EFFICIENCY OF AUTONOMOUS SMOKE DETECTORS DEPENDING ON OPERATION TIME PERIOD

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Abstract. Every year there are a lot of fires in Latvia in the residential sector and in a great number of fires people are killed. Fires often break out in the middle of the night or early in the morning, when people sleep and do not feel smoke starting to spread through housing. Fatal fires are very common fires with a small area of burning when people die inhaling poisonous burning products without even waking up. Thus, the autonomous smoke detector is compulsory equipment that should be in every home. In the event of a fire, it helps inform the inhabitants of the fires that have broken out and provides them with the opportunity to evacuate from filled with smoke rooms in good time. And time shows that smoke detectors are effective means and there are several cases where people have only saved themselves from burning homes due to hearing the sound of the smoke detector. Meanwhile, as the mandatory installation of a smoke detector in each dwelling was introduced, the Latvian State Fire and Rescue Service notes that there are more and more cases where smoke detectors are installed in dwellings, but do not work or perform their primary and sole function – to inform people of the smoke by a high sound signal. The authors of the article examined the reasons for the failure of smoke detectors, which have been identified in other countries and conducted an experiment where the effect of the dirtiness of the smoke detectors on the failure of them when smoke occurs, was checked. As well as a survey among residents of Latvia was conducted regarding whether they had installed smoke detectors in their dwellings, how much and in what rooms the detectors had been installed, what prompted them to purchase smoke detectors, whether before installation people had read the instructions for use and were informed how to correctly install smoke detectors, whether they know that for smoke detector maintenance inspection of them had to be performed and whether people did that. As part of this study, the authors examined how the service time of smoke detectors changes and whether it changes if the smoke detector is operated in different rooms and for different time periods, but their regular cleaning from dust and other dirt is not done. As well as it was checked how quickly the smoke detector would start working if the fire breaks out in the next room and the time for a person to evacuate from those rooms was calculated. The operational efficiency of the autonomous smoke detector was examined and recommendations for effective extension of its operational capacity were put forward.

Key words: fire, autonomous smoke detector, instruction, operation time, operational efficiency.

Introduction

Several studies that evaluated the impact of smoke alarms found that their presence was important for reducing fire risk. A higher percentage of fires are reported to the fire department in homes without smoke alarms than in homes with them. Ahrens [1] reports that more than 25% of reported home fires occur in homes where there are no smoke alarms or no working smoke detectors. It is worth noting that these studies relate to reported fires. Ahrens suggests that while smoke alarms are traditionally considered tools for fire protection rather than prevention, they may in many situations activate before a full fire develops, a condition the report calls “almost-fires”, thus serving to prevent some ignitions [1].

Every year there are a lot of fires in Latvia in the residential sector and in a great number of fires people are killed. Fires often break out in the middle of the night or early in the morning, when people sleep and do not feel smoke starting to spread through housing. Fatal fires are very common fires with a small area of burning when people die inhaling poisonous burning products without even waking up. Thus, the autonomous smoke detector (hereinafter – smoke detector) is a compulsory equipment that should be in every home. In the event of a fire it helps inform the inhabitants of the fires that have broken out and provides them the opportunity to evacuate from filled with smoke rooms in good time. And time shows that smoke detectors are effective means and there are a number of cases where people have only saved themselves from burning homes due to hearing a sound of the smoke detector. Data from the National Fire Protection Association (NFPA) shows that of all house fires that occurred in the US, 61 per cent occur at homes with smoke detectors and 43.9 per cent at homes without detectors. Studies show that deaths in homes without smoke detectors occur twice as often as in houses with smoke detectors [2].

Responsible services around the world understand that the smoke detector is a small and affordable device capable of saving several lives in the event of a fire. According to the data provided by the World Health Organisation, around 180,000 people a year die in fires around the world [3]. As research proves, two thirds of the total number of the victims die right at night in their sleep [4] because they cannot feel smoke or hear the noise of the fire that has broken out while sleeping.

Meanwhile, as the mandatory installation of a smoke detector in each dwelling was introduced, it has been established that there are more and more cases where smoke detectors are installed in dwellings, but do not work or perform their primary and sole function – to inform people of the smoke by a high sound signal. There are several possibilities why they do not work – the battery could discharge, the smoke detector has broken or been defective, and there is a possibility that the smoke detector has not worked because it had not been cleaned of dust and other dirt for a long time. Everyday, people who have already installed smoke detectors do not pay due attention to the need to check regularly whether the smoke detector is in working order and to maintain it, at least minimally.

As part of the National Smoke Detector Project study it was established that sixty million smoke detectors in US homes are not working. The study has shown that smoke detector batteries have been discharged, detector electronics had corrosion or detector openings were clogged with dirt, dust or grease [5].

Since the initial smoke detector was developed, research is underway to reduce the handling response time to fire sources and improve the detectors' ability to ignore interference sources (cooking activities, ranging from normal cooking to the flashing ignition of food products with the intent of identifying the printers to flashing ignition). Studies and analyses have been carried out so that the alarm before ignition is sufficient to allow people in the house to evacuate from smoke rooms in good time [6].

Reliability of the smoke detector is one of the decisive factors. Indeed, you cannot ignore even one fire detection report. If there are many false alarms, this will increase distrust, and this may lead to the disconnection of the smoke detector by the user [7].

The aim of the study was to study the effectiveness of an autonomous smoke detector during operation and to develop recommendations for effective prolongation of its operational capacity. The study uses monographic, analytical, logically constructive, and empirical methods, a method of comparing and grouping experimental data in data analysis.

Fire statistics in Latvia

In Latvia, the State Fire and Rescue Service extinguished an average of nine thousand fires a year during the period from 2015 to 2019, of which approximately one quarter of fires had broken out in residential buildings – apartments, detached houses, garden houses, summer cottages and other residential buildings. On 1 January 2020, the requirement of the Cabinet Regulation No. 238 of 19 April 2016 "Regulations on Fire Safety" (hereinafter – Fire Safety Regulations), regarding mandatory provision of an autonomous fire detector responding to smoke, came into force in Latvia [8].

Fire statistics in Latvia during the period 2015-2021 are summarised in Table 1.

Table 1

Fire statistics in Latvia during the period from 2015 to 2021 [9]

Place where fire started	Year						
	2015	2016	2017	2018	2019	2020	2021
Total number of fires	10311	9288	8714	9134	8985	6970	6717
Number of fires in the residential sector	2552	2465	2587	2087	1930	1957	1952
%	24.75	26.54	29.69	22.84	21.48	28.08	29.07

Looking at fire data specifically in residential homes over a seven-year period, we can see that the number of fires in the residential sector has decreased. There had been 1,952 fires in homes in 2021, 600 fewer than there were in 2015, when there were 2,552 fires. The number of fires in residential homes has decreased by nearly 23% in seven years. The breakdown of fires by type of dwelling is summarised in Table 2.

Table 2

Distribution of fires by residential type during the period from 2015 to 2021 [9]

Types of dwelling houses	Year						
	2015	2016	2017	2018	2019	2020	2021
Total number of fires in the residential sector	2552	2465	2587	2087	1930	1957	1952
Block of flats/ apartment	1464	1413	1498	1365	1307	1315	1243
Detached house	758	811	881	494	420	428	534
Garden house	306	212	187	202	162	176	155
Summer cottage	13	18	13	15	28	22	19
Other	11	11	8	11	13	16	1

Of the total number of fires recorded in residential homes, in 53.69% cases, the fire area did not exceed 1 m^2. Most of the fires in residential homes with a burning area of less than 5 m^2 are the result of the burning of household appliances, household electrical appliances, waste, electrical wiring, electrical switchboards and burnt food [10].

According to information compiled by the State Fire and Rescue Service, in 2021 only 32% of appartments where fires had been extinguished had an active smoke detector, while in 56% of cases no detector had been installed. In detached houses, in 33 per cent of all fires extinguished, the smoke detector had worked, while in almost 53 per cent of homes it had not been installed at all. Only 16% of summer cottages had a smoke detector, only 1% in garden houses (see Table 3).

Table 3

Activated smoke detector statistics in fires in residential homes in 2021 [9].

Place of fire	Total number of fires	Active smoke detectors	%	Smoke detectors are not installed	%	No information on the presence of smoke detectors	%
Number of fires in the residential sector	1952	575	29.46	1037	53.13	340	17.42
Block of flats/ apartment	1243	394	31.70	699	59.23	150	12.07
Detached house	534	176	32.96	1037	53.17	78	14.74
Garden house	155	2	1.29	48	30.97	105	67.74
Summer cottage	19	3	15.79	10	52.63	6	31.58
Other	1	0	0	0	0	1	100

Reasons for failure of smoke detectors

According to the National Fire Protection Organization, in the U.S. three of the five homes affected by the fire were fatalities in properties that were without smoke detectors (41%) or with smoke detectors that do not work (16%). Deaths per thousand homes are 55% lower in homes with working smoke alarms than in homes without alarms or with alarms that do not work [4]. It is known that in the fires where there were working smoke detectors but yet people died, these were people who were near the scene where the fire originated, or were disabled, or over the age of 65, or those who tried to extinguish the fire by themselves or acted extremely irrationally. It is important to mention that in almost two-thirds of cases (65%) where people had died in the fires, it was found there were smoke detectors working from batteries, rather than connected to the grid. Compared to fires where no notification system was installed, the mortality rate per thousand people decreased by only 35% if battery smoke detectors were installed, by 51% if smoke detectors were connected to the current source [10].

Between 2014 and 2018, local U.S. services responded to about 24,300 fires at homes in which a smoke detector should work, but it did not work. 410 people died in those fires and more than 1,300 had suffered. 53% of households had smoke detectors installed and active.

In 26% of cases, dwellings were not equipped with smoke detectors, in 7%, smoke detectors were not in working order, while in 14% cases fires were too small for smoke detectors to work. And if one looks at a graph of the deaths, then quite a sad statistic is reflected there. In 42% of cases, people died in those fires where smoke detectors were installed and active [10].

According to data collected by a U.S. scientist, the most common reason the detector had not worked was problems with batteries. The study's authors write that lithium batteries, still called a ten-year battery, are common in U.S. detectors because it is thought they can last a decade and should not be changed. On the other hand, studies carried out have shown that the battery needs to be checked regularly to ensure the quality of the smoke detector [10].

According to the authors of the work, unfortunately, there is also such a myth in society in Latvia that a battery can be installed in the smoke detector and one can forget about it for several years. However, as the data from the above study shows, the battery needs to be regularly inspected and monitored so that it is in working order and not disconnected from the detector contact.

Population survey on the use of smoke detectors

There is very little analysis of the situation with smoke detector owners performed over the last decade aiming to understand the knowledge of and understanding of the use and operation of smoke detectors. But there are still several researches on the topic. The focus groups were conducted across Greater Manchester (UK) from late 2013 until mid-2014. Between 2010 and 2013, 6724 accidental dwelling fires were reported in Greater Manchester. A report by Greater Manchester Fire and Rescue Service (GMFRS) shows that while smoke alarms were present in the majority of incidents, they failed to operate. Non-functioning alarms accounted for 22% of the three-year total where alarms failed to operate. GMFRS incident data were previously analysed to reveal which groups are less likely to own a smoke alarm.

The focus groups aimed to address attitudes towards smoke alarm ownership. Six focus groups with members of the purposefully sampled groups, plus a pilot focus group with undergraduate students in higher education who lived in the private-rented sector were surveyed. Irrespective of ownership, almost all participants understood the purpose of installing the fire detectors and their importance. Despite this, the participants who did not own the smoke detectors acknowledged that abscence of smoke detectors was dictated rather by reluctance than by lack of knowledge [11].

In order to clarify the situation in Latvia for the given moment, the authors of the work carried out a survey of residents regarding the use of smoke detectors. The survey included 11 questions and the survey was distributed to the population via social networks, as well as residents were asked verbally and a questionnaire was completed. As a result, 296 respondents participated in the survey.

After collecting the information gathered during the survey analysis, the authors of the work can conclude that smoke detectors have been installed by a large proportion of the population (80% of respondents in the survey). There is a positive trend that a large number of respondents (45% of all those with smoke detectors installed) have more than one smoke detector installed in their homes. People also say that it is not enough to install one detector in a dwelling, but everything depends on the number of premises, the area of the dwelling and other factors. People with smoke detectors thinking about their safety understand that one smoke detector is not enough (75% of respondents) to be timely informed at the time of the fire. It is also positive that 72% of those surveyed who have home detectors responded that they did so because of safety concerns. People had the right thinking and motivation - to take care of the safety of themselves and those around them, rather than buying a smoke detector just because the Cabinet of Ministers requires it, or because of the fear of being punished.

Practical experiment for activation of smoke detectors

As part of an experiment to establish the activation of smoke detectors, in the event when the smoke detector is brand new and in cases where smoke detectors have been operated for three and six months in the rooms and kitchens of the detached houses and multistorey building apartments, without any maintenance, research work was carried out. This experiment will show whether inadequate operation of smoke detectors affects its sensitivity and ability to work as quickly as possible – this is without any kind of cleaning and whether there is a difference in which place the smoke detector is located.

Two scenarios were envisaged in the experiment:

- the smoke detector located in the room where the fire has occurred (hereinafter – room 1);
- the smoke detector located adjacent to the room in which the fire broke out (hereinafter – room 2).

The building where the experiment was organised had two rooms with an area of 4.2 m^2 and 5 m^2. For each artificially formed fire, the same raw material was used: fabric for upholstery finishes of 40 × 40 cm in size and porolon of 30 × 30 cm below. The choice of materials was influenced by the fact that in most fires in apartments it is furniture – sofas, chairs and beds containing these materials – that burns. The material was set on fire with fire cubes for the fireplace and barbecue, which allows burning to be developed quickly. Each experiment was repeated five times.

For the first time, each smoke detector was placed in one room and a fire was modulated five times for each smoke detector. This was done to establish the average working time. Each smoke detector was then placed in an adjacent room and the time it worked was checked.

The following smoke detectors were tested five times in each room:

- new smoke detectors from packaging;
- smoke detector from the apartment living room that was operated for three months;
- smoke detector from the apartment living room that was operated for six months;
- smoke detector from the apartment kitchen operated for three months;
- smoke detector from the apartment kitchen operated for six months;
- smoke detector from the living room of the private house, which was operated for three months;
- smoke detector from the living room of the private house, which was operated for six months;
- smoke detector from the private house kitchen operated for three months;
- smoke detector from the kitchen of the private house that was operated for six months.

The new smoke detectors were purchased from one of the leading providers of fire protection services and equipment in the Baltics.

The experimental data (time) from the start of the fire to the signal from the smoke detector was recorded by a stopwatch and analysed by the method of comparing and grouping the data.

Table 4 summarises the average activation times of the smoke detectors resulting from the experiment.

Table 4

Smoke detector activation data obtained

Pre-installation location of the smoke detector	Experiment room	Activation time, min		
		new	3 months	6 months
Apartment/ room	1	00:43	01:14	01:19
Apartment/ room	2	01:09	01:35	02:10
Apartment/ kitchen	1	00:43	01:30	02:23
Apartment/ kitchen	2	01:09	02:08	03:15
Detached house/ room	1	00:43	01:14	01:25
Detached house/ room	2	01:09	01:40	01:46
Detached room/ kitchen	1	00:43	01:32	02:13
Detached house/ kitchen	2	01:09	02:07	02:56

Summarising all the above information, the authors of the work can conclude that, in case of this experiment, smoke detectors, during operation when they were not serviced, responded to smoke later than the detectors that were not operated. The detectors, which were placed for three months in the living rooms, activated an average of thirty seconds later than the new detectors, both in the first and second rooms. In addition, smoke detectors placed in living rooms for half a year and tested in the first room worked on average forty seconds later than the new ones. In the second room, the working times of these smoke detectors varied slightly – the smoke detector in the apartment worked one minute later compared to the new one. But the detector in the detached house room was thirty-seven seconds later compared to the new one. According to the authors of the work, such a difference is not very significant, but still it

is. You cannot assess and compare the pollution size of each smoke detector with a glance. They look roughly the same in external signs - there is small dust on the surface, you can see that smoke detectors have been used and are not new.

Determination of critical evacuation time

During the fire outbreak it is very important to evacuate from the danger zone as soon as possible, so that dangerous factors, such as toxic substances, temperature or declining oxygen concentrations do not start to affect the person. Each of these dangerous factors occurs in its own time, they almost never occur all at once together. It is important to evacuate from the building before any of these factors occur. Smoke detectors are the ones that respond quickly to smoke and inform people as soon as possible of the smoke that has developed. They allow timely departure from the danger zone before the building has been overfilled with smoke and toxic substances and the amount of oxygen in the premises has reduced.

A critical evacuation time determination has been carried out in rooms where fires were modulated and smoke detector service times were checked to determine if smoke detectors would be able to inform people of the fire that broke out before the critical fire time sets in.

The time of occurrence of the critical temperature was determined using formula (1) [7]

$$T_t = \sqrt[3]{\frac{W*c*(t_{crit} - t_{start})}{(1-\varphi)*\pi*Q*n*v^2)}}\ , \tag{1}$$

Where W – air space, m^3;
c – air heat capacity, $kkal\cdot(m^3\cdot ^oC)^{-1}$;
t_{crit} – critical room temperature, ^oC;
t_{start} – starting temperature in a room, ^oC;
φ – coefficient of heat loss due to warming of surrounding objects and structures;
Q – heat of combustion of the substance, $kkal\cdot kg^{-1}$;
n – load burning rate, $kg\cdot(m^2 min)^{-1}$;
v – rate of fire spread, $m\cdot min^{-1}$.

The critical fire duration leading to the concentration of toxic substances dangerous to human life is calculated according to formula (2).

$$T_{CO} = \sqrt[3]{\frac{W*p}{g*n*\pi*v^2}}\ , \tag{2}$$

where p – maximum permissible concentration of the substance under fire conditions, $km\cdot m^{-3}$;
g – amount of toxic substance released from the amount of combustible substance, $kg\cdot m^{-3}$.

Determination of the critical time of oxygen concentration in the air is based on formula (3).

$$T_{O2} = \sqrt[3]{\frac{0.07W}{\pi*n*v^2}}\ , \tag{3}$$

where T_{02} – oxygen consumption by burning 1 kg of substance, $m3\cdot kg^{-1}$.

For the determination of the allowable evacuation time, we use all three determinations according to formula (4).

$$T_{allow} = k_0*\min(T_t, T_{CO}, T_{CO2},\ldots,T_{O2}), \tag{4}$$

where k_0 – safety factor, which is assumed to be 0.8.

The critical temperature setting time, critical fire duration and critical time for reducing oxygen concentrations in the air were determined for both materials used in the experiment, porolone and cotton. The data obtained was used in calculating the permissible evacuation times at burning of both materials.

The results of the calculation are presented in Table 5.

Table 5

Calculation results for combustion of cotton and porolone

Burning material	Time, min			
	T_t	T_{CO}	T_{O2}	T_{all}
Cotton	4:29	50:82	11:23	3:42
Porolone	2:45	17:20	2:99	1:10

Calculations show well that if porolone burns, then the allowable evacuation time decreases three times compared to when cotton burns. Porolone is a material at which burning the critical temperature of burning occurs relatively quickly, and the oxygen concentration in the air decreases quickly.

If comparing the activation of smoke detectors with the permissible evacuation time (for the room where the experiment took place) (Table 6), it can be concluded that if cotton (or, for example, any other material with similar heat of combustion of the substance, rate of burning of the load, amount of release of toxic substances from the amount of combustible substance and oxygen consumption by burning the same mass of the substance) burns, the smoke detector in both the first and second rooms is likely to activate before the time of occurrence of the dangerous fire factors and the person will be able to evacuate from the room (although everything also depends on a person's reaction time).

Table 6

Data on the activation time of smoke detectors and permissible evacuation time from premises

Pre-installation location of the smoke detector	Experiment room	Activation time, min			T_{all}	
		New	3 months	6 months	Cotton	Porolone
Apartment/ room	1	00:43	01:14	01:19	03:43	01:10
Apartment/ room	2	01:09	01:35	02:10		
Apartment/ kitchen	1	00:43	01:30	02:23		
Apartment/ kitchen	2	01:09	02:08	03:15		
Detached house/ room	1	00:43	01:14	01:25		
Detached house/ room	2	01:09	01:40	01:46		
Detached room/ kitchen	1	00:43	01:32	02:13		
Detached house/ kitchen	2	01:09	02:07	02:56		

On the other hand, as the data from the experiment shows, if a porolone or a similar material is burning in a fire, then there may be a possibility that a smoke detector will not help a person evacuate from the danger zone sooner, because the smoke detector will respond to smoke after the time of the dangerous fire factors occurring in the premises.

It can be seen that the new smoke detectors in both the first and second room activated on average before the time of the dangerous fire factors set in. The smoke detectors that were in operation for three and six months in living rooms were able to respond to smoke in the first room at approximately the same time when the dangerous fire factors occurred in the rooms, according to calculations. In the second room, however, these smoke detectors were delayed from 25 seconds to one minute compared to the allowable evacuation time. All the detectors, that had been in the kitchen for three and six months, worked later than the time when the dangerous fire factors would occur, according to calculations. In particular, in the second room, the time of activation of smoke detectors are drastically higher than the time when the dangerous fire factors occurred – in the kitchen of the apartment, the half-year-old smoke detector activated after three minutes and fifteen seconds, almost three times more than the permissible evacuation time. It can be concluded from all of the above mentioned that smoke detectors, which were in operation and were not adequately maintained and cleaned, were not capable of responding to smoke and of signalling smoke before the time of occurrence of the dangerous fire factors.

Conclusions

1. The experiment showed that the new autonomous smoke detectors, which had not been previously operated, responded to smoke faster than the operated and unserved smoke detectors, while the smoke detectors, which were operated in the kitchen, responded to smoke later than the smoke

detectors operated in the living room, from which it can be concluded that a dirtier smoke detector responds to smoke later.

2. The hours of service of the smoke detectors located adjacent to the room in which the fires were modulated exceeded the time of occurrence of the dangerous fire factors in the event of burning of porolone, from which it follows that one smoke detector in the living quarters cannot warn people in good time of the resulting smoke during a critical evacuation period, in particular if the fire occurred in the adjacent room.
3. The authors of the work recommend increasing the minimum number of autonomous fire detectors in apartments in the fire safety regulatory enactments, making it mandatory to place them in bedrooms, children's rooms and corridors if they serve as escape routes, as well as making it mandatory to leave the requirement that there be an autonomous fire detector on the apartment floor of each single or multi-apartment facility.
4. It is necessary to update information in the public space that smoke detectors must be serviced and have an expiry date and that it is not possible to use detectors after they have expired.

Author contributions

Conceptualization, I.S.; methodology, I.S., V.J. and M.Z.; validation, I.S.; formal analysis, I.S. and V.J.; investigation, I.S. and M.Z.; data curation, I.S., V.J. and M.Z.; writing-original draft preparation, I.S.; writing-review and editing, I.S., V.J. and M.Z.; project administration, V.J.; funding acquisition, V.J. All authors have read and agreed to the published version of the manuscript.

References

[1] Ahrens M. Smoke alarms in US home fires. National Fire Protection Association, Fire Analysis and Research Division Quincy, MA, 2019.
[2] Crapo W.R. Smoke Detection and Life Safety. Fire Engineering, 00152587, May2000, Vol. 153, Issue 5
[3] Estonian Rescue board. (2022) Tulekhajud 2021 [online] [20.10.2022]. Available at: https://www.rescue.ee/files/2022-04/tulekahjud-2021-a4.pdf?fbf4bf00c8
[4] Fire Safety CWS. (2022) Smoke detector maintenance [online] [21.10.2022]. Available at: https://www.cws.com/en/news/smoke-detector-maintenance-2022-04-11
[5] Cooper, Leon. Does your smoke detector really work? Consumers' Research Magazine, 00952222, Oct. 96, Vol. 79, Issue 10
[6] Milke J., Zevotek R. Analysis of the Response of Smoke Detectors to Smoldering Fires and Nuisance Sources. Springer Science + Business Media New York. Manufactured in The United States DOI: 10.1007/s10694-015-0465-2
[7] Shin H., Noh J. Kim D., Kim Y. The System That Cried Wolf: Sensor Security Analysis of Wide-area Smoke Detectors for Critical Infrastructure. ACM Transactions on Privacy and Security, Vol. 23, No. 3, Article 15. Publication date: June 2020.
[8] LR Ministru kabineta noteikumi Nr. 238 "Ugunsdrošības noteikumi" (LR Ministry Cabinet regulations Nr. 238 "Fire-Prevention Regulations") [online] [13.10.2022.]. Available at: https://likumi.lv/ta/id/281646-ugunsdrosibas-noteikumi (In Latvian)
[9] Valsts ugunsdzēsības un glābšanas dienests, 2021.gada operatīvā darba analīze (State Fire and Rescue Service. Operational work analysis, year 2021). VUGD: 2022, 27 p. (In Latvian)
[10] Fire Safety Journal. (2021) Analysis of the effectiveness of the smoke alarm obligation – Experiences from practice [online]. [14.09.2022]. Available at: https://www.sciencedirect.com/science/article/pii/S0379711220307815
[11] Clark A., Smith J. Owning and testing smoke alarms: findings from a qualitative study. Journal of Risk Research, 2018 Vol. 21, No. 6, pp. 748-762. DOI: 10.1080/13669877.2016.1240707