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THE FIRE RISK ANALYSIS OF MONGOLIA

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ABSTRACT

In recent years, the frequency of fires has been on the rise due to climate change, urbanization, and population concentration, leading to escalating damage and losses. This study seeks to showcase the potential of mathematical modeling in assessing fire risk levels on a global scale, drawing on statistical analysis of fires across Mongolia. The findings can inform strategic planning for fire prevention and mitigation efforts, aiding in effective risk management.

KEYWORDS

Fire Statistics, Fire Danger, Fire Risk Level, Types of Homes, Residential Buildings and Structures in Which The Population Lives

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Introduction.

Fire risk assessment is essential for implementing measures to safeguard people, animals, property, and the environment from fire hazards, ensuring safe living conditions, and serving as a foundation for urban and engineering development planning.

Risk can be interpreted in various ways depending on the context. According to the Mongolian Standard Risk Management MNS ISO 31000-2020, risk is defined as the uncertainty that affects achieving objectives. "Explanation 1: Uncertainty is a deviation from expected outcomes, which can be positive, negative, or both, creating opportunities or threats. Explanation 2: Objectives can vary in direction and scope, applicable at different levels. Explanation 3: Risk is typically described in terms of sources, potential events, consequences, and probabilities.

Risk is connected to various aspects of events in the world. The concept of risk theory originated from the theory of probability introduced by the French physicist Blaise Pascal. In 1703, the German mathematician and philosopher Gottfried Leibniz further developed it by incorporating the theory of relativity of uncertainty. He emphasized that the natural world generates situations that emerge and evolve in reaction to events, but not entirely predictably. His cautionary statement that "but only in the greater part" is crucial in defining risk, highlighting the limitation of predictability.

Based on information from the World Fire Statistics Center (WFSC) and the Fire Statistics Center of the International Technical Committee for Fire Prevention and Extinguishment (CPC CTIF), approximately 10 million fires occur worldwide each year. However, only 7.0-7.5 million of these fires are officially recorded, with an average of 19 fires happening every minute.

There are more than 220 countries in the world, and the global population is projected to reach 8.12 billion by August 2024, with this number expected to increase further. On average, 7-8 million fires are reported each year, leading to 85-90 thousand fire-related deaths.

Table 1. Global Fire Statistics by Country [1]

№	Country	Population thousands of people	Fire					Average annual fire	
			2018	2019	2020	2021	2022	Year	Per 1000 people per year
1.	USA	327167	1240000	1298000	1345500	1242000	1319500	1309000	4,00
2.	Bangladesh	154 331	17912	17 830	17 488	-	-	17 743	0,11
3.	Russian Federation	146 544	152959	150 437	145 900	139 500	132 844	144 328	0,98
4.	Japan	128 130	48 095	43 741	39 111	36 831	-	41 945	0,33
5.	Vietnam	93 000	2 540	2 375	2 451	3 006	4 197	2 914	0,03
6.	Germany	82 218	-	175 354	192 078	179 083	-	182 172	2,22
7.	France	66 628	281908	270 900	300 667	285 700	306 600	289 155	4,34
8.	Great Britan	63 786	192700	212 500	191 647	201 009	199 894	199 550	3,13
9.	Ukraine	42 486	61144	68 879	79 640	74 221	84 089	73 595	1,73
10.	Poland	38 413	125425	145 237	184 847	126 228	125 892	141 526	3,68
11.	Kazakhstan	17 500	13 621	14 477	14 452	13 952	14 724	14 245	0,81
12.	Switzerland	8 372	12 893	11 658	12 477	11 803	13 437	12 454	1,49
13.	Israel	8 300	52 024	-	-	47 000	-	49 512	5,97
14.	Kyrgyzstan	5 522	4 288	4 361	4 029	3 813	-	4 123	0,75
15.	Mongolia	3 201	3 819	4 222	4 561	3 710	3 536	3 970	1,24
16.	Qatar	1 975	1 158	1 135	1 179	1 444	-	1 229	0,62
TOTAL		1187573	2210486	2403276	2518539	2369300	2204713	2469718	2,0

Fire statistics from various countries worldwide compare the average annual fire rate of a country to the number of fires per 1,000 people in the total population of that country, as illustrated in Figure 1

[1] World Fire Statistics www.ctif.org

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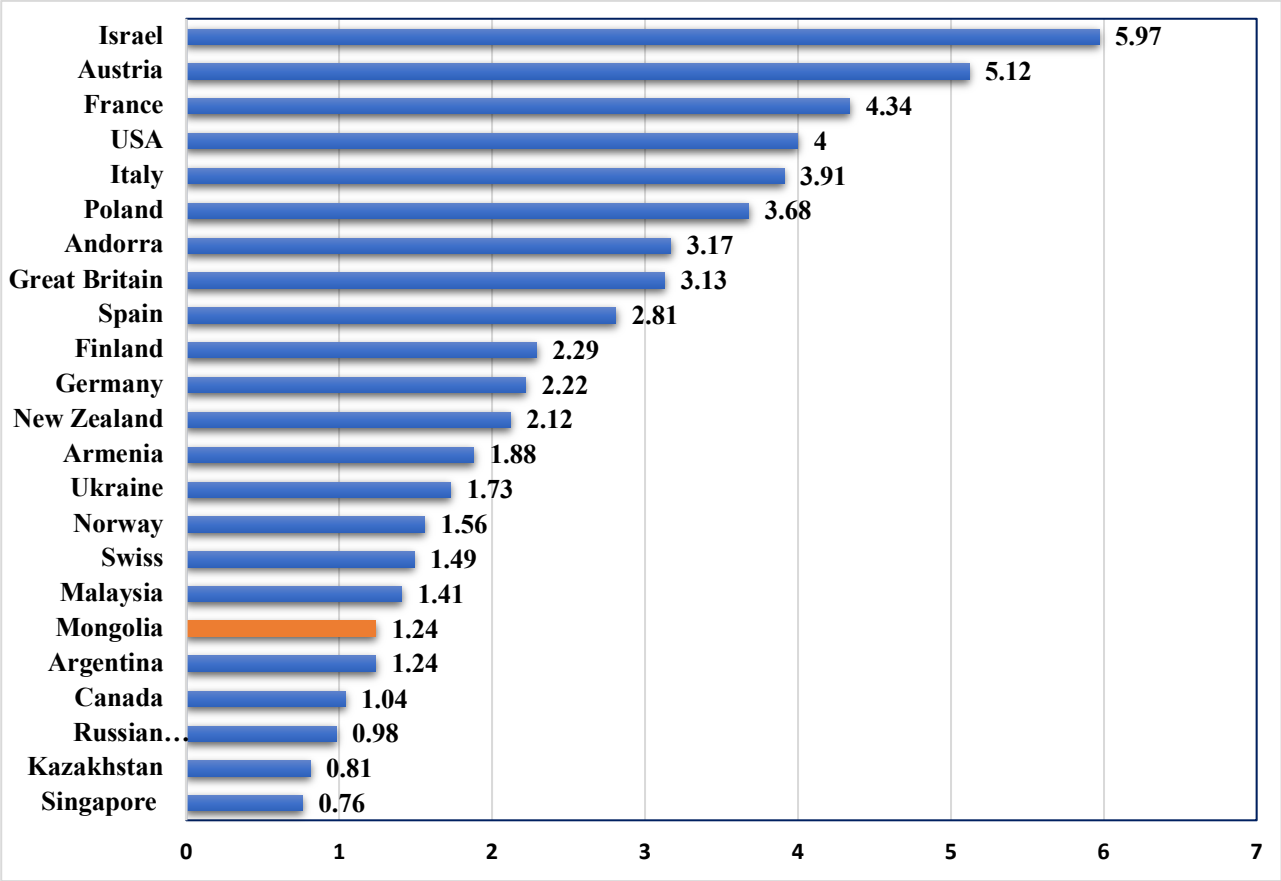

Fig. 1. Comparison of fires per 1,000 population

Around the globe, approximately 70-75 thousand individuals lose their lives in fires annually, with around 1 million sustaining injuries or burns. The majority of fatalities (65-75%) happen during the initial stages of a fire (5-6 minutes after suffocation), with 15-20% resulting from burns, 0-10% from injuries due to building collapse, and 15% from falls from significant heights.

International researchers have compared the losses caused by fires to military losses. For example, during the Vietnam War (1961-1972), 45,925 US military personnel died, while in the United States, 143,550 people died due to fires, which is three times more than the number of deaths. Similarly, during the war in Afghanistan (1979-1989), the former Soviet Union (Russia) lost 14,500 people, while in the same period, 96,748 people died due to fires, which is 6.7 times more than the number of deaths.[1]

Over the past 5 years, around the globe, roughly 200,000 buildings and structures covering 14 million square meters have been lost to fires, rendering them unusable. This has resulted in approximately 500,000 people being displaced annually.

The significant loss can be attributed to various factors such as building architecture, structural characteristics, fire scale, delayed response measures, adherence to fire safety regulations, population density, and specific natural and climatic conditions.

From 2018 to 2022, Mongolia recorded a total of 19,668 fire calls, resulting in 258 fatalities. This data indicates that, on average, 1.3 people lost their lives for every 100 fire incidents. Table 2.1 provides further details on these statistics.

[1] Source: The Federation of Judicial Experts of the Russian Federation https://sud-expertiza.ru/ekspertnaya-ocenka-pozharnoy-bezopasnosti/

Table 2. Fire statistics across Mongolia in 2018-2022

Year	Population, millions of people			Fire			Death			Material damage, billions		
	Ulaanbaatar	Province, locality	Total	Ulaanbaatar	Province, locality	Total	Ulaanbaatar	Province, locality	Total	Ulaanbaatar	Province, locality	Total
2018	1431,0	1728,0	3159,0	3040	1182	4222	22	15	37	15,2	13,2	28,4
2019	1455,3	1736,3	3191,6	3249	1312	4561	37	17	54	16,3	12,4	28,7
2020	1482,6	1742,5	3225,1	2474	1236	3710	23	35	58	10,8	10,5	21,3
2021	1519,1	1763,6	3282,7	2479	1084	3563	13	32	45	14,6	15,2	29,8
2022	1567,7	1772,7	3340,4	2408	1204	3612	36	28	64	13,2	11,5	24,7
Annual average			3239,7	2730	1203	3933	26,2	25,4	52	14,0	12,5	26,5

Source: General Directorate of Emergency Situations database

In the last 5 years, there have been 8,828 fires (44.8% of all fires) in residential buildings and structures, leading to 255 fatalities (90% of fires). The average fatality rate is 2.8 (3) deaths per 100 fires.

The National Statistics Committee of Mongolia conducts the census every 10 years. The 2020 Population and Housing Census (PHC) provides data on the number of households in Ulaanbaatar city by type of housing, as shown in Figure 3. The survey reveals that out of the total 414,292 households in Ulaanbaatar city, 1,499,140 reside in apartments, detached houses, and houses. Additionally, 50.2 percent of the 208,049 households surveyed live in ger districts, while 50.1 percent of the population, totaling 751,157 individuals, reside in private houses and traditional Mongolian houses.

Based on the statistical data of fires in Ulaanbaatar city, the fire risk was assessed using the internationally recognized risk formula. This allowed for the calculation of the fire risk per person by comparing the annual fire risk to the number of deaths resulting from 100 fires per 100,000 population.

1. **Fire risk R1 – the ratio of fires per unit of time to the population.**

$$R_1 = \frac{N_{fire.}}{Q_{population.}}\left[\frac{Fire}{person.year}\right]; \quad (1)$$

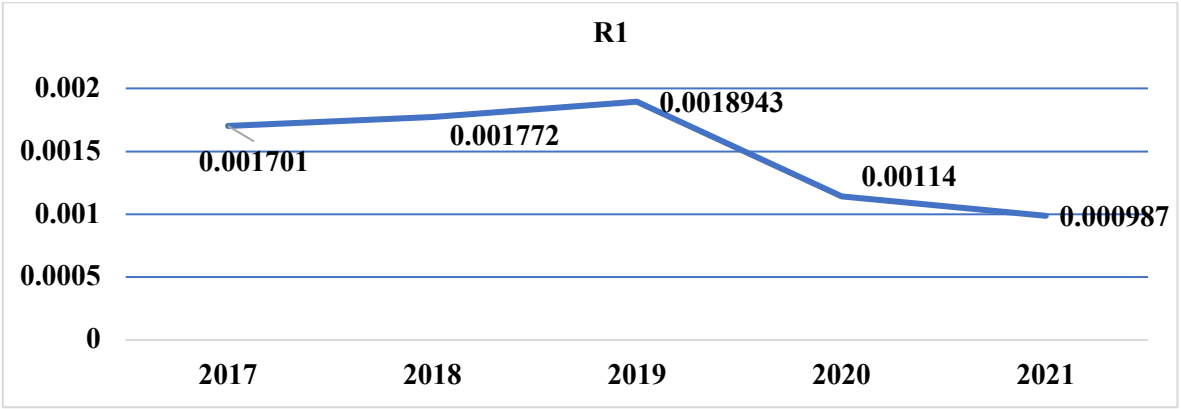

Fig 2. The ratio of fires to population.

2. Fire risk R_2

$$R_2 = \frac{Q_{death.}}{N_{fire.}}\left[\frac{Death}{10^2 fire}\right]; \quad (2)$$

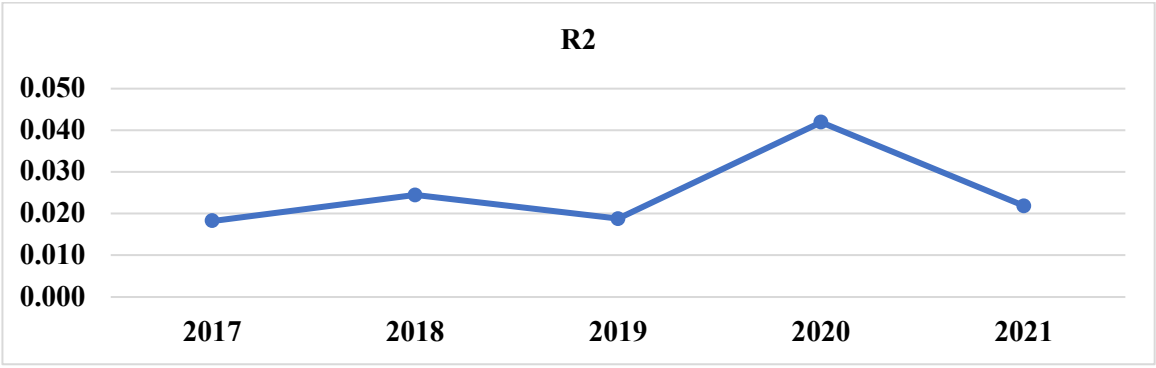

Fig. 3. The estimated of death counts from fires.

3. Fire risk R3 – probability of death due to a fire per unit time

$$R_3 = \frac{Q_{death}}{Q_{population.}}\left[\frac{death}{10^5 person.year}\right]; \quad (3)$$

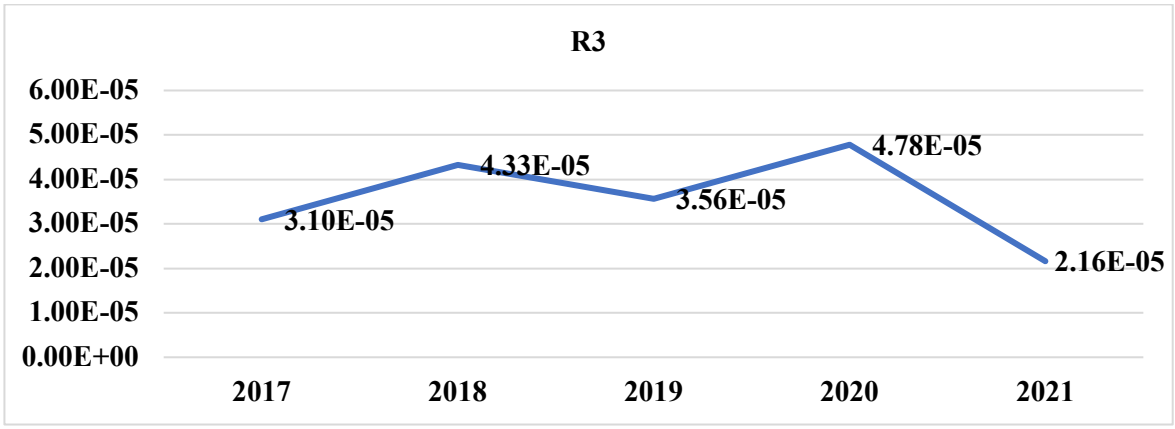

Fig. 4. Estimated probability of death due to fire

The direct fire risk can be assessed based on the interplay of R_1, R_2, and R_3.$R_3 = R_1 \cdot R_2$.

Table 3. Fire risk indicators

№	Fire Risk	$R_1 \cdot 10^3$	$R_2 \cdot 10^2$	$R_3 \cdot 10^5$
1	2017	1,70	1,82	3,10
2	2018	1,77	2,44	4,33
3	2019	1,89	1,88	3,56
4	2020	1,14	4,19	4,78
5	2021	0,99	2,1	2,16
	Fire risk of 5-years average	1,50	2,25	3,56

Based on the formula provided, Table 2 indicates that in Ulaanbaatar, where half of Mongolia's population resides, there are 1.5 fires per 1,000 individuals, 2.25 fire-related deaths per 100 individuals, and 3.56 fire-related deaths per 100,000 individuals annually.

Based on the calculations above, it is feasible to normalize the fire hazard for residents in Ulaanbaatar city based on housing type (assigning a numerical value between 0 and 1). This step involves converting each of the three primary fire indicators into a numerical value between 0 and 1 using the formula:

$$\boldsymbol{R_i^* = \frac{R_{ij} - R_{i\,min}}{R_{i\,max} - R_{i\,min}}, 0 \le R_i^* \le 1} \quad (4)$$

Where R_i^* - the standardized value of the main fire risk (i=1,2,3);

R_{ij} - the main fire indicator of residential building, structure, house j in the analyzed aimag capital city in the corresponding dimension;

R_(i min) - the minimum fire risk value of i in the analyzed numerical value of the aimag capital city;

$R_{i\,max}$ – the maximum fire risk value of the i-th province in the analysis of the capital city of the aimag being studied is denoted as R.

The main fire risks are categorized based on their significance using weighting factors, as determined by the Fishburne assessment method. These risks include:

$k_1 = 0{,}5$ indicator $R_{\text{г}}^*$;

$k_2 = 0{,}33$ indicator $R_{\text{т}}^*$;

$k_3 = 0{,}17$ indicator $R_{\text{у}}^*$

(* indicates standardized performance).

Formula (5) defines the approach for combining the three primary standardized fire risk indicators.

$$\boldsymbol{R_j^{\text{сэ}} = R_{\text{г}}^* \cdot k_1 + R_{\text{т}}^* \cdot k_2 + R_{\text{у}}^* \cdot k_3;\ 0 \le R_{\text{сэ}} \le 1,} \quad (5)$$

$R_j^{\text{сэ}}$ – the estimated result of the average indicator j of the social and economic integral of fire risk.

The level of fire risk in Mongolia can be assessed by analyzing changes in risk levels over time. Risk levels are categorized as "Red" for extreme risk, "Orange" for high risk, "Yellow" for medium risk, and "Green" for low risk (see table 1).

Table 4. Classification of fire hazard levels for the socio-economic integral of fire risk.

Numerical Value	Fire Hazard Level
(0,75; 1]	Extreme level
(0,5; 0,75]	High level
(0,25; 0,5]	Medium level
[0; 0,25]	Low level

Table 5 displays the mean categorization of fires in residential buildings, structures, and homes, derived from fires that took place in Ulaanbaatar within the last 5 years.

Table.5

Housing type	Residence	People who died in fire	People who burned in fire	Direct damage from fire and loss.
Apartment building	484907	2	1,2	1011324
Private House	854920	18	4	4602651
Yurts	1129926	32	9	3795325
Other	234	-	-	123

The table above can be utilized to assess the risk level of residents in the household based on formulas (1)–(2).

$$R_{\text{г}} = \frac{N_{death}}{N_{Residence}} = \frac{32}{1129926} = 2,832 \qquad \left[\frac{Death}{10^5 \cdot person. \cdot year}\right];$$

$$R_{\text{т}} = \frac{N_{burned}}{N_{Residence}} = \frac{9}{1129926} = 0,796 \qquad \left[\frac{burned.}{10^5 \cdot person. \cdot}\right];$$

$$R_{\text{у}} = \frac{Damage}{N_{Residence}} = \frac{3795325}{1129926} = 3,358 \qquad \left[\frac{MNT., unit.}{person. \cdot year}\right];$$

But the standard classification type:

$$R^*_{death} = \frac{R_{death\ (home)} - R_{death.\ other}}{R_{death\ (yurts)} - R_{other}} = \frac{2,796}{2,796} = 1,0$$

$$R^*_{burned} = \frac{R_{\text{т}\ (yurts)} - R_{\text{т}.\ other}}{R_{\text{т}\ (yurts)} - R_{\text{т}\ other}} = \frac{0,761}{0,761} = 1,0$$

$$R^*_{damage} = \frac{R_{damage\ (yurts)} - R_{\ damage}}{R_{damage\ (yurts)} - R_{damage.\ other}} = \frac{2,833}{4,858} = 0,583$$

The calculation of the socio-economic risk index of Mongolian ger[1] fires using formula (5):

$$R^{\text{СЭ}}_{yurts} = 1,000 \cdot 0,5 + 1,000 \cdot 0,33 + 0,583 \cdot 0,17 = 0,929$$

Table 6 shows the estimated socio-economic fire risk integral based on statistical data for each housing type. $Rsefri$ - Socio-economic fire risk integral

Table 6. Fire risk by housing type

Housing type	$R_{\text{н.б}} \cdot 10^{-5}$ $\left[\frac{Death}{person. \cdot year}\right]$	$R_{\text{т}} \cdot 10^{-5}$ $\left[\frac{burned}{10^3 person. \cdot year}\right]$	R_{damage} $\left[\frac{MNT}{person. \cdot year}\right]$	$R^*_{\text{н.б}}$	$R^*_{\text{т}}$	$R^*_{\text{х}}$	$Rsefri$
Apartment	0,412	0,242	2,085	0,147	0,318	0,321	0,233
Private house	2,105	0,467	5,383	0,752	0,613	1,000	0,748
Yurts	2,796	0,761	3,358	1,000	1,000	0,583	0,929
Other	0,000	0,000	0,525	0,000	0,000	0,000	0,000

[1] Yurts –Mongolian traditional house /Ger/

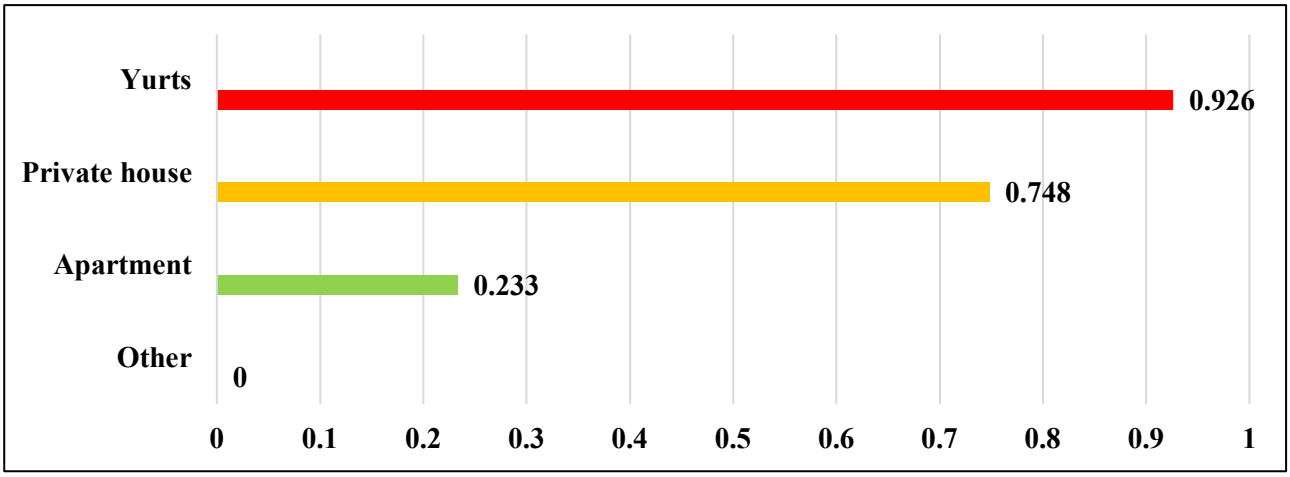

Fig. 5. Graphical comparison of fire hazard levels.

Based on the calculations, Mongolian gers and private houses are the most vulnerable types of housing. Introducing high-tech fire smoke detectors that function consistently and effectively is crucial for mitigating disaster damage, reducing fire vulnerability, and minimizing risks.

Therefore, the installation of automatic fire extinguishing systems and fire smoke and heat detection alarm systems in ger neighborhoods is essential.

A survey found that 50.2 percent of the 208,049 households, equivalent to 751,157 people or 50.1 percent of the population, reside in private houses and traditional Mongolian houses in the ger districts of Ulaanbaatar city. To ensure citizen safety, Article 51.2 of the Disaster Prevention Law mandates that "State and local administrative bodies must allocate at least 1.0 percent of the annual budget towards disaster risk reduction measures."

In accordance with this clause, meeting the legal requirement to safeguard human life, health, and property by minimizing the risk of future fires can be achieved by installing top-notch, battery-powered smoke detectors that adhere to international standards and carry UL certification.

The Russian smoke detector IP 212-52SI is priced at around 300 rubles or 12,000 tugriks, with the average cost in Mongolia ranging from 15,000 to 25,000 tugriks.

$$К = 15000 \cdot 2 \cdot 208049 = 6\ 241\ 470\ 000\ MNT$$

An investment of 6.2 billion tugriks to enhance the capabilities of businesses, organizations, and citizens in preventing fires in the capital city and minimizing damage is expected to decrease future losses.

Conclusions

A survey conducted in Ulaanbaatar city included 1,499,140 households out of a total of 414,292 households. The results showed that 50.2 percent of the 208,049 households, equivalent to 50.1 percent of the population, reside in ger neighborhoods. Additionally, 751,157 households, representing 50.1 percent of the population, live in private houses and Mongolian houses.

Over the past 5 years, an average of 1,894 fires have been reported in the Fire and Rescue Departments of the structural units of the Capital City Emergency Management Department. On average, 55 individuals have lost their lives in fires, and the average damage caused by fires amounts to 12.1 billion tugriks.

45.1% of all fires took place in homes and buildings, resulting in an average of 1.5 fires per 1,000 individuals in Ulaanbaatar. Additionally, 2.25 individuals lose their lives in fires for every 100 fires, leading to an estimated 4 deaths per 100,000 people annually.

When assessing the risk of fires in residential buildings, structures, and homes in Ulaanbaatar, Mongolian gers and private houses are identified as the most vulnerable types of housing based on the recent fire incidents.

To ensure the safety of residents in Mongolian ger and private homes, it is essential to install affordable automatic fire smoke detectors that comply with regulations in 208,049 households in ger districts. This will help detect potential fire hazards early and minimize harm to individuals while preventing the spread of fires.

To minimize the occurrence of fires in the capital, it is proposed to install two fire detection smoke detectors per household (costing 6.2 billion tugriks) as part of the Disaster Prevention Law, Fire Safety Law, and other applicable legal regulations.

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