BUILDINGS REGULATIONS ON FIRE SAFETY IN EUROPE

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Abstract

There is still a broad variety of systems of technical requirements for buildings in the various European countries, despite the existence of the Construction Products Directive of the European Union and the development of Euro Codes. The goals and topics are quite similar, and most countries call their regulations 'performance based,' but a detailed study reveals considerable variety of functional requirements, performance requirements, and specifications, with inconsistency within the requirements of some countries.

This paper is based on the findings of a comparative analysis of building regulations for housing in eight European countries, carried out on behalf of the Dutch Ministry of Housing and intended to locate the Dutch Building Decree within the spectrum of regulations in other European countries. The project makes a detailed comparison of systems of building control, the formulation of the requirements, and the contents of selected subjects.

This paper focuses on the conclusions of the analysis of the fire safety requirements. Comparisons proved particularly difficult due to differences in the structure, description, and content of the requirements, which may reflect the long history of the regulation of fire safety. It identifies several differences in levels of requirements and strategies which may be significant in practice and illustrates many impediments to the harmonisation of the description of fire safety strategies.

Keywords: Building Regulations, Fire safety requirements, Performance requirements

1. Introduction

The protection of the health and safety of citizens was an early motive underlying legislation to safeguard the quality of the built environment. In the course of time, concerns for energy conservation and the welfare of disabled people have also been translated into building regulations for housing, but fire safety remains a fundamental issue.

Internationally-orientated research in the field of technical building regulations and building control is scarce. Economic Commission for Europe, 1985 and Institute of Building Control, 1997, provide basic insight in the different systems in the European countries. Bowen, 1997, provides basic definitions to understand systems of technical requirements, with a focus on performance-based building codes, such as the Dutch Building Decree. Within this field the OTB Research Institute for Housing, Urban and Mobility Studies has undertaken a range of national and international projects on systems of technical building control. These projects focussed on analysis of the organization of building control in various European countries (Meijer and Visscher, 1998) and supported studies for the Dutch government in the search for alternative instruments. Sheridan, 2001, analyses a broad range of regulations and financial incentives to promote housing quality in European countries. Most recently, the Dutch Ministry of Housing, Physical Planning and Environment commissioned a comparative study of the Building Regulations in Belgium, Denmark, England and Wales, France, Germany, the Netherlands, Norway, and Sweden, focussed on technical requirements for dwellings and systems of implementation. The project resulted in two publications: Part 1 (Meijer, Visscher and Sheridan, 2002), a description and comparison of the systems of building control, and Part 2 (Sheridan, Visscher, Meijer and Bos, 2003), a comparative analysis of the technical requirements for eight subjects (Stairways and ramps, Fire safety, Prevention of burglary, Noise, Noxious materials and substances from the ground, Daylight, Accessibility and Dimensions of habitable space and habitable rooms).

This paper reflects on the project's comparative analysis of fire safety requirements, which is probably the first successful attempt to tackle the subject in detail. The method of analysis was similar to that used in Sheridan 2001, but the analysis was structured on the Dutch Building Decree and developed to a much greater level of detail. Selected sections of the Dutch Building Decree were transcribed to tables that were devised to reflect the topics of those sections. Requirements from other countries were then analysed and incorporated in the same tables. A topic-by-topic comparison was developed in a commentary which

attempted to identify key features of each relevant issue and, where possible, the highest and lowest levels of requirements amongst the countries studied.

Section 2 outlines differences between countries in approaches to regulation and in the formulation of fire safety requirements. Section 3 analyses the differences in content and levels of requirements for fire safety. Section 4 considers the harmonisation of requirements within European countries. Section 5 presents general conclusions on the comparative study of the fire safety regulations.

2. Systems and formulations of fire safety regulations

Historically, fire safety was one of the earliest issues addressed by building regulations and the variations between countries belie long, differing traditions. Although there are many similarities between countries in the subjects and objectives of building regulations, there are differences not only in technical requirements, but in the system of requirements. The structure of legislation varies between countries, but that is not the reason for the most salient differences in the formulation and expression of building regulations. There is now a range of approaches, which vary from broad functional requirements, through qualitative performance requirements, to prescription. This paper does not go into depth in the classification of systems of requirements, but it should be noted that there is sufficient inconsistency in the formulation of requirements, to question the validity in practice of the Nordic model of five classifications of the various systems of building regulations, often referred to by CIB Taskgroup 37 (Bowen, 1997; Foliente, 2000; Scholten, 2001). For instance, in both the Netherlands and Sweden, there is inconsistency between topics in both the degree of detail, and the degree of prescription. There is also considerable variation in the degree of reliance on secondary sources, such as national standards (e.g. NBN, DS, BS, NF, NEN, NS, SS), to interpret the requirements.

Mostly, the national approaches are similar if differently expressed, but there are some significant differences in levels of requirements. It is difficult to understand why there should be such diversity in travel distances, or in periods of fire resistance between neighbouring dwellings, for there cannot be national differences between the speed of people's movements, and the development of fire.

Fire safety was by far the most difficult topic to analyse, due to the range of requirements and the importance of detail. There are further issues which complicated the comparative analysis of fire safety: the scope of building regulations; the description of requirements; the application of requirements; and bases for the evaluation of levels of requirements. The difficulties were compounded by basing the analysis on the particular requirements of one country, and by a limited selection of topics for analysis.

Scope of building regulations. Despite the length and complexity of the analysis that has been carried out within this project, it does not yet represent a complete account of fire safety controls for residential buildings. Firstly, national building regulations do not encompass all the issues of fire safety and there is often further legislation at national level which addresses provision for high risk accommodation or mixed-use buildings, and local bye-laws which address site-specific issues. Also, there is a considerable body of controls on the management of buildings, including the licensing of certain types of premises. All the systems studied refer to national standards for background information, but the Building Decree in the Netherlands relies particularly heavily on national standards for the interpretation of strategic issues.

Description of requirements. The particular nature of the research contract with the Dutch Ministry of Housing, Physical Planning and Environment also influenced the scope of the analysis. Any comparative analysis tends to reflect the approach of the commissioning country, and the Building Decree makes a difficult starting point. Although it incorporates all the elements of the Nordic System and the recommendations of CIB/TG11, it presents technical regulations in a different format from any other country. The Netherlands reviewed building regulations as part of an Action Programme for deregulation. It is intended that each requirement of the Building Decree should be an unambiguous legal statement that is measurable and verifiable. At the same time, the expression of requirements is intended to minimise constraints on design freedom and innovation. Each clause is introduced by a functional description which

expresses the intention of the subsequent performance requirements. Where relevant, performance requirements identify limit values which indicates the minimum acceptable level of performance, and determination methods, usually by reference to standards of the Dutch Standardisation Institute (NEN). The application of requirements and any variable limit values are indicated by means of a navigation table. This is demonstrated in the following example. Article 2.91 comprises a functional requirement, which is elaborated in six further articles. The table and paragraphs reproduced below in an unofficial translation are extracts relevant to the user function 'living':

Heading 2.12 Limitation of fire development: Section 2.12.1 New Buildings

Article 2.91 1. A construction must be built so that fire cannot develop quickly.

2. The requirement stated in the first paragraph is complied with by applying those regulations that are associated with the relevant user function in table 2.91.

Table 2.91

User function	Applicable paragraphs						Limit values								
							side inside			outside			top	
	Inside area	Outside area	Area which can be walked upon	Exempt	Alterations	Temporary building	fire-free and smoke-free escape route	smoke-free escape route	other	fire-free and smoke-free escape route	smoke-free escape route	other	fire-free and smoke-free escape route	other
Article	2.92	2.93	2.94	2.95	2.96	2.97	2.92			2.93			2.94	
paragraph	*	1 2 3 4 5 6	1 2	1 2	1 2	1 2	*			1			2	
							[class]			[class]			[class]	
1 Living function														
a living function in a caravan	*	1 - - - - -	1 2	1 -	- -	- -	-	-	4	-	-	4	-	T3
b living function with use area maximum 500 m2, not in a block of flats or caravan.	*	1 2 - - 5 -	1 2	1 -	1 -	1 -	2	4	4	2	4	4	T1	T3
c other living function	*	1 2 3 - 5 -	1 2	1 -	1 -	1 -	2	2	4	2	2	4	T1	T3

Article 2.92 On a side not exposed to the outside air, a construction component has a contribution to fire propagation determined in accordance with NEN 6065 which complies with the class indicated for that side in table 2.91.

Article 2.93 1. A construction component not being a door, window, fram or equivalent construction component has a contribution to fire propagation in accordance with NEN 6065 which complies with the class indicated for that side in table 2.91. A door, window, frame or equivlent construction component complies with class 4.

2. A part of a construction component which is situated more than 13 m above the measuring level has, on a side which is exposed to the outside air, a contribution to fire propagation in accordance with NEN 6065 which complies with class 2… etc.

Fig. 1 Example of the formulation of requirements of the Dutch Building Decree

More significantly, the project contract prescribed a selection of sections from the Building Decree that did not include all the strategies relevant to fire safety, despite the inter-relationships of certain strategies.

Nonetheless, the analysis gives a good indication of approaches and levels of requirements in each country, and raises issues for the methods to be used in the comparative analysis of fire safety regulations.

Description of requirements. Comparison was further complicated by some difficult aspects of the Dutch Building Decree's fire safety requirements:

- limited explanation of the strategies that underlie the requirements;
- use of specialised terminology with insufficient explanation of its interpretation in terms of spatial conditions and insufficient definition of the expressions used
- the formulation of requirements followed by qualifying conditions or exemptions;
- use of performance requirements which rely on detailed interpretation and / or calculation methods in national standards
- the generic description of 'user functions,' which creates long-winded descriptions.

The guidance notes offer some clarifications, but secondary sources are essential to the interpretation of requirements. For example, the requirements for resistance to spread of flame across the enclosure of a fire compartment refer to a national standard (an *NEN*) which does not specify conditions, such as the distance of openings from party walls, but gives a method to calculate fire radiation at particular points on façades. Examples of practical solutions are given in further guidance (an *NPR*), including the size of windows related to the distances between facades.

The tasks of the designer of buildings and the designer of building regulations should be complementary, but each has a different perspective on information about fire safety. Ideally, designers would develop proposals for buildings by considering the possible sources of fire, the nature of occupancy, and the requirements for escape from different places around the building. Their approach to design would be informed by a set of strategic principles, from which detailed tactics could be deduced. However, it is probably just as common for designers to apply the requirements of building regulations to already-developed designs. In either case, there is a design that can be tested against the demands of fire safety.

In contrast, building regulations must provide information that is capable of being applied in a good many different situations. Unless there is a demonstration of the application of fire safety requirements to a variety of planning configurations, the information is essentially generic and requires a degree of interpretation in practice. Guidance can supply such interpretation or refer to secondary sources. It can also have an educational role in describing the rationale that underlies the requirements.

The most notable contrast to the Building Decree is the explicit, informative approach in England and Wales. The approach in England and Wales means that the Approved Document works autonomously, as a basic design tool. The requirements and guidance on housing should be understood by designers with relatively little reference to secondary texts and without recourse to specialist advisors. The Building Regulations requirements are presented together with guidance in Approved Document B Fire Safety, which includes:

- information about the principles and assumptions that underlie the requirements;
- description of parts of buildings using everyday language;
- definitions of specialised terminology;
- diagrams to demonstrate the application of requirements to common configurations in buildings;
- discussion of detailed implementation, including diagrams to illustrate key conditions;
- separate sections, where appropriate, for domestic and non-domestic buildings, including differentiated requirements for houses and flats or maisonettes, for different heights of houses and blocks of flats, and for house conversions.

One example of the trend towards less accessible information is the 2002 revision to the building regulations in Hesse. For instance, unlike the previous revision, it does not specify appropriate periods of fire resistance for elements of construction. In common with regulations in each of the countries it does not give examples of constructions that satisfy the requirements, but it also does not refer to secondary sources to interpret the requirements.

Examples of diagrams and explanation of assumptions in primary documentation. England and Wales is unusual amongst the countries studied in explaining the underlying assumptions of requirements. For instance, Approved Document B, paragraph 3.3, states:

"The provisions for means of escape for flats and maisonettes are based on the assumption that: a. the fire is generally in a dwelling; b. there is no reliance on external rescue (eg by a portable ladder); c. measures in Section 9 (B3) provide a high degree of compartmentation and therefore a low probability of fire spread beyond the dwelling of origin, so that simultaneous evacuation of the building is unlikely to be necessary; and d. although fires may occur in the common parts of the building, the materials and construction used there should prevent the fabric from being involved beyond the immediate vicinity (although in some cases communal facilities exist which require additional measures to be taken)."

Requirements and guidance in other countries can mostly be understood from the main documentation which is freely available (as opposed to national standards which are only available for sale), but generally, there is much less supporting information than in England and Wales.

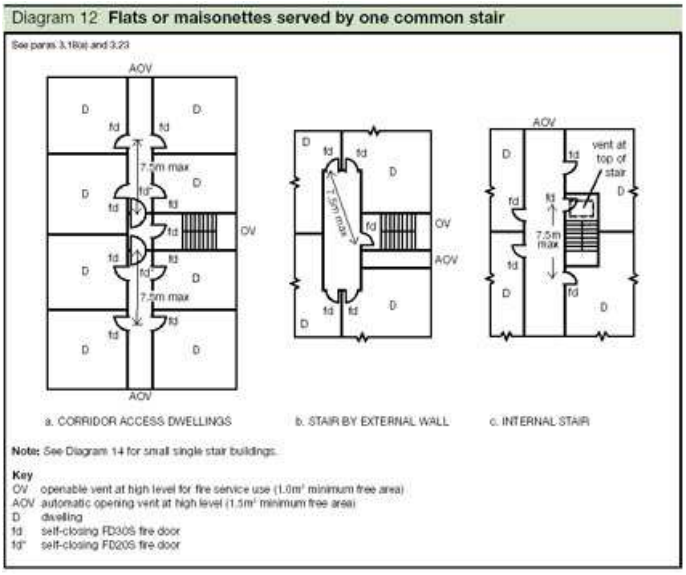


Fig. 2 England and Wales: Maximum travel distances and fire doors, flats or maisonettes served by one common stair

Of the other countries studied, only Norway includes diagrams in the main documentation, in the Guidebook to the Technical Regulations.

Application of requirements. The international comparison of levels of requirements of fire safety requirements was further complicated by differences in the application of requirements, with differing criteria and classifications of buildings. Often, it was possible to identify the highest and lowest levels of requirements overall, but in the case of the fire-resistance of structure and compartments, the comparison had to be rationalised by considering the requirements that would apply to two-storey houses and to blocks of flats with differing numbers of storeys. Product standards were not explored in the analysis, but it is worth noting that until the harmonised European standards for testing are adopted, there may be differences between countries in the constructions that satisfy the same requirements for fire resistance.

There are three common bases for the classification of buildings, by function, typology, and height. There are relatively few instances where the application of requirements for dwellings is related to floor area.

Countries vary in the ways in which they differentiate between requirements for living accommodation and other functions. In some cases this reflects the overall format of the regulations, for instance in France where there is dedicated legislation for residential buildings. More commonly, fire safety regulations must

make special mention of dwellings, with sub-sections for dwellings and other buildings for certain issues, but not for others. In the Netherlands, the application of requirements is identified in 'navigation' tables. Belgium is unusual in having requirements which are applied without differentiation of function, but do not apply to single family houses. Some countries have clearly different requirements for flats and houses; some also differentiate between detached and joined single family houses; others have combined requirements for flats and houses, but with differences related to height.

One result of basing the analysis on parts of the Building Decree is that it does not fully explore requirements for mixed use buildings. One of the most demanding areas of fire safety design is the interface between accommodations for different functions in mixed use buildings. Mixed-use buildings raise issues about the separation of different functions with fire-resisting construction, the protection of escape routes, the extent of alarm systems, implications of security systems for fire safety, external spread of flame between functions, and, in tall buildings, the extent of sprinkler systems. The drafting of the Building Decree, with its use of generic user functions, was intended to clarify the requirements of differing functions in mixed use buildings, but the structure of the regulations means that it is left to the accompanying notes to explain that the highest level of requirement must be used where differing functions use the same space. There are also requirements specific to housing for vulnerable people, such as residential care homes for the elderly, which are not addressed in the analysis, due to the limited selection of sections of the Building Decree.

One might anticipate that the fire safety classification of buildings would clearly relate to fire-fighting equipment and the time it would take to evacuate the building, but there is considerable variation in the classification of buildings by height. The upper limit of the first safety class varies from 4.5m in England and Wales, to 28m in France. There is similar variation in the highest safety class, with tall buildings classified either directly (for instance in France, as buildings over 50m tall), or by implication (for instance in Sweden, as buildings with three or more storeys). In Belgium, the only classification of buildings is by height, with differing requirements for low, medium and tall buildings.

3. Comparisons of levels of requirement for fire safety in different countries

The BD includes four fire safety strategies that are common to all, or almost all, of the countries studied:

- stability in case of fire (fire resistance of structure)
- limitation of spread of fire (compartmentation)
- escape routes
- limitation of the development of fire (spread of flame, characteristics of internal and external surfaces)

It includes one issue that is only addressed by two other countries for general needs housing:

- fire or smoke detectors and alarms

Some countries have requirements to limit the spread of smoke, but none uses the same strategy as the Building Decree:

- limitation of spread of smoke (smoke compartmentation)

None of the other countries includes requirements for:

- limitation of development of smoke (density of smoke production of internal surfaces).

There is considerable similarity between countries in the four primary strategies, but there is variation in levels of requirements, as well as in the description and detail of requirements.

Variation in levels of requirements. There are some notable differences in the application and levels of requirements for fire safety. The lack of any requirements for single-family houses in Belgium is probably easiest to understand as a political, non-interventionist policy. Similarly, the Netherlands no longer controls the fire resistance of doors on escape routes, as the result of a Market Forces, Deregulation and Legislative Quality (MDW) inquiry which decided that performance requirements for fire safety were too rigorous.

It is more difficult to understand why levels of requirements should vary. For instance, each country specifies periods of fire resistance to protect the **stability of elements of structure**. There is usually no difference between levels of requirements for walls and floors, but there are varying levels of requirements related to height, except in France and Norway. Presumably, periods of fire resistance are calculated to provide sufficient time for escape and fire-fighting, or based on empirical study. It would be interesting to know – but probably impossible to discover - why France has lower levels of requirements than other countries for both single family houses and blocks of flats. Equally, it would be interesting to discover whether there is any correlation between the rate of death and injury in fires and the levels of requirements for fire resistance.

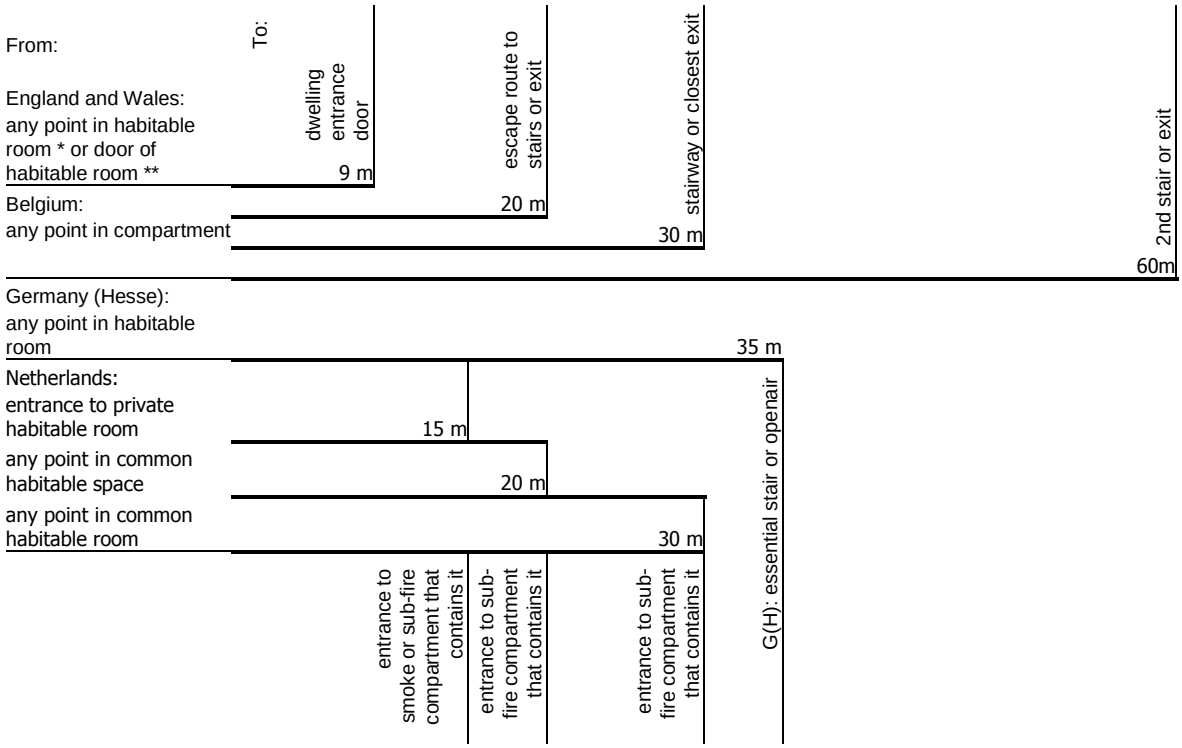
Compartmentation is a strategy to limit the spread of fire by containment within fire resisting walls and floors. Each country, apart from France and Germany (Hesse) has some requirements for the compartmentation of residential buildings, but only the Netherlands uses the additional concepts of 'sub-fire compartments' and 'smoke compartments.' In practice, the strategic requirements in the Netherlands are similar to those in Denmark, England and Wales, Norway and Sweden, where each self-contained dwelling, whether it is a house or a flat, must form a fire compartment. In theory, this would allow one flat to be occupied, even if there was a fire in a neighbouring flat. Where each flat must form a compartment, the wall between flats and the escape route protects the escape route from a fire that starts in a flat, but the degree of protection varies: for instance, in the Netherlands the entrance door to a flat need not be self-closing, unlike other countries. There are no specific requirements for the compartmentation of individual flats in Belgium and neither France, or Germany (Hesse) uses the term 'compartmentation' in relation to dwellings. Although France and Germany (Hesse) have requirements for the fire resistance of walls and floors between flats, this is not equivalent to compartmentation because they appear not to control the fire resistance of entrance doors to flats. Compartmentation or fire-resisting construction is required to separate the functions in mixed use buildings, and in this situation France requires fire resistant doors between occupancies, but there is no specific mention of this issue in Belgium, Denmark, and Norway. It is common to require the separation of basements from other parts of the building, by means of a fire-resisting floor and a door to separate basement escape stairs and stairs from upper storeys, but this is not usually described as compartmentation.

The greatest diversity in strategies lies in the **provision of means of escape**. Although there are some requirements for two independent escape routes, several countries allow rescue as a second route, and all allow a single escape route in various circumstances. The only absolute requirements for two independent escape routes are for tall buildings, in Belgium (buildings with floor of top storey > 25 m), and Denmark (lower edge of rescue opening > 23 m). In France, a second stairway is optional even in category 4 buildings (top floor 28-50m). Relaxations allowing alternative routes are usually related to the height of buildings, but some are also related to the protection of stairways or to travel distances. Rescue is allowed as an alternative route from dwellings in blocks of flats, in Denmark, France, Germany (Hesse), Norway, and Sweden. None of the countries requires a protected escape route from upper storey bedrooms in two-storey houses. There is no explicit mention of the situation when a fire starts (or is started) in the hallway of a dwelling, or a corridor outside a dwelling, so that the first stage of escape is blocked. Indeed, in Denmark and France there are no controls on escape from within dwellings. There are requirements in England and Wales for the protection of hallways within dwellings by fire-resisting room doors, but this strategy is intended to allow long internal travel distances, rather than protect the rooms within the flat. However, the provision of alternative exits via windows, balconies or doors to escape routes distant from the entrance, could provide a safe escape from such a fire.

The issues of **maximum travel distances**, and the number and location of exits are common to most countries, but expressed quite differently. The requirements are probably mostly clearly explained in England and Wales, where diagrams are used to demonstrate various conditions. Each country limits horizontal travel distances in common escape routes, but only Belgium, England and Wales, Germany (Hesse), and the Netherlands address travel within flats or maisonettes. Comparisons require particular care because different start or finish points are described, and there are qualifying conditions for some of the requirements (see Figure 3).

Limits on travel distances from dwelling entrances to a stairway fall into two categories: relatively short distances which seem to relate to blocks with a single, central stairway, and much longer distances for corridor or balcony access. The lowest standard is in Sweden, which has a single recommendation, 30m.

The requirements for **smoke alarms** in England and Wales, the Netherlands, and Norway may be seen as enhancements to a generally low standard. However, in the Netherlands, an escape route may pass through a living room if an additional alarm is provided, instead of through a separate circulation route, which is clearly a lower level of requirement.



* If hallway protected by 30 minute fire-resisting construction, self-closing FD20 fire doors. ** If cooking facilities are remote from entrance and do not prejudice escape route. Both apply only to flats with a floor > 4.5m above ground level

Fig. 3 Differences in description of travel distances from within dwellings in blocks of flats or maisonettes

Each country limits **characteristics of internal surfaces** of stairways or escape routes, in terms of surface spread of flame and rate of heat emission when burning. Some also have requirements for rooms. There are more requirements for ceilings and walls than for floors. It is not possible to compare the specified levels of requirements, due to the different testing and classification systems. Although England and Wales states that the upper surfaces of floors and stairs "do not play an important part in fire spread in the early stages of a fire that are most relevant to the safety of occupants," each of the other countries has requirements for floor surfaces, at least in escape routes. Only the Netherlands limits the rate of smoke production of surfaces. Only Denmark and England and Wales have requirements for the internal surfaces of private areas of single family housing.

All countries have some limitations on **characteristics of external surfaces** of façades, but there is considerable variation in the scope of requirements. Some distinguish different levels of requirements for parts of façades related to: the height of the façade; the height of buildings; the distance of the façade from a boundary; or the classification of the building. There are few requirements to limit the vertical spread of flame between storeys. Norway is alone in allowing reduced levels of requirements for external surfaces related to access for fire services. The Netherlands is unusual in differentiating between external surfaces on certain categories of escape routes and other parts of the building. Other countries do not deal with the protection of buildings *from* neighbouring buildings. Differences in classification systems and reliance on secondary sources to explain such systems make it difficult to compare levels of requirements

for characteristics of external surfaces. The analysis did not discuss limits on the size or location of unprotected areas of façades, such as windows, because there are no requirements in the Building Decree, but this is clearly a significant strategy in some countries, including Denmark, and England and Wales. Also, we were not asked to analyse the section that contains requirements for external spread via roofs.

The comparative analysis encountered relatively few requirements specific to **tall buildings**. In part, this was because the research contract did not require the analysis of requirements for fire fighting, which are likely to include provision of access for fire-fighters and fire-fighting stairs, lifts, or water supply points in tall buildings. It also appears that very little special provision is made for tall buildings in the Netherlands: apart from 'smoke compartment' protection of stairways in buildings with a floor over 50m, the Building Decree section on high buildings only refers to the performance requirements that apply to lower buildings (sections 2.11 to 2.21). In the documentation studied, only Belgium, England and Wales, and France specified higher levels of requirements for the fire resistance of elements of structure and compartments in tall buildings, such as 15 storey blocks of flats (see Table 1). France has consistently lower levels of requirements for fire resistance than other countries, at all heights, but it has separate legislation for buildings over 50m tall, which was not analysed.

None of the fire safety regulations addressed the issue of **explosions or catastrophic collisions**, but this may be considered in requirements for structure, and a comparative analysis should be made of provisions concerning disproportionate collapse.

Emphases peculiar to one country. Despite the independent development of fire safety regulations, there are very few instances of emphases peculiar to only one country. However, these few examples raise some interesting questions. For instance, the predominance of single family houses in England and Wales, coupled with the age of the housing stock, probably explains the inclusion of a section on attic conversions, but it isn't clear why there is no explicit mention of the issue in other countries. It may be that escape within a dwelling from a third storey room is not perceived as a particular risk, or because it is not politically acceptable to control the interiors of single-family houses, except where they affect their neighbours.

Of the countries studied, only the Netherlands controls the smoke production of internal surfaces, particularly the walls and ceilings of escape routes. Other countries do not address the limitation of smoke production but requirements to limit spread of flame would often serve the same purpose, with the use of materials of limited combustibility. The primary strategy in most countries is to keep escape routes clear of smoke, by limiting the ingress of smoke with smoke control doors and smoke ventilation.

The Netherlands appears to be unique in specifying the sub-division of fire compartments into smoke compartments, but apart from specifying periods of resistance to smoke leakage between smoke compartments and enclosed rooms, details are given by reference to a national standard. It is not possible to tell from the Building Decree whether there is a significant difference between the practical implementation of its requirements for smoke compartmentation and requirements in some other countries to limit smoke leakage at doorways or for fire dampers operated by smoke detectors. In contrast to the Netherlands, Belgium only addresses the issues of fire and not smoke, to the extent that the word 'smoke' does not appear in the annexes giving the requirements.

Instead of requirements for the fire resistance of doors on escape routes, the Netherlands requires mains-wired smoke alarms. It seems peculiar to prejudice the success of sub-fire compartmentation and smoke compartmentation and it is difficult to support the argument that early warning is an appropriate substitute.

4. Harmonisation of fire regulations in Europe

CEN completed approval of a harmonised system to classify the reaction to fire performance of construction products in 2002, but there is no harmonisation of the description of fire safety strategies. The project revealed considerable variation in strategies, tactics, and terminology, which indicates that the formulation of a model European building code for fire safety is a distant but worthwhile ambition. Potential difficulties in international working caused by the lack of harmonisation were mirrored in the difficulties of comparative analysis. Without a common framework of strategies and tactics, it was difficult to confirm the

absence of requirements, and without common terminology or criteria, it was difficult to compare levels of requirements.

Important issues for harmonisation include the classification of buildings and the description of parts of buildings, which are used to describe the application of requirements. The generic description of spaces that is found in the Dutch Building Decree is probably unhelpful in practice, and it should be possible, in a code describing requirements for housing and for mixed use buildings, to establish common terminology in a series of annotated diagrams of typical configurations of blocks of flats, or single-family houses, without threatening the independence of designers or opportunities for innovation.

Table 1 Example of the tabulation of requirements: Comparison of minimum periods of fire resistance or fire retardance, vertical load-bearing elements of structure

	Single-family house	**Blocks of flats**		
	2 storeys	**3 storeys**	**8 storeys**	**15 storeys**
Belgium *AR du 07-07-1994* modified by *AR du 19-12-1997*	— (no requirements for single-family dwellings)	60 (BB top floor < 10m)	60 120 in basements (BM top floor 10-25m)	120 (BE top floor > 25m)
	KEY: BB: batîments bas < 10m (low buildings); BM: batîments moyens 10-25m (medium height buildings); BE: batîments élevés > 25m (tall buildings).			
Denmark *Building Regs. for Small Dwellings BR-S 98* (1998); *Building Regs.* (1995)	BD 30 (fire retarding)	BS 60 (load-bearing structures up to top floor, with top storey floor ≤ 12m)	BS 60 (top 12m) BS 120 (load-bearing structure, storeys supporting top 12m)	
	KEY: BD: fire–retardant; BS: fire-resistant			
England and Wales *Approved Document Part B Fire Safety* (2000)	30 60 (walls separating buildings) (ground, upper storeys; with top floor ≤ 5m)	60 (ground, upper storeys; with top floor ≤ 18m)	90 (ground, upper storeys; with top floor ≤ 30m);	120 (ground, upper storeys; with top floor > 30m);
		60 (basement < 10m), 90 (basement > 10m)		
France *Arrêté du 31.1.1986*	15 (category 1)	30 (category 2)	60 (category 3)	90 (category 4)
	KEY: *Category 1:* ≤ 2 storey detached houses, semi-detached houses, terraced houses with independent structure; 1 storey terraced houses; *Category 2:* > 2 storey detached, semi-detached or terraced houses with independent structure, 2 storey terraced houses without independent structure, ≤ 4 storey blocks of flats or 5 storey if top floor in duplex accessed at 4th storey; *Category 3:* Lowest floor of highest dwelling ≤ 28m, accessible to rescue and fire fighting appliances; *Category 4:* Buildings with lowest floor of highest dwelling 28-50 m above ground; accessible to rescue and fire fighting appliances; access to protected stairs max 50m from appliance route.			
Germany Hesse *Hessische Bauordnung* (1993, amended 1994)	— (no requirements for categories A, B)	F30-A or F60-B (category E)	F90-B (category G)	more stringent requirements may be applied (buildings with storeys > 22m)
	KEY: Materials: - A: non-combustible; -B: combustible. F30, F90: fire-retardant; F90: fire-resistant. Building categories: A: detached residential building, weekend or holiday house, containing maximum 2 dwellings, usually ≤ 2 floors; B: residential building, weekend or holiday house, not class A, containing maximum 3 dwellings, ≤ 5.85m height of highest storey; C: other buildings with habitable rooms, not class A, ≤ 5.85m; D: residential building, weekend or holiday house, not class A or B, containing maximum 6 dwellings, ≤ 7m; E: Building, not class A-D, ≤ 7m; F: Building, not class A-E, ≤ 14m; G: Building, not class A-F, ≤ 22m. NB: 2002 revision does not specify periods of fire resistance and uses slightly different building classes.			
Netherlands *Bouwbesluit* 2001	30	60	90	
Norway *Guidebook to the Technical Regulations* (1997, amended 1999)	R 30 (fire class 1)	R 60 (fire class 2; including 1st basement)	R 90 (fire class 3; including 1st basement)	
	KEY: R: fire resistance for loadbearing capacity. Fire classes are based on the potential consequences of a fire, in terms of life, health, community interests and environment: fire class 1: minor consequences; fire class 2: medium consequences; fire class 3: serious consequences; fire class 4: very serious consequences			
Sweden *Boverkets Byggregler (BBR-94: 3) BFS 1993:57* (1997)	R 15 (class Br3)	R 60 (class BR1, ≤ 4 storeys; including topmost basement)	R 90 ($f \leq 200$ MJ/m^2) (class Br1; including topmost basement)	
	KEY: R: fire resistance for loadbearing capacity. f = fire load intensity. Building classes: *Class Br1:* buildings where a fire entails a high risk of injury to people (general recommendations suggest this means buildings of ≥ 3 storeys); *Class Br2:* moderate risk of injury (2-storey buildings for > 2 apartments, with habitable rooms or workrooms on the attic storey; *Class Br3:* other buildings (other dwellings).			

It would also be helpful to specify the assumptions and constraints that underlie strategies and to describe the relationships, inter-dependencies, or equivalences of certain strategies. This is probably the most difficult aspect of harmonisation, for it may call into question the advisability of certain policies. For instance, it is questionable whether one escape route plus the alternative of rescue through a window is always less

safe than two escape routes, or whether the Dutch specification of smoke detectors compensates, as intended, for the absence of requirements for the fire resistance doors on escape routes.

This paper has emphasised the difficulty in comparative analysis that arises from the Building Decree's abstraction, specialised terminology, and structure, but it is only fair to point out that it is used successfully by the Dutch construction industry. Instead of official guidance on measures to satisfy the requirements, in the manner of the *Approved Documents* in England and Wales or the *Guidebook to the Technical Regulations* in Norway, interpretation is offered by Stichting Bouwresearch (SBR), an organisation sponsored by partners in the construction industry which acts as an intermediary between government and practice. SBR publishes guidance documents and runs training courses, unfortunately only in Dutch (see www.sbr.nl), so that it appears that the formulation of the Building Decree is only problematic in practice for non-Dutch speakers and newcomers to the Dutch construction industry. However, the difference in approach between the Building Decree and approaches in other countries might well present problems for harmonisation. Although juridical in format, it has the liberal intent of avoiding prescription in design and promoting the innovative use of materials, whilst establishing minimum levels of requirements and methods of calculation. It does not tie itself to existing design solutions and this results in specialised terminology and avoidance of detailed official guidance. Other countries with performance-based requirements have a similar intent, but do not ally themselves to a similar degree of abstraction. It seems unlikely that the process of harmonisation would accept that design freedom is imperilled by using the expression 'kitchen or kitchen area' instead of 'communal [habitable] room with an installation point for a cooking appliance,' particularly when this is translated in the Building Decree's own explanatory notes as 'kitchen.' A wider issue is the advisability of reliance on specialist advice or an induction process in order to understand legislation.

5. Conclusions

The project continued the development of a methodology of comparative analysis (Sheridan, 2001), but highlighted the difficulties of an analysis structured around the requirements of a single country. Also the selection of topics, specified by the research contract, limited the scope of the analysis and risked an incomplete view of the inter-relationship of strategies. There are differences in the regulation of fire safety between the countries studied, which made it difficult to compare levels of requirements, but the project identified some significant differences in strategies and differing levels of requirements.

The process of comparative analysis revealed that some systems were easier to use than others. The formulation of regulations as brief functional requirements elaborated by official guidance, and available on-line (as exemplified in England and Wales, and Norway) means that the principle requirements for fire safety in housing are freely available and can be readily understood from the official guidance. This contrasts with less accessible systems of functional requirements which rely on secondary sources for detailed interpretation, whereby instead of consulting a single document, designers and contractors must buy national standards or independent guidance, or rely on consultants.

Apart from tests for characteristics of construction products, there is no harmonisation of fire safety requirements in Europe. There is a clear need for the harmonisation of terminology to describe the context for application of requirements, and of the strategies and tactics of fire safety.

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