Fire safety of high-rise residential buildings: scope of fire engineering and comparison between UK and Turkish Practice

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ABSTRACT: The main aim of this paper is to promote the practice of performance based fire engineering in achieving fire safety of buildings. Using case studies of high-rise residential buildings designed according to the UK practice of fire safety, this paper explains how the fire engineering practice decisions are made and illustrates the benefits of using a performance based fire engineering approach to achieve fire safety in buildings. Through a comparison between aspects of the UK and Turkish regulations and practices for fire safety, this paper identifies some scopes why introduction of a fire engineering approach would be beneficial. Modern fire safety design in the UK has undergone a long period of development to have now reached a stage where performance based fire engineering is widely accepted as an alternative method to the traditional, prescriptive, approach to fire safety. The paper will point out preparatory work necessary to enable a fire engineering approach to be introduced and implemented in Turkey.

1 INTRODUCTION

While fire safety is a universal requirement of building design and construction, the practice of meeting this requirement is different in different countries. In almost every country, there is a set of prescriptive rules that prescribe, or dictate, what the different aspects of buildings, including their layout, their use of materials and structures, their fire precaution measures and their provision of facilities for firefighting, should be. A building is "deemed" to have achieved fire safety if its design and construction comply with these rules. In countries where these prescriptive rules are the only rules, deviation from these rules is not allowed, even though strict adherence to these rules may lead to a building that is costly, restrictive in its functions, and with an unknown degree of safety.

The availability of guidance documents which specify a prescribed route to code-compliance is of great use to the construction industry as it allows for a measure of certainty when proposing new schemes for approval and also for being able to implement previously approved 'off-the-shelf' developments in different locations within the same jurisdiction.

However, although an extensive body of guidance exists for reference when designing a building in accordance with the Regulations, it is recognised that such guidance cannot address every specific design solution that may be devised for a particular scheme. In particular, if followed to the letter, the impact would be a less diverse building stock with less innovation in architectural design – particularly for high profile projects for which the architectural concept may include features not envisaged at the time the guidance to the regulations was devised. Sometimes such features may potentially offer a life-safety improvement over existing design solutions in certain circumstances but lack the necessary legislative approval or approved guidance documents. An example of this in the UK may be the recent development of water misting systems as an alternative to traditional sprinkler systems, a design solution which has been offered commercially for several years but for which formal British Standards are only recently being published.

Furthermore, amendments to legislation and guidance documents are regularly made, but the consultation and implementation process may, of necessity, lag behind developments in construction techniques and technology.

Recognising the limitations of the prescriptive approach, the UK allows fire safety designers to choose alternative methods to achieve fire safety. In this method, the requirements of fire safety are clearly articulated and quantitative methods, based on engineering principles, are used to verify that the fire safety requirements are satisfied. This alternative approach is termed "performance based fire safety engineering". For example, instead of specifying the maximum distance of travel permitted in the building as in the prescriptive method, in the fire safety engineering approach, it is recognised that travel distance is one element of means of escape of the building occupants to safety. Therefore, in the fire engineering approach, if it can be proved that the Available Safe Escape Time (ASET) is greater than the Required Safe Escape Time (RSET), with an appropriate degree of safety, the means of escape requirement is satisfied, regardless of the maximum travel distance. Since RSET includes a number of components of time, of which the time taken for the building occupants to travel from the point of fire to a place of safety is one component, other features of the RSET, e.g. fire detection and alarm, can be shortened and ASET can be increased (e.g. by smoke extraction), to allow for a longer travel distance.

This framework is formally enabled by a clause in the UK's Building Regulations (Approved Documents B for Fire Safety on Fire Safety Engineering (FSE) where it states "Fire safety engineering can provide an alternative approach to fire safety. It may be the only practical way to achieve a satisfactory standard of fire safety in some large and complex buildings, and in buildings containing different uses, e.g. airport terminals. Fire safety engineering may also be suitable for solving a problem with an aspect of the building design which otherwise follows the provisions in this document."

It goes on further to say that "Some variation of the provisions set out in this document may also be appropriate where Part B applies to existing buildings, and particularly in buildings of special architectural or historic interest, where adherence to the guidance in this document might prove unduly restrictive. In such cases it would be appropriate to take into account a range of fire safety features, some of which are dealt with in this document, and some of which are not addressed in any detail, and to set these against an assessment of the hazard and risk peculiar to the particular case."

Taking into account the above there is a role for specialised consultancy in order to develop evidence-based justifications for reasonable deviations from the code-compliant design solutions in present published guidance.

It should be pointed out, as made clear in the statement above, that the FSE approach and the traditional prescriptive approach are not mutually exclusive. In almost all buildings, it is sensible to take a mixture of both approaches to take advantage of the benefits of the two different approaches. Invariably, the FSE approach will be more complex and requires more advanced knowledge, therefore, it should only be applied to replace the prescriptive approach where there are clear and significant benefits to be had, in terms of reducing the construction cost, improving flexibility or enhancing safety.

Obviously, adopting the FSE approach requires confidence in this approach and buy-in and competence of all those involved, in particular fire safety engineers and regulatory approvers. Confidence in this approach is demonstrated by large bodies of research over many years; buy-in of the approach can be ensured by demonstration of clear benefits of using FSE to key stakeholders such as developers; competency can be developed through publication of FSE standards, guidance, training and education.

The UK fire engineers are in a favourable position to be able to practice fire safety engineering. This paper will provide some details of implementation of this approach and identify some significant benefits of FSE to inspire others where FSE is not yet allowed. In particular, this paper will compare aspects of UK and Turkish practices to identify some scopes of adopting FSE in Turkey and the some of the specific and urgent tasks that should be completed to facilitate introduction of FSE in Turkey.

2 PRINCIPAL UK DESIGN STANDARDS AND GUIDANCE DOCUMENTS FOR FIRE SAFETY ENGINEERING

To support FSE practice, a large number of regulatory documents, design standards and guidance are available in the UK. The following is a summary of the main documents and their main functions. Wherever available, the Turkish documents are mapped to give a comparison between the practices of the two countries.

2.1 *Guidance documents in the UK*

Building Regulations in England and Wales (in terms of fire) require reasonable standards of fire safety for proposed new buildings and those buildings subject to material alteration for the health and safety of persons in or about the building.

The Regulations are written in functional terms, expressed in terms of what is, for example, reasonable, appropriate and acceptable.

Schedule 1 and Regulation 7 of the Regulations determine the five categories to be addressed in terms of fire safety:

(B1) Means of warning and escape, (B2) Internal fire spread (linings), (B3) Internal fire spread (structure), (B4) External fire spread, (B5) Access and facilities for the fire service

Code compliance against the above categories is achieved by interpreting the building design against Approved Documents / Codes of Practice such as:

• Prescriptive method: Approved Document B Fire Safety (ADB).

• Prescriptive method with some input of established FSE solutions: BS 9999 (or similar specialised standards for particular occupancy types such as BS 9991 for residential buildings which is based on fire engineering principles, but offers defined limits on design)

• FSE method: BS 7974 (and/or other engineering guides such as the SFPE Handbook) – Purely fire-engineered approach which may be used to supplement the code-based approach

Further to the above, many buildings are also subject to the Regulatory Reform (Fire Safety) Order 2005 (previously described).

Internationally there are other alternatives to the above which are accepted locally, for example the NFPA suite of documents, which is the general standard in North and Central America.

Both the NFPA and above-mentioned UK codes set out clear guidance which comment on acceptable limitations to design (for example, the maximum permissible distances which occupants may travel to an exit in a building) but also acknowledge that it may be appropriate to approve a building design based on engineered analysis which demonstrates ‘equivalence’ with the functional requirement of the Regulations.

2.2 *Building Regulations in Turkey*

The building regulations related to fire safety is in Turkey’s Regulation on Fire Protection, which is revised every 5 or 6 years. It is allowable in Turkey to follow the ISO and CEN Standards, however, Turkey’s Regulation on Fire Protection generally overrules these Standards if similar requirements exist even if the Regulation leads to a more costly construction. Therefore, European codes are used only when specific fire safety requirement cannot be found in Turkey’s Regulation on Fire Protection. The regulation covers both new buildings and existing buildings, where the rules are significantly relaxed.

The Turkish regulation consists of 12 chapters, namely:
1- General provisions, occupation and hazard classification of buildings
2- General provisions on fire safety of buildings
3- Escape, escape stairs and special cases
4- Regulations related to building sections and facilities
5- Electrical installation and systems
6- Smoke control systems
7- Fire extinguishing systems
8- Storage and use of dangerous substances
9- Fire safety responsibility, teams, training, control, collaboration, funds and internal regulations
10- Provisions applicable to existing buildings
11- Historical buildings
12- Fire provisions

Although organised differently, these chapters can be mapped to the five general categories addressed in the UK Regulation (ADB):

(B1) Means of warning and escape:

- (3) Escape, escape stairs and special cases
- (5) Electrical installation and systems

(B2) Internal fire spread (linings):

- (2) General provisions on fire safety of buildings

(B3) Internal fire spread (structure):

- (2) General provisions on fire safety of buildings
- (5) Electrical installation and systems

(B4) External fire spread:

- (2) General provisions on fire safety of buildings

(B5) Access and facilities for the fire service:

- (2) General provisions on fire safety of buildings
- (9) Fire safety responsibility, teams, training, control, collaboration, funds and internal regulations
- (7) Fire extinguishing systems

The other chapters, which cannot be directly mapped to the 5 general categories, either are general provisions (e.g. 1), or specific detailed guidance for special fire risks (e.g. 8 storage and use of dangerous substances, 11 historical structures), or detailed product standards (e.g. 6 smoke control systems, 7 fire extinguishing systems) which would be provided elsewhere in the UK system.

3 CASE STUDY – RESIDENTIAL TOWER BUILDINGS, SALFORD, GREATER MANCHESTER

A recent project undertaken by Exova Warringtonfire concerned a pair of residential towers in Salford, Greater Manchester which are currently (2016) under construction. The towers proposed are 10 and 15 storeys in height respectively but in terms of internal floorplate are largely similar, characterised by a single stair with flats accessed from a common corridor. Figure 1 shows a sketch of the floor plan. The fire strategy for both blocks was developed to BS 9991 (2015), referred to as the 'code' below. Figure 2 indicates how the same building would be constructed in Turkey.

The comparison of both Figures suggests that UK fire code requires fire protection on flats since the evacuation in residential buildings follows a 'stay-in-place' strategy. In Turkish regulation, 'simultaneous evacuation' strategy is assumed and hence, two fire-protected stairs (one with a fire safety hall) are required. Further, FSE approach in the UK allows an extended corridor with mechanical ventilation whereas in Turkey, such approach is not allowed and generally not necessary since the required two stairs already allow sufficient travel distance. Lastly, UK code seems to be less stringent on fire and elevator doors.

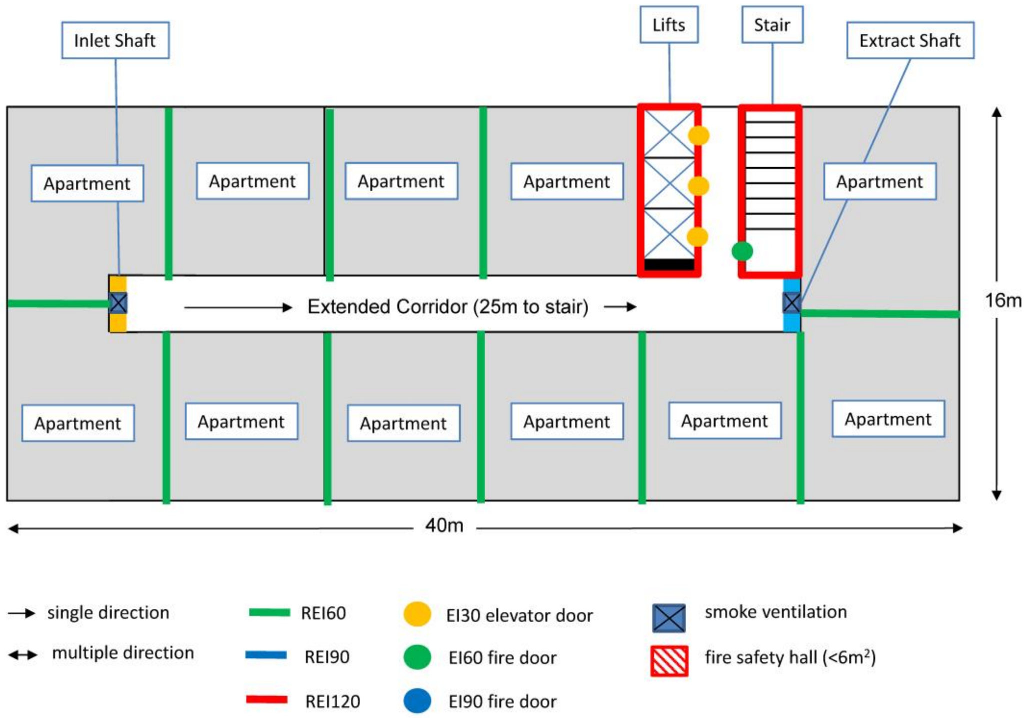

Figure 1: Fire safety concept for a residential building (height > 30m) in the UK.

3.1 *Fire safety design according to the UK Code*

The key features with regard to fire safety provision for these buildings relate to the provision of sprinkler protection to the flats and protection from smoke of the common corridor. The single stair access to each floor of the building requires robust fire safety provisions due to this being the only escape route for occupants and approach route for the fire service.

The requirement for sprinklers stems from the top floor of the building being more than 30m above ground level. Above this height the code does not permit unsprinklered buildings. However, the provision of sprinklers may also be used as a benefit when considering other design features. For example, the presence of sprinklers permits in principle an open-plan design to the flats (individual flats are still fire separated from one another) which in turn can allow an increase in liveable area, making the property more attractive to market. A corollary of providing sprinklers is therefore that taller buildings can be approved, increasing the number of flats in this case which may be put to market.

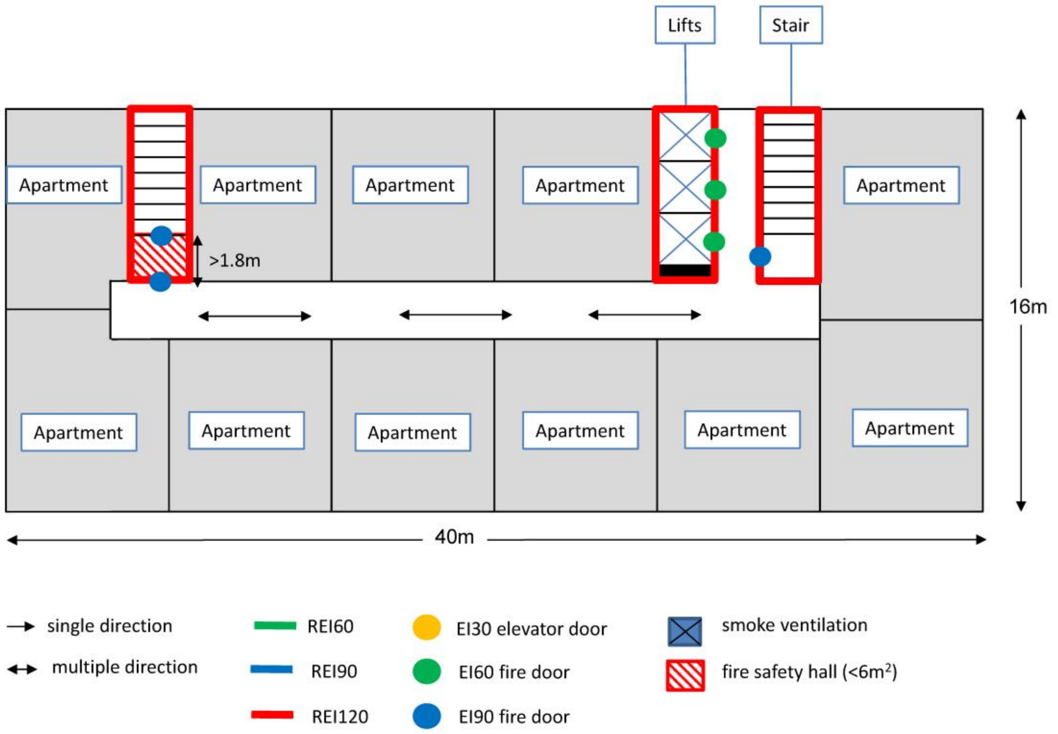

Figure 2: Fire safety concept for a residential building (height > 30m) in Turkey.

Within these buildings a domestic sprinkler installation to BS 9251 was justified, subject to adequate water supply being demonstrated in line with the standard. The adoption of this standard rather than BS EN 12845 is advantageous in that it allows features such as concealed sprinkler heads (which reduce the risk of tampering or damage in a residential occupancy). In addition a single power supply is acceptable and mains water may be used (in addition to a sufficient stored volume).

Further fire engineering features related to the degree of structural fire protection (which also impacts on floor compartmentation). The basic requirement from BS 9991 would be for a 120 minute period of fire resistance to the structure, but this may be reduced to 90 minutes by taking account of potential ventilation to the flats and the fire by breaking of glazing or other fixed openings. This is based on tabulated guidance in BS 9991 which takes account of the time-equivalent approach set out in BS EN 1991-1-2 (and the Background Paper to the UK National Annex of this Eurocode, PD 6688-1-2). In brief, this is a parametric expression for post-flashover fires which considers factors such as fire load density, ventilation, thermal properties of the enclosure and compartment geometry. Therefore although detailed fire engineering calculations are referenced by BS 9991, the designer is not required to undertake such calculations.

A further element of the design for which fire engineering input was required was for the extended corridor access to the flats from the single stair. On each floor there are typically 9 flats arranged such that the distance from the storey exit to the furthest flat is of the order of 24m.

This is over the general single direction travel distance of 15m (for sprinklered buildings, 7.5m if unsprinkered) set out in BS 9991 for corridor access to flats in single stair buildings over 11m tall (by contrast for multi-stair sprinklered residential buildings the upper travel distance limit is 60m where there are two directions of escape, noting that there is also a requirement for hose coverage from a firefighting shaft of 60m for buildings of this height).

However BS 9991 does recognise that extended corridors are possible if additional features such as a smoke control system are installed to the corridor, the key criteria being to demonstrate that tenable conditions are achieved in the corridor for occupants using the escape route. For this particular project an 'off-the-shelf' system was installed for which validation has previously been achieved in generic extended corridor geometry. This system relies on a shaft at one end of the corridor through which air / smoke is extracted mechanically with inlet air provided from another shaft at the opposite end of the corridor, to prevent dead spots where smoke could pool and to ensure the system is balanced. The extract and openings to the shafts are activated upon a smoke detection within the corridor and operate only on the floor of fire origin.

Should such an analysis be required to be carried out from scratch a common tool would be to undertake a smoke modelling analysis, typically using Computational Fluid Dynamics (CFD) software. The procedure would be to carry out a Qualitative Design Review (QDR) between the design team, fire consultant and Regulatory Authority to pre-agree the acceptance criteria for the analysis. The criteria relate to showing that the system can clear smoke within the corridor to tenable limits either within a defined time period or to compare it to a similar 'code-compliant' corridor with natural ventilation to show that the proposed system is superior.
This not only reduces the level of risk to the project approval but also helps speed up the review process. The tenability criteria are usually drawn from an agreed standard (for example PD 7974-6) and are expressed in terms of acceptable ranges for smoke visibility, temperature and CO exposure. Discussion may also be held concerning the CFD program used, the input parameters such as fire growth and soot yield, and parameters which would influence the amount of smoke entering the corridor (for example the time period at and for which the flat door is considered to open and close). Typically, a range of parametrical studies is then undertaken to determine the extract rate required to clear smoke or maintain a tenable layer for an agreed time period. Alternatively the basis of comparison may be a 'like-for-like' study compared to a nominal code-compliant corridor. The outcome is beneficial to the design team as primarily it helps justify a larger building with a single stair (thus increasing the amount of floor plate which can be given over to flats) which can make a project more commercially viable than it otherwise would be.

For residential buildings in the UK the presumption is that in the event of a fire only the occupants of the flat in which the fire is located will evacuate with other occupants being considered to 'remain in place'. This is supported by robust requirements in the code for fire resisting construction between individual flats and the rest of the building. The walls between flats, and floors above and below which separate flats are all required to be 'compartmented' to a 60 minute standard in the former case and a 90 minute standard in the latter. In addition for buildings over 18m in height, the stair and lift enclosure should be designed as a 'fire-fighting' shaft, which requires 120 minute fire rated enclosure.

In contrast, in Turkey, dwellings have no limitation in fire compartmentation (i.e. unlimited m2). Therefore, there is no requirement on fire resistance in the walls between flats. However, it is generally assumed that the separating brick walls between flats have more than 30 minute fire resistance. According to the Code, the fire resistance period for apartments is 120 minute with building height (above ground) above 30.5m. All compartment walls, floors, all load-bearing columns, beams and walls must be fire-rated. The walls separating the protected stairwell for escape from the rest of the building shall have 120 minute fire rating. Within the protected stairwells, the walls between the elevators, fire safety hall and escape stairs shall be 60 minute fire rated. Relevant fire resistance requirements are indicated in Figure 2 which can be contrasted with the UK requirements show in Figure 1.

3.2 *General BS9999 type Approach and a Comparison with Turkish Regulations*

The above case study illustrates the benefits of FSE and the process of making FSE decisions. Since FSE is not practised in Turkey, it is not possible to compare the UK and Turkish practices. However, In recent years (since 2008), there has been a move in the UK towards development of guidance documents which, although prescriptive, are derived from fire-engineering analysis and permit beneficial variations in guidance subject to assessment and mitigation of the fire risk and consequence in a building. Examples of such documents are BS 9999 (2008) and BS 9991 (2015). As a first step in introducing FSE in Turkey, it is beneficial to make a comparison between the UK practice BS 9999 with relevant Turkish rules to identify possible easy benefits to be gained.

BS 9999 was developed from the BS 5588 suite of documents which originated in 1970 and were subsequently developed and expanded. The development of BS 9999 was intended to consolidate duplication within the different parts of BS 5588, provide a more focused approach and also take account of more recent developments in fire engineering. BS 9999 is intended for use by Designers and Enforcers alike.

The document gives a more flexible approach to fire safety design through the use of a structured risk-based approach where designers can take account of varying factors (both design and human). While it is based on basic fire safety engineering principles it is not a guide to fire engineering. The design principles are based on ‘risk’ associated with ‘time’, and the quality and level of management of fire safety and building maintenance is a critical feature.

As an example of how the ‘risk’ based approach of BS 9999 can be applied to a building, by contrast with the more prescriptive approach of Approved Document B, a brief example may be illustrated. They are compared with the Turkish practice.

Consider a new-build office block of five floors (including ground) with a height to top floor of 15m. The office has a relatively large floor plate of 1300m2 per floor. From BS 9999 the ‘risk profile’ may be classed as ‘A2’. This is derived from considering that occupants will be ‘awake and familiar’ with the building (occupancy classification ‘A’) and that the contents are such that a medium growth rate fire may be considered (fire growth category ‘2’). There are similar other categories associated with different occupancy types (for example a premises where occupants may sleep). According to Turkish regulations, although some building types (e.g. industrial buildings) are categorized as low, medium and high risk, residential buildings are categorized only as “Moderate Risk -1” in Appendix 1B.

Under this risk profile designation, BS 9999 gives a range of minimum provisions which must be provided or adhered to, including recommendations for estimation of occupancy numbers. With different provisions, the building design requirements from the Approved Document B can be relaxed to different degrees. Table 1 summarises relevant building design requirements according to ADB, and relaxed provisions in BS 9999 based on different fire precaution provisions. Even though BS 9999 is prescriptive, the different options give some flexibility in design, for example permitting greater travel distances and a higher occupancy which might be important to the architect.

There are limitations to the above, for example the travel distance of 75m for escape in two directions is in practice limited to 60m due to requirements for hose distances from firefighting shafts, however it may be seen that there is a degree of flexibility to the designer which might be considered beneficial to a particular building design and which therefore could be used in principal to justify higher occupancy figures or similar benefits.

As described above, a comparative exercise is made below for high-rise residential buildings (assuming in this case that each apartment is a single-level (not duplex). Here the relevant British Standard is BS 9991 rather than BS 9999 (though BS 9999 may be used).

It may therefore be seen that although BS 9999 is a complex document it does not require fire safety engineering knowledge to use it. For certain projects it is therefore a useful alternative to the more prescriptive Approved Document B and the more detailed fire engineering approach from first principles which might be achieved from following the guidance in the BS 7974 suite of documents.

- A brief comparison of the provisions in Table 1 between UK and Turkey fire precautions can quickly identify the following FSE opportunities in Turkey for residential buidings: Reduced number of staircase and escape route (from 2 to 1)

- Reduced stair/exit width

- Reduced fire resistance rating for buildings not exceeding 30 m (from 90 to 60 minutes)

- Increased number of occupancy

However, the above benefits are offset by the necessity of providing fire resistance construction between individual flats.

4 PROSPECT OF ADOPTING FSE IN TURKEY

In Turkey, fire protection of buildings is controlled by municipalities not only at the architectural design stage but also at the stage of construction just before occupancy permit is issued. Industrial projects are controlled by the fire brigade departments of each city.

Turkey is an emerging country embarking on an extensive and long-term program of urban development. The construction boom in the last decade witnessed fast-track construction of many large-scale shopping centres and tall residences. However, recent tragic fire incidents in Turkey indicate inadequacy of the existing fire protection regulation system in Turkey in meeting the demands of special construction projects, and suggest a need for performance based Fire Safety Engineering (FSE).

To facilitate FSE in Turkey, a legal and regulatory environment allowing FSE must be created. Such a top-down approach will harmonize the contents of the regulation with the current technology, terminology and methodology to provide consistent solutions to the construction sector. The revised regulation must be compatible with national and harmonized international standards. As an example of standardization, the Turkish Standards Institute (TSE) is expected to prepare a new national standard for on-site inspection of fire doors. TSE is now seeking international practices and standards such as the NFPA 80 “Standard for Fire Doors and Other Opening Protectives” used in the U.S. This new Turkish national standard will also need to be in accordance with European standards, EN 16034 and EN 14351-1, which have recently been published for CE marking.

At the same time, a suite of education and certification programs must be initiated in order to raise the knowledge base and qualifications of fire protection practitioners, inspectors and local authorities. Such a bottom-up approach will ensure that the people who are responsible for the design, construction and operation of buildings have adequate knowledge and experience in passive and active fire precautions, evacuation models as well as human behavior. FSE consultants will need to be regularly assessed and re-certified, the process of which may be adopted from the U.S. licensed engineer system.

Service life inspections must be established in accordance with the revised regulation to ensure that the assumed performance of any measure of the project is met in the event of a fire throughout the life of the building.

5 CONCLUSIONS

This paper has outlined the approaches that may be taken in the UK to achieve fire safety of buildings, spanning the whole spectrum of “deemed to satisfy” to full “performance based fire safety engineering (FSE)”. It explains roles of the different stakeholders, in particular emphasizing on the role of fire engineering consultants, and outlines the guidance documents that are available. Using a high-rise residential building as example and comparing the UK and Turkish practices, this paper identifies FSE opportunities that are practiced in the UK that may be implemented in Turkey, including reduced number of staircase and escape route (from 2 to 1), reduced stair/exit width, reduced fire resistance rating for buildings not exceeding 30 m (from 90 to 60 minutes) and increased number of occupancy. On the other hand, fire resistant construction should be used for each individual apartment of the building in UK practice. Implementing FSE in a country where it is not permitted requires an enabling mechanism in the regulatory system and investment in expertise. This paper outlines how Turkey may approach this problem to exploit the benefits of FSE.

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Table 1 Comparison between Guidance Documents for High-Rise Residential Buildings

	Building Height *h*	**Approved Document B**	**BS 9991**	**Turkish Fire Code**
Occupancy	$h > 21.5$m	N/A[a]	N/A	< 50 persons[b]
Sprinklers	$21.5\text{m} < h < 30.5\text{m}$	NO (up to 30m)	NO (up to 30m)	NO
	$30.5\text{m} < h$	YES (> 30m)	YES (> 30m)	YES
Fire detection	$h > 51.5$m	YES (not dependent on building height)	YES (not dependent on building height)	YES
# of stairs	$21.5\text{m} < h < 30.5\text{m}$	1[c]	1	2 (1 fire-protected)
	$30.5\text{m} < h < 51.5\text{m}$	1[c]	1	2 (both fire-protected and 1 with fire safety hall or pressurized)
	$h > 51.5$m	1[c]	1	2 (both fire-protected and with fire safety hall and pressurized)
# of escape routes	$h > 21.5$m	1	1	2
Travel distance (single / multiple directions)	$h > 21.5$m	9m [d] / 30m [e] 7.5m [f] / 30m [e]	**No Sprinklers**	**No Sprinklers**
			9m [d] / 30m [e] 7.5m [f] / 30m [e]	15m / 30m
			Sprinklers	**Sprinklers**
			20m [g] / 60m [h] 15m [i] / 60m [h]	30m / 75m
Minimum exit width	$h > 21.5$m	800mm (based on AD M)	800mm	1200mm
Minimum stair width	$h > 21.5$m	1100mm [j]	1100mm [j]	1200mm
Fire resistance period	$21.5\text{m} < h < 30.5\text{m}$	90min (h ≤30m)	60min (h ≤30m)	90min
	$h > 30.5$m	120min (h >30m)	120min (h >30m)[k]	120min

[a] In UK guidance the assumption for evacuation from residential buildings is 'stay put', that is, only the apartment where the fire originates would be expected to evacuate due to the high level of compartmentation between flats and the protective measures to common escape routes. Occupancy is in practice limited by physical factors such as the maximum travel distances to exits, the number of exits and therefore the number of flats which can be adjusted into a building floorplan based on these constraints.

[b] no guidance is given but the occupancy per floor is assumed to be smaller than 50 persons.

[c] One staircase is permitted, but requires additional fire safety measures with increased building height

[d] 9 m within flat or within protected (30min) entrance hall

[e] 30m where more than one escape route from common areas

[f] 7.5m in common areas to protected lobby or stair for single stair building

[g] 20m within flat, also required LD1 Grade alarm system

[h] 60m where more than one escape route from common areas

[i] 15m in common areas to protected lobby or stair for building or for single direction escape

[j] width required is based on requirement for firefighting shaft

[k] may be reduced to 90 minutes for 30m < h ≤ 50m or 105 minutes for h > 50m subject to demonstrating a minimum level of natural ventilation provision (e.g. window breakage in fire condition