# REDUCTION OF THE RISK OF FIRES IN OPERATIONAL AREA OF UNIT 9 OF WARSAW FIRE DEPARTMENT

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## Abstract

Progressing development and urbanisation brings with it an increasing risk of fire. According to Sendai Framework for Disaster Risk Reduction 2015–2030 and its universal assumptions the concept of fire risk reduction in operational area of Rescue and Firefighting Unit 9 of the Warsaw Municipal Headquarters of the State Fire Service was presented. Using the database of the State Fire Service the profile of fire events occurring in this area in 2021 was determined. By analysing the causes of fires in urban areas and using own operational experience, conclusions were presented that were used to formulate guidelines for reducing the risk of fires.

**Keywords:** fire, risk reduction, SFDRR, safety

## 1. Introduction

Safety is one of fundamental human needs. It also guarantees the development of civilization, which translates into reduced impact of the destructive forces of nature (Kołodziński, 2016; Koziej, 2011). However, as urbanization progresses, so does the likelihood of a fire. Those events may arise not only due to the human factor, but also as a result of, for example, failures of technical installations. In the firefighting community, this term means "uncontrolled combustion process in a place not intended for this purpose" (Zagórski, 1990) and has been always identified with the quintessence of a firefighter's work. Over time, we learn more and more about fires and the accompanying phenomena. In the second half of the 19th century the book "Fire Prevention and Fire Extinction" was published of a Scottish firefighter James Braidwood who indicated the need of limiting the oxygen to the fire. Another milestone in the fight against fires was the technique of operating with a diffused water current. It was proposed in 1950 by Lloyd Layman,

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a Parkersburg Fire Chief at the time, at a fire instructors' conference in Memphis. This technique was based on short pulses of water was designed to cool the ceiling zone (Kokot, 2020). As a result, it allowed reducing the smoke temperature, which in turn translated into its flammability, and that significantly enhanced the safety of firefighters staying in the firefighting operation zone. Furthermore, the technique also reduced the mobility of the smoke and its ability to spread a fire. The growing awareness among firefighters about the phenomena that occur during the combustion process translates into their safety today and also helps to adopt the best tactical solution during firefighting operations. This knowledge, combined with developed schemes and acquired skills, such as efficient operation of extinguishing currents, allows putting out a fire much faster, and as an effect contributes to the reduction of material losses.

However, fighting fires is not only about extinguishing them. Understanding the risk of fires gives one the opportunity to become familiar with the basic components of a fire hazard. In such a way, the effects of fire may become minimised, and even a reduction in the risk of its occurrence may be achieved. This is done by adopting active (technical), passive (construction) and organizational security measures. Organizational measures intended to minimize the risk of fire include: fire safety training for employees and users of the facility, method of marking and storing combustible materials, type of materials used for interior finishing, as well as assuring proper conditions of firefighting devices. Among the construction and technical protection we may distinguish: fire protection of the structure, the fire detection system and smoke exhaust ventilation. Those components allow minimising the probability of fire occurrence and its potential effects to some extent (Pecio, 2016; Polish Journal of Laws/Dz.U. 2002, No. 75, item 690 as later amended).

During a conversation with long-term officers of the State Fire Service (SFS), we often hear a common opinion that there are fewer and fewer fires over the years. This opinion is most likely related to the growing disproportion between fires and local hazards. In 2001, for the first time, the number of local threats exceeded the number of fires, and since 2004 it has become a constant trend (Marzec, 2018). Taking into account the statistics from the past 10 years (2010–2021) – Fig. 1 concerning the number of fires in Poland, it can be seen that despite significant fluctuations, we have been observing a constant downtrend trend for only 3 years.

Despite that, fires cause huge losses every year. Estimating the costs of fires is a very difficult process not only because of the access to a wide range of data but also due to the complicated methodology. According to the World Fire Statistics of the Geneva Association, it is estimated that this value reaches even 1% of the global GDP every year (The Geneva Association, 2014). Analysing the research on the economic and social effects in Poland, this value fluctuated around 3.5 billion PLN in 2012 (Pecio, 2016). It is the total of such components as the operating costs of state institutions (administrative and operational), material losses and costs related to the loss of future state budget revenues.

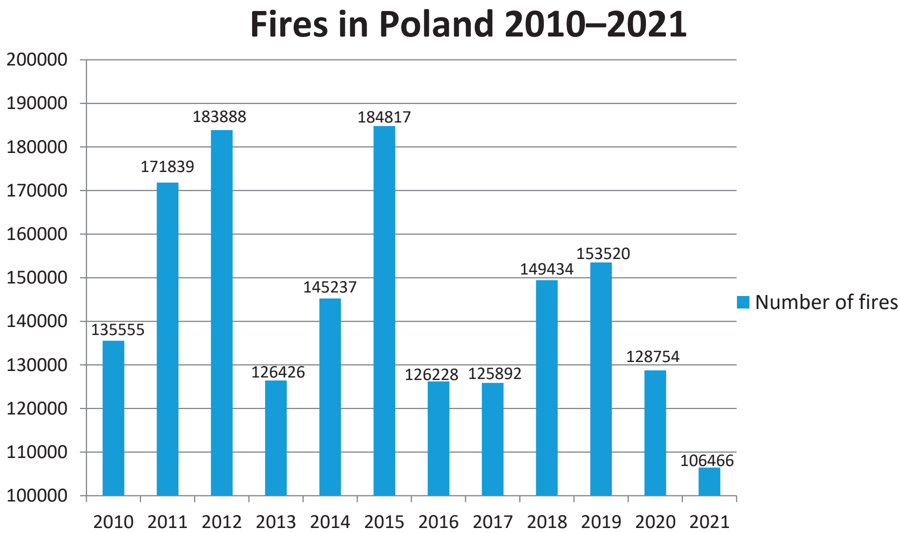


**Figure 1**. Number of fires in Poland in 2010–2021

Source: own study based on SFS data

In order to categorize the problem of losses sustained by the state as a result of fires, the sum obtained for 2012 can be related to the losses incurred as a result of natural disasters. For example, the "Flood of the millennium", which Poland in 1997 hit, among others, caused material losses, which were estimated at about USD 3.5 billion (Wikipedia: powódź tysiąclecia). Another example may be the fire in Kuźnia Raciborska, which was the largest forest fire in post-war Europe. Over 9 000 hectares of forest burned in 26 days, and over 10 000 people were involved in fighting the fire. The losses estimated by the State Forests amounted to almost PLN 380 billion (Mróz, 2020). Considering the fact that fires in Poland cause losses of several billion PLN each year, in the perspective of several decades (estimated frequency of disasters of such a scale) this problem grows to the rank of a real catastrophe.

The subject of disasters was taken up in a broader sense in 2015 in the city of Sendai (Japan) during the Third World Conference of the United Nations (UN) on Disaster Risk Reduction. The discussion of 187 UN member states resulted in the adoption of the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) (RCB, 2021). Although no catastrophes were recorded in the operational area of Firefighting and Rescue Unit 9, the universality of the Sendai approach makes it possible to apply the directions of actions indicated therein as reference to reduce the risk of hazards (in this case, reducing the risk of fire). Due to the existing connection between fires and disasters, in this article the Sendai Framework of Actions will be applied in terms of reducing the risk of fires in the operational area of Unit 9 of SFS in Warsaw. To do this, the following objectives will be achieved:

1) Analysis of data on fires in the operational area of Unit 9 in Warsaw in 2021;
2) Development of an event profile for the resulting fires;

3) Presentation of the concept of disaster risk reduction (SFDRR) in the context of fire risk reduction;
4) Formulating guidelines to reduce the risk of fires in the operational area of Unit 9 of State Fire Service in Warsaw.

To achieve the first two goals, use was made of data collected by the State Fire Service in 2021. A holistic study combining the features of a quantitative and qualitative analysis of 232 fires presents the point of view of the emergency services and defines in detail the specificity of each fire. The tabular presentation of the analysed events allows presenting the concepts of fire risk reduction and formulating adequate guidelines, which the author specified on the basis of his own operational experience with rescue services. The results of the analysis will also be related to the 5 main ways of reducing risk: 1) minimising the impact of the threat, 2) reducing vulnerability to threats, 3) reducing exposure to threats, 4) increasing the ability to cope, and 5) increasing resilience. Due to the characteristics of the operational area of Unit 9, fires related to two categories of objects definitely dominated the other categories and accounted for nearly 75% of all fires in 2021. For this reason, the author devoted his attention to formulating risk reduction guidelines only in these categories of objects.

Given the scarcity of literature available in Polish on this subject, this article is also intended to promote risk management based on SFDRR, and to illustrate its versatility, which translates into reducing the occurrence of adverse events (not only natural disasters).

## 2. Materials and methods

### 2.1. Priority actions and global goals

The Sendai Agenda for Action (2015–2030), the successor to the Hyogo Framework for Action (2005–2015), proves the continuity of the efforts of UN countries intended to reduce the risk of disasters and their consequences. Based on the experience and observations from the implementation of the previous programme, the SFDRR distinguishes four priorities and sets seven global goals. The adopted strategy is based on close cooperation between individual entities and institutions at the local, national, regional and global level through:

1) Understanding disaster risk;
2) Strengthening disaster risk management;
3) Investing in disaster risk reduction for resilience;
4) Enhancing disaster preparedness to take effective action, including reconstruction (“Build Back Better”) (UNDRR, 2015).

SFDRR presents concepts of simultaneous disaster risk reduction and building resilience as an integral part of the 2030 Agenda for Sustainable Development and Sustainable Development Goals. These two initiatives are connected to build overall resilience (Hofmann, 2021). The term resilience can be understood as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management" (UNDRR, *Terminology: resilience*).

The Sendai Framework for Action indicates that investing in adverse event risk reduction is fundamental to economic, social, health and cultural resilience for all humanity. As a result, these measures can become a driving force for comprehensive development. Thanks to this, operations focused on reducing risk become profitable and helpful in saving human lives and limiting losses and thus faster reconstruction (UNDRR, 2015). The importance of efficient reconstruction can be seen in Japan's two biggest natural disasters after World War II, which affected Kobe and Tohoku. In both cases, long-term reconstruction resulted in significant cost increases. In the case of Kobe, public sector spending was finally 64.6% more than expected, while for Tohoku damage could be up to 89.3% more (Dąbrowski, 2019).

Global goals of SFDRR:

1) Significant reduction of global disaster mortality by 2030, by lowering the average global mortality per 100 000 people in 2020-2030 as compared to 2005–2015;
2) Significant reduction in the number of people affected by disasters by lowering the average per 100 000 people in 2020–2030 as compared to 2005–2015;
3) Reduction of economic losses directly caused by disasters by 2030 based on global GDP;
4) Significant reduction of damage caused by disasters caused to critical infrastructure facilities and disruptions in basic services, e.g. in healthcare and education facilities, among others by developing their resilience by 2030;
5) Significant increase of the number of countries with national and local risk reduction strategies by 2020;
6) Significant expansion of international cooperation with developing countries by providing appropriate assistance in implementing the Sendai Framework for Action by 2030;
7) Significant increase in the presence and availability of early warning systems against various threats, as well as information and assessment of disaster risk for the population by 2030 (UNDRR, 2015).

The UN approach highlights the importance of pursuing resilience as a countermeasure. Moreover, on the basis of the listed global goals of the SFDRR, 5 paths have been specified that should be followed in order to reduce the risk of disasters. Objectives 1–3, i.e. reducing mortality, the total number of people affected by the disaster and economic losses, can be summarized as limiting the impact of the threat. Objectives 4 and 5 make it possible to reduce vulnerability to threats, and thus strengthen weak points by, for example, developing a risk reduction strategy (objective 5). Exposure to a hazard can be linked to the exposure of people and resources in a given area. This is to a certain extent related to Goal 4, which concerns the continuity of critical infrastructure operation. International cooperation in risk reduction strategies (e.g. INSARAG – International Search And Rescue Advisory Group) and the ability to ensure the continuity of functioning of critical infrastructure can also be summarized as increasing the ability to cope with the consequences of disasters. All the goals of the SFDRR can be linked to the term of resilience, i.e. the ability of the structures of society to respond to and recover from disasters, thus restoring the necessary functions and structures in a timely manner.

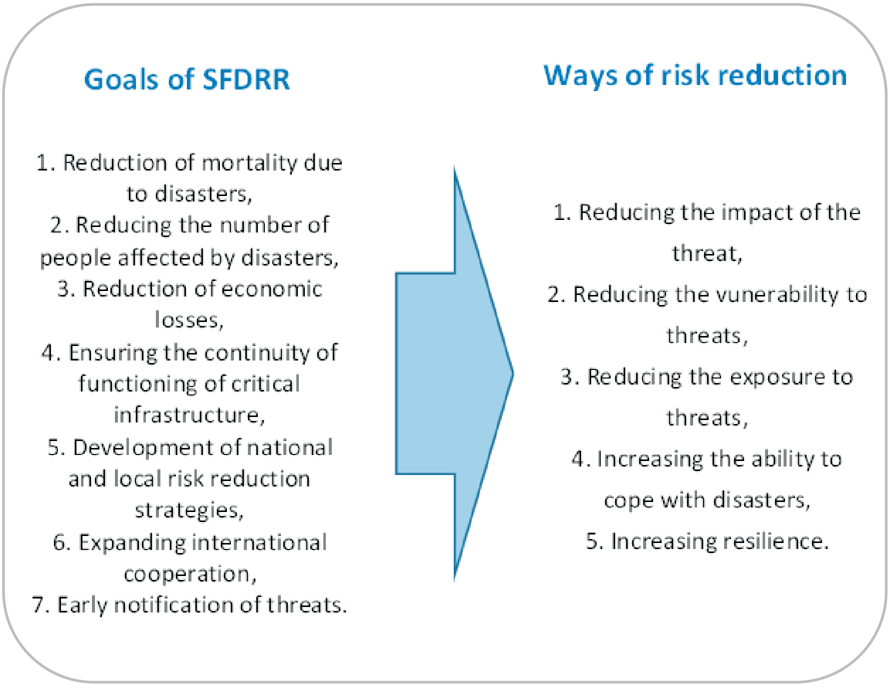


**Figure 2**. Ways of risk reduction

Source: own study based on (UNDRR, 2015; Gromek, 2021)

## 2.2. Risk assessment

Enhancing resilience requires improving the system to be able to deal with threats by for example raising risk awareness (Gromek, Sobolewski, 2020). Therefore, the risk assessment can be interpreted as a way of understanding resilience needs. In order to estimate the risk of fires in the operational area of Unit 9 in Warsaw, a wide range of detailed data should be used. Access to such a database will translate into a more effective risk assessment process. This information should primarily be based on real and up-to-date data, and should allow defining the specifics of facilities affected by fires. Currently, the State Fire Service is the leading state institution in Poland. The spectrum of threats and their characteristics translate into high operational efficiency of the formation, which as a result makes State Fire Service a prime rescue entity in the country. Nowadays the SFS makes use of the command support system (CSS) which contains a broad range of information. This makes the database of the CSS detailed and reliable for the risk assessment. Each time after completion of rescue operations, the commander of rescue operations (CRO) prepares information on the event in the form of a report in CSS. Based on the guidelines for drawing up of reports the CRO defines, among others: the class of fire consequences, the code of the facility affected by the fire, resources used in firefighting operations and the number of injured people (KG PSP, 2019). Thanks to this solution, a reliable data base is created that can be invaluable in similar analytical work. In addition, on the basis of data from CSS, it is possible to characterize the effects of each single fire using 4 classes (Tab. 1) depending on its area, cubic capacity or the number of extinguishing currents used to extinguish it.

**Table 1**. Classes of fires recorded in the State Fire Service

| A measure of consequences | Class of consequences | Requirements |
|---|---|---|
| 1 | Small (F/S) | • Burning area not exceeding 70 $m^2$ or<br>• Volume not exceeding 350 $m^3$ or<br>• Forests, fields, peat bogs and wasteland at area lower than 1 ha or<br>• Fires which require maximum 4 extinguishing jets |
| 2 | Medium (F/M) | • Burning area from 70 $m^2$ to 300 $m^2$ or<br>• Volume of 351 $m^3$ to 1500 $m^3$ or<br>• Forests, fields, peat bogs and wasteland at area from 1 ha to 10 ha or<br>• Fires which require from 5 to 12 extinguishing jets |
| 3 | Big (F/B) | • Burning area from 301 $m^2$ to 1000 $m^2$ or<br>• Volume of 1501 $m^3$ to 5000 $m^3$ or<br>• Forests, fields, peat bogs and wasteland at area from 10 ha to 100 ha or<br>• Fires which require from 13 to 36 extinguishing jets |
| 4 | Very big (F/VB) | Parameters that exceed values for F/B |

Source: (KG PSP, 2019)

Taking into account the possibility of assigning the consequence measure to specific classes (sizes) of fires, there is a way to relate data from CSS on fires to the developed method of estimating the risk of their occurrences. Interpreting the definition of risk as a derivative of the frequency of the event and its effects, the measure of risk can be expressed by the equation (Kozioł, Gromek, 2017):

$$RY_{(F)i,j} = PY_{(F)i,j} \cdot C_i \tag{1}$$

where: $RY_{(F)i,j}$ – fire risk index for $i$ – class of consequences, $j$ – category of infrastructural object in $Y$ – year; $PY_{(F)i,j}$ – frequency of events for $i$ – class of consequences and $j$ – category of infrastructural object in $Y$ – year; $C_i$ – consequence measure which corresponds to $i$ – class of consequences (Kozioł, Gromek, 2017).

Infrastructure can also be categorized based on SFS guidelines (Table 2). This allows a precise establishment of the type of facility where the fire has occurred. This information is also available in the CSS and is a component of the each event information. There are 8 categories of objects, however, due to the specificity of the operational area of Unit 9 and the lack of events related to agricultural crops and forests, this group has been narrowed down to 6 categories.

**Table 2**. Categories of objects

| Code | Name of category | Kinds of infrastructural facilities comprised by category |
|---|---|---|
| O1 | Public utility buildings | Office administration facilities, banks<br>Education and science facilities, kindergarten, school<br>Health service facilities, hospitals, sanatoriums, nursing homes, clinics, nurseries<br>Commercial and service facilities, shops, department stores, catering venues, wholesale warehouses<br>Railway and bus stations, ports, airports<br>Performance and entertainment facilities, sports facilities<br>Religious and sacral facilities<br>Museums, open-air museums, exhibitions, galleries<br>Libraries, archives<br>Prisons, detention centres, correctional facilities<br>Others |
| O2 | Residential objects | Hotels, lodging houses<br>Orphanages<br>Dormitories, student houses<br>Barracks<br>Retirement houses<br>Holiday houses, boarding houses<br>Shelters<br>Single-family buildings, including semi-detached houses, terraced houses<br>Multi-family buildings<br>Other residential objects |
| O3 | Production facilities | Production buildings<br>Outbuildings, including sheds without garages<br>Social rooms, cloakrooms, canteens<br>Technological installations outside buildings<br>Machines and technological devices<br>Pipelines |

| Code | Name of category | Kinds of infrastructural facilities comprised by category |
|---|---|---|
| O4 | Warehouse facilities | Warehouses, sheds<br>Construction sites<br>Storage yards<br>Storage tanks<br>Petrol stations<br>Fuel depots |
| O5 | Transport facilities | Road<br>Railway<br>Aviation<br>Sea<br>Inland<br>Rail public transport<br>Traction |
| O6 | Others | Free-standing trash cans, landfills<br>Trash cans inside buildings<br>Garages, car workshops<br>Monuments of culture<br>Natural objects<br>Hydro technical facilities<br>Leakages<br>Military facilities<br>Consulates, embassies |

Source: (KG PSP, 2019)

The operating area of the Rescue and Fire Fighting Unit No. 9 in Warsaw comprises the area of the Włochy, Ochota and Mokotów districts. It is a vastly urbanized area, excluding the vicinity of the Chopin Airport, which borders to the south with allotment gardens and wasteland. Table 3 presents the number of fires in the operational area of Unit No. 9 in 2021, taking into account the class of consequences of a fire and the code of the facility that was affected by the fire.

According to the table above, 232 fires occurred in the operational area of Unit 9 in 2021, which are classified as minor fires. As a result, the risk indexes will correspond with the values of the number of fires (the measure of consequence is equal to 1). Despite this, the threats that accompany "minor" fires should not be underestimated.

**Table 3**. Number of fires in 2021

| $C_i$ | Class of consequence *(i)* | Category of object | | | | | |
|---|---|---|---|---|---|---|---|
| | | O1 | O2 | O3 | O4 | O5 | O6 |
| 1 | F/S | 17 | 93 | 1 | 17 | 28 | 76 |

Source: own study based on (KG PSP, 2019)

**Table 4**. Other parameters of fires in the area of Unit 9 in 2021

| |
|---|
| Number of victims |
| 7 |
| Number of fires involving more than 11 firefighters |
| 65 |
| Number of fires involving more than 3 fire trucks |
| 56 |
| Number of fires involving Operational Group of Provincial Commander |
| 1 |
| Number of fires involving Operational Group of City Commander |
| 7 |
| Number of fires involving specialist rescue group of SFS |
| 2 (chemical and ecological rescue group) |
| Fires extinguished by more than one water current |
| 10 |
| Fires involving at least 1 extinguishing powder current |
| 8 |
| Fires involving at least 1 extinguishing foam current |
| 6 (fires of cars) |

Source: own elaboration based on SFS (CSS) data

According to the table above, 7 people were injured in the fires that occurred in 2021. Among them, 5/7 people were over 65 (people at a retirement age). In addition, 1/3 of the fires were extinguished by resources exceeding the duty shift of Unit 9 (11 firefighters). What is more, every fourth fire required additional firefighting vehicles (including light operational vehicles, e.g. operational groups or unit commander). Eight times the operational group took part in firefighting operations, of which 1 was the group of Provincial Commander and 7 times the group of City Commander. This group includes the Operations Officer and the Officers Assistant, whose task is to support the firefighting commander or to take over the command of the firefighting operation. A specialized chemical and ecological rescue group was dispatched to two fires that involved suspicious substances. In addition, 10 fires were extinguished with more than one water jet, 8 times extinguishing powder and 6 times extinguishing foam were applied (vehicle fires).

Using equation (1), the values obtained in Table 3 were converted into risk indices for individual categories of objects adopted in Table 2.

**Table 5**. Risk indices for individual categories of objects

| $C_i$ | Class of consequence *(i)* | Category of object | | | | | |
|---|---|---|---|---|---|---|---|
| | | O1 | O2 | O3 | O4 | O5 | O6 |
| 1 | F/S | 17 | 93 | 1 | 17 | 28 | 76 |

Source: own study based on (KG PSP, 2019)

## 2.3. Formulating methods of risk rationalization

In order to reduce the number of fires in a selected operational area, it is necessary to develop a catalogue presenting the degree of fire exposure of individual categories of facilities. This method is based on the method of morphological analysis, which includes the results of a holistic fire risk assessment. Moreover, in order to achieve the assumed research goal, the morphological analysis must refer to all categories of facilities (O1-O6), as well as the existing class of consequences (F/S). This is due to the fact that out of 232 fires that occurred in 2021, there were no fires with a greater consequence class than a minor fire (F/S). Consequently, the multiplication of 6 categories of facilities and 1 class of consequences gives a total of 6 potential analysis connections. This number of connections maximizes the chances of formulating practical guidelines, which translates into greater accessibility of the results received to stakeholders and decision makers. On the basis of the obtained risk indexes, categories of objects were presented according to the priorities assigned to them where: 1 – first priority (objects with the highest risk), 2 – second priority for lower-risk facilities.

**Table 6**. Prioritization of connections in the relations ”facility category – class of consequences”

| Class of consequences | Categories of facilities | | | | | |
|---|---|---|---|---|---|---|
| | O1 | O2 | O3 | O4 | O5 | O6 |
| F/S | 2 | 1 | 3 | 2 | 2 | 1 |

Source: own elaboration based on (KG PSP, 2019)

The table above presents the results of prioritization of connections ”facility category – class of consequences” assigned on the basis of the risk assessment that has been carried out. Each connection is described by a number corresponding to a risk-based priority. According to the above, residential buildings (category O2) and other facilities (category O6) such as containers, trash cans or garages are at the greatest risk of fire. On the other hand production facilities (category O3) are assigned to the last risk priority. The presented prioritization process allows specifying the most endangered groups of objects. This determines the need to pay special attention to the most endangered objects.

## 3. Results and discussion

### 3.1. Directions of activities

When considering fire safety, there are 3 basic issues to be analysed: safety of facility users, safety of the facility (structural and organizational) and the surroundings of the infrastructure in certain cases. In this regard, three issues need to be considered:

1) Hazard characteristics (level of exposure to society, scope of consequences, possibility of cascading development),
2) Operational specification (speed of spreading the threat, possible difficulties),
3) Resource needs (adequacy, limitation, obstacles).

Each of them, in certain situations, can lead to the so-called "domino effect", so the level of safety of the surroundings affects the safety of infrastructure, which in turn affects the safety of its users. A simple example would be suspicious luggage at the Chopin Airport in Warsaw. Luggage left behind always raises suspicions of a potential terrorist threat. This, in turn, forces the launch of adequate procedures: excluding part of the airport infrastructure from use, securing the luggage spot, recognizing and eliminating the threat. Therefore, it is necessary to approach the problem comprehensively and precisely identify the directions of action to reduce the risk of fires:

a) Reducing the hazard impact – reducing the impact of potentially harmful physical events, phenomena or human activities that may cause loss of life or health, property damage, social and economic disruption or environmental degradation (UNDRR, 2005),
b) Reducing vulnerability to the hazard – reduction of factors such as physical, social, economic and environmental processes that increase the vulnerability of an individual, community, resource or system to the effects of hazards (UNDRR. *Terminology: vulnerability*),
c) Shortening the exposure to the hazard – shortening the time during which people, infrastructure, production capacity or other material resources are exposed to a threat (UNDRR. *Terminology: exposure*),
d) Enhancing resilience – enhancing the capacity of a system, community or society to resist a threat and successfully recover from it (Zhou et al., 2010),
e) Increasing the ability to cope with the hazard – increasing the capacity of an organization, community or society to manage disaster risk and increase resilience by restoring their functionality (additional resources) (Gromek, 2021; UNDRR. *Terminology: capacity*).

It should be borne in mind that the combustion process that results in a fire may also arise as a consequence of other hazards. This includes:

- Traffic accident involving vehicles (road, rail) transporting dangerous (combustible) materials, such as fuel tankers, oxygen and acetylene cylinders, etc.
- Plane crash (both passenger and transport).

- Bombing (suspicious cargo at the airport).
- Occurrence of a flammable/explosive atmosphere (carelessness with an oxygen installation in the hospital, improper storage of flammable liquids – petrol canisters in cellars without ventilation, failure of the transmission system – gas).

The above directions of action can be summarized in the form of three key areas of resilience:

1. Physical resilience: the infrastructure must be physically resilient to the impact of a threat and its consequences. The facility staff responsible for its safety should be adequately prepared to use appropriate equipment.
2. Resilience of the structure and surroundings: the ability of relevant entities related to the security of a given infrastructure to react and cooperate.
3. Organizational resilience: development of multi-scenario plans and mechanisms in the event of an emergency.

These infrastructure resilience areas and key vulnerability issues can be summarized in a tabular form. Based on available literature (Gromek, Sobolewski, 2020; Gromek, Wróbel, 2017; Gromek, Wróbel, 2018) and own experience a framework for action to increase safety in the event of fire was presented (Table 6).

**Table 7**. Action framework for fire safety

| No. | Type of resilience | Resilience area | Example |
|---|---|---|---|
| 1 | Physical resilience | 1. Ability to identify physical resistance to cascading threat consequence | Use of passive and active forms of fire protection. Proper storage and marking of combustible materials. |
| | | 2. Ability to physically limit the spread of the threat | Use of non-combustible materials for interior finishing. Appropriate fire protection of the structure. Providing smoke exhaust ventilation. |
| | | 3. Physical resource flexibility | Equipping the facility with portable firefighting equipment. Providing proper service to fire protection devices. |
| 2 | Structural resilience and that of the surroundings | 1. Preparedness for the cascade of potential threats | A multi-scenario approach to possible threats to maintain continuity of operations in a crisis situation. Training of the facility staff and its users. |
| | | 2. Multi-response to threats | Knowledge of the characteristics of potential threats. Implementation of appropriate procedures: securing the spot of incident, carrying out evacuation, calling adequate rescue entities. |
| | | 3. Multi-vector cooperation | Familiarity with the facility, ability to provide comprehensive information and cooperation with other entities responsible for safety. |

table 7 cont.

| No. | Type of resilience | Resilience area | Example |
|---|---|---|---|
| 3 | Organizational resilience | 1. Ability to ensure continuity of conducting operations | Development of special action plans in emergency situations. Conducting training and exercises in the field of their implementation. |
| | | 2. A systemic approach to potential threats | Development of action plans in the event of a threat and its potential consequences. |
| | | 3. Versatility of cooperation | Equal training of personnel capable of substitutability of performer tasks in the face of a threat |

Source: own study based on (Gromek, Sobolewski, 2020)

In order to understand the risk of a single fire, it is necessary to consider its sources and place of occurrence. In the conducted risk assessment, the frequency of fire occurrence in individual categories of facilities in relations to the class of fire effects was analysed.

Based on Fig. 2 the most endangered objects have been prioritized. These are residential buildings and other buildings not included in the other categories. From the perspective of operational experience, many of the fires that occur in residential buildings are incidents resulting from the inattention of the household members. On the other hand, among the 06 group (their facilities), fires of garbage sheds, free-standing garbage dumps and containers tend to dominate. Considering that all fires in 2021 were classified as ”minor” consequences, those events did not cause any spectacular threats to the society. Nonetheless, the activities carried out by the State Fire Service and other rescue services involve costs, which in the end are charged to the state budget, and comprise primarily the costs of used fuels and consumables as well as extinguishing agents. These may also be costs related to the use of sorbents, neutralizers or dispersants, which during rescue operations may be used in the event of fires of transport means (fires as a result of collisions/accidents). In estimating the costs of rescue operations, the “Principles of analysing events for organizational units of the State Fire Service” are helpful, in particular appendix 1, which defines the components for the determination of costs, and namely (Jopek, 2016):

- Time of conducting operations by rescuers,
- Running time of motor equipment,
- Value of used extinguishing agents and neutralizers,
- The value of used and damaged rescue and personal protection equipment,
- Food and other resources (long-term operations).

Therefore, one should not jump to conclusions or underestimate the risk of fires due to the class of its consequences.

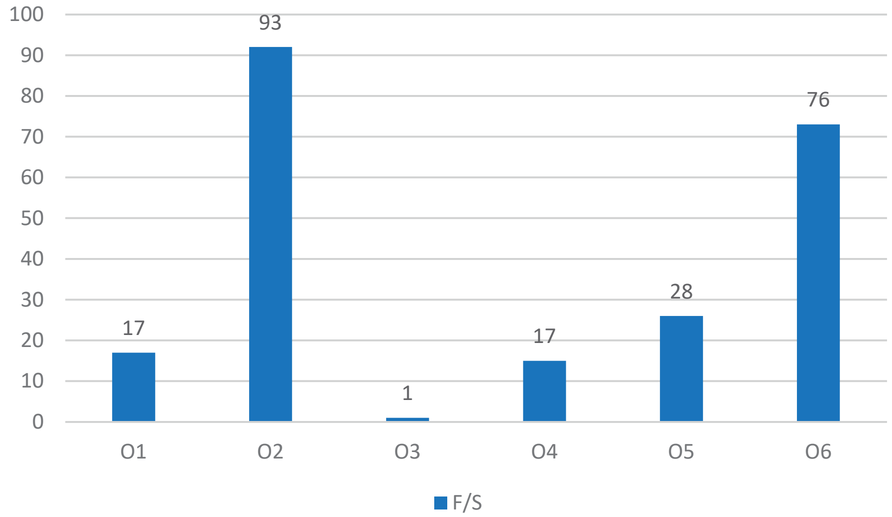


**Figure 3**. Risk indexes for individual categories of facilities
Source: own study based on (KG PSP, 2019)

### 3.2. Guidelines of fire risk reduction

Focusing on the facilities most exposed to fires, the following guidelines have been formulated.

**Table 8**. Guidelines for fire risk reduction

| Resilience area | Guidelines | |
|---|---|---|
| | Category O2 | Category O6 |
| The ability to identify and withstand the cascading threat consequence | Increasing awareness of fire safety among residents through social campaigns. Considering the introduction of fire safety training for residents. Equipping the facility with a fire detection system. | Conducting a social campaign on the possibilities of starting a fire. The use of a garbage can enclosure reducing the likelihood of starting a fire from for example a cigarette butt. |
| Ability to limit the spread of the threat | The use of active (technical) and passive (construction) fire protection means. Introduction of a social campaigns on how fire spreads. | Location of sheds and waste storage sites at a safe distance from flammable materials, including natural elements. |
| Physical resource flexibility | Equipping facilities with portable firefighting equipment and raising awareness in the society regarding its use. Performing regular maintenance. | Raising awareness in the society regarding fire extinguishing. Increasing the readiness of the society to make independent decisions in this regard. |

table 8 cont.

| Resilience area | Guidelines | |
|---|---|---|
| | Category O2 | Category O6 |
| Preparedness for the cascade of potential threats | Regular maintenance of technical installations in the facility. Compliance with the regulations on fire-hazardous works and storage of fire-hazardous materials. No parking of LPG-powered cars in underground garages. | Placing garbage cans at a safe distance from buildings in such a way that thermal radiation is not able to threaten them. Appropriate marking of rubbish bins, including the use of pictograms prohibiting the disposal of certain materials (e.g. batteries). |
| Multi-response to threats | Development and effective implementation of safety procedures in the event of a fire, for example conducting evacuation. Sufficient knowledge of the facility that allows employees to quickly reach the place indicated by the fire alarm control panel. | Early and effective alerting of entities adequate to possible threats. Raising awareness among residents about the importance of information provided during the notification to the emergency number 112. |
| Multi-vector cooperation | Preparing the building for rescue operations – fire roads, facility plans, and SOS controllers for barriers or gates. | Cooperation of SFS with other entities for example with the energy emergency service in the event of a damaged electrical installation or the police in the event of property damage due to a fire. |
| Ability to ensure continuity of conducting operations | Ensuring easy access to hydrants, water tanks for firefighting purposes. Equipping and correct marking of fire-fighting power switches. Providing employees of the facility with appropriate training in the use of the fire alarm control panel. | Provide access to the hydrant mains and access roads – not obstructing roads by improper parking and not using blockades without the possibility of their immediate release (key locks or faulty SOS systems for barriers). |
| A systemic approach to potential threats | Developing universal and accessible patterns of behaviour in the face of a fire hazard. Carrying out an information campaign in this field. | Paying special attention to thermal radiation that may arise as a result of a shed fire. Installation of electrical installations in the fire impact zone in a way that prevents their accidental contact with an outsider (cables run along the facade). |
| Versatility of cooperation | Raising awareness of fire safety in society. | |

Source: own study based on (Gromek, Sobolewski, 2020; Gromek, Wróbel, 2017; Gromek, Wróbel, 2018)

## 3.3. The perspective of the rescue services

### 3.3.1. Residential buildings

Considering that over the years fires are becoming more intense (due to the arrangement with a predominance of synthetic materials) (Kokot, 2020) the risk of loss of health and life increases rapidly (Konciak, 2015). Therefore, early fire detection translates into faster response to a threat. Although the regulations in Poland do not oblige residents to use a fire alarm system (e.g. smoke detectors), they are more and more often used as an individual initiative. Early detection and effective alarming will allow reacting at an early stage of the fire, thanks to which the household member would have a better chance of extinguishing the fire or evacuating himself. In this case, there is also a need of effective alarming so that the sound of the alarm would spread throughout the house. The best location of the detector must combine the parameter of early detection capability (e.g. kitchen) and alerting of a threat. Considering the audibility of the alarm, it would be best to leave the bedroom door open in this case. However, from the point of view of fire safety, closed doors limit the access of oxygen and the possibility of smoke spreading (Swedish Civil Contingencies Agency, 2018). For this reason, the compromise in the location of smoke detectors may turn out to be a debatable and largely individual matter. Nevertheless, the widespread use of smoke detection systems could reduce the number of calls to the SFS by at least 25% (Gilbert, 2018).

Under ideal conditions, the risk of a fire could be eliminated by strict fire prevention requirements. Unfortunately, in most cases, the human factor is to be blamed for the fire (which is confirmed by our own observations). The analyses conducted in the United States based on ignition source data from 2003-2006 distinguishes 6 main sources of ignition:

**Table 9**. Leading ignition sources in the United States in 2003–2006

| Ignition sources | Number of fires | Percent [%] |
|---|---|---|
| Intentional | 17 900 | 4.7 |
| Open fire (candle, lighter, matches) | 25 500 | 6.7 |
| Electrical installation | 21 200 | 5.6 |
| Heating devices | 67 400 | 17.8 |
| Cooking | 150 200 | 39.7 |
| Tobacco products | 13 400 | 3.5 |

Source: own study based on (Hamins et al., 2012)

Accordingly, more than 2/3 of the fires recorded by US firefighters were caused by cooking and the use of heating appliances. In such situations, there are two leading factors contributing to the resulting fires: negligence and flammability of adjacent materials. Let us take a look at the leading fire starting materials:

**Table 10**. Leading fire starting materials

| Type of material | Number of fires | Percent [%] |
|---|---|---|
| Upholstered furniture | 7400 | 3.2 |
| Mattress/bedding | 11 200 | 4.9 |
| Thermoplastic | 29 400 | 12.8 |
| Structural element/insulation | 32 500 | 14.2 |
| Other furniture or accessories | 6000 | 2.6 |
| Pots/pans | 134 900 | 58.8 |
| Interior wall covering | 8200 | 3.6 |

Source: own study based on (Hamins et al., 2012)

Most often, fires involve kitchen utensils, e.g. pots or pans. This is in line with the previous table showing the prevalence of cooking-related fires. A similar relationship can be seen between thermoplastics contained in curtains or carpets and heating devices (Hamins et al., 2012). To a large extent, fires occur as a result of several overlapping events, however, greater awareness of fire hazards and understanding of the basic phenomena occurring during a fire would certainly reduce the number of dangerous events.

### 3.3.2. Other (including sheds and free-standing bins)

In the case of the source of ignition in fires that involve dumpsters or dumpster sheds, we are most often talking about cigarette butts, i.e. unintentional (or intentional) human action. Firefighters from all over the world are struggling with this problem, and it is quite difficult to find a systemic solution to this case. Despite the material losses that are connected with garbage fires, these fires are sometimes accompanied by hidden hazards such as batteries or metals present in the garbage. Those materials reach very high temperatures during a fire and lead to rapid chain reactions in contact with water. Evolved hydrogen forms an explosive atmosphere with oxygen, which is rapidly combusted due to the current temperature. While there are tobacco products that are not hot enough to ignite after use, intentional arson is almost impossible to eradicate. However, it is possible to limit the cascading risk by placing garbage cans at a safe distance from buildings, parked cars or natural objects. Another solution may be the construction of a free-standing dumpster or a dumpster shed that allows cutting off oxygen supply to the fire by closing the lid of its housing or the entrance to the shed. However, there are two main problems, the non-combustible construction of the dumpster and the ability of the society to react independently before the arrival of the fire brigade.

## 3. Conclusions

Fire risk reduction is a complex process. Not only due to of the complex methodology, but also because of the wide range of data needed to estimate the risk. The framework of activities from Sendai provides a certain azimuth that allows perceiving potential threats in a systemic way. It emphasizes the understanding of risk connected with the hazard and managing the assessed risk and also makes it possible to understand the needs for increasing resilience to a threat. This gives the methodology of disaster risk reduction (SFDRR) a holistic view of the safety not only of the inhabitants of Warsaw, but also of the entire civilization.

In the course of an analysis of SFS statistical data on fires for 2021 on the area of Firefighting and Rescue Unit 9 in Warsaw, it was found that the greatest risk occurs for residential buildings and garbage sheds. When analysing the needs for resilience of these facilities, three areas were characterized, such as physical resilience, surroundings and structural resilience and organizational resilience. Each area has three sub-categories addressing characteristics of threat, operational specification and the need for resources for a specific resilience. The result of these considerations was the fire safety framework. The framework is concisely presented with the aim of identifying sensitive areas. In order to extend the results obtained by referring them to the directions of risk reduction that result from the SFDRR, they can be presented as follows:

a) Reducing the hazard impact – structural solutions ensuring for example the appropriate fire resistance of the building, as well as a fire detection system are an important aspect aimed at limiting the impact of fire. The key role here is played by the applicable regulations regarding for example the fire resistance of the building, depending on its intended use (category of human risk) and the height of the building. For example, in the case of new residential buildings with a height between 25-50 meters, the tightness and fire insulation of internal walls should be ensured for a minimum of 30 minutes in fire conditions (Polish Journal of Laws/Dz.U., 2002). This prevents the fire from developing within a given time. In addition it is quite likely that a few minutes after the start of the fire, the smell of smoke would alert the residents, who, based on their own experience, react very quickly to such alarming signals. The situation is different in the case of old buildings, i.e. residential houses the age of which is often over 50 years old. The problem arises not only from less restrictive fire safety regulations that result, for example, from difficult access for rescue services, but also the average age of its inhabitants whose reaction to the emerging threat is limited. This confirms my own observations that older buildings are much more vulnerable to fires. The correct response to the current fire situation can also have a significant influence on the impact of a threat. In the case of minor fires in residential buildings, attempts may be made to minimise the air supply to the fire by closing doors or windows, or by using handheld extinguishing equipment. By limiting the potential number of people injured as a result of fire, the number of people exposed to a fire or related hazards (smoke, burnt insulation of the electrical installation) should also be minimized. This can be achieved through evacuation, which should be carried out in a decisive manner (people often have no idea how to act in the event of an emergency or fire alarm, thinking that this is merely a drill or that it does not apply to them).

b) Reducing vulnerability to the hazard – in order to reduce vulnerability, certain processes related to the understanding of risks and weaknesses must take place. In the context of residential buildings, this will be largely social education thanks to which the public will become aware of fire hazards. The good will of decision-makers, such as the building administration that strive for, which will strive for systemic solutions to increase fire safety, will also be important here.
c) Shortening the exposure to the hazard – the duration of exposure to the threat will be closely related to the duration of the threat itself. In this situation, it is extremely important to notify the emergency services early. The ability to quickly extinguish a fire also involves the ability of manoeuvring fire vehicles (fire roads), and correctly marking power switches or gas valves. The last of these aspects is of particular importance, as it often contributes to prolonging the firefighting operation due to the impossibility of stopping the gas supply. An important consideration in such a situation is to equip the facility with a fire safety manual, which should be available at the entrance to the building in a locker with a key, as in the case of hydrant lockers. If the gross volume does not exceed 1000 $m^3$ (there is no requirement to develop a fire safety manual [32], a substitute solution may be to work out a building plan containing key information regarding electrical or gas installations and the possibility of their disconnection.
d) Enhancing resilience – the biggest obstacle in strengthening the system is probably due to the significant involvement of decision makers at various levels. It also requires extensive work to implement the agreed improvements. In fact, for this purpose, the Sendai Framework for Action was developed which is a comprehensive guide to increasing the resilience of societies to threats (disasters). In order to meet the requirements related to resilience resistance, one should focus on bottom-up initiatives for fire education in the society. Also good habits for fire safety should be promoted and information about the possible cascading of the resulting threat should be notified.
e) Enhancing the ability to cope with the hazard – increasing the capacity can be achieved through additional human, technical or financial resources. Knowing that quantity does not translate into quality, we are talking at this point about constantly improving the qualifications of rescue services

due to new and more numerous threats that can lead to a fire (directly or indirectly). Equipping rescue entities with equipment adequate to the existing situation may also prove to be an important factor. An example of this is the equipment of the State Fire Service in Warsaw with high-efficiency pumps capable of supplying water to the top floors of Warsaw's skyscrapers.

During the analysis, special attention was paid to the importance of public awareness of fires for fire safety. Even with the most restrictive requirements in the field of passive or active safety measures, the risk of a fire will still most likely be determined by the human factor. Therefore, the sustainable development of society must also include fire prevention. In the era of the growing power of the mass media and social media, this can be achieved through social and information campaigns.

The article does not fully exhaust the topic related to reducing the risk of a fire based on the Sendai framework, therefore there is still a wide field for discussion here. The countermeasures presented are based on the perspective of the emergency services, which is rarely found in literature. They can serve as a starting point and provide a new perspective for further analyses. The presented conclusions draw attention to raising awareness of threats among the society and give them a universal character that allows the conducted research to be related to other spheres in the area of safety.

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## REDUKCJA RYZYKA POŻARÓW W REJONIE OPERACYJNYM JRG 9 KM PSP W WARSZAWIE


### Abstrakt

Postępujący rozwój oraz urbanizacja niesie za sobą coraz większe ryzyko powstawania pożarów. W oparciu o Ramowy Program Działań z Sendai 2015–2030 oraz jego uniwersalne założenia przedstawiono koncepcję redukcji ryzyka pożarów w rejonie operacyjnym JRG 9 KM PSP w Warszawie. Posługując się bazą danych PSP, określono profil zdarzeń dotyczących pożarów, które miały miejsce na tym obszarze w 2021 roku. Analizując przyczyny powstania pożarów na terenach zurbanizowanych oraz korzystając z własnego doświadczenia operacyjnego, przedstawiono wnioski, które posłużyły do sformułowania wytycznych redukcji ryzyka pożarów.


**Słowa kluczowe:** pożar, redukcja ryzyka, SFDRR, bezpieczeństwo