Closing data gaps and paving the way for pan-European Fire Safety Efforts. Part II - terminology of fire statistical variables

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Closing Data Gaps and Paving the Way for Pan-European Fire Safety Efforts: Part II—Terminology of Fire Statistical Variables

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Abstract. A well-defined terminology of fire-related variables is important for correct analyses and supporting knowledge-based decisions regarding the evaluation of building fires at the European level. After developing an overview of current practices for fire statistics in Part I, the terminology used and the data collected by the EU Member States and eight other countries regarding fire incidents, property damage and human losses were mapped to increase awareness of their practice and support a comprehensive assessment of several fire statistical datasets. A questionnaire was distributed to relevant authorities responsible for the collection, elaboration/analysis, and fire statistical data publications to define and select the essential variables for an appropriate fire assessment and fire incident description. Based on the results of the questionnaire able to identify the essential fire statistical variables and a detailed analysis of current definitions adopted in the fire statistics of the EU Member States and other countries, a common terminology is proposed to collect the necessary data in the EU Member States and obtain meaningful datasets based on standardised terms and definitions. The results will generate essential outputs to move towards harmonised fire statistics at the EU level and contribute to an appropriate analysis able to improve fire prevention and fire mitigation in building fires.

Keywords: Fire statistics, Fire incidents, Building fires, Fire statistical variables, Terminology

1. Introduction

The evaluation of fire safety in buildings involves complexity in terms of fire risk identification, analysis, evaluation and treatment [1], the coexistence of several actors, such as fire engineers, regulators and occupants, and the interaction between the social, societal, technical, organizational and economic dimensions [2]. Therefore, the fire safety issue could represent an unbounded problem with endless questions [3] and a series of guesses [4] that could be overpassed by the analysis of fire incidents in buildings collected in the fire statistics of several countries.

It is in this light that in the EU Member States and other international countries, data of fire incidents in buildings are recorded in fire statistical datasets and represent fundamental information on building performance, the effectiveness of safety measures, and human safety during fire events. These data represent relevant information for several authorities such as the fire safety community in terms of identification of fire risk and related consequences, fire brigades to optimize fire response and resources allocation, and national and local governments to implement fire prevention campaigns. However, as presented in Part I [5] when an overview of current practices for fire statistics was developed, the variety of fire statistical practices, collection methodologies and recorded variables need to be investigated in detail to develop a comprehensive assessment.

Moreover, when the definitions adopted in the fire statistics are examined, there could be multiple organisations collecting the data, which can reduce the data accuracy. For example, fire statistics from insurance companies could not correspond to those used by the fire and rescue services. This is the case in Spain where an annual report of fire statistics is published based on data provided by the fire services and the Legal Medicine Institutes [6], and a different one by the Association of Insurers [7]. The coexistence of multiple domains implies further difficulties in assessing the essential variables required for a comprehensive fire investigation and fire description.

In France [8], where an official terminology for fire statistical variables is not available, or in Australia and other countries where data are collected at the state level [9] or local level without a national centralized system, various fire departments could attribute different fire aspects to the same fire statistical variable. Furthermore, even in countries where a national fire statistics collection is available, such as in the USA [10], or where a structured and continuously implemented system is present, such as in England [11] and Sweden [12], the method for reporting and interpreting data may locally vary according to the approach adopted by the fire brigade in filling in the fire incident report. Only in a limited number of cases, there is a follow-up during the data elaboration phase when recorded fire statistical data appear to present inconsistencies or uncertainties (e.g. Ireland [13]).

The issue related to the interpretation and adopted definitions is particularly relevant when international fire statistical data are provided. The ''World Fire Statistics'' reports [14, 15] are published yearly by the International Association of Fire and Rescue Service (CTIF) for European countries and selected other countries. Data could be provided by fire and rescue services or other institutions responsible for the fire statistics and when variables related to fire incidents, deaths and injuries are plotted over time, the differences could be attributable to geographical locations [16], collection methodologies, fire safety regulations in place [17], and most of all to the adopted terminology. For example, in the fire statistics published by the Home Office in England, there is a subdivision between fire and total damage. The Home Office defines fire damage as the total horizontal area damaged by the flame and heat (in m^2) at the end of the fire and refer to a total aggregate of all horizontal damage in the building [18]. In contrast, in the USA, flame damage is recorded and defined as the area actually burned or charred and does not include areas receiving only heat, smoke, or water damage, and it is recorded as the number of stories damaged by flame spread [10].

Based on the above, there is clearly a necessity to map the current fire statistical terminology and the data collected regarding fire incidents in residential and non-residential buildings in the EU Member States to support a more meaningful evaluation of fire statistical variables and enable a more accurate analysis of the fire aspects covered by each of them. Furthermore, it is important to select and identify the essential fire statistical variables able to provide a complete description of the fire incidents.

The ISO/TR 17755:2014 [19] presents data on national fire statistics practices of ten countries (Australia, Canada, China, France, Japan, Kenya, (Republic of)

Korea, Russia, United Kingdom, and the USA) highlighting data collection methodologies and recorded fire statistical variables based on the information gathered in a survey. The differences found in the definitions adopted for the fire statistical variables are covered by the research developed by the ISO/TS 17755-2:2020(E) [20] that introduces a lack of common terminology and methodology, and weaknesses in the training and qualification of fire investigators faced by fire safety experts involved in fire statistics. The ISO/TS 17755-2:2020(E) [20] harmonizes the definitions of specific terms commonly used in fire statistical data. However, a detailed analysis of current fire statistical practice of the EU Member States and other countries is necessary to understand the adopted terminology and enable an accurate evaluation of the fire incidents in buildings.

It is in this light that the analysis developed in this research investigated the fire statistics of 27 EU Member States and eight other countries (Australia, Canada, New Zealand, Norway, Russia, Switzerland, UK and USA) to determine adopted definitions and available fire statistical variables. The selected other countries are included in the analysis due to their structured and detailed fire statistics. A variety of challenges was encountered during the research due to language barriers, confidentiality policies, private databases, and non-response to requests for information. Therefore, direct contacts were established with responsible authorities for the fire statistics of the 35 countries.

This research aims to identify several essential fire statistical variables necessary for the description and assessment of fire incidents, determine the adopted definitions in existing fire statistics, compare them with those provided by the ISO TS 17755-2 standard [20], and, finally, propose a common terminology to move towards a homogeneous collection methodology and terminology at the European level. The developed analyses are considered the foundations to support future actions able to create meaningful datasets based on standardized terms and definitions and improve fire safety in buildings.

The structure of the paper introduces the steps followed in the analysis. Section 2 provides the adopted methodologies for the investigation of the existing definitions for fire statistical variables, created questionnaire, and proposed terminology. Section 3 extensively describes the existing definitions for fire statistics in the EU Member States and other countries. Section 4 is focused on the explanations of how the questionnaire was created and the outcomes obtained. Based on the findings from Sects. 3 and 4, Sect. 5 proposes the terminology for the selected fire statistical variables based on the results of the questionnaire. Finally, Sect. 6 discusses the conclusions of the work highlighting suggestions and future areas of investigation.

The research presented was part of the EU FireStat project [21] and developed an extended investigation of fire statistical practices in the EU Member States and other countries where further details are provided by the related EU FireStat reports [22–25]. The analyses introduced in this paper need to be contextualized in a broader research context and considered in combination with the outputs generated by Paper I [5].

2. Methodology

The methodology adopted to achieve the aim of the research is mainly composed of three steps. The analysis has been first focused on a detailed investigation of the existing definitions and classifications of the fire statistical variables in the 27 EU Member States and eight other countries to increase awareness of current terminologies and covered fire incident fields (Sect. 2.1). The variety of current practices in terms of recorded fire statistical fields and the diversity in the related definitions inevitably highlighted the necessity to define a list of essential fire statistical variables that should be recorded and uniquely defined. It is in this light that based on current practice in complex and structured fire statistics, the analyses were consequently focused on the creation of a survey with the aim to define a list of essential fire statistical variables chosen by relevant authorities and consortium members and compared with the existing fire statistics of the 27 EU Member States (Sect. 2.2). Finally, once the variables have been selected and subdivided according to three different tiers, definitions for each of them were provided based on the detailed overview of the existing definitions developed in the first phase of the analysis and optimized in terms of accuracy and clarity (Sect. 2.3).

2.1. The Existing Definitions and Classification of the Fire Statistical Variables

The analyses focused on the investigation of the existing fire statistics in 27 EU Member States and eight other countries (Australia, Canada, New Zealand, Norway, Russia, Switzerland, UK, and the USA) by establishing key aspects of fire incidents related to pre-and post-fire conditions in buildings as well the effectiveness of fire safety measures and life safety.

The existing fire statistical variables were identified through subdivision into ten main categories of interest defined as fire incident, building description, fire causes, fire consequences, fatalities, casualties, fire safety measures, fire response, fire costs, and fire prevention (Table 1) where each category of interest has several variables. Direct contacts with the relevant authorities responsible for the fire statistics in the examined countries were ensured and a summary table was created as a guide to follow where each country could fill in their current practice and recorded variables. In this paper, only the information gathered for the definitions adopted in the fire statistics will be discussed while the information on the authorities responsible for the collection, methodology and data elaborations are covered by the reports published by the EU FireStat [22, 23] and in the research by Manes et al. [5], which also include a comprehensive literature review of the studies focused on European and international fire statistics.

When the 35 selected countries were investigated, no response was received from Luxembourg, Malta and Portugal, and only limited information from Lithuania and Spain. In addition to those five, seven EU Member States (Belgium, Bulgaria, Croatia, Cyprus, Greece, Latvia, and Poland) affirmed their lack of appropriate definitions for the fire statistical variables. Therefore, as the analysis is focused on the definitions available, a total of 23 countries (15 EU and eight

Table 1
Fields Covered in the 10 Categories of Interest

Category of interest	Variables	Category of interest	Variables
Fire incident	Accidental fire	Casualties	Injured people
	Deliberate fire		Type of injury
	False alarm	Fire safety measures	Alarm
Building description	Building fire		Type of alarms
	Residential buildings		Automatic extinguishing systems
	Non-residential buildings		Type of automatic extinguishing systems
Fire causes	Fire causes		Compartmentation
	Source of ignition		Fire barriers
	Area of fire origin		Safe areas
Fire consequences	Fire spread		Smoke extractors
	Fire horizontal spread		Fire brigades on site
	Fire vertical spread		Escape routes
	Damage		Evacuation
	Fire	Fire response	Fire service time of response
	Flame		Occupant fire response
	Smoke	Fire financial costs	Direct financial costs
	Water		Indirect financial costs
	Total	Fire prevention	Fire regulations and prevention
Fatalities	Victims		
	Type of fatality		

other countries), as listed in Table 2, were included in the analysis. The relevant supplied information was then reclassified according to the major categories as shown in Table 1. Moreover, the gathered definitions were compared to those provided in the ISO/TS 17755-2(E):2020 [20].

Therefore, prior to the creation of a common terminology able to standardize fire statistical variables, the research defined the need to evaluate the fire statistical variables that are considered fundamental in the assessment of fire incidents and fire scenarios by preparing a questionnaire.

2.2. The Quest for Essential Variables to be Collected

Following the analysis of current fire data practices, the research has created a questionnaire to propose fire data elements best suited for harmonization and collection in datasets maintained by the EU Member States. The main goal of the questionnaire was to identify visions, opinions and experiences regarding the data required for a comprehensive investigation of fire incidents able to support knowledge-based decisions regarding fire safety and inform legislative and policy decisions.

The model of influencing factors developed by Kobes et al. [26] was adopted to create the questionnaire as it introduces four factors that influence fire safety:

Table 2
EU Member States and Other Countries Where Definitions for Fire Statistical Variables Exist

EU Member States with definitions	Other countries with definitions
Austria	Australia
Czech Republic	Norway
Denmark	Canada
Estonia	USA
Finland	New Zealand
France	UK—England, Scotland and Wales
Germany	Russia
Hungary	Switzerland
Ireland	
Italy	
Netherlands	
Romania	
Slovakia	
Slovenia	
Sweden	

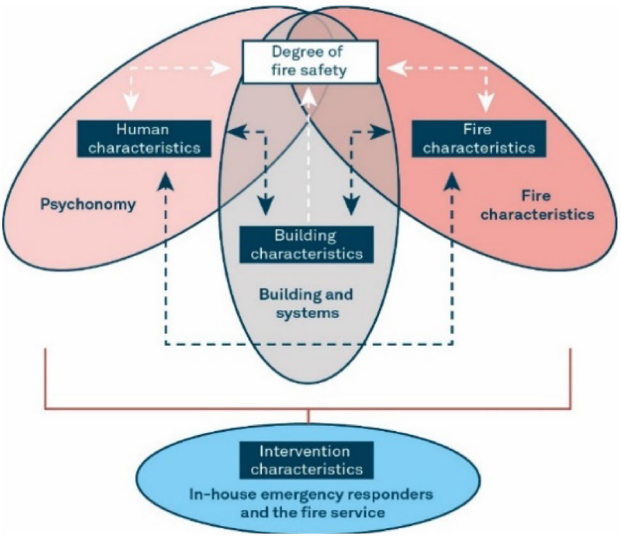

Figure 1. Model of influencing factors including human, building, fire and intervention characteristics [24].

human characteristics, building characteristics, fire characteristics and intervention characteristics (Figure 1). Based on the detailed investigation of current fire statistics developed in the first phase of the research, the characteristics related to fire consequences were also considered in the analysis. Therefore, the fire statistical

variables in Table 1 clustered per type of characteristics were adopted in the questionnaire as they represent a comprehensive list and appear to be in line with structured and complex existing fire statistical datasets. The full questionnaire can be found in the report published by the EU FireStat project [24] where some specific examples of the variables are available to provide a more accurate description and enhance clarity.

The questionnaire solicited feedback from stakeholders in the 27 EU Member States regarding the data required to create and implement fire safety policies. The stakeholders involved in policy and legislation were subdivided into three categories, listed by order of priority:

1. Authorities (such as the Ministry of Interior).
2. National fire services.
3. Others (including national statistics institutes, insurance companies, research bodies and fire prevention and fire service associations).

In some cases, several respondents from the same organization and the same country completed the questionnaire and the individual responses were aggregated to one average response per country per type of organization to avoid potential skewed values. For some countries, up to nine respondents completed the questionnaire, while for other countries only one. In order to ensure that the results of the countries with several respondents do not count disproportionately, the data have been aggregated. The responses, therefore, represent an average response per type of organisation, or per country, which does not automatically reflect a response comparable to a country for which one response was received. The responses have been aggregated into one answer per type of organization (authorities, national fire services and others) per country. In several cases, respondents from the same organization and the same country completed the questionnaire, often providing the same answer. As a result, a skewed picture may arise for the average overview of all countries. Therefore, it was decided to aggregate the individual responses to one average response per country per type of organization. The individual responses are aggregated at the organizational level. When there is only one response from an organization within a country, the aggregated response is identical to the response at the individual level. When there are multiple responses from an organization within a country, the responses within this group are replaced by one aggregated response that summarises the individual responses. This aggregated response is composed of a majority vote principle. The criterion for selecting a variable during the aggregation is obtaining the majority (50% or more) within an organization. This has resulted in 16 responses from the authorities being merged into 15 responses, 21 responses from the national fire services into 12 responses, and 24 responses from other types of organisations into 14 responses. Finally, to provide an overview per country, the responses were aggregated into one response per country. For example, the nine responses from Sweden were combined into one average response. The same procedure was followed for the aggregation per type of organization. As a result, all 65 responses were

merged into 27 responses. This aggregation choice was necessary to obtain one response per country.

The responses received by the stakeholders were consequently compared to those provided by the EU FireStat consortium members and to the variables already collected in the fire statistics of the EU member States. The consortium members are experts in fire safety, fire investigations and data analyses with extended experience in the fields of fire statistics. It was important to consider not only the view of the responsible authorities but also the opinion of experts in the fields as their interests, experience and vision could capture different aspects of fire incidents. The majority of the consortium members are based in Europe; however, none of them is part of a responsible fire statistical authority in the 27 EU Member States.

The survey was filled in separately by the "stakeholders" composed of three types of organizations: authorities (ministry of interior), national fire services and others (fire protection association or insurance) in each country. The consortium separately completed the survey and there is no duplication in the answers (e.g. answers of consortium members did not count in answers from stakeholders and did not skew the answers). The responses from stakeholders and from the consortium are then compared to the data already collected in the EU Member States. It is possible that there could be an underrepresentation of what is collected in some of the countries, especially in those three countries that did not provide detailed reports (Luxembourg, Malta and Portugal). However, it appears that those countries do not collect extensive fire statistics (only the number of fire and fire deaths for Malta and Luxembourg, and no data on structural fires in Portugal). Hence the error margin should acceptable.

Moreover, based on the outcomes obtained in Paper I [5], the frequently recorded fire statistical variables in the EU Member States appear to be focused on the description of fire incidents, identification of the fire causes, assessment of fatalities and casualties and the presence of alarms. Despite the existing fire statistics in the EU Member States producing an effect in the selection of the essential fire statistical variables, at the same time, this will support a reasonable implementation in the existing fire statistical practices.

The criteria used for the selection of the data needed for fire statistics are:

1. Variables with a majority of votes ($\geq 50\%$).
2. Variables that have at least more than 40% of the votes of the respondents. Including a margin of error of $\pm$ 10 points, allows for a larger coverage of opinions, such as a near majority, considering more variables in the selection process.
3. Variable already being collected by the majority of the 27 EU Member States (EU-27) with more relevance than a variable not yet being collected, even if not currently harmonised.

Finally, the fire statistical variables were classified according to three Tiers: Tier 1 includes variables that are already collected by the majority of the EU Member States and also covered by the sets of variables selected by the majority of the

stakeholders and the consortium or by the set of the stakeholders only, Tier 2 is referred to those variables selected by the majority of stakeholders and the consortium and are not collected by the majority of countries while Tier 3 identifies those variables chosen by the stakeholders, the consortium or already collected by the 27 EU Member States excluding those in Tier 1 and 2.

2.3. Proposed New Terminology

The results obtained from the questionnaire highlighted the main variables to be collected by the stakeholders. Based on these variables, a terminology for each of them was developed. The proposed terminology was restricted to building fires in which the fire service confirmed that a fire was either ongoing or had been extinguished, and resulted in damage to people, property, or the environment. In particular, the damage was defined as:

- Injuries at the fire scene.
- Fatalities at the fire scene.
- Damage to property of at least 100 Euros.
- Environmental contamination requiring clean-up.

Incidents known as "false alarms" were thereby excluded from the definition of a fire event. It is also important to specify that "fire" is referred to as the uncontrolled self-supporting flaming, glowing or smoldering combustion. Explosions, flashes and discharges of static electricity and suicide by self-immolation are only included if they caused a fire after the initial event. The objective when proposing the new terminology was to identify the most appropriate terminology and definitions for variables that describe the categories of interest to be recorded by fire officers in the aftermath of a fire incident and subsequently collected at the European level, as well as appropriate values which these variables can assume. This terminology would constitute a minimum dataset for collection at the local level especially for those countries not collecting these variables or without available definitions. It would not prevent a fire department or national authority from having a more detailed data collection than the one proposed in this research if data according to the terminology of the pan-European statistics are provided.

Several criteria were established in identifying appropriate values for a variable:

- Values must be unique to avoid overlapping alternatives.
- Values must avoid terms associated with moral failings or culpability since such values could inflate the selection of "undetermined" responses even in the face of better information.
- The proposed number of values must be suitable to allow a meaningful analysis avoiding a long list of alternatives.

It is desirable that the option "Other" is accompanied by a short text field that permits the respondent to describe a specific value and explanation of the proposed alternative. Having the option of adding a text field increases the complex-

ity of the data collection. However, it can be important for the data analysis, accuracy and evaluation of the missing value [25].

The following sections will be focused on the analysis of the existing terminology, results obtained from the questionnaire and proposed unified terminology.

3. Mapping of the Existing Definitions in the Investigated Countries

The definitions were grouped according to the categories of interest presented in Table 1 and compared to those available in the ISO/TS 17755-2 [20]. Detailed definitions for each country and the extended definitions available in the ISO/TS 17755-2 can be found in the report published by the EU FireStat [23]. In this paper, the analysis is focused on the main conclusions for each category of interest derived from the investigation.

For *fire incidents*, in the ISO TS 17755-2, definitions for accidental, fire false alarm, arson, deliberate fire, incendiary fire, intentional fire and voluntary fire are available. In many of the EU countries, the definition of fire incident includes the various fire incident classifications. For example, in Estonia and Finland, specific definitions for accidental, deliberate fire and fire false alarm are available while in Romania and Hungary, only a definition for fire false alarm is present. In Italy and Ireland, there is no proper definition. Moreover, in Italy, fire incidents are recorded as a false alarm and in Ireland, as a false alarm, malicious and good intent. When the other countries are examined, in Canada and the USA, a general definition for fire incidents is available with the subdivision of accidental, deliberate fires and false alarms. Accidental and deliberate fires are also available in New Zealand, Russia, and the UK. Norway defines false alarms while in Australia, Russia and the UK, false alarms are recorded without a proper definition.

The ISO/TS 17755-2 definitions for *building*, building fire, the height of the building, dwelling fire, home fire and residential fire are available. Buildings are classified as residential and non-residential with several classifications adopted in the EU and other countries according to various property types.

Fire causes, source of ignition and area of origin are covered by the definitions provided by the ISO/TS 17755-2. Definitions for fire causes are available without being explicitly expressed in many examined countries. For example, several countries present a dropdown menu instead of a specific definition. Furthermore, interpretations of fire causes vary in the investigated countries. In some cases, options are available for specific possible causes, fuels, and circumstances of the fire incident (as stated in the ISO/TS 17755-2), leading to difficulties in the comparison. Even the field referred to as the source of ignition is subject to a wide variation; for example, response options could refer to heat transfer or to the type of energy that leads to a fire. In some countries, material first ignited is included in this field.

When *fire consequences* are analysed, these are collected in only five EU countries and seven other countries. The major difference in the collection is represented by some fire statistics which provide a definition while others quantify the

consequences. For example, Estonia, Finland, New Zealand, the UK, and the USA similarly define fire spread, which is evaluated as "at the stop," generally referred to as when the fire is extinguished. Fire is evaluated at arrival and departure or extent in Sweden. In Australia, the reasons or factors that allowed the flame spread is recorded as the fire spread. While horizontal and vertical fire spread is generally recorded as two separate fields, in the Netherlands they are merged. Moreover, if the damage is caused by natural causes or accidents, then there could be different definitions. For the quantification of damage, the extent of damage is generally evaluated in m^2 or percentage of property damage where in Estonia, a formula is provided to calculate the property damage as a function of building m^2 burnt area, depreciation percentage, sanitary repairs, renovation, capital repairs and warranty repair. Finally, the fire and flame damage definitions could be qualitative or referred to their evaluation.

The analysis of *fire safety measures* appears to be more complex when existing fire statistics are examined. The ISO/TS 17755-2 defines alarms as the time to the notification to fire service or other local services. It is important to affirm that the definition provided by the ISO/TS 17755-2 does not have any correspondence to those available in the examined fire statistics. It is in this light that definitions for fire safety measures can be found in six EU countries, with specified details available for five of them. There are few fields related to fire safety measures even in the USA and Canada. Many EU countries affirm that this terminology is unclear or not reported. Alarm, type of alarms and information on extinguishing systems are the fields consistently reported and this could also be attributable to the other examined countries. When fire statistics authorities have been surveyed by the research, they found the fire safety measures difficult to understand and their responses indicated inconsistencies in interpretation. An example could be seen in the field referred to the presence of a fire brigade on site that was often considered as the municipal fire brigade and not the industrial fire brigade. Moreover, escape routes, evacuation and compartmentation are referred to as fire safety design features but could also be interpreted for evacuated people. Limited information is found on fire barriers, safe areas, and smoke extractors.

The *fire response* can be generally subdivided into the "occupant response" and "fire service response". Usually, fire service response includes several time designations, such as alarm time, departure, arrival, and departure time. In this case, the ISO/TS 17755-2 definition is similar to the ones provided by several countries, while in other fire statistics, the fire service response time is calculated based on the different entries provided. It is also important to highlight that relevant fire authorities appear to have difficulties in understanding information sought by the term "occupant fire response". In the UK, this is referred to as the time between ignition to discovery and discovery to call, while in other countries the definition is related to the actions that the occupants take to control the fire.

Fire financial costs are defined for damage, direct losses specifying property damage and indirect losses by the ISO/TS 17755-2. While direct and indirect financial costs of fire incidents appear to be rarely evaluated in the EU Member States and the other investigated countries, the fire damage to property including contents is usually covered by the direct financial costs. In Russia, there is a defi-

nition for the indirect financial costs of fire referred to as material losses from impeding economic plans in the economy (e.g. a decline in production, a decline in trade and banking operations, decrease in income, losses due to delays in the transport of goods) while in Slovenia, indirect financial costs are related to the cost of the firefighting operations. Another source of collection of indirect financial costs is represented by insurance companies. However, their estimates are rarely publicly available.

Finally, for the *fatalities and casualties*, in the ISO/TS 17755-2, the terms casualty or victims are equally used and refer to a person killed or injured. This ambiguity could potentially cause misunderstandings. When existing fire statistics are investigated, usually, the number of victims and type of fatality are recorded in fire data collection systems. However, a clear distinction between fatalities and casualties is not always available and the two terms are grouped. In some countries, the term fatality could be associated only with occupants or fire brigades. Most countries have definitions referring to the victims killed due to the fire. Generally, victims are recorded at the fire scene, such as in France, Hungary, and Italy, or within a specific time from the fire incident, as is the case in Estonia, Finland, Slovakia and Sweden while in the ISO/TS 17755-2, ''a fire victim is a person killed or injured as a direct effect of a fire without any limit of time''. A distinction between civilian and fire service victims is present in Germany, Austria, Switzerland, Canada, and the USA. Moreover, the cause of death could be deduced only in the Netherlands, Romania, and the UK.

Unfortunately, usually, countries use different criteria for defining fire fatalities and injuries. However, understanding the terminology is an essential requirement to develop a correct comparison between countries. From the developed analysis, it is possible to affirm that the accuracy of the definitions available for specific fields of fire statistics is strictly linked to the high number of countries collecting those fields. Therefore, the more accurate definitions have been found when they are collected by the fire statistics of most of the investigated countries. This is supported by the precision of the definitions provided for fire incidents and the inconsistency of those referred to as fire safety measures. It is, therefore, important to understand the meaning of the variables collected in the fire statistics and relate them to their data source. Moreover, the analysis developed in this section will support the proposed terminologies for fire statistical variables described in Sect. 5. In the following section, the essential variables to be collected are presented based on the opinion of relevant stakeholders and consortium partners.

4. Selection of the Data Needed for Decision Making

A questionnaire was created based on the analysis presented in Sect. 3 and shared with a group of stakeholders in the EU Member States as defined in Sect. 2.2 for a total of 65 respondents from all 27 EU Member States. In some cases, several respondents from the same organization and the same country completed the questionnaire. To avoid a potentially skewed picture, the individual responses were aggregated to one average response per country per type of organization.

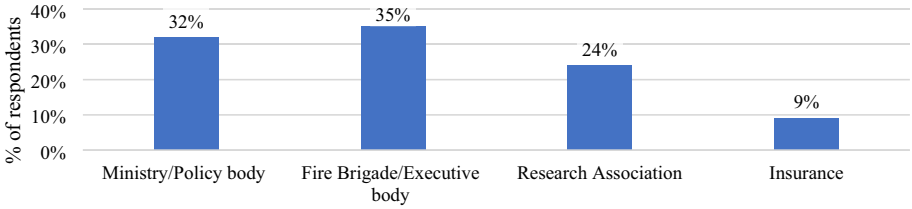

Figure 2. Percentages of type of respondents participating in the questionnaire of the EU Member States.

The 65 responses are merged into 27 responses, one response per country (Figure 2) and compared to the answers of the consortium (average of 9 responses, 1 per organisation) and the data already collected by the EU Member States.

As already introduced in Sect. 2.2, the criteria used within the process for the selection of the data needed for fire statistics are:

1. Variables with a majority of votes (≥ 50%).
2. Variables that have at least more than 40% of the votes of the respondents. Including a margin of error of ± 10 points, allows for a larger coverage of opinions, such as a near majority, considering more variables in the selection process.
3. Variable already being collected by the majority of the 27 EU Member States (EU-27) with more relevance than a variable not yet being collected, even if not currently harmonised.

The results presented in Table 3 are subdivided into variables selected by the majority of the stakeholders, the majority of the consortium members, and the variables already collected by the majority of the EU Member States. In particular, Figure 3 shows the quantification of the overlapping of variables chosen by the stakeholders, consortium members and current fire statistics in the EU Member States based on a Venn diagram.

The list of variables per section of the Venn diagram is classified according to three tiers: Tier 1, 2 and 3 (Table 4) and are described as follows:

– Tier 1 includes the variables that are already collected by the majority of the EU Member States and also covered by the sets of variables selected by the majority of the stakeholders and the consortium (four variables), or by the set of the stakeholders only (five variables).
– The variables in Tier 2 are selected by the majority of stakeholders and the consortium and are not collected by the majority of countries (four variables).
– The variables in Tier 3 are only selected by the stakeholders, the consortium or are already collected by the 27 EU Member States excluding those in Tier 1 and 2.

In the following sections, the variables included in the three tiers will be extensively described.

Table 3
Responses of Stakeholders and Consortium Partners Compared to Current Fire Statistics in the EU Member States [24] (Color table online)

Category of interest	Variable	Stakeholders	Consortium	EU-27
Human characteristics	Number of fatalities	Yes, 89 %	Yes, 100 %	Yes, 93 %
	Number of injuries	Yes, 93 %	No, 11 %	and 52 %*
	Number of occupants in the building	Yes, 52 %	No, 0 %	No, 19 %
	Age of fatalities	Yes, 48 %	Yes, 78 %	Yes, 52 %
	Gender	No, 19 %	Yes, 56 %	No, 37 %
	Disability	Yes, 48 %	No, 22 %	No, 26%
	Role (e.g., occupant or firefighter)	Yes, 48 %	No, 0 %	No, 37 %
Building characteristics	Type of building (e.g., residential)	Yes, 93 %	No, 11 %	Yes, 67 %
	Fire safety measures present (alarms & Automatic extinguishing systems)	Yes, 81 %	No, 11 %	Yes, 41 % and 29 %**
	Number of floors	Yes, 67 %	Yes, 44 %	No, 30 %
	Construction type (e.g., reinforced concrete, steel)	Yes, 70 %	No, 0 %	No, 15 %
	Construction characteristics (e.g., façade, claddings)	Yes, 41 %	No, 0 %	No
Fire characteristics	Primary causal factor of fire	Yes, 96 %	Yes, 78 %	Yes, 56 %
	Area of origin	Yes, 74 %	Yes, 89 %	No, 33 %
	Heat source	Yes, 74 %	Yes, 67 %	No, 33 %
	Item first ignited	No, 30 %	Yes, 67 %	No, 27 %
	Article contributing to fire development	Yes, 41 %	Yes, 44 %	No, 19 %
	Size of smoke spread	No, 15 %	Yes, 44 %	No
Consequences	Effectiveness of fire safety measures in reducing the fire	Yes, 78 %	No, 11 %	No, 22 %
	Quantification of property damage	Yes, 59 %	No, 11 %	No, 19 %
	Reason for failure of fire safety measures	Yes, 56 %	No, 0 %	No
	Type of property damage	Yes, 56 %	No, 11 %	No, 15 %
	Direct fire costs	Yes, 52 %	No, 0 %	No, 33 %
	Fire spread at final situation	No, 30 %	Yes, 67 %	No
	Fire spread at fire brigade arrival	No, 19 %	Yes, 44 %	No, 15 %
Incident characteristics	Incident location	Yes, 70 %	No, 33 %	Yes, 56 %
	Incident date	Yes, 52 %	Yes, 56 %	Yes, 85 % (*) and 78 %***
	Incident time	Yes, 52 %	No, 33 %	Yes, 59 %
	Fire detection time	Yes, 52 %	No, 11 %	No
	Fire brigade response time	Yes, 56 %	No, 11 %	No, 33 %
	Time between fire brigade arrival and withdrawal	No, 7 %	No, 0 %	Yes, 67 % (*)
	Operation of fire safety measures	Yes, 44 %	No, 0 %	No, 33%

Green = selected by 50% or more, orange = selected by 40% to49%, red = selected by less than 40%
(*) data extracted from Task 0 [22]
*93% number of fatalities, and 52% number of injuries
**41% smoke alarm system, and 29% fire extinguishing system
***85% day, and 78% month

4.1. Tier 1 (9 Variables)

The nine variables in Tier 1 are considered essential, being already collected by the majority of the EU Member States and also covered by the sets of variables selected by the majority of the stakeholders and the consortium, or by the set of the stakeholders only. They include the *Number of fatalities, Age of fatalities, Number of injuries, Type of building, Fire safety measures present, Primary causal factor of fire, Incident date, Incident time and Incident location*.

The most frequently selected variables regarding human characteristics are the *number of fatalities* and the *number of injuries*. Currently, the majority of EU

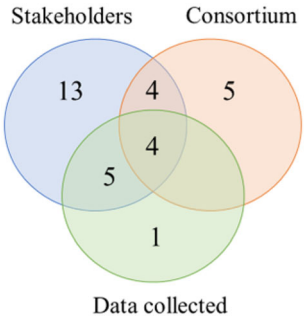

Figure 3. Data confirmed by stakeholders, the consortium, and available in the fire statistics of the EU Member States.

Member States already collect data about the *number of fatalities* and the *number of injuries*. *Number of fatalities* and *number of injuries* are important variables able to distinguish between fatal and non-fatal fires. A research study into fatal residential fires in Europe [27] reveals that several fire risks can be identified by comparing the characteristics of fatal fires to those of non-fatal fires. Insight into the fire risks is important to evaluate existing policy and determine the focus of citizens' education and information on fire safety.

Data about the *age of fatalities* are collected by the majority of the EU Member States (52%). The inclusion of this variable is supported by the choice of stakeholders and the consortium, as well as findings from the literature. Indeed, a research study into fatal residential fires in Europe [27] shows that age is relevant to the collection in several countries. For example, in the Netherlands and the USA, the elderly (age 61 and older or in some literature 65 and older) are overrepresented among victims of fatal residential fires due to physical and cognitive limitations and are a risk group for serious injuries from fire [28, 29].

The variable *type of building* is frequently mentioned by the stakeholders and is currently already collected by the majority of the EU Member States enabling the distinction between the fire risk of different types of buildings. This distinction is important as most of the fire-related fatalities are attributable to dwelling fires in England [30].

The variable *fire safety measures present* is mentioned by the stakeholders and is currently collected by the majority of the EU Member States in terms of the smoke alarm systems (41%) and by some countries in terms of the fire extinguishing system (29%).

Both the stakeholders and the consortium identified the *primary causal factor of fire* as an important variable for information relating to fire characteristics. Information on the primary causal factor of fire is currently collected by the EU Member States. Examples of values for this variable are human acts, equipment failure and natural phenomena. It is also important to better specify to what primary causal factor of fire is referred. Considering a real fire incident, a cigarette (heat source) igniting paper (item first ignited) due to an unintentional human act (pri-

Table 4
Variables per Section of the Venn Diagram Shown in Fig. 3 Classified According to Tiers 1, 2 and 3

Tier	Intersection	Total	Variables
1	Consortium & Data collected & Stakeholders	4	Number of fatalities Age of fatalities Primary causal factor of fire Incident date
	Data collected & Stakeholders	5	Type of building Fire safety measures present Number of injuries Incident time Incident location
2	Consortium & Stakeholders	4	Area of origin Number of floors Heat source Article contributing for fire development
3	Only stakeholders	13	Construction type Construction characteristics Number of occupants in the building Role of the victim (e.g. firefighter, citizen) Disability of the victim Quantification of property damage Type of property damage Operation of fire safety measures Effectiveness of fire safety measures in reducing the fire Reason for failure of fire safety measures Fire detection time Fire brigade response time Direct fire costs
	Only consortium	5	Item first ignited Gender of the victim Fire spread at fire brigade arrival Fire spread at final situation Size of smoke spread
	Only data collected in fire statistics	1	Time between fire brigade arrival and withdrawal

mary causal factor) and then spreading via curtains (articles contributing to fire development).

The variables regarding fire incident characteristics that are frequently mentioned by the stakeholders and are also currently collected by most of the EU Member States include *incident location, incident date* and *incident time*. Different values may be used in assessing the incident location, such as geographical coordinates or building address.

4.2. Tier 2 (4 Variables)

Four other variables voted by the stakeholders and the consortium are not currently collected by most of the countries included in Tier 2 which are:

Area of origin, Heat source, Number of floors and Article contributing to fire development.

At least 33% of EU countries collect information on the *heat source and area of fire origin*.

Information about *the number of floors* may be considered relevant in the case of fires in high rise buildings. Data about the *number of floors* can provide a substantial amount of information about the efficiency of fire safety and any evacuation measures that have been adopted (e.g. the evacuation strategy of a high-rise building is usually different than for single floor buildings). This can also be a strong indicator when comparing data between different countries.

4.3. Tier 3 (19 Variables)

Other variables are only covered by the set of the stakeholders (13), the consortium (five), or existing data collection (one). Those variables are not considered to be essential aspects to be covered by fire statistics and will not be included in the proposed terminology, except for the *item first ignited*. The variables defined in Tier 3 are the following and may be of interest for the future development of data collection:

Construction type, Item first ignited, Fire spread at the final situation, Time between fire brigade arrival and withdrawal, Quantification of property damage, Gender of the victim, Reason for failure of fire safety measures, Fire brigade response time, Type of property damage, Number of occupants in the building, Fire detection time, Direct fire costs, Disability of victim, Role of the victim (e.g., firefighter or citizen), Operation of fire safety measure, Fire spread at fire brigade arrival, Size of smoke spread and Construction characteristics.

Based on detailed discussions amongst consortium members, the item first ignited was considered an important variable that should be collected to assess the origin of the fire and the initial fuel load. Therefore, for the item first ignited, a unified definition was created.

It is important to note that excluding these variables from a harmonized European fire statistics system should not prevent the European countries from continuing collecting other variables in parallel. In the following section, a unified terminology for the variables of Tier 1 and 2 is proposed.

5. Proposed Terminology for the Variables Defined in Tier 1 and Tier 2

The variables obtained in the questionnaire and defined in Tier 1 and Tier 2 plus the item first ignited, are considered the core of the essential information that should be gathered in a fire incident. Therefore, to achieve the aim to move

Table 5
Proposed New Definitions and Values of Incident Characteristics

Incident characteristics		
Variable	Definition	Values
Incident date	The earliest available moment at which a fire event occurred, registered in the day, month and year at the local date and time	dd/mm/yyyy (European notation)
Incident time	The earliest available moment at which a fire event occurred, registered in hours (24 h) and minutes at local time	hh/mm (24H) or undetermined + local time (example: UTC + 01:00)
Incident location	The most precise place where a fire event occurred, registered in (by availability) coordinates, name of the country, region, town, postal code and/or street name and number	If available: coordinates (latitude and longitude), country, region, town, postal code and/or street name and number where the fire occurred or unknown (then: only country)

The earliest available moment refers to the earliest moment that the fire is reported to an official authority/system (for example, the detection time by an automatic detection system linked to the control room or calling the emergency number)

toward harmonized fire statistics, it is necessary to have common terminology for the fundamental fire statistical variables.

As introduced in Sect. 2.1, for the 35 selected countries, no response was received from Luxembourg, Malta and Portugal, and only limited information from Lithuania and Spain. In addition to those five, seven EU Member States (Belgium, Bulgaria, Croatia, Cyprus, Greece, Latvia, and Poland) affirmed their lack of appropriate definitions for the fire statistical variables (Table 2). Therefore, the proposed definitions and values for the variables are based on a deep analysis of the fire statistics of the 23 countries (15 EU Member States and eight other countries) investigated in Sect. 3. Some examples are the definitions for the fire statistical variables available in the fire incident form of the Incident Recording System [11] in England, the US National Fire Incident Reporting System [10], and the Australian Incident Reporting System [9]. Moreover, the analyses also included the information produced by specialized documents, such as the ISO/TS 17755-2:2020(E) [20] and ISO/TR 17755:2014 [19] already described in Sect. 1 as well as the definitions established by Eurostat [31], NFPA Guide for Fire and Explosion Investigations [32], European Network of Forensic Science Institutes Best Practice Manual for the Investigation of Fires and Explosions [33].

All the gathered information supported a detailed analysis of current fire statistical practice. Extended discussions amongst the consortium members of the EU FireStat project were organized to identify potential improvements and optimizations to be able to provide a better description of fire statistical variables and reduce potential uncertainties faced by the fire brigades or responsible authorities in filling in the form in the aftermath of a fire event. Limiting possible errors in the input data of the datasets will enable more accurate analysis and enhance data

Table 6
Proposed New Definitions, Notes and Values of Human Characteristics

Human characteristics			
Variable	Definition	Notes	Values
Number of fatalities	The number of person(s) who died as a result of injuries sustained during a fire incident	Note 1: Fire-related fatalities are those that would not have occurred had there not been a fire Note 2: Fire fatalities include people who die within 1 year because of injuries sustained from the incident. A shorter time period is accepted, but not shorter than 3 months. Fire fatalities also include fatality from natural or accidental causes sustained whilst involved in the activities of fire control, attempting rescue or escaping from the dangers of the fire, including blast and defenestration Note 3: Fire fatalities are composed of all persons discovered or declared dead on the location of the fire, during their transportation to the hospital or after their admission at the hospital Note 4: The number of the variable should include self-intended fires/suicidal fires but they should be marked as such Note 5: People who died before a fire started (natural death, victims of a violent crime) are to be excluded from the statistics as soon as a forensic medical report is available	Numerical value*
Number of injuries	The number of persons who are injured and/or ill (but not accounted for as deaths) as a result of a fire incident	Note 1: Fire-related injuries are those that would not have occurred had there not been a fire Note 2: Fire injuries include people who are injured within 1 year. A shorter time period is accepted, but not shorter than 3 months Note 3: Fire injuries are those treated at the scene or taken to the hospital Note 4: Fire injuries also include injuries from natural or accidental causes sustained whilst involved in the activities of fire control, attempting rescue or escaping from the dangers of the fire, including blast and defenestration	Numerical value*

Table 6
continued

Human characteristics			
Variable	Definition	Notes	Values
Age of fatalities	Numerical value of age of fatality at time of the fire	If actual age is not known, it should be estimated with the closest possible estimate. Particular care should be used in estimating the age for young adults aged 15 to 25 and older adults aged 60 to 70 as the threshold between youth and adult is often set at 18 years and between adult and senior at 65 years. For children less than 12 months old the age should be estimated to be 1 year	Numerical value*

*To be approximated when unknown

quality and data reliability that represent essential steps in the assessment of fire causes and consequences.

The created definitions represent the outcomes of a detailed analysis based on current fire statistical practice, previous studies and discussions with experts, and need to be considered as proposals to harmonise fire statistics based on common understandings, current practice in the existing fire statistics and valuable aspects necessary to support future optimization and improvements in data collection and analysis of real fire incidents in buildings.

The fire statistical variables obtained in Tier 1 and 2 plus the item first ignited (Sect. 4) were subdivided into four groups: fire incidents, human characteristics, building characteristics and fire characteristics. For each fire statistical variable, detailed definitions and the related values that should be inserted in the fire incident reports are provided. The values could be represented by numerical values, approximated numerical values, or specific classifications adopted to record the information of each fire statistical variable. Moreover, it is also specified where multiple choices are allowed. For those variables that need accurate explanations, appropriate notes are also added due to potential difficulties in the interpretation.

Table 5 presents the definitions, notes, and values for the incident characteristics. The *incident time*, *incident date* and *incident location* are already collected in more than half of the EU countries, nevertheless, some effort is expected for these countries to harmonize the existing definitions with the proposed ones and obtain harmonized data. In particular, the *incident location* is referred to as the most precise place where a fire event occurred, registered in (by availability) coordinates, name of the country, region, town, postal code and/or street name and number. Devices for automatically recording the incident location could be added to the fire vehicle enabling the recording of the exact location and allowing further studies related to the evaluation of the fire frequency according to specific urban and rural areas.

Table 7
Proposed New Definitions, Notes and Values of Building Characteristics

Building characteristics			
Variable	Definition	Notes	Values
Type of buildings	*Buildings* are roofed constructions which can be used separately, have been built for permanent (or semi-permanent) purposes, can be entered by persons and are suitable or intended for protecting persons, animals or objects Buildings are subdivided into residential, non-residential and mixed-use buildings: *Residential buildings* are constructions that are exclusively used for residential purposes *Non-residential buildings* are constructions that are exclusively used for non-residential purposes *Mixed-use buildings* are constructions which are used for both residential and non-residential purposes	The definitions and classifications are extracted from the classification of types of constructions [34] and adapted to the scope of the current project. This classification system is used by Eurostat for European statistical purposes, such as providing indicators on the development of granted building permits [35] in the European Union (EU). The classification mainly differentiates the use of buildings, according to the main use (e.g., residential, non-residential and mixed-use) as well as their respective sub-divisions	Buildings *Residential buildings*: unknown, one-dwelling building, two-and more dwelling buildings, residences for communities *Non-residential buildings*: unknown, hotel and similar buildings, office buildings, wholesale and retail trade buildings, traffic and communication buildings, industrial buildings and warehouses, public entertainment, education, hospital or institutional care buildings, other non-residential buildings Buildings under constructions
Number of floors	The number of floors above is the numerical value to capture the number of floors above and including the ground level The number of floors below is the numerical value to capture the number of floors below and excluding the ground level	The floor is defined as the distance from the pavement to the ceiling of one floor The ground level is referred to the level of the main entrance of the building	Numerical value for floors above* Numerical value for floors below*
Fire safety measures present	Devices and systems that aim at reducing the impact of a fire. They can be detecting (smoke, fire etc.), alarming (local, central etc.) and/or preventing fire spread (sprinklers, automatic extinguishing equipment, compartmentation etc.) or any combination of those		Detection Alarm Extinguishing system Passive fire protection (Fire doors—other compartmentation means) Smoke control systems

*To be approximated when unknown

Table 6 presents the definitions, notes, and values for the human characteristics which are also already collected in most EU countries as stated in the results of the questionnaire (Sect. 4). In the definition of the *number of fatalities*, all people discovered or declared dead at the location of the fire, during their transportation to the hospital or after their admission to the hospital are included. This represents a major difference from most of the fire statistics in the examined countries where fire fatalities are only recorded at the fire scene. In the proposed definitions, the *number of fatalities and injuries* are recorded within a year and a follow up appears to be necessary after the fire incident. For the implementation of such variables, it is expected that the process will be difficult, especially for those countries that are currently reporting them only at the fire scene without a follow up from the hospitals or Legal Medicine Institutes. In countries already updating the victim information by cross-checking with data from the medical records, it is estimated that there should be no difficulties in adapting their terminology to the harmonized one.

Table 7 presents the definitions, notes and values for variables related to building characteristics. While information about the *type of building* is already collected in at least 18 EU countries, the *number of floors* is only recorded in at least eight EU countries and fire safety measures are available in at least 11 EU countries for smoke alarms and seven EU countries for automatic extinguishing systems. In detail, the floor is defined as the distance from the pavement to the ceiling of one floor where the ground level is referred to as the level of the main entrance of the building. The *presence of fire safety measures* is referred to as detection, alarm, extinguishing system, passive fire protection (e.g. fire doors, other compartmentation means), and smoke control systems. *Type of buildings* is classified according to Residential buildings, Non-residential buildings and mixed-use buildings where the latter is referred to as constructions which are used for both residential and non-residential purposes based on the main apparent use, with the addition of the flag "m" following their initial classification. The "m" flag is adopted to attribute a primary use (residential/non-residential types) and to create a third class of buildings for which there is apparent mixed use as perceived by compilers. Moreover, there is a specific class for building under construction, not including buildings under maintenance or renovations. Due to the variety of classifications for building types in the available fire statistics, it is expected that adding these data to the fire statistics will require a higher effort for implementation.

The definitions, notes, and a few examples of values for the variables of the fire characteristics are presented in Tables 8 and 9, respectively. The *area of origin* is currently collected in at least eight EU countries, the *item first ignited* in at least seven EU countries, the *article contributing to fire development* in at least five EU countries and the *heat source* in at least eight EU countries.

Considering the *area of origin, item first ignited, article contributing to fire development* and *cause of the fire*, it was observed that the classifications adopted could be very different in the existing fire statistics of the examined countries. Hence, the proposed definitions harmonize the available definitions based on their similarities. For the above-mentioned variables, the most challenging aspect is expected to be

Table 8
Proposed New Definitions and Notes of Fire Characteristics

Fire characteristics		
Variable	Definition	Notes
Area of origin	The localized area where the fire started	
Item first ignited	The initial fuel of the fire—the first item that had sufficient volume or heat intensity to extend to uncontrolled and self-supporting combustion	The values for this variable must be at a level of detail which a fire officer is able to identify, hence the use of the word "item". It is sufficient to know the item at a general level without going into more detail about the item's structure or the material it is made from In items powered by electricity, an ignition can occur in the casing or heat insulation of the item. The heat for this ignition may be internal, coming from an electrical fault in the equipment itself, or external. We can illustrate this with two examples of fires where a coffee machine is the item first ignited. In the first case a fault in the coffee machine ignites the plastic casing, and the coffee machine is both the heat source and item first ignited. In the second example, someone carelessly leaves the coffee machine on a hot plate of a freestanding cooker which then gets turned on by accident. In this case the coffee machine is the item first ignited, but the freestanding cooker is the heat source
Article contributing to fire development	Any specific article assessed by the fire officer or fire investigator to have had a significant contribution to the development of the fire beyond the *item first ignited*	This variable is only relevant if the fire spread from the *item first ignited*
Cause—heat source	The source of energy that initiates combustion in the *item first ignited*	*Item first ignited* and *heat source* will allow us to understand how ignition occurred, but it is not in itself sufficient for fire prevention purposes—it is necessary to know why the item first ignited was exposed to the heat source for long enough for ignition to occur, as described in *primary causal factor*
Cause—primary causal factor	The general causal factor that the fire officer assesses to have been the most important in explaining why the *item first ignited* was exposed to the *heat source* in a way that led to an uncontrolled combustion	The term "causal factor" is proposed instead of "fire cause" because the direct fire cause is already clear: the item first ignited has been exposed to the heat source for long enough for ignition to occur The word "primary" is used to signal that it is the most important factors that should be recorded

the adoption of the values proposed for each variable. Since the way these variables are recorded in the examined countries can vary greatly, there will be a need to adapt the existing classifications to the proposed new structure.

To better understand the use of the fire statistical variables related to the fire characteristics, the following examples are provided to better specify their use when there is a fire where a coffee machine is the item first ignited:

- A fault in the coffee machine ignites the plastic casing, and the coffee machine is both the heat source and item first ignited.
- Someone carelessly leaves the coffee machine on a hot plate of a freestanding cooker which then gets turned on by accident. In this case, the coffee machine is the item first ignited while the freestanding cooker is the heat source.

For the *article contributing to fire development*, this variable is only relevant if the fire spread from the item first ignited while the fire causes are subdivided into heath source and primary causal factor. The *cause—heat source* is referred to the source of energy that initiates combustion in the item first ignited while the *cause—primary causal factor* is the general causal factor that the fire officer assesses to have been the most important in explaining why the item first ignited was exposed to the heat source in a way that led to uncontrolled combustion. Table 9 presents some examples of the values attributable to the fire statistical variables related to the fire characteristics.

Some comparisons between the proposed terminology and the ISO/TS 17755-2:2020(E) [20] and the ISO/TR 17755:2014 [19] are presented as an example. The *incident date*, *incident time*, *incident location*, *article contributing to fire development* and *fire safety measures* are not defined in the ISO/TS 17755-2:2020(E). Having definitions and collecting these variables could be important for the fire statistics and the resulting mitigation methods.

For the *number of fatalities* and the *number of injuries*, the ISO/TS 17755-2:2020(E) proposes several variables for the same definition and for some cases there are multiple definitions with relatively similar meanings. For example, *fatal fire casualty*, *fire fatality*, *fatal fire injury* and *fire death* have all the same definition, and it refers to a person who has died as a result of injuries sustained during a fire incident. *Fire casualty* and *fire victim* is defined as a person killed or injured as a direct effect of a fire without any limit of time following the date on which the injury was sustained. *Fire injury* is defined as a person who is injured (but not fatally) as a result of a fire incident, without any limitations on time after the fire. These definitions proposed in the ISO/TS 17755-2:2020(E) are very similar and several variables have the same meaning, thus might cause confusion when used. The proposals developed in this analysis suggest using one variable that carries a certain meaning, instead of several. Another difference is that the time span to collect the proposed variables is limited to 1 year (a minimum of 3 months is also accepted), compared to no time limit mentioned in the ISO/TS 17755-2:2020(E). It is more difficult to assess if the fatalities or injuries were triggered by a fire incident when the time span is longer than a year. For the variable *age of fatalities*,

Table 9
Some Examples of Values for the Variables of the Fire Characteristics

Fire characteristics	
Variables	Values
Area of origin	*Functional Area*: e.g., Sleeping area, Bathroom/toilet, Kitchen, Living room, Other (write a value) *Area of Egress*: e.g., Hallway or corridor, Elevator, Other (write a value) *Assembly or Sales Areas*: e.g., Showroom, Lounge area, Other (write a value) *Technical Processing Area*: e.g., Operating area, Stage/Scene, Other (write a value) *Storage Areas*: e.g., Parking area/garage, Trash, Other (write a value) *Service/Equipment Area*: e.g., Machinery area, Heating area, Other (write a value) *Structural Areas*: e.g., Wall assembly, Roof, Façade, Other (write a value)
Item first ignited	*Food-related*: e.g. Cooking fat or oil, Food *Furnishing and clothing*: e.g., Sofa, Curtains, Bed, Clothes, Other (write a value) *Combustible material in household electric appliance*: e.g., Freestanding cooker, Dishwasher, Heater, Other (write a value) *Combustible material in other electric appliance, tool or distribution*: e.g., Battery, Wiring, Photovoltaic panels, Other electrical item (write a value) *Building element*: e.g., Façade and cladding elements, Windows, Other (write a value) *Other*: e.g. Paper or cardboard, Flammable liquid or gas, Rubbish, Other (write a value) *Undetermined*
Article contributing to fire development*	Fire did not spread from *item first ignited* Fabric Upholstered furniture Foam mattress Flammable liquid Flammable gas Paper or cardboard (*including books*) Building elements Rubbish Renovation or maintenance related items Other (write a value)
Cause—heat source	*Household electric appliance*: e.g., Freestanding cooker, Dishwasher, Heater, Other (write a value) *Other electric appliance or tool*: e.g., Battery, Other (write a value) *Electric distribution*: e.g., Wiring, socket, Other (write a value) *Consumer electronics*: e.g., TV; radio; laptop or tablet computer *Fire or flame*: e.g., Cigarette, Candle, Gas cooker, Other (write a value) *Other*: e.g., Lightning, Explosive substance, Other (write a value) *Undetermined*

Table 9
continued

Fire characteristics	
Variables	Values
Cause—primary causal factor	*Human act or omission* Intentional (A fire which is intentionally ignited under circumstances in which the person knows that the fire should not be ignited) Unintentional (the damage caused by the fire was unintentional) Undetermined intent *Equipment failure* *Natural phenomenon* *Undetermined*

The entire list of values can be found in the Task 4 report of the EU FireStat project [25]
*Multiple choices are allowed

the developed research does not propose any categories compared to the ISO/TS 17755-2:2020(E), nevertheless offers some suggestions for some age groups.

Regarding the *type of building* variable, the current research classifies the buildings as residential, non-residential and mixed-use buildings, and values are presented for each category. In the ISO/TS 17755-2:2020(E), there is no clear classification of the buildings, nevertheless, the residential, commercial, industrial and public buildings are mentioned. The current research proposes a definition for the *number of floors*, while the ISO/TS 17755-2:2020(E) defines the *height of the building*. The height of the building is more difficult to estimate compared to the number of floors.

The *area of origin* is defined in the current analysis and a list of values is introduced. No values are presented for the *area of origin* in the ISO/TS 17755-2:2020(E); however, additional definitions are available for the variables *location of fire* and *point of origin of the fire*. The *item first ignited* is defined in this research, with a list of values, as opposed to the *material first ignited*, with no values in the ISO/TS 17755-2:2020(E). The *cause-heat source* and *cause-primary causal factor* are defined in this analysis, with a list of values for each one of them. The ISO/TS 17755-2:2020(E) presents definitions for *cause of a fire*, *source of the fire*, *classification of the primary cause of a fire* and *circumstances of the fire*. The two variables proposed in this research capture the essence of the four variables defined in the ISO/TS 17755-2:2020(E).

The results obtained from the analysis of existing fire statistical definitions show that the majority of variables currently collected appear to lack a proper definition in the majority of the examined countries. For those variables recorded in more than half of the surveyed countries, significant effort will be required to align them with the proposed definitions and obtain harmonized data. Moreover, it is expected that adding the variables collected in fewer than half of the EU countries to a harmonized fire statistics system will require a substantial effort.

Depending on the nature of the data, some variable will require more effort to be harmonized in practice than others.

Further variables could be introduced in the collection and uniquely defined in future implementations. For example, the collection of variables such as *effectiveness of fire safety measures in reducing the fire*, *reason for failure of fire safety measures* and *operation for fire safety measures* could provide outputs for the fire safety measures producers and potentially improve the inspection methodologies. Having a better overview of the *number of occupants in the building*, along with the *disabilities* of the people, could be important in creating and/or validating evacuation models. The fire detection time and fire brigade response could underline the effects of distance on the fire damage.

6. Conclusions

The need to determine a more comprehensive evaluation of fire scenarios in buildings as well as the evaluation of existing data related to fire incidents and identification of current fire statistical practices supported the investigation of fire statistics in the EU Member States and other countries. Such analysis highlighted the differences in the definitions for the fire statistical variables even when a similar terminology is adopted.

Therefore, due to the lack of common terminologies or variables with a similar nomenclature covering different aspects, it is not possible to compare fire incident data between countries. To develop a comprehensive evaluation, the research developed in this paper examined current fire statistics in the 27 EU Member States and eight other countries to determine the adopted terminology in current practice. The analysis of current fire statistics showed the differences in the existing terminology and, where a similar nomenclature is available, this could be referred to include different aspects. The fields recorded by most of the examined countries appear to present more detailed and accurate definitions compared to those rarely recorded. From the analysis of the existing definitions, the necessity of a common terminology arose based on a prioritization of the most relevant variables able to comprehensively assess fire incidents.

A questionnaire was created to identify the essential fire statistical variables that should be recorded in fire statistics to comprehensively describe the fire incidents. Such questionnaire was shared with relevant stakeholders responsible for the fire statistics in the examined countries, and EU FireStat consortium partners. The obtained responses were then compared to existing EU fire statistics to select the essential fire statistical variables necessary for the complete identification of the fire events in buildings. The selected variables were grouped into three tiers where Tier 1 presents the variables collected by the majority of the EU Member States and also selected by the majority of the stakeholders and the consortium or by stakeholders only, Tier 2 the variables selected by the majority of stakeholders and the consortium and not collected by the majority of the examined countries and, Tier 3 the variables selected by the stakeholders, the consortium or already collected by the 27 EU Member States.

The fire statistical variables defined in Tier 1 and Tier 2 plus the item first ignited, were considered the core of the essential information that should be gathered in the aftermath of a fire incident as they were identified as already recorded in the EU Member States and selected by the stakeholders and consortium. This will support a reasonable implementation in current practices and should not prevent the European countries to continue collecting other variables in parallel. The obtained information was used to propose essential fire statistical variables and provide definitions and values for each of them based on a deep analysis of available definitions and values in the fire statistics of various countries, and a variety of specialized documents. The proposed terminology constitutes a minimum dataset for collection at the local level and it does not prevent a fire department or national authority from having a more detailed data collection if they can provide simplified data according to the terminology of the pan-European statistics.

The analysis of the fire statistics inevitably implies a correct and common understanding of the recorded variables to enable an appropriate investigation of details relating to the fire incident, building occupants, the building structure, and fire characteristics. Finally, the outputs generated are intended to increase awareness of current definitions and propose a common terminology that will generate the foundations for harmonized fire statistics at the EU level. The introduction of these fire statistical variables could have applications in the identification of fire scenarios and fire risks, factors influencing fires and evaluation of the performance of buildings and fire safety measures being implemented in fire design, computational models and evacuation strategy. Fire statistics could provide useful information for fire brigades to optimize their organization and authorities to determine investments and create prevention campaigns. Future research should be considered in terms of the reasons for the selection of certain data by each country, what policy decisions data can inform, and an analysis of the efficacy of the data in supporting the defined policy decisions. Future work should also be performed to understand how the fire investigation and/or police reports can improve the quality of fire statistics.

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Declarations

Competing Interests The authors declare that they have no competing financial interests or personal relationships that could have influenced the work developed in this paper.

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