, improvement in this area depends mainly upon the awareness of the majority and also the repressive politics of local communities.

3.6 Heating

There are a great number of differences in heating systems amongst apartments. The majority of apartments today (79%) have central heating (Internet 5). From a fire safety perspective, district heating is the safest. Fire statistics show that chimney fires are the second most frequent, after fires that have had their source in the kitchen (Internet 6; Kušar, 2008). Modern heating technology that uses solid, liquid and gas fuels enables for a simple boiler management regime and it at the same time achieves considerably better heat efficiency, which means lower temperatures of flue gas and consequently less risk of chimney fires. The regular maintenance of combustion and smoke outlet installations contribute to a reduction in chimney fires.

3.7 Ownership

Another characteristic of multi-residential buildings in Slovenia is dispersed ownership, which is mainly a consequence of the possibility of buying socially-owned apartments at the end of the previous century. Dispersed ownership is precisely what makes the efficient renovation of an entire building, which would also increase fire safety measures more difficult or even impossible to attain.

4 Analysis of fires

4.1 Historical overview of the development of fire safety principles in multi-residential buildings

A historical overview of town development shows that development and the advancement of towns, was hindered mainly because of fires. At the same time, fires contributed to great changes in the use of construction materials and thus actually changed the architectural image of towns (Kušar, 2006). Conflicting with earthquake construction principles in Slovenia, the system of fire protection based on town statutes and later also fire orders remained in use for a long period of time. The first fire orders appeared in the 13th century an important milestone in Slovenia is the *Fire order for Carniola,* published in 1773 and was also written in the Slovene language. Authorities used fire orders as an attempt to reduce fire outbreaks and damage, since they included fairly detailed descriptions of individual fire safety requirements and measures needed to prevent and stop the spread of fires, quick evacuation and the reduction of damage. Putting these requirements into effect contributed to reducing the number of fires, mainly due to the replacement of wood as a flammable construction material with a non-flammable one – brick, brick roofing tiles and later concrete (Kušar, 2008). This also helped prevent the spread of fire between apartments. The transfer of fire through the entrance door was usually prevented by fire-fighters, who then also ventilated circulation paths.

Historical experience has enables us to better understand why in our country wooden construction of multi-residential buildings almost disappeared. At the same time we can monitor the rapid development of fire-fighting in Slovenia, which, aside from its strictly professional function also had an important social and national role. A combination of non-combustible materials and fire-fighting was a relatively successful way of preventing large scale fires. As a result, the development of legal regulations did not follow the developments within the rest of the construction industry. So in 1988, Yugoslavia still did not have a systematically organized fire safety regulation code. In design, different foreign regulations, especially German regulations were followed only partially, which was often a source of confusion. Our regulations at the time were technically not effective enough; they were even harmful and did not ensure fire safe construction (Urbas, 1988). The independence of Slovenia, accession to the EU and the adoption of new construction regulations were all important steps to improvements in this area. By adopting positive domestic and foreign (TSG refers to Swiss, American and German regulations) experiences, mainly those in Germany, Switzerland, the USA, and incorporating them into our legislation, a new framework for safe construction was established. Due to the rapid development of science and the industry itself, this framework is quickly changing and is being complemented.

4.2 Analysis of fires in multi-residential buildings

Today, reducing the number of fires is limited to the construction measures for prevention of spreading fires and evacuation procedures and significantly less attention is devoted to analysing the causes of fires and the methods of fire prevention. For this purpose, the assessment of statistical data regarding fires in multi-residential buildings in Slovenia has been conducted. In the period under analysis – in the year 2005, and in the period from the 1st of October 2006 to the 31st of December 2008 – there were 859 fires in multi-residential buildings, which equals one fire per 21 multi-residential buildings or 4.8 fires per 100 multi-residential buildings. There were five or more fires in 35 municipalities, where there are 13,874 multi-residential buildings or 77.1% of all such buildings in Slovenia. Fires in these municipalities represent 85.6% of all fires in multi-residential buildings in Slovenia. The most threatened were buildings in Škofja Loka, where there were 14.9 fires per 100 buildings, in Tolmin (12.0), in Nova Gorica (11.7), in Lendava (11.1) and in Kanal (10.2); the lowest values were recorded in Ravne na Koroškem (2.9), Krško (2.8), Novo mesto (2.5) and Radovljica (2.3).

Regarding the causes of fire, most fires occurred in the kitchen (39.1%) in the period under consideration. The leading municipalities here are Ajdovščina, Novo mesto, Trbovlje, Žalec and Hrastnik, in which more than one half of all fires took hold in the kitchen. It would be possible to reduce the number of kitchen fires or even prevent them, if the person who is usually nearby, could be warned about the fire in time. They would be able to take action in time and prevent the fire or the spreading of the fire itself to other areas.

The second most frequent type of fire is that which occurred in combustion and smoke outlet installations (17.2%). According to the descriptions, the fire usually started in older buildings with individual solid fuel (wood) boilers, and where the safety of their combustion installations and chimneys was problematic. These are often the dwellings of socially disadvantaged people, who cannot afford a different type of heating system.

The largest proportion of such fires was recorded in the municipalities of Ilirska Bistrica, Tolmin, Kanal, Idrija and Črnomelj (over 50%). The smallest proportion of this type of fire was recorded in large Slovenian cities (Ljubljana 0.81%, Kranj 6.45%, Velenje 7.1% and Maribor 10.5%), which is a consequence of safer heating methods (district heating, gas, etc.).

5 Condition of multi-residential buildings in Slovenia from a fire safety perspective

5.1 Fire prevention

As already mentioned, from the viewpoint of basic construction material of a structure in multi-residential buildings under consideration, the situation in our country is positive, as 84% of all multi-residential buildings are built from non-combustible concrete, brick or stone, and there are less than 1% of wooden buildings. There are not many multi-residential building with a steel bearing structure in Slovenia and the 2002 Census does not classify them into a separate category, but into the category of 'other', which also comprises combinations of different materials (wood-brick, brick-concrete etc.).

The quality of installations cannot be checked and therefore it is not possible to provide a thorough assessment of this field. However, the analysis of fires showed that defects in installations and appliances within apartments can also be the causes of fire.

5.2 Fire detection and warning

Field work showed that technical devices for fire detection and alarm are almost non-existent in Slovenia. There are probably many reasons for this. Firstly, such systems for apartments are not required by law and their use is not promoted enough by insurance companies. The second reason is probably distrust, and a lack of knowledge about such devices and a lack of awareness on the part of the residents.

Warnings of fire usually happen by telephone, which is enabled by landlines and mobile telephone networks within Slovenia. Greater safety can be achieved by installing fire detectors and fire alarms and their connection to a suitable security or fire service department.

5.3 Evacuation

Assessment of the present day situation showed deficiencies in the field of evacuation procedures. The design of a building with a central open circulation path and wooden entrance doors to apartments is unacceptable, with respect to fire safety and does not meet contemporary requirements.

The safety of people in these buildings decreases with the height of a building (Table 2), since evacuation from outside requires a greater effort and also the requirement of better technical equipment of fire-fighters. According to the criteria in Table 2, multi-residential buildings could be classified into three categories with regard to fire safety: low fire risk, medium fire risk and high fire risk.

The statistical data shows that, according to the criteria in Table 2, the high fire risk category with buildings constructed before 1995, contains 6.5% of all multi-residential buildings in Slovenia, located in 28 municipalities. Most of the buildings are in Ljubljana (423), the largest proportions are in Velenje (17%), Škofja Loka (16%), Celje and Murska Sobota (13% each) and in municipalities by the river Sava, from Ljubljana to Brežice, and in individual larger industrial centres (Figure 3). It needs to be stressed that the classification to the high fire risk category does not necessarily mean a greater possibility of a fire outbreak, but only difficulties in fire extinction and evacuation procedures in the event of a fire.

There are 47.5% of multi-residential buildings which fall into the category of medium fire risk (height from the ground floor + 3 to the ground floor + 7 storeys) in Slovenia, and they represent the largest group amongst such buildings. The majority of such buildings can be found in Ljubljana (2,313), and their proportion is the highest in the municipalities of Žužemberk (100%), Cerkno (73.9%) and Piran (72.5%) (Figure 4).

Table 2: Factors and 'risk' in relation to height.

Group	Storeys	Estimated height of the building	Fire- fighting intervention possibilities	Present-day escape route requirements
Low fire risk	From G do G + 2	8metres	Portable ladder	General requirements
Medium fire risk	From G + 2 to G + 7	up to 22metres	Mobile swivel ladder	General requirements + requirements for staircase protection
High fire risk	G + 8 or more	over 22metres	Mobile crane with a basket (up to 50metres)	General requirements + special requirements for staircase protection in high-rise buildings

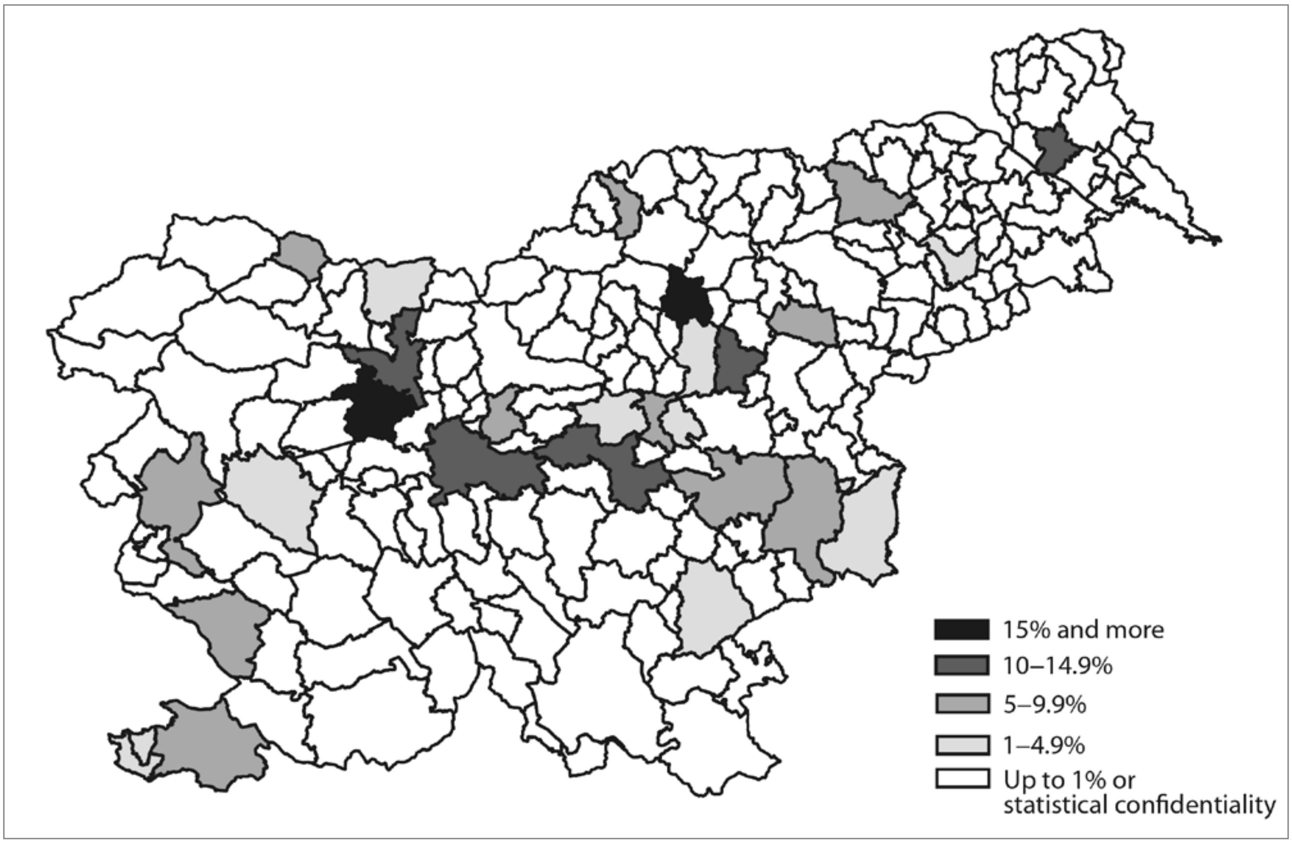

Figure 3: Proportion of high fire risk multi-residential buildings by municipality (source: Statistical Office of the Republic of Slovenia, 2009).

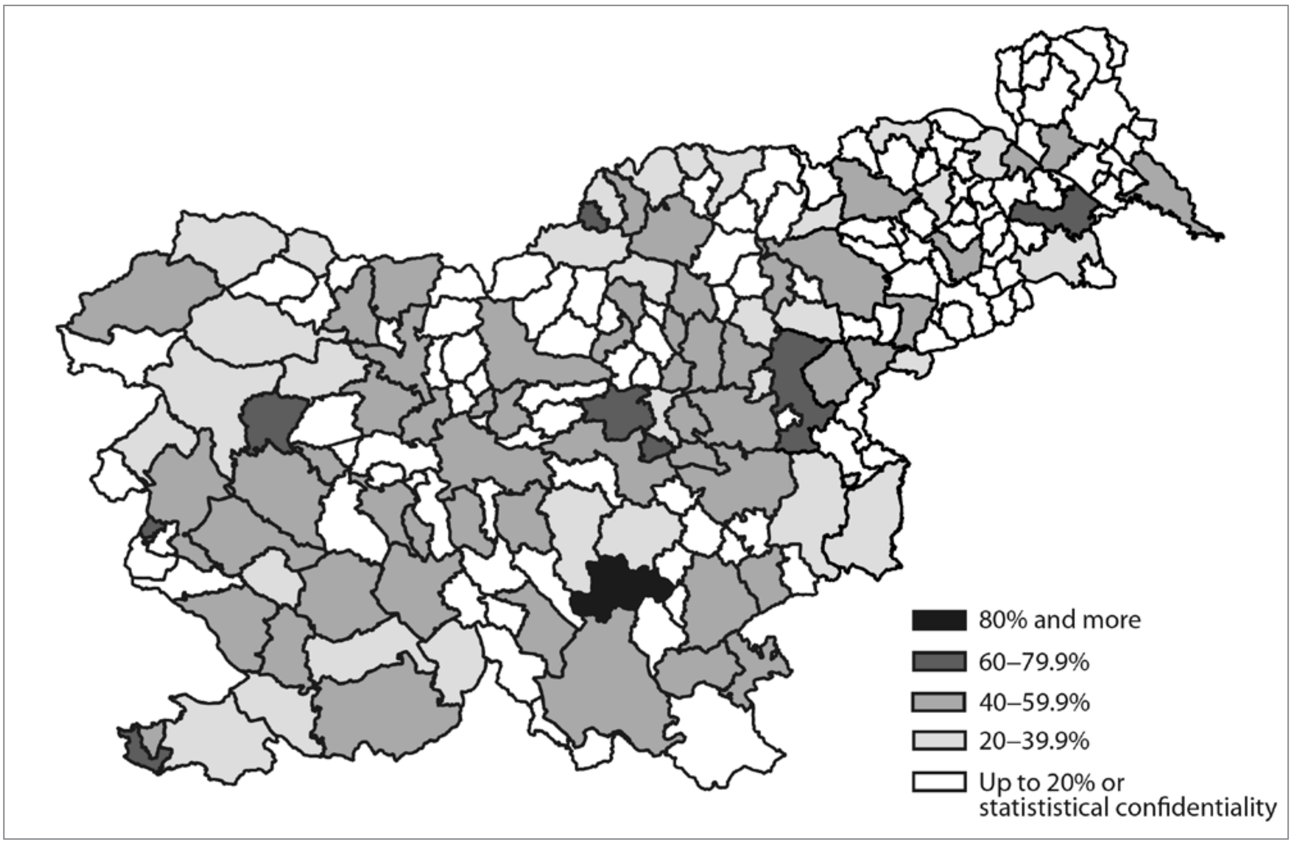

Figure 4: Proportion of medium fire risk multi-residential buildings by municipality (source: Statistical Office of the Republic of Slovenia, 2009).

5.4 Intervention possibilities

The Slovenian fire service is effectively pursuing its mission despite the problems faced, mainly by volunteer fire-fighters associations (equipment, evaluation of their work, etc.). Therefore intervention happens promptly, which is very important in the event of fire. Parked vehicles can make access to a building difficult. Circumstances are specific to each building and also depend on the specific day, time of day and the awareness of the residents. Thus it is not possible to provide a detailed assessment of the situation in this field.

6 Discussion

Approaches to actually reducing the number of fires in multi-residential buildings, differs among countries. The most advanced are the USA (Bukowski and Budnick, 1995; Butry et al., 2008) and the Scandinavian countries (Ahačič, 2006). One of the reasons for this is also the fact that in these countries, wood is an important construction material. Improvements in this field happen through general requirements for structural resistance and the transfer of fire, but they are mainly oriented towards early fire detection (Brown, 2005) and quick extinction, since a fire can most easily be extinguished when it is not yet fully developed.

Present-day technology offers numerous methods of fire detection and the communication of fire information. The simplest and lowest-priced are smoke detectors, which use an acoustic signal to sound the alarm. A person nearby can respond quickly and extinguish the fire. Results have shown that most fires occur in the kitchen and this is the type of fire that could most easily be reduced. In Slovenia, the use of such systems is unfortunately growing at a slow pace. What are interesting are the findings of research undertaken from Western countries, where the use of these systems are required and are promoted. In doing so, insurance company policies are offering lower premiums for buildings that have such systems installed proved effective. The results of a study from Denmark (Ahačič, 2006) and the experience of countries where smoke detectors are required (the USA, Great Britain and Sweden) confirm that these devices reduced the number of fatalities by 40% (Internet 3).

In the USA, where the most frequent causes of fire in apartments are connected with cooking (32% of all fires in apartments in the USA) and heating (16% of all fires in apartments in the USA) (Internet 7), it has been established that smoke detectors alone do not provide adequate fire safety and they are now researching the possibilities of installing automatic sprinkler systems, also in single residential houses and they are also conducting 'cost-benefit' analyses on how reasonable it is to install automatic sprinkler systems in apartments (Brown, 2005; Butry et al., 2008; Internet 2). In settlements where more skyscrapers are located together, it would be reasonable to create one device for the entire set of skyscrapers when considering the ratio between the price of a basic device (water source, pump etc.) and the price of installation and sprinkler nozzles. Then the system installation would go into every skyscraper, where sprinklers would be installed in the basement area, circulation paths and in also every apartment. It needs to be stressed again that the installation of an automatic sprinkler system in the USA has been obligatory for all multi-residential buildings with 4 or more storeys since 1992 (Bukowski and Budnick, 1995). Similarly, an adequate level of fire safety will be achieved in 7- and 8-storey, multi-residential wooden buildings being built in Berlin and the town of Vaexjoe in Sweden with the help of non-combustible covering materials and an automatic sprinkler system (Linse and Natterer, 2008; Internet 8).

Much more simple and less expensive devices are extinguishing ampoules, which contain a wrapping sensitive to temperature and extinguishing substance. In the event of high temperatures, the wrapping decomposes and then the extinguishing substance is sprayed, putting out the fire. Ampoules are usually installed above the area where fires are likely to occur. In apartments, the installation of such ampoules is advised above cookers. New approaches and solutions presented at the Ljubljana furniture fair in 2008, show that manufacturers are not yet thinking about the automatic installation of fire safety devices into kitchen elements.

A necessary measure that would have to be taken in buildings under consideration would be the replacement of all doors with fire resistant, smoke stop doors. This measure does not require the replacement of all doors at the same time, although that would be the best policy and also from the financial perspective, and it would probably be the only feasible measure due to the dispersed ownership of apartments. The purpose of this measure is to prevent the transfer of fire, particularly smoke, into an apartment and so enable more time for evacuation.

A useful, but probably (economically) unreasonable and less feasible measure would be the installation of smoke and heat outlets, and the arrangement of a safe staircase in compliance with TSG requirements. This measure would most often require extensive work on the infrastructure and building design (construction of additional vertical shafts and a hall on every storey and the construction of a new and safe stairs).

On the basis of adopted and non-adopted measures, an insurance company could define the risk level and consequently the premium amounts that an individual would actually have to bear. Insurance companies can contribute significantly to the development of safety principles and thus raise people's awareness about the importance of e.g. fire prevention measures and safety. Their role is very important in certain countries, since their premium policies generate the development and adoption of safety principles. In Switzerland, the association of canton fire insurance (Association des établissements cantonaux d'assurance incendie) determines fire safety principles that have to be followed. The information acquired at the Triglav insurance company, the company with the largest proportion of apartment insurance premiums in Slovenia, suggests that the installation of fire alarms in apartments is not enough for further reducing premium policies. A fire alarm is considered adequate, only if it has a suitability certificate issued by a competent institution, authorized by the Institute of Standardization and Metrology. A fire detector means a 5% discount on the basic insurance and a 10% discount on movable property insurance. A higher discount (up to 15%) is possible only if a system is connected to an emergency fire unit, a 12% discount if a system is connected to an emergency centre, a 10% discount if, besides a fire detector, there is also a 24-hour surveillance service.

7 Conclusion

In Slovenia nearly a third of all apartments are located in multi-residential buildings. An average building includes 13 apartments, which means that these buildings are mainly medium-sized buildings. It is positive that with respect to fire safety that a large proportion of buildings are constructed from non-combustible materials. High-rise buildings are most problematic, mainly because of evacuation procedures. There are 1,171 high-rise buildings in Slovenia or 6.5% of all multi-residential buildings. In this article, their proportion is shown by municipality.

Present-day safety legislation, regulates construction-architectural measures to reduce the number of fires to a certain standard, however, measures that would compel residents to take appropriate action are still exempt. Such measures are most easily carried out with the aid of financial stimulation packages (insurance companies) and also receiving a lot of media attention.

Basement areas are particularly problematic due to dangerous (flammable and dangerous) substances stored there by the occupants of the buildings. Here, a clear measure at a state level is missing, which would inform apartment owners and users and then encourage the suitable storage of items and substances that may be of danger of combustion. Although certain regulations managing this field already exist (they are used mainly in industry and trade), it would probably be reasonable to transform and adjust them to create a set of short instructions for the use of non-residential basement areas in apartment buildings.

This research unveiled another problem. Contemporary design and the free organisation of façade openings in multi-residential buildings, does not devote enough attention to the transfer of fire over the façade, which is sometimes dealt with after the construction process and sometimes it is not dealt with at all. More frequent use of wood in construction – also in multi-residential buildings – will require an even greater knowledge in this field as well as an in-depth and careful analysis of the design, construction and supervision of fire safety in this field.

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