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Article

External fire-escape stairs risk analysis: A case study in İstanbul

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ABSTRACT

External fire escape stairs are used in many countries. They are recognised as building elements that can minimise loss of life in case fire safety precautions are inactive or inadequate. However, external fire escape stairs pose more risk than fire exit stairs, and they have characteristics that pose hazards during access or usage in terms of fire safety. A pilot study conducted in 10 districts of Istanbul showed that the risks are high in external fire escape stairs in the city. According to the results of this study, the districts with the highest number of hazard sources on the external fire-escape stairs are Beyoğlu, Beşiktaş, and Şişli. The aim of this study is to reveal the risks related to fire safety and to prevent or reduce the harm that these risks may cause to users by reviewing the physical conditions of the fire escape stairs in the buildings in the three districts of Istanbul, where the number of hazard sources is the highest, in order to ensure that escape from the buildings in fires is both easy and fast and does not pose a danger to the safety of the user. In this context, using a model consisting of three stages a case study was carried out in the Şişli, Beşiktaş, and Beyoğlu districts of Istanbul. Data on hazard sources were collected in a total of 600 buildings, including 200 buildings with external fire-escape stairs in each of the three districts where the case study was conducted. The risks that may be experienced in the fire escape stairs in these districts were analysed, the results of the analysis were discussed and district-based risk maps were created. The number of hazard sources questioned in the pilot study was increased by new hazard sources identified in the research project. According to the results of the analysis study, a total of 3,580 hazard sources were determined in the interrogation conducted on 18 hazard sources. Among the three districts, the district with the highest risk value is Beyoğlu and the district with the lowest is Beşiktaş. In these districts, necessary actions are decided and recommendations are developed to control the risks and eliminate or reduce the effects of the hazard sources on the users.

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INTRODUCTION

Fire is one of the most catastrophic events that threaten the safety of life and property. While it's not possible to completely eliminate the risk of fire, measures can be taken to minimise the loss of life and property if it happens (Başdemir and Demirel, 2010). Evacuating the building quickly and safely is a priority to prevent loss of life, and to do this, the most important escape route is the external fire escape stair, which is known to minimise loss of life

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in case fire safety precautions are inactive or inadequate. However, past fires have demonstrated that the risk of external fire escape stairs pose to loss of life cannot be ignored. On November 29, 2016, a fire broke out in a three-story dormitory building in the Aladağ district of Adana, and 12 people lost their lives. Loss of life was attributed to a locked fire escape door (Kılıç, 2016). On June 14, 2017, 79 people died in the Grenfell Tower social housing building fire in North Kensington, London. This 24-story building contained 129 independent sections (apartments) and nearly 350 people lived there, but it lacked a fire escape, which increased the death toll (Potton et al., 2017). In March 2018, 64 people, 41 of them children, lost their lives in a fire at a shopping mall in Kemerovo, Russia (Gigova et al., 2018). Later, it was reported that the mall alarm system was not working and some fire escape doors were locked (Neuman, 2018).

According to Istanbul Metropolitan Municipality Fire Brigade Departments' 2019 data, 22,546 fires occurred in the city of Istanbul, where 15.52 million people live. About 53.4% of the fires were building fires (4,966 houses, 179 factories, 6,895 other buildings) (Department Fire of Brigade, 2020). This rate is higher than the world average. According to the latest data (2018) from the International Fire Prevention and Protection Association, the rate of building fires in cities is 37.4% (Brushlinsky et al., 2020). When statistics for 2015 and 2019 for Istanbul are compared, a 20% decrease in housing fires and a 27% decrease in other buildings can be seen, but there has been an increase in factory fires of 8%. And 51.4% of fires occurred in the evening, approximately 36% occurred between 18.00 and 23.59, and 15.5% between 00.00 and 05.59. Approximately 22% of housing fires took place in January–February–March. Istanbul fire statistics do not show the number of people killed and injured in the fires. Only the numbers of ambulances responding to the emergency medical response to fires are given in these statistics. The number of ambulances in 2019 was 1,244 (Department Fire of Brigade, 2020).

External fire escape stairs are staircases with at least one side open to the outside environment, and they are used in many countries. For these stairs to be considered exits, they must be protected from the effects of the fire inside the building (NFPA 101, 2021). External fire escape stairs are designed similarly to fire exit stairs, but for a few rules governing the terms of fire protection for the exterior wall and the wall openings where the staircase is located. Since these stairs are open, smoke and heat have smaller impacts on preventing escapes. However, national laws do not stipulate that external fire escape stairs must be arranged in a fire-resistant slot, and therefore, such stairs pose a risk of falling, being affected by exterior conditions, and are difficult for people with a fear of heights (Jeffrey and Brain, 2007).

Most countries use external fire escape stairs and have laws governing them. External fire escape stairs are generally allowed for buildings where fires can be fought from outside the building, and this is accepted as the access limit of the countries' fire-fighting systems. External fire escape stairs are generally allowed except in high-rise buildings, and the height limit for buildings varies by country. The countries with the lowest building height limit are the UK and Canada (18.00 m), and the country with the highest limit is Australia (25.00 m). This value is 20.00 m in Russia, 22.86 m in the US, and 24.00 m in Sweden. External fire escape stairs in Turkey can be used instead of internal fire exit stairs in new buildings up to 21.50 m high if they comply with the relevant conditions. The section of the same regulation permits the use of these stairs on existing buildings up to 51.50 m in height for residences and in other buildings up to 30.50 m (Turkey's Regulation on Fire Protection, 2015).

In addition to a height limit, some countries have other rules as well. In the US, external fire escape stairs are allowed in buildings of up to six floors provided that parts of the building have access to the roof or the roof of a neighbouring building, its materials and building elements are fire-resistant, and the fire escape route from the roof is always safe (NFPA 101, 2021). In the UK, an external fire escape stair can be used if it is not the only escape route, that there is a fire exit stair in the building and it serves each floor (BS 9999, 2017). In Sweden, external fire escape stairs must be built separate from the building, and there must be a protected hall providing access from each floor to prevent fire and smoke from reaching the stairs (BBR 2016:6, 2016). In Russia, external fire escape stairs are allowed if they are made of non-combustible materials, there are no windows opening on the stairs, the height of the railing is not less than 1.20 m, and there is at least 1.00 m distance from the window (SNIP 21-01-97, 1997).

Although there are different rules regarding fire escape stairs in the laws of the countries, it is important to determine the risks that may occur in the fire escape stairs of the existing building stock and new structures and to produce solutions accordingly. For this reason, a study specific to Istanbul was carried out. This study includes the results of a scientific research project carried out at Yıldız Technical University. The aim of this study is to reveal the risks related to fire safety and to prevent or reduce the harm that these risks may cause to users by reviewing the physical conditions of the external fire escape stairs in the buildings in the three districts of Istanbul, in order to ensure that escape from the buildings in fires is both easy and fast and does not pose a danger to the safety of the user.

Before this study, which was carried out within the scope of the scientific research project, a pilot study was conducted in 10 districts of Istanbul with different characteristics in many ways to determine the risks of fire escape stairs in buildings. Data were collected from a total of 200 buildings with a random sampling method, including 20 buildings with fire escape stairs in each district, and a city-based risk map was created according to the risk scores obtained. The results of this study showed that the risks in the external fire escape stairs in the city are high. In the ranking of hazard source scores, Beyoğlu, Şişli and Beşiktaş are in the first three places among 10 districts (Avlar and Yıldırım, 2020). As stated in the conclusion section of the pilot study, it is assumed that the recommendations to be developed as a result of large-scale screening and preparation of district-based risk maps in the districts where the number of hazard sources in the external fire escape stairs is high and the risk score is high will be beneficial and contribute to the prevention of risks related to fire safety in existing buildings in three districts of Istanbul.

RESEARCH MODEL

The study includes quantitative research. In the study, the research model in Figure 1 was used. This model is adapted to the Risk Analysis Model for Fire Escape Stairs (DKM-RAM) developed by Avlar and Yıldırım. Consisting of three stages, the research model's first stage includes a case study collecting data pertaining to hazard sources. According to the results of the pilot study conducted in Istanbul, Beyoğlu, Beşiktaş, and Şişli districts with the highest number of hazard sources in the external fire escape stairs were selected for the case study. The study prepared an identification form for each building with a total of 22 questions about 18 hazards regarding access and use in terms of fire safety as well as the number of floors and their functions that might change their hazard impact coefficients. The number of hazard sources questioned in the pilot study was increased by new hazard sources identified in the research project. The data collected was then transferred to district inspection forms, so that the model could be fully and flawlessly implemented. As a result of the emergence of comparable quantitative data sets, these data sets were analysed and it was determined whether the hazard sources in the external fire escape stairs had a significant effect on fire safety.

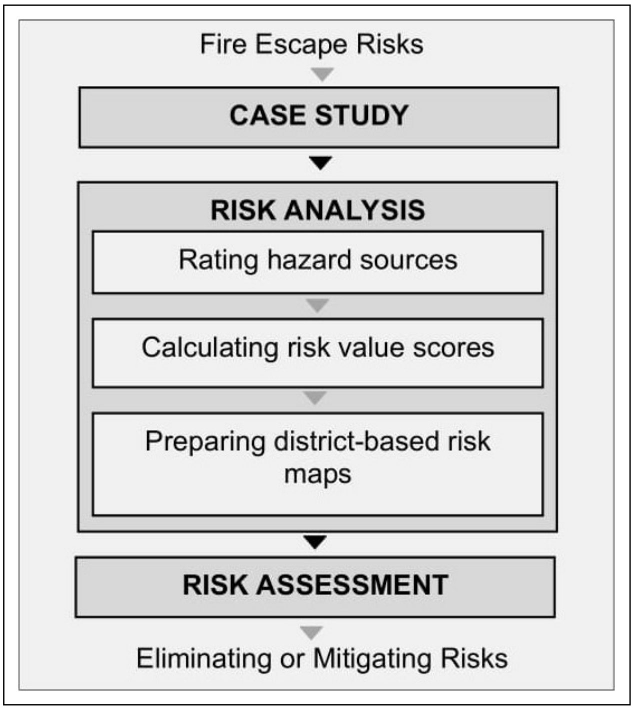

Figure 1. The research model used in the study (adapted from Avlar and Yıldırım, 2020).

The second stage of the model was a risk assessment. According to the data obtained from the case study in the first step of this stage, the hazard sources on the external fire escape stairs were rated by a calculation based on the following formula: Hazard rate - % **(R)** = Number of Hazards **(N)** / Number of Stairs **(S)**. The number of hazards is determined not by the frequency of damage caused by hazards, but by their repetition in different buildings. This value is the number of external fire escape stairs each with a different hazard. According to the resulting hazard rates, hazard coefficients were defined as in line with the acceptances R=0–5 – F=1 (insignificant), R=6–15 – F=2 (low), R=16–40 – F=3 (average), R=41–70 – F=4 (high) and R=71–100 – F=5 (critical). Later, hazard risk value scores were calculated using the following formula: Risk Value (V) = Hazard Coefficient (F) × Hazard Impact Coefficient (E). The hazard effect coefficient (E) is the degree of damage that may occur after the realisation of the hazards posed by the hazard sources, and a value is determined according to the level of risk that the hazards may pose to users. This coefficient rates the seriousness of hazards on external fire escape stairs as first-aid free (1), first-aid-outpatient treatment (2), mild injury-inpatient treatment (3), severe injury-long-term treatment (4), and loss of life (5) (Avlar and Yıldırım, 2020).

In the last step of the second stage of the model, the results of the risk analysis are discussed and risk maps are created to determine the risk values on the external fire escape stairs of the three districts. The risk maps prepared in this step are district-based. In the last stage of the model, by evaluating the risk value scores, the necessary actions are decided to control the risks in the districts and to eliminate or reduce the effects of the hazard sources on the users.

CASE STUDY

The case study was carried out in the Beşiktaş, Beyoğlu, and Şişli districts of Istanbul. Located in the Boğaziçi region, these neighbouring districts are bordered by Sarıyer in the North, the Bosphorus to the East, Kağıthane in the West, and the Golden Horn in the South (Figure 2).

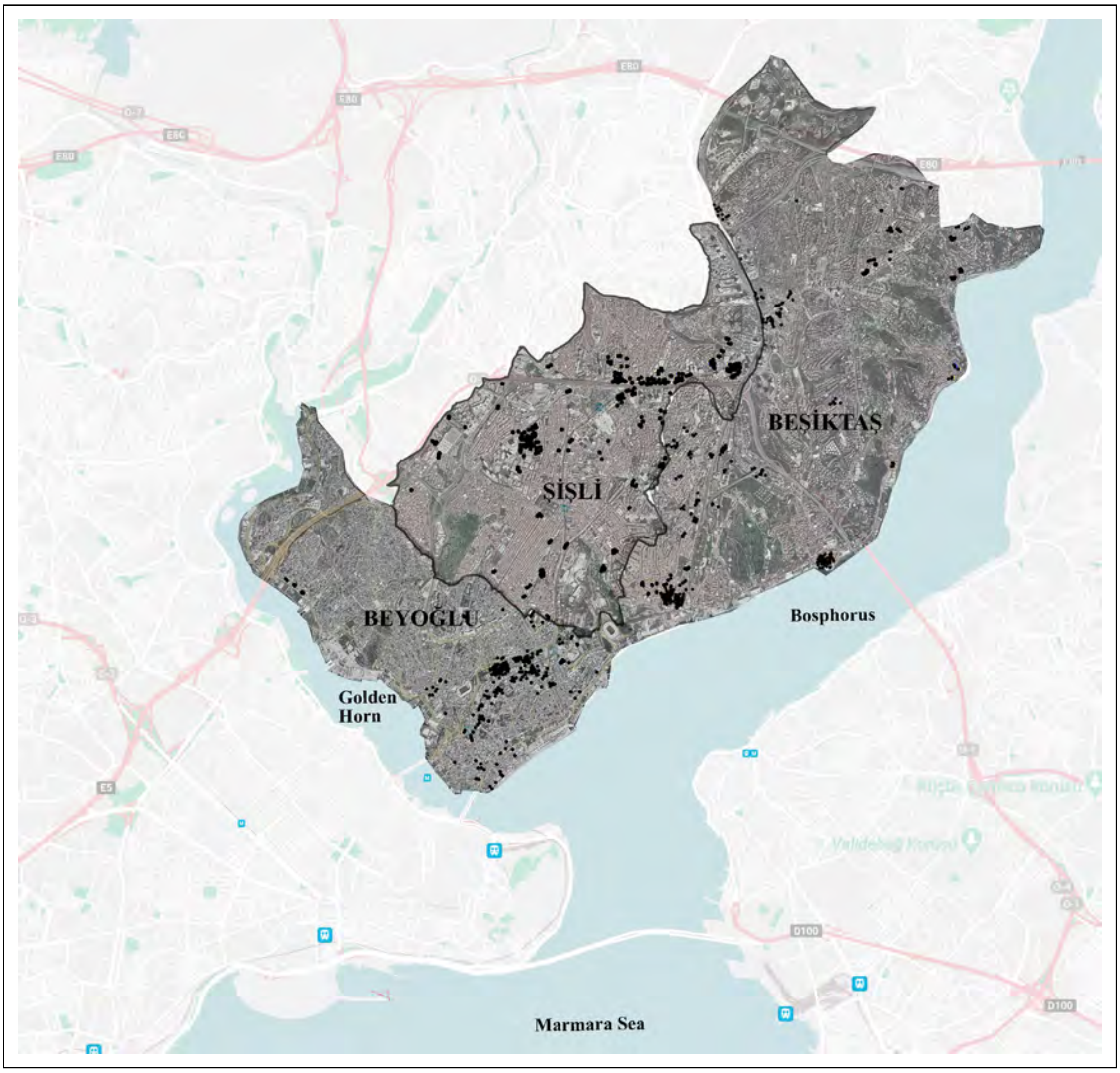

Figure 2. The locations of the Beyoğlu, Şişli, and Beşiktaş districts and the buildings where case studies were conducted. (The map was created by using Google Earth data.)

According to the address-based population data of the Turkish Statistical Institute in 2019, there were 279,817 people living in Şişli, 182,649 in Beşiktaş, and 233,323 in Beyoğlu (Department Fire of Brigade, 2020). The total population of the region is 696,789. The area of the study is residential, educational, commercial, industrial, and touristic, comprising the most dynamic districts of Istanbul including accommodation, art, culture, educational buildings, and consulates. Beşiktaş and Beyoğlu are two of Istanbul's tourist centres with their old city vibe and many historical buildings.

The total surface area of the three districts is 61.99 km^2 of which Sisli is 35.02 km^2, Beşiktaş is 18.01 km^2 and Beyoğlu is 8.96 km^2. There are 16,037 buildings in Beşiktaş, 27,335 buildings in Beyoğlu, and 20,534 buildings in Şişli. The building density of the Beyoğlu district is higher than the other districts. In all three districts, the proportion of buildings built before 1980 is higher. Beşiktaş and Beyoğlu have more buildings with 1–4 floors, and Şişli has more buildings with 5–8 floors. The ratio of reinforced concrete buildings is high in all three districts (IMM and BU, 2020) (Table 1).

In the first step of the model used in the study, a case study was carried out to determine the sources of hazards. Data on hazard sources were collected from 200 buildings with external fire escape stairs in each district where the study was carried out (Figure 2) for a total of 600 buildings. There are no statistics on buildings with external fire escape stairs in the three districts, so a general screening was carried out and 200 buildings with external fire escape stairs in each district were randomly identified. The building ratios examined according to the total number of buildings in the districts are 1.25% in Beşiktaş, 0.73% in Beyoğlu, and 1.95% in Şişli.

In the Beşiktaş district, 40% of the buildings examined were scattered throughout the district and 60% were concentrated

Table 1. Building data in the districts where fieldwork was conducted (IMM and BU, 2020)

		Beşiktaş	Beyoğlu	Şişli
Construction year	Before 1980	7,272	17,052	10,601
	Between 1980 and 2000	5,195	7,940	8,487
	After 2000	3,570	2,343	1,601
Number of floors	1–4-storey buildings	9,709	15,964	7,237
	5–8-storey buildings	5,924	10,992	12,267
	9–19-storey buildings	404	2,343	1,185
Construction type	Reinforced concrete	13,069	17,383	15,219
	Masonry construction	2,560	9,304	5,284
	Other	408	648	31

in certain areas. One of the areas where the buildings with fire escape stairs are dense is the Çarşı district of Beşiktaş. The external fire escape stair is located in the majority of the buildings on Barbaros Boulevard and Ortabahçe Street. It was determined that the number of buildings with fire escape stairs in the Gayrettepe district was also high. However, these buildings are not concentrated in only one area as in the Çarşı region but are scattered throughout the district. In the Ortaköy district, there is also an increase in buildings with fire escape stairs. Especially there is concentration on arteries such as Mecidiye Bridge Street, Cami Street, and Canfener Street. At the same time, the number of buildings with external fire escape stairs at the entrance of Nispetiye Street and on this street is higher than in other parts of the district.

There were 13 different functions in the buildings examined in the Beşiktaş district, where offices and food & beverage (restaurant) functions are quite high in number. Other buildings are categorised with eleven functions and are distributed at different rates below 15%. Buildings with a high user density have functions such as industrial workshops, private teaching institutions, school buildings, food & beverage establishments, stores, and dormitories. There is one building (health centre) with a high-risk user profile. The buildings examined in the study range are from 1–15 floors. There are 11 different floor groups in this range. 10.5% of the buildings are high-rise buildings with over seven floors.

In the Beşiktaş district, access to external fire escape stairs from main corridors (51.5%) was higher than access from independent sections. Of these buildings, 56.3% are businesses, 13.6% are residential buildings and 10.7% are school buildings. In food & beverage (restaurant) buildings, the rate of access to the external fire escape stairs from independent sections was 94.7%, 75% in industrial workshops, and 74.4% in office buildings. This rate decreases to 64.9% in accommodation buildings and 60% in school buildings. External fire escape stairs are accessible from an independent section in all banks, public buildings, housing, and office buildings, but are accessible from main corridors in private teaching institutions and garages. In the Beşiktaş district, the access rate from the main corridor to the fire escape is 23.3% in 3-storey buildings, 20.4% in 4-storey buildings and 19.4% in 5-storey buildings. Access in all 8- and 9-storey buildings is provided from the main corridor, while access in 1- and 13-storey buildings is from independent sections. The rate of access to the fire escape from the main corridor was observed to be higher in 5, 6, 7, 8 and 10-storey buildings.

The buildings in the Beyoğlu district are generally located in the area bordered by Tarlabaşı Boulevard in the North and Sıraselviler Street in the South, Taksim Square in the East, and Yeni Çarşı Street in the West. The number of buildings with fire escape stairs on Istiklal Street, Refik Saydam Street and Tarlabaşı Boulevard is increasing. Fire escape stairs have been identified in many of the historical buildings in the area between Istiklal Street and Tarlabaşı Boulevard. At the same time, the number of buildings with fire escape stairs on Cihangir, Gümüşsuyu, and Tershane Street is high.

There are 10 different functions in the buildings examined in the Beyoğlu district. Accommodation, offices and food & beverage buildings make up the majority of the district, with other buildings gathered under seven functions dispersed at different rates below 10%. Buildings with high user densities have functions such as industrial workshops, private teaching institutions, school buildings, and food & beverage establishments. No building in the district has a high-risk user profile. The buildings examined in the study ranged from 2 to 11 floors. There are nine different floor groups in this range. 6.5% of the buildings are high-rise buildings with over seven floors. It is seen that the different functional distribution is more in 4-storey buildings.

Access to external fire escape stairs in the Beyoğlu district from independent sections (73%) was higher than access from main corridors. Of these buildings, 43.2% were accommodations, 24.7% were food & beverage establishments, and 21.9% were businesses. In food & beverage (restaurant) buildings, the rate of access to the external fire escape stairs from the independent section was 94.7%, 75% from industrial workshops, and 74.4% from offices. This rate decreases to 64.9% in accommodation buildings and 60% in school buildings. External fire escape stairs were accessible from independent sections in all banks, public buildings, housing, and office buildings, but were accessible from main corridors in private teaching institutions and garages. In the Beyoğlu district, the access rate from independent sections to the fire escape was 91.7% in 3-storey buildings. All 2-storey buildings provide access to external fire escape stairs from independent sections, but 11-storey buildings provide access from the main corridor. Access to external fire escape stairs from independent sections was observed to be higher in 3, 4, 5, 6, 7 and 8-storey buildings.

It was determined that there were more buildings with external fire escape stairs in the Mecidiyeköy and Bomonti districts of the Şişli district. The buildings to the North of Mecidiyeköy Yolu Street and the following Büyükdere Street and following streets constitute approximately 50% of the buildings examined in the field study. In addition, in the area between Çifte Cevizler Street located in the Northwest of Bomonti district, and Sıracevizler Street located in the Southeast, the number of buildings with fire escape stairs is higher than in other parts of the district.

There were 11 different functions in the buildings examined in the Şişli district. The district has many industrial workshop buildings and businesses, and other buildings with nine other functions are gathered at different rates below 10%. Buildings with a high user density have functions such as industrial workshops, private teaching institutions, food & beverage establishments, and stores. There are five buildings with high-risk user profiles (hospitals and elderly care centres). Buildings examined for the study range from 3 to 14 floors. There are eleven different floor groups in this range. 30% of the buildings are high-rise buildings with over seven floors.

Access to external fire escape stairs in the Şişli district from independent sections (57%) was higher than access from the main corridors. Of these buildings, 48.2% were industrial workshops, and 40.4% were businesses. Independent section access to external fire escape stairs in industrial workshops was 86%. This rate drops to 47.4% in office buildings or offices. External fire escape stairs are accessible from independent sections in all public buildings, stores, and food & beverage (restaurants, etc.) buildings, but are accessible from main corridors in private teaching institutions and elderly care centres. In the Şişli district, access to external fire escape stairs from independent sections is 91% in 3-storey buildings. Access to external fire escape stairs from independent sections is seen to be high in 4, 6, 9, and 10-storey buildings. For both forms of access, the rate is evenly distributed in 7- and 11-storey buildings, and this rate is also almost equal in 5- and 8-storey buildings. On the other hand, fire escape access is provided through the main corridors in all 12- and 14-storey buildings.

In terms of fire safety, there are different factors for access and use in fire escape stairs, which are open to external effects and contain more risky arrangements than interior escape stairs, and these factors create many dangers. It has been determined that these factors for access and use constitute 18 sources of danger. In the case study, Table 2 summarises the districts' hazard source scores of external fire escape stairs. A total of 3580 hazards were identified on the external fire escape stairs in 600 buildings examined in three districts, with a total of 964 hazards in 200 buildings with external fire escape stairs in the Beşiktaş district. The building average of hazard sources in this district is 4.8. The sources with the highest scores are sources nos. 16, 7, 13, and 12, respectively. Buildings with the highest hazard source scores are by height: 13, 2, and 3-storey buildings respectively; and by function: industrial workshops, food & beverage (restaurant), and accommodation buildings. Office buildings are ranked 9th which has the highest number of floors. Industrial workshops, residential housings + businesses, accommodation (hotels, etc.) food & beverage (restaurants, etc.,) and health centres (by function,) and 1, 2, 3, 13 and 15-storey buildings (by a number of floors) are above the overall average. Buildings with the lowest hazard source score are school buildings.

A total of 1419 hazards were identified in the analysis of 200 buildings with external fire escape stairs in the Beyoğlu district, which had a building average of hazard sources 7.1. The sources with the highest scores were Nos. 16, 7, 13, and 12, respectively. By number of floors, buildings with the highest hazard source score were 7, 8 and 4-storey buildings, respectively; and by function, banks, food & beverage, and industrial buildings had the highest. Accommodation buildings – the highest number of buildings – rank 4th and office buildings rank – 7th. A 4-storey buildings with the highest number of floors rank 3rd, 5-storey buildings 4–5th and 6-storey buildings rank 6th. Industrial workshops, banks, accommodation, and food & beverage buildings (by function) and 3, 4, 5, 7, and 8-storey buildings (by the number of floors) are above the overall average. Buildings with the lowest score of hazard source, on the other hand, are buildings with garages.

A total of 1197 hazards were identified in the analysis of 200 buildings with external fire escape stairs in the Şişli district. The building average of hazard sources in this district was 6.0, and the sources with the highest scores were Nos. 16, 13, 7, 12, and 9, respectively. Buildings with the highest hazard source average were 14, 3, and 10-storey buildings respectively (by the number of floors) and food & beverage, banks, and public buildings (by function). Industrial workshop buildings (the highest number of buildings) were

Table 2. Hazard source scores on external fire escape stairs by districts

No	Hazard Sources	Beşiktaş	Beyoğlu	Şişli	In Three Districts
1	Lack of wall opening to the access fire escape	-	1	1	2
2	The Wall opening is far from the fire escape	1	3	3	7
3	Fire escape doors are locked on the floors	61	125	69	255
4	External fire escape stairs are accessed through the window	60	114	66	240
5	The fire escape exit door is locked	4	32	58	94
6	The floor door is made of flammable material	76	122	69	267
7	The floor door is not self-closing	139	168	146	453
8	The fire escape does not reach the ground	18	48	9	75
9	Access from the 1st floor to the ground is provided by an articulated staircase	77	109	102	288
10	The building is a high-rise	21	13	60	94
11	Facade lining is flammable	12	5	14	31
12	There is a window in the immediate vicinity of the fire escape	117	149	142	408
13	Circular or climbable external fire escape stairs are used	139	163	154	456
14	External fire escape stairs are too small	11	32	11	54
15	The load-bearing system of the fire escape is damaged	15	36	29	80
16	Lack of emergency lighting	181	198	193	572
17	External fire escape stairs are cluttered with personal belongings	24	70	62	156
18	There is no railing on the stairs / The height of the railing is insufficient	8	31	9	48
	Total (N)	964	1,419	1,197	3,580
	Differences in the number of hazards by districts	- 233 - 455	+ 222 + 455	- 222 + 233	
	Building hazard average	4.8	7.1	6.0	6.0
	Rank	3	1	2	

N: Number of hazards.

ranked 4th and office buildings were ranked 5–6th. Four-storey buildings with the highest number of floors rank 7–8th, 5-storey buildings rank 10th and 6-storey buildings ranked 9th. Industrial workshops, banks, offices, public buildings, housing + offices and food & beverage buildings (by function) and 3, 9, 10, 11 and 14-storey buildings (by the number of floors) were above the overall average. Scores of hospitals and elderly care centres with high-risk user profiles were low. Stores had the lowest hazard source scores.

By hazard score ranking, the district with the highest number of hazards was Beyoğlu, and the district with the lowest number of hazards was Beşiktaş, with a 455-point difference between them. Şişli's score was 233 points higher than that of Beşiktaş and 222 points lower than Beyoğlu. These scores show that the hazard sources determined on the fire escape stairs in the Beyoğlu district are higher than in the other two districts. Among the three districts, Beşiktaş was determined as the district with the lowest hazard level in fire escape stairs.

RISK ANALYSIS

The risk analysis phase of the model used in this study consists of rating the hazard sources, calculating risk value scores and preparing a district-based risk map. For the rating of hazard sources, hazard rates in the three districts were determined separately (Table 3). The district with the highest average hazard source (39.4) was Beyoğlu, and the district with the lowest rate (26.8) was Beşiktaş. The average hazard source across the three districts was 33.2%. Hazard source scores in Beyoğlu and Şişli were over the average. The scores of hazard sources Nos. 1, 2 and 11 were low according to the data.

Hazard coefficients are determined for each hazard source according to hazard rates (Table 4). These coefficients are given comparatively in Figure 3 for the three districts. The coefficient of hazard source No. 16 is high in Beşiktaş, while the coefficients of hazard source Nos. 7, 12, 13, and 16 are high in Beyoğlu and Şişli. The average scores of hazard sources Nos. 7, 13, and 16 in the three districts stand out. On the other hand, hazard sources Nos. 1, 2, 5, 14, and 19 in Beşiktaş, hazard sources Nos. 1, 2, and 11 in Beyoğlu;

Table 3. Hazard rates and coefficients on external fire escape stairs by district

No	Beşiktaş		Beyoğlu		Şişli		In three districts	
	R	F	R	F	R	F	R	F
1	0	0	0.5	1	0.5	1	0.3	1
2	0.5	1	1.5	1	1.5	1	1.2	1
3	30.5	3	62.5	4	34.5	3	42.5	4
4	30	3	57	4	33	3	40	3
5	2	1	16	3	29	3	15.7	2
6	38	3	61	4	34.5	3	44.5	4
7	69.5	4	84	5	73	5	75.5	5
8	9	2	24	3	4.5	1	12.5	2
9	38.5	3	54.5	4	51	4	48	4
10	10.5	2	6.5	2	30	3	15.7	2
11	6	2	2.5	1	7	2	5.2	1
12	58.5	4	74.5	5	71	5	68	4
13	69.5	4	81.5	5	77	5	76	5
14	5.5	1	16	2	5.5	1	9	2
15	7.5	2	18	3	14.5	2	13.3	2
16	90.5	5	99	5	96.5	5	95.3	5
17	12	2	35	3	31	3	26	3
18	4	1	15.5	3	4,5	1	8	2
Average	26.8	2.4	39.4	3.2	33.3	2.8	33.2	2.8

Hazard Rate (R) Hazard Coefficient (F) R=0–5 / F=1 (insignificant), R=6–15 / F=2 (low), R=16–40 / F=3 (average), R=41–70 / F=4 (high), R=71–100 / F=5 (critical)

and Nos. 1, 2, 8, and 14 in Şişli demonstrate the lowest coefficients. The average coefficient of hazard sources is 2.4 in Beşiktaş, 3.2 in Beyoğlu, and 2.8 in Şişli. The average of the three districts is 2.8.

In the next step of the risk assessment phase, risk value scores for hazard sources on the external fire escape stairs examined in the three districts were calculated (Table 4). These scores are given comparatively in Figure e for the Beşiktaş, Beyoğlu, and Şişli districts. The average fire escape risk value for the 600 buildings in the three districts is 179.5. Beyoğlu has the highest risk value and Beşiktaş has the lowest. Risk value scores for hazard sources Nos. 3, 7, 12, and 16 are the highest in the three districts. Source No. 6 is also high Beyoğlu. On the other hand, hazard sources Nos. 1 and 14 in Beşiktaş, Nos. 10 and 14 in Beyoğlu, and source No. 14 in Şişli demonstrate the lowest risk value scores. The average risk value scores of hazard sources are 8.5 in Beşiktaş, 11.5 in Beyoğlu, and 9.7 in Şişli. The average of the three districts is 10.0.

It is predicted that the risks will increase with the increase in the number of hazard sources in buildings with external

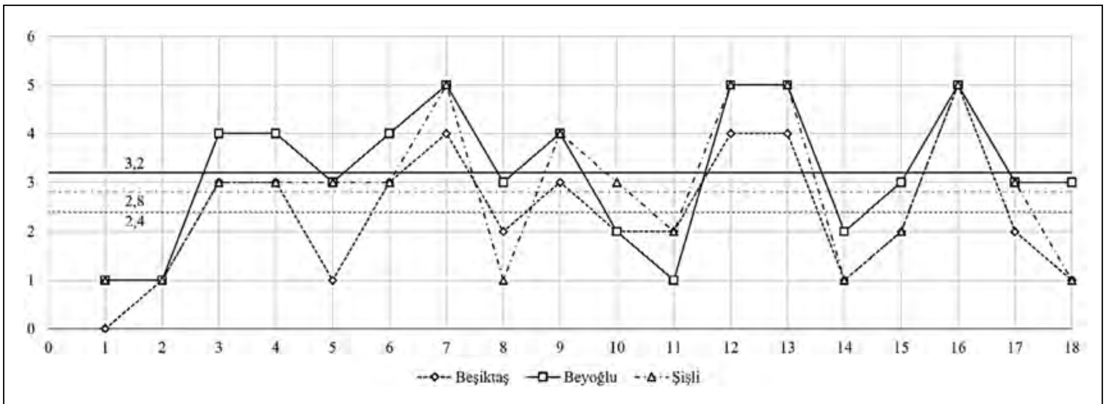

Figure 3. Hazard coefficients on external fire escape stairs in the three districts (F).

Table 4. Risk value scores on external fire escape stairs in the three districts

No	E	Beşiktaş	Beyoğlu	Şişli	In three districts
1	5	0	5	5	3.3
2	5	5	5	5	5
3	5	15	20	15	16.7
4	3	9	12	9	10
5	4	4	12	12	9.3
6	4	12	16	12	13.3
7	4	16	20	20	18.7
8	4	8	12	4	8
9	2	6	8	8	7.3
10	2	6	4	6	5.3
11	5	10	5	10	8.3
12	4	16	20	20	18.7
13	2	8	10	10	9.3
14	2	2	4	2	3.3
15	5	10	15	10	11.7
16	3	15	15	15	15
17	3	6	9	9	8
18	5	5	15	5	8.3
Total (V)		153	207	175	179.5
Average		8.5	11.5	9.7	10.0
Rank		3	1	2	

Hazard Impact Coefficient (E): first aid-free (1), first aid-outpatient treatment (2), mild injury-inpatient treatment (3), severe injury-long-term treatment (4), loss of life (5).

fire escape stairs. For this reason, before preparing district-based risk maps, the risk status of buildings was evaluated according to the number of hazard sources. For this, buildings are grouped according to the number of hazard sources. This grouping is between buildings that do not have a source of hazard and buildings with the most sources of hazard. The maximum number of hazard sources is 13. According to this, buildings with external fire escape stairs are divided into five groups: Buildings without a source of hazard, buildings with a source of hazard between 1 and 3 (low level) and 4–6 (medium level), buildings with a source of hazard between 7 and 9 and 10 and 13 (high level) (Table 5). Of the three districts, only three of the buildings in Beşiktaş have no source of hazard. In other buildings, a source of hazard has been identified between 1, 13 and 15. The number of buildings with 3 hazard sources in Beşiktaş, 8 in Beyoğlu, and 5 in Şişli are high. Although the hazard scores of buildings with the same number of hazard sources in Beyoğlu and Şişli are high, buildings with 9 hazard sources in Beşiktaş have a higher score.

The number of buildings where the source of hazard is from 1 to 3 is 79 (39.5%) in Beşiktaş, 35 (17.5%) in Beyoğlu, and 36 (18%) in Şişli. The sources of hazard in these buildings are sources 4, 13, and 16. The number of buildings where the source of hazard is from 4 to 6 is 55 (27.5%) in Beşiktaş, 42 (21%) in Beyoğlu, and 82 (41%) in Şişli. The number of buildings with a hazard source from 7 to 9 is 59 (29.5%) in Beşiktaş, 74 (37%) in Beyoğlu, and 61 (30.5%) in Şişli. The number of buildings with a hazard source from 10 to 13 is 4 (2%) in Beşiktaş, 49 (24.5%) in Beyoğlu, and 21 (10.5%) in Şişli. There are three buildings that are the most hazardous source. These buildings are a 4-storey office building in Beyoğlu, a 6-storey hotel and a 9-storey office building in Şişli. According to these results, there are a maximum of 1–3 sources of hazard in the buildings in Beşiktaş, while in Beyoğlu it is between 7 and 9 and in Şişli it is between 4 and 6.

A total of 53 risk groups were identified in the districts where the case study was conducted, including 17 very severe, 15 severe, 9 moderate, and 12 mild. There are no risks at a very mild level. According to the hazard coefficients of these risks, 9 are critical, 8 are high, 15 are medium, 9 are low and 12 are insignificant. According to the risk value results, there are 15 significant, 20 moderate, and 18 tolerable levels of risk. There are no intolerable and insignificant

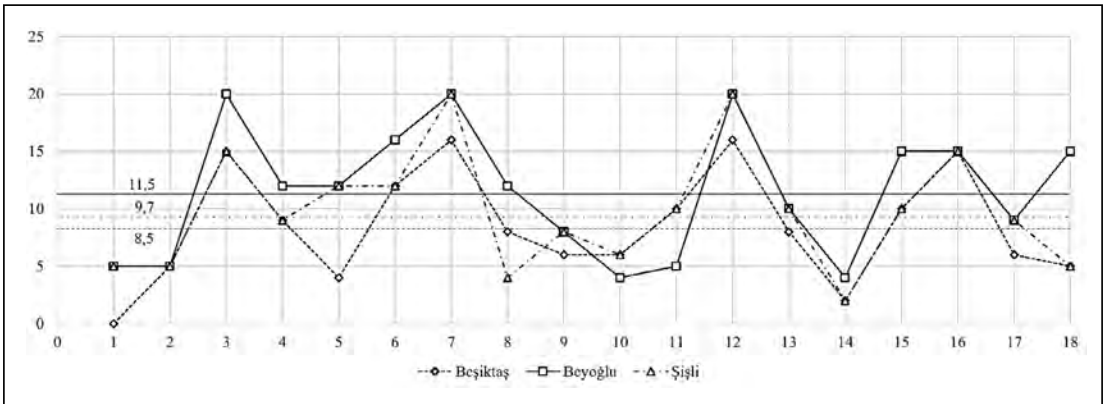

Figure 4. Risk value graph on external fire escape stairs in the three districts (E).

Table 5. Hazard source scores of buildings in three districts

District	Beşiktaş			Beyoğlu			Şişli		
N (in a building)	Number of buildings	N (Total)	Average	Number of buildings	N (Total)	Average	Number of buildings	N (Total)	Average
0	3	3	0.3	0	0	0.0	0	0	0.0
1	24	24	2.5	3	3	0.2	7	7	0.6
2	22	44	4.6	17	34	2.4	16	32	2.7
3	33	99	10.3	15	45	3.2	13	39	3.2
4	17	68	7.1	15	60	4.2	23	92	7.7
5	19	95	9.9	16	80	5.6	34	170	14.2
6	19	114	11.9	11	66	4.6	25	150	12.5
7	21	147	15.3	17	119	8.4	21	147	12.3
8	19	152	15.9	35	280	19.7	21	168	14.0
9	19	171	17.8	22	198	14.0	19	171	14.3
10	2	20	2.1	19	190	13.4	15	150	12.5
11	2	22	2.3	18	198	14.0	3	33	2.8
12	0	0	0.0	10	120	8.5	1	12	1.0
13	0	0	0.0	2	26	1.8	2	26	2.2
Final Total	200	956	100	200	1,419	100	200	1,197	100

N: Number of hazards.

risks. Hazard sources with impact coefficients at the very severe level are concentrated below the moderate level. The sources at severe and mild levels are scattered throughout the regions. The density of moderate-level sources, on the other hand, is at the critical and moderate levels.

In the final step of the risk analysis, district-based risk maps were prepared. Three buildings that are not a source of hazard in Beşiktaş are Emirhan Street, Mukataacı Street, and Çatalca Street. Two of these buildings are 7- storey residential buildings and one is a 5-storey education building. The number of buildings with 10–13 sources of hazard in Beşiktaş is very low compared to the other two districts. In this district, there are no buildings with 12 or 13 hazard sources. The number of buildings where the number of hazard sources is 10 and 11 is 4. One of the buildings with 10 sources of hazard is Mosque Street, the other is Ehram Street. One of the buildings where there are 11 sources of hazard is on Yelkovan Street and the other is on Mecidiye Bridge Street. Three of these buildings have three floors and the function of these buildings is food and beverage, the other has four floors and the function of the building is accommodation. The highest number of external fire escape stairs in Beşiktaş is determined on Nispetiye Street. In only two of the 16 buildings with an external fire escape stair on this street, the number of sources of hazard was over seven, while the number of sources of hazard was over seven determined in all five buildings on Cami Street and in four of the six buildings on Mecidiye Bridge Street. It can be said that the number of hazard sources in buildings with external fire escape stairs in Beşiktaş is variable. The risk level is especially high in Ortabahçe Street, Şehit Asım Street, Mumcu Bakkal Street, Gazi Umur Paşa Street, Ihlamurdere Street, Şair Leyla Street, Kazan Street and Camcı Hüseyin Street (Figure 5).

The three buildings with the least hazard source in Beyoğlu are Canfeda Street, Ambar Arkası Street, and Müellif Street. These buildings are 5-storey office buildings, and an education and parking building. The highest number of external fire escape stairs in this district has been determined on Tarlabaşı Boulevard. In three of the nine buildings with an external fire escape stair on Tarlabaşı Boulevard, the number of sources of hazard is over nine. On Istiklal Street, there are more than eight sources of hazard in four of the five buildings. One of the two buildings with 13 sources of hazard is located on Tarlabaşı Boulevard and the other on Mis Street. In the six buildings on Mis Street, the number of hazard sources is high. These buildings are 5 and 6 storey accommodation buildings, except for one. It can be said that the number of hazard sources in the buildings located on the streets between Istiklal Street and Tarlabaşı Boulevard is variable. The source of hazard is high in many buildings with external fire escape stairs in Beyoğlu. Especially Nevizade Street, Kurabiye Street, Sahne Street, Parmakkapı Street, Hasnun Galip Street, Billurcu Street, Atıf Yılmaz Street, Topçekenler Street, İmam Adnan Street, Süslü Potsı Street, Yüksek Kaldırım Street have a

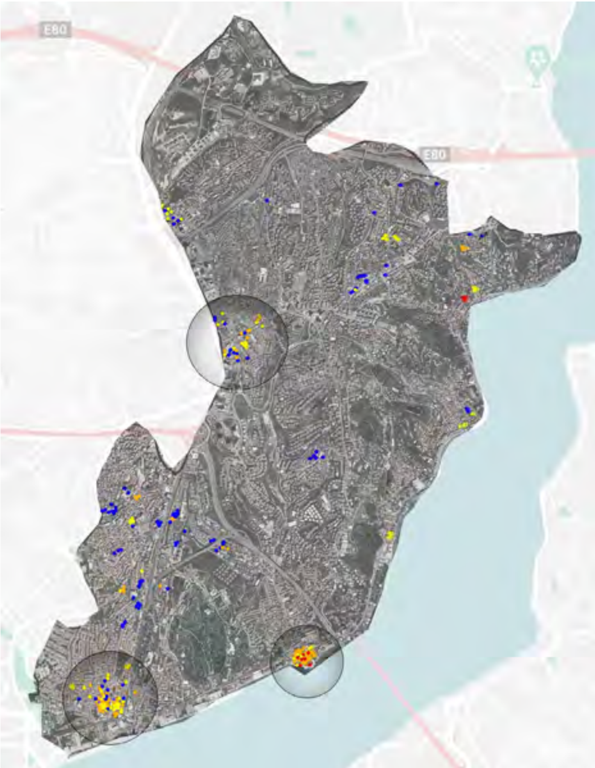

Figure 5. District-based risk map of Beşiktaş.

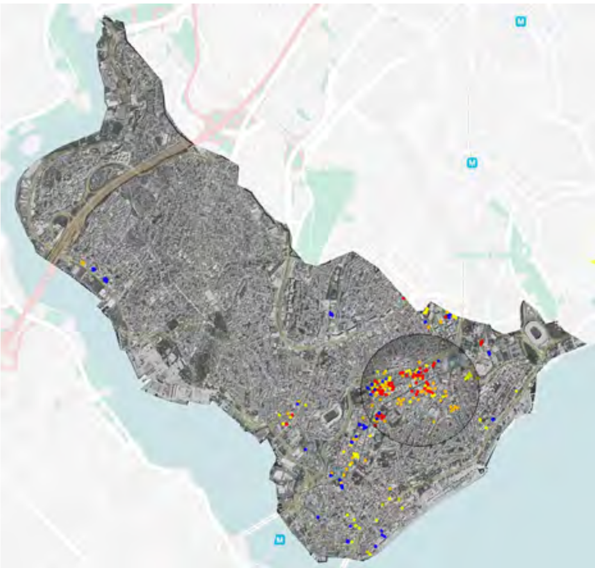

Figure 6. District-based risk map of Beyoğlu.

high-risk level. The number of buildings with more than ten sources of hazard in this district is very high compared to the other two districts (Figure 6).

The number of buildings with the least source of hazard in Şişli is seven. The highest number of external fire escape stairs in this district is determined on Büyükdere Street. In six of the 13 buildings with an external fire escape stair on Büyükdere Street, the number of sources of hazard is over eight. On the street, nine out of eleven buildings have more than seven sources of hazard. On Birahane Street, where the external fire escape stair is designated in nine buildings, the number of sources of hazard outside a building is less than five. One of the two buildings with thirteen sources of hazard in Şişli is located on Ergenekon Street and the other on Halaskargazi Street. These buildings are 9- and 11-storey office buildings. Twelve sources of hazard have been identified in a 3-story industrial workshop building on Kazım Orbay Street. Eleven sources of hazard are located in one building each on Koca Mansur Street, Feriköy Fırın Street, and Mecidiye Street. On the three external fire escape stairs on Mecidiye Street, the number of sources of hazard is above ten. It can be said that the number of hazard sources in buildings with external fire escape stairs in Şişli is variable and that there are more than five hazard sources in many buildings. Especially Cemal Sahir Street, Lati Lokum Street, Feriköy Fırın Street, Huzur Street, Atakan Street and Güvenç Street have a high-risk level (Figure 7).

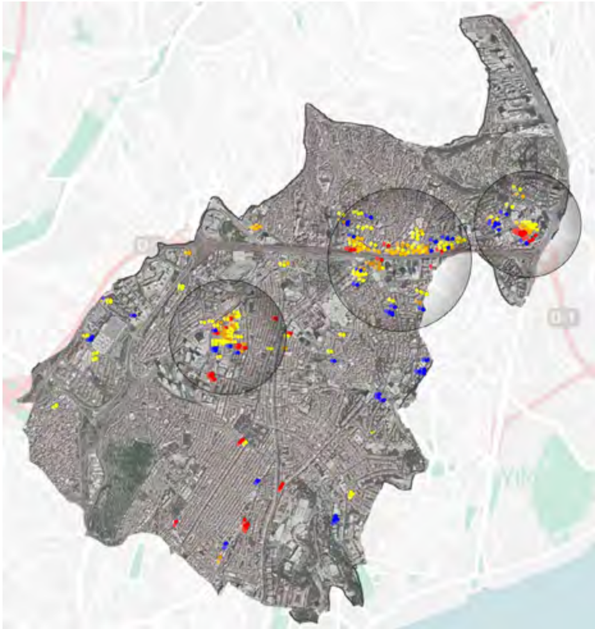

Figure 7. District-based risk map of Şişli.

RISK ASSESSMENT

In the final phase of the model used in the study, risks were assessed according to risk value scores, and the actions necessary to take hazards under control were decided on. The two most important hazard sources of external fire escape stairs in the three districts were the lack of a wall opening to access the stairs (No. 1) and the distance of the wall opening from the stairs being too far (No. 2).

Although the risk value scores of these sources were low in all three districts, their hazard impact coefficients are at a very severe level. In buildings with hazard sources Nos. 1 and 2, the fire escape is inaccessible, and the life safety risk increases during escapes. These hazard sources were identified in nine buildings (Figure 8). A wall opening must be constructed on two stairs in Beyoğlu and Şişli to provide access to the fire escape. In the other seven buildings where the wall opening is far from the stairs, access to the fire escape should be provided from each floor. The use of these buildings must be stopped until these risks are eliminated.

In the three districts, the impact coefficients of hazard source Nos. 3, 6, 7, 12, and 16, all of which have significant risk value scores, register between moderate and very severe (Figure 9). Entrance to and exit from these buildings are expected to be supervised during use. However, external fire escapes stairs that are used in an uncontrolled manner give rise to numerous safety problems. Thus, doors to the external fire escape stairs in 42.5% of the buildings are kept locked to control entrance and exits. This rate rises to 62.5% in Beyoğlu. The highest number of casualties on external fire escape stairs are known to result from keeping their access doors locked, which is why national law prohibits locking fire escape access doors.

In 59.5% of the buildings in the three districts, independent sections have access to the fire escape. This rate rises to 73% in Beyoğlu. The risks in buildings with this type of use are similar to those with locked fire escape access doors. Due to the way the space is used, especially in accommodation buildings, room door locking is mandatory. Escape routes in these buildings must be re-arranged so that they can be accessed comfortably and without obstruction from any location. During a fire, each user must have direct access to the fire escape without passing through another user's space. National laws do not address how space should be provided to allow access to external fire escape stairs. In Turkey, however, new buildings are required to provide direct access to the fire escape without having to go through the rooms, while existing buildings are allowed access from the room if the door is not locked (Turkey's Regulation on Fire Protection, 2015).

In 44.9% of the buildings examined in the three districts, combustible material was determined to have been used in the doors providing access to the external fire escape stairs. This rate rose to 59% in Beyoğlu. In these buildings, fire can affect the fire escape through the door wells. At the same time, the rate of buildings without self-closing fire escape doors was 75.5%, giving rise to similar risks. For external fire escape stairs where these hazard sources are present, where the hazard impact coefficient is severe, the fire resistance duration of the access doors must be brought into compliance with the law. In addition, these doors should be equipped with self-closing mechanisms that allow firefighters or authorised personnel to enter from the outside as needed. Although there is a rule in Turkey governing the allowed distance between windows and external fire escape stairs, 68% of the buildings examined do not comply with it.

Emergency lighting is one of the most important components necessary for fire escape users to reach safety during fires at night. However, 95.3% of buildings examined in the three districts do not have emergency lighting. Lighting the stairs is necessary so users can see direction changes on the stairs, the stair steps, and story landings, and understand elevation changes (Chris, 2012). External fire escape stairs are more difficult to use in the dark – people go slower, so time is wasted during escapes, and the possibility of accidents increases due to lack of supervision. Therefore, all escape routes and external fire escape stairs must be illuminated according to national laws.

Based on the results of this study, emergency measures should be taken on the stairs where hazard sources Nos. 3, 6, 7, 12 and 16 are present; physical conditions should be brought into compliance with national laws, and risks should be eliminated in a short time. External fire escape stairs featuring hazard source No. 3 should have the access door locks removed, and provide users obstacle-free access during

Figure 8. Hazard sources Nos. 1 and 2.

Figure 9. Hazard sources Nos. 12 and 16.

escapes to prevent waste of time. Door design measures should be simple and effective, and safety measures should be increased using audible warning and video systems.

The impact coefficients of hazard sources Nos. 4, 5, 11, 13, and 17 with moderate risk value scores in the three districts register between mild and very severe levels (Figure 10). In 40% of the buildings examined in the three districts, external fire escape stairs are accessed through windows. This practice is permitted in the laws of many countries. However, in case of emergency, escapes through windows are difficult and can result in injuries from falling. In buildings where external fire escape stairs are accessed through windows, the risks for disabled, elderly, pregnant, sick and child users in particular increase. Therefore, the windows used to access the external fire escape stairs should be converted into fire-resistant and self-closing doors that open towards the staircase.

The use of circular, external stairs in external fire escape stairs is prohibited in some countries and restricted by special rules in others. Climbing ladders, on the other hand, are only allowed to provide access from the 1st to the ground floor. Circular stairs create conditions that make escapes more difficult, with changing step widths in the constantly rotating stair posing risks. In addition, the hazard coefficients of circular stairs and climbing ladders increase in high-rise and high-risk user profile buildings. As for storing or putting items, etc. on external fire escape stairs, not only might it prevent escape, but it also might cause fires. The responsibility for emptying external fire escape stairs to make them suitable for use is determined by national laws. In Turkey, for example, the owner of the building or business and the building manager is responsible (Turkey's Regulation on Fire Protection, 2015). Such external fire escape stairs should be constantly monitored with video systems to prevent misuse, and necessary measures should be taken to prevent people from putting items on the stairs.

The risk values of hazard source No. 5 in Beşiktaş and hazard source No. 11 in Beyoğlu are at a tolerable level. However, the risk value of these hazard sources, whose hazard impact coefficients are very severe and severe, increases to moderate in Beyoğlu and Şişli. The locked access doors are important because they prevent escapes from the building. In addition, a total of 31 buildings examined in the three districts used combustible exterior cladding. In many countries, the fire resistance time of the wall external fire escape stairs are adjacent to are required to be no less than 30 minutes. Exterior fires inevitably affect external fire escape stairs and the people using them. Therefore, in buildings with combustible façade cladding, either the façade cladding materials must be replaced, or the external fire escape stairs must be reinforced with protection. In high-rise buildings with high-risk user profiles, work on external fire escape stairs featuring hazard sources Nos. 4, 5, 11, 13, and 17 should be started as quickly as possible. Hazards on the stairs, which have very severe and severe levels of hazard impact coefficients, must be eliminated in accordance with national law.

The risk value of hazard source No. 8 with a severe risk impact coefficient is determined as moderate. External fire escape stairs are expected to reach the ground so that escapes can be completed during a fire. However, in 12.5% of the buildings examined in the three districts, the external fire escape stairs stopped at the 1st floor, both to prevent theft and encroachment on public space (Figure 11). External fire escape stairs that end on the 1st floor may prevent the completion of escapes and may trap people on them during escapes, resulting in injury or disability to those forced to jump to the ground. For this reason, external fire escape stairs should extend from the floor where they start to the ground, and external fire escape stairs that terminate above ground level should not be allowed. Buildings with hazard source No. 8 should have access to the ground with an articulated staircase. In 48% of the buildings examined in the three districts, articulated stairs provide access to the ground floor from the 1st floor (Figure 10). The risk value of hazard source No. 9 with a mild hazard impact coefficient is at the moderate level. Although such external

Figure 10. Hazard sources Nos. 4, 13, and 17.

Figure 11. Hazard sources Nos. 8 and 9.

fire escape stairs do provide a means of escape, they are very difficult to use and can take up valuable time during an escape. Furthermore, many of these stairs have been shown to have problems with their opening systems or that there are elements such as fringes, awnings, or signage that prevent the opening of the stairs. Nevertheless, the laws of many countries allow access to the ground by an articulated staircase component onto pedestrian sidewalks, narrow streets, or garage entrances where it is not possible for external fire escape stairs to reach the ground level. If this type of stair is used to access the ground, easy-to-open systems should be preferred. In addition, the area the stairs open on must be obstacle-free.

Although the coefficient of hazard source No. 15 is low, its hazard impact coefficient is at a very severe level. These external fire escape stairs are constantly vulnerable to external environmental impacts, such as precipitation and temperature differences, which can cause damage to the stairs such as wearing them down, cracking, breaking, or corrosion. In the three districts examined, external fire escape stairs in eighty buildings were identified as damaged by corrosion in the steel carrier system (Figure 12). The risk can be said to be very high in buildings where this source is present. In high-rise buildings with high-risk user-profiles and large numbers of people, the risk increases further. Structural problems on these external fire escape stairs were inevitable over time due to insufficient steel material sections used in load-bearing systems, non-compliance with rules of material combinations and corrosion of steel materials. The external fire escape stairs in these buildings must be renewed. Regular maintenance of external fire escape stairs will prevent them from being affected by external conditions that increase hazards.

The overall risk value of hazard sources Nos. 10 and 14 are tolerable in all the districts. These sources may not require immediate action. However, during escapes, users' safety decreases as the height of the building increases. About 15.7% of the buildings in the three districts examined are high-rise buildings (Figure 13). Emergency evacuations from high-rise buildings are different from low-rise structures. The ergonomic structure of users, motivational levels, group behaviour, gender, and mobility affect the speed of escape during the evacuation process. The merger of evacuations, especially on floor sites, is one of the most important problems for fire escape evacuations in high-rise buildings. In fact, an increase in the number of users on external fire escape stairs and user encounters has been revealed to extend the escape route and duration, by directing users to the outer boundaries of the stairs (Ronchi, 2014).

The number of high-rise buildings with external fire escape stairs in Şişli was determined to be very high. Especially in buildings with a high number of users such as offices, hotels, and hospitals, external fire escape stairs, which are built without calculating user load or considering user profiles, become a building element that causes loss of life instead of ensuring the safety of life in case of fire. Especially in buildings that exceed the height limit, the use of such external fire escape stairs in bad weather and in night-time conditions increases the safety problem. It is known that disabled people have a slowing effect on group movement during the evacuation from high-rise buildings, thus causing evacuation problems (Ronchi and Nilsson, 2013). Another factor to consider during evacuations from high-rise buildings is fatigue. Many past fires have shown that evacuations can be disrupted due to fatigue, causing delays in the evacuation process (Spearpoint and Maclennan, 2012). That there may be elderly, child, pregnant and disabled users in buildings and that external fire escape stairs can also be used by people who are afraid of heights should also be considered.

In 9% of the buildings examined in the three districts, the arm width was not suitable for escape, the stairs were too high and narrow, there were no railings on the stairs, or the railing height was too low were factors that make it difficult to escape during a fire (Figure 13). In particular, scaling ladders and circular stairs with low step width prevent evacuation from buildings in a short time. In addition,

Figure 12. Hazard source No. 15.

Figure 13. Hazard sources Nos. 10 and 14.

fire escape step surfaces should be designed to provide protection against the effects of fire, and measures should be taken against factors on step surfaces that make the fire escape difficult to use.

CONCLUSION

External fire escape stairs are used in many countries. This case study was carried out in three districts of Istanbul to analyse the conditions of use of external fire escape stairs in order to determine possible sources of hazards on them. However, in the case study, carried out by collecting data from a total of 600 buildings, with 200 buildings from each district, different hazard sources for users were encountered on the external fire escape stairs. Starting with 18 hazard sources, the inquiry identified a total of 3,580 hazards in terms of access to and use of external fire escape stairs that were open to external environmental impacts. The building average of these hazards was 6.0. It is understood that the most hazard in all three districts is in buildings with 7–9 sources of hazard (470 in Beşiktaş, 597 in Beyoğlu, and 486 in Şişli). Due to a large number of hazards and their consistency, the use of buildings in the Beşiktaş, Beyoğlu, and Şişli districts of Istanbul was considered risky. In particular, the risk value scores in Beyoğlu are higher than in the other districts. In order to take these fire escape hazards under control, they must first be brought into accordance with the rules of national law, and the hazards must be eliminated in accordance with the suggestions developed in this study. This will allow users to evacuate from buildings quickly, easily, and safely in case of fire.

Risk levels of hazard sources on external fire escape stairs are important for fire safety. The types of hazard sources they possess determine risk levels. Hazard sources that pose a very high level of risk are related to fire escape access, exterior cladding, and the fire escape load-bearing system. In 59.5% of the buildings in the three districts, access to the fire escape stairs is from an independent place, in 42.5% of the fire escape stairs, the landing doors are locked, and in 13.3% there is damage to the carrier system, and in 9 stairs there is no wall space for access, or it is noteworthy that the wall space is far from the staircase. In buildings where these hazard sources are located, the risk of life safety increases due to the inaccessibility of the external fire escape stairs. It can be said that interventions on these stairs have priority.

In the case study; it has been observed that it is common for external fire escape stairs to be accessed through a window (240 buildings), to reach the floor by an articulated staircase from the 1st floor (288 buildings), and to use circular or climbing stairs (456 buildings). Especially these hazard sources are very high in Beyoğlu, where accommodation, office buildings, and buildings with food and beverage functions are the majority. However, the user profile is important in determining the risk level in external fire escape stairs. For example, in a building where access to the external fire escape stair is provided through the window, the level of risk will increase compared to other users as it will be difficult for a person who is accompanied by an accompanying person to use the ladder. For this reason, the physical characteristics of the building users (blind, physically disabled, elderly, children, seriously ill, pregnant, etc.) should be taken into consideration in the design of external fire escape stairs.

Under normal conditions of use, there is an interaction of hazard sources with each other. For example, the height of a building without emergency lighting on the external fire escape stair will increase the level of risk in night conditions. In the case study, the absence of emergency lighting (572 buildings) appears to be common. Ninety-four of these buildings are high-rise buildings. In addition, placing items, etc. on the stairs in these buildings (156 buildings) makes it difficult to escape. Therefore, it is important to take measures that reduce the risks in high-rise buildings.

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