TÆC
Torero, Abecassis Empis and Cowlard

PHASE 2 GRENFELL TOWER: LONDON FIRE BRIGADE AND COMPLEX BUILDING FIRES – FURTHER CONSIDERATIONS ON THE PRESUMPTION OF TECHNICAL COMPETENCY

Prof. José L. Torero CEng, RPEQ, FREng, FRSE, FTSE, FIFE, FSFPE, FICE, FCI

15th August, 2021

EXECUTIVE SUMMARY

This is a second report written in response to instructions provided to me by the Chairman and is part of a wider set of reports. This report is specific to point (b) of my instructions

b. The correlation between fire safety provisions (and the fire safety strategy for Grenfell Tower) and (i) the adequacy of the London Fire Brigade's ("LFB") procedures for dealing with fires in high-rise buildings, including any applicable procedures if compartmentation fails and (ii) the adequacy of training provided by LFB to its fire-fighters for dealing with fires in high-rise buildings, including any applicable procedures if compartmentation fails.

As indicated in my first report, the tragic consequences of the Grenfell Tower fire highlight the significant shift in complexity that has occurred as a result of intricate façade systems being incorporated onto high rise buildings[1].

Functional requirements, guidelines and simple standardized tests, if not accompanied by an appropriate level of competency of all those using them, become insufficient tools in their own right, for establishing adequate performance[2] of systems where performance is a function of the interactions of the building and building envelope.

In what concerns fire safety of high-rise buildings, these tools are used by many organizations that fulfil a diverse set of functions. These functions cover the manufacturing of building materials, components and systems; design and construction; management, maintenance and inspection; logistic provisions as well as emergency response. In all cases, it is necessary for these organizations to guarantee that all tools will be used in a competent manner.

For this report, my instructions ask me to provide an analysis of the London Fire Brigade, therefore, this assessment focuses on this specific organization. Any omission to highlight the failures of organizations other than the LFB should not be interpreted as me concluding that these organizations acted in an appropriate or competent manner but as the result of the required focus of this report.

This report incorporates the findings of Phase 1 of the Public Inquiry and compiled in the Chairman's Phase 1 report,[3] puts the role of the LFB in the context of the fire safety strategy for a high-rise residential building such as Grenfell Tower (based on my Phase 1 report[4]), and builds also on the general analysis presented in my April 21st, 2021 report.[5] The reports by Prof. Johnson,[6] Mr. McGuirk[7] and Dr. Stoianov[8] provide the necessary information on matters of communication equipment, fire

---

[1] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018.

[2] Performance is defined as adequately fulfilling all functions that support and enable the fire safety strategy to deliver an acceptable level of safety.

[3] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[4] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018.

[5] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

[6] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.

[7] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021.

[8] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.

service organizational structure and response tactics and water supply systems that enables a complete analysis of the institutional structure of the Fire and Rescue Services and the professional attributes, qualifications, education and training of its members.

The fire and rescue services represent an integral component of the Fire Safety Strategy. Conceptually, its primary role is in compensating for design failures, in which, once the built-in systems have been overcome, fire brigade intervention is necessary to prevent disaster. The response of the fire brigades can follow standard protocols and tactics, nevertheless, it has to be able to adapt to different situations that might require departures from the original protocols and tactics. These departures should be established as a function of an adequate Dynamic Risk Assessment.

The Fire and Rescue Services will only be capable of fulfilling their duties, as defined by the Fire and Rescue Services Act (2004), if the institutional structure of the Fire and Rescue Services and the professional attributes, qualifications, education and training of its members, result in a level of competency consistent with the nature and complexity of the buildings they are required to operate in.

Through Phase One of this inquiry[9] it has been shown that personnel from the London Fire Brigade responded in an effective manner to the initial event, a "one compartment fire." This event was consistent with standard protocols and tactics. Nevertheless, it was clearly established that the London Fire Brigade failed to attain the expectations of the Fire and Rescue Services Act (2004) once a "design failure" occurred and it was necessary to implement an adequate Dynamic Risk Assessment.

Given that the evolution of the Grenfell Tower fire was a foreseeable event, that there was awareness in the London Fire Brigade of such events and that the link between these fires and specific types of products was known, a competent inspection would have identified the potential for a large external fire. Therefore, in regard to Grenfell Tower, the London Fire Brigade failed to obtain the necessary information through inspections, to enable them to conduct an adequate Risk Assessment.

An adequate Risk Assessment would have identified the potential for the June 14th, 2017 scenario and would have determined two possible paths of action, rectification or a change in response tactics.

An adequate Risk Assessment would have alerted any individual possessing the appropriate professional attributes, qualifications and training to the fact that any fire occurring in Grenfell Tower had a significant potential to dismantle the existing fire safety provisions (i.e. fire safety strategy[10]). The structure and policies of the London Fire Brigade are currently not conducive to the recruitment, education and training of professionals with such attributes, qualifications and training.

Furthermore, during the events of June 14th, 2017, the London Fire Brigade failed to identify that an external fire breached one of the fundamental assumptions backing almost all aspects of the fire safety strategy of a tall residential building such as the Grenfell Tower, specifically the "stay-put" strategy.

The LFB did not show sufficient understanding of the technical aspects underpinning the correct operation of the water supply systems used in fire suppression tactics. During the Grenfell Tower fire, the Incident Commanders were not capable of defining the problems of the water supply systems and

[9] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[10] Fire Safety Strategy, as referred here, is not a specific document but a conceptual representation of the ensemble of measures introduced to guarantee adequate fire safety.

as a consequence the actions taken did not make best use of the available water supplies. This, combined with the poor flow characteristics of the hydrants[11] resulted in under-utilised firefighting equipment on the night of the fire.

LFB Incident Commanders were not capable of adequately communicating with Thames Water Utilities Ltd. (TWUL) and personnel from TWUL did not provide the support required to enable the correct diagnosis and resolution of the key problems.[12]

Given the simplicity of the technical knowledge required to understand fire suppression hydraulics, this level of misunderstanding of such a crucial support system is not acceptable.

Like with all other aspects of firefighting that require a significant level of technical knowledge, communications equipment is addressed in a manner where the presumed level of competency is much higher than the true competency of LFB staff. Furthermore, all technical aspects necessary for adequate decision making are underplayed leading to many misconceptions. In the case of communications equipment, it also results in self-imposed, but potentially unnecessary restrictions, such as the need for low power sets. The evidence shows[13] that, the real competency is so low that it leads to practices that endanger the public and LFB staff and prevents the organization from learning.

An assessment of firefighting tactics shows an unwarranted reliance on experiential knowledge. The technical complexity of fire suppression is such that the value of experiential knowledge is very limited, in particular, when officers have very little opportunity to acquire real fire event experience. In these circumstances, the only mechanism to achieve adequate competency is by means of enhanced technical knowledge. None of the officers who were in command exhibited such a knowledge. The structure and policies of the London Fire Brigade are currently not conducive to the recruitment, education and training of professionals with such technical competency.

The description of many of the LFB functions is done in terms of frameworks such as the Provision of Operational Risk Information System (PORIS). These frameworks hide an extraordinary amount of complex technical knowledge. The technical knowledge required to properly use these frameworks is inconsistent with the level and nature of the competency of the users. As a result, instead of these frameworks serving as a mechanism to organize information in an effective manner, they act as tools to hide the lack of technical competency of the users.

Prof. Johnson closes his report suggesting the creation of a National Fire Safety Investigation Board and the development of a National Framework for Fire Safety Research in support of a more coherent communications framework for the fire and rescue services.[14] While it is not possible to disagree on the value of such organizations and activities, it is essential that the fire and rescue services reformulate their structure and culture first.[15] Only an organization that values and seeks technical

---

[11] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.

[12] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.

[13] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.

[14] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, pp.36-37.

[15] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

knowledge can be receptive of these activities. The current structure of the LFB will, therefore, not be capable of taking advantage of these activities.

The reform of the recruitment, education and training practices of the London Fire Brigade, and indeed the entirety of the Fire and Rescue Services, is a very complex matter that requires a detailed and comprehensive assessment. The Fire and Rescue Services Act 2004 has delivered the current structure, competencies and culture of the Fire and Rescue Services, thus its principles also need to be revisited.

This second report serves to confirm the conclusion of my first report[16] that indicates that the current structure and culture of the Fire and Rescue Services does not allow for this review to be driven from within the service. It is, therefore, essential that government enacts a comprehensive external evaluation of the Fire and Rescue Services as well as the Fire and Rescue Services Act 2004.

[16] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

CONTENTS

1 INTRODUCTION

1.1. THE INQUIRY'S TERMS OF REFERENCE

The Inquiry's Terms of Reference have been approved by the Prime Minister and have been published on the Inquiry's website. The Inquiry has also published on its website a detailed provisional List of Issues which identify the matters with which its investigation will be concerned. This provisional List may be revised in due course.

1.2. STRUCTURE OF THE INQUIRY

The Chairman has indicated that the Inquiry will be conducted in two phases. The present report pertains to Phase 2. The Chairman asked me to provide a report for Phase 2 on:

a. Your final conclusions on the relative contributions of the cladding design and materials to the fire spread at Grenfell Tower, taking account of the findings made in the Phase 1 report. This work will include collaboration with Professor Luke Bisby in relation to a programme of experimentation aimed at understanding and quantifying the respective roles of the various materials and products that made up the cladding system at Grenfell Tower under a range of relevant fire conditions and system geometries. This work is to be undertaken by Professor Bisby with a team from the School of Engineering at the University of Edinburgh including Dr Angus Law and Dr Rory Hadden. The experimental work will be developed in on-going consultation with you and will aim to establish the manner and extent to which each component of the cladding system contributed to the rate and extent of fire spread during the Grenfell Tower fire.

b. The correlation between fire safety provisions (and the fire safety strategy for Grenfell Tower) and (i) the adequacy of the London Fire Brigade's ("LFB") procedures for dealing with fires in high-rise buildings, including any applicable procedures if compartmentation fails and (ii) the adequacy of training provided by LFB to its fire-fighters for dealing with fires in high-rise buildings, including any applicable procedures if compartmentation fails.

c. An analysis of the adequacy of the current testing regime.

d. An overview of conclusions to be drawn about the Grenfell Tower fire, including the lessons to be learned when comparing the Grenfell Tower fire with other fires, both international and domestic.

The current Phase 2 Report is a second report corresponding to task (b), the first one being dated April 21st, 2021.[17]

1.3. STRUCTURE OF REPORT

The report will be structured around the facts gathered during Phase 1 of the Public Inquiry and compiled in the Chairman's Phase 1 report.[18] The general description of the structure of the necessary fire safety strategy for a high-rise residential building such as Grenfell Tower will be based on my Phase

[17] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

[18] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

JTO000

1 report.[19] Thus this report should be read in conjunction with the Chairman's Phase 1 Report and my Phase 1 Report. This report builds also on the general analysis presented in my April 21st, 2021 report in response to point (b) of my instructions[20] as well as on the reports of Prof. Johnson,[21] Mr. McGuirk[22] and Dr. Stoianov.[23]

1.4. FIELD OF EXPERTISE

1.4.1. My expertise and background are set out in my previous reports and will not be repeated here.

1.5. STATEMENTS

I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on the matters to which they refer.

I was assisted in the production of this report Dr Adam Cowlard - Director and senior engineer at Torero, Abecassis Empis and Cowlard Ltd. Dr Cowlard holds a PhD in Fire Safety Engineering and an MEng in Civil Engineering from the University of Edinburgh. He has undertaken a wide range of consultancy and research work encompassing development of fire safety strategies for a wide range of complex infrastructure, development of design fires and heat transfer modelling, and fire and evacuation modelling. Dr Cowlard supported my work primarily on data analysis, reporting and reviewing.

I confirm that I understand my duty to assist the Inquiry on matters within my expertise, and that I have complied with that duty. I also confirm that I am aware of the requirements of Part 35 and the supporting Practice Direction and the Guidance for the Instruction of Experts in Civil Claims 2014.

I confirm that I have no conflict of interest of any kind, other than any which I have already set out in this report. I do not consider that any interest which I have disclosed affects my suitability to give expert evidence to the Inquiry on any issue on which I have given evidence and I will advise the Inquiry if, between the date of this report and the Inquiry hearings, there is any change in circumstances which affects this statement.

Signed:  Dated: 1st August, 2021

---

[19] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018.

[20] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

[21] Prof. C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.

[22] Steve McGuirk, Report for the Grenfell Tower Inquiry, January 2021.

[23] Ivan Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.

2 THE FIRE SAFETY STRATEGY

To fully understand what is required from the Fire and Rescue Service, it is essential to discuss the relationship between firefighting and building performance. This discussion has to be framed in technical terms to clarify not only the nature of the required performance but also the expectations of competency that current building design practices place on the fire service. This report aims at presenting a skeletal view of the issues, and as such it is not comprehensive, prior studies have conducted more comprehensive analyses and can be consulted for details.[24]

Fire safety strategy, as referred to in this document, is the concept by which different measures are taken so that, as an ensemble, they guarantee a societally accepted level of safety for people against fire. It is also implied that by guaranteeing the adequate safety of people, material losses will also be mitigated. The fire brigade response is an essential element of the fire safety strategy.

Given that the objective of a fire safety strategy is to mitigate the consequences of a fire, the first assumption of the fire safety strategy is that the fire will occur. Thus, all buildings need a fire safety strategy.

In what concerns the fire safety strategy of high-rise buildings, many organizations fulfil a diverse set of functions. These functions cover the manufacturing of building materials, components and systems; design and construction; management, maintenance and inspection; logistic provisions as well as emergency response. In all cases, it is necessary for these organizations to guarantee that all actions they perform are conducted in a competent manner.

For this report, my instructions ask me to provide an analysis of the London Fire Brigade, therefore, this assessment focuses on the role of this specific organization as part of the fire safety strategy. Any omission to highlight the failures of organizations other than the LFB should not be interpreted as me concluding that these organizations acted in an appropriate or competent manner but as the result of the required focus of this report.

The fire safety strategy is linked to how the building is defined or classified. The definition of a building that is to be classified as a high-rise building is also complex. Regulations many times propose simple definitions of a high-rise building only on the basis of height,[25] nevertheless numerous assumptions hide behind the classification. These assumptions, together with the many protective measures implemented, allow these buildings to be used in a safe manner. The assumptions and protective measures will vary depending on the specific characteristics and use of a building.

The design of such a strategy requires careful consideration because the safe use of a high-rise building is a complex problem.[26,27] So, to guarantee the safety of people occupying a high-rise building during a fire event, it is necessary to implement a complex and precise fire safety strategy.[28]

---

[24] P. Favro, "Advances in firefighting techniques," Fire Safety and Engineering, International Symposium Papers, The Warren Centre for Advanced Engineering, The University of Sydney, May 1989, pp. 131-150.

[25] C. Todd, "Legislation, Guidance and Enforcing Authorities Relevant to Fire Safety Measures at Grenfell Tower," Report for the Grenfell Public Inquiry, February 2018.

[26] J.L. Torero, "The Risk Imposed by Fire to High Rise Buildings, Introduction," Fire Safety in High Rise Buildings, VDM Publishing, 1-16, 2009.

[27] A. Cowlard, A. Bittern, C. Abecassis-Empis, and J. L. Torero, "Some Considerations for the Fire Safe Design of Tall Buildings," International Journal of High-Rise Buildings, March, Vol 2, No 1, 2013.

[28] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018.

JTO000

Conceptually, the fire safety strategy for a high-rise building recognises that the main characteristic that defines a high-rise building is a convergence of time scales. In a high-rise building, people will take significant time to evacuate (several minutes), therefore the time to egress is of the same order of magnitude as the time for failure or the time required for fire and rescue service intervention.[29] Time for failure could be defined in many ways, such as attainment of conditions that are untenable, structural failure, etc.

In buildings that are not classified as high-rise, egress times are generally very short compared to all other characteristic times, therefore occupants are not expected to interact with firefighting operations or with the different potential modes of failure. It is clear that this will only be the case if the fire safety strategy works appropriately during the fire event.

Given this convergence of time scales, there is insufficient time to evacuate everyone and therefore a high-rise building requires the existence of safe areas within the building. These safe areas are intended to assure the wellbeing of occupants while the fire grows and while countermeasures and fire fighter operations are in progress. Furthermore, in the case of vulnerable people, these safe areas will serve to provide protection until rescue is achieved.[30]

If the building is to be evacuated, the most common safe areas are the stairwells. Stairwells are intended to remain isolated from the event during the duration of the fire, therefore they guarantee the egress process. There is no limit to the time where stairwells are to remain safe. To maintain the stairs as safe areas during the fire, these have to be constructed such that the fire is prevented from damaging the enclosure (i.e. walls and doors). Furthermore, redundancies are necessary for all safety systems; therefore, supplemental protection can be introduced to prevent smoke from entering the stairs. Typical approaches are: ventilated lobbies that create a buffer between areas with combustible materials and the stairs, or increasing the pressure within the stair thus ensuring a flow of air from the stair to the lobby (as opposed to smoke from the lobby to the stair), etc.

Also, it is important for safety systems to have redundancies, therefore having more than one means of egress can be considered desirable. Nevertheless, it is recognised that emergency stairs can occupy a significant fraction of the surface area of a high-rise building, challenging its functionality. Limiting the number of stairs therefore might be necessary. In this case, other forms of redundancy can be introduced. A common form of redundancy is to prevent the fire or smoke from escaping the sector of the building where the fire originated. This is achieved by means of barriers that block the progression of a fire and smoke out of a sector. Egress, in this case, can be contained to the high-risk sectors of the building and the rest of the occupants will remain in place. All other sectors of the building are deemed safe.

Firefighting operations will proceed with occupants in the building, therefore, provisions have to be made to account for firefighter-occupant interactions. These provisions are in part designed into the building but also relate to firefighting operations. This strategy is generally named 'stay put.'

Buildings will bound these sectors by means of barriers that are qualified as 'fire resistant.'[31] Typically, for residential units, each unit represents a sector, therefore the perimeter of the unit needs to meet 'fire

[29] A. Cowlard, A. Bittern, C. Abecassis-Empis, and J. L. Torero, "Some Considerations for the Fire Safe Design of Tall Buildings," International Journal of High-Rise Buildings, March, Vol 2, No 1, 2013.
[30] C. Todd, "Legislation, Guidance and Enforcing Authorities Relevant to Fire Safety Measures at Grenfell Tower," Report for the Grenfell Public Inquiry, February 2018.
[31] BS 476-22:1987 - Fire tests on building materials and structures. Method for determination of the fire resistance of non-loadbearing elements of construction.

resistance' requirements. Certain boundaries of the sector can be deemed more important than others, therefore a higher 'fire resistance' might be imposed.

It is typical to recognize that global structural integrity and containment of a fire to the floor of origin are of critical importance for high-rise buildings, therefore floor slabs and main structural elements generally will have higher fire resistance requirements than doors or non-load bearing partition walls.

It is recognized that certain components of these sectors cannot behave as barriers to the same extent as walls or floor slabs. Windows are some of these necessary components. Windows will incorporate glazing and could be potentially open, nevertheless, provisions are still necessary to prevent a fire from entering the adjacent sectors.

It is important to note that robustness and redundancies are paramount for high-rise buildings because for these buildings the evolution of a fire, as it scales-up, can be extremely complex[32] and the behaviour of occupants over such long time-scales is highly uncertain. Given the characteristics of high-rise buildings, Building Regulations will therefore stipulate robust solutions and many redundancies.

The Grenfell Tower was classified as a high-rise residential building due to its height and occupancy. As such, a fire safety strategy that is consistent with this classification would have been implemented. The building had limited means of egress (one stair) and required a 'stay put' strategy.

Smoke/heat detection and alarm is required only in the unit of fire origin. Adequate detection and alarm mark the onset of egress, and the short travel distances between the units and the stairs will guarantee that occupants of the residential unit where the fire originates will reach a safe area before conditions, within the residential unit, are untenable.

The residential unit is the sector that is enclosed (walls, floor and ceiling) such that the fire/smoke cannot escape the unit until the full burn-out of all combustible materials (fire resistant compartmentalization). In the Grenfell Tower the smoke detector in the lobby was not required to be interconnected but was introduced to activate a smoke control system whose objective was to maintain egress paths clear from smoke.

The pathway between the residential units and the safe area (i.e. the stairwell) has no redundancy, therefore the smoke management system is used, in Grenfell Tower, to provide a system that could clear smoke in the event that any of the barriers does not fulfil its function. As such this requirement acts as a redundancy to the protection of the means of egress.

In the event of a fire, occupants within the residential units at risk will proceed to evacuate immediately. The lobby is expected not to contain any combustible materials and to be separated from all combustibles by a barrier. These barriers can be properly designed walls, enclosures or doors. The units at risk could be interpreted as those in the floor of the fire or even just the unit where the fire originated.

The occupants might interact with the fire brigades, although such interactions are expected to be in sufficiently small numbers that they will be well structured. Fire brigade predefined procedures will enable adequate interactions. Occupants in units that are not deemed at risk will remain in their flats ('stay put') until instructions are received from the fire brigade. Fire brigade procedures will enable proper management of information to all building occupants.

---

[32] J.L. Torero, "Scaling-Up Fire," Proceedings of the Combustion Institute, v. 34 (1), pp. 99-124, 2013.

JTO0

Fire brigade operations have the potential to affect the displacement of smoke and flames, therefore, firefighting operations take priority and occupant/fire fighter interactions are expected to be minimized. Fire brigade protocols govern these interactions.

The building design will consider measures for firefighters to perform their duties adequately. This includes water supplies, means of access but also all provisions necessary for firefighters to conduct their duties in a manner that is effective and safe.

Through the entirety of any firefighting intervention the structure should keep sufficient mechanical strength so that it can fulfil its functions. All structural elements are, therefore, required to withstand a fire until full 'burn-out' of the combustible content. This is normally expressed in terms of 'fire resistance.'

A fundamental assumption of the fire safety strategy is that all professionals involved in the design, building, commissioning, inspection, operation and maintenance of the building have the competency necessary to perform their duties in regards to the fire safety strategy. This includes the fire brigades. As a result, it is assumed that all systems will perform as intended and that the fire service will exhibit the necessary competency under all required circumstances.

Through testimony presented in Modules 1 & 2[33] it has become evident that, among many other problems, serious issues of competency existed with all those associated with every aspect involving Grenfell Tower (i.e. product manufacturers, testing laboratories, designers, contractors, inspectors, etc.). This report focuses and summarizes some key aspects of competency pertaining to the London Fire Brigade.

3 THE ROLE OF THE FIRE AND RESCUE SERVICE

To understand the role of the fire service within a fire safety strategy it is worth explaining how a fire safety strategy should respond to a fire event. No specific fire safety strategy existed for Grenfell Tower, nevertheless the different components of such strategy can be reconstructed.[34] Figure 1 presents a schematic that describes the key elements of the fire safety strategy that should have been developed for Grenfell Tower.

If the fire safety strategy had performed as intended in Grenfell Tower on June 14th, 2017, the following would have been the sequence of events.

The onset of the fire would have resulted in the early activation of one or more of the fire detectors within Flat 16. The activation of an alarm would have informed the occupants that a fire was growing within the unit and this would have happened early enough that the fire would have had no impact on egress. All occupants would have exited the unit and called the fire service. The call would have arrived to LFB Control Room which would have communicated with the caller, provided instructions and proceeded to initiate the process of dispatch of the required equipment and personnel.

LFB Control Room would have also responded to other calls from occupants or bystanders, informing the callers that the fire and rescue services had been dispatched and confirming that the 'stay-put' strategy was still being enforced. This is described as task (1) of the diagram presented in Figure 1 and was indeed what

[33] https://www.grenfelltowerinquiry.org.uk
[34] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018, pp. 99 and 100.

happened during the fire.[35] Task (1) is labelled in blue because this is a support action not a direct responder activity within the fire scene. Direct responder actions are labelled in red.

Even if evacuation was delayed, the occupants of Flat 16 would have safely egressed the unit protected by 'fire resistant' compartments (including self-closing fire doors). If the compartmentalization of the room where the fire started failed (or the door failed/or failed to close), the fire-resistant walls and fire door of the unit would have protected the elevator lobby (1st level of redundancy), still guaranteeing a safe egress path. The significant extent of the available time serves to mitigate behavioural uncertainties.

If the compartmentalization of the unit failed, the smoke detector in the elevator lobby would have activated, warning all the occupants of the floor and initiating smoke extraction from the lobby. This would have delivered a clear path for all the occupants in the floor to evacuate and represents a 2nd level of redundancy for the occupants of the unit where the fire started.

Compartmentalization within the unit of origin would have contained the fire within this unit, so only smoke could affect egress for the occupants of adjacent units, thus the smoke management system would have been designed under this premise (Figure 1).

Egress distances from the units to the stairs are limited and thus require only a very short period of time for all occupants to access the stairs (safe area). The stairs are protected by fire resistant walls and doors, thus would have provided a clear egress pathway for all those evacuating. Further details on the role of compartmentalization in protecting the means of egress are provided in my Phase 1 Report.[36] The floor plan presented in Figure 1, and extracted from my Phase 1 report, shows the different levels of compartmentation and the pathway towards the stair.

Given typical arrival times for the fire service (on average less than 9 minutes at the time of the fire[37]) and the location of the fire in the case of Grenfell Tower (Flat 16), it would be likely that the occupants of Flat 16 would have been out of the building at the time of arrival of the first firefighters. This was the case on June 14th, 2017, thus, supporting task (2) was completed adequately.

All other occupants would have remained in their unit ('stay-put') and the firefighters would have initiated response protocols as described in the Inquiry's Phase 1 report.[38] Response protocols will involve the presence of an incident commander, thus, at this point, support task (3) becomes part of the fire safety strategy as well as direct response, tasks (A) and (B).

Further communication with residents will support the fire safety strategy, which in this case would have resulted in occupants being directed to 'stay-put.' The evidence confirms the conclusion that this support role was performed adequately in the earlier stages of the fire.[39]

---

[35] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[36] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018, pp. 99 and 100.

[37] Home Office, Response times to fires attended by fire and rescue services: England, April 2017 to March 2018, Statistical Bulletin 01/19, 17 January 2019.

[38] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[39] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

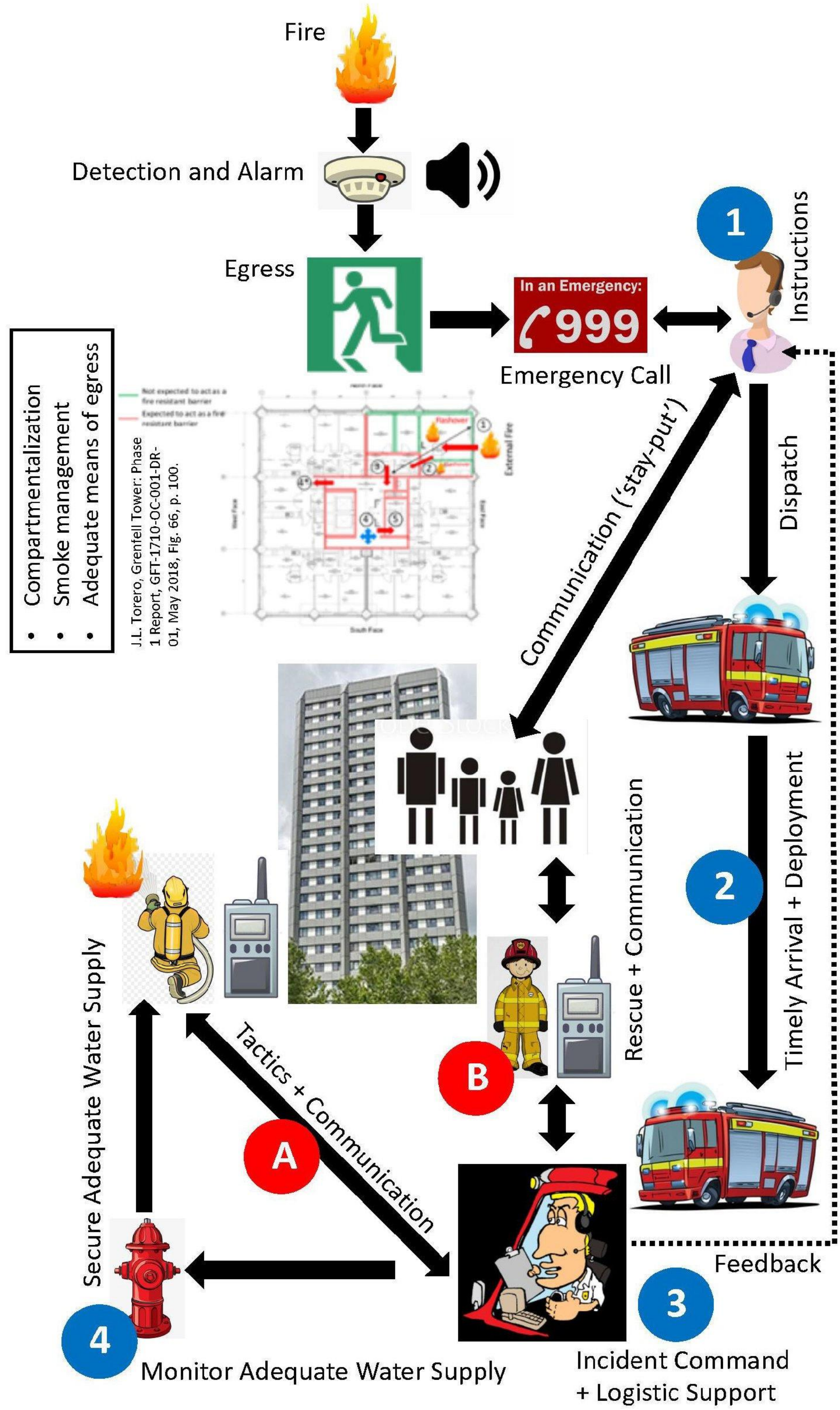

Figure 1 Schematic of the overall Fire safety Strategy for Grenfell Tower incorporating the different components associated with the Fire and Rescue Services. Labelled in blue ((1) to (4)) are supporting tasks and labelled in red ((A) and (B)) are direct tasks.

Upon timely arrival, the fire service will identify any need for rescue and initiate procedures to fight and extinguish the fire. Fighting and extinguishing the fire corresponds to the first active task that the fire brigade performs as part of the fire safety strategy. This task is labelled (A) in Figure 1. The supporting actions correspond to tasks (1), (2), (3) and (4).

If the building performance had been adequate, the fire could have burnt until the full consumption of all combustible materials (burn-out) without exiting the unit of origin, even in the absence of any firefighting. In that sense, firefighting and building performance provide redundancy to each other.

To what extent poor building performance can disable firefighting is a key issue that needs to be considered by building regulations, enforcement as well as firefighting practises. This is necessary because firefighting and building performance provide redundancy to each other. If a form of poor building performance is foreseeable, then it is the responsibility of the Fire and Rescue Services to put in place provisions, within their protocols, to mitigate for this poor performance. If this foreseeable poor building performance is disabling, then it is incumbent on the fire service to identify this and explicitly require rectification. This is normally done through the process of inspection.

Favro makes some clear statements in regards to the role of firefighting indicating that "It is viewed – and rightly so – as an emergency response to building or system failure."[40] Furthermore, Favro establishes the complementary relationship between building performance and the need for firefighting response as "firefighting is, therefore, a basic necessity. However, closer scrutiny would, perhaps, more clearly indicate that as building design and construction improves, system failures lessen, and as system failures lessen, intervention activities are required less and less." In his summary, he states that "one point seems clear: Fire suppression's role is in compensating for design failures, in which, once the built-in systems have been overcome, fire brigade intervention is necessary to prevent disaster."[41] The use of the term fire suppression, when describing the fire brigade intervention, is not fortuitous, in that automatic fire suppression (ex. sprinklers) will perform an equivalent suppression role to the fire service in the context of the fire safety strategy, i.e. once the other systems have been overcome, fire suppression (automatic or manual) is there, as a redundancy, to prevent disaster.

Within the context of a 'stay-put' strategy and with a single staircase, firefighting and egress are not compatible. Securing water supply would have been initially done internally which would have inevitably resulted in smoke entering the stair.[42,43] The firefighters would have secured an adequate water supply that will enable effective operation of their equipment (Task (4)).

Within the bounds of presumed fire fighter competency, the firefighters would reasonably be expected to:

- Recognize that fighting the fire would have compromised the stair and therefore be incompatible with egress
- Identify whether the water supply was inadequate for effective use of their equipment
- Any problems with the water supply should have been communicated to command. Command is supported by a Bulk Media Advisor (BMA) who provides advice to the Incident Commander

[40] P. Favro, "Advances in firefighting techniques," Fire Safety and Engineering, International Symposium Papers, The Warren Centre for Advanced Engineering, The University of Sydney, May 1989, pp. 131-150.
[41] P. Favro, "Advances in firefighting techniques," Fire Safety and Engineering, International Symposium Papers, The Warren Centre for Advanced Engineering, The University of Sydney, May 1989, pp. 131-150.
[42] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.
[43] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018.

- If the problem could be resolved (ex. boosting the pressure of the riser) actions towards resolution could have been taken
- If resolution required external intervention, the Incident Commander (or BMA) should have been able to establish contact with any organization that could resolve these problems (in the case of Grenfell Tower it would have been Thames Water Utilities Limited (TWUL))[44]
- Incident Command would have been expected to adequately communicate the problem to TWUL

Once adequate water supply has been secured firefighters can proceed to fight and extinguish the fire according to well specified tactics. Firefighting tactics determine the manner in which a fire will be fought and the water flow rate required for an effective management of the fire. The different documents that describe appropriate firefighting tactics are listed in Mr. McGuirk's report[45] and the necessary water requirements are detailed in the National Guidance Document on the Provision for Water for Fire Fighting.[46,47]

Dr. Stoianov describes these requirements in detail in Section 4.2 of his report[48] but summarizes the water requirements for internal firefighting as follows:[49]

'Section 4.2 reviews empirical approaches to estimating an 'adequate' water flow rate for fighting a fire based on the characteristics of a building and drawing upon historic data from UK fires. These methodologies suggest a significant range for the estimated `adequate` flow rate to fight a fire at Grenfell Tower of between 1,200 l/min (20 l/s) to 10,000 l/min (167 l/s).'

As indicated, this 1,200 to 10,000 l/min range is the result of Dr. Stoianov applying empirical methodologies derived from historical fire data to the approximate circumstances of Grenfell Tower and he notes that the range is *"an illustrative example with assumptions and variables that are outside the scope of* [his] *investigation."*[50] Dr. Stoianov also notes that similar methodologies and simple formulas could be used by incident commanders to assist with the estimation of the required flow rate at an incident.

While it is unquestionable that water requirements for fire suppression are related to firefighting tactics, these tactics need to be supported by technical arguments.

The suppression of a fire by means of water is a complex physical process that depends on a multiplicity of variables. Complex processes are many times described by utilizing empirical evidence such as historic data. Nevertheless, this approach only applies if the scenario being tackled sufficiently resembles the scenarios described by the data. It is therefore important, that the requirements are caveated by the limitations associated with the manner in which these requirements are established.

Given the importance of water in firefighting it is essential that Incident Command understands the assumptions implicit in the water supply systems and their equipment. Furthermore, it has to be understood

---

[44] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.
[45] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.35 to 52.
[46] National Guidance Document on the Provision for Water for Fire Fighting, LGA & Water UK, 2007.
[47] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 4-5.
[48] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 4-22/29.
[49] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-7.
[50] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 4-29.

that the methodologies for estimating expected water usage are determined by historical data associated with the successful application of their tactics. The later point implies an understanding of what type of fires informs that data and what are the fundamental mechanisms of fire suppression by water that will allow extrapolation of this information to fires that are different to those on which the data is based. This is the level of competency required of the Incident Commander, and those supporting command (ex. BMA), if they are to be able to estimate the required water flow rate to support fire suppression at an incident.

Following the logic of Favro, that establishes that fire brigade intervention is necessary to prevent disaster,[51] it is clear that fire brigade intervention needs to define provisions that enable (a) extinguishing fires, and (b) protecting life and property in the event of fires[52] in the case where it is necessary to compensate for design failures.

As mentioned before, a different and much more complicated question is: what is the extent of the design failure that the fire and rescue services should be able to compensate for? Furthermore, what is the role of the fire and rescue services in defining what should be the limits of this expectation?

As indicated in my earlier Phase 2 report,[53] the "fire and rescue authority must, in particular, secure the provision of the personnel, services and equipment necessary to efficiently meet all normal requirements and secure the provision of training for personnel. Most importantly, the fire and rescue authority must plan for obtaining information needed on the building for the adequate fulfilment of their functions." Therefore, the role of the fire and rescue services in defining the fire scenario that they can fight cannot be circumvented.

The process by which command assesses the situation and contrasts the specific scene with the information underpinning tactics is part of the Dynamic Risk Assessment.[54,55] The Dynamic Risk Assessment will enable the Incident Commander to support and alter actions (A) and (B) to fit the evolution of the fire and compensate for design failures as well as unexpected occupant behaviour. This might include changing firefighting tactics, establishing rescue operations or securing further logistical assets. An important role for the Incident Commander will be to inform the LFB Control Room of the evolution of the fire and tasks (A) and (B) so that further assets can be committed in a timely fashion and occupants informed appropriately.

The external spread of the fire is the initial design failure in the case of Grenfell Tower. This design failure and the subsequent escalation of the event are described in the Phase One report[56] showing that the design failure marks the transition from Stage One (building performing as intended) to Stage Two (external spread).[57]

Once the building is no longer performing as intended the Dynamic Risk Assessment should enable the Incident Commander to change the overall response strategy. This will require effective communication between those performing the active response tasks ((A) and (B)) and Incident Command (Task (4)). Communication utilizes equipment including the Breathing Apparatus Radio Interface Equipment ("BARIE") sets described in detail in Prof. Johnson's report.[58] Like any other technology, the BARIE sets have to be used in a manner appropriate

[51] P. Favro, "Advances in firefighting techniques," Fire Safety and Engineering, International Symposium Papers, The Warren Centre for Advanced Engineering, The University of Sydney, May 1989, pp. 131-150.
[52] Fire and Rescue Services Act (2004)
[53] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.
[54] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021, p.16.
[55] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.43.
[56] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.
[57] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018, p.29.
[58] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.

to the technology and within the bounds of its limitations[59] and therefore competency in the use of the equipment is expected from all relevant LFB staff.

Competency implies not only knowing how to use the equipment, but also the understanding of the limitations of the equipment. Furthermore, given the importance of information for the formulation of a Dynamic Risk Assessment, it is expected that confidence in the competency of all users should be high. To achieve such competency and confidence, appropriate training is essential.

Beyond Stage One, the response has to be informed by the Dynamic Risk Assessment process and through effective communication the evolving needs should be coordinated by the Incident Commander (Task (3)). These needs include:

- Communication with occupants through active response (Task (B)) as well as through LFB Control Room (Task (1))
- Rescue operations (Task (B))
- Suppression activities (Task (A))
- Securing appropriate water supply (Task (4))
- Escalation of resources and support (Task (2))

While this is a non-comprehensive list of needs, it serves to highlight the key activities that the fire and rescue service has to perform in direct support of the Fire Safety Strategy and once a design failure has occurred. Incident Command will perform many other tasks, these are described in Mr. McGuirk's report,[60] and while important, will not be repeated here.

4 UNDERSTANDING THE BASIS FOR FIRE SUPPRESSION TACTICS

Fire suppression tactics require the understanding of where to place the water, how much water needs to be supplied and how to bring an adequate amount of water to the correct place. How to bring the water to the correct place is defined by the characteristics of the water supply and by the equipment used (hoses, nozzles, hydrants, pumps, etc.). Fire suppression tactics establish where to place the water and how much water needs to be supplied. Therefore, fire suppression tactics require an understanding of the fire that is being fought.

Fire suppression tactics recognize the limitations of the equipment, water supply systems and accessibility in a manner that enables to establish how to best fight the fire but also what fires can be fought.

From a technical perspective, fire is a combustion process governed by the fundamental laws of physics and chemistry that are known as an ensemble as fire dynamics. As a consequence, the interaction between water and a fire is governed by the same laws. A fire is predictable, and therefore mathematical models can be created to describe fire growth as well as suppression. That being said, the processes governing the behaviour of a fire, and the means to supress it, are very complex,[61] therefore predictive models are either very complex or rely on simplifications that pose severe limits to their applicability.

The increased complexity of buildings has resulted in an increased complexity of the detailed mathematical models of fire dynamics as well as a reduction in the range of applicability of simplified approaches. It is

[59] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.
[60] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021.
[61] J.L. Torero, "Scaling-Up Fire," Proceedings of the Combustion Institute, v. 34 (1), pp. 99-124, 2013.

possible to ascertain that, currently, we do not have the capacity to deliver comprehensive fire predictions by means of first-principle mathematical models. Most models incorporate large simplifications, have important limitations and therefore require highly competent professionals to interpret them.

The simplest form of predictive modelling is the empirical law which could ultimately translate simply to experience. Experience based understanding of a complex process such as fire dynamics is therefore inherently limited. In the case of fire, it has led to fundamental misunderstandings that have defined the fire and rescue services' mindset for more than a century. This is explained very clearly by Mr. McGuirk who maintains the need for a Dynamic Risk Assessment at all levels of intervention (Tasks (3), (A) and (B)) and thus "*the predicament*" between encouraging initiative as opposed to strictly following orders from Incident Command.[62]

The reasoning behind this "*predicament*" comes from a long-standing perception, expressed in the Manual of Firemanship, that requires improvisation on the spur of the moment because "*no two fires are alike*" and therefore the fire is not predictable. If the fire is not predictable, then the Incident Commander (Task (3)) cannot perform a Dynamic Risk Assessment unless information is transferred from the active responders. This is because obtaining the necessary information is an experiential process that requires proximity to the fire. In that case, it is the active responders (Tasks (A) and (B)) who have the greatest potential to perform such an assessment in a timely manner. Nevertheless, the manual actually states:

"'No two fires are alike' is an old and very true Fire Service saying, and therefore technical knowledge must be backed up by intelligence and the ability to grasp the fundamentals of a situation, to initiate a plan of action and to improvise on the spur of the moment ..."[63]

While the manual does indicate that "*no two fires are alike*" it also emphasizes "*technical knowledge*" as well as "*ability to grasp the fundamentals of the situation*." The most common take-away from this statement is that "*no two fires are alike*" leading to the conclusion that the outcome of a fire cannot be predicted. As a consequence, decisions have to be made purely on the basis of direct observation and experience. As indicated in my first Phase Two report, this conclusion naturally diminishes the role of the Incident Commander and the need for technical competency to conduct an adequate Dynamic Risk Assessment.[64]

At the core of the misunderstanding is the disregard for technical knowledge. As a problem becomes more complex and difficult to understand, experiential knowledge becomes very limited and, while experiential knowledge will always be valuable, it is technical knowledge that becomes the primary source of information for decision making. Instead, if technical knowledge is perceived as having no value,[65] then the weaknesses of experiential knowledge are attributed to the randomness of the event, i.e. *"No two fires are alike"* is interpreted as meaning that fire is a random event that cannot be predicted.

This is further exacerbated when experiential knowledge is also limited. Mr. McGuirk explains how the reduction in frequency of fires (particularly large fires) and the career structure of officers that favours managerial training, as opposed to on-the-ground training, has resulted in a significant decrease in experiential knowledge among LFB officers.[66]

---

[62] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.35.
[63] *Manual of Firemanship, Book 11, Practical Firemanship 1 (Fourth Impression – 1989)*, pp.19-20.
[64] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021, p.16.
[65] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021, p.24.
[66] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.47.

While this situation is real, it does not exempt the LFB from its responsibility to maintain competency among its officers. Given that Incident Commanders have to be able to conduct an adequate Dynamic Risk Assessment that informs the evolution of fire suppression tactics, they cannot be exempted from understanding fire dynamics.

The consistent approach followed by the fire and rescues services is to argue that the reduction of experiential knowledge is a key reason for many of the problems that relate to Incident Command. Thus, the unavoidable conclusion is that an increase in training with large scale fires is necessary. This was clear through the Phase One testimonies of firefighters[67] as well as from the report by Mr. McGuirk, who states:

"While simulation and realistic training can go so far, it can never be the same as the real thing, as training will always be constrained by the need to balance the risks to which personnel are exposed against the training benefit. Added to this is the problem of scale, whereby the ability to recreate large fires with any authenticity is virtually impossible. Generally speaking, this means that training, however effective, will always face a challenge to make good the shortfall of experience that is caused by this diminution in exposure to real incidents."[68]

Mr. McGuirk further recognizes that the problem goes beyond a lack of understanding of the nature of a fire but also of the risks that it can pose:

"the reduction in activity has dampened the sense of the real risk that continues to be posed by fires, especially big fires, and has led to a sense of complacency."[69]

The conclusion emerging from this reasoning is that the lack of experiential based knowledge in real fires is at the core of a fundamental problem that disables the Incident Commander from conducting an adequate risk assessment. Once again, the possibility of enhancing technical knowledge as a means to enable risk assessments and improve firefighting tactics is not considered. Mr. McGuirk does acknowledge the requirement for technical knowledge that is referred to in the Manual of Firemanship text,[70] but does not consider the possibility of enhancing technical knowledge as a key means to compensate for the reduction of practical training.

It is clear that simulations (particularly digital simulations) are not sufficient means for training. This is because the complexity of the fire problem does not allow for sufficiently realistic digital simulations, in particular when it comes to understanding suppression.[71,72] Furthermore, exposure to realistic risks and complex search and rescue situations is difficult to achieve without direct incident experience. Furthermore, large fires are difficult and expensive to create, therefore controlled training under these conditions will always be limited. None of these arguments are invalid, nevertheless, that does not mean that adequate training cannot be achieved without *"exposure to real incidents."*

While fire is complex in nature, it is predictable. The initial fire in the kitchen of Flat 16 was highly predictable and could be modelled to a level of resolution and precision that is adequate to the generation of training

---

[67] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[68] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.47.

[69] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.48.

[70] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.35.

[71] J.L. Torero, "Scaling-Up Fire," Proceedings of the Combustion Institute, v. 34 (1), pp. 99-124, 2013.

[72] A. Cowlard, W. Jahn, C. Abecassis Empis, G. Rein and J. L. Torero, "Sensor Assisted Fire Fighting," Fire Technology, 46, 3, 719-741, 2010.

materials in support of firefighting tactics.[73] The models used were simple and easy to utilize and there is no reason why an Incident Commander should not be able to understand the benefits, limitations and uncertainties of such models.

Given the complexities of the Grenfell cladding system, it is very difficult to predict how such a fire will evolve from an internal fire to an external fire. Nevertheless, once the fire has exited the building, the evolution of the vertical spread of the fire, as well as the implications towards fire re-entry through the windows, could have been predicted. Furthermore, the response of the building could have also been predicted and further design failures could have been identified. It is clear that these predictions would have carried a high degree of uncertainty but they could have been competently interpreted in support of Tasks (A) and (B). All this technical information would have supported the Incident Commander's process of conducting an adequate Dynamic Risk Assessment.

5 UNDERSTANDING THE CONSEQUENCES OF DESIGN FAILURES

As explained in Section 3, fire brigade intervention needs to define provisions that enable (a) extinguishing fires, and (b) protecting life and property in the event of fires in the case where it is necessary to compensate for design failures. Therefore, the fire and rescue services play a critical role in establishing how design failures can affect the evolution of a fire and what should be the limits of the expectation that the fire and rescue service have to compensate for these failures. At the fire scene, the process by which Incident Command assesses the situation and contrasts the evolution of a specific scenario with the information underpinning tactics is part of the Dynamic Risk Assessment.[74,75] The Dynamic Risk Assessment enables the Incident Commander to support and alter actions (A) and (B) to fit the evolution of the fire and compensate for design failures as well as unexpected occupant behaviour.

Response protocols and Dynamic Risk Assessments are supported by information on the building that is obtained by the fire and rescue services through inspections. An adequate technical understanding of the Fire Safety Strategy, the role that the fire and rescue services play as part of this strategy, and the implications of the different possible design failures on LFB operations, has to inform the process of inspection. Only such understanding can lead to an effective process of inspection. This is highlighted in my prior Phase Two report.[76]

The chronic disregard for the value of technical knowledge and the complexity of the problem at hand is manifested in the manner in which the required inspection process is articulated. When referring to the 2001 Expectations Manual, Mr. McGuirk indicates that the existing documentation "does not address the question of how firefighters should collate risk information at high-rise buildings" which requires for the "how to collate risk information" to be defined by the fire and rescue services. Furthermore, the required risk information is defined, in some of the earlier guidance documents, in terms of (i) Occupancy and use; (ii) Access (both to and within the premises); (iii) Structural features and layout; (iv) The presence of hazardous materials and processes; (v) Firefighting resources and fixed installations; (vi) Power intake controls; (vii) Site specific operational procedures; (viii) Potential environmental effects.[77] The information incorporated in points (i) to (viii), as it pertains the prediction of the fire growth, the impact of design failures on the evolution of the fire

[73] J.L. Torero, Grenfell Tower: Phase 1 Report, GFT-1710-OC-001-DR-01, May 2018.
[74] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021, p.16.
[75] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, p.43.
[76] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021, p.25.
[77] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, pp.10-11.

JTO0

and the characteristics of the fires that can be fought, is enormous in quantity and links between the information collected and outcomes are of extraordinary complexity. The more recent Provision of Operational Risk Information System (PORIS),[78] provides more detailed guidance under which information is to be gathered and collated. Nevertheless, it defines an even more complex framework that adds complexity to the interpretation of the information collected. So, by defining risk information in these terms, both the HMFSI Expectations Manual[79] and the PORIS document presume an exceptionally high level of technical competency of the fire service.

None of the LFB testimonies[80] or Mr. McGuirk's report[81] provide an alternative method by which the magnitude of the fire can be explicitly linked to the collected information.

Mr. McGuirk assesses that the PORIS guidance is adequate in the advice it provides the fire and rescue services in matters that pertain to the information to be collected. Nevertheless, nowhere in this guidance or in the other documents referred to by Mr McGuirk is any statement on how this information is to be used to support tactics (i.e. Tasks (A) and (B)) or predict the growth of the fire as a function of potential design failures. Of particular importance, is the absence of any methodology that allows to establish what are the fires that can be controlled or suppressed with the equipment and personnel available to the LFB and when rescue should be prioritised over fire suppression actions. Finally, none of this guidance provides any information as to the technical competency required from the user of these systems. Thus, the presumed technical competency of the Incident Commander remains undefined.

In summary, when it comes to understanding the consequences of design failures it is essential to be able to predict the evolution of a fire in the event of a design failure and to understand the basis for fire suppression tactics. The Dynamic Risk Assessment is the manifestation of this understanding and the means by which the Incident Commander alters Tasks (A) and (B).

Technical knowledge, in conjunction with current levels of real incident exposure and reasonable experiential learning, has to enable the Incident Commander to conduct an adequate Dynamic Risk Assessment. The adequate Dynamic Risk Assessment will then enable the Incident Commander to properly alter Tasks (A) and (B) in the event of a design failure. Therefore, the critical question being asked should be: what is the technical knowledge that needs to be provided to Incident Commanders?

Before this question can be answered, a thorough review that looks in detail at the culture of LFB in regards to technical knowledge needs to be conducted. This review needs to also look at the training practices that have been implemented as a result of this culture.

---

[78] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, pp.13-14.
[79] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021, pp.10.
[80] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.
[81] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021.

JTO0

It is necessary to finish this section by stating that it is profoundly revealing that none of the expert reports,[82,83,84] Dame Judith Hackitt's report[85] or the LFB testimonies to the Inquiry [86] address the required technical knowledge of an Incident Commander in terms that pertain to the prediction of fire growth in the event of a design failure. This shows that LFB personnel, and society at large, do not see the fire and rescue services as an integral part of the Fire Safety Strategy or understand the magnitude of the competency expected from the Incident Commander responsible for conducting a Dynamic Risk Assessment in the event of a Design Failure.[87] It also reveals that, while the necessary technical competency remains undefined, society at large presumes that the Incident Commanders already have the required technical knowledge.

6 UNDERSTANDING WATER SUPPLY

Given the importance of an adequate water supply to the fulfilment of Task (A), it is essential to look carefully at how an adequate provision of water is guaranteed. This discussion is focused on technical matters as they pertain the adequate fulfilment of Task (A). The information presented is based on the analysis provided by Dr. Stoianov, therefore all information supporting this section can be extracted from his report.[88]

The technical field supporting the provision of water for cities is hydraulics. In a similar manner as with the prediction of fires, water supply hydraulics is a complex technical matter. Nevertheless, in contrast to fire dynamics, hydraulics modelling can be simplified while retaining precision. Thus, simple models can, many times, deliver precise predictions of flow.

Figure 2 presents a schematic of the different components of a hydraulic system that supports firefighting operations. As shown in the figure, water reservoirs supply complex networks of pipes and other fixtures that deliver an adequate supply of water to the user. There will be an interface between the supply side of the system and the user side of the system. The utility (in this case Thames Water Utilities Ltd (TWUL)) is responsible for the supply side up to this interface and the user is responsible for the user side of this interface.

There are two important factors when considering adequacy: water flow rates (Q_N) and pressure (P_N). Water supply is regulated so that sufficient pressure rates are guaranteed to users. Water flow rates are not regulated because they result from the pressure provided at the interface between the supply and the user. The user side has typical characteristics and requirements that will, for a given pressure, result in a water flow rate that the supplier is capable of delivering. The users would include LFB, nevertheless the regulation is not explicit about providing water supply for the purpose of firefighting.[89] It is important to point out that if firefighting

---

[82] S. McGuirk, Report for the Grenfell Tower Inquiry, January 2021.

[83] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.

[84] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.

[85] J. Hackitt, Building a Safer Future – Independent Review of Building Regulations and Fire Safety: Final Report, Crown Copyright, May 2018.

[86] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[87] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

[88] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021.

[89] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-15.

requirements can be satisfied with standard provisions then it is not necessary to have explicit regulation for this activity.

As shown in Figure 2, for firefighting the interface between the utility and the user is the hydrant, therefore, it is the responsibility of TWUL to deliver an adequate pressure (P_H) throughout the duration of the firefighting operations (t). The flow rate (Q_H) will result from the pressure (P_H) and the characteristics and state of the fire hydrant. If adequate pressure is delivered and the fire hydrant is in good operating state, then it will be the responsibility of LFB to use that water supply adequately.

To describe the adequate use of the water supply by LFB, it is important to discuss firefighting tactics (Task (A)). Firefighting tactics are intended to assure effective suppression and therefore require first the delivery of sufficient water flow rates and pressure (Q_R, P_R) to the correct location (i.e. the nozzle). This requires the layout of hoses and fixtures, each of which will alter the pressure reaching the nozzle. The pressure changes occur because hoses and fixtures introduce friction losses that translate into a pressure drop (P_{LH}, P_{LB}). Thus, the layout of hoses and fixtures is part of firefighter tactics and thus the responsibility of LFB. It is therefore presumed that those who devise standard equipment operation protocols and hose layouts will have the necessary competency to understand how a specific layout and operating conditions deliver an adequate water supply (Q_R, P_R). Furthermore, in the event that a Dynamic Risk Assessment requires alterations to the standard arrangements, it is presumed that those who conduct the assessment (Incident Commander, BMA, etc.) and make the decisions will have sufficient competency.

Firefighters will then ensure that the water is directed towards the fire in a manner that enables suppression (Task (A)). The tactics associated with the effective delivery of Task (A) are presumed to be part of the standard training of firefighters.

From a hydraulic perspective, the requirement is that a sufficient pressure (P_R) has to reach the nozzle and that there is sufficient water volume (V_t) (i.e. tanks, reservoirs, mains, etc.) to guarantee the required flow rate (Q_R) for the firefighting period (t). The following expression then describes the relationship between the required flow rate and the volume of the tank in the appliance.

$$V_t = Q_R t \qquad (1)$$

For a required water flow rate (Q_R) the tank will empty in a time given by t. The time to empty the tank is generally very short, so the tank needs to be refilled constantly.

The pressure necessary for the nozzle to operate appropriately (rated pressure - P_R) is generally greater than the pressure delivered by the tank of the appliance and therefore it is necessary for the appliance to have a pump. The only purpose of a pump is to increase the pressure so that the nozzle can receive adequate pressure (P_R) and consequently deliver required water flow rate (Q_R) to the fire.

Provided that the flow rate delivered from the hydrant to the tank is larger than the required water flow rate (Q_R), water will flow through the pump and the pump will deliver sufficient pressure to the nozzle to guarantee the required water flow rate (Q_R) for as long as it is necessary and without emptying the tank. Therefore, firefighting operations do not necessarily require a specific pressure rate from the network. As a result, at the interface between Thames Water Utilities Ltd. (TWUL) and the London Fire Brigade (LFB) there is only one simple requirement, that the water flow supplied by the hydrant that feeds the appliance tank (Q_H) is at least equal to the required water flow (Q_R). Equation (2) represents this condition.

$$Q_H \geq Q_R \tag{2}$$

Thus, the responsibility of TWUL is to deliver sufficient water flow to enable this condition to be met. In more general terms, this condition should apply, not only to a single hydrant, but to the entire water requirement of the firefighting operation.

The Incident Commander will potentially request more appliances and deploy a number of branches (N) as a function of the escalation of the event. Each branch will require a flow rate[90] and the ensemble of branches will define the water flow rate required from the city hydraulic network (Q_N). Dr. Stoianov demonstrates that all points of the firefighting operations at Grenfell Tower, the water provision of the network far exceeded the demand.[91]

There is a difference between the water provision of the network and the flow rate (Q_H) that emerges from the hydrant. As indicated above, this depends on the pressure (P_H) and the characteristics and state of the fire hydrant. It is also important to note that an adequate water flow rate can be achieved in many different ways and it is not limited to a single hydrant. Multiple hydrants can be connected to the appliance tank, the pump can suck water directly from other reservoirs larger than the tank (ex. pools), etc. Many of these options were potentially available at Grenfell Tower as ways to meet the required condition illustrated in Equation (2).[92]

To understand whether water flow rates were a real problem at Grenfell Tower it is important to understand the operation of a fire hydrants and nozzles. Hydrants and nozzles operate in a similar manner and on the principle of a discharge orifice.[93] The flow through a discharge orifice is defined by the pressure available at the orifice and the physical characteristics of the orifice. The physical characteristics are defined by a constant named the flow coefficient (K). Equations (3) and (4) describe the discharge orifice relationships for a hydrant and a nozzle respectively

$$Q_H = K_H\sqrt{P_H} \tag{3}$$

$$Q_R = K_R\sqrt{P_R} \tag{4}$$

Equation (3) corresponds to a hydrant and thus the sub-index 'H' and Equation (4) to a nozzle and thus the sub-index 'R' (for 'Required'). Each hydrant or nozzle will have a different coefficient that needs to be calibrated by means of testing. With the calibrated constant, Equations (3) and (4) provide models that predict the flow rate. If all these flow coefficients are properly calibrated, equations (3) and (4) provide reliable mathematical models for the flow.

---

[90] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-17/18.
[91] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-24.
[92] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-19/20, 3-10/11.
[93] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 4-16.

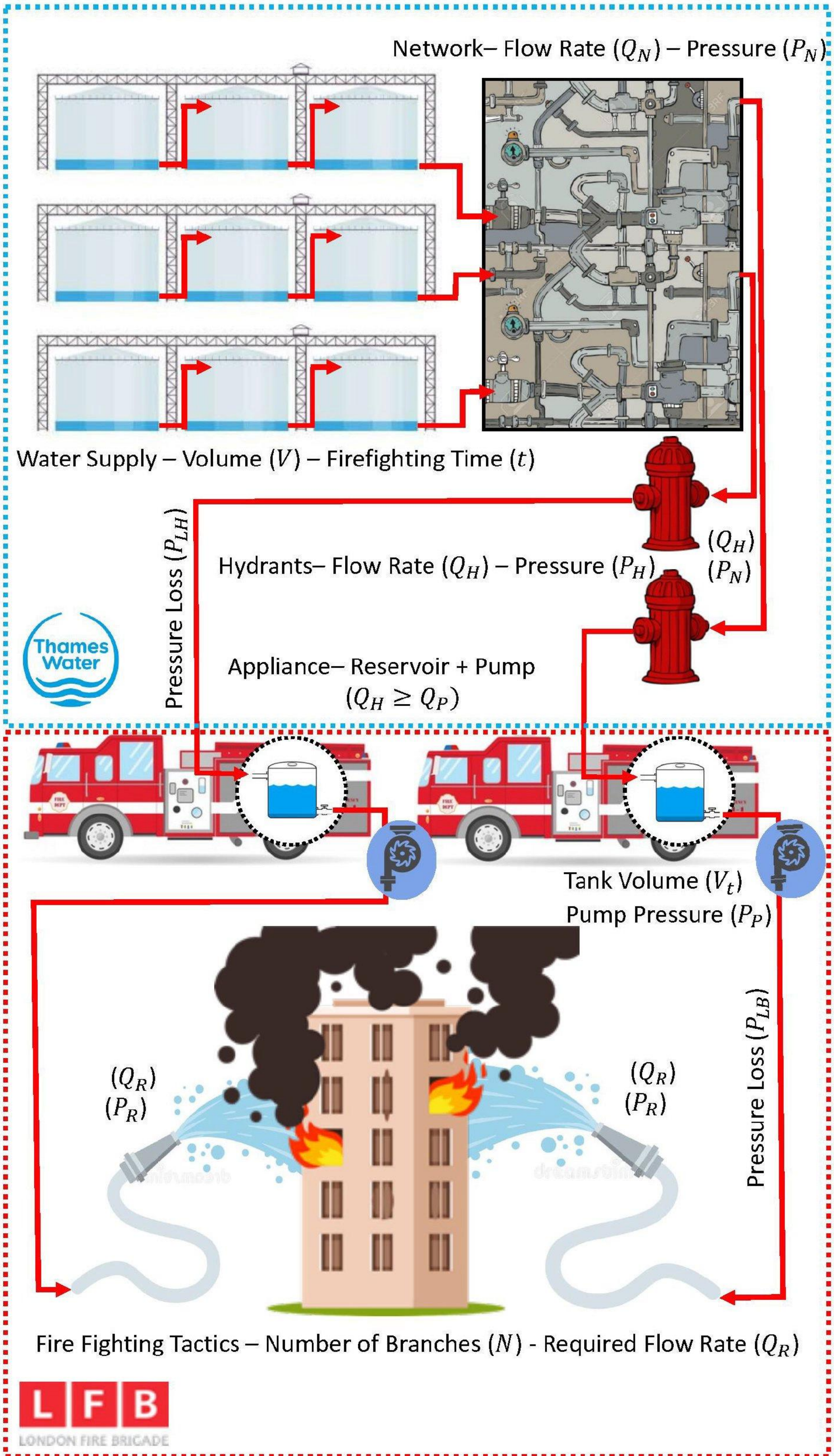

Figure 2 Schematic of the hydraulic system supporting fire suppression (Task (A)). The blue box defined the responsibility of Thames Water Utilities Ltd. (TWUL) and the red box the responsibility of the London Fire Brigade (LFB).

As explained before, the required pressure is delivered by the mains for the hydrant and by the appliance pump for the nozzles and, as can be seen from Equations (3) and (4), an increase in pressure will result in an increase in flow rate. Given that the relationship is given by the square root of the pressure, a significant increase in pressure will result in a modest increase of the flow (ex. to double the flow the pressure needs to quadruple).

During firefighting operations at Grenfell Tower, the hydrants did not deliver the necessary flow rate[94] and as a result the condition of equation (2) was not satisfied and all branches operated significantly below their rated values.[95] Therefore, firefighters did not manage to deliver water to the right location and in the correct quantities. Given the importance of water in appropriately fulfilling Task (A), it is essential to explore in more detail the reasons for these problems.

As explained by Dr. Stoianov, water supply to the appliance tanks was not sufficient to attain and maintain the required water flow and the necessary pressure at the nozzle. Thus equation (2) was not satisfied. The LFB failed to recognize that it was necessary to change the strategy towards securing sufficient water flow. The realization that the hydrants were not supplying the expected amount of water prompted LFB to request from TWUL an increase in pressure. TWUL did not deliver this request, nevertheless, even if they would have it would have not resolved the problem. As indicated above, and given the relationship described in equation (3), a significant increase in pressure would have only delivered a modest increase in flow.[96,97] A more effective approach would have been to seek additional sources of water.

Dr. Stoianov describes a multiplicity of other potential strategies that would have delivered the necessary flow rate. This would have prevented the delays incurred by the consistent emptying of the water tanks.[98]

An important issue to point out is that the flow coefficients of all the fire hydrants were much lower than those required and prescribed by the manufacturers. The deterioration of these flow coefficients is a common occurrence, this is why in many countries, regular calibration of these flow coefficients is conducted by the fire and rescue services conducting flow tests.[99] As indicated by Dr. Stoianov this is not the case in the UK where it is discouraged to calibrate the flow coefficient.[100] I cannot think of a reason that could justify this practice. So, while TWUL failed to provide properly functioning fire hydrants (including inappropriate labelling),[101] basic understanding of the simple models that govern hydraulic flow would have enabled LFB, with advice from TWUL, to change strategy and secure adequate water flow.[102]

---

[94] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 6-42.

[95] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-17/18.

[96] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-21/22.

[97] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-25.

[98] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-19/20.

[99] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-16, 4-33, 4-37.

[100] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 4-20.

[101] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-19.

[102] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-19/20.

In summary, at the interface between LFB and TWUL the problem was not one of pressure but one flow rate of water (Q_H). Poorly functioning (and labelled) fire hydrants with low flow coefficients (K_H) leading to flow rates lower than those required (i.e. $Q_H < Q_R$). This resulted in the need for constant refilling of the appliance tank.

The adequate delivery of water to the fire is a very different problem governed by the appliance pump. Appliance pumps operate in a manner by which the pressure and flow can be varied according to the firefighting requirements.[103] The operator can regulate the rotational speed of the pump to deliver the necessary flow and pressure.

The projection distance required by the water jet to reach the fire defines the necessary pressure at the nozzle (P_R). The characteristics of the hose layout and the height of the nozzle determine the pressure losses in the branch (P_{LB}). So, the required pressure at the pump (P_P) is given by

$$P_P = P_R + P_{LB} \qquad (5)$$

The operator of the pump will set the pump pressure (P_P) and required flow rate (Q_R) to deliver the rated requirements of each appliance. It is important to note that the water demand can be very dynamic and therefore adjusting pump operation is not easy and requires specialist skills.

Improper understanding of the manner in which the appliance pump works resulted in the LFB maintaining the pump pressure at a constant value (10 bar), independent of the layout and operational characteristics of the specific branches. This resulted in all branches operating below their rated capacity and, thus, not complying with their appropriate conditions of use.[104]

In summary, in what concerns the deployment of water to the fire pressure and flow rate are fully in control of the LFB (red box in Figure 2) and can be modelled in a very simple manner according to equations (4) and (5).

The water flow rate requirements allowing to satisfy Equations (1) and (2) were delivered by TWUL by means of hydrants that can be modelled by equation (3). While individual hydrants performed poorly delivering less water than expected, the conditions required by equations (1) and (2) could have been fulfilled by alternative ways of filling the tanks. The overall hydraulic network had the capacity to deliver the demand.[105]

Both LFB and TWUL failed to deploy personnel with adequate competency to be able to assess the problems and to communicate in a manner that information being transferred across the boundary of the two organizations was appropriate.[106]

Given the importance of water supply and the simplicity of the models describing its performance, it is not acceptable that among the staff deployed by LFB there was nobody with a sufficient level of competency to

---

[103] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 3-15/16.
[104] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-18/19.
[105] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 2-23 to 2-26.
[106] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, pp. 2-19/20 and 2-31/32.

make the correct decisions. While beyond the scope of this report, it is necessary to emphasize that the same expectations should apply to personnel deployed by TWUL.

Given the simple summary of Dr. Stoianov's analysis presented here, it is clear that water supply hydraulics is governed by very simple technical concepts, therefore it important to ask if it is unwarranted to expect from LFB this minimum level of technical competency.

An important aspect that needs to be reiterated is that firefighter tactics that define the quantity of water that needs to be deployed and the manner in which it has to be deployed are not based on solid technical principles. In particular, in cases such as external fires like that of Grenfell Tower, there is no clear and quantitative evidence that these tactics are effective. Therefore, it is not possible to establish what would have been the outcome if an adequate supply of water would have been deployed at Grenfell Tower.

Dr. Stoianov[107] extracts from the National Fire Protection Association[108] a list of factors that affect fire suppression tactics. The factors are as follows:

1. The fuel's physical and chemical properties.
2. The fire load density (MJ/m^2) and the heat release (MW/m^2).
3. The geometry of the building façade (for external firefighting) or the geometry of a compartment (for internal firefighting).
4. Ventilation conditions.
5. Ambient conditions.
6. The water application and its speed/timing including:
    a. the water flow rate.
    b. the form/shape and reach of the applied water jet (e.g. fog versus solid stream jets).
    c. the water application technique/s; and,
    d. how timely (fast) water is applied particularly at a growing fire, which is time dependent.

Perusal of all these variables shows that they cover a wide range of complex processes. Introducing these variables implies the use of a first-principles predictive model. The creation of a first-principles model that can predict how all these variables will affect the adequacy of firefighting tactics is impossible. In consequence, these long lists of variables do not provide guidance on how to predict the effectiveness of fire suppression tactics, instead they are just a mechanism to hide the lack of technical understanding behind fire suppression tactics.

It is consistently the case that these long lists of variables are presented to justify the fact that the problem is extremely complex and therefore performance of fire suppression tactics cannot be predicted. While it is impossible to disagree with this assessment, it is essential to recognize that if firefighting is going to be used as an integral part of the fire safety strategy, then it is essential to be able to predict the adequacy of the tactics utilized.

It is of even greater importance to recognize that for such complex problems, with ever changing building technologies, experiential knowledge will always have to be supported by technical knowledge. The aim should be to understand water suppression by a combination of experiential and technical knowledge in a

[107] I. Stoianov, Grenfell Tower Inquiry, Phase 2 Report, The provision and use of water for fighting the fire at Grenfell Tower on 14 June 2017, 20th July, 2021, page 3-28/29.
[108] NFPA (2003), Operation of Fire Protection systems, ISBN 0-87765-584-7

manner that the list of variables can be simplified. The simplification has to enable a predictive model with adequate predictive capabilities but sufficiently simple that it can be used by an Incident Commander to conduct a Dynamic Risk Assessment. Only by following this approach is it possible to implement changes in tactics that have a positive and predictable outcome.

To be able to achieve this objective it is essential to change a culture that entirely dismisses the value of technical knowledge. It is therefore necessary to conduct a thorough review that looks in detail at the culture of LFB in regards to the technical knowledge underpinning suppression tactics. This review needs to also look at the training practices that have been implemented as a result of this culture.

7 UNDERSTANDING COMMUNICATIONS EQUIPMENT

Adequate communication is essential to the delivery of Tasks (A), (B) and (4) and therefore it is of paramount importance to guarantee that all provisions that enable effective communications are put in place. Poor communications have been highlighted as a key problem during the response operations at Grenfell Tower on the night of June 14th, 2017. Prof. Johnson addresses many of the issues and highlights that communications problems endangered occupants and firefighters.[109] The key issues, root causes and consequences have been described through testimony, the Phase One report[110] and my previous Phase Two Report.[111] Thus, this section will focus purely on technical aspects associated with the use of the BARIE sets. This section relies on the information presented in Prof. Johnson's report.[112]

The use of low power communication systems such as the BARIE set results in a key compromise. Because of the low power of the communication systems, signals may not reach their intended recipients. Additionally, congestion can occur on radio channels, which is a recognized problem.[113,114,115,116] Nevertheless, Prof. Johnson highlights that there is little confidence that the *"lessons learned from previous incidents will be applied across the country to protect the safety of fire crews and of the public."*[117] This is mostly because of the inconsistent approach of the LFB towards addressing these communication problems.

In the process of analysing the communications problems, LFB focuses on the equipment and not on the fundamental objectives. Communications plays a role in Tasks (A) and (B) and that role has a context that is defined not only by the event but by the response culture of the LFB. Equipment that is being used outside the bounds of its capabilities cannot be expected to deliver the intended service. In these cases, the problem can be solved by either improving the equipment or by changing the practices that lead to its utilization outside

---

[109] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, p.156.

[110] Grenfell Tower Inquiry: Phase 1 Report, Report of the Public Inquiry into the Fire at Grenfell Tower on 14 June 2017, Chairman: The Rt Hon Sir Martin Moore-Bick, October 2019.

[111] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

[112] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.

[113] Fatal Fire Investigation - report of the Hampshire Fire and Rescue Service Investigation into the deaths of Firefighters in Flat 72, Shirley Towers, see page 53, paragraph 3.10 and page 163, paragraph 23 {LFB00107130}

[114] Letter from Frances Kirkham (Coroner) to Ron Dobson (LFB) containing Rule 43 recommendations arising from the Lakanal House fire on 3 July 2009, page 3 {LFB00004652}

[115] LGA Fire Peer Challenge Report March/April 2015, page 23, paragraph 86 {LFB00047856}

[116] CLG Incident Ground Communications Study Final Report - Fire Research Technical Report 21/2008, page 20, paragraph 5.3 {CWJ00000092}

[117] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, p.19, p. 92.

its capabilities. LFB's own post-incident review found that congestion and interference was the key problem,[118] nevertheless the LFB's Review of its Specification for Fireground and Breathing Apparatus Radios focuses on the power of the BARIE sets and does not mention congestion or interference.[119] Furthermore, inspection visits and training are done in a manner that does not introduce problems of congestion and interference, thus circumventing the real and well known problem.[120] This can only be interpreted as an incapability of the organization to question its practices and as a result, and despite their own evidence, changing the focus towards the equipment so as to avoid the introspection on the manner the equipment is being utilized.

This brings Prof. Johnson to conclude: *"A precondition for change is the acceptance that the LFB should move away from a culture of focusing on device specifications towards resilient and systemic approaches where policy, training and procurement are continually examined in the light of operational experiences, not just from within their own organisation but also from other FRS and from other industries."*[121]

Following a similar pattern, the logic behind the utilization of low power units is not developed in a sufficiently rigorous manner. The argument in favour of low power units is that the low power makes it difficult for the set to act as an ignition source and therefore there is a perception that the sets can be used in a broader range of conditions. As indicated by Prof. Johnson, higher power units cannot be used if gases classified in Groups A and B are present (Group A: acetylene and Group B: flammable gas, flammable liquid vapour, combustible liquid vapour such as hydrogen).[122]

The presence of any flammable or combustible gas that can mix with air in the absence of an ignition source can lead to an explosive mixture if the fraction of fuel is between what is generally referred to as the Lean and Rich Explosive Limits (LEL and REL respectively).[123] In the case of a fire, because the fire is already burning, it acts as a permanent ignition source as soon as any combustible gases get released or produced. The result is that these combustible gases will continuously burn and not allow the generation of a combustible mixture. Thus, the LEL cannot be attained. In consequence, the risk of ignition of combustible mixtures in a fire is an extremely rare, almost impossible, event.

While it is possible that firefighter operations can occur during a gas leak and before ignition occurs (i.e. allowing a combustible mixture to be formed), it is not likely that this will be acetylene or hydrogen. If such a scenario was to be managed by LFB, protocols will have to be very different to those of a fire such as the one in Grenfell Tower. Even in the case where a backdraught condition might result in a combustible mixture between the LEL and REL, the gases, given the characteristics of the combustible materials, will not correspond to Groups A or B. Furthermore, it is clear that the conditions will not be suitable for a firefighter to be in a space that is occupied by such mixture, thus the radio carried by the firefighter cannot act as an ignition source.

It is therefore possible that the self-imposed constraint of using low power radio sets might not be necessary. A detailed assessment of this constraint is therefore warranted and, given the severe limitations that this

---

[118] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, p.19, p. 21.
[119] LFB's Review of the Specification for Fireground and Breathing Apparatus Radios, page 3, paragraph 14 {LFB00105466}
[120] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, p.19, p.20.
[121] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, p.36.
[122] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, p.42.
[123] D.D. Drysdale, Introduction to Fire Dynamics, 3rd Edition, John Wiley and Sons, 2011.

constraint poses, it is a matter that I would have expected to have been already resolved. No technical explanation is proposed either by Prof. Johnson or any of the LFB guidelines that explain the technical reasoning for this choice beyond manufacturer recommendations that truly do not include the firefighting context.[124]

Like with all other aspects of firefighting that require a significant level of technical knowledge, communications equipment is addressed in a manner where the presumed level of competency is much higher than the true competency of LFB staff. Furthermore, all technical aspects necessary for adequate decision making are underplayed leading to many misconceptions. In the case of communications equipment, it also results in self-imposed, but potentially unnecessary restrictions, such as the need for low power sets. The evidence shows[125] that, the real competency is so low that it leads to practices that endanger the public and LFB staff and prevents the organization from learning.

Prof. Johnson closes his report suggesting the creation of a National Fire Safety Investigation Board and the development of a National Framework for Fire Safety Research in support of a more coherent communications framework for the fire and rescue services.[126] While it is not possible to disagree on the value of such organizations and activities, it is essential that the fire and rescue services reformulate their structure and culture first.[127] Only an organization that values and seeks technical knowledge can be receptive of these activities. The current structure of the LFB will, therefore, not be capable of taking full advantage of these activities. Furthermore, given the lack of value assigned to technical knowledge, it is highly probable that the LFB, with its current characteristics, will directly question and oppose the outcomes of such activities.

8 A REQUIRED NEW APPROACH

The Grenfell Tower fire has provided clear evidence that the Fire and Rescue Services are required not only to incorporate sufficient understanding of building behaviour in their activities but also a much deeper technical understanding of fire suppression operations as well as all the equipment associated with their activities. This knowledge will only be effective if it is introduced within a context where this knowledge is respected and valued. Respect and value are critical because they demonstrate the recognition that this information is important for making response effective. Thus, the present report just serves to extend and support the call to revisit the structure and practices of the fire and rescue services presented in my earlier report[128]. This process of transformation has to aim to emphasize the value and importance of technical knowledge.

[124] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.
[125] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020.
[126] C.W. Johnson, Assessment of the Design and Operation of Fireground Communications Systems available at Grenfell Tower on the Night of the Fire, Phase 2 Report, 27th November 2020, pp.36-37.
[127] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.
[128] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

9 SUMMARY

In my previous Phase Two report[129] it was established that the Grenfell Tower fire demonstrated that the London Fire Brigade, in its current structure, is not capable of delivering the role that society expects from this institution.

The nature of the modern built environment and current construction practices require a Fire and Rescue Service that is capable of conducting Plan Formulation when faced with complex modern infrastructure. This must include all components of the Plan Formulation process; from information gathering, its interpretation, its use in a dynamic risk assessment, the handling of communications, and an effective command structure to deliver an appropriate response.

The London Fire Brigade still operates in a Plan Execution mode which is no longer sufficient. For the London Fire Brigade to deliver the level of service expected by society when operating in respect to complex modern infrastructure, it requires a deep transformation that involves not only improvement of skills and professional attributes but also requires a drastic change of culture.

This report assessed the specifics of the Fire Safety Strategy and the role of the LFB as part of this strategy. Firefighting tactics, fire suppression equipment, water supply systems and communications equipment were analysed as a function of how they were used during the Grenfell Tower fire. This enabled to identify patterns of behaviour of the LFB in the context of a scenario where a Dynamic Risk Assessment was necessary.

The manner in which the LFB used its tactics and equipment demonstrated that there is a need for a cultural change that defines the role of technical knowledge and emphasizes its value and importance. In contrast, this change in culture needs to deemphasize experiential knowledge as the primary means to acquire competency. Given the complexity of firefighting and rescue operations in modern buildings, experiential knowledge, while still part of the operational decision-making process, must be supplemented by robust technical knowledge. The more complex the firefighting environment the more technical knowledge becomes a necessity. Thus, at the core of this change of culture is transforming the value structure of the organization to introduce respect and value for technical knowledge. Currently, the culture of the London Fire Brigade exhibits, at all levels, a total disregard for technical competency, in particular in matters that pertain the understanding of building performance and the manner in which building technologies can affect the fire dynamics.

The necessary transformation requires a deep, extensive and fundamental review of the structure of the London Fire Brigade as well as a redefinition of skills and attributes of those employed by the London Fire Brigade. This report does not provide such a review. A simple conceptual structure that could serve as a starting point is described in my previous Phase 2 report.[130]

The review of the London Fire Brigade, and in general any Fire and Rescue Services, must be a long term, extensive and multi-disciplinary effort. The current culture prevailing in the London Fire Brigade, and Fire and Rescue Services globally, prevents them from leading such a review.

[129] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

[130] J.L. Torero, Grenfell Tower: Phase 2 Report, Grenfell Tower: London Fire Brigade and Complex Building Fires, April 21st, 2021.

JTO0