ANALYSIS OF FIRE SAFETY SYSTEMS IN REGIONS OF LATVIA: POSSIBILITY OF BUILDING NEW FIRE STATIONS

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Abstract. More than 2 million people die and over ten million are poisoned and injured every year in the world as a result of fires, explosions and various types of accidents. In Latvia, more than 12 thousand fires occur yearly, destroying more than 3,500 buildings of different importance, bringing death to almost 100 people and causing injuries to more than 250. The experts assess the direct and indirect losses in the amount up to 5 % of GDP. The economic damages are caused not only to the national economy but also to the environment. The present study has examined the data of the Population Register during the period 2010 to 2015, which in general shows that the number of inhabitants in Latvia has declined in some regions very significantly. For example, in the town of Jekabpils the urban population has decreased by 1662 people per km^2, while the growth is observed in the towns Jelgava, Jurmala and Ventspils as well in regions neighboring Riga. The authors in their work draw attention to the possibilities of creating fire station networking and new fire stations in major cities, with the objective to find out whether the increase in the number of the fire houses will provide the possibility to save both the financial resources for extinguishing of fires and elimination of their consequences and to prevent the loss of material values and, which is most important, to save human life, as well as to identify the necessity for the construction of new fire stations in towns of Latvia's regions not only in accordance with the population density, the arrival time, as specifiedby the regulations of the Cabinet of Ministers, but also by the medical-biological criteria.

Keywords: firefighting, fire stations, fire and rescue service.

Introduction

Each year fires in Latvia kill people. This year their number in the first three months is already 32 while 89 people died in 2015. In radio and television news we hear the words "a man has burnt to death in fire...", but more than 75 % those died in fires had suffocated with the smoke in those fatal minutes even before the open flame appeared, before neighbors' or passers-by called the firefighters or also during the time interval until the fire brigade arrived at the scene, because 50 % of fires break out in the residential sector [1]. In addition, the statistical data point to a significant number of fires and the number of fatalities in Latvia (Table 1).

The authors believe that the increase in the number of the fire houses will provide the possibility to save both the financial resources for extinguishing of fires and elimination of their consequences and to prevent the loss of material values and, which is most important, to save human life, and therefore, the present article analyzes the possibilities of creating the fire station networking and constructing new fire houses in Latvian towns of national and regional importance.

Table 1

Development of number of fires and fatalities in Latvia within 2010-2016

Period	2010	2011	2012	2013	2014	2015	2016, Q1
Number of fires	8997	8812	8536	9821	12175	10311	2663
Number of fatalities	102	122	99	104	94	89	32

Source: Statistical data of the State Fire and Rescue Service [1]

To view from which funds the renovation and construction of fire stations is financed, the budget of the State Fire and Rescue Service (SFRS) should be looked over, which in 2014 amounts to 37 million EUR wherefrom 33 million are allocated to the labour compensation. Every year SFRS receives an additional funding for purchase of equipment and work clothing. The Latvia Ministry of Interior has provided the long-term liabilitiesfor the renovation of fire station buildings and construction of new ones. The Ministry's provided funding amount in 2017: EUR 10.7 million for fire vehicles and 7.7 million EUR for improvement of fire stations [1; 2].

Measures included in the action plan state that the number of SFRS fire station buildings is insufficient and the government in the budget formation has to find a funding for systematic

construction of new fire station buildings, as well as for reconstruction and renovation of the existing fire stations in Latvia [3].

1. Comparison of population density and SFRS units arrival time in 2010 and 2015 in Latvia according to the Cabinet of Ministers regulations

Time of arrival of SFRS units at the scene is determined in accordance with the territorial (towns and rural areas) principle and the population density: in Riga, Daugavpils, Jelgava, Jurmala, Jekabpils, Liepaja, Rezekne, Valmiera and Ventspils within 5 minutes after the call is received, but in other towns and in rural areas with population density 10 and more people per square kilometer – within 15 minutes after receiving the call, in rural areas with population density less than 10 people per square kilometer – 25 minutes after receiving the call [4].

Table 2

Actual arrival times of SFRS units at the scene in regional importance towns

Town	Area, km^2	2010	2015	Population density comparison 2010 vs 2015	Arrival times		
		Population density, inhabitants per km^2	Population density, inhabitants per km^2		15 min, CM Regulation	25 min, CM Regulation	Actual time, min
Aizkraukle	102	91	83	-8	15	-	16.20
Aluksne	1699	10	9	-1	-	25	18.50
Balvi	1045	14	12	-2	15	-	17.75
Bauska	786	34	31	-3	15	-	13.72
Cesis	173	109	98	-11	15	-	19.87
Dobele	888	26	24	-2	15	-	15.46
Gulbene	1872	13	12	-1	15	-	14.65
Kraslava	1079	17	15	-2	15	-	18.31
Kuldiga	1756	15	14	-1	15	-	14.73
Limbazi	1170	16	15	-1	15	-	17.04
Ludza	966	15	14	-1	15	-	17.36
Madona	2160	12	11	-1	15	-	19.24
Ogre	990	37	35	-2	15	-	20.45
Preili	364	30	27	-3	15	-	17.59
Saldus	1682	16	14	-2	15	-	17.55
Smiltene	947	14	13	-1	15		17.51
Talsi	1763	18	17	-1	15	-	17.73
Tukums	1194	26	24	-2	15	-	17.09
Valka	908	11	9	-2	-	25	17.85

Source: The Cabinet of Ministers regulations No 61 [4]; The Office of Citizenship and Migration Affairs[5]

Analysis of the Population Register data for the period 2010 to 2015 generally shows a significant change in the number of inhabitants in several municipalities of Latvia. These changes should be also accompanied by changes in services provided by the firefighters, construction of new fire stations and changes in their location in order to successfully and quickly fight the fires and cope with accidents.

To view the implementation of arrival time at the scene specifiedin the regulation of the Cabinet of Ministers, a table was created, which includes the areas of regional importance towns, population density comparison between 2010 and 2015 and actual arrival times of SFRS units compared with the standard time.

Comparing with the arrival times specifiedin the Cabinet of Ministers regulation, in 2015 a number of municipalities demonstrate a longer arrival time than the standard time provided in the Cabinet of Ministers regulation. It can be expected that in the coming years, without a change in the existing situation, the potential arrival time in a number of sparsely populated municipalities will increase, which may lead to both the increasing number of fatalities and growing material damages.

Therefore, more attention should be paid to the number of fire units and the area of the serviced territory.

2. Estimate of number of fire units

In accordance with effective building design standards, the accepted determination of locations of the fire stations uses the criterion "time required by firefighters to reach the place of fire (arrival time)". In effective regulatory enactments of the Republic of Latvia this time is specified as follows: towns and more densely populated areas – 5 minutes, rural territories – 15 and 25 minutes.

However, identification of the required number of firefighting formations, which would be sufficient from tactical point of view, as well as reasonable from economic point of view, based solely on the criterion of "arrival time", is not correct [6]. In many cases, the fire cannot be established immediately, as soon as it has broken out, or it is also impossible to inform the fire service about it. Often the firefighters receive information about the fire only when the fire from its initial stage has already gone over to the developed phase. Therefore, determination of the service radius of fire formations based solely on the "arrival time" indicator as the criterion is not sufficiently substantiated in the aspect of postconditions used in the estimate. On the other hand, addressing the issue of fire stations layout is subject to the requirements on necessary accounting and other important factors, such as driving speed, road conditions, peculiarities of the service area, district fire safety (or fire hazard) level, etc. Unfortunately, the regulatory enactments do not contain information on the determining role (effect)of the medical-biological factor as well as its impact on the operational efficiency [7].

The basis for the estimates was the operational work analysis of the State Fire and Rescue Service in 2014, and the average speed figures in both towns and rural areas were calculated based on the arrival times.

2.1. Determination of number of fire stations in national importance towns

The following formula is developed for the estimate of the number N_d of fire stations necessary for a town [8]:

$$N_d = \frac{aK_n^2 S}{V_{avg}^2 \tau_{avg}^2} + \lambda \bar{\tau}, \quad (1)$$

where S – town territory area, km^2;
K_n – street network non-linearity non-dimensional coefficient of value variable within 1 and 1.4;
V_{avg} – average driving speed of fire trucks, km·min^{-1};
τ_{avg} – average time required by fire trucks to reach the place of fire, min;
a – non-dimensional empiric coefficient accounting for the town topology, the value may fluctuate within 0.3 and 0.5.

The above formula is verified in practice, it is employed in planning of construction and layout of new fire stations in towns and municipalities. Parameters a, S, K_n incorporated in this formula take into account the peculiarities of urban infrastructure while parameters λ, τ, a, V_{avg}, τ_{avg} feature situation in the town.

Table 3

Required number of fire stations in national importance towns

City/town	Urban area, km^2	K_n	V_{avg}	τ_{avg}	a	Service territory of unit, km^2	N_d
Riga	307.17	1.4	30	9.32	0.5	10.57	29.1
Daugavpils	72.48	1.4	30	6.23	0.5	23.66	3.1
Jelgava	60.1	1.4	30	4.77	0.5	40.36	1.5
Jurmala	100	1.4	30	9.32	0.5	10.57	9.5
Liepaja	60.37	1.4	30	6.21	0.5	23.81	2.5
Rezekne	17.48	1.4	30	5.67	0.5	28.57	0.6
Ventspils	55.4	1.4	30	6.6	0.5	21.08	2.6
Valmiera	19.35	1.4	30	5.27	0.5	33.07	0.6
Jekabpils	23	1.4	30	7.81	0.5	15.06	1.5

Calculations show that Riga would need in total about 30 firefighting units, Jurmala – 10, while the least number of units is in Rezekne and Valmiera – 0.6, or one unit. In big towns with high population density the territory serviced by the units is much smaller compared to other Latvian towns, for example, according to the estimates one unit in Riga could service 10.57 km^2 area, just the same situation is in Jurmala while the largest territory would be serviced by a unit in Jelgava – 40.36 m^2. This number of fire units was estimated taking into account the driving speed, road condition and serviced region area.

However, in order to more precisely identify the required number of fire stations, it is necessary to take into consideration also the medical-biological factors not included in the regulatory enactments but having a very essential impact on the progress of rescue works.

2.2. Determination of number of fire stations according to medical-biological factors

A serious risk factor is smoke and toxic gas generation in a fire. Additional risks may be caused by the combined effects, such as explosions. Fire development speed depends on combustibility of the material and energy therein, its physical form (solid, liquid, gaseous) and oxygen availability. Fire hazard arises from accumulation of substances capable to ignite when heated or contacting other substances. Fire danger is also created by some strong oxidizers or self-igniting substances [9; 10]. According to the fire development theory and practical experience, factors hazardous to human health occur within the first five minutes after the fire has broken out.

In urban circumstances where the average driving speed of operative vehicles does not exceed 30-35 $km \cdot h^{-1}$, the firefighters can quickly, before the dangerous factors start acting, help and efficiently protect people within 1.25 km radius, i.e. within the area of 4.9 km^2. Therefore, the estimates according to the medical-biological factors are based on the urban area and the fire station service area, which is specifiedas 4.9 m^2 [11].

The service territory area according to the medical-biological factors was determined taking into account the following assumptions:

- only gas discharge from the premises takes place through the areas of free openings;
- absolute gas pressure in the premises does not change in case of fire;
- peculiar features of premises and criteria specific to combustible material (lower combustion temperature, smoke-forming capability, release of toxic and corrosive gases, etc.) do not change during combustion.

$$N_d = \frac{S}{4.9}, \tag{2}$$

where S – urban territory area, km^2;
4.9 m^2 – service territory area.

Using the above formula, it is possible to calculate the required number of fire stations at any residential location, taking into account not only its area but also the medical-biological factors.

According to the calculation results, it can be concluded that the biggest number of fire stations would be needed for the capital city Riga – 63, while the smallest number of stations, the smallest by area, for Rezekne and Valmiera – only 4 stations. Other towns of national importance need the following number of fire stations: Jurmala – 20, Daugavpils – 15, Jelgava and Liepaja – 12, Ventspils – 11, Jekabpils – 5.

Of course, in real circumstances this calculation is informative since the assessment of the need to build a new fire station in a particular territory should take into consideration the population density in each microdistrict of the town. Where the population density is very low, it would be unprofitable to build a new fire station. Given the general economic situation in the country, it would be reasonable to install automatic fire-extinguishing systems in such places.

Currently 92 fire stations are operating in the territory of Latvia. Functional efficiency of fire unitsdeployed in these stations is restricted by certain factors of fire (temperature, smoke content, fire area, etc.). These factors have a critical value, and when it is reached, the hazardous fire factors start affecting humans and animals, continuing with the fire growth [5].

However, it is necessary to solve the problem of optimal layout of fire stations together with SFRS.

Conclusions

Standards, which specify the norms for the creation of fire station networking and construction of new stations in national importance towns, have already become obsolete and do not meet the current criteria any longer. It is important to understand that the standards are of a general relative nature [12]. Respective corrections would have to be introduced for each particular town with consideration of its peculiarities. The performed analysis of statistical data shows that the efficiency of firefighting and rescue services should be improved. Statistical data on fires evidence that measures taken, norms adopted and safety requirements in the country do not provide an efficient reduction in damages caused by fires. Fire safety requirements in effective regulatory documents are defined explicitly, but such regulatory documents are missing, which would describe the methods and versions for solution of these problems.

Changes in population should be also accompanied by changes in services provided by the firefighters, construction of new fire stations and changes in their location in order to successfully and quickly fight the fires and cope with various accidents.

When specifying the fire station networking in national importance towns, the service territory of 12 km^2 average area would have to be planned for one station. Furthermore, it is recommended to take into account that in the most insecure areas of the town a station can provide service on area smaller than 12 km^2, but in any case the fire brigade's arrival time at the place of fire may not exceed 5-6 minutes.

Calculations performed by the current equation show that Riga would need 30 fire units, Jurmala – 10, while the least number of units is in Rezekne and Valmiera – 0.6, or one unit. In big towns with high population density, the territory serviced by the units is much smaller compared to other Latvian towns, for example, according to the estimates one unit in Riga could service 10.57 km^2 area, just the same situation is in Jurmala while the largest territory would be serviced by a unit in Jelgava – 40.36 m^2.

Based on the medical-biological criteria (a unit can provide service on urban area of 4.9 km^2), it can be concluded that the largest number of units would be needed in the capital city – 63, while the smallest number of units, the smallest by area, in Rezekne and Valmiera – only 4.

The tasks and activities to be carried outin accordance with the Government Action Plan specify that the number of buildings of SFRS fire stations is insufficient and the government when drawing up the budget should find a funding for systematic construction of new fire station buildings. Based on the performed study data, the authors concluded that it would be necessary to build at least 15 new fire station buildings. Assessing the technical condition of the existing buildings, it was concluded that 32 existing stations needed reconstruction and 40 – renovation, and also that the rescue vehicle fleet should be restored since the vehicles are outworn and did not meet the requirements any longer.

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