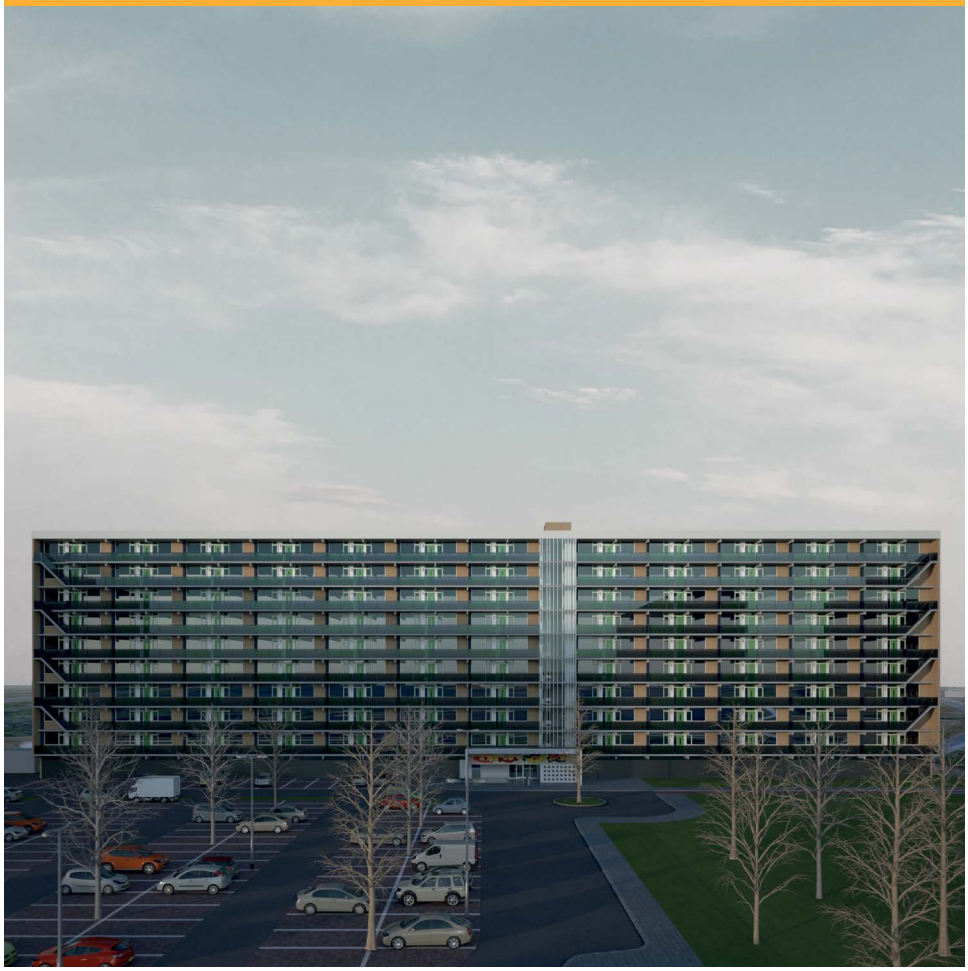
DUTCH
SAFETY BOARD

# Fatal fire in a block of flats in Arnhem

## Lessons for fire safety



# Fatal fire in a block of flats in Arnhem

## Lessons for fire safety

*The Hague, September 2021*

*The reports issued by the Dutch Safety Board are publicly available on www.safetyboard.nl.*

*Cover photo: Dutch Safety Board*

## The Dutch Safety Board

When accidents or disasters happen, the Dutch Safety Board investigates how it was possible for these to occur, with the aim of learning lessons for the future and, ultimately, improving safety in the Netherlands. The Safety Board is independent and is free to decide which incidents to investigate. In particular, it focuses on situations in which people's personal safety is dependent on third parties, such as the government or companies. In certain cases the Board is under an obligation to carry out an investigation. Its investigations do not address issues of blame or liability.


**Dutch Safety Board**

Chairman: J.R.V.A. Dijsselbloem
M.B.A. van Asselt (until 14 June 2021)
S. Zouridis

Secretary Director: C.A.J.F. Verheij

Visiting address: Lange Voorhout 9
2514 EA The Hague
The Netherlands

Postal address: PO Box 95404
2509 CK The Hague
The Netherlands

Telephone: +31 (0)70 333 7000

Website: safetyboard.nl
E-mail: info@safetyboard.nl


N.B. This report is published in the Dutch and English language. If there is a difference in interpretation between the Dutch and English version, the Dutch will prevail.

# CONTENTS

# SUMMARY

*The fire*
During New Year's night 2020, fire broke out in a block of deck-access flats in Arnhem, after a small firework had been set off in the entrance hall. The firework led to a fire in a sofa that had been placed in the entrance hall to the building, several days previously. At the point when the fire was at its height, the lift descended, containing two parents and their two young children. Upon entering the lift, the family was not aware of the fire in the entrance hall. On arrival at the ground floor, the lift door opened, and the family was confronted with tremendous heat and an influx of hot smoke containing toxic substances. Because on the way down they had pressed the button for the third floor, the lift door once again closed, and the lift transported them back to the third floor. Within around thirty seconds of coming into contact with the fire, all four were rendered incapable. They were no longer able to leave the lift on the relatively safe third floor.

The fire brigade arrived, and extinguished the fire in the entrance hall. The entire block of flats was then systematically searched by the fire brigade. On the third floor they came across the lift containing the family, at which point they took the family members outside. The father and youngest child died as a result of thermal radiation, asphyxiation and smoke poisoning. The mother and elder child were treated in hospital, and survived the fire.

During the fire, many of the residents of the block of flats assembled on the galleries: they felt unsafe, and wanted to escape from the building. This was a dangerous undertaking because the only exit route was blocked by smoke and fire. The fire brigade attempted to make it clear to the residents that they could remain in safety at either end of the gallery or could return safely to their homes. However, communication was made more difficult by language barriers. Although from a rational viewpoint they remained safe during the fire, during the course of the fire and in the subsequent period, these residents felt unsafe in their own living environment.

The Dutch Safety Board concludes that the fire in the building developed so violently and had such tragic consequences due to the coincidence of two circumstances. (1) The location where the fire raged was on the only (escape) route outwards. As a result, the family was overwhelmed by the fire when attempting to leave the building in the normal manner, and it was impossible for other residents and visitors to escape from the block of flats. (2) Because the fire took place in a sofa filled with plastic foam, it developed extremely rapidly and fiercely, producing large volumes of toxic smoke, which spread rapidly. On the basis of these findings, the Dutch Safety Board decided in this report to consider in more detail escape routes in residential buildings and fire hazardous furniture. The lift and the use of the lift in the event of a fire was not further investigated by the Dutch Safety Board, because it is uncommon for a lift to transport people directly to a fully developed fire and because technical solutions that (could) prevent a recurrence in the future are complicated and costly. In addition, these technical solutions are not

expected to bring about any broader safety gains. An investigation by *Liftinstituut* also showed that from a technical point of view, during the occurrence, the lift functioned correctly.

*Underlying principles for escape routes from residential buildings*
In the event of fire in a residential building, such as the block of flats in Arnhem, people must be able to escape safely from the building. A single escape route is sufficient, on condition it remains free from fire and/or smoke for a sufficient length of time. That in turn requires that no fire is able to develop on the escape route and that the escape route is protected against smoke and fire elsewhere in the building, for a certain amount of time. In order to satisfy these conditions, structural and installation regulations have been formulated and laid down in law. These regulations must be complied with during the design and construction phase, and respected during the use phase. In addition, regulations are in place aimed at ensuring that fire safety in the use phase of a residential building is maintained at the required level by the building owner and residents.

*Safe escape in the event of fire in practice*
In order to maintain the fire safety of a residential building at the level achieved during construction, the owner of the building and the residents must remain alert to fire safety during the use phase. This means that during daily maintenance and in the case of minor repairs and alterations not subject to compulsory permits, the owner must guarantee that fire safety does not deteriorate. In addition, residents are responsible together with the owner for keeping escape routes clear. In practice, however, these responsibilities are not always fulfilled. In the case of the building fire in Arnhem, for example, there was a sofa in the entrance hall, that forms part of the single escape route outwards. In addition, a number of structural changes had been made such as the placement of a Lexan panel in the door between the entrance hall and the stairs, and a wooden wall construction below the stairs, that did not match the designed and licenced level of fire safety. Various residents and employees of the housing association had seen the sofa in the entrance hall, but no one removed it. There was insufficient recognition of how fire hazardous furniture can be, and how important it is to keep (part of) the single escape route clear of objects of this kind, even if they are not in the way.

The Safety Board notes that the various stakeholders were insufficiently alert to fire safety in the use phase, and failed to realize that the sofa was a fire hazardous object in the single escape route. The housing association that owns the block of flats in Arnhem is not alone in this situation; fire safety awareness could also be improved at many other housing associations. Problems with fire safety often only emerge in the event of incidents, and even then only receive brief attention. In practice, this attention wanes rapidly, again allowing fire safety awareness to lapse quickly. Moreover, as a rule, municipal authorities are not active in supervising compliance with fire safety requirements in the use phase, as a result of which less than fire-safe situations – as for example on the escape route from the block of flats in Arnhem – go unnoticed for long periods of time.

*Fire hazardous furniture*

The majority of seating and mattresses today are filled with plastic foam. This was also the case with the sofa that was placed in the entrance hall in the block of flats in Arnhem. Plastic foam-filled furniture and mattresses can catch fire relatively easily. In this case, a firework from the lightest category of consumer fireworks was sufficient to ignite the sofa. Once an object of this kind catches fire, the fire develops far more quickly than is assumed in the fire safety principles. Furniture fires of this kind also generate more smoke than an average fire. Smoke is recognized as representing a hazard, because in thick smoke it is not possible to breathe or see. The smoke generated in furniture fires spreads more quickly than the fire itself. In addition, this smoke is extremely toxic because it not only contains carbon monoxide but also hydrogen cyanide. Hydrogen cyanide is far more toxic than carbon monoxide and can be fatal only a very short time following inhalation. All these characteristics together - rapid inflammability, rapid fire development, high heat production, toxicity, rapid smoke spread - mean that in the event of a fire in a seat or mattress filled with plastic foam, there is less time to escape than in an average fire. In the Netherlands, each year around ten people are killed and one hundred injured in residential fires as a result of fire hazardous furniture. In Europe, fire hazardous furniture results in around 1250 fatalities per year.

Neither the European Union nor the Netherlands impose legal requirements on the fire safety of seats and mattresses for the consumer market while a number of other countries do have national legislation covering these products. The most commonly used method for increasing the fire safety of furniture is to add flame retardants to the plastic foam filling. However, flame retardants also have disadvantages: they can have a harmful effect on human health and the environment. This certainly applies to the older types of (halogenated) flame retardants. Less harmful flame retardants are now also available, and innovative solutions are coming onto the market to improve the fire safety of furniture and mattresses. The fire in the block of flats in Arnhem shows the need for these improvements. Because no one recognized the sofa in the entrance hall as a fire hazardous object, a fierce toxic fire took place, with rapid smoke propagation which overcame the family in the lift, and proved fatal for two of them. In addition, the residents of the block of flats were unable to escape, because the fire was blocking the single escape route leaving them with a feeling of unsafety and fear.

The fire in the entrance hall of a block of flats in Arnhem, that was part of the single escape route to outside, was able to develop into a dangerous and even fatal fire, because it was a furniture fire. The fire broke out in a sofa, and was caused by what was thought to be an extinguished firework of the lightest category. Seating such as this sofa and mattresses are often filled with plastic foam. The plastic foam used for this purpose is easily flammable and the resultant fire develops quickly and violently, generating large volumes of toxic smoke. The rapid development of the fire and the toxic substances released in the fire meant that within thirty seconds after initial fire contact, the victims were rendered incapable and were unable to independently reach safety.

*Making fire hazardous furniture safer*
Every year, around 1250 people are killed in Europe as a result of fire hazardous furniture and mattresses. In the Netherlands, there are on average ten fatalities and a hundred people are injured. Against that background, the Netherlands Fire Service (Brandweer Nederland) and the Institute for Safety (Instituut Fysieke Veiligheid) have been calling for years to make furniture more fire safe, for example by including fire safety requirements in legislation. Ideally, the requirements governing the flammability of these furniture items should be laid down in European legislation; to date, this has not happened. Various European countries do impose national requirements on the fire safety of seating. It is time that the Netherlands joins the countries that have taken the lead, and ensures that any furniture and mattresses placed on the market in the Netherlands comply with fire safety performance requirements.

*Safe escape from residential buildings*
The fire raged in the entrance hall of a block of deck-access flats. This was the only exit and also the single escape route outwards. A fire of this kind in a block of flats affects many households. Residents and other persons present in the building wish to escape, but are unable to do so and are not aware of safe alternatives. This leads to a sense of unsafety and unsafe behaviour. Many blocks of flats in the Netherlands, just like the block of deck-access flats in Arnhem, have only one escape route outwards. This situation is in compliance with existing legislation and regulations, but in practice results in a vulnerable situation. This is because although in the emergency escape concept from residential buildings the possibility that smoke and/or fire can make their way into the single escape route is excluded, this proves not always to be the case in practice. As a result, it is possible that the single escape route outwards - of crucial importance in the event of a fire - becomes unusable.

The escape concept from most blocks of flats takes no account of the scenario in which the only escape route becomes unusable. As a result, in situations when this does happen, the emergency services have to respond accordingly. Even in the ideal situation, in which residents are capable and know the building well, the loss of the escape route is a problem. If, as was the case in Arnhem, the residents are afraid and are restricted by

language barriers, the response of the emergency services is made more difficult. It is then not always immediately clear to them, when they arrive on the ground, what this means for the message they need to send, and the way in which they can communicate with the residents. The challenge facing emergency services when the only escape route outwards becomes unusable is further exacerbated if the residents are less capable as a result of old age and psychological or physical health problems. The trend within society that residents who are less self-reliant remain living at home (for longer) deserves the attention of the owners of the residential buildings, because of its consequences for (emergency) assistance.

In buildings where the function is not residential, for example hotels and office buildings, situations can also arise in which people are required to or want to escape from the building. Unlike blocks of flats, hotels and office buildings are obliged to be prepared for this situation. Escape routes are marked, an easily audible alarm is sounded, and evacuation exercises are held, so that people know how to respond in the event of an emergency situation. At present, there are no such requirements for residential buildings. For owners of residential buildings, it can be worthwhile exchanging knowledge about the fire safety measures used in offices and hotels, that could also be used in residential buildings.

In this investigation into the fatal fire in Arnhem, the Safety Board observes that two underlying principles crucial to fire safety in residential buildings are not always complied with in practice. Firstly, it became clear that (single) escape routes are not always kept free from smoke and fire for long enough, so that it is not always possible for people to escape safely from residential buildings. Secondly, it became clear that fires in seating and mattresses filled with plastic foam develop in a different way than is assumed in fire safety theory. These fires develop more quickly and more fiercely, and also produce more and more toxic smoke, that can spread very rapidly. This in turn leads to unforeseen unsafe situations in residential buildings that can end fatally, as was the case in the tragic fire in Arnhem.

*Owner responsible for everyday fire safety in residential buildings*
The owners of residential buildings bear primary responsibility for fire safety in the buildings they own. The Safety Board therefore expects them to be aware of the fire safety risks in the residential buildings on their books, and to act accordingly. These risks for example lie in the fact that a building has only a single escape route outwards. In that case, the owner must consider in advance what keeping the emergency escape route safe means in terms of building management, including repairs and maintenance. In addition, owners must inform tenants of what is expected of them in the framework of keeping the building fire safe, not only in respect of their own home but also maintaining order in communal areas and keeping escape routes safe. Understanding and recognizing fire safety risks and implementing mitigating measures are essential for owners of residential buildings in fulfilling their responsibility for fire safety. In this report, the Safety Board observes that not all owners of residential buildings are sufficiently aware of the extent to which this responsibility for fire safety extends, also in daily use.

For the fire safety of residential buildings, owners and residents of residential buildings are mutually dependent. They have a shared responsibility. Because risks for fire safety can occur in respect of so many aspects in the daily use of a building, it is essential that the owners and residents, possibly supported by an expert party, actively seek out the fire safety status of the building. That expert party could for example be the fire service or the municipal building control department. Recognizing and identifying unsafe situations and actively contributing to correcting those situations promotes fire safety in the building and underlines the shared responsibility of owners and residents.

*Reinforcing supervision of the fire safety in residential buildings*

In the same way that owners can reinforce internal supervision and attention for fire safety by proactively calling in the expertise, for example of the fire service, municipalities can also reinforce their role. At present, municipal supervision is restricted to responding to reports of unsafe situations and supervising renovations subject to compulsory permits and large-scale maintenance on residential buildings. If they wish to reduce the number of residential fires in the Netherlands, municipalities will have to more actively supervise the fire safety of residential buildings, in particular those buildings with (partly) single escape routes, during the use phase. With regard to one specific group of owners of residential buildings, namely the housing associations, municipalities could for example actively reinforce supervision by explicitly including fire safety and internal supervision in the performance agreements they enter into with the housing associations. Internal and external supervision of fire safety could then reinforce each other, thereby offering improved safeguards.

*Structural attention for fire safety*

The background to this investigation was a tragic fire in a block of flats. The circumstances which led to this fire are however not unique. The Safety Board underlines the need to reinforce not temporarily but on a structural basis the attention for fire safety among owners, residents and supervising bodies. With that in mind, the Safety Board has issued recommendations to owners of residential buildings, and to government. These recommendations relate to making seating (furniture) and residential buildings structurally more fire safe. This will in turn reduce the risk of furniture and/or building fires of this kind, in which people lose their lives, are injured and panic.

# RECOMMENDATIONS

The Dutch Safety Board issues six recommendations. Five recommendations are aimed at ensuring better compliance in practice with the underlying principles for fire safety, and one recommendation is aimed at reassessing the underlying principles for fire safety, themselves.

**Recommendations**

*To Aedes and other owners of residential buildings, combined among others in the Vereniging Eigen Huis, Vastgoed Belang, Kences, VvE Belang, Vereniging van Institutionele Beleggers in Vastgoed and the sector association VvE Beheerders:*

1. Improve awareness of fire safety among building owners. This includes:
   - the exchange of knowledge and experience (in the form of best practices) of fire safety in residential buildings and the relevant specific risks;
   - encouraging an inventory of fire safety risks in the residential buildings in your members' housing stock;
   - making fire safety part of the governance requirements. Among housing associations, this could be achieved by including fire safety in the performance agreements with municipalities.

2. Ensure among building owners particular and permanent alertness with regard to premises with single escape routes. Focus specific attention on:
   - maintenance, repair and renovation work by the owner;
   - daily use of the residential building;
   - the provision of information to residents on the potential actions they can take in the event of a fire breaking out. It is essential that the owner matches the information/communication to the social and societal characteristics of the residents.

*To the Dutch Minister of the Interior and Kingdom Relations:*

3. Ensure an improvement in the supervision of fire safety in the use phase of residential buildings. Focus specific attention on:
   - internal supervision by building owners, by explicitly including continuous responsibility for fire safety at strategic and operational level;
   - external supervision by municipal authorities, by commissioning them to more actively supervise residential buildings in the use phase.

Determine whether this requires amendments to existing legislation and regulations.

4. Reassess existing underlying principles for fire safety in such a way that account is taken of a scenario in which fire and/or smoke can occur and/or make its way into a (partially) single escape route more quickly than is currently assumed. Integrate the outcome of this reassessment in the legislation and regulations governing fire safety.

*To the Minister for Medical Care and Sport:*

5. Introduce legislation and regulations to improve the fire safety of seating furniture and mattresses.

*To the Netherlands Fire Service:*

6. Use your expertise on fire prevention and fire safety in residential buildings to provide - solicited and unsolicited - advice to owners of buildings of this kind. Focus particular attention on the risks in specific building types such as blocks of flats and specific residential forms, such as accommodation for the elderly.

ir. J.R.V.A. Dijsselbloem
Voorzitter van de Onderzoeksraad

mr. C.A.J.F. Verheij
Secretaris-directeur

# LIST OF ABBREVIATIONS

| | |
|---|---|
| BGB | (Assessment Guideline) Fire-safe Use of Buildings |
| BMI | Fire alarm installation |
| BZK | Dutch Ministry of the Interior and Kingdom Relations |
| CBS | Statistics Netherlands |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| FEU | Federation of the European Union Fire Officer Associations |
| FFR 1988 | Furniture and Furnishings (Fire) (Safety) Regulations 1988 |
| GRIP | Coordinated Regional Incident Management Procedure (GRIP) |
| HCl | Hydrochloric acid |
| HCN | Hydrogen cyanide |
| HF | Hydrogen fluoride |
| IFV | Institute for Safety |
| JenV | Dutch Ministry of Justice and Security |
| Mkba | Social cost-benefit analysis |
| NFI | Netherlands Forensic Institute |
| $NO_2$ | Nitrogen dioxide |
| ODRA | Environmental Service Arnhem Region |
| ppm | parts per million; unit of concentration |
| PUR | Polyurethane |
| REACH | Registration, Evaluation, Authorization and Restriction of Chemicals; EU Regulation no. 1907/2006 |
| RW-MMB | Fire Safety Maturity Model from Regieweb |
| VGGM | Central Gelderland Health and Safety Region |
| VWS | Dutch Ministry of Public Health, Welfare and Sport |
| WBDBO | Resistance to fire penetration and fire spread |
| WODC | Research and Documentation Centre (of the Ministry of Justice and Security) |

# 1 INTRODUCTION

## 1.1 Background

A family that was celebrating New Year's Eve with relatives in a block of deck-access flats in Arnhem left shortly after one o'clock in the morning of 1 January 2020, to return home. They took the lift from the fifth floor to the ground floor. On arriving at the ground floor, a fierce fire was raging, to which they immediately fell victim. Although the lift returned the victims back to the third floor, they were not independently able to reach safety. The victims were discovered almost 30 minutes later by a resident of the building, in the lift, and subsequently taken outside by the fire service. Father and son lost their lives in this drama. Mother and daughter suffered serious injuries. The response to this terrible fire in Arnhem and the rest of the Netherlands was one of dismay and sympathy.

This tragic fire attracted much media attention and led to discussions on fire safety in residential buildings. The fire led the Dutch Safety Board to launch an investigation.

## 1.2 Objective and investigation questions

The objective of this investigation is to learn safety lessons that could contribute to preventing similar incidents occurring in the future. With this in mind, the following two investigation questions were determined:

- How was it possible for this fire to result in two fatalities and two injured persons?
- Are there differences between fire safety in residential buildings[1] in practice and fire safety according to the statutory rules and the underlying principles on which fire safety is based? If yes, what are the causes of this discrepancy, what is the effect of the differences on fire safety in residential buildings and what lessons can be learned?

The first investigation question is aimed at the course of the occurrence, and in the first instance will be answered in the form of a reconstruction. Based on that reconstruction, an analysis is then carried out into the factors that determined the course of the occurrence, the risks and the fatal nature of this fire. The relevant factors that emerged from this analysis, in respect of which according to the Safety Board broader safety gains

1 Wherever the term residential building or block of flats is used in this report, this does not refer to a high-rise tower block (higher than 70 metres).

can be achieved, will be further elaborated in the response to investigation question 2. Consideration will thereby be given to the extent to which practice, in the case of the building fire in Arnhem, is in line with the fire safety theory employed in the Netherlands, and to the lessons that can be learned about fire safety, if this proves not to be the case. The following characteristics influence fire safety of a (residential) building[2,3]:

- Building characteristics: the architectural, structural and installation-specific building design; for example the location and design of emergency exits, compartmentalization and automatic fire extinguishers;
- Human characteristics: the behaviour of people in relation to fire safety; for example the degree of self-reliance, the keeping clear of escape routes and the observation of the environment;
- Fire characteristics: the occurrence, the development and effects of fire; for example the temperature, smoke production and toxic smoke components;
- Intervention characteristics: the emergency assistance in the event of fire by company emergency response teams and the fire service;
- Environmental characteristics: the location of the building in relation to fire safety; for example the distance to a fire station, environmental risks such as storage and transport of hazardous substances.

The combination of these characteristics and the way they are implemented represents the underlying principles for fire safety. These underlying principles and the relevant legislation and regulations in which these principles are to a large extent reflected are viewed in combination by the Safety Board as the fire safety theory in practice in the Netherlands. It is worthwhile noting that in this report, the Safety Board has not attempted to make an exhaustive assessment of all relevant legislation and regulations, but instead, on the basis of a comparison between the underlying principles and practice, has considered the extent to which in the case of this occurrence, there was a safety shortcoming of broader relevance.

## 1.3 Demarcation

The Safety Board did not consider the setting off of the firework in the entrance hall and the risks that can arise as a consequence of such action in the scope of this investigation, having previously published an investigation into the risks relating to fireworks during New Year's Eve celebrations.[4] It was however considered in the investigation that the New Year's Eve celebration may have been an element that affected behaviour in terms of the victims and other residents (not) taking note of the fire.

2 A residential building is a building containing more than one residential function, depending on a common circulation route (Dutch Building Decree 2012). According to this definition, single family homes are not residential buildings; blocks of deck-access flats and other apartment complexes are.
3 Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings*. Arnhem: IFV.
4 Onderzoeksraad voor Veiligheid (2017). *Veiligheidsrisico's jaarwisseling*. Though the full report is in Dutch, there is an English summary available: Dutch Safety Board (2017) *Summary New Year's Eve Safety Risks*.

The lift and the deployment of the fire service are included in the investigation, but feature only to a limited extent in the final report. This is because during the course of the investigation, the Safety Board reached the conclusion that fewer safety gains could be achieved with regard to these points, within this investigation, than in respect of the safety shortcomings that are discussed in detail in this report. In addition, with regard to the use of lifts in the event of fire, developments have already been initiated.

In its investigation, the Safety Board focused on residential buildings. The design and use of residential buildings differs considerably from that of other building types. The same applies to the relevant regulations. Wherever differences between residential buildings and other building types are relevant, they are mentioned and if necessary explained.

The fire was investigated from the perspective of fire safety. During the course of the investigation, however, questions of social safety and quality of life or liveability also emerged. Although not investigated extensively, specifically because the Safety Board maintained the perspective of fire safety, it became clear that these problems played no determining role in the course of events of this occurrence. On the other hand, it became clear that these aspects were relevant in terms of context. In this building, the group of residents came from different cultural backgrounds, and many of the residents demonstrated limited command of the Dutch language. Relatively high numbers of residents also face social and societal challenges. A group of residents with this particular composition represents additional challenges for building owners, in ensuring the fire safety of a building in the use phase. This aspect is discussed in more detail in chapter 3 of this report.

## 1.4 Investigation approach

As part of this investigation, the Safety Board collected and analysed different types of information. Affected parties were interviewed, and the Safety Board consulted various experts and reviewed publications in the field of fire safety. Documents relevant to the occurrence were retrieved and studied. Other investigations undertaken in response to the occurrence were monitored and in some cases evaluated (see section 1.6). Camera images of the fire were analysed. The Safety Board also paid working visits to the block of flats in order to obtain a picture of the building itself and the fire damage. The Safety Board also carried out experiments with the lift in a similar block of flats. The Safety Board commissioned the Netherlands Forensic Institute (NFI) to determine the cyanide content in the blood sample taken during the external autopsy of the deceased adult victim. The main statistics about residential fires in the Netherlands were reviewed, to gain an indication of the size of the safety problem addressed by the Safety Board in this report. Annex D contains the results of this inventory. The Safety Board also followed reports of fires in blocks of flats in 2020 in the media. These results appear in Annex E.

Annex A contains a more detailed explanation of the approach taken in the investigation.

## 1.5 Reference framework

During its investigations, the Safety Board draws up a reference framework for identifying the best way to manage a specific safety risk, based on its current understanding. In preparing this reference framework, the Safety Board draws information both from tried and tested approaches from the Netherlands and other countries, and from its own experience. The reference framework is then used to assess where safety shortcomings occur, in the modern way of living, work and life.

The reference framework aimed at safeguarding fire safety in residential buildings appears in Annex C. The themes included in this reference framework are first design and construction, second the use of residential buildings and finally fires and firefighting. Within the theme 'use', we distinguish between maintenance and repair by the owner and daily use by the residents. This approach brings to light two key sets of players: owners of residential buildings and the residents. Other relevant actors are architects, contractors, engineering consultants, the fire service, municipal authorities and national government. The reference framework describes what the Safety Board expects from the various players in safeguarding fire safety in residential buildings.

## 1.6 Other investigations into this occurrence

The fire in the block of flats in Arnhem also led the police and justice authorities, the housing association Vivare and the Central Gelderland Health and Safety Region (VGGM)[5] to undertake investigations.

Under the auspices of the Dutch Public Prosecution Service (OM), the police carried out an investigation[6] to determine whether or not any criminal offences had been committed. This investigation led to a trial in which two minors were found guilty of causing this fire by setting off fireworks between the cushions of a sofa that had been left in the entrance hall to the block of flats. The court imposed no penalty on these minors[7], because they were unable to oversee the far-reaching consequences of their actions, because they did not deliberately start the fire, and because the fire had already brought about serious consequences for them. Within these criminal proceedings, this part of the course of events (the setting off of legal fireworks at an inappropriate location with fatal consequences) was already dealt with in detail. For that reason, the Safety Board has assessed this part of the course of events only from the perspective of fire safety. In this framework, the Safety Board also emphasizes that its investigations and reports do not allocate blame or liability, but are intended to learn lessons to help prevent disasters and accidents recurring, in the future.

5 Central Gelderland Health and Safety Region (VGGM) is a complete emergency services organization for Fire Service and Public Health (Ambulance Service and Municipal Health Service) for the Central Gelderland security region).
6 The police provided the investigation file from the forensic investigation to the Safety Board.
7 The court did award compensation to the surviving dependents/next of kin, for emotional loss.

The police commissioned Liftinstituut to carry out a technical investigation on the lift in which the victims were found. The investigation question in this case was whether the victims had become locked in the lift due to technical causes.

Vivare commissioned Crisislab to investigate the relevance of the occurrence on 1 January 2020 to fire safety at that moment in the block of deck-access flats in question and in other comparable residential buildings. Vivare also wanted to find an answer to the question of the relevance of the fire to the planned maintenance and improvement for this block of flats.

The Central Gelderland Fire Service, part of the VGGM, investigated how a fire in the entrance hall of a residential building could result in a life-threatening situation in a lift cabin and the central stairwell, as a consequence of which two persons lost their lives and two persons suffered injuries. The fire investigation contained no evaluation of the operational performance of the fire service.

The VGGM carried out a multidisciplinary evaluation into the functioning of the disaster management and crisis organization, from the first reporting of the fire through to the downscaling from GRIP 1 to GRIP 0.[8]

The Safety Board took note of the results of these investigations, and wherever relevant included them in its own investigation.

## 1.7 Reading this document

This report starts in chapter 2 with a description and analysis of the course of events of the fire in the block of flats in Arnhem. Chapters 3 and 4 focus on factors that played an important role in this fire and in respect of which, in the judgement of the Safety Board, broader safety gains can be achieved: fire in the only escape route from the building in chapter 3, and toxic furniture fires in chapter 4. The analyses in these chapters identified safety shortcomings for which the Safety Board has formulated safety lessons. These are discussed in the conclusions and recommendations in chapters 5 and 6, respectively.

8 GRIP stands for Coordinated Regional Incident Management Procedure. Depending on the scale and complexity of an incident, the GRIP structure features four levels for coordinated disaster management and contingency planning within a security region, with a further two levels for supraregional incidents.

# 2 COURSE OF EVENTS

As a result of the fire in the block of flats in Arnhem, two people lost their lives and two people suffered injuries. This chapter considers what happened that night, and seeks to answer the question how this could happen. Consideration is also given to the sense of unsafety among the people who wished to escape from the building, but were unable to do so. This reveals the potential learning points that can help to prevent similar fires in the future. These learning points are considered in greater depth and where possible greater breadth, in chapters 3 and 4. This chapter deals in succession with the location of the fire, the start of the fire and its development, the contact between the victims and the fire, and the escape from the building by residents and visitors.

## 2.1 Fire location

This section deals with the aspects of the fire location that are necessary to be able to understand the rest of this chapter and the report. Consideration is given to the block of flats, the entrance hall, the lifts and the sofa that was present in the entrance hall.

### 2.1.1 The block of flats

There are two blocks of deck-access flats on the Gelderseplein in Arnhem. These blocks of flats, owned by housing association Vivare, were built around 1968 and together consist of a total of 228 dwellings. The block of flats where the fire raged (see figure 1) consists of ten floors.

*Figure 1: Block of flats where the fire raged on New Year's Day 2020. (Source: Dutch Safety Board)*

The entrance hall, the storerooms and a number of communal areas are located on the ground floor, see figure 4 for a floor plan. Above these are nine floors with a total of 108 apartments, that were occupied by around 240[9] people. Each of these flats[10] could be reached from the entrance hall, via the central stairwell or via the lift. On each floor, the stairs and lifts discharge into a lift hall (see figure 2 for the layout of these lift halls). From the lift hall, the non-enclosed gallery hall could be reached, from which walking access was possible via the galleries, to the flats, and vice versa.

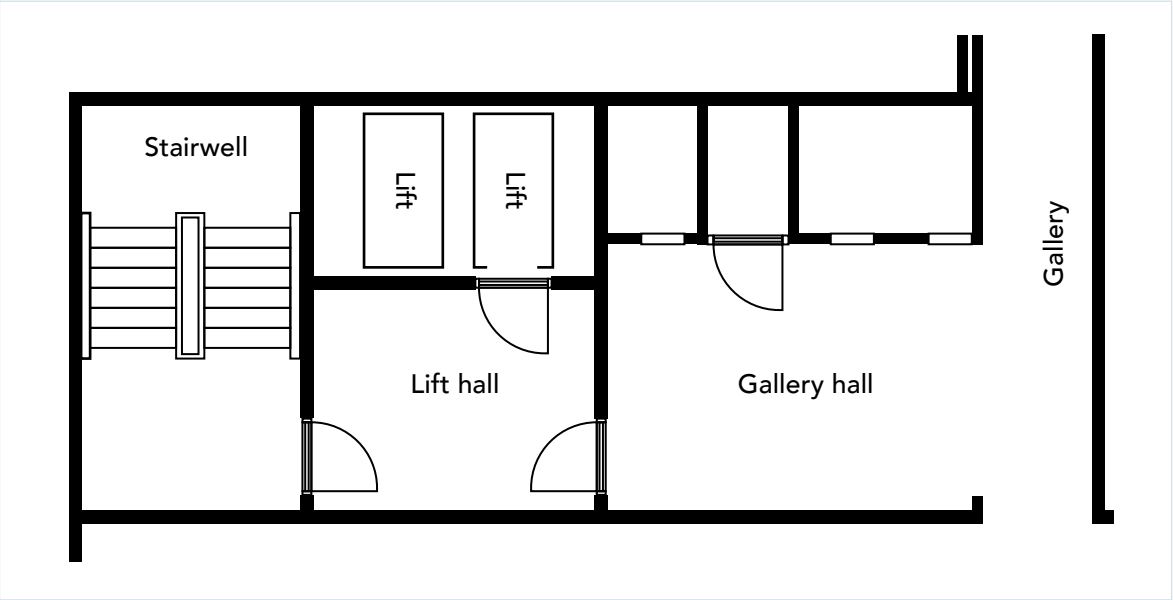



*Figure 2: Schematic floor plan of the lift halls on the block of flats.*

The primary escape route from the flats on all floors passed via the gallery, through the gallery hall, the lift hall, the central stairwell and eventually via the entrance hall outside. From the flats on the 2nd through to the 9th floor, it was also possible to reach the central stairwell via a second route. This was made possible by the presence of emergency stairs at each end of the galleries on those floors, each of which linked two galleries together. This meant that from the flats on those floors, it was possible to escape to the central stairwell, via two different routes. The first route travelled via the gallery on the floor where the flat was located directly to the central stairwell. The second travelled along this gallery to the emergency stairs at the end of the gallery, and subsequently via the gallery to the floor above or below, back to the central stairwell. The gallery on the first floor had no emergency stairs at the end, so that from the flats on that floor, the only way to escape was directly to the central stairwell. The escape routes are shown in figure 3 below.

9 Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). *Evaluatie GRIP 1 Flatbrand Arnhem 01-01-2020* (Central Gelderland Health and Safety Region (2020) *Evaluation GRIP 1 Building fire Arnhem, 01-01-2020)*, page 10. Here 238 - 239 residents are referred to.

10 Since the occurrence, the block of flats has been renovated. For that reason, the description of the fire location appears from here on in the past tense. This renovation work was already in progress, when the fire took place.

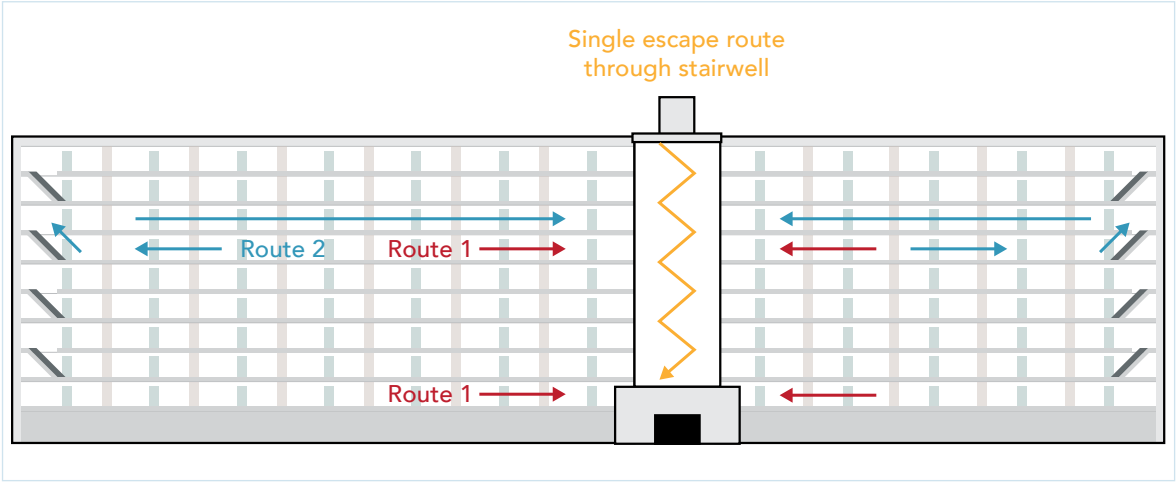



*Figure 3: Escape routes from the block of flats.*

### 2.1.2 The entrance hall

The entrance hall was located centrally in t he block of flats. The entrance hall featured a main entrance, used regularly by residents and visitors to enter the building. There was a second entrance/exit at the rear. The entrance hall was 8 metres deep and 'L' shaped. The short leg of the 'L' was the lift hall. It should be noted that this was not separated from the rest of the entrance hall. Entrance hall and lift hall together had a floor area of 37 $m^2$. Figure 4 below shows a floor plan of the entrance hall.

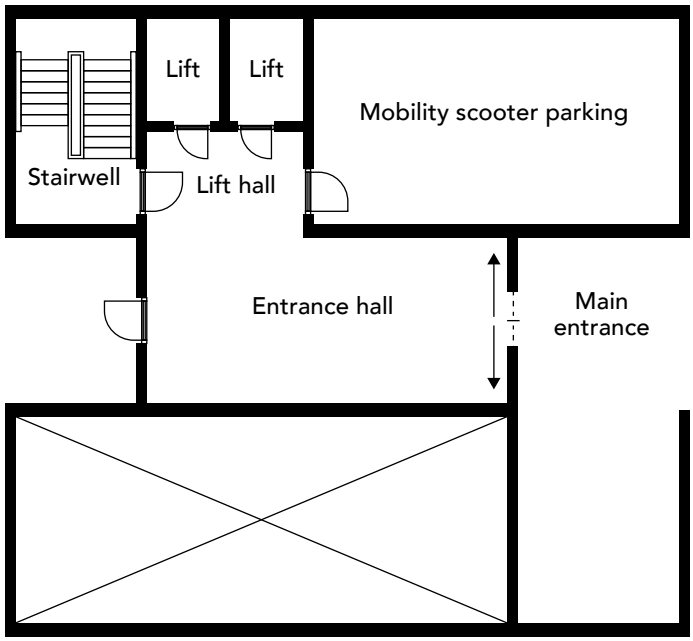



*Figure 4: Schematic floor plan of the entrance hall to the block of flats.*

There were four doors in the lift hall: two metal lift doors with small round windows, one windowless door to the mobility scooter parking and a fourth door fitted with a Lexan panel[11] to the stairwell.

### 2.1.3 The lifts

The lift section of the entrance hall featured two entrance doors to the lift (see figure 4) side by side. The left-hand lift served the uneven floors (1-3-5-7-9); the right-hand lift served the even-numbered floors (2-4-6-8). Both lifts stopped on the ground floor. Both lifts were fitted with manually operated landing doors, opening outwards. The landing doors could only be opened if the lift cage was present on the floor in question. If the lift cage was not present, the lift landing door was blocked. In addition, both lift cages were fitted with an automatic sliding door in the cage entrance, also referred to as the cage door. When the lift was (stationary) at a floor or on the ground floor, this sliding door was open. In other words, in this situation, people could walk from inside the lift by pushing the landing door open, and enter the lift by pulling the door open. The lifts were not fitted with an automatic return setting to the ground floor. A parked lift remained parked on the floor where it was left by the last user.

### 2.1.4 The sofa in the entrance hall

On the morning of 30 December 2019, the day before New Year's Eve, a resident of the block of flats deposited a sofa in the entrance hall, marked with a sheet of paper indicating that the item of furniture could be removed, free of charge. This resident was attempting in this way to pass on the sofa to a new owner. If there were no takers, the resident intended to remove the sofa at a later stage.

The sofa consisted of two elements, together forming a corner sofa. The resident had placed the two components side by side, against the left-hand side wall of the entrance hall (as seen from the main entrance), directly opposite the lift doors (see the red areas marked on the floor plan in figure 5). The sheet of paper was placed on the seat of the left-hand sofa.

11 Lexan is a well-known trade name for polycarbonate.

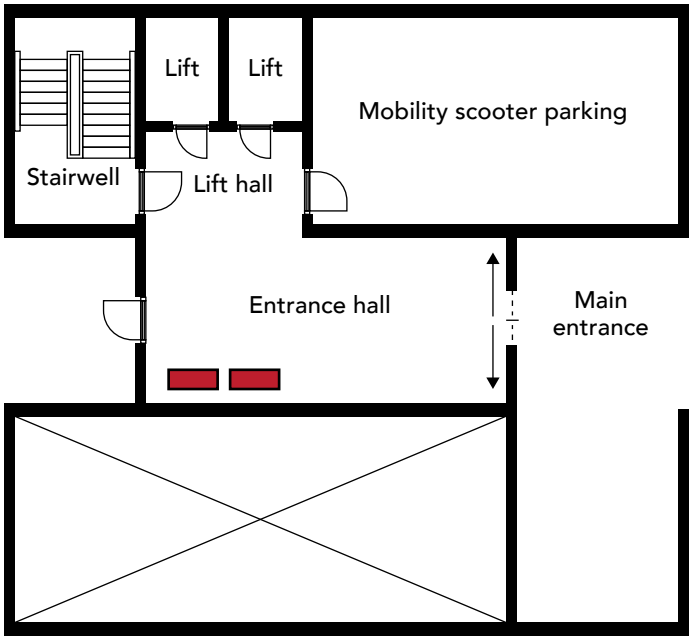



*Figure 5: Schematic floor plan of the entrance hall to the flat showing the sofa marked in red.*

Figure 6 below shows that the sofa had a black, imitation leather covering. This type of sofa is generally filled with plastic foam.

*Figure 6: Stills of camera images showing both sofa sections opposite the lift doors. The sheet of paper is placed on the left-hand sofa.*

## 2.2 Development of the fire

This section describes and analyses the lighting and development of the fire on 1 January 2020. The description appears in section 2.2.1. The purpose of the analysis in section 2.2.2 is to identify the elements that played an important role in the development of the fire.

### 2.2.1 Description of the development of the fire

On New Year's Eve 2020, various people set off fireworks in front of the main entrance to the block of flats. At that time, the area was busy with residents and visitors entering and leaving the building via the entrance hall and the lifts. At around 01.00 hours, things quietened down in the entrance. Two minors entered the entrance hall, to spend a few more minutes lighting fireworks inside the entrance hall and in the lifts. At 01.05 hours, a so-called ground bloom flower (see block) was inserted between the seat and the backrest of the right-hand sofa and lit. The ground bloom flower spat out bright coloured sparks for six seconds, and appeared to go out. However, this was not the case, because thirty seconds later, at the point where the firework had been inserted in the sofa, flames became visible. The minors did not notice and left the entrance hall by taking the lift upstairs.

**Ground bloom flower**

The firework inserted in the sofa was a ground bloom flower. This is a powder-packed cylindrical paper object. The powder does not explode but once ignited blasts outwards through an opening in the side wall. The ground bloom flower then rotates rapidly with a whooshing noise. The ground bloom flower is classified in the lightest European category of consumer fireworks (F1); in the fireworks trade also known as 'children's fireworks.[12]

Between 01.06 and 01.10 hours, the fire spread across the sofas, initially across the seat of the right-hand sofa. Beneath the ceiling, a layer of flue gas quickly formed. As the fire developed further, the flames started to creep up the wall. At around 01.09 hours, the flames reached the flue gas layer: the start of the flashover phase (see block).

12 See also: Onderzoeksraad voor Veiligheid (2017) *Veiligheidsrisico's jaarwisseling* (Dutch Safety Board (2017) *New Year's Eve Safety Risks*). In this report, the Safety Board issued recommendations relating to heavier consumer fireworks, such as decorative fireworks and firecrackers.

**Flashover phase**
The majority of indoor fires start with a small, primary fire seat (burning wastebin, burning furniture, burning mattress). The primary seat of the fire disperses heat through conduction, convection and radiation, as a result of which the seat of the fire gradually increases in size, while flammable objects in the immediate vicinity of the seat of the fire receive thermal radiation, whereby they themselves can catch fire. This process of gradual growth is known as the development phase of the fire. From the growing seat of the fire, a column of hot combustion gases (flue gases) rises vertically. The flue gases collect beneath the ceiling of the room where they form a layer of flue gas. During this phase of the fire, it is still possible for persons wishing to escape to move below the flue gas layer and seek a safe haven, as long as the flue gas layer does not give off too much thermal radiation. As the seat of the fire grows, the flue gas layer becomes thicker and hotter; at the same time, it produces ever growing levels of downward directed thermal radiation. When the flue gas layer reaches the critical temperature of 400-600 °C, this thermal radiation is so powerful that any flammable objects present below the layer develop large volumes of flammable gases. After a short time, the concentration of these gases is so high that the gases and the objects throughout the room ignite. If there is sufficient oxygen present, the result is a boiling sea of flames. This phase of accelerated fire development (accelerated temperature rise and accelerated heat production) is known as flashover. Without protective equipment, it is impossible for a person exposed to a fire in the flashover phase to survive for more than a few seconds.

By 01.10 hours, the fire was fully developed (see block below). From that moment, the ceiling began to participate in the fire. A short time later, the flames passed through the main entrance of the building to the outside. The fire produced large volumes of smoke which spread through the stairwell across the upper floors. Via the main entrance, a black cloud of smoke travelled up the outside of the building.

**Fully developed fire**
The stage following flashover is known as a fully developed fire. It depends on the fuel available and the ventilation conditions whether the capacity of the fire continues to increase after the flashover. If the fuel becomes exhausted or if the oxygen supply is too restricted to maintain the fire in its full size, the fire will not grow further and will gradually decline in intensity. This is known as the fire's extinguishing phase.

At 01.15 hours, the regional emergency control room received the first of a series of reports of a fire on the Gelderseplein. It was not immediately clear to the control centre operators precisely what was going on - various of the callers spoke broken Dutch - but on the basis of the number of reports and the panicky tone, the control room operators decided to give priority to the incident. They immediately scaled up to medium-sized

fire[13] and sent two units, an aerial ladder truck, and a duty officer (OvD)[14] and an ambulance to the address of the fire. Despite the thick mist on New Year's Eve, the first fire service unit (from Arnhem South) arrived on the scene after eight minutes (at 01.23 hours); the second unit (from Arnhem North) arrived three minutes later (at 01.26 hours).

The commander of the first unit to arrive was faced with a fully developed fire, whereby the flames were escaping through the building's main entrance outside. In response he decided to attack the fire with both crews[15] and two high-pressure jets. One crew attacked the left-hand side of the fire room, while the other crew attacked the right-hand side. This approach proved rapidly effective: by the time the second fire service unit arrived on the scene (at 01.26 hours), the majority of flames in the entrance hall had been extinguished. At that moment, it was possible for the fire crews to enter the fire room, to extinguish the last seats of the fire, and to start damping down and reconnaissance. At 01.48 hours, the fire in the central hall was under control, but there was still considerable smoke propagation.[16] At 03.14 hours, the fire was declared 'under control'.[17]

13 'Medium-sized fire' is the second escalation level employed by the fire service, following on from 'small fire'. In the case of 'medium fire', two basic units (fire engines) are deployed to the fire.

14 Because the fire service operates according to the principle of single-person operational command, when multiple units are deployed, a fire officer is added to the command structure.

15 In the standardized deployment protocol, the 'attack team' (2 people) is responsible for putting out the fire while the 'water team' (2 people) is responsible for the water supply. By deploying both the attack team and the water team to fight the fire, the commander in this case opted for a non-standard attack strategy.

16 Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). Evaluatie GRIP 1 Flatbrand Arnhem 01-01-2020 (Central Gelderland Health and Safety Region (2020). *Evaluation GRIP 1 Building fire Arnhem 01-01-2020*).

17 Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). Evaluatie GRIP 1 Flatbrand Arnhem 01-01-2020 (Central Gelderland Health and Safety Region (2020). *Evaluation GRIP 1 Building fire Arnhem 01-01-2020*).

The timeline below shows the stages of the fire described above.


*Figure 7: Timeline of the fire development.*

### 2.2.2 Analysis of the fire development

The development of the fire leads to a number of observations:

- The fire was started by a low-energy ignition source. The description of the fire development shows that the fire was caused by a so-called ground bloom flower. A ground bloom flower is a firework classified in the lowest European category of consumer fireworks (F1) and is a low-energy ignition source. This type of ignition source will only cause a highly inflammable object to catch fire.
- The fire developed rapidly and fiercely. The description of the fire development shows that 5 minutes after the start of the fire, the flashover occurred, resulting in a fully developed fire. In fire safety theory, for the period between the start of a fire and the flashover, on average 15 minutes are assumed.[18] In practice in this fire, the time to flashover was one third of the average time assumed in fire safety theory.

18 Institute for Safety, *The Basis for Fire Safety. Substantiating fire protection in buildings*, December 2017. According to this document, this assumption applies successfully to most building types, with the exception of industrial buildings.

- There was considerable smoke propagation, which spread through the building. This fire gave off large volumes of smoke. This took the form of a thick smoke column that travelled via the main entrance upwards along the front of the building. Inside, the smoke also spread upwards. In part it passed via the lift shaft, but to a considerable extent via the stairwell.

With regard to all these three aspects, the composition of the sofa placed by a resident in the escape route plays an important role. The sofa contained plastic foam, which is known to be highly inflammable, to burn fiercely and to produce much toxic smoke. Chapter 4 of the report deals with this in greater detail.

Besides the sofa, three other elements that were added to the escape route during the use phase of this building contributed to this fire development:

- The suspended ceiling in the entrance hall. There was a lowered (suspended) ceiling in the entrance hall. A construction had been built using wooden beams to which sheets of compressed wood fibres were attached. During the fire, this ceiling construction was ignited. After the fire, the precise type of sheet material could no longer be determined because the sheets were almost entirely incinerated.[19]
- The Lexan panel in the door between the entrance hall and the stairwell. The Central Gelderland Fire Service concluded in its investigation into the fire that the Lexan panel in the door between the entrance hall and the stairwell slipped down and was burned during the fire, as a consequence of the high temperature.[20] As a result, on the one hand oxygen from the stairwell was able to flow into the entrance hall, thereby feeding the fire. On the other hand, the fire and the smoke were able to spread to the stairwell. Based on the fire damage in the stairwell on the ground floor and on the landings between the ground floor and the first floor (see figure 8), it could be determined that the fire burned fiercely at the bottom of the stairwell, and that flue gases flowed throughout the stairwell up towards the upper floors.
- The wooden wall construction below the stairs. A wooden wall construction with a wicket door had been installed in the stairwell, on the ground floor. This wall construction sealed off the area beneath the stairs. The Central Gelderland Fire Service concluded in its investigation into the fire that this wooden wall construction contributed to the development and spread of the fire in the stairwell.[21]

19 Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). *Brand Gelderseplein Arnhem – 1 januari 2020*. (Central Gelderland Health and Safety Region (2020). Fire Gelderseplein Arnhem – 1 January 2020).
20 Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). *Brand Gelderseplein Arnhem – 1 januari 2020*. (Central Gelderland Health and Safety Region (2020). *Fire Gelderseplein Arnhem – 1 January 2020*).
21 Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). *Brand Gelderseplein Arnhem – 1 januari 2020*. (Central Gelderland Health and Safety Region (2020). *Fire Gelderseplein Arnhem – 1 January 2020*).

*Figure 8: Picture taken from the landings between the ground floor and the first floor (Source: Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). Brand Gelderseplein Arnhem – 1 januari 2020.)*

All of these three elements are known to have not formed part of the entrance hall and the stairwell, when the block of flats was completed. The Lexan panel and the wooden structure below the stairs were added in the early nineteen nineties by or on the instructions of the then building owner; the suspended ceiling was installed well before 2015. Beyond this, little is known about this work by Vivare, the current owner of the building. Vivare has no information as to why this suspended ceiling was installed. The reason for installing the wooden wall structure beneath the stairs, according to Vivare, is that the space below the stairs was used for a whole range of activities that detracted from the quality of life in the building. According to Vivare, the Lexan panel was installed to replace the safety glass[22] that was originally in the door, because the glass was regularly broken by vandals. The lack of documentation about this work makes it unclear to what extent consideration was given to fire safety. This is dealt with in more detail in chapter 3.

22 There are various types of safety glass. The doors in the stairwells on the upper floors are fitted with wired glass. This is very probably the material that was originally fitted in the door on the ground floor.

## 2.3 The contact with the fire by the victims

This section describes and analyses the contact between the family and the fire, and the way this contact led to such a dramatic conclusion.[23] The description of the fire contact, in section 2.3.1, deals with the passage of the family from the moment they entered the lift to the moment they were found. The analysis in section 2.3.2 examines the factors that meant that the contact with the fire resulted in four victims.

### 2.3.1 Description of the fire contact

At around 01.12 hours[24] the family entered the lift on the 5th floor of the block of flats. At that moment, the fire on the ground floor in the entrance hall has already reached the stage of full development. There was a small amount of smoke, that may have been attributed to the fireworks. Once in the lift, the family sent the lift to the ground floor. During the descent, more and more smoke penetrated the lift cabin, at which point the family pressed the button for the third floor, to stop the lift, or to send it back up.[25] However, at that moment, the lift was just before or already below the third floor, and was programmed in such a way that the downward travel was continued.

Twenty-one seconds after it left the fifth floor, the lift arrived on the ground floor. The cage door opened automatically, at which point the father pushed open the landing door and stepped out of the lift with his right foot, into the entrance hall where a fully developed fire was blazing at that moment.[26] Because while taking the step forward, the father bent forward with his upper body, his head and hands came into contact with the intense thermal radiation that the fully developed fire was producing at that moment (see also the block below). By opening the lift doors, a volume of hot flue gases also penetrated directly into the lift, which caused thermal injury to the other three members of the family (see also the block below). At the same time, the family was exposed to the toxic components of the penetrating flue gases. The inferno they found themselves in probably also caused a huge shock effect on the family.

23 The reconstruction of the fire contact is only to a very limited extent based on actual observations (for example on the basis of camera images) The other sources consulted (statements of witnesses and the persons involved, the victims' injuries, the father's blood sample, etc. (see Annex A for a full summary of the sources)) however provide an unequivocal picture of the fire contact.

24 It was not possible to determine the precise time, because the camera system that could have provided this information had failed. The camera in the lift did still register at 01.11 hours that the family was close to the lift. The mentioned time of 01.12 hours is therefore a minimum time - the precise time is unknown.

25 The mother of the family stated that during the lift's descent, they pressed a button for a higher floor. The Safety Board deduced that this must have been the third floor, because that is where the lift was eventually located.

26 A light yellow-grey substance was discovered under the sole of the father's right shoe: probably combustion products that had formed a layer of ash on the floor of the entrance hall. The sole of the left shoe was still clean.

**Radiation intensity and flashover temperature**
During a flashover, as a rule, a flue gas layer generates thermal radiation with an intensity of more than 20 kW/m$^2$. The family came into contact with the fire almost 3 minutes after the flashover; it is probable that in that period, the radiation intensity had increased further due to the incineration of the wooden ceiling.

During a flashover, the temperature below the ceiling is between 400 and 600 °C. Just like the intensity of the thermal radiation, the temperature at the top of the fire room had probably also risen further during the subsequent 3 minutes.

In response to the unexpected confrontation with the fully developed fire, the father fell or jumped backwards, ending up back in the lift. The landing door fell closed and, because the lift had already received the instruction to travel to the third floor, the cage door automatically closed and the lift travelled upwards. Twelve seconds later, the lift arrived in the regular manner, on the third floor. The cage door then opened automatically. The landing door opened a crack.[27] The family was no longer able to exit the lift, probably because they were already all unconscious. This means that barely 30 seconds[28] after having been exposed to the heat and smoke of the fire, the four family members had been incapacitated, at around 01.13 hours.

Shortly after the second fire service unit arrived on the scene at around 01.30 hours, the fire service started reconnaissance of the building with three teams of two firefighters. Two teams investigated the stairwell and the adjacent areas, from bottom to top, whereby one team was responsible for the left-hand side and the other team for the right-side side of the building, in respect of the stairwell. The third team worked in the opposite direction: from top to bottom.[29], [30] One of the teams working from the bottom to the top of the building in the initial phase of its reconnaissance above all concentrated on the many worried residents of the building, who had gathered on the galleries.

27 The technical investigation carried out after the accident by the Liftinstituut on behalf of the Central Gelderland District Police Investigation Department revealed that this probably happened because of an underpressure situation in the hall in front of the lift on the 3rd floor, as compared with the pressure in the lift shaft.
28 These are the 12 seconds the lift took to travel from the ground floor to the third floor plus the time the doors took to close and open.
29 Because flue gases tend to collect in the top of the building, the stairwell in the upper floor deserved special attention.
30 This team first went to the top of the building via the stairs, equipped with protective clothing and breathing apparatus.

Around thirty minutes after the lift containing the family had arrived at the third floor, just before 01.45 hours, the family was discovered by a resident. The resident then ran to the stairwell in panic, in order to escape the building. As he ran down the stairs, he came across one of the fire service reconnaissance teams. On his instructions, the firefighters then immediately continued up to the third floor, where they bumped into another team, that had just run in from the gallery side. It was at this point that the four firefighters found the family in the lift. Following the discovery, the firefighters took the victims outside as quickly as possible, partly via the stairs and partly via the gallery and the elevating aerial ladder truck. Once outside, it quickly became clear that the mother and young daughter were still alive. Attempts were made to resuscitate the father and son, but without success.

After the victims had been taken away by ambulance, the operational command relieved all firefighters who had been involved in the rescue, and called in the Fire Service Peer Support Team (CBOT). The newly called out units were then tasked with providing aftercare for the despairing residents and temporary repairs to the accessibility of the block of flats.

The figure below shows the timeline for the development of the fire together with the timeline for the fire contact, resulting in a complete picture of the timeline for the occurrence.

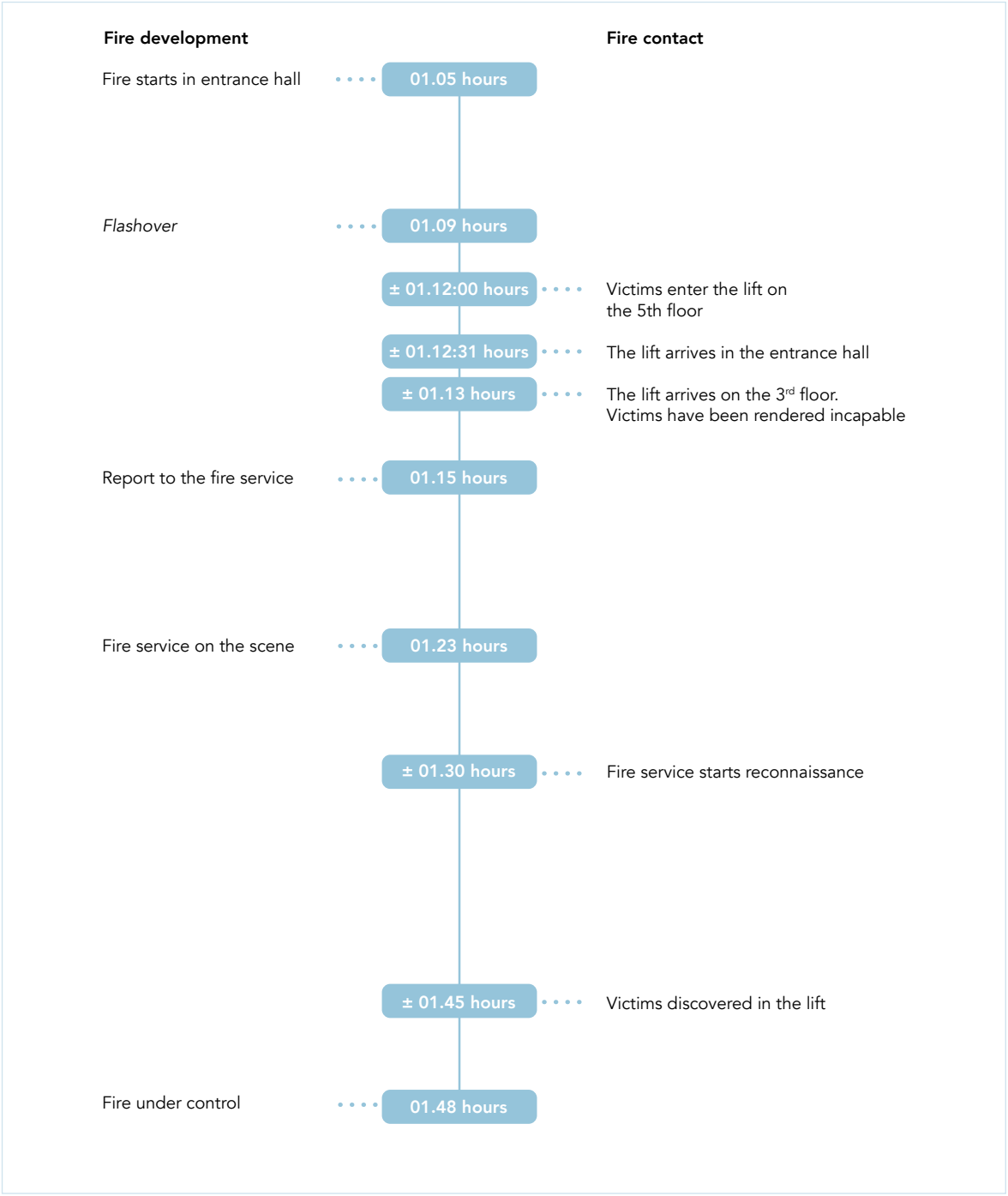



*Figure 9: Timeline of fire development and fire contact.*

### 2.3.2 Analysis of the fire contact

The analysis of the fire contact focuses on two points. Firstly, we examine how it is possible that the contact with the fire had such fatal and serious consequences. We then zoom in on the role played by the lift in the course of events of this occurrence.

Fatality of the fire

The four victims were rendered incapable within thirty seconds following their brief confrontation with the fully developed fire in the entrance hall. That is very quick. This can be explained by the combination of threatening circumstances to which the victims were exposed. Three elements of the fire represented a relevant threat: (1) thermal radiation, (2) hot smoke and (3) toxic smoke.

1. *Thermal radiation*

A fully developed fire generates considerable thermal radiation. The majority of thermal radiation comes from above. As a consequence, above all the father's head was affected by the thermal radiation at the moment that he took a step outside the lift. This, possibly in combination with convective heat transfer by flame contact led to serious burns to his head. It is likely that this made a major contribution to rapidly rendering him incapable and eventually his death. The rest of the family did not leave the lift, and were therefore not or to a lesser extent exposed to thermal radiation. As a consequence, they suffered less serious burns than the father. The rapid loss of consciousness of the three other members of the family cannot be explained by thermal radiation alone.

*2. Hot smoke*

When the lift door was opened after it arrived on the ground floor, a wave of flaming, red-hot smoke washed into the lift from the entrance hall. This smoke caused thermal injuries to the remaining three family members, in the form of burns. All four family members also inhaled this hot smoke. Inhaling hot smoke can result in burning of the airways. If the extent of this damage is very serious, it is referred to as inhalation trauma. In that case, as a rule, victims also demonstrate external burns to the face. Because there were no such serious burns affecting the other three victims, it may be assumed that thermal damage to the airways was not the primary cause of their being rendered incapable.

*Toxic smoke*

The smoke that washed into the lift at the moment the lift door opened on the ground floor was also toxic. The main toxic components of this smoke were carbon monoxide and hydrogen cyanide.

*a. Carbon monoxide*

Carbon monoxide is the most well-known toxic component of smoke. All four victims were examined to determine the extent to which carbon monoxide (CO) poisoning played a role in rendering them incapable. This examination revealed that although the measured values were raised, they were clearly too low to be able to explain the loss of consciousness. Because all four victims were resuscitated with 100% oxygen - after having been found in the lift - the CO values in their blood may have fallen. Exactly what levels these values reached can therefore no longer be determined. As a rule, carbon monoxide poisoning is a gradual and stealthy process. However, the effect of very high levels of carbon monoxide is not completely clear. As far as the Safety Board knows, the

loss of consciousness within thirty seconds due to the inhalation of carbon monoxide has not been documented in the relevant fire investigation literature.[31]

*b. Hydrogen cyanide*

Fires in furniture filled with PUR foam result in smoke that in addition to 'normal' components also contains hydrogen cyanide (HCN).[32] The quantity of hydrogen cyanide in smoke in a room containing a burning sofa filled with PUR foam can be so high that inhalation of that smoke can result in immediate loss of consciousness. Poisoning through inhalation of hydrogen cyanide can be traced by determining the cyanide content in a blood sample. Hydrogen cyanide is approximately twenty-five times more toxic than carbon monoxide.[33]

**Hydrogen cyanide**

Hydrogen cyanide is an inorganic compound of hydrogen (H), carbon (C) and nitrogen (N) with the chemical formula HCN. Hydrogen cyanide is a highly toxic, colourless gas, that smells of almonds. The toxic component of hydrogen cyanide as the name suggests is cyanide (KCN). Hydrogen cyanide occurs naturally in small, non-toxic quantities in stone fruits such as almonds, cherries, apricots, plums and peaches. It is also used in industry (among others) in the production of plastic.

To determine with greater certainty the presence of hydrogen cyanide gas in the smoke, the Safety Board commissioned the determination of the cyanide content in the blood sample taken from the father, during the post-mortem investigation.[34] In this blood, a toxic quantity of cyanide was identified, that was nonetheless of a level too low to identify cyanide poisoning as the only cause of death. One complication in interpreting the identified cyanide content was that the blood sample was taken approximately 14 hours after exposure to the fire. It is well known that the cyanide content in blood decreases rapidly over time.[35] The cyanide content in the blood of the father was therefore almost certainly higher than the measured value. The inhalation of hydrogen cyanide gas in the smoke could certainly have resulted in the other family members being incapacitated very rapidly.

31 Purser, D.A. & McAllister, J.L. (2016). Assessment of hazards to occupants from smoke, toxic gases and heat. In M.J. Hurley (Ed.), SFPE Handbook of fire protection engineering (pages 2308-2428). USA: Springer.

32 Purser, D.A., Bensilum, M. (2001). Quantification of Behaviour for Engineering Design Standards and Escape Time Calculations. In: *Safety Science 38*, 157-182.

33 Fire Service Academy (2020). *Smoke propagation in residential buildings: Main report from practical experiments in a residential building with internal corridors*. Arnhem: IFV.

34 No blood samples were taken of the other family members. The deceased father only underwent an external post-mortem investigation . Greater clarity about the precise cause of death could have been obtained by carrying out an internal autopsy. This was not carried out. It is also not standard practice in the Netherlands to carry out an internal autopsy in cases of this kind.

35 Baud, F.J. et al (1991). Elevated blood cyanide concentrations in victims of smoke inhalation. In: *New England Journal of Medicine*, 325(25), 1761-1766.

Role of the lift

An investigation of the lift following the occurrence showed that the lift functioned technically correctly.[36] Nonetheless, the lift played an important role in the course of the occurrence. Being unaware of the fire in the entrance hall, the family entered the lift on the fifth floor, which subsequently transported them to a dangerous fire. Confronted with the fire, they were then unable to escape, because they were in the lift which after only a short delay once again took them away from the fire. In its investigation, the Safety Board noted that it is very unusual for people to be transported by a lift to a fully developed fire. Interviews with lift experts also revealed that technical solutions for preventing this scenario in the future are both complex and costly, and deliver no broader safety gains. For these reasons, the Safety Board decided to shift the focus of the investigation to other aspects. Lifts and the use of lifts in the event of fire are not dealt with in detail, in this report. A number of recent developments relating to the use of lifts in the event of fire are however briefly discussed in the blue block below.

36 Liftinstituut (2020). *Rapportage technisch onderzoek lift naar aanleiding van ongeval betreffende: brand op 1 januari 2020 in woongebouw Gelderseplein 241 – 455 Arnhem (Report of technical investigation of lift following an accident relating to: fire on 1 January 2020 in residential building Gelderseplein 241 - 455 Arnhem).*

**Use of lifts in the event of fire**

According to current legislation and regulations, lifts are not part of escape routes, so that as a rule, no measures are taken aimed at making lifts safe for use in the event of fire. In the theory of fire safety, therefore, the widely used adage for decades has been: 'do not use lifts in the event of fire'.[37] This is a broadly recognized principle. [38] More recently, however, it has become increasingly clear that it could be worthwhile changing this principle in the near future, because such a change could improve the fire safety of blocks of flats. This insight has above all grown as a result of the rising number of people with limited self-reliance living in blocks of flats, and who are for example unable to escape from the building via the stairs, in the event of a fire.[39] However, even for fully mobile people, the use of lifts can make the difference between life and death. Specifically in the event of tower blocks, the use of a lift can reduce the evacuation time.[40] Incident evaluations have also shown that in practice, people sometimes also tend to escape via the lift in the event of fires, above all if residents or visitors are used to taking the lift up and down, and as a result are not conversant with the location of the stairwells.[41] Finally, improved lift safety could also result in preventing people being injured or dying if they enter a lift when a fire is burning elsewhere in the building (of which they are not aware) as was the case in the occurrence in Arnhem. A number of these considerations have led to the current development whereby legislators and the lift industry intend to change the principle that lifts should not be used in the event of fire in a block of flats. Against this background, the Dutch Minister of the Interior and Kingdom Relations, in the proposal for the new building regulation, included an obligation to make lifts in a new built block of flats also suitable for use in the event of fire.[42], [43] These regulations will specify that the lift must be sufficiently protected in the event of fire, that the electrical power supply to the lift is separated fully fire-resistant from other rooms and that there is a vestibule that protects the lift against smoke penetration, and that also offers protection to persons waiting for the lift.[44] At the same time, the lift industry[45] is working to draw up guidelines that will provide acceptable conditions for use of a lift in the event of a fire in existing buildings.

37 Nonetheless, it has never been laid down in law; in other words, it is permitted.
38 As revealed by the study by Motivaction (commissioned by the Liftinstituut) in 2018.
39 During the prevention week in 2017, the professor of Fire Prevention at the IFV, R. Hagen said that in the event of a fire, a lift is often the safest and only escape route for an elderly person who is unable to independently escape via the stairs.
40 Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings*. Arnhem: IFV.
41 Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings*. Arnhem: IFV.
42 In the collective amendment to the *Environment Structures Decree*, sent to the Dutch House of Representatives on 12 May 2020. The proposal is to introduce this by 1 January 2022.
43 This requirement will apply to residential buildings with an accessibility sector. Residential buildings with an accessibility sector are residential buildings that are independently usable and accessible for persons with a functional impairment, and that for that reason are required to be equipped with a lift.
44 Minister of the Interior and Kingdom Relations, *Voorhang Verzamelwijziging van het Besluit bouwwerken leefomgeving (Preamble Collective Amendments to the Environment Structures Decree)*, 12 May 2020.
45 More specifically: the technical committee of the Netherlands Association for Lifts and Escalators (VLR).

## 2.4 Escape by residents and visitors

At around 01.30 hours, some 30 people who had noticed the fire, had gathered on the galleries. Together with the police in attendance, the fire service attempted to attract the attention of these people, and to make it clear to them that they should seek the safety offered by the ends of the galleries. This was because the rising column of smoke represented a hazard on the galleries in the central part of the building, above the entrance.

The people on the gallery, however, made it clear that they wished to leave the building. This was not possible, because they could not reach the main entrance as result of the smoke and heat in the central stairwell.[46] The emergency stairs at the ends of the galleries were also of no use in helping them to leave the building, because these stairs did not continue through to the ground floor. Initially, the people on the gallery of the first floors were helped to evacuate by the police, via two parked vans. When the fire service observed this happening, they installed a ladder to help the evacuation take place more safely. For the people on the higher floors, however, this escape route was not an option because they were unable to reach the first floor, from which they could leave the building via the improvised escape route.

When it became clear that it was neither possible nor necessary to rapidly evacuate the building, the fire service instructed the people on the galleries as far as possible to return to their flats, as long as they were clear of smoke. It took some time to convince the people who had gathered to follow this advice. The different nationalities of these people caused a language barrier. In terms of content, too, it was difficult to convince people to remain in the building while a major fire raged in the entrance hall. A number of people were eventually evacuated via an aerial ladder truck, but the majority of people present never left the building. The people on the gallery who were unable to leave the building later reported in the media[47] that they felt like 'rats in a trap'.

When the fire was announced as being under control at 03.14 hours, it became clear that all the flats in the residential building were habitable, so that none of the residents had to be housed elsewhere. From that point, the emergency services asked Vivare to take the lead in providing aftercare for the residents. In the period that followed, supported by people from Victim Support (Slachtofferhulp) and the Municipality of Arnhem, Vivare provided this aftercare. The experience proved so traumatic for a number of residents that they eventually expressed the wish to move and/or actually moved after the fire.

46 The only resident who is known to have left the building via the stairwell and the entrance hall is the resident who discovered the victims in the lift.

47 Omroep Gelderland (2020), *Woede bij bewoners na Arnhemse flatbrand: 'We zaten als ratten in de val'* (*Anger among residents following fatal fire in block of flats in Arnhem: 'We were like rats in a trap'*); Het Parool (2020), *Woede na fatale brand flat Arnhem: 'Geen enkele klacht wordt serieus genomen'* (*Anger following fatal fire in block of flats in Arnhem: 'None of our complaints are being taken seriously'*); RTL Nieuws (2020), *Bewoners flat Arnhem in rouw, maar ook boos na brand waarbij vader en kleuter omkwamen, (Residents block of flats in Arnhem in mourning, but also angry following fire in which father and toddler die')* NOS Nieuws (2020), *Vader en zoon (4) omgekomen bij flatbrand Arnhem, vuurwerk oorzaak. (Father and son (4) killed in fire in block of flats in Arnhem, cause fireworks*).

Before analysing the escape behaviour described above, it is first necessary to further explain the escape concept employed in the block of flats. The analysis of the escape behaviour therefore appears in chapter 3.

## 2.5 Conclusions

Shortly after 01.00 hours on New Year's Day 2020, fire broke out in the entrance hall of a block of flats in Arnhem, in a sofa, that had been placed there by a resident two days previously. The sofa was filled with plastic foam, more specifically PUR foam. It is known to experts that plastic foam is highly flammable, burns fiercely, and gives off large volumes of toxic smoke. This filling of the sofa meant that a low-energy ignition source, a ground bloom flower firework that was set off in the sofa, was sufficient to set the sofa alight. In addition, as a result of the plastic foam, the fire was able to develop rapidly and fiercely, producing large volumes of toxic smoke.

Precisely at the moment that the fire had reached full development, a family that was on its way out of the building was exposed to the fire. These people were confronted with a fire that was producing so much heat and toxic smoke that within 30 seconds, they were rendered incapable. Although the lift containing the family did return to the third floor of the building, the members of the family were no longer able to reach safety.

The entrance hall was part of the only escape route outwards. In the event of just a single escape route in a residential building, this route must be designed in such a way that no fire can occur or develop on that route. In the case of this building fire, this principle was not borne out; a fire did develop on the only escape route leading out of the building. The cause of the occurrence of the fire was the presence of a flammable sofa on the escape route. The fact that the fire was able to develop further was (jointly) caused by three structural elements installed by or on behalf of the owner, during the use phase (suspended ceiling, plastic panel in the fire retardant door and the wooden panelling beneath the stairs). These elements contributed to the fierceness of the fire, the scale of the smoke production and the spread of the smoke. Residents and visitors who observed the fire wanted to leave the building, but were unable to do so at that moment. Although from a rational viewpoint, these people remained safe throughout the fire, during the fire and in the subsequent period, they felt unsafe in their own living environment.

# 3 ESCAPE FROM BLOCKS OF FLATS

The previous chapter shows that the fire in the block of flats in Arnhem had major consequences for those present, since the fire broke out in the only escape route to the outside. In the escape concept employed for blocks of flats, a scenario of this kind is not taken into account. Nonetheless, precisely that scenario occurred, with fatal and far-reaching consequences for the people in the lift (whereby the plastic foam filling of the sofa played an important role (see chapter 4)) and anxious moments for residents and visitors who were unable to leave the building.

This chapter deals with the area of tension between the escape concept – consisting of central principles that are embedded in statutory regulations – and actual practice. Section 3.1 discusses the escape concept. The extent to which this is in line with actual practice is discussed in section 3.2. From section 3.3 onwards, we zoom in on the use phase of the building. 3.3 deals with the way in which fire safety is safeguarded in the use phase, while sections 3.4 (structural alterations) and 3.5 (objects on the escape route) analyse actual risks to fire safety in the use phase. Section 3.6 deals with the (im) possibilities of escaping from a block of flats, if the only available escape route is blocked by fire. The chapter closes in section 3.7 with conclusions.

## 3.1 Escape concept from blocks of flats

The heart of the current escape concept from blocks of flats is that in the event of fire, there must always be at least one route that remains clear of fire and smoke[48] for sufficient time to allow those persons present to escape safely from the building[49]. This principle assumes a timeframe of 30 minutes[50], so that people have the opportunity to leave a building after a fire breaks out. Escape routes in blocks of flats should therefore be produced in such a way that in the event of fire, at least one escape route always remains clear of smoke and flames, for at least 30 minutes.

To ensure that buildings comply with these principles for safe escape, statutory requirements are imposed on the design and use of escape routes. These requirements can be found in the Building Decree 2012 (in Dutch: *Bouwbesluit 2012*; hereinafter: Building Decree). The design requirements from the Building Decree can be specified in

48 Within this principle, a very limited volume of smoke in the escape route is permitted. Therefore, wherever reference is made in this report to no smoke, then this is considered as meaning the absence of large volumes of smoke that make escape impossible.

49 This is more formalistically designated in the legislation and regulations as 'the adjacent site and from there to the public road'.

50 In setting these 30 minutes, it is assumed that (1) the fire is discovered within 15 minutes of its breaking out, that the residents threatened by the fire have been notified and that the fire has been reported to the central emergency control room, and (2) within 15 minutes after being notified, the residents threatened by fire are able to escape without assistance from the fire service to a safe location outside the building. These given times are general principles. They refer to maximum times and are not goal-setting.

the building plan on which the environmental permit (in the past: the building permit) is based. The client, architect, contractor and building owner must all comply, with regard to their contribution to the design and construction.[51] The Building Decree distinguishes between requirements for new buildings and requirements for existing buildings.[52] New blocks of flats to be built must comply with the requirements for new buildings. Existing blocks of flats must at least comply with the requirements for existing buildings.[53] As a rule, these requirements are less strict. This is an economic choice and results in a higher residual risk than new building. This chapter deals primarily with the rules for existing buildings because these apply to the block of flats in Arnhem and to the majority of other blocks of flats in the Netherlands.

To ensure that in the event of a fire in a block of flats an escape route outwards is always available, the following three relevant sets of regulations for the design and implementation of escape routes can be distinguished between, within the Building Decree:

1. If a block of flats has a single escape route, this must be an *extra protected escape route*. On the one hand, the regulations are aimed at preventing a fire developing along the route, and on the other they should prevent fire and/or smoke from elsewhere in the building penetrating the escape route.
2. If there are multiple independent escape routes, the regulations applicable to those escape routes are less stringent.
3. If (part of) a single escape route gives access to homes with a combined floor area of more than 1500 $m^2$, there must be a *safety route*. This type of escape route enjoys the highest safety status contained in building regulations, and is subject to additional regulations to keep the escape route clear of fire and/or smoke.

These three sets of regulations are further elaborated below. Different sets of requirements can be relevant to different parts of the escape route. Within a single building, part of an escape route outwards can for example be an extra protected escape route, while another part is a safety route.

*1. Single escape route - extra protected escape route*
In accordance with the Building Decree, a single escape route is sufficient for a block of flats, on condition that the escape route is produced extra protected.[54] This extra protection consists of requirements, the aim of which is to ensure that the escape route

51 Article 1b of the Housing Act (*Woningwet*).
52 There are also separate rules for building renovation. See also section 3.4.
53 Any exceptions to this requirement are based on the so-called 'legally attained level', that applies for renovation (see also section 3.4). The legally attained level of fire safety is the level for which the original building permit was issued, where necessary revised with later additional rules for existing buildings. The legally attained level is therefore at least the level of existing buildings in the Building Decree, and at most the level for new buildings. In short, therefore, the legally attained level is the current quality level of a building section as far as legally attained with a level that is between the level for existing buildings and new buildings.
54 This is the underlying principle in the Building Decree 2012. This is a subtle change as compared with the Building Decree 2003, in which the underlying principle was the presence of two escape routes while in certain cases a single route could be accepted if additional measures were taken to make this route extra safe. (Netherlands Government Gazette (*Staatscourant*) 2011, 416, p. 146 and 236. Article 2.156 of the Building Decree 2003.)

always remains usable for as long as necessary to allow those persons present sufficient time to escape from the building. For that reason, the possibility of fire must be ruled out along the escape route, and a fire that breaks out in a flat (or some other part of the building) must not be able to reach the escape route or only after sufficient delay. After all, there is no other escape route. Among others this is subject to the requirement[55] that:

a. Escape must be possible without having to use a lift.[56] The route passes only via corridors, stairs or ramps.[57]

b. The structural components must comply with fire class[58] 2.[59]

c. Flats or other enclosed spaces along the escape route must be built in such a way that the escape route remains free of flames for at least 20 minutes.[60] It is assumed that fire resistant also means smoke resistant. It is notable that these 20 minutes, that apply to existing buildings, do not tie in with the underlying principle that persons present should be able to escape from the building within 30 minutes following the breaking out of a fire.

*2. Multiple independent escape routes*
If there is more than one independent escape route, less strict requirements are imposed.[61] According to the Building Decree, escape routes are independent of one another if a fire in one escape route requires at least 20 minutes to reach the other escape route. The thinking behind this is that if one escape route is blocked by fire, residents are still able to follow the other escape route. There are for example blocks of deck-access flats whereby there is not only a stairwell in the centre of the building, but also at the ends fire steps that lead downwards and outwards. In other words, from each flat there are always two escape routes outwards available. If there are multiple escape routes, point a of the summary under 1 above also applies. However, points b and c no longer apply because the risk of the loss of one of the routes can be compensated for by the presence of one or more other routes.[62]

*3. A single escape route - safety route*
If the only escape route gives access to flats with a total usable floor area of more than 1500 $m^2$ (often the case for central stairwells in blocks of flats), this must be a safety route. In this case, in addition to the requirements for an extra protected escape route (points a to c sub 1), there must be a space between the flats and this safety route, that is

55 This is not a full summary of the regulations applicable for an extra protected escape route. Only the relevant regulations in the framework of this investigation are listed here.
56 As indicated in chapter 2, this point is currently being reconsidered.
57 nterpreted freely according to article 1.1(1) of the Building Decree 2012, definition of 'escape route'.
58 A fire class is a measure for the contribution to fire propagation of a specific structural element.
59 Article 2.76(1 and 2) and 2.77(2) of the Building Decree 2012. The method of determination is no longer available. rticle 2.80 of the Building Decree 2012 specifies conversion to Euro classes.
60 Article 2.90(1) of the Building Decree 2012.
61 Article 2.116 Building Decree 2012.
62 Instead of point b no longer applying, a lower requirement is contained in the Building Decree, namely that the structural elements must meet the requirements of fire class 4.

partially open, so that smoke can escape via the open air from the adjacent open space, so that the escape route is kept clear of smoke.[63] Requirements are also imposed on the permissible permanent fire load[64] per m² floor area of the safety route.

Figure 10 summarizes the three sets of regulations in diagrammatic form.

**Statutory regulations**

**Number/type escape route(s)**

| | Escape without use of lift | Construction elements fire class | At least 20 minutes free from fire | Separated from flats by open space | Maximum permanent fire load |
|---|---|---|---|---|---|
| 1 escape route (extra protected) | ✓ | ✓ | ✓ | | |
| >1 escape route | ✓ | | | | |
| 1 escape route (safety route) | ✓ | ✓ | ✓ | ✓ | ✓ |

*Figure 10: Table showing statutory regulations for the design and implementation of escape route(s) from blocks of flats.*

It can be concluded from the above that based on the regulations for the design and construction of escape routes, no explicit requirements are laid down for the (non-structural) elements. It is implicitly assumed that no variable fire load will be present in the escape route. To safeguard this also during the use phase of the building, for all of the escape routes described above, Article 7.10 of the Building Decree applies: '(...) *it is forbidden in or near to a building to place, to deposit or to have objects or substances, to undertake or refrain from actions, to use or not to use machines, tools and equipment or otherwise to raise or cause a hindrance as a consequence of which: a. danger of fire is caused, or b. in the event of fire, a dangerous situation is caused.*' In other words, this Article is among others aimed at preventing flammable materials being placed in the building, in particular on the escape route.

Finally, the Building Decree shows that no measures are laid down, in the event of a fire in the single escape route from a block of flats, to still make a safe escape possible. This is the consequence of the underlying principle that this escape route must always be clear of smoke and flames for long enough to permit a safe escape. There are therefore no requirements imposed on the design of escape routes with regard to sounding the alarm (for example smoke alarms or a fire alarm installation), (automatic) fire extinguishers (such as sprinklers or fire hose reels) or alternative methods of taking those persons present to safety (for more information about fire alarm installations and sprinklers see the block below).

63 Ventilation requirements in Article 2.117(6) of the Building Decree 2012.
64 According to the NEN 6090 standard, this is the fire load of the flammable materials as determined in the structural elements of a building or of a space in a building, or the structural elements that form the boundary of that building or that space.

**Fire alarm installations and sprinklers in residential buildings**

By means of automatic and/or manual fire alarms, a fire alarm installation detects fire, and sends a signal to a central fire alarm in the building. From the central fire alarm, a fire alarm installation can activate other (fire protection) systems such as an evacuation alarm or the lift operating system. The central fire alarm can also pass on the alarm signal to the emergency services control room or the control room of a private security organization. The Building Decree specifies those situations in which a fire alarm installation is required. The function, size and height of the building are the determining factors. In most buildings, the installation of a fire alarm installation is compulsory, whereby the requirement is imposed that as the building becomes larger and higher, and the use of the building increases in risk, so the building alarm installation itself must be more extensive (better with wider ranging monitoring of the building). Residential buildings form an exception to these requirements, because a fire alarm installation is never[65] required in these buildings. Smoke alarms, which are due to be made compulsory in all homes in the Netherlands as from 1 July 2022, are different from the detectors of a fire alarm installation, because they only sound an alarm, without passing on a signal to a central fire alarm in the building.

The installation of sprinklers is not a compulsory requirement in any residential building in the Netherlands. Nonetheless, they are sporadically installed in residential buildings. In most cases, sprinklers are then used as an equivalent solution to compensate for a performance requirement from the Building Decree. They are commonly used in tower blocks higher than 70 metres, because they are required by a regulation in the *Fire Safety Guide for Tower Blocks*.[66] In a number of other countries, sprinklers are compulsory in residential buildings, but generally only in new buildings. [67]

## 3.2 Escape concept from blocks of flats in practice

In this section, we examine the extent to which the escape concept from blocks of flats operates as intended, in practice. To do this, the situation during the fire in Arnhem is compared with the escape concept. An outline assessment is then made of the extent to which in the case of other fires, practice matches with the escape concept.

65 Buildings with a residential function for care recipients are once again an exception.

66 For buildings higher than 70 metres, the Building Decree provides no universal structural regulations. In designing fire safety in tower blocks, the competent authority or the fire service have the option of themselves imposing further requirements on the fire safety measures to be taken. The *Fire Safety Guide for Tower Blocks* offers guidelines for bringing about optimum fire safety in tall buildings of this kind.

67 In 2014, the WODC commissioned the SEO Economic Survey to make an estimate of the costs of equipping all residential buildings in the Netherlands with sprinklers, set off against the monetary advantages or social benefits. The result was that at that moment, it was not considered opportune to introduce a wide-ranging obligation to install sprinklers in residential buildings, based on the judgement that the costs for equipping all (new built and existing) blocks of flats with sprinklers did not measure up to the social benefits.

### 3.2.1 Escape concept in practice in the fire in the block of flats in Arnhem

In the case of the block of flats in Arnhem, part of the building was served by two escape routes and partly a single escape route. From the flats on the second through to the ninth floor, as far as the stairwell, there were two routes to the central stairwell (see also section 2.1.1). One route travelled directly from the flats to the central stairwell, and one route via the emergency stairs at the end of the gallery, via the gallery on the floor above or below, to the stairwell (see the block below for an assessment of this route). On the first floor, there was only one route from the flats to the central stairwell, because on this floor there were no emergency stairs at the ends of the gallery. This is a consequence of the old regulations whereby up to a floor height of six metres above ground level, a single escape route was sufficient, because in an emergency, people could be evacuated from the gallery, using a ladder.

**Risk of the design of stairs at the ends of blocks of deck-access flats**

The aim of the design of flights of stairs, in pairs, at the ends of the galleries in the block of flats in Arnhem is that in the event of a fire at a location between the flat and the central stairwell, people could still reach the central stairwell. One major disadvantage of this design is that in this scenario, people are required to pass the seat of the fire when walking to the central stairwell via the gallery above or below. This means that people that pass above the seat of the fire could be forced to escape as a result of the rising smoke and/or blazing fire on the floor below. This could render this escape route unusable, so that people are still unable to reach the central stairwell.

The escape routes on the various floors combined into a single escape route, that passed through the central stairwell and the entrance hall, outside. Because this single escape route gave access to more than 1500 $m^2$ of flats, it should have been produced as a *safety route*. Because the entrance hall was part of the safety route, it should have been designed and implemented according to the escape concept in such a way that it satisfied the applicable regulations (as specified in the previous section) as to keep the escape route clear of fire and/or smoke. There are no indications that this was not the case when the building was delivered. However, the Safety Board was unable to irrefutably draw this conclusion, because too little information about the original design and its implementation was available during the investigation.

It is however clear that the status of the safety route at the start of 2020 was such that a fire was able to start and develop along the route. The relevant structural elements are already referred to and elaborated in chapter 2: the suspended ceiling, the Lexan panel in the door to the stairwell and the wooden wall construction installed to enclose the space beneath the stairs. Even more important is the fact that a highly flammable sofa had been placed in the safety route. At that moment, therefore, the escape route did not satisfy the underlying principles – and all the accompanying statutory regulations – from the escape concept, and was therefore not safe enough. All of the elements referred to above were added to the escape route, during the use phase of the building. Sections 3.3, 3.4 and 3.5 analyse how this could take place, and how it was allowed to continue.

### 3.2.2 Practice in other fires

Many residential buildings in the Netherlands have a single (or partially single) escape route outwards. See block. Evidence indicates that it is quite common in practice for the only escape route outwards to be unavailable, in the event of fire, and that persons present in the building are unable to escape. First and foremost, this is because fires in blocks of flats do not always start inside the flats, but also in communal areas, that themselves sometimes form part of the escape route. In an investigation into fires in accommodation for the elderly carried out by the IFV in 2016[68], it emerged for example that in more than 20 percent of cases, the fire did not start inside a flat. A quick scan of serious fires in blocks of flats that attracted media attention in 2020 undertaken by the Safety Board[69] shows that around one third of these fires started elsewhere than in the flats. The fire in the building in Arnhem was therefore not unique, in this respect.

68 Brandweeracademie (2016). *Branden in seniorencomplexen: regelgeving en praktijk*, Arnhem: IFV (Fire Service Academy (2016). *Fire incidents in senior citizen complexes: regulations and practice*).

69 See Appendix E.

**Escape routes in other residential buildings in the Netherlands**

It is common in residential buildings in the Netherlands for there either to be a single escape route that leads out of the building, or that there are multiple escape routes that combine into a single escape route. The design with flights of stairs only joining the floors in pairs (see section 2.1.1), as in the block of flats in Arnhem, is not unique, but is not widespread. Many blocks of deck-access flats with a central stairwell have an emergency stairwell at the ends, that joins all floors together, and in some cases continues down to the ground floor or in other cases, ends on the first floor. In the latter case, too, effectively there is only a single escape route that leads out of the building.

In response to the investigation *Smoke propagation in residential buildings* by the Fire Service Academy[70] and recent fires in residential buildings, including the fire in a block of flats in Arnhem, the Ministry of the Interior and Kingdom Relations commissioned the IFV at the start 2021 to draw up an overview of the practical situation with regard to escaping from residential buildings. The results of this investigation are expected in the summer of 2021.

It also emerges from other occurrences that in practice, smoke regularly penetrates into an escape route which according to its design should be sufficiently protected against fire and smoke from outside. The investigation by the IFV for example revealed that the escape routes in the fire in an accommodation for the elderly in Nijmegen in 2015 were rapidly rendered unpassable by smoke, because the divisions between adjacent rooms were not sufficiently smoke resistant, and because doors were left open, because no automatic closing mechanism was required, and because during their escape, people did not close doors behind them. The escape routes did satisfy the requirements on this point, but in practice, these requirements did not safeguard sufficient protection against smoke.[71] Another incident investigation by the IFV also shows that in the event of a fire in a block of flats in Diemen in 2017, the escape route quickly became impassable. In this case, an open door between the flat where the fire was blazing and the central stairwell meant that the escape route rapidly filled with smoke. The escape route did satisfy the requirements, but fire safety could easily be compromised, by a simple human action.[72]

70 Brandweeracademie (2020) *Rookverspreiding in woongebouwen: Hoofdrapport van de praktijkexperimenten in een woongebouw met inpandige gangen.* (Fire Service Acadamy (2020) *Smoke propagation in residential buildings: Main report from practical experiments in a residential building with internal corridors*). Arnhem: IFV.

71 Brandweeracademie (2015) *Brand in De Notenhout* (Fire Service Academy (2015) *Fire in De Notenhout*).

72 Instituut Fysieke Veiligheid (2017). *Brand Rode Kruislaan in Diemen. Een onderzoek naar het brandweeroptreden.* Arnhem: IFV. (Institute for Safety (2017). *Fire on the Rode Kruislaan in Diemen. An investigation into the fire service response).*

**Conclusion**
In theory, in the event of fire in a building, there is always at least one route that remains clear of fire and smoke for a period of time long enough to allow the persons present to escape outwards, in safety. However, in practice this does not always prove to be the case. In the case of the fire in the building in Arnhem, the fire started in the only (escape) route outwards. Sadly this resulted in four victims, as well as preventing the other persons present in the building from escaping in safety. The fire was able to start because fire safety of the building was compromised, during the use phase. As a consequence, at that moment, the situation was unsafe. Other fires show that similar loss of safety caused by flames and/or smoke in the escape route occurs regularly, in practice. The theoretically always available safe escape outwards is in practice not always safeguarded. Because no measures were taken to limit the consequences of this scenario (no alarm system, sprinkler installation or alternative escape route was required), the consequences can be considerable.

## 3.3 Fire safety in the use phase

It becomes clear from the previous section that fire safety in a building is not only dependent on the design of the building and its correct implementation, but also on the way in which the building is used. This section examines what lessons the fire in the block of flats in Arnhem can teach us about (safeguarding) fire safety in a building, in the use phase.

### 3.3.1 Tasks and responsibilities

Legislation and regulations contain provisions, the aim of which is to ensure that a building that is built to a specified level of fire safety remains fire safe during the use phase. Article 1b of the Dutch Housing Act contains provisions, the purpose of which is to ensure that throughout its entire lifecycle, a building continues to comply with the regulations applicable to that building, therefore also the regulations relating to fire safety. Although the specific article in the Housing Act does not specify precisely which party is responsible for fulfilling this principle, the Explanatory Memorandum clearly shows that the responsible party is the owner, or another party authorized to carry out measures on the building.[73] Article 1a of the Housing Act also contains what is known as the general duty of care. This duty of care specifies that the condition of the building may not allow any danger to health or safety to arise or to continue. Safeguarding fire safety in the use phase is an integral part of the duty of care. The duty of care is an addition to the previously mentioned Article 1b, because it also relates to situations in which there is a (threat of) danger to health or safety, even if the condition of the building is not yet in contravention of specific regulations from the Housing Act or the Building

73 *Parliamentary Papers II 2003/2004*, 29392, no. 3.

Decree.[74] Both the owner and the user of the building have been allocated a role in this respect, in law.[75]

The regulations that buildings must comply with according to the Housing Act appear in the Building Decree. Throughout its entire lifecycle, the building must comply with the regulations contained in this Decree, that are relevant to that building. A number of these regulations are directed specifically at the use phase of the building. This above all applies to chapter 7 of the Building Decree. The first two sections of this chapter relate to fire safety in the use phase, and section three contains the other provisions governing healthy and safe use. Specific articles from this chapter are referred to wherever relevant in the remainder of this section.

The municipality is responsible for supervising compliance with the building regulations, including the statutory fire safety regulations. This responsibility applies both in the design and construction phase, and in the use phase. The municipality becomes more specifically relevant in the use phase at the moment that an existing residential building undergoes major renovation. A major renovation requires an environmental permit to be applied for, whereby the municipality (among others) checks whether the renovation plans satisfy the fire safety regulations. This is dealt with in more detail in subsection 3.4.

Within the law, the fire service has no formal role in supervising the fire safety of residential buildings during the use phase, or in supervising the compliance by building owners with statutory regulations. On the other hand, the fire service does have the statutory task of preventing, limiting and fighting fires, and advising other government authorities and organizations on fire prevention and firefighting.[76] In practice, the fire service therefore regularly acts as advisor to municipalities in evaluating permit applications, which includes assessing the material used (does it comply with the required fire class?), fire compartmentalization, smoke alarms, fire extinguishing equipment and escape routes. In line with its designated statutory task, the fire service can also support owners in improving the fire safety of their buildings.

74 *Parliamentary Papers II 2003/2004*, 29392, no. 3.

75 Section two of Article 1a states that: *'any person building, using, allowing the use or demolishing a building, or using or allowing the use of property or land, in as much as in his capacity ensures that as a consequence of said building use or demolition, no risk to health or safety occurs or continues.'*

76 In accordance with Article 25 of the Safety Regions Act (*Wet veiligheidsregio's*). In addition, under all circumstances the fire service also has the following tasks: limiting and mitigating danger to humans and animals in the event of accidents other than fire, warning the population, examining hazardous substances and carrying out decontamination and advising other public authorities and organizations as regards fire prevention and firefighting and preventing and containing and combating incidents with hazardous substances.

**Conclusion**
Both the owner and the user(s) of a residential building have a responsibility during the use phase of a building to ensure the fire safety of that building. The municipality is responsible for supervision. The fire service has no formal role in the fire safety of a building during its use phase, but in many cases does act in practice as advisor to municipalities and building owners.

### 3.3.2 Safeguarding fire safety during the use phase by the owner

In order to comply with its statutory responsibility for a fire-safe residential building, a building owner must also make sure during the use phase of a building that the fire safety of that building is in good order. Exactly how an owner should do this is not further laid down in legislation and regulations. The Safety Board investigated how the owner of the block of flats in Arnhem, housing association Vivare, fulfils this responsibility. The investigation focused specifically on the extent to which there is a fire safety management system (see the reference framework in Annex C for the expectations of the Safety Board in that respect).

Vivare explained that it safeguards the fire safety of its residential buildings by integrating those buildings in the organization's project-based work approach. This means that the fire safety of houses and residential buildings is considered in the event of major renovations and maintenance projects on buildings. When asked how the fire safety risks in existing residential buildings outside building projects are assessed, it was suggested in interviews that buildings are regularly visited by service employees[77] and by contractors brought in by Vivare for (minor) structural maintenance, all of whom are instructed to keep a close eye on the fire safety in the flats. It was also explained that every building is subject to an interim inspection once every three years, to gain an indication of the technical maintenance condition of the building complex.[78] However, in this regard, during the interviews, reference was above all made to intensive cooperation between Vivare and the fire service. Discussions are held once every six weeks between Vivare and the Central Gelderland Fire Service and, whenever necessary, visits are made in the company of the fire service, to check the buildings. In this cooperation between Vivare and the Central Gelderland Fire Service, a covenant concluded between the two organizations in 2012 plays an important role. Vivare was the first housing association in the region to establish this kind of covenant; others followed later. In the covenant, Vivare undertook to improve the fire safety of its buildings.[79] In that framework, an assessment was made for all building complexes of their continued compliance with an acceptable level of fire safety. Vivare and the fire service together determined that level of fire safety. In addition, Vivare and the Central Gelderland Fire Service discussed which measures needed to be taken in order to raise the buildings to the required level of fire safety. A period of ten years for this work was agreed in the covenant. The underlying principle for this ten-year period was that Vivare would be able to include all observed improvement

77 These are employees of Vivare, who carry out minor repairs.
78 This is what is known as a Fitness for Maintenance (CVO; *Conditie voor Onderhoud*) review.
79 Covenant Vivare - Central Gelderland Fire Service regarding the approach to the fire safety of commercial rented buildings.

points in the planned (renovation) projects for the buildings in question. Only if it emerged during the implementation of the work that safe escape from a building was not possible, would that aspect be dealt with immediately.

Since signing the covenant, Vivare has set to work on putting it in practice, in its buildings. The block below indicates the outcome for the block of flats that forms the central object of this investigation. However, implementation of the process agreements never actually took off. Vivare, for example, never established the safety monitoring system they should have created according to the covenant, in order to provide an insight into the progress of the work. In addition, Vivare is not in possession of the documents which according to the covenant should have been in place, by way of background information.

**Implementation of the covenant with the fire service - block of flats Arnhem**
The block of flats where the fatal fire took place is one of the buildings that falls within the scope of the covenant. A one-off survey of the fire safety situation was held in the block of flats, in mid-2015. This took the form of a so-called BGB survey. BGB stands for *Brandveilig Gebruik Bouwwerk* (Fire Safe Building Use). Normally speaking, a BGB survey is part of a fire safety certification programme. This programme is implemented according to a procedure approved by Kiwa, the testing, inspection and certification organization. The programme is concluded with the issuing of the BGB label, on behalf of Kiwa. It was agreed in the covenant that a BGB survey would be carried out on the buildings. With regard to obtaining the label, it was agreed in the covenant that this would be carried out on a voluntary basis.

The BGB survey revealed that in respect of a number of points, the building failed to comply with the regulations from the Building Decree 2012.[80],[81] According to the covenant, Vivare had until the end of 2022 to tackle any observed non-conformities. The points which according to the survey were not up to scratch were included in the implementation of the large-scale maintenance project that was started in 2019. It should be noted that these attention points - that had not yet been tackled - played no role of any significance in the fire on 1 January 2020. The points that did play a significant role (suspended ceiling, wood panelling and Lexan panel) were not observed during the survey in 2015. This may be because the BGB survey that was carried out did not include a full assessment of the entire building. Finally, it is notable that in the BGB survey, the escape route was found to be sufficiently free from obstacles, despite the fact that according to the report, rubbish bags and other items had been observed in the escape routes.

80 Obex (2015). Obex rapportage BGB: Complex 20.03.07.01 Gelderseplein 1 to 455 Arnhem.
81 An example of an observed non-conformity is that fire-resistant and smoke-resistant separating structures remain insufficiently closed, because the door closers were either broken or missing.

Other elements that could contribute to safeguarding the fire safety of buildings in the use phase are missing at Vivare. There is, for example, no integrated fire safety strategy; as previously indicated, fire safety above all emerges as a point for attention during major (renovation) projects. There is also no staff officer who has been made explicitly responsible for drawing up, implementing and monitoring a fire safety policy. Moreover, fire safety is only considered during management discussions on an ad hoc basis, if a decision has to be taken on the projects, in the event of changes to legislation and regulations, if changes are made to the fire safety-related processes and during the annual round of decision making on the resources for fire safety-related service contracts. According to the Safety Board, Vivare does not have an elaborated fire safety management system.

**Conclusion**
Building owners are required to ensure that the fire safety of a building remains up to standard during the use phase. A fire safety management system is the ideal instrument for fulfilling this requirement. Vivare has no elaborated fire safety management system. Collaboration with the fire service, in particular the building management approach as part of the covenant, means that there is a certain degree of attention for fire safety in the use phase of residential buildings, at Vivare.

### 3.3.3 Supervision of fire safety of residential buildings in the use phase

Based on discussions in the sector, the Safety Board has noted that the majority of municipalities do not actively supervise buildings in the use phase. Only if there are indications of shortcomings in a building, which represent risks for the environment, will a municipality employ its authorities. With regard to a number of building types specified in the Building Decree[82], namely not residential buildings, municipalities do actively supervise fire safety in the use phase, because for these buildings, a use permit or notification of fire-safe use is required (see block).

82 As laid down in Article 1.18(1) of the Building Decree 2012.

**Use permit and notification of fire-safe use**

Municipalities do actively supervise the fire-safe use of a number of building types[83] specified in the Building Decree. Examples of these building types are buildings in which night-time and daytime accommodation is provided to vulnerable groups and buildings where rooms are let. The building owner or user of these buildings is required to apply for a use permit from the municipality, or to submit a notification of fire-safe use, according to which the building owner or user indicates that the use of the building satisfies the fire safety regulations imposed. These for example relate to regulations about the fire resistance of the construction, the escape routes and the presence of fire extinguishing equipment. The municipality supervises compliance with these fire safety regulations. These inspections are carried out annually by the fire service or a specially trained fire safety inspector from the Building Control Department (BWT).

The municipality of Arnhem does not actively supervise the fire safety of residential buildings in the use phase.[84] This means that they do not carry out any periodic (preventive) checks or inspections on these buildings. Only if unsafe situations are reported does the municipality take action and visit a building. The municipality of Arnhem receives reports of this kind approximately twice a month. The municipality also fulfils a role in permit applications for renovations, and checks whether the renovation plans comply with the fire safety regulations. The reason why the municipality of Arnhem does not actively supervise the fire safety of residential buildings in the use phase is that the municipality has chosen to give priority to other building types. Because no permit was applied for the renovation work in the block of flats, and the municipality of Arnhem had received no report of an unsafe situation, the municipality was not aware of the elements referred to in chapter 2 that resulted in reduced fire safety in the block of flats in Arnhem.

**Conclusion**

The majority of municipalities do not actively fulfil their supervisory role for buildings in the use phase. The municipality of Arnhem does not actively supervise the fire safety of residential buildings in the use phase. Partly as a consequence, the less fire-safe elements in the block of flats in Arnhem remained unnoticed by the municipality of Arnhem.

83 As laid down in Article 1.18(1) of the Building Decree 2012.

84 The exception relates to residential buildings for residents with limited or no self-reliance. According to the enforcement plan of the municipality of Arnhem, these groups enjoy priority in the supervision of fire safety.

### 3.3.4 Fire safety awareness of building owners

Maintaining the fire safety of buildings at the required level in the use phase for a building owner not only requires an operational fire safety management system but also a high degree of fire safety awareness.[85] The investigation shows that at Vivare, in the recent past, there was a well-developed level of fire safety awareness within the organization. Ten years ago, Vivare was the first housing association to enter into a covenant with the fire service to improve the fire safety of its buildings. This example has now been followed by many housing associations across the region. The limited procedural safeguarding of the progress of the implementation of that covenant however shows that fire safety awareness does require continuous attention within the organization. In the remainder of this chapter, a number of other examples will be presented, which show that attention for fire safety has declined within the organization over the past few years.

There is also room for improvement in the fire safety awareness of many other housing associations. This is confirmed by an inventory by Regieweb[86], which examined fire safety awareness at 29 housing associations[87], see figure 11. Interviews by the Safety Board show that this can be explained by the fact that fire safety must compete with numerous other subjects that also require attention. Such competing subjects referred to include the sustainability challenge and, in respect of safety, the problems of asbestos and lead pipes in homes and residential buildings. The Safety Board notes that problems with fire safety above all emerge in the event of incidents, at which point they briefly receive extra attention. In practice, this attention wanes rapidly, again allowing fire safety awareness to lapse quickly.

85 Awareness of the fire safety of a building among the affected persons and organizations, such as the owner, the user, fire service and municipality, contactors, technical consultants, etc.

86 Regieweb is an organization that assists real estate owners in managing their property. The focus is on fire safety.

87 Regieweb developed the Maturity Model for Fire Safety (RW-MMB) according to which it is possible to assess the fire safety awareness of housing associations, expressed in a score. In this assessment, both the Building dimension and the Human dimension are considered. The Building dimension relates to the structural and installation engineering components, while the Human dimension considers both the integration of fire safety in the organization and the degree to which attention is focused on the fire safety behaviour of the tenant/user. The figure in this section contains scores based on application of this RW-MMB model.

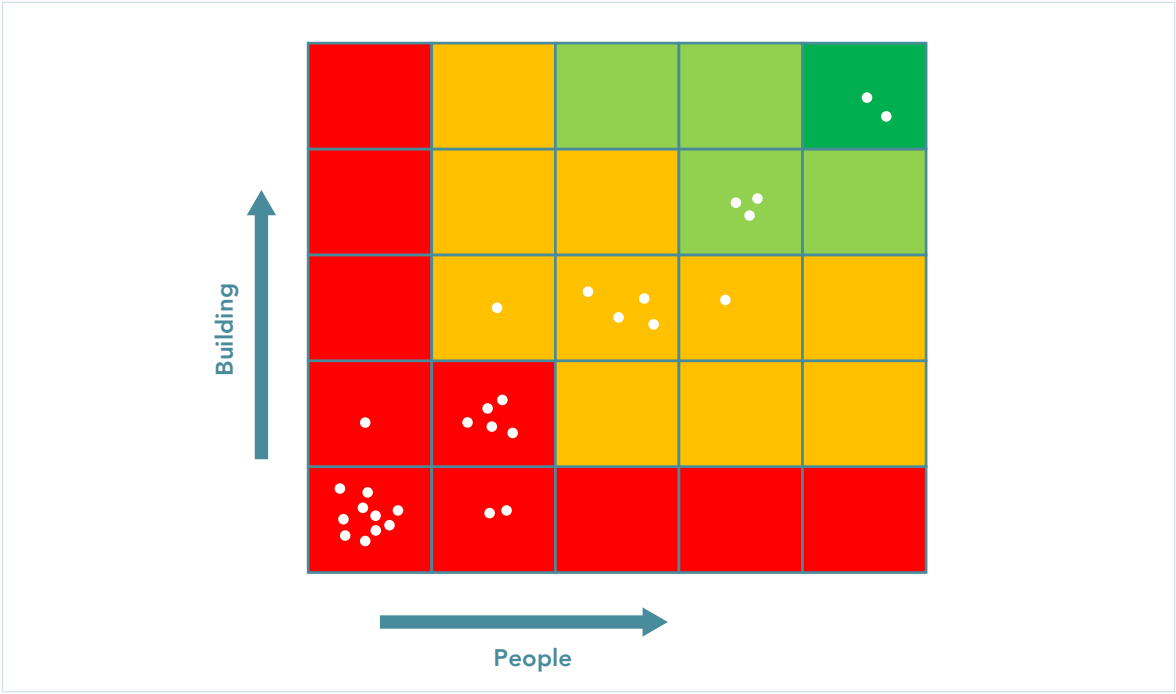



*Figure 11: Overview of scores for fire safety awareness of the 29 housing associations evaluated by Regieweb. Each point on the figure represents a housing association. The further along the horizontal and the vertical axes, the higher the fire safety awareness level. The horizontal axis shows the human dimension and the vertical axis the building dimension. Building relates to the structural and installation engineering elements and human to both the integration of fire safety in the organisation and the extent to which attention is focused on fire-safe behaviour by tenants/users.*

**Conclusion**

Building owners are required to ensure that the fire safety of a building remains up to standard during the use phase. This requires a high level of fire safety awareness. The Safety Board notes that the level of fire safety awareness at Vivare fluctuated in the years leading up to the fire in the block of flats. Other housing associations also do not always demonstrate a high level of fire safety awareness, although there certainly are housing associations where a high level of fire safety awareness is shown.

## 3.4 Use phase of the building - Structural alterations

The implementation of structural alterations in the use phase can have major consequences for the fire safety of a building. On the one hand, Vivare suggested that specifically during (renovation) projects, the fire safety of buildings receives attention, while on the other hand, the description given in chapter 2 above shows that the structural elements that played a role in the development of the fire on 1 January 2020 were in fact installed during work in the use phase of the building. This subsection analyses how the two aspects relate to one another, and what this teaches us about safeguarding fire safety in implementing structural alterations to a building.

Vivare views a renovation as a 'project' if large-scale interventions are made to one or more buildings. This for example includes large-scale maintenance, or a renovation or sustainability improvement project. In reaching decisions on the implementation of projects of this kind, fire safety is always one of the aspects that is explicitly considered (as already indicated in section 3.3.2). In addition, in the event of such projects, contact is sought during the preparation phase with the fire service, to jointly assess whether improvements are needed in the fire safety of the building.

An environmental permit is required for any major building renovation work[88], defined in the Building Decree as: the full or partial renovation, alteration or extension of a building. With regard to fire safety, a new environmental permit is also always required if the layout of the building in fire compartments is altered. In the application for an environmental permit, the municipality assesses in advance whether the renovation plans comply with the fire safety regulations. The general rule is that the part of the building to be renovated must comply with the rules for new building as laid down in the Building Decree.[89], [90]

88 Unless the work is declared as not requiring a permit in Annex II to the Environmental and Planning Decree (Besluit omgevingsrecht).

89 Article 1.12(1) Building Decree 2012.

90 This general rule is subject to specific exceptions which under the various subjects in the Building Decree can be found in an Article entitled: *Renovation*. The general rule applies only if a *Renovation* article is missing. A relevant example of such an exception is that in the event of a major renovation, the new building rules for compartmentalization (WBDBO of 60 minutes) do not apply. Then the 'legally attained level' must be assumed or that a minimum WBDBO of 30 minutes applies. If the legally attained level is a WBDBO of 20 minutes, in the event of major renovation work, the fire resistance will have to be increased.

**Renovation of the block of flats in Arnhem**
An example of the process that accompanies 'a project' is reflected in the preparation and implementation of the major maintenance work on the block of flats. This major maintenance work was started in 2019. In the renovation plans, that were drawn up ahead of the fire in the block of flats, a number of improvements to fire safety had been included. Vivare called in the fire service to advise on these fire safety measures. In response, the fire service proposed a number of changes to the renovation plan. The fire service for example advised giving the lift shaft walls and the landing accesses to the lifts a WBDBO of 30 minutes. After implementing these changes in the contractor's renovation plans, the fire service issued no further objections to the renovation. Subsequently, an environmental permit was applied from the Arnhem Region Environmental Service (ODRA), the organization responsible for building control work on behalf of the municipality of Arnhem. In August 2020, on behalf of the municipal executive of the municipality of Arnhem, the ODRA issued a permit for the work. The work has then been started, and in the meantime, the ODRA has carried out visual inspections to ensure that the work was carried out in accordance with the permit. Following completion of the work, the permit will be signed off.

The three structural alterations to the entrance hall - and hence to the escape route of the block of flats - relevant to this fire (installation of a suspended ceiling, installation of a wall structure beneath the stairs and replacement of the glass by a Lexan panel) were not part of 'a project'. As a result, the process stages described above that apply to 'projects' were not followed. These alterations are considered minor maintenance work of a kind carried out on many thousands of occasions by Vivare in any year.

The Building Decree states in respect of minor alterations of this kind that they must not be permitted to bring about any decline in the fire safety of a building. The building owner is then bound by the 'legally attained level'. This means that the block of flats, and the escape route, must be just as fire safe as they were before, after each minor alteration.

Various employees of Vivare indicated in interviews that it is highly unlikely[91] in the implementation of this work that attention was paid to the possible consequences for the fire safety of the area, and hence of the escape route. Unlike with alterations that are carried out in the framework of the larger projects, fire safety considerations are not an explicit part of the process for minor repairs and alterations. Instead, in terms of fire safety, above all, the knowledge, expertise and alertness of the employees and/or contractors involved is relied on. It is therefore possible that in the event of minor, everyday repairs and alterations, the fire safety of (part of a) building is compromised unintentionally, unconsciously and/or unnoticed. This is also not corrected by means of municipal supervision, because no environmental permit is necessary for repairs and

91 This cannot be stated with absolute certainty, because the background to these alterations was not documented, and no one at Vivare has any memories of this alteration work.

alterations of this scale. [92] As a consequence, during the use phase, a building can gradually become less fire safe, without this decline being noted by the responsible building owner, the residents and/or regulatory bodies.

**Conclusion**
In the use phase of a building, renovations are moments in time that can have consequences for fire safety. Whereas large-scale maintenance work and renovation work are the ideal moments for improving the fire safety of a building, everyday repairs specifically engender the risk that fire safety will be compromised. It is up to the building owner to safeguard that even during small-scale alterations and regular maintenance work, account is taken of the consequences of the work for fire safety in general and of the escape route in particular. In the block of flats in Arnhem, minor alterations to the entrance compromised the fire safety. Due to a lack of documentation about these alterations, it is no longer possible to determine how this could happen. It is however clear that fire safety considerations are not an explicit element of the process operated by the owner of the block of flats – housing association Vivare – for more everyday repairs and renovation work, and that in this respect, above all, the knowledge, expertise and alertness of the employees and/or contractors responsible is relied on.

## 3.5 Use phase of the building - Flammable objects on the escape route

The principle that no fire can break out in the escape route may be threatened during the use phase of the building because residents (or others) place flammable items in the escape route. As already suggested earlier in this chapter, the Building Decree includes a broadly formulated prohibition, in respect of this point, in Article 7.10. The Housing Act also specifies that compliance with this Article is a joint responsibility of owner and user.[93] In the case of a residential building with rented housing, both the lessor and the tenants are responsible for keeping the communal areas clear of flammable material or objects that could hinder the tackling of a fire or the use of the escape route. If a tenant nonetheless places (flammable) goods in the communal areas, thereby creating an unsafe situation, the lessor can take action. If the tenant does not comply with the demands of the lessor to remove the goods, the lessor can call the tenant to account, in court. In extreme cases, the courts can be requested to terminate the tenancy agreement.

92 Except if a change is made to the layout of the fire compartments.
93 According to the Explanatory Memorandum to the Housing Act, Article 1b of the Housing Act (the objective of which is to ensure that throughout its entire lifecycle a building continues to comply with the fire safety regulations applicable to that building) it is concluded that the owner of the building or any other party authorized to make provisions (for example the manager) is responsible for compliance with this Article. The general duty of care (Article 1a of the Housing Act) also leads to the conclusion that in addition to the owner, the user of a building is also responsible for fire safety.

### 3.5.1 Responsibility of the building owner

The Safety Board examined how the owner of this block of flats observes and lives up to this responsibility. This revealed that according to Vivare, keeping the communal areas clear of (flammable) items is primarily the responsibility of the residents. According to Vivare, it is up to the housing association to inform the residents of this responsibility. The housing association must also call residents to account if items are found in the escape route. Only when these items are not removed quickly enough by the resident(s) does Vivare take action.

Vivare indicated that it informs the residents of their responsibility in several different ways. According to various employees of Vivare, this is carried out via the tenancy contract and/or the accompanying general conditions. According to them, the contract and conditions state that tenants are not permitted to place any (flammable) items in the communal areas of residential buildings. However, after studying a tenancy agreement (including the accompanying general conditions) provided by Vivare, the Safety Board noted that there is no explicit mention that personal items that could result in a fire hazard may not be placed in the communal areas. It is stated in the general conditions to the tenancy agreement that it is forbidden to store 'environmentally harmful goods' in, on or in the immediate vicinity of the flat. This is notable because the general conditions (at the point where a provision of this kind would logically be included) of Vivare show considerable similarity with the *Model tenancy agreement and general conditions for independent living space* of Aedes[94], in which a unequivocal provision on this matter is explicitly included[95], [96] In the tenancy agreements and accompanying general conditions of other housing associations too, that were consulted by the Safety Board in the framework of this investigation, there is not always an explicit provision that tenants may not place any (flammable) property in the communal areas of residential buildings.

Vivare also uses newsletters and flyers to communicate on keeping the communal areas clear of goods and property.[97] Shortly before the fire, in a newsletter from Vivare, the residents were in fact called upon to keep the galleries clear of bicycles and other goods, because they can prove obstacles in the event of disasters. At that time, Vivare was only aware to a limited extent of the fire hazard these obstacles can represent, as a result of which this aspect was not specifically referred to. According to Vivare, the fact that only the galleries were referred to as a place where bicycles and personal items should not be stored can be explained by the fact that in the months leading up to the fire, goods had

94 Aedes. *Model huurovereenkomst zelfstandige woonruimte (Model tenancy agreement for independent living space.)* Via https://www.aedes.nl/artikelen/klant-en-wonen/huurbeleid/standaardmodel-huurovereenkomst-zelfstandige-woonruimte.html. Last consulted on 4 May 2021.

95 In Article 6.11 of these general conditions, it is stated: *'The tenant is not permitted to use the garden or other rented (outdoor) area(s) for the storage and/or parking of vehicles or vessels, caravans, trailers, trade goods, waste or hazardous or environmentally harmful goods and any other goods of whatever kind. The tenant is also not permitted to use the communal areas for the storage and/or parking of bicycles, perambulators, mobility scooters, trade goods, waste, hazardous or environmentally harmful goods and other goods of whatever kind. If the tenant does make such use, the lessor is entitled to remove these goods for the account of the tenant.'*

96 Aedes indicated that it was unable to say since when this provision has been part of its model agreement.

97 In the runup to the occurrence, newsletters (in Dutch) were drawn up. The flyers, that use pictograms, were produced after the occurrence.

above all been left lying around on the galleries and to a lesser extent in other communal areas.

Residents are also informed of their responsibility by employees of Vivare, when they visit the residential buildings. In the period in the runup to the fire, for example, employees of Vivare were regularly present in the block of flats. Normally speaking, the employees in question are specifically the two neighbourhood managers employed by Vivare in the neighbourhood of which the block of flats forms part. In the period in which the occurrence took place, both were present in this neighbourhood nine hours a week, during which time they regularly visited the blocks of flats. They have taken over the role of the caretaker, who was active in the blocks of flats until 2015. The caretaker role was removed as part of a reorganization.[98] The tasks of the caretaker have been transferred to the role of the neighbourhood manager. The neighbourhood managers were therefore responsible for carrying out the caretaker's tasks on the Gelderseplein. The owner of the similar blocks of flats in the neighbourhood, the Volkshuisvesting housing association, does employ a caretaker, who is present in the blocks of flats on a daily basis, and sometimes shows his face in the weekends too.

In the months before the fire, additional Vivare staff were actively present in the blocks of flats informing the residents of the upcoming renovation work, and to improve the quality of life in the block. These were employees of the contractor who was due to carry out the renovation work, two client consultants of Vivare and staff insourced by Vivare as part of the Behind-the-Front-Door-team.[99] These employees also organized activities aimed at removing litter from in and around the blocks of flats. In 2019, for example, a working group of residents regularly met to tidy up litter. Special clean-up days were and still are organized for residents, twice a year, to give them a low-threshold opportunity to dispose of goods they no longer require, free of charge. One such clean-up day had been organized three weeks prior to the accident, for the residents of the blocks of flats. Vivare has no formal policy on what its employees should do if they discover (flammable) goods in the communal areas and/or escape routes. In practice, the staff of Vivare who are regularly present in the buildings, for example the neighbourhood managers, service employees and client consultants, do call residents to account if they come across goods in the communal areas and/or escape routes. If it is unclear who the goods belong to, the neighbourhood manager will attempt to identify the resident in question. If this proves unsuccessful and/or if a resident refuses to immediately remove the item, the neighbourhood manager will place a sticker on the object , stating that the resident is required to remove the item from the communal area. If in the end these attempts to have the residents remove their goods fail, in principle, Vivare will store the object temporarily in a separate room, where it can be collected by the owner. If the item is not collected, Vivare will eventually dispose of the object.

98 Vivare has in fact since reappointed a caretaker for 10 hours a week.
99 These people were employed by 'Behind the front door Project office' (*Projectbureau Achter de voordeur*). This is a social organization that provides welfare and social services, that had been insourced at the time by Vivare.

Despite these initiatives, during the New Year period, a sofa was placed in the only escape route from the building. The staff of the Behind-the-Front-Door team did speak to the owner of the sofa, when they coincidentally observed the sofa being deposited in the entrance hall. The owner indicated that if the sofa had not already been taken away, he himself would remove it after a few days. Although the staff of the Behind-the-Front-Door team recognized the abandoned sofa as a problem in terms of quality of life in the block of flats, they were not aware of the potential fire hazard, and for that reason at that time took no further action. The next day, New Year's Eve, the neighbourhood managers of Vivare also observed the sofa. At that time, the note on the sofa stated that a pick-up appointment had been made with the waste disposal service, for 3 January 2020. Because a pick-up appointment had been made, the neighbourhood managers decided to take no further action.

Until the fire, staff of Vivare indicated that they above all viewed the responsibility of the housing association for keeping the communal areas and/or escape routes clear of goods as being important in respect of accessibility (for the emergency services) and the quality of life in the building. Until the fire, the fire safety risk played little if any role. This was because the rule that no obstacles should be placed in the escape route was already generally recognized; it is however not a self-evident conclusion that an object is not only an obstacle, but also a fire hazard.

### 3.5.2 Responsibility of the residents

As already stated, the residents of blocks of flats, including those of the block in Arnhem, have a statutory responsibility to keep communal areas, and escape routes in particular clear from (flammable) materials, in accordance with the Housing Act and the Building Decree. Nonetheless, many tenants in their daily life probably never concern themselves with statutory provisions. It is also not ideal that the tenancy agreement of the residents of the block of flats does not clearly specify that residents are not permitted to place property in the communal area and/or the escape routes. Nonetheless, this does not detract from the importance of a safe escape route and the personal responsibility for maintaining that route. In many blocks of flats, there is only one possible escape route, and its usability depends on the way in which the residents approach their responsibility. For that reason, residents should do their utmost to keep the escape route safe and clear of (flammable) materials, for themselves and for their fellow residents. In addition, the residents are in the best position to do this because they are present in the building on a daily basis.

The leadup to the occurrence shows that the residents were not aware of this responsibility to keep the only escape route outwards clear of obstacles. First and foremost this applied to the owner of the sofa, who placed the two halves of a corner sofa in the entrance hall to the block of flats. The wish of the owner was that other residents could reuse the sofa, so he deliberately placed the sofa in the entrance hall, and not outside, because it was then unclear what would have happened with the furniture. Other residents of the block of flats also demonstrated behaviour that implies that they were not aware of the responsibility to keep the escape route clear of obstacles. Other residents of the block, who saw the sofa in the entrance hall failed to then report

the situation according to Vivare. A second indication that the residents were generally not aware of their responsibility to keep the communal areas clear of property is that for some time, large amounts of bulky waste items and litter had been observed in and around the block of flats. Waste of this kind and other objects were also left behind in the communal area such as the entrance hall. The presence of litter in the neighbourhood and the fouling of the communal areas in the block of flats had become normal, despite the efforts of Vivare and some of the residents to deal with the problem. In addition, in the perception of the general public, a sofa is above all a comfortable item of seating and not a potential fire hazard. The fire hazard is, as it were, camouflaged. Residents often consider objects left behind in the communal areas and escape routes in terms of physical obstacles, and the flammability of these objects and the toxic smoke they give off in the event of fire are less well-known. Because residents are not aware of the fire hazard these types of objects represent, there is no urgency to keep the communal areas and escape routes clear of such items.

Residents are not in all cases even capable of taking their share of the responsibility for safeguarding fire safety in the use phase. This applies in particular in the social housing sector in blocks of flats such as those in Arnhem, that house people from different (cultural) backgrounds, some of whom have only a limited command of the Dutch language. Moreover, relatively large numbers of the residents face social and societal challenges. This context did not help in preventing the accident, but at the same time it was not a factor in the starting of the fire; in other districts too, sofas are placed in communal areas for reuse by other residents. Within this context, however, there can be no automatic expectation that residents are at all times aware of the way in which they should behave in order to avoid compromising fire safety. In such circumstances, the owner, in this case the housing association, will have to bear a greater share of the joint responsibility for fire safety.

**Conclusion**

Keeping communal areas clear of obstacles and flammable objects is a shared responsibility between the owner and the residents of residential buildings. In particular from the point of view of social management, Vivare has attempted in practice to fulfil its responsibility. The employees of Vivare above all viewed objects in escape routes as obstacles and less as potential fire hazards. Among residents, too, there was insufficient knowledge of the fire hazard represented by items left behind in communal areas and escape routes. The nuisance represented by items left behind in communal areas and escape routes, in the perception of the residents and building owners, often remained limited to reduced accessibility of (escape) routes and reduction in the quality of life. The urgency of preventing and/or removing items representing a fire hazard in the escape route is therefore only present to a limited extent.

## 3.6 Escape without an escape route

In the initial period following the outbreak of a fire, the people present in a building are above all dependent on themselves, and the people in their immediate vicinity.[100] At this point, the fire service still has to be called, and is not yet able to take responsibility for safety. For that reason, the behaviour of people in this initial phase is of huge importance in preventing victims of fire.[101],[102]

In the ideal situation, the design of a building offers support during this crucial initial phase. The design helps people reach safety, and offers people the perfect conditions in which to demonstrate safe evacuation behaviour. Possibilities include escape routes that tie in with the natural escape behaviour of people in making their escape, in that these escape routes coincide with the known routes they use on a daily basis.[103],[104],[105] Another example relates to the timely notification of residents with clear instructions for a safe response perspective. In an escape situation, people will not automatically demonstrate the safest escape behaviour. Design requirements and the escape concept can contribute to safe escape behaviour by tying in with or taking account of automatic behaviour and the needs of people in an escape situation.

### 3.6.1 Escape behaviour of residents and visitors of the block of flats in Arnhem

The situation in Arnhem whereby residents and visitors were unable to escape from the block of flats can be explained by the fact that the escape concept from blocks of flats fails to take into account the possibility of fire breaking out in a single escape route, thereby rendering this escape route impassable. For that reason, legislation and regulations also contain no obligation to equip escape routes in residential buildings with additional fire safety measures to mitigate the consequences of fire. It is also partly for that reason that no sprinkler installation was fitted in the entrance hall to the block of flats in Arnhem. It was also partly for this reason that the escape route from the block of flats was not equipped with smoke alarms or a fire alarm installation (BMI)[106] to sound the alarm for residents and visitors. Vivare has indicated that the reasons for not installing a (non-compulsory) fire alarm installation and/or sprinklers in the block of flats in Arnhem are the relatively high costs and the vulnerability to vandalism. The considerations of Vivare in reaching this conclusion are no different from the overall picture within the sector.

100 Kobes, M. & Oberijé, N. (2010), *Analysemodel vluchtveiligheid: Systematische analyse van vluchtveiligheid van gebouwen*. Arnhem: NIFV. (*Analysis model escape safety: Systematic analysis of evacuation safety from buildings*)
101 Purser, D.A., Bensilum, M. (2001). Quantification of Behaviour for Engineering Design Standards and Escape Time Calculations. In: Safety Science 38, 157-182.
102 Pires, T., de Almeida, A. & Duarte, D. (2005). A Decision-Aided Fire Risk Analysis. In: Fire Technol 41, 25-35.
103 Sandberg, A. (1997). Unannounced Evacuation of Large Retail-Stores: An Evaluation of Human Behaviour and the Computer model Simulex. Lund: Lund University.
104 Graham, T.L. & Roberts, D.J. (2000). Qualitative overview of some important factors affecting the egress of people in hotel fires. In: International Journal of Hospitality Management 19(1), 79-87.
105 Benthorn, L. & Frantzich, H. (1996). Fire alarm in a public building: How do people evaluate information and choose evacuation exit? In: LUTVDG/TVBB—3082—SE, vol. 3082, Department of Fire Safety Engineering and System Safety. Lund University.
106 For more information about sprinklers and fire alarm installations, see the blue block at the bottom of section 3.1.

According to the escape concept, an escape route must at all times be kept free of smoke and flames for a period of time such that those present in the block of flats are always able to escape outwards, in the event of fire. When the escape route was lost in the block of flats on the Gelderseplein, because the fire had broken out on the escape route itself, an unforeseen situation arose that was beyond the scope of the escape concept in use. Around 30 people who had observed the fire and therefore wished to leave the building, had gathered on the galleries. However, the only exit was blocked and the only option for people who felt threatened by fire or smoke was to escape deeper into the building. For people wishing to escape from the building, this was a counterintuitive movement.

Although in rational terms, the residents at the end of the galleries and in their own flats during the fire were practically in no danger, the people who wished to escape from the building did not experience the situation in this way. In their perception, with the loss of the route outwards, their route to safety had also disappeared. This perceived unsafety can be explained by the fact that the persons present during the initial phase of the fire, when the emergency services were not yet available to offer assistance, were dependent on their own assessment of the situation, for a safe response perspective. There was no general escape plan for residents. They had never received instructions on what to do in the event of fire in the block of flats in general, or in the event of fire in the entrance hall in particular; there was no organized (internal) emergency response organization, and no verbal or visual instructions. It is understandable that the sudden incapacity to fulfil what they estimated as being necessary - they were unable to leave the building – led to fear and/or panic.

Such feelings of unsafety are in themselves already undesirable, but they can also lead to unsafe behaviour. There are known examples from other occurrences where people who were unable to leave the building in any other way, ended up jumping from the building, even when they were not immediately threatened by the fire. Other examples of unsafe behaviour include searching for an exit through the smoke or even attempting to pass through the area of the seat of the fire (before it has been ventilated). This latter behaviour was in fact demonstrated in Arnhem, too. One man is known to have made his way outside through the stairwell and the entrance hall shortly after the fire service had put out the fire. At that time these areas were not yet ventilated and were still filled with harmful substances. The man in question later reported to the emergency services with breathing difficulties.

It was not until the emergency services arrived on site and after putting out the fire, the fire service were able to send a number of firefighters in the direction of the persons present in the building, that those persons were no longer entirely dependent on their own assessment of safe escape behaviour. However, a language barrier between the emergency services and the persons of different nationalities present in the building made it difficult to give clear instructions. Together with the police on the ground, the fire service attempted to attract the attention of the people on the gallery and with the use of signals to instruct them to seek safety at the ends of the galleries. This was because the rising column of smoke also represented a hazard. In principle, these people

could have safely returned to their flats, but the fire service estimated that it would probably have been pointless to encourage them to return to their flats.

The fact that the people present on the galleries and in the flats were in fact safe throughout the course of the fire did not match their perception of safety. Even after the fire, the feeling of unsafety never fully left the block of flats. Various residents have in fact moved since the fire, because they no longer felt safe in their flat.

### 3.6.2 Support from the building and design

The escape concept from a building places considerable demands on the self-reliance of people threatened by fire. This is because in the initial period following the outbreak of a fire, they are reliant on themselves, and the people in their immediate vicinity. 'Self-reliance' is a catch-all term, that not only relates to unchanging personal characteristics (such as mobility and sentience), but also to the question of how well an individual can deal with the circumstances of a specific occurrence.[107] In the event of fire, it is a question of the capacity of individuals 'to take note of and to interpret danger signals, and to take and implement decisions aimed at surviving a fire situation.'[108] In this sense, self-reliance is the result of interaction between the individual and his or her environment. 'To a certain extent, all people in a fire situation can be faced with limitations, and as a consequence are potentially restricted in or incapable of self-reliance.'[109]

The effects of fire, such as smoke, heat and toxic gases can result in situations which mean that the persons present are themselves no longer able to reach safety. For the four victims in the lift in Arnhem, this was the result of a combination of toxic and hot smoke and thermal radiation; for the other people in the block of flats, it was caused by the loss of the escape route. The feelings of unsafety among those present in the building and the sense of unrest that resulted from their inability to respond are an indication of reduced self-reliance. The absence of other possibilities of escape meant that they no longer had the capacity to autonomously take the decision to leave the building for their own safety, and to act accordingly. This suggests a shortcoming in the escape concept: on the one hand, the persons present were expected to demonstrate a high degree of self-reliance but on the other hand, the opportunities for escape and the instructions to aid escape offered by the building were insufficient to fulfil this need.

107 Sime, J.D. (2001). An occupant response shelter escape time (ORSET) model. In: *Safety Science 38*, 109-125.
108 Kobes, M. (2008). *Zelfredzaamheid bij brand: Kritische vragen voor het veilig vluchten uit gebouwen.* The Hague: Boom Juridisch (*Self-reliance in the event of fire: Critical questions for safe escape from buildings*).
109 Kobes, M. (2008). *Zelfredzaamheid bij brand: Kritische vragen voor het veilig vluchten uit gebouwen.* The Hague: Boom Juridisch (*Self-reliance in the event of fire: Critical questions for safe escape from buildings*), page 100.

**Conclusion**
In the initial phase of evacuation, human escape behaviour plays a crucial role, because it is in this phase that people are reliant on themselves and the people in their immediate vicinity. The possibility of falling back on an escape plan, and informing residents of the nature of that plan, or the design and layout of the building itself can help guide safe escape behaviour. In Arnhem, none of these were offered. There was no general escape plan for residents. The building itself also offered no indications to determine the desired escape behaviour. If at that moment, fire or smoke remove the only route outwards, the result is a sense of unsafety, and unsafe behaviour.

## 3.7 Conclusions

This chapter set the escape concept from blocks of flats against the practical situation surrounding the fire in Arnhem. Other fires were also considered. The analysis reveals that the underlying principle that in the event of fire, at least one route outwards is always clear of smoke and fire is not always lived up to, in practice. As a result of this underlying principle, no measures are taken to minimize the consequences, if such a scenario does arise. This then represents a safety shortcoming. Just as was the case in the fire in the block of flats in Arnhem, it is possible that people who are en-route to leave a building are overtaken by fire and smoke. In addition, in blocks of flats, no provisions are made to assist people attempting an escape in this scenario to arrive at a new, safe response perspective, if the only escape route is lost. If a building does not support escape behaviour, and fails to offer an accessible alternative to people in an escape situation, the result can be a feeling of unsafety, and unsafe behaviour.

The building owner is responsible for ensuring that a building complies with the fire safety regulations, also in the use phase, so that (among others), there is a guarantee that in the event of a fire, at least one route outwards is always clear of smoke and flames. This requires the building owner to be in possession of a correctly functioning fire safety management system and that the owner demonstrates a high level of fire safety awareness. Municipalities are required to supervise compliance with the building regulations (including those relating to fire safety) in the use phase of buildings. The majority of municipalities do not actively fulfil this role, with the exception of the fire safety of a number of building types, not being residential buildings, in respect of which a use permit or a notification of fire-safe use is specified.

In the use phase of a building, renovations are moments in time that can have consequences for fire safety. Whereas large-scale maintenance work and renovation work are the ideal moments for improving the fire safety of a building, everyday maintenance tasks specifically engender the risk that fire safety will be compromised. This investigation shows that fire safety considerations were not an explicit component of the process for minor repairs and renovation work of this kind, for the owner of the block of flats in Arnhem, the housing association Vivare. In the case of such work, the knowledge, expertise and alertness of the responsible employees is above all relied on, as a means of safeguarding fire safety in work of this kind.

A second point that can compromise the fire safety of a building in the use phase is that residents leave flammable items behind in the communal areas and/or escape routes. Preventing this from happening is a shared responsibility between the owner and the residents. Fulfilling these responsibilities above all demands attention for the fact that property left behind in communal areas (that are part of escape routes) not only results in poorer accessibility of (escape) routes outwards and detracts from the quality of life, but that it can also lead to situations that represent a fire hazard. The items in question may be fire hazardous objects (which is certainly the case with furniture and mattresses filled with plastic foam), but they are not seen as such. If they are not in the way, they may appear harmless, but the fire in Arnhem teaches us that this is not the case.

The fire hazardous sofa in the entrance hall resulted in an unsafe situation because it was located on the escape route. A fire on the escape route prevents people from leaving the building safely, particularly if it is the only escape route available, and as such brings about a feeling of unsafety and unsafe behaviour.

# 4 FIRE HAZARDOUS FURNITURE

The fatality of the fire in the block of flats in Arnhem was primarily caused by the fact that the fire broke out in a sofa filled with plastic foam. Fatal furniture fires of this kind are fairly common. Figures show that at least one quarter of all deaths and injuries in residential fires in the Netherlands are caused by burning mattresses and upholstered furniture such as sofas.[110], [111] In the Netherlands, every year this relates to around ten deaths and one hundred injured. In the EU, there are around 1,250 fatalities in residential fires, as a consequence of fire hazardous furniture.[112] This chapter examines this safety shortcoming further. In section 4.1, an explanation is given of the nature of plastic foam, followed in section 4.2 by the burning behaviour of furniture filled with plastic foam and the related risks. Section 4.3 deals with the degree of (general) awareness of this fire hazard, and finally relevant legislation and regulations in this field (4.4) and the possibilities of influencing the burning behaviour of furniture and mattresses to make them more fire safe are analysed (4.5).

## 4.1 Plastic foam in furniture and mattresses

Upholstered furniture has changed over time. Items of furniture have become softer and more comfortable, because the proportion of filling beneath the upholstery and in the cushions has grown in relation to the proportion of structural materials such as wood and metal. At the same time, furniture has also become more voluminous. Until around fifty years ago, the filling of furniture consisted of natural materials such as kapok, seagrass, horsehair and natural rubber. Later these materials were replaced almost entirely by synthetic materials, referred to in common usage as foam rubber. When we talk of plastic foam, however, we are certainly not referring mainly to synthetic rubber, but above all to polyurethane (PUR).

110 Fire Service Academy (2020). *The burning behaviour of sofas during smoke propagation experiments.* Arnhem: IFV.

111 Hagen, R. et al (2017). *Fire safety of upholstered furniture and mattresses in the domestic area: European fire services recommendations on test methods,* Federation of the European Union Fire Officer Associations (FEU).

112 IFV. *Overview page relevant investigations.* Via https://www.ifv.nl/onderzoek/Paginas/Onderzoeken-brandveiliger-meubilair.aspx. Last consulted on 4 May 2021.

**Polyurethanes (PUR)**
Polyurethanes are plastics that are created by causing isocyanates to react with polyols. There are various types of both of these copolymers. The length of the chains and the number of NCO (isocyanate) or OH groups (alcohol/polyol) can be varied. The copolymers can also be mixed in different ratios. The result is a variety of types of polyurethane, that although strongly chemically related, can demonstrate considerable differences in physical characteristics/properties.

For use as a filling in furniture and mattresses, PUR foam with an open structure is used, that feels soft and comfortable. There are various different types of PUR foam with an open cell structure on the market, that differ among others in terms of density[113], strength, softness and flexibility. PUR foam with a closed cell structure is for example used as an insulation material, and feels hard.

The fact that the filling of the sofa in the entrance hall in the block of flats in Arnhem consisted of plastic foam is based on the following four findings:
- Plastic foam is the most widely used filling material in furniture of this kind;
- The sofa was ignited by a low-energy ignition source, which matches well with furniture filled with plastic foam (see section 4.2.1);
- The rapid development of the fire matches furniture filled with plastic foam (see section 4.2.2);
- The fire gave off hydrogen cyanide gas, which is a typical component of smoke from burning PUR foam (see section 4.2.3).

## 4.2 Burning characteristics of plastic foam

Plastic foam in furniture and mattresses easily catches fire and burns rapidly and fiercely, producing large volumes of highly toxic smoke. These characteristic properties are discussed in the subsections below. If relevant, the extent to which this burning behaviour is in line with the fire safety theory is also considered.

### 4.2.1 Inflammability
Upholstered furniture and mattresses with a plastic foam filling, depending on the type of covering, catch fire relatively easily and then quickly burn further. A low-energy ignition source like a cigarette or a match is generally sufficient to set light to a chair or mattress filled with plastic foam.[114] This is demonstrated both in practice and in practical experiments and laboratory tests.[115], [116]

113 Density is another word for specific mass (mass per volume unit).
114 The ignition behaviour also depends on the upholstery (top layer and interliner). A leather sofa for example 'requires' a larger ignition source than a sofa with a fabric covered in plastic or fabric.
115 Fire Service Academy (2017). Impression tests upholstered furniture and mattresses. Arnhem: Institute For Safety.
116 Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: *Fire and Materials*, 44, 624-639.

### 4.2.2 Development of the fire

When a fire starts in a chair or mattress filled with plastic foam, in the presence of sufficient oxygen, the fire develops rapidly. Flashover, for example, the point where the temperature in a room rises rapidly thereby also igniting other flammable materials in the room, occurs after between just 3 and 6 minutes.[117], [118] The temperature in a room containing a burning sofa filled with plastic foam reaches a maximum temperature of around 1000 °C in between 5 and 10 minutes (depending on the quantity and nature of all flammable materials in the room, the ventilation and the dimensions of the room).[119] The fire in the block of flats in Arnhem is exemplary for a rapidly developing fire of this kind.

In drawing up Dutch legislation and regulations on fire safety, a 'standard' fire development was assumed, known as the normative fire development.[120] In this normative fire development, the fire develops relatively slowly at the start, whereby the temperature in the room rises gradually. Flashover occurs after 15 minutes. It then takes up to more than 30 minutes following the outbreak of the fire for the maximum temperature of around 1000 °C to be reached.[121]

Figure 12 below shows the temperature development in a room as a function of time from the moment of starting of a fire, for both the normative fire and the fire started in a plastic foam-filled item of furniture or a mattress in the case of a fuel-controlled fire (with no shortage of oxygen).

117 Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: *Fire and Materials*, 44, 624-639.

118 See section 2.2.1 of this report for an explanation of the flashover phenomenon.

119 Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: *Fire and Materials*, 44, 624-639.

120 In The Basis for Fire Safety (Source: Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings.* Arnhem: IFV, page 54) it is suggested that the normative fire development is related to the general assumptions of the Dutch Building Decree. It is a reference that sets a norm and enables the fire safety of buildings to be implemented using a rule-based approach. It is also demonstrated that situations can occur in practice with rapid fires, caused by fire hazardous materials and/or the product choice, as a result of which the flashover moment occurs earlier. The fire in the block of flats in Arnhem is an example of just such a situation.

121 The subdivision of the normative fire development into time periods should not be considered as an attempt to set target values. These are only maximum times. (Source: Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings.* Arnhem: IFV, p. 122)

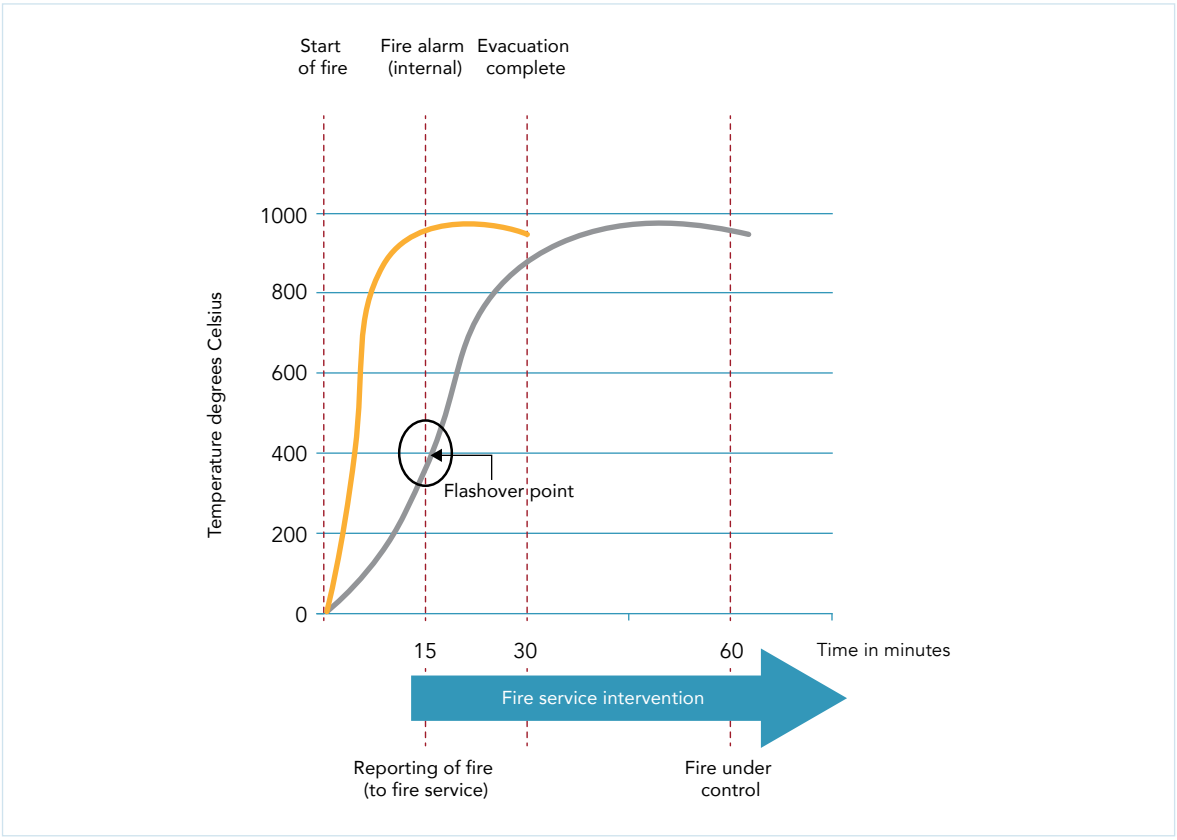



*Figure 12: Current normative fire development in grey. (Source: Hagen, R. & Witloks, L. (2017), The Basis for Fire Safety) and the faster fire development of a furniture fire in yellow. Both curves are indicative and may develop differently depending on the fire conditions, for example size of the room, level of ventilation and the quantity of other flammable materials.*

The burning behaviour of furniture and mattresses filled with plastic foam has serious consequences for residential fires. Whereas years ago, after hearing a smoke alarm, people had approximately ten minutes to escape from their home, a house furnished with plastic foam-filled furniture can be fully ablaze and/or filled with smoke in less than three minutes.[122],[123] This is faster than the normative fire development used in legislation and regulations and the assumed underlying principles for fire safety.[124] This means that in the event of a residential fire involving furniture or mattresses filled with plastic foam, the residents have less time to report the fire to the fire service, and escape from their home. In particular less self-reliant individuals run a greater risk, as a consequence. In order to be able to start putting out a fire on time and rescuing victims, the fire service needs to be at the location of the fire sooner than the arrival time currently specified. Given the current number of fire stations and the distribution of fire stations across the country, this is barely if at all achievable.

122 De Stentor (2018). *Fatale vuurzee voorkomen? 'Stop met brandgevaarlijke meubels' (How to prevent a fatal sea of flames? 'Stop using fire hazardous furniture').*
123 NOS Nieuws (2011). *Steeds kortere vluchttijd bij brand.* (*Ever shorter escape times from fires*)
124 Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings.* Arnhem: IFV.

### 4.2.3 Smoke propagation

How much smoke is generated in a fire varies widely depending on the burning material. In general, burning synthetic materials generate more smoke than burning natural materials. In comparison with other synthetic materials, plastic foam produces large volumes of smoke.[125], [126] A sofa filled with plastic foam burns so rapidly and so violently that at a given moment, the amount of oxygen available becomes the limiting factor for the speed at which the fire develops.[127] Fires of this type are referred to as ventilation-controlled fires. Fires in which the volume of flammable material is the limiting factor, and where there is sufficient oxygen, are referred to as fuel-controlled fires. The smoke from ventilation-controlled fires contains more solid, not fully combusted particles than the smoke from fuel-controlled fires. The smoke from burning PUR foam therefore contains relatively large numbers of not completely combusted particles.

Because of overpressure in a fire room as a consequence of the rising temperature, smoke is forced through all holes, cracks and openings. This effect is particularly enhanced in fires involving furniture and mattresses filled with plastic foam, due to the relatively high volume of smoke production from fires of this kind. Smoke - and with it the danger - spreads faster and further than the fire itself.[128] However, legislation and regulations assume that the spread of fire and smoke take place at about the same speed.

### 4.2.4 Toxicity of smoke

Smoke consists of combustion gases containing a mix of liquid and solid particles. A proportion of smoke is easily visible, in particular the soot particles and the liquid particles. Another part, the flue gases, are invisible. Smoke restricts visibility for people, who as a result can become disoriented. Smoke is always toxic and irritates the eyes and airways, but the degree of toxicity depends on the nature of the burning material and the burning conditions.

The primary components of smoke are water vapour, carbon dioxide ($CO_2$) and soot. Well-known toxic components of smoke are carbon monoxide (CO) and polycyclic aromatic hydrocarbons (PAHs). Ventilation-controlled fires produce more CO and other toxic substances than fuel-controlled fires. In fuel-controlled fires, there is so much oxygen present that carbon monoxide continues to react to form carbon dioxide.
Smoke from plastics also often contains specific combustion gases, such as hydrochloric acid (HCl) when PVC burns, and hydrogen fluoride (HF) when Teflon burns. When PUR foam is burned, the smoke also contains small but significant quantities of hydrogen cyanide gas (HCN). More hydrogen cyanide gas occurs in smoke from ventilation-controlled fires than in smoke from fuel-controlled fires. In the latter fire type, the hydrogen cyanide gas reacts with oxygen to form water vapour, carbon dioxide and

125 Centexbel-VKC (2018). Brandgedrag & Vlamvertrager. In: *Nieuwsbrief voor de textiel- en kunststofverwerkende industrie* (Burning behaviour & Flame retardant. In: *Newsletter for the textile and plastic processing industry*).
126 Fire Service Academy (2020) *Smoke propagation in residential buildings: Main report from practical experiments in a residential building with internal corridors*. Arnhem: IFV.
127 This applies in particular in enclosed spaces.
128 Fire Service Academy (2020) *Smoke propagation in residential buildings: Main report from practical experiments in a residential building with internal corridors*. Arnhem: IFV.

nitrogen dioxide ($NO_2$). Generally speaking, fires in furniture and mattresses filled with plastic foam are ventilation-controlled fires, and as a consequence produce more toxic combustion gases, mainly carbon monoxide and hydrogen cyanide gas, that cause more victims than the fire itself.[129] People who come into contact with toxic smoke, absorb the toxins in their blood via their lungs. Research has shown that victims of residential fires often demonstrate raised levels of cyanide and carbon monoxide in the blood.[130] Exposure to small quantities of hydrogen cyanide gas results in loss of consciousness far more rapidly than exposure to larger quantities of carbon monoxide.[131] As suggested earlier, hydrogen cyanide is twenty-five times more toxic than carbon monoxide.

Experimental fire investigation on an armchair filled with plastic foam, in an enclosed room, resulted in approximately 1000 ppm[132] hydrogen cyanide gas, in the development phase.[133] The fire in this test did not develop into a flashover or fully developed fire, but after reaching a maximum temperature of almost 300 °C slowly extinguished. In this extinguishing phase, the concentration of hydrogen cyanide gas slowly fell to approximately 600 ppm eight minutes after the maximum temperature was reached. The concentration of hydrogen cyanide gas can fall as a result of more ventilation. Hydrogen cyanide gas concentrations of more than 200 ppm can rapidly result in loss of consciousness. Inhalation of smoke with 1000 ppm hydrogen cyanide gas results in immediate unconsciousness. The speed with which a person loses consciousness upon inhalation of smoke containing hydrogen cyanide gas also depends on body weight. The heavier the person the longer it takes before they lose consciousness as a result of intoxication with hydrogen cyanide gas.

129 Centexbel-VKC (2018). Brandgedrag & Vlamvertrager. In: *Nieuwsbrief voor de textiel- en kunststofverwerkende industrie* (Burning behaviour & Flame retardant. In: *Newsletter for the textile and plastic processing industry*).

130 F.J. Baud et al (1991): Elevated blood cyanide concentrations in victims of smoke inhalation; The new England journal of medicine, 325 (25), 1761-1766.

131 Purser, D.A. & McAllister, J.L. (2016). Assessment of hazards to occupants from smoke, toxic gases and heat. In M.J. Hurley (Ed.), SFPE Handbook of fire protection engineering (pages 2308-2428). USA: Springer.

132 ppm stands for parts per million and is a measurement for concentration. A concentration of 1 ppm indicates that there is one part of a product in a total of one million parts, generally expressed in mass. One ppm is thousand times as small as one part per thousand.

133 Purser, D.A. & McAllister, J.L. (2016). Assessment of hazards to occupants from smoke, toxic gases and heat. In M.J. Hurley (Ed.), *SFPE Handbook of fire protection engineering* (pp. 2308-2428). USA: Springer.

**Conclusion**
Fires in furniture and mattresses filled with plastic foam represent a serious safety problem on two fronts: (1) relatively little energy is required to set alight furniture items and mattresses of this kind, at which point they continue burning very quickly, producing large volumes of particularly toxic smoke; (2) in the principles for fire safety, the normative fire development is assumed, which is far slower than the development of fires in furniture and mattresses filled with foam. This has consequences for the time available for calling the fire service, the time available to escape the block of flats, the arrival times for the fire service and the time for putting out the fire and rescuing people in residential fires of this kind. In addition, it can result in very rapid incapacitation, because of a result of the toxic smoke and gases, and in particular the hydrogen cyanide gas, people can very quickly lose consciousness.

## 4.3 Awareness of the fire hazard of furniture and mattresses

The previous chapter shows that the majority of people involved in this occurrence had not realized that the sofa in the entrance hall was an extremely fire hazardous object. The Safety Board notes that the fire hazard of modern furniture and mattresses is underrepresented, in the broader public, too. It is true that the consumer programme Kassa broadcast by the Dutch TV broadcaster VARA already focused attention on this issue in 2010 (see block below). The sector association for the furniture industry is not in favour of regulating the burning behaviour of furniture. Consumer organizations also apply little pressure on the industry to make furniture more fire safe. There is also resistance to an obvious solution to the problem, namely the addition of chemical flame retardants to plastic foam in furniture and mattresses, because these chemicals can represent a danger to people and the environment.

**Fire hazard of modern furniture and mattresses in TV programme Kassa**
In 2010, the consumer programme *Kassa* broadcast by the Dutch TV broadcaster VARA drew attention to the fire hazard of modern furniture and mattresses. Part of this programme was an experiment which demonstrated the potential effect of legislation on flammability of furniture and mattresses. In the framework of this experiment, two sofas of the same make and type were purchased, one in the United Kingdom where legislation is in place (see subsection 4.4.3) and the other in the Netherlands, where there was no legislation (see subsection 4.4.1). Both sofas were then ignited using a candle. The Dutch sofa rapidly caught fire, after which the entire sofa started burning; in the English sofa, the fire barely spread.[134], [135]

134 Video via https://www.youtube.com/watch?v=jnuORp8jVJ8. Last consulted on 4 May 2021.
135 Video via https://www.youtube.com/watch?v=1Vq3-t0lmUU. Last consulted on 4 May 2021.

Fire experts are well aware of the danger of plastic foam-filled furniture. The IFV and the Dutch Fire Service have for some time been drawing attention to the fire hazard of furniture and mattresses filled with plastic foam, and have intensified their own research in this field over the past few years.[136]

**Involvement of furniture and mattresses in fatal residential fires**
Data from the IFV on fatal residential fires shows that for 269 fatal residential fires that occurred between 2008 and 2020 (from a total of 369), it is known which object first caught fire. In 45 cases (17%) this was a bed or mattress. In 61 cases (23%) a seat. In total, therefore, around 40% of fatal residential fires where the first object to catch fire is known, started in mattresses or seating. For a further 92 fatal residential fires, it is known that plastic foam in furniture or mattresses contributed to accelerated fire development and/or smoke propagation.

The IFV is also working to encourage the industry itself to take action to improve the fire safety of the furniture and mattresses it produces, preferably in an environmentally friendly manner. To restrict flammability and burning speed, the Netherlands Fire Service[137], the IFV[138] and at a European level the FEU (Federation of EUropean Fire Officers)[139] recommend making furniture for use in homes more fire safe if at all possible without having to make use of flame retardants (see section 4.5). The IFV and the Netherlands Fire Service are also working hard to ensure that fire-safe furniture and mattresses be embedded in legislation.[140] However, these calls have not resulted in practical steps in the Netherlands aimed at making residential furniture more fire safe (see section 4.4).

## 4.4 Legislation and policy on flammability of seats and mattresses

This section deals with the way in which the flammability of furniture and mattresses filled with plastic foam are dealt with in legislation and policy making.

### 4.4.1 The Netherlands

There is no legislation or regulations in the Netherlands relating to the fire safety of seating or mattresses for the consumer market. In 2014, the Dutch Minister of Justice and Security explained in a letter to the Dutch House of Representatives that the Cabinet saw insufficient reason to introduce national statutory fire safety requirements for seating

136 See for example: Fire Service Academy (2020). *The burning behaviour of sofas during smoke propagation experiments*. Arnhem: IFV.
137 Brandweer Nederland (2015). *RemBrand: Brandveiligheid is coproductie* (Netherlands Fire Service (2015). *RemBrand: Fire is a coproduction*).
138 Fire Service Academy (2020). *The burning behaviour of sofas during smoke propagation experiments*. Arnhem: IFV.
139 Hagen, R. et al (2017). *Fire safety of upholstered furniture and mattresses in the domestic area: European fire services recommendations on test methods*, Federation of the European Union Fire Officer Associations (FEU).
140 *IFV. Kennisplein.* Via https://www.ifv.nl/kennisplein/brandpreventie-fire-safety-engineering/publicaties/the-burning-behaviour-of-sofas-during-smoke-propagation-experiments (Last consulted on 4 May 2021).

and mattresses.[141] This position was adopted on the basis of a social cost-benefit analysis.[142] With regard to fire safety requirements for upholstered furniture, this cost-benefit analysis delivered no clear conclusion as to whether the costs outweighed the benefits or vice versa.

In a series of letters sent since that time by the government to the Dutch Parliament, this position has been further reinforced. In the most recent letter to the Dutch Parliament in which this subject was discussed, which dates back to the start of 2019, it is also explained that the Ministry of Health, Welfare and Sport (VWS) entered into discussions in mid-2018 with manufacturers of furniture, the fire service and the IFV on the possibility of limiting the speed of fire by promoting the use of fire-safe upholstered furniture, without flame retardants. According to the Minister, during these discussions, a number of suggestions were put forward, with which the fire service and the sector can continue their work. [143] It was also indicated that the furniture industry was considering organizing a seminar on how the various developments could be brought together, in order to facilitate further practical steps, by the fire service and the industry.[144] To what extent steps have been taken in this dossier remains unclear, on the basis of the documents sent to the Parliament by the Minister. Following the fire in the block of flats, and during the course of the investigation by the Safety Board, the Ministry of Health, Welfare and Sport did relaunch discussions with the relevant parties, in mid-2020.

For application in specific circumstances such as penitentiary facilities and psychiatric hospitals, mattresses are often used that offer greater fire safety than the standard mattresses placed on the market for use in homes.[145] This is not based on any statutory obligation. Fire-retardant mattresses of this kind often contain flame retardants or are fitted with a fire-resistant cover or interliner (a sort of in-between layer). For use in aircraft, strict requirements are imposed on the flammability of seats.

### 4.4.2 Europe

An inventory of the legislation and regulations applicable in 27 European countries reveals that 22 countries have imposed no statutory requirements on the fire safety of furniture and mattresses for use in homes, as compared with five who have introduced such requirements.[146] These countries are Finland, Ireland, the Czech Republic, the United Kingdom and Sweden.[147] The requirements imposed are performance requirements with regard to flammability: the furniture and mattresses may not catch fire

141 *Parliamentary Papers II* 2013-2014, 26956, no. 197.
142 SEO Economisch Onderzoek (2014). *Maatschappelijke kosten-batenanalyse brandveiligheid in woningen Amsterdam. (Social cost-benefit analysis fire safety in homes*).
143 Dutch Minister of the Interior and Kingdom Relations, Parliamentary Letter on the status of the implementation of various promises and motions on fire safety for the elderly (32 757, no. 151), 2019.
144 Dutch Minister of the Interior and Kingdom Relations, Parliamentary Letter on the status of the implementation of various promises and motions on fire safety for the elderly (32 757, no. 151), 2019.
145 Onderzoeksraad voor Veiligheid (2012). *Brand in Rivierduinen: veronderstelde veiligheid* (Dutch Safety Board (2012) *Fire in Rivierduinen: presumed safety*).
146 Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: *Fire and Materials, 44*, 624-639.
147 On the basis of recommendations from the Swedish consumer association, Sweden follows the same rules as those imposed in law, in Finland.

in contact with a specific ignition source. These are ranked according to rising energy levels (with between brackets the countries where the requirement in question applies):

- Cigarette; smouldering (Finland, Ireland, Czech Republic, United Kingdom and Sweden)
- Small flame; comparable to match, lighter or (fallen) candle (Ireland, Czech Republic and United Kingdom)
- Larger flame (in Ireland and United Kingdom for furniture and mattresses in public buildings, not in private homes)

In these countries there are no statutory regulations about the way in which furniture and mattresses should be manufactured in order to satisfy the performance requirements imposed. In practice, flame retardants are generally added to the plastic filling, in order to satisfy these requirements.

### 4.4.3 United Kingdom

In the period between 1960 and 1970, the number of fatal victims of fire in the UK rose from 400 to 700 per year.[148] This rise continued through the nineteen seventies. The growing use of easily flammable plastic foam in furniture was identified as a primary cause of this rise. The dramatic fire in 1979 in a Woolworths department store in Manchester, which led to ten fatalities, reinforced this picture. The fire spread at lightning speed and with considerable smoke propagation through the furniture department, that was stacked with furniture with plastic foam filling.

The British government wished to develop regulations for imposing requirements on the flammability of furniture. There was no broad-based support for these wishes in the EU. For that reason, the British government drew up national regulations in the form of The Furniture and Furnishings (Fire) (Safety) Regulations 1988 (hereinafter FFR 1988). These rules contain performance requirements regarding the flammability of materials used in furniture. To ensure that furniture filled with plastic foam could satisfy these requirements, the use of flame retardants was at the time the most obvious solution.

Around twenty years following its introduction, the British government evaluated the FFR 1988. The first stage of this evaluation consisted of a statistical study into the effectiveness of these regulations.[149] The conclusion of this study was that the regulations in this area delivered clear added value, and that the existing FFR 1988 needed to be revised in a number of areas, for example as regards the test methods employed.[150] Other studies that considered this legislation and regulations specifically called for amendments to the

148 British Department for Business Innovation & Skills (BIS). *Presentation 'UK Furniture Flammability Regulations and Standards: How They are Developed, Implemented and Amended'*. Via https://www.soci.org/~/media/Files/Conference%20Downloads/2013/Flame%20Retardant%20Textiles_October%202013/Terry_Edge.ashx. Last consulted on 4 May 2021.

149 Greenstreet Berman (2009). *A statistical report to investigate the effectiveness of the Furniture and Furnishings (Fire) (Safety) Regulations 1988*. London.

150 British Department for Business Innovation & Skills (2011). *Review of the Furniture and Furnishings (Fire) (Safety) Regulations 1988 (FFRs)* (letter dated 7 April 2011).

test methods, which failed to sufficiently predict burning behaviour in practice.[151],[152] A series of other studies raised questions about the balance between the advantages and disadvantages of the FFR 1988, and suggested that the advantages were overestimated and the disadvantages possibly underestimated.[153] The reduction in the number of fatal victims of fire since the introduction of the FFR 1988 was not necessarily a direct consequence of this new legislation. A number of other possible causes were identified, for example the increased use of smoke alarms and fire extinguishers in homes, the reduction in the number of smokers, increased prosperity and improvements in public information about fire prevention and behaviour in the event of fire. The process of updating the FFR 1988 (at the moment of writing this report, April 2021) was not yet concluded.[154] The parties involved have since been consulted.[155]

A recently undertaken comparative study into the burning behaviour of upholstered furniture from various European countries shows that a fire in sofas from countries without requirements on the fire safety of furniture reaches a peak after 3-7 minutes, whereas in sofas from the United Kingdom and Ireland, the peak is not reached until after 15-25 minutes.[156]

**Conclusion**
Although the risk of fire hazardous furniture is recognized in the Netherlands by the relevant parties, national government has drawn up neither policy nor legislation or regulations to make furniture more fire safe. In a number of other countries, including the UK, this situation is different, and performance requirements have been imposed on the burning behaviour of furniture. The fact that this results in a clear difference in burning behaviour becomes clear when two sofas of the same make and type from different countries (the Netherlands and the UK) are set alight. To satisfy the performance requirements, at present, in practice, use is made of flame retardants.

151 Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: Fire and Materials, 44, 624-639.
152 Hagen, R. et al (2017). Fire safety of upholstered furniture and mattresses in the domestic area: European fire services recommendations on test methods, Federation of the European Union Fire Officer Associations (FEU).
153 Dedeo, M. et al (2013). British Furniture Fire Regulations: Do the benefits justify the health and environmental risks? Sixth International Symposium on Flame Retardants (conference paper), San Francisco.
154 This means that to date work has been going on on the evaluation for around thirteen years.
155 British Department for Business, Energy & Industrial Strategy: Office for Product Safety & Standards (2019). Updating The Furniture and Furnishings (Fire) (Safety) Regulations 1988: Government response to consultation. London: Crown copyright.
156 Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: *Fire and Materials, 44*, 624-639.

## 4.5 Influencing the flammability of furniture

The burning properties of furniture and mattresses with plastic foam filling have mainly to date been (positively) influenced by the addition of flame retardants[157] to the plastic foam, above all in countries that have introduced performance requirements for flammability. That is why we first consider this aspect, in subsection 4.5.1. Our considerations reveal that there are also disadvantages to the use of flame retardants. To discuss those, subsection 4.5.2 considers alternative methods of positively influencing the flammability of furniture.

### 4.5.1 Flame retardants

The American National Institute of Environmental Health Sciences (NIEHS) defines flame retardants as chemicals that are added or applied to materials to slow or prevent the start or growth of fire.[158] Flame retardants are also used in many products and sectors in the Netherlands, in construction materials (for example in electricity cables and insulation materials), electronics and electrical devices (for example computers, telephones, televisions) and in the transport industry (for example in car seats, bumpers and various other parts of cars, aircraft and trains). Worldwide, at least two hundred different compounds are used as flame retardants, that can be classified in the following five main groups:[159], [160]

- Halogenated[161] flame retardants, of which the organobromine compounds are the best known. See the block below for more information about this group of flame retardants.
- Inorganic[162] flame retardants, such as aluminium hydroxide, magnesium hydroxide, zinc hydroxy stannate and antimony trioxide.
- Organophosphorus compounds, such as aluminium diethylphosphinate.
- Nitrogen-bearing flame retardants, such as melanin and compounds derived from it.
- Expandable graphite and certain nano additives such as nano-magnesium oxide and nano clay, generally in combination with other flame retardants.[163]

157 Hoog, A. van 't (2017).Vlamvertragers (Flame retardants). In: *Chemische Feitelijkheden, volume 82, no. 333.*
158 National Institute of Environmental Health Sciences (2016). *Flame Retardants Fact Sheet.*
159 Hoog, A. van 't (2017).Vlamvertragers (Flame retardants). In: *Chemische Feitelijkheden, volume 82, no. 333.*
160 Centexbel-VKC (2018). Brandgedrag & Vlamvertrager. In: *Nieuwsbrief voor de textiel- en kunststofverwerkende industrie*, België.
161 Halogens refers to a group of chemical elements from Fluorine (F) via Chlorine (Cl) and Bromine (Br) to Iodine (I); halogenated flame retardants above all contain bromine or chlorine.
162 Inorganic compounds are compounds that contain no carbon hydrogen bonds. Organic compounds have a structure with carbon-carbon bonds and carbon-hydrogen bonds.
163 Centexbel-VKC (2018). Brandgedrag & Vlamvertrager. In: *Nieuwsbrief voor de textiel- en kunststofverwerkende industrie*, België.

**Halogenated flame retardants**
This group of flame retardants consists of brominated and chlorinated flame retardants. Brominated flame retardants have been widely used since the nineteen sixties. They are relatively cheap, have a good flame retardant effect, do not excessively affect the material properties of the plastic, are effective in relatively small quantities and can be used in many different types of plastics and products.[164]

A disadvantage of using brominated flame retardants is that they are persistent (difficult or impossible to decompose), bio accumulative (they continue to build up in the food chain) and toxic.[165] Flame retardants migrate very gradually from the plastics, and are easily demonstrated for example in air samples in large cities and in domestic dust. Certain brominated and chlorinated flame retardants share similarities with PCBs (polychlorobiphenyls), pesticides and dioxins. A number of brominated flame retardants have now been prohibited. The use of alternative, preferably bromine-free flame retardants such as polyphosphates and inorganic, mineral flame retardants is growing.[166] New brominated and chlorinated flame retardants are also being used, the effects of which on the environment and health are not yet fully clear, but are suspect.[167]

The fire retardant effect is achieved via several different mechanisms. Flame retardants can act at two points:

- They prevent or delay furniture being set alight by a relatively low-energy ignition source such as a cigarette or a match; in this way they prevent or delay the ignition stage in the development of the fire.
- They delay the development/growth of a fire following the ignition phase.

Although the use of flame retardants in furniture and mattresses makes them more fire safe, they have the possible disadvantage of representing a hazard to human health and the environment. This dilemma was expressed as follows in a publication from 2006[168]: '*The means and the malice. Flame retardants save lives. In the event of a fire, they give people more time to escape because they reduce the formation of smoke and toxic gases. However, are flame retardants themselves safe, or do they cause more harm than they prevent?*'. In 2010, 145 scientists from twenty different countries signed the *San Antonio Statement*[169] in which they came out against the use of brominated and chlorinated flame retardants. According to them, these substances cause serious environmental and health problems, and for that reason should be forbidden. In a

164 Hoog, A. van 't (2017). Flame retardants. In: *Chemische Feitelijkheden, volume 82, no. 333.*
165 Hoog, A. van 't (2017). Flame retardants. In: *Chemische Feitelijkheden, volume 82, no. 333.*
166 Within Cefic (the European interest group for the chemical industry), a sector group was established in 2009 that brings together the interests of manufacturers of halogenated flame retardants. This organization Pinfa (Phosphorus, Inorganic and Nitrogen Flame Retardants Association) is continuously working to further improve the environmental and health profile of their flame retardants.
167 Boer, J. de & Stapleton, H.M. (2019). Toward fire safety without chemical risk. In: *Science 364*(6437), 231-232.
168 Wentzel, B. (2006). Vlamvertragers (Flame retardants). In: Chemische Feitelijkheden, volume 49, no. 224.
169 Di Gangi, J. et al (2010). San Antonio statement on brominated and chlorinated flame retardants. In: Environmental Health Perspectives 118(12), A516 – A518.

number of countries and/or for specific applications, such prohibitions have been introduced, but there is no worldwide ban. The risk to human health and the environment of alternative flame retardants (without bromine or chlorine) is often still unclear. Their safety must first be proven, before they can be placed on the market. The Dutch toxicologist Hester Hendriks underlined this position in her doctoral thesis.[170] Although alternative flame retardants have been developed, in her judgement there were still not sufficient empirical data to be able to make a reliable risk assessment of these substances.

Flame retardants can only be used within the EU if they comply with the REACH (Registration, Evaluation, Authorization and restrictions of Chemicals) regulation (no. 1907/2006) which imposes requirements on the safety of the production, trading and application of chemicals.[171] Manufacturers must be able to demonstrate the safety of chemicals before they are allowed to trade in them or use them in products. This was less clear before the introduction of REACH. In the pre-REACH era, the safety of chemicals was often only investigated by universities, NGOs and by researchers employed by research institutions, following production and use. In 2020, the European Commission further elaborated this policy in the framework of the European 'Green Deal'.[172] This new policy is aimed at combining objectives in the field of safety and sustainability. This once again places the question of how plastic treated with flame retardants fits into the route to a circular economy in the spotlight.[173]

### 4.5.2 Alternative methods

Over the past few years, various industrial parties have been working on the development of more fire-safe seating and mattresses. The focus is on flame retardants that are not harmful to human health and the environment, other plastics than PUR as a filling for furniture and mattresses and fire-resistant interliners between the foam filling and the upholstery.

One of the major players on the international market for the production and sale of furniture, for example, aims in the long term to halt the use of all types of chemical flame retardants in furniture. This company stopped using brominated flame retardants in its products for the British market in 2000, and started to replace these chemicals with other methods for slowing down the fire development. Among the methods employed are the use of natural materials with flame-retardant characteristics, such as wool, and the use of fire-resistant interliners in the construction of upholstered furniture.

170 Hendriks, H.S (2015). *Neurotoxicity of past, present and future flame retardants: neurotoxic hazard characterization and risk assessment of brominated and alternative flame retardants.* Utrecht University.

171 Dutch national government. *Information page on REACH.* Via https://www.rijksoverheid.nl/onderwerpen/gevaarlijke-stoffen/vraag-en-antwoord/wat-is-reach. Last consulted on 28 April 2021.

172 Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee on the Regions (2020). *Chemicals strategy for sustainability: towards a toxic-free environment.*

173 European Furniture Industries Confederation (EFIC) et al (2016). *The case for flame retardant free furniture* (policy paper).

Another example of a recent development of seating and mattresses that offer greater fire safety while representing less hazard for human health and the environment is the development of polyester mattresses by a large Dutch mattress manufacturer. These mattresses were placed on the market in the Netherlands in the spring of 2020. Without flame retardants being added to these mattresses, they catch fire less easily than PUR foam-filled mattresses without flame retardants.[174] Even if they do catch fire, they generate less smoke, which is also less toxic than the smoke from a burning mattress filled with PUR foam.

**Conclusion**
The use of flame retardants in plastic foam leads to a reduction of the fire hazard represented by furniture and mattresses filled with plastic foam. The first generation of flame retardants, however, was harmful to human health and the environment. The latest generation of flame retardants must satisfy European regulations on product safety. In addition to flame retardants, there are also alternative, innovative methods for limiting the fire hazard represented by furniture. To date, these have only been summarily investigated.

## 4.6 Conclusions

The current generation of seating and mattresses filled mainly with PUR foam catch fire faster and subsequently burn faster and more intensely than past generations of furniture with no plastic foam filling. In addition, in the event of fires in furniture and mattresses of this kind, more smoke is generated which in particular in the case of PUR foam is also more toxic. The smoke from burnt PUR foam not only contains carbon monoxide but also often toxic quantities of hydrogen cyanide gas. The fact that these products can easily be set alight in practice leads to more fires involving furniture and mattresses, and to a considerably faster and more dangerous fire development, and the faster spread of toxic flue gases, than in the normative fire development on which legislation and regulations are based. This burning behaviour reduces the escape time available, and results in more victims of smoke poisoning. Fires in furniture and mattresses filled with plastic foam are responsible for approximately ten fatalities and one hundred injuries in residential fires in the Netherlands, each year. The danger that this furniture and these mattresses represent is broadly unknown to the general public. As shown by the analysis of the fire in the block of flats in the previous chapters of this report, furniture and mattresses are often not viewed or treated as fire hazardous objects.

174 CBM, Sector association for interiors and the furniture industry (2020). *Alternatieven voor schuimmaterialen in matrassen (Alternatives for foam materials in mattresses)*. Via https://www.cbm.nl/nieuws/alternatieven-voor-schuimmaterialen-in-matrassen/. Last consulted on 4 May 2021.

It is possible to improve the fire safety of furniture and mattresses. Certain countries such as the UK and Ireland have imposed performance requirements on the flammability of furniture and mattresses to make improved fire safety compulsory. A sofa that satisfies these performance requirements will generally not be set alight by a low-energy ignition source. Even if such a sofa were to catch fire, the fire would develop far more slowly, and burn less vigorously. In order to satisfy the performance requirements, as a rule, in practice, flame retardants are used. However, these also have disadvantages, in particular with regard to the environment and human health. The majority of flame retardants used in the past are more harmful than most alternative flame retardants, that are becoming increasingly widely used. Innovations aimed at making furniture more fire safe without having to use flame retardants are slowly gaining ground.

The fire safety of furniture and mattresses are not subject to any statutory requirements in the Netherlands. The political consideration of this issue was last made in 2014, and the letters addressed since that time to the Dutch Parliament contain no indication of any plans to change this policy.

# 5 CONCLUSIONS

*Toxic furniture fire led to victims in block of flats in Arnhem*
In the fire in the block of flats in Arnhem, two people lost their lives and two were injured. The Safety Board asked how this could have happened. In reply to that question, the Safety Board notes that the victims found themselves confronted by a very furious fire in the entrance hall. As a consequence, they were exposed to thermal radiation and also inhaled hot and toxic smoke. As a result, within a period of 30 seconds, they were rendered incapable. Although the lift returned the victims back to the third floor, they were not independently able to reach safety. The victims were discovered in the lift almost 30 minutes later and subsequently taken outside by the fire service.

The fire in the building developed so fiercely and had such tragic consequences due to the coincidence of two circumstances.

- The entrance hall where the fire started was part of the regular exit route. It was also the only escape route leading out of the building. The possibility that a fire could start here, and then develop further was not considered in the statutory regulations for fire safety, or the principles on which those regulations are based.
- The fire started in a plastic foam-filled sofa, that had temporarily been left behind in the entrance hall by a resident. One of the elements of the sofa was set alight by a low-energy ignition source, namely a ground bloom flower firework.[175] Subsequently, a fierce fire rapidly developed, with large quantities of toxic smoke.

*Escape routes are not always as smoke and fire-free as assumed, in practice*
The escape concept from blocks of flats assumes that in the event of fire, at least one escape route outwards will always be available. The investigation by the Safety Board shows that as in the fire in the block of flats in Arnhem, this is not always the case, in practice. With some regularity, the only escape route is affected by flames or smoke either because – as was the case in Arnhem – the fire starts in the escape route itself, or because the escape route is penetrated by smoke and/or flames from a fire elsewhere in the building. Because the escape concept took no account of the possible presence of flames and/or smoke along the only escape route, no provisions were made to mitigate the possible consequences. In addition, the residents were not informed of the response perspective in the event of fire. In the fire in Arnhem, this not only resulted in four victims but also in a situation in which a number of people present in the block wished to leave the building, but were unable to do so. Moreover, because of their different nationalities, not everyone present understood the instructions of the fire service, due to a language barrier. Although from a rational viewpoint, the residents and their visitors remained safe

175 The ground bloom flower is classified in the lightest European category of consumer fireworks (F1); in the fireworks trade also known as 'children's fireworks.

throughout the fire, during the fire and in the subsequent period, they felt unsafe in their own living environment.

*Limited fire safety awareness leads to reduced fire safety in the use phase of residential buildings*
Because it is possible during the use phase that alterations will be made to the (theoretically) fire-safe design of the building, the presence of flames and/or smoke along the only escape route is a practical possibility. Due to limited fire safety awareness among the persons involved, unintentionally, unconsciously and/or unnoticed, the fire safety of a residential building can decline as a result of alterations during the use phase. This was also the case in the block of flats in Arnhem. The fire was able to start because flammable material had been added to the escape route, in the form of a sofa left behind by a resident (shortly before the fire). The fact that fire was able to develop further was (in part) caused by three structural elements added by or on the instructions of the building owner (a suspended wooden ceiling, a plastic panel in a fire-resistant door and a wooden panelling wall below a set of stairs). These alterations in the use phase meant that at the time of the fire, the building did not (any longer) comply with the principles for fire safety in residential buildings - and the accompanying legislation and regulations - and was therefore not sufficiently fire safe.

For the fire-safe use of residential buildings, it is essential that communal areas in these buildings be kept clear of obstacles and flammable objects. This is a shared responsibility between the owner and the residents. In practice, however, they do not always fulfil this responsibility. This can above all be explained by the limited fire safety awareness in relation to this situation. Leaving property in communal areas, also if they are part of the escape routes, is above all associated with less easily accessible (escape) routes and a diminution of the quality of life. There is little if any awareness of the fire hazard represented by these items. This certainly applies to furniture and mattresses, that at least by the general public are above all associated with comfort, rather than fire hazard.

To a considerable degree, fire safety in the use phase of a building depends on the fire safety awareness of everyone involved. If one or more parties has only limited fire safety awareness, this can result in the fire safety being compromised, as in the block of flats in Arnhem. The relevant parties in this respect include the owner of the residential building, maintenance staff, installation engineers, contractors, technical consultants, residents and their visitors and the municipality. A high level of fire safety awareness is above all important for building owners because they bear primary responsibility for the fire safety of a building in the use phase. This responsibility relates both to the structural and installation engineering maintenance of the building and to the process of influencing residents' behaviour. This latter aspect is above all important in situations in the social housing sector, where a relatively large proportion of the residents face social and societal challenges. In certain cases, this makes it more difficult for them to adopt their share of the responsibility for fire safety in the use phase. The Safety Board notes that housing associations, as owners of a large proportion of residential buildings in the Netherlands, generally speaking demonstrate limited fire safety awareness, although the differences are considerable. Also for the owner of the block of flats in Arnhem, housing

association Vivare, despite the covenant the association has taken out with the fire service with regard to fire safety, there is clear room for improvement.

*Limited supervision of fire safety in the use phase of residential buildings*
Although the municipality has administrative and legal responsibility for supervision of compliance with the building regulations in the use phase of residential buildings, the majority of municipalities are not active in fulfilling that role. As a rule, municipalities do actively monitor the fire safety of buildings with other functions than exclusively residential, such as hotels and hospitals. Within the supervisory task for fire safety, the municipality of Arnhem also gives no priority to residential buildings in the use phase. Partly due to the absence of active supervision, it is possible that less fire-safe situations – such as the escape route from the block of flats in Arnhem – remain unnoticed for a long time, in the use phase of residential buildings.

The fire service has no formal role in (supervising) the fire safety of a residential building during its use phase, but in many cases does act in practice as advisor to the municipality and building owners. This advisory role is based on the statutory task of the fire service to advise other government services and organizations on fire prevention and fire fighting. Cooperation between Vivare and the Central Gelderland Fire Service should be seen in that light. Nonetheless, this cooperation did not result in the decline of the fire safety level in the use phase of the block of flats in Arnhem being noticed.

*Fire in furniture and mattresses filled with plastic foam is life threatening*
In the entrance hall to the block of flats in Arnhem, any flammable object could have resulted in de development of a fire, but with regards to the development of this fire, the fact that the object in question was a sofa proved crucial. The fierce and rapid development of the fire in the building, and the associated generation of large volumes of toxic smoke can primarily be attributed to the fact that the fire started in a sofa with a plastic foam filling. Specifically the combination of heat and toxic gases, more specifically hydrogen cyanide gas and carbon monoxide, led to the fatal outcome of the fire. This is in fact not an exception: at least one quarter of residential fires resulting in fatalities and/or serious injuries are caused by furniture and mattresses filled with plastic foam. Seating and mattresses of this kind easily catch fire, burn rapidly and fiercely, and produce large volumes of toxic smoke. If the filling is of PUR foam, this smoke is additionally toxic due to the presence of hydrogen cyanide gas. The burning behaviour reduces the escape time available, and results in more victims of smoke poisoning. Although the risk from such furniture and mattresses is known to fire safety experts, the same does not apply to the general public.

Despite calls from the IFV and the fire service to make furniture and mattresses more fire safe, at present, there are no legal requirements on fire safety in the Netherlands. Various other European countries do have national legislation and regulations that help limit the fire hazard of furniture and mattresses. In these countries, furniture and mattresses must satisfy the performance requirements imposed on flammability. To satisfy the performance requirements, in practice, use is made of flame retardants. However, these flame retardants, in particular of the first generation, contain chemicals some of which

are harmful to human health and the environment. Within the furniture industry and the Dutch government, for this reason there is considerable resistance to the use of (chemical) flame retardants for furniture and mattresses, despite the fact that flame retardants are used in many other products and sectors, such as construction materials, electronics and in the transport industry. There are now safer flame retardants and alternative methods available or under development, aimed at limiting the fire hazard of furniture and mattresses.

# 6 RECOMMENDATIONS

The Dutch Safety Board issues six recommendations. Five recommendations are aimed at ensuring better compliance in practice with the underlying principles for fire safety, and one recommendation is aimed at reassessing the underlying principles for fire safety, themselves.

**Recommendations**

*To Aedes and other owners of residential buildings, combined among others in the Vereniging Eigen Huis, Vastgoed Belang, Kences, VvE Belang, Vereniging van Institutionele Beleggers in Vastgoed and the sector association VvE Beheerders*:

1. Improve awareness of fire safety among building owners. This includes:
   - the exchange of knowledge and experience (in the form of best practices) of fire safety in residential buildings and the relevant specific risks;
   - encouraging an inventory of fire safety risks in the residential buildings in your members' housing stock;
   - making fire safety part of the governance requirements. Among housing associations, this could be achieved by including fire safety in the performance agreements with municipalities.

2. Ensure among building owners particular and permanent alertness with regard to premises with single escape routes. Focus specific attention on:
   - maintenance, repair and renovation work by the owner;
   - daily use of the residential building;
   - the provision of information to residents on the potential actions they can take in the event of a fire breaking out. It is essential that the owner matches the information/communication to the social and societal characteristics of the residents.

*To the Dutch Minister of the Interior and Kingdom Relations:*

3. Ensure an improvement in the supervision of fire safety in the use phase of residential buildings. Focus specific attention on:
   - internal supervision by building owners, by explicitly including continuous responsibility for fire safety at strategic and operational level;
   - external supervision by municipal authorities, by commissioning them to more actively supervise residential buildings in the use phase.

Determine whether this requires amendments to existing legislation and regulations.

4. Reassess existing underlying principles for fire safety in such a way that account is taken of a scenario in which fire and/or smoke can occur and/or make its way into a (partially) single escape route more quickly than is currently assumed. Integrate the outcome of this reassessment in the legislation and regulations governing fire safety.

*To the Minister for Medical Care and Sport:*

5. Introduce legislation and regulations to improve the fire safety of seating furniture and mattresses.

*To the Netherlands Fire Service:*

6. Use your expertise on fire prevention and fire safety in residential buildings to provide - solicited and unsolicited - advice to owners of buildings of this kind. Focus particular attention on the risks in specific building types such as blocks of flats and specific residential forms, such as accommodation for the elderly.

# BIBLIOGRAPHY


Aedes. *Model huurovereenkomst zelfstandige woonruimten*. Via https://www.aedes.nl/artikelen/klant-en-wonen/huurbeleid/standaardmodel-huurovereenkomst-zelfstandige-woonruimte.html. Last consulted on 4 May 2021.

Baud, F.J. et al (1991). Elevated blood cyanide concentrations in victims of smoke inhalation. In: *New England Journal of Medicine, 325*(25), 1761-1766.

Benthorn, L. & Frantzich, H. (1996). Fire alarm in a public building: How do people evaluate information and choose evacuation exit? In: *LUTVDG/TVBB—3082—SE, vol. 3082, Department of Fire Safety Engineering and System Safety*. Lund University.

Boer, J. de & Stapleton, H.M. (2019). Toward fire safety without chemical risk. In: *Science 364*(6437), 231-232.

Brandweer Nederland (2015) *RemBrand: Brandveiligheid is coproductie*.

Brandweeracademie (2015). *Brand in De Notenhout*. Arnhem.

Brandweeracademie (2016). *Branden in seniorencomplexen: regelgeving en praktijk*. Arnhem: IFV.

Brandweeracademie (2017). *Impression tests upholstered furniture and mattresses*. Arnhem: Institute For Safety.

British Department for Business Innovation & Skills (2011). *Review of the Furniture and Furnishings (Fire) (Safety) Regulations 1988 (FFRs)* (letter dated 7 April 2011).

British Department for Business, Energy & Industrial Strategy: Office for Product Safety & Standards (2019). *Updating The Furniture and Furnishings (Fire) (Safety) Regulations 1988: Government response to consultation.* London: Crown copyright.

British Department for Business Innovation & Skills (BIS). *Presentation 'UK Furniture Flammability Regulations and Standards: How They are Developed, Implemented and Amended'*. Via https://www.soci.org/~/media/Files/Conference%20Downloads/2013/Flame%20Retardant%20Textiles_October%202013/Terry_Edge.ashx. Last consulted on 4 May 2021.

CBM, Branchevereniging voor interieurbouw en meubelindustrie (2020). *Alternatieven voor schuimmaterialen in matrassen (Alternatives for foam materials in mattresses)*. Via https://www.cbm.nl/nieuws/alternatieven-voor-schuimmaterialen-in-matrassen/. Last consulted on 4 May 2021.

Centexbel-VKC (2018). Brandgedrag & Vlamvertrager. In: *Nieuwsbrief voor de textiel- en kunststofverwerkende industrie*, België.

Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee on the Regions (2020). *Chemicals strategy for sustainability: towards a toxic-free environment*.

De Stentor (2018). *Fatale vuurzee voorkomen? 'Stop met brandgevaarlijke meubels'*.

Dedeo, M. et al (2013). *British Furniture Fire Regulations: Do the benefits justify the health and environmental risks?* Sixth International Symposium on Flame Retardants (conference paper), San Francisco.

Di Gangi, J. et al (2010). San Antonio statement on brominated and chlorinated flame retardants. In: *Environmental Health Perspectives 118(12)*, A516 – A518.

Dutch Safety Board (2017) *Summary New Year's Eve Safety Risks*.

European Furniture Industries Confederation (EFIC) et al (2016). *The case for flame retardant free furniture* (policy paper).

Fire Service Academy (2020). *The burning behaviour of sofas during smoke propagation experiments*. Arnhem: IFV.

Fire Service Academy (2020). *Smoke propagation in residential buildings: Main report from practical experiments in a residential building with internal corridors*. Arnhem: IFV.

Graham, T.L. & Roberts, D.J. (2000). Qualitative overview of some important factors affecting the egress of people in hotel fires. In: International Journal of Hospitality Management 19(1), 79-87.

Greenstreet Berman (2009). *A statistical report to investigate the effectiveness of the Furniture and Furnishings (Fire) (Safety) Regulations 1988*. London.

Guillaume, E., Feijter, R. de & Gelderen, L. van, (2020). An overview and experimental analysis of furniture fire safety regulations in Europe. In: *Fire and Materials, 44*, 624-639.

Hagen, R. & Witloks, L. (2017). *The Basis for Fire Safety: Substantiating fire protection in buildings*. Arnhem: IFV.

Hagen, R. et al (2017). *Fire safety of upholstered furniture and mattresses in the domestic area: European fire services recommendations on test methods*, Federation of the EUropean fire officers (FEU).

Hendriks, H.S (2015). *Neurotoxicity of past, present and future flame retardants: neurotoxic hazard characterization and risk assessment of brominated and alternative flame retardants.* Utrecht University.

Het Parool (2020). *Woede na fatale brand flat Arnhem: 'Geen enkele klacht wordt serieus genomen'.*

Hoog, A. van 't (2017). Vlamvertragers. In: *Chemische Feitelijkheden, volume 82, no. 333.*

Instituut Fysieke Veiligheid (2017) *Brand Rode Kruislaan in Diemen. Een onderzoek naar het brandweeroptreden.* Arnhem: IFV.

Instituut Fysieke Veiligheid. *Kerncijfers Veilgheidsregio's.* Via https://kerncijfers.ifv.nl/dashboard/kerncijfers-veiligheidsregio-s/kerncijfers-incidenten. Last consulted on 4 May 2021.

Instituut Fysieke Veiligheid. *Onderzoeken brandveiliger meubilair.* Via https://www.ifv.nl/onderzoek/Paginas/Onderzoeken-brandveiliger-meubilair.aspx. Last consulted on 4 May 2021.

*Kamerstukken (Parliamentary Papers) II 2003/2004*, 29392, no. 3.

*Kamerstukken (Parliamentary Papers) II 2013-2014*, 26956, no. 197.

Kobes, M. (2008). *Zelfredzaamheid bij brand: Kritische vragen voor het veilig vluchten uit gebouwen (Self-reliance in the event of fire: Critical questions for safe escape from buildings).* The Hague: Boom Juridisch.

Kobes, M. & Oberijé, N. (2010), *Analysemodel vluchtveiligheid: Systematische analyse van vluchtveiligheid van gebouwen*, Arnhem: NIFV.

Liftinstituut (2020). *Rapportage technisch onderzoek lift naar aanleiding van ongeval betreffende: brand op 1 januari 2020 in woongebouw Gelderseplein 241 – 455 Arnhem.*

Minister van Binnenlandse Zaken en Koninkrijksrelaties, Kamerbrief inzake stand van zaken uitvoering diverse toezeggingen en moties over brandveiligheid ouderen (32 757, nr. 151), 2019.

Minister van Binnenlandse Zaken en Koninkrijkrelaties, *Voorhang Verzamelwijziging van het Besluit bouwwerken leefomgeving*, 12 May 2020.

National Institute of Environmental Health Sciences (2016). *Flame Retardants Fact Sheet.*

NOS Nieuws (2011). *Steeds kortere vluchttijd bij brand.*

NOS Nieuws (2020). *Vader en zoon (4) omgekomen bij flatbrand Arnhem, vuurwerk oorzaak.*

Obex (2015). *Obex rapportage BGB: Complex 20.03.07.01 Gelderseplein 1 t/m 455 Arnhem.*

Omroep Gelderland (2020). *Woede bij bewoners na Arnhemse flatbrand: 'We zaten als ratten in de val'.*

Onderzoeksraad voor Veiligheid (2012). *Brand in Rivierduinen: veronderstelde veiligheid.*

Onderzoeksraad voor Veiligheid (2017). Veiligheidsrisico's jaarwisseling.

Pires, T., de Almeida, A. & Duarte, D. (2005). A Decision-Aided Fire Risk Analysis. In: *Fire Technol 41*, 25-35.

Purser, D.A., Bensilum, M. (2001). Quantification of Behaviour for Engineering Design Standards and Escape Time Calculations. In: *Safety Science 38*, 157-182.

Purser, D.A. & McAllister, J.L. (2016). Assessment of hazards to occupants from smoke, toxic gases and heat. In M.J. Hurley (Ed.), *SFPE Handbook of fire protection engineering* (pp. 2308-2428). USA: Springer.

Rijksoverheid. *Informatiepagina over REACH*. Via https://www.rijksoverheid.nl/onderwerpen/gevaarlijke-stoffen/vraag-en-antwoord/wat-is-reach. Laatst geraadpleegd op 28 april 2021.

RTL Nieuws (2020). *Bewoners flat Arnhem in rouw, maar ook boos na brand waarbij vader en kleuter omkwamen.*

Sandberg, A. (1997). *Unannounced Evacuation of Large Retail-Stores: An Evaluation of Human Behaviour and the Computer model Simulex*. Lund: Lund University.

SEO Economisch Onderzoek (2014). *Maatschappelijke kosten-batenanalyse brandveiligheid in woningen.* Amsterdam.

Sime, J.D. (2001). An occupant response shelter escape time (ORSET) model. In: *Safety Science 38*, 109-125.

Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). *Brand Gelderseplein Arnhem: 1 januari 2020.*

Veiligheids- en Gezondheidsregio Gelderland-Midden (2020). *Evaluatie GRIP 1 Flatbrand Arnhem 01-01-2020.*

Wentzel, B. (2006). Vlamvertragers. In: *Chemische Feitelijkheden, volume 49, no. 224.*

# APPENDIX A

## ACCOUNTING FOR THE INVESTIGATION

### Background

On New Year's Eve night, 1 January 2020, a fire raged in the entrance hall on the ground floor of a block of deck-access flats, on the Gelderseplein in Arnhem. The fire was started when a sofa, that had been left behind in the entrance hall, was set alight by fireworks. The entrance hall, which was fully burned out, represented the only entrance and exit to the building. The fire left four victims, two of them fatal.

### Initial investigation

On 14 January 2020, on the basis of the consideration framework, the Safety Board decided to launch an (initial) investigation into this fire. They identified three points for attention:

- the design and use of the hall and escape routes;
- the use of lifts in the event of fire;
- the fire service deployment.

These formed the starting point for the initial investigation. The initial investigation in turn generated input for the focus of the investigation, which resulted in the following investigation questions.

### Investigation questions

The investigation activities were aimed at providing answers to the following main questions:

- How was it possible for this fire to result in two fatalities and two injured persons?
- Are there differences between fire safety in residential buildings in practice and fire safety according to the statutory rules and the underlying principles on which fire safety is based? If yes, what are the causes of this discrepancy, what is the effect of the differences on fire safety in residential buildings and what lessons can be learned?

The interplay between the properties of the building, human characteristics, the nature of the fire, the intervention method and the environmental characteristics, and the way they interact are the basis for the principles of fire safety. These underlying principles and the relevant legislation and regulations in which these principles are to a large extent reflected are viewed in combination by the Safety Board as the fire safety theory in

practice in the Netherlands. Based on a comparison between the conceptual principles and practice (the answer to the first investigation question), the Safety Board examined to what extent safety shortcomings emerged in this occurrence, that have broader application.

**Demarcation**

The following remained beyond the scope of this investigation:

- The lighting of the fireworks in the entrance hall, because the Safety Board has previously published an investigation into the risks of fireworks during the New Year's celebrations.[176] It was however considered in the investigation that the New Year's Eve celebration may have been an element affecting behaviour in terms of the victims and other residents (not) taking note of the fire.
- The fire safety of other buildings than residential buildings, since the design and use of residential buildings differs considerably from other building types. The same applies to the relevant regulations.
- Issues relating to social safety. Although not investigated extensively, it became clear that these problems played no determining role in the course of events of this occurrence. The sofa had not been placed in the entrance hall as a result of social degradation but as a result of good intentions of helping fellow residents. In addition, it has been common for decades during the New Year's Eve period for fireworks to be set off at numerous locations where this is unwise. The investigation did however recognize that there are additional challenges in the field of fire safety in the use phase of residential buildings where quality of life problems play a role.

The lift and the deployment of the fire service are included in the investigation, but feature only to a limited extent in the final report. This is because during the course of the investigation, the Safety Board reached the conclusion that fewer safety gains could be achieved with regard to these points, within this investigation, than in respect of the safety shortcomings that are discussed in detail in this report. In addition, with regard to the use of lifts in the event of fire, developments have already been initiated.

**Investigation approach**

By means of a document study and holding interviews with key individuals, the project team investigated the course of events, the system and relevant themes, on which the analysis and reconstruction were eventually based.

*Document study*

To analyse the fire safety theory (underlying principles and legislation and regulations) with regard to residential buildings, the team carried out a document study. Above all the team consulted the document 'The Basis for Fire Safety', published by the IFV in 2017, the Building Decree 2012 and the Housing Act. The team also studied documents in order to gain a broader picture of the risks of furniture fires, and key statistics on residential fires in the Netherlands were considered, in order to give an indication of the

176 Dutch Safety Board (2017) *Summary New Year's Eve Safety Risks.*

scale of the safety problem. Information provided by the police, fire service and the housing association Vivare was also studied.

*Interviews*
During the course of the investigation, the project team held 26 semi-structured interviews. Some of these interviews were held in order to reconstruct the course of the occurrence, and to gain an insight into the direct and underlying factors that contributed to the accident. The project team spoke among others to one of the victims, a resident, the fire service and people from Vivare. In respect of the analysis of the broader safety shortcomings, the project team firstly spoke to parties involved in the fire safety of the block of flats in Arnhem. These were the fire service, Vivare and the municipality. To gain a broader picture, the team also spoke to parties that are part of the system that works to prevent accidents of this kind recurring, such as Aedes, the Netherlands Fire Service and two housing associations. The team also interviewed various specialists in the field of fire safety. Finally, the team spoke to parties in the furniture industry, in order to obtain the latest information about developments relating to fire-safe furniture.

Contact was also made by telephone and/or digital means with a number of other parties relevant to the investigation, such as the Ministry of Justice and Security, the Ministry of the Interior and Kingdom Relations and the Institute for Safety.

*Analysis sessions*
The project team examined those parties that have a role in preventing the accident. The circumstances and context of the parties that occupy a position within the system were examined, and the investigators asked a number of questions during the analysis, such as:
- Could this type of accident recur elsewhere?
- Who in the system is able to contribute to preventing a repetition of accidents of this kind?
- What was it about the incident that led the parties involved to do what they did? What was the context?
- What possible improvement points are there for the future, to prevent accidents of this kind recurring?

The project team analysed the principles underlying fire safety, and the assumptions on which those principles are based. The project team then mapped out possible improvements both to the theoretical aspects of fire safety and in practice.

*Reconstruction*
Specifically for the reconstruction of the course of events, the team used the following sources/methods:
- an interview with one of the victims;
- an interview with a resident who was present in the block of flats during the fire;
- the interviews with the firefighters who put out the fire and who carried out the rescue operation;
- the police file and other information supplied by the police;

- the fire investigation by the VGGM;
- the camera images from the lift (1 camera) and from the entrance hall (2 cameras with images). As a result of the fire, these cameras failed at around 01.11 hours;
- a reconstruction of the lift passage with an (identical) reference lift in the adjacent building;
- an analysis of the blood sample taken from the deceased adult victim, carried out by the NFI on the instructions of the Safety Board.

*Fire test*

The Safety Board considered the necessity of carrying out fire tests. Fire tests had recently been carried out on furniture (see also chapter 4), so the question was to what extent a so-called full-scale fire test, in which the situation of the fire was reconstructed, could add any further insights to those already acquired from the past fire tests. In the initial phase of the investigation, a full-scale fire test of this kind was not considered necessary to answer the investigation questions. The option was, however, left open. Later in the investigation, the question once again arose as to the value and necessity of such a full-scale fire test. It was concluded that a fire test was not necessary to answer the investigation questions. In addition, a fire test would not result in any conclusions about the precise cause of death of the victims, because this was due to a combination of factors. At the same time, it was concluded that a full-scale fire test could have added value in verifying the investigative findings, further specifying the composition of the flue gases over time, and that it could generate additional picture material that would add greater urgency in illustrating the nature of the safety problem. The most suitable fire laboratory for carrying out a fire test of this kind, however, is located in England. Given the COVID-19 situation, it was impossible to prepare and carry out a fire test at that location, attended by investigators from the Dutch Safety Board.

**Quality assurance**

To guarantee the quality of the investigation, the following steps were taken:
A quality plan for the investigation was drawn up with the project team, in which risks to the quality of the investigation and the appropriate management measures were formulated.

- During the course of the investigation process, sessions were held on various occasions with the project team. During these sessions, the investigative findings were shared and interpreted, while team members constructively criticized each other's approach, interviews and analysis. A number of other sessions were intended to: 1) focus the investigation questions and the investigation as a whole, 2) formulate the final conclusions and 3) formulate recommendations.
- During the course of the investigation, three critical consideration sessions were organized. These are sessions during which investigators not involved in the project team read and comment on the intermediate products from the investigation. These sessions covered the action plan for the investigation and the draft version of the report. The outcomes of the critical consideration sessions were used to improve the analysis and the report.
- To ensure the quality of the content, external professionals were consulted at various points during the investigation.

- The investigation was discussed with a supervisory committee. For the specific work approach, see the heading supervisory committee.
- In accordance with the Dutch Safety Board Act, a draft version of this report was submitted to the involved organizations and persons, with the request to check the report for errors, omissions and inaccuracies and to provide comments where applicable. See Appendix B.

*Supervisory committee*

For this investigation, the Dutch Safety Board assembled a supervisory committee. This committee consisted of external members with expertise relevant to this investigation, under the chairmanship of Marjolein van Asselt (portfolio manager for the investigation). The external members were appointed to the supervisory committee in their personal capacity. The committee met three times during the investigation to discuss the design and results of the investigation with the Board member and the project team. The committee fulfils an advisory role within the investigation. Final responsibility for the report and the recommendations lies with the Dutch Safety Board. The committee is composed as follows:

| Name | Position |
|---|---|
| L. (Louis) Witloks | Expert in the field of fire safety, specifically fire prevention. Until his retirement in 2014, he was employed at IFV, and since that time has remained active in the sector. Co-author of the book: *The Basis for Fire Safety* published by the IFV. |
| P. (Paul) Verlaan | Expert in the field of physical safety, fire and firefighting. Since 2019 retired as director of the Security Region and regional fire service commander. Former board member of the CCRB (Board of Commanders of the Regional Fire Agencies) and the national fire services association (formerly the NVBR, later Netherlands Fire Service). Also former chair of the Fire Services Scientific Council) |
| L.C. (Louis) Boer | Retired expert in the field of human behaviour in emergency situations at TNO Human Technology Soesterberg. Responsible for research into escape behaviour from tunnels and passenger vessels. |
| P.C. (Pauline) Westerman | Since 2001 Professor of Philosophy of Law at the University of Groningen and also since 2007 programme manager at the Academy for Legislation (post doctorate studies). Research background in alternatives for the classical approach to legislation. |
| C.K. (Kees) Pasmooij | Chairman of an independent management foundation for the inspection bodies for lifts SBCL (Stichting Beheer Certificatie Liften) and retired director of the inspection body Aboma (construction and vertical transport sector). |
| M.B.T. (Maria) Molenaar | Since 2011 member of the Board of Woonstad Rotterdam. Also between 2011 and 2015 member of the Board of Aedes (association of housing associations). Previously Supervisory Director at the housing association Portaal. |

**Project organization**

Marjolein B.A. van Asselt acted as portfolio manager for this investigation on behalf of the Dutch Safety Board. The investigation was carried out by the project team that was made up of the following persons (excluding team members during the initial investigation).

| Name | Position/role |
|---|---|
| M.B.A. (Marjolein) van Asselt | Portfolio manager (until 14 June 2021) |
| G.W. (Erwin) Medendorp | Investigation manager (until 14 December 2020) |
| A. (Arzu) Umar | Investigation manager (from 14 December 2020) |
| W.M.M. (Wim) Heijnen | Project leader |
| J. (Jale) Demir | Project office assistant |
| R.J.P.N. (Ruud) van Schijndel | Investigator and deputy project leader |
| P.J.J.M. (Peter) Verhallen | Investigator (until 1 March 2021) |
| W.J. (Willem) Dekker | Investigator |
| C.S.M. (Clemon) Tonnaer | Investigator (from 17 May 2021) |
| C. (Christiaan) Roorda | Secretary / Investigator (until 31 December 2020) |
| I.C. (Isabel) Elias | Secretary |
| J.L.D. (Laura) Timmermans | Secretary / Investigator (from 15 March 2021) |
| E.J. (Elsabé) Willeboordse | Research and development consultant |
| R.T. (Ron) Koppes | Research and development consultant (from 1 February 2021) |

# APPENDIX B

## REACTIONS TO THE DRAFT REPORT

A draft version (without summary, consideration and recommendations) of this report was sent to the various parties involved, for consideration, in accordance with the Dutch Safety Board Act. The draft report or parts of the report were submitted to the following organizations and persons for verification of factual inaccuracies and to allow various points to be clarified:

- Ministry of Justice and Security;
- Ministry of Health, Welfare and Sport;
- Ministry of the Interior and Kingdom Relations;
- Housing association Vivare;
- Central Gelderland Health and Safety Region;
- Municipality of Arnhem;
- Direct surviving dependents.

The reactions received and the way they have been dealt with appear in a table that is available on the website of the Dutch Safety Board (www.onderzoeksraad.nl).

The reactions fall into two categories:

- Corrections of factual inaccuracies, additional comments at detail level, and editorial comments have been incorporated by the Safety Board (wherever correct and relevant). The appropriate sections of text have been adjusted in the final report.
- The reactions that were not incorporated are shown in the table with reasons from the Dutch Safety Board for their non-inclusion.

# APPENDIX C

## REFERENCE FRAMEWORK

In this reference framework, the Safety Board has formulated what it considers reasonably necessary in order to manage the safety risk of the occurrence and consequences of fire in a residential building. The reference framework consists of a specific part and a general part. For the specific part of the reference framework, investigation was carried out into the factors that play a role in a safety risk, and the way in which this risk can be reasonably managed (see C.1). With regard to a number of aspects, that recur in many investigations by the Safety Board, the Safety Board employs a general reference framework, for example for safety management (see C.2). The Safety Board assumes that in carrying out the risk inventory and evaluation and selecting the appropriate measures, the various parties involved take into account the relevant laws, rules and guidelines, and that they consult the best practices from their sector. The parties involved are also expected to include past experiences in their risk assessment. The Safety Board also expects all threats and aspects that influence the risk to be included in the risk inventory.

### C.1 Reference framework fire safety of residential buildings

The Safety Board distinguishes between the following themes with regard to responsibilities for the fire safety of residential buildings:

1. Design and construction
2. Use:
   a. maintenance, repair and renovation by the owner
   b. daily use by residents
3. Fire and firefighting

To some extent, these themes are sequential, but nonetheless demonstrate some degree of overlap in time. In addition, different actors are involved in each of the different themes, and some of those actors are involved in multiple themes. Because national government is responsible for the system in which fire safety in residential buildings is organized, at the end of the first section, after the list of the themes covered, this actor (national government) is especially discussed.

With regard to the theme **design and construction**, the Safety Board expects the client and the architect to arrive at a building design that in terms of fire safety[177] at least satisfies the requirements laid down in the Building Decree, and the best practices for

177 Aspects of fire safety of residential buildings within the theme design and construction include fire compartmentalization, escape routes, use of material and technical installations.

fire safety in the sector. Depending on their estimation of specific risks for the building to be realized, they take additional measures aimed at improving fire safety, in the design. An environmental permit has to be applied for from the municipality, for the overall design. The Safety Board expects the municipality to assess the application according to relevant legislation and regulations. The municipality is also required to consider fire safety. Construction can start once the permit has been issued. The Safety Board assumes that the contractor and any subcontractors will build the residential building in accordance with the permitted design produced by the client and the architect, and the provisions and choices made in respect of fire safety, in that design. The Safety Board expects the municipality to supervise the construction process.

The theme **use: maintenance, repair and renovation by the owner** relates to minor alterations and repairs. Large-scale renovation work on residential buildings is subject to compulsory permit regulations and must be dealt with as described for the phase design and construction.

The Safety Board expects that small-scale, everyday renovations and repair work will not result in a reduction of the fire safety of a residential building (the level of fire safety must at least remain at the legally attained level[178]) and the Safety Board feels that all alterations should ideally contribute to further improving fire safety. Primarily, this is a responsibility for the building owner. The Board expects contractors and installation engineers who carry out work in the framework of maintenance, repair and renovation as competent professionals, to be alert to any alterations which could influence the fire safety of a residential building. This should be supported by the owner. In helping to ensure fire safety of residential buildings in the use phase, cooperation between owner and the fire service can provide additional knowledge and advice. The Safety Board expects this element to form part of a system for monitoring the fire safety of residential buildings and as such to be part of the governance system operated by the owners of residential buildings. Moreover, the Safety Board expects the fire service as part of its general task (preventing, limiting and fighting fires, and advising other government bodies and organizations on fire prevention and firefighting) to support the owners during this phase, in maintaining and improving the level of fire safety of their buildings. In that connection, the Board expects the municipality to fulfil its supervisory role for the fire safety of residential buildings in the use phase.

With regard to the theme **use: daily use by residents**, the Safety Board expects building owners to inform the residents of the location of escape routes in the event of fire, and about the behaviour the building owners expect of residents with regard to keeping escape routes fire safe. This, above all, relates to keeping escape routes and communal areas clear of obstacles and flammable objects. It is essential that the owner matches the communication to the social and societal characteristics of the residents. The Safety Board expects the owner to translate for the residents the legally imposed responsibility

178 The legally attained level of fire safety is the level for which the original building permit was issued, wherever necessary amended for subsequent additional rules for existing buildings. The legally attained level is therefore at least the level of existing buildings in the Building Decree, and at most the level for new buildings.

of the residents to keep escape routes clear of obstacles and flammable objects. This can for example be achieved by laying down these requirements in the tenancy agreement (or any general conditions and/or house rules accompanying the tenancy agreement). The Board also feels that the owner of a residential building should monitor and where necessary enforce the fire-safe behaviour of residents.

In part on the basis of the information and instructions issued to them by the owner, the Safety Board expects residents to behave in such a way that the fire safety of the residential building is not threatened. In many blocks of flats, there is only one escape route, and this should be handled with due care. The Safety Board therefore believes that it is up to the residents to keep the only escape route secure, and therefore clear of (flammable) items, for themselves and their fellow residents. The Safety Board also expects residents to report fire hazardous situations to the building owner.

As is the case with the theme *maintenance, repair and renovation*, cooperation with the fire service on this point can result in additional knowledge and advice. The Safety Board expects building owners to include this as part of their governance tasks.

With regard to the theme **fire and firefighting**, the Safety Board expects the building owner to proactively inform the residents of the response perspectives available to them, in the event of a fire breaking out. This refers to the building escape concept, for example by clarifying how many escape routes there are outwards, in what cases the resident's own flat is a safe place to remain in the event of fire elsewhere in the building and identifying the specific safe assembly points in the event of fire or smoke in the escape route.

The Safety Board expects the residents to have a clear idea of how to respond in the event of fire, as a result of clear information provision by the building owner. This applies both to reporting fires to the emergency services, and to the safe way of leaving the building.

The Safety Board expects the emergency services to respond adequately to fire alarms, to be in attendance within the specified arrival times, to expertly fight the fire, to offer assistance to any victims, and to instruct the residents and their visitors and if necessary to assist them to escape from the residential building.

The Safety Board expects **national government** to establish, to maintain and to uphold a sound system of legislation and regulations on fire safety. This maintenance process should include a periodic evaluation of the regulations and a system of adaptation based on new insights. Essential elements of any such evaluation are the practical implementability and the relationship with practice. The Safety Board also expects any legislation and regulations on fire safety to be mutually harmonized between the various appropriate Ministries. Based on its system responsibility for the fire service, in 2015, the Ministry of Justice and Security (JenV) established the Fire Safety platform, the task of which is to exchange developments in the field of fire safety with the various stakeholders, around four times a year. These consultation sessions should be interdepartmental,

because policy development and legislation in the field of fire safety encompass several Ministries. The Ministry of the Interior and Kingdom Relations is responsible for building regulations, the Ministry of Justice and Security for the fire service and the Ministry of Medical Care and Sport for regulations relating for product safety and as a consequence the fire safety of products used in residential buildings. The Board believes that attention for product safety should be focused on the most high-risk products.

## C.2 Reference framework safety management of the Safety Board

These safety management points are intended for parties who in any way bear or are able to take responsibility for situations in which citizens are dependent for their safety on third parties. Such as is the case for owners of residential buildings.

**1. The safety strategy is based on insight into risks**

The starting point for achieving the required level of safety is an inventory of the risks. Professionals and relevant experts with the required knowledge and insight into risks are closely involved in the safety strategy.

The safety strategy is based on:

a. a systematic inventory of undesirable events that can occur;
b. the best possible underpinned estimation of the probability that these undesirable events will occur;
c. the best possible underpinned estimation of the nature and scale of their consequences.

Based on the risk inventory, each party determines which risks it wishes to manage, to what level. Wherever possible, each party formulates appropriate measurable safety targets.

**2. The safety strategy is realistic and recorded explicitly**

Each party formulates the safety strategy according to which it wishes to realize the proposed safety targets. The safety strategy satisfies the following conditions:

a. the safety strategy provides an explicit description of the relationship between the risks to be managed and the preventive and repressive management measures to be taken;
b. the safety strategy does justice to:
    i. applicable legislation and regulations;
    ii. standards, guidelines and best practices from the sector;
    iii. own insights and experience of the organization.
c. the safety strategy encompasses procedures for notifying the safety strategy to the parties responsible for its implementation;
d. the safety strategy encompasses procedures that ensure supervision and enforcement of implementation;
e. the safety strategy is recorded.

**3. The safety strategy is implementable**

The implementation of the safety strategy satisfies the following conditions:

a. sufficient resources and expertise are available for implementation of the safety strategy;
b. each element of the safety strategy is understandable and implementable by those persons responsible for its implementation.

**4. The safety strategy is a responsibility of the management**

The management:

a. demonstrates involvement in the formulation, implementation and monitoring of the safety strategy;
b. promotes an organization culture in which the central focus is on internal and external safety;
c. promotes the existence of realistic expectations in respect of the safety ambitions, inside and outside the organization;
d. reaches agreements with other parties on joint risk management, if a safety risk or the possibilities for managing that risk extends from one organization to another.

**5. The safety strategy is continuously evaluated and where necessary adjusted**

This takes place at least:

a. proactively, in the event of proposed changes that affect the operational processes;
b. periodically, during inspections, evaluations, etc. of the operational processes;
c. periodically, during evaluations of the safety strategy itself;
d. reactively, during investigations into accidents, near-accidents and other incidents.

On each occasion, the management clearly announces whether the information that becomes available provides grounds for adjusting the safety strategy and which adjustments are to be carried out.

Specifically for **fire safety in the use phase of residential buildings**, it is up to building owners to identify and manage the most important risks. To that end, the Safety Board expects building owners to operate a fire safety policy that is an integral part of the governance of the organization, and that is regularly updated. In that framework, the Safety Board expects building owners to draw up and implement an integrated fire safety policy aimed at (recognizing and) managing fire safety risks. The government body of the organization must place responsibility for this policy at a clear location within the organization, and closely monitor progress of the implementation of the policy. On a periodic basis, the policy including the accompanying risk analyses must be reassessed, on the basis of new knowledge and insights.

# APPENDIX D

## RESIDENTIAL FIRE STATISTICS

This appendix is a summary of the most important statistics about residential fires in the Netherlands. Until 2018, fire statistics were maintained by Statistics Netherlands (CBS) but since that time the responsibility has been transferred to the Institute for Safety (IFV). In 2013, a series of important changes were made both to the way in which the figures were collected, and the type of figures collected. Until 2013, figures about fires were collected by means of questionnaires to be completed by the fire service. After that time, the CBS started using automatically generated figures from emergency control rooms. After 2013, no further figures were registered at national level about for example the number of persons injured in fires, the number of residential fires per type of home and the causes of fire. The IFV, which took over responsibility for the registration of fire data from the CBS in 2018, does now collect and register detailed data about fires involving at least one rescue, and about non-deliberate residential fires, whereby people died as a consequence of the fire. The fact that good-quality national data is only available about a limited number of subjects means that the analysis of developments is incomplete.

### Number of residential fires attended by the fire service

In 2020, the fire service received 44,961 notifications of (unique) fire incidents[179] which in 41,555 cases actually led to at least one fire service unit attending the fire. 6,066 cases referred to the notification of a residential fire. 5,893 of these notifications actually resulted in the fire service attending on location.[180], [181] This means that 14% of all fires attended by the fire service relates to a residential fire.

### Victims of residential fires

No figures are available about the number of injuries caused in residential fires in the Netherlands. The IFV does record figures for the number of (non-deliberate) residential fires resulting in fatalities. In 2020, according to the definition of the IFV, there were 31 fatal residential fires[182] leading to 32 fatalities. The figure below shows how 2020 compares with the previous year.

179 This relates to the number of incidents with the notification 'fire', 'building' and 'residential', in other words irrespective of how often a notification was issued of the same incident.

180 This relates to the number of incidents whereby the fire service reported on the ground (at the emergency control room).

181 IFV. *Key figures incidents*. Via https://kerncijfers.ifv.nl/mosaic/kerncijfers-veiligheidsregio-s. Last consulted on 28 May 2021.

182 These are residential fires with a fatal outcome, not involving deliberate arson. Residential fires whereby people died a (proven) natural death are not included. The given figure therefore excludes 12 fires that were the result of deliberate arson and 7 fires in which people died a (proven) natural death. The IFV classified the investigated fire in the block of flats in Arnhem as 'arson'. For that reason, this fire does not match the definition of the IFV for a fatal residential fire, so that this fire is not included in the figures.

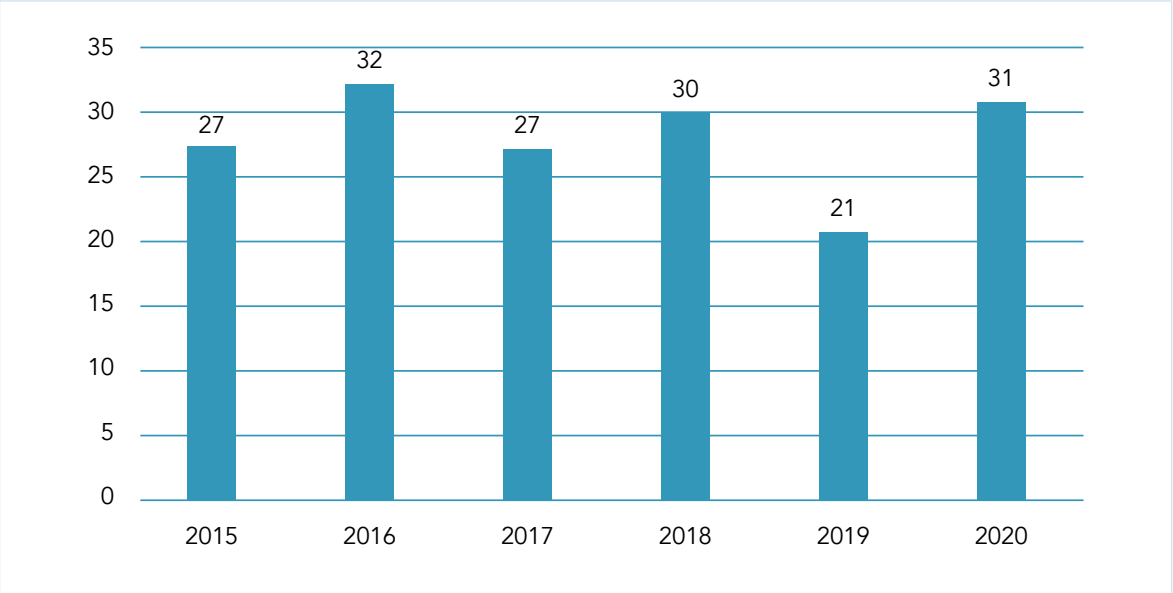



*Figure 13: Number of fatal residential fires per year (Source data: IFV)*

**Fatal residential fires in blocks of deck-access flats**[183]

Four of the 31 fatal residential fires in 2020 occurred in a block of deck-access flats. Although the figures for the period 2015 to 2020 vary annually, they do show that a large proportion of the fatal residential fires each year take place in blocks of deck-access flats, see the figure below.

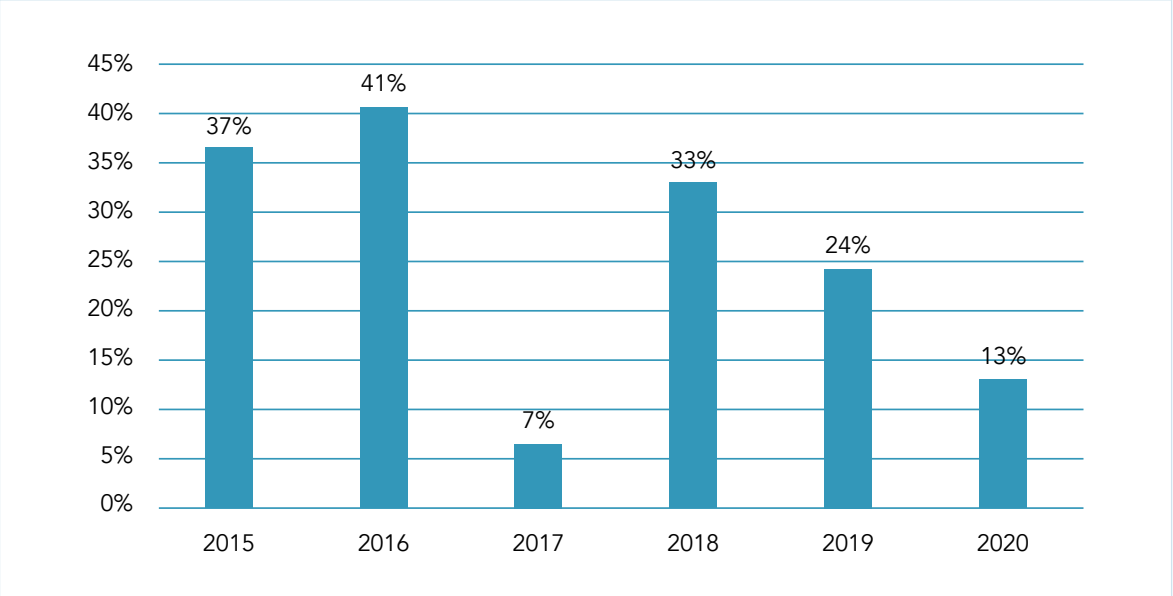



*Figure 14: Number of fatal residential fires in a block of deck-access flats (open and closed gallery) as a percentage of the total number of fatal residential fires (Source data: IFV)*

183 The Netherlands has in total around 7.9 million homes. Of these, around 64% are single family homes and 36% multiple family homes. No further breakdown of multi-family homes (for example into blocks of deck-access flats, staircase-access flats and corridor flats) is not publicly available.

**Involvement of furniture and mattresses in fatal residential fires**

Data from the IFV on fatal residential fires shows that for 269 fatal residential fires that occurred between 2008 and 2020 (from a total of 369), it is known which object first caught fire. In 45 cases (17%) this was a bed or mattress. In 61 cases (23%) a seat. In total, therefore, around 40% of fatal residential fires where the first object to catch fire is known, started in mattresses or seating. For a further 92 fatal residential fires, it is known that plastic foam in furniture or mattresses contributed to accelerated fire development and/or smoke propagation.

# APPENDIX E

## FIRES IN BLOCKS OF FLATS 2020

Shortly after the start of the investigation into the fire in the block of flats in Arnhem, the Safety Board started to record fires in blocks of flats in 2020, by collecting a limited number of characteristics for each fire. Only those fires in blocks of flats were registered that reached the local and/or national digital media, and were brought to the attention of the Safety Board. The result, shown in the table below, is therefore incomplete and the information in the overview is not verified, but is usable to gain an impression of the characteristics of fires in blocks of flats in a given year.

The table shows (among others) the following information on fires in blocks of flats in 2020:

- Of the 73 fires in blocks of flats registered, 37 took place in a block of deck-access flats and 36 in a staircase-access flat and/or corridor flat. In other words, about half of all fires in blocks of flats in 2020 took place in a block of deck-access flats.
- Of the 73 fires in blocks of flats, 26 started somewhere else than in an individual flat. This amounts to 35.6%.
- These 73 fires in blocks of flats in 2020 resulted in 3 fatalities and 59 injured.

| No. | Date | Place | Type of flat | Seat of fire | Fatalities | Injured |
|---|---|---|---|---|---|---|
| 1 | 1-1-2020 | Arnhem | Deck-access flat | Central hall | 2 | 2 |
| 2 | 2-1-2020 | The Hague | Deck-access flat | Carpark | 0 | 12 |
| 3 | 19-1-2020 | Den Bosch | Porch-/Corridorflat | Flat | 0 | 1 |
| 4 | 29-1-2020 | Rotterdam | Porch-/Corridorflat | Flat | 0 | 2 |
| 5 | 2-2-2020 | Rotterdam | Porch-/Corridorflat | Storage cellar | 0 | 8 |
| 6 | 5-2-2020 | Apeldoorn | Porch-/Corridorflat | Cellar | 0 | 0 |
| 7 | 9-2-2020 | Zwolle | Porch-/Corridorflat | Flat | 0 | 0 |
| 8 | 18-2-2020 | Katwijk | Deck-access flat | Flat | 0 | 1 |
| 9 | 29-2-2020 | Rotterdam | Deck-access flat | Cavity wall | 0 | 0 |
| 10 | 29-2-2020 | Waddinxveen | Deck-access flat | Flat | 0 | 0 |
| 11 | 1-3-2020 | Nieuwegein | Deck-access flat | Storage cellar | 0 | 0 |
| 12 | 3-3-2020 | Ede | Porch-/Corridorflat | Flat | 0 | 0 |
| 13 | 4-3-2020 | Breukelen | Deck-access flat | Storage cellar | 0 | 0 |

| No. | Date | Place | Type of flat | Seat of fire | Fatalities | Injured |
|---|---|---|---|---|---|---|
| 14 | 6-3-2020 | Venray | Porch-/Corridorflat | Flat | 0 | 1 |
| 15 | 9-3-2020 | The Hague | Deck-access flat | Storage unit | 0 | 0 |
| 16 | 13-3-2020 | Capelle a/d IJssel | Deck-access flat | Flat | 0 | 2 |
| 17 | 21-3-2020 | Den Bosch | Deck-access flat | Flat | 0 | 1 |
| 18 | 24-3-2020 | Haarlem | Deck-access flat | Flat | 0 | 0 |
| 19 | 28-3-2020 | Zoetermeer | Porch-/Corridorflat | Flat | 0 | 1 |
| 20 | 5-4-2020 | Rotterdam | Porch-/Corridorflat | Unknown | 0 | 0 |
| 21 | 5-4-2020 | Schiedam | Porch-/Corridorflat | Outside | 0 | 0 |
| 22 | 15-4-2020 | Haarlem | Porch-/Corridorflat | Flat | 0 | 0 |
| 23 | 18-4-2020 | Middelburg | Deck-access flat | Stairwell | 0 | 0 |
| 24 | 19-4-2020 | Maassluis | Deck-access flat | Balcony | 0 | 0 |
| 25 | 22-4-2020 | Tiel | Deck-access flat | Storage cellar | 0 | 0 |
| 26 | 23-4-2020 | Rotterdam | Porch-/Corridorflat | Balcony | 0 | 0 |
| 27 | 5-5-2020 | Rosmalen | Deck-access flat | Flat | 0 | 0 |
| 28 | 5-5-2020 | Haarlem | Deck-access flat | Portiek | 0 | 0 |
| 29 | 6-5-2020 | Delft | Deck-access flat | Flat | 0 | 1 |
| 30 | 7-5-2020 | Apeldoorn | Deck-access flat | Cellar | 0 | 0 |
| 31 | 10-5-2020 | The Hague | Porch-/Corridorflat | Flat | 0 | 3 |
| 32 | 16-5-2020 | Capelle a/d IJssel | Porch-/Corridorflat | Cellar | 0 | 1 |
| 33 | 22-5-2020 | Breda | Deck-access flat | Flat | 0 | 0 |
| 34 | 30-5-2020 | Middelburg | Deck-access flat | Flat | 0 | 0 |
| 35 | 5-6-2020 | Leidschendam | Porch-/Corridorflat | Stairwell | 0 | 0 |
| 36 | 10-6-2020 | Groningen | Deck-access flat | Flat | 0 | 0 |
| 37 | 18-6-2020 | Wageningen | Porch-/Corridorflat | Internal corridor | 0 | 1 |
| 38 | 28-6-2020 | Breda | Porch-/Corridorflat | Flat | 0 | 1 |
| 39 | 29-6-2020 | Gorinchem | Deck-access flat | Flat | 0 | 1 |
| 40 | 10-7-2020 | Eindhoven | Porch-/Corridorflat | Flat | 0 | 0 |
| 41 | 12-7-2020 | Purmerend | Deck-access flat | Flat | 0 | 0 |

| No. | Date | Place | Type of flat | Seat of fire | Fatalities | Injured |
|---|---|---|---|---|---|---|
| 42 | 16-7-2020 | Groningen | Porch-/Corridorflat | Flat | 0 | 1 |
| 43 | 17-7-2020 | Alkmaar | Deck-access flat | Flat | 0 | 0 |
| 44 | 27-7-2020 | The Hague | Porch-/Corridorflat | Hall | 0 | 0 |
| 45 | 29-7-2020 | Tilburg | Porch-/Corridorflat | Flat | 0 | 0 |
| 46 | 30-7-2020 | Vlissingen | Porch-/Corridorflat | Flat | 1 | 5 |
| 47 | 5-8-2020 | Geleen | Deck-access flat | Flat | 0 | 0 |
| 48 | 10-8-2020 | Rotterdam | Deck-access flat | Flat | 0 | 1 |
| 49 | 3-9-2020 | Geleen | Deck-access flat | Flat | 0 | 0 |
| 50 | 4-9-2020 | Zwolle | Deck-access flat | Flat | 0 | 0 |
| 51 | 5-9-2020 | Groningen | Porch-/Corridorflat | Facade | 0 | 0 |
| 52 | 13-9-2020 | Assen | Porch-/Corridorflat | Balcony | 0 | 0 |
| 53 | 15-9-2020 | Baarn | Deck-access flat | Flat | 0 | 1 |
| 54 | 18-9-2020 | Heerlen | Porch-/Corridorflat | Flat | 0 | 4 |
| 55 | 26-9-2020 | Apeldoorn | Porch-/Corridorflat | Storage cellar | 0 | 0 |
| 56 | 4-10-2020 | Capelle a/d IJssel | Porch-/Corridorflat | Flat | 0 | 0 |
| 57 | 9-10-2020 | Zwijndrecht | Porch-/Corridorflat | Flat | 0 | 1 |
| 58 | 15-10-2020 | Hilversum | Porch-/Corridorflat | Flat | 0 | 0 |
| 59 | 17-10-2020 | Oosterhout | Porch-/Corridorflat | Carpark | 0 | 0 |
| 60 | 23-10-2020 | Sneek | Porch-/Corridorflat | Flat | 0 | 0 |
| 61 | 6-11-2020 | The Hague | Deck-access flat | Flat | 0 | 0 |
| 62 | 11-11-2020 | Den Bosch | Deck-access flat | Flat | 0 | 1 |
| 63 | 21-11-2020 | Deventer | Porch-/Corridorflat | Flat | 0 | 1 |
| 64 | 22-11-2020 | Haarlem | Deck-access flat | Balcony | 0 | 0 |
| 65 | 25-11-2020 | Capelle a/d IJssel | Deck-access flat | Flat | 0 | 3 |
| 66 | 2-12-2020 | Sittard | Deck-access flat | Cellar | 0 | 0 |
| 67 | 12-12-2020 | Drachten | Porch-/Corridorflat | Flat | 0 | 0 |
| 68 | 14-12-2020 | Hoogezand | Porch-/Corridorflat | Flat | 0 | 0 |
| 69 | 15-12-2020 | Hengelo | Porch-/Corridorflat | Flat | 0 | 2 |

| No. | Date | Place | Type of flat | Seat of fire | Fatalities | Injured |
|---|---|---|---|---|---|---|
| 70 | 22-12-2020 | Capelle a/d IJssel | Deck-access flat | Flat | 0 | 0 |
| 71 | 23-12-2020 | Alphen a/d Rijn | Deck-access flat | Flat | 0 | 0 |
| 72 | 24-12-2020 | Utrecht | Deck-access flat | Flat | 0 | 0 |
| 73 | 29-12-2020 | Oegstgeest | Porch-/Corridorflat | Flat | 0 | 0 |

DUTCH
SAFETY BOARD

**Visiting address**
Lange Voorhout 9
2514 EA The Hague
The Netherlands
T +31 (0)70 333 70 00
F +31 (0)70 333 70 77

**Postal address**
PO Box 95404
2509 CK The Hague
The Netherlands

www.safetyboard.nl