A competency framework for fire safety engineering

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Abstract

Fire safety engineering accreditation and licensing is a subject of much debate in many jurisdictions especially following the Grenfell Tower fire and as a result of the many issues that have been brought to light following similar cladding related fires around the world. It is argued elsewhere that the lack of a well defined accreditation and licensing framework is one of the most significant weaknesses in the provision of fire safety engineering services in some jurisdictions; and in other jurisdictions where these frameworks do exist, they lack a well articulated definition of competency that fully reflects the expectations of those seeking to enter the profession.

This paper discusses the motivation for stronger accreditation of fire safety engineers. Describing an idealised accreditation system, the unique role of the fire safety engineer is then discussed as is the need to redefine competency expectations to reflect the current needs of the public who the profession serves.

Finally, a proposed competency framework is detailed. This links technical competencies to the skill in their application to complex engineering problems – namely the design of a fire safety strategy, and also highlights additional non-technical competencies which should be expected of those seeking to enter the profession.

Keywords: competency, education, fire safety strategy, accreditation, professionalisation

1. Introduction

Fire safety engineering, when done in such a way that it reflects the application of the fundamental knowledge of the discipline, can result in designs that are well suited to the specific needs of building users as well as society more broadly. .Many jurisdictions allow this approach to fire safety engineering under the guise of performance based codes, while others allow some degree of flexibility and application of fire safety engineering within the restrictions of a prescriptive code. Regardless of the process followed, the result of the fire safety design process is the specification of a fire safety strategy for a building. This strategy is the ensemble of design elements and control measures (such as detection, alarm, evacuation, active suppression and passive protection, smoke control, the structure) that function holistically to ensure the adequate performance in fire of a building [1 - 7]. The elements of the fire safety strategy serve to control or to guide the evolution of a fire inside of a building, the response of the building itself to a fire, and the response of the building occupants and the first responders to that fire.

As widely acknowledged (e.g. [8 – 10]), the specific attributes which differentiate a profession from a trade generally include: 1) A systematic body of theory and skill in its application; 2) professional authority, both assumed and granted; 3) a binding code of ethics; and 4) a professional culture. The identification of these attributes in the profession of fire safety engineering has been discussed elsewhere, e.g.[7, 11]. Whilst there exists an ongoing discourse as to whether or not such a taxonomic approach is the most insightful way to define a profession [12], the body of knowledge and skill in the application of that knowledge within the domain of practice of the professional remains consistent across various definitions and forms a signfiicant part of the basis of admission to a profession. Central, therefore, to any discussion about fire safety as a profession is the existence and rigour of the process whereby individuals are admitted to professional practice.

Normally this process of admission to professional practice is based on a demonstrated attainment of the competencies (comprising knowledge, skills and other attributes) required to fulfill the role of the professional with a high degree of efficacy. In the case of fire safety engineering, the primary role that a fire safety engineer should be expected to be able to perform is to develop from first-principles during the design process the specifications of a fire safety strategy that balances the requirements of all stakeholders whilst ensuring adequate building performance in case of fire. Ensuring that potential practitioners have adequate competence to undertake such activities should therefore form a part of the process for admission to professional practice.

It is the unique nature of the process for admission to practice that enables a profession to establish its authority over the provision of related services and therefore justify its authority over a particular field. Clarity in the identification of those who have the right to perform specific tasks and of the responsibilities entailed by this privilege can provide better societal outcomes. Thus, exercising this authority is both a right and a privilege of the professional, with professional bodies enforcing the required quality of practice. In developing the framework which admits individuals to professional practice, it is therefore essential to structure mechanisms that both support and enforce this professional authority (whilst avoiding undue favour or restrictions) [13].

Regarding this enforcement, two forms of policing mechanisms are needed: one legislative to ensure that professional status is necessary to carry out a particular role (e.g. doctor, lawyer, engineer); the other based on regulation internal to the profession, that ensures that those with this status have the necessary competence based on education and experience. The first of these requires a jurisdiction to 'protect' a profession by legislating so that only those recognized as having the necessary competence are allowed to carry out relevant functions. The second control mechanism depends upon the existence of an authoritative body encharged with both accreditation* of individuals and of organisations to confer professional qualifications.

* Throughout this article, the term accreditation is used in discussion about individuals and degree programs which are offered by tertiary education institutions. In both instances as used in this article the term refers to an attestation by a professional engineering body. As applied to the individual the attestation is that the individual possesses all of the competencies required for professional practice; as applied to degree programs the attestation is to the fact that the program delivers exit level graduates which are of an acceptable level for entry to practice.

The need for accreditation of individuals stems from the approval given by governments for professionals to have authority to practise within the area of their discipline. Generally, therefore, professional accreditation requires as a first stage proof of basic knowledge and certain other personal and professional attributes that can be taught and acquired as part of a structured program of learning. This first stage certification is typically achieved through the completion of a program of study at a university that is accredited by a relevant professional body as providing education covering not only the relevant systematic body of theory but also the application of that theory, amongst other necessary graduate attributes. In many instances completing an accredited program of study can also be recognised internationally as fulfilling the requirements for this first stage in the professional accreditation process. This kind of mutual recognition of the accreditation processes of professional organisations is covered under various international agreements. One such agreement, the Washington Accord, is discussed in detail in section 2 of this paper.

The specific elements of content required for this first stage accreditation are generally established through a dialogue between national or international professional bodies and degree granting institutions. If an institution or a degree program is accredited, the institution granting the degree program can grant degrees that are recognised by the relevant professional body. An individual obtaining such a degree is deemed to have met the requirements for the entry to practice at this first stage of the professional accreditation process. Although some practitioners may enter professional practice through an alternate route (for example on the basis of an unaccredited degree in FSE or on the basis of a degree in another engineering discipline followed by further study), the expectations in terms of competency of those individuals must be equivalent to those who take the preferred route. This means that there must be significant emphasis placed on the individual being able to demonstrate the required competency to avoid any dilution of competency. The accreditation of degree programs is therefore the principal mechanism whereby the profession is able to maintain the quality of practitioners. Without this mechanism any growth in the profession risks diluting the quality of the practitioners and the ability of the profession as a group to adequately discharge their responsibilities. The interaction between the profession and the degree granting institutions in setting the requirements for accreditation of programs is therefore an important part of the professional culture.

This first stage of the certification process should provide the rigour, through the checks and balances consistent with tertiary education, in confirming that an individual has the knowledge, skills, and attributes required for entry to practice. For final professional accreditation, however, there is a further component necessary and that is the experience in the application of the skills obtained whilst studying. Following first stage accreditation, therefore, degree exit level graduates are admitted to a second stage in the process which comprises practice under the supervision of an accredited professional or professionals.

Between jurisdictions and regulatory models this terminology will vary. For example, in a co-regulatory model the professional body will accredit individuals as having the required competency to practice whereas other bodies will register those individuals for practice; this is contrary to a self-regulation model where the professional body both accredits competency of individuals and registers them for practice.

Once a suitable body of work has been undertaken that demonstrates competence in a professional environment in the application of the attributes attained during the degree program, then the individual can be fully accredited and admitted to the profession [14]. This process, summarised in Figure 1, describes the basis of the route to professional practice promoted by the International Engineering Alliance (IEA) – which maintain various international agreements governing the recognition of engineering qualifications and professional competence [15]. The process in individual jurisdictions should always be managed by a body representing the profession and therefore some jurisdictions and some professions adopt a co-regulatory model whereby this certification process is followed by a process of final registration to practice in a local territory [16, 17].

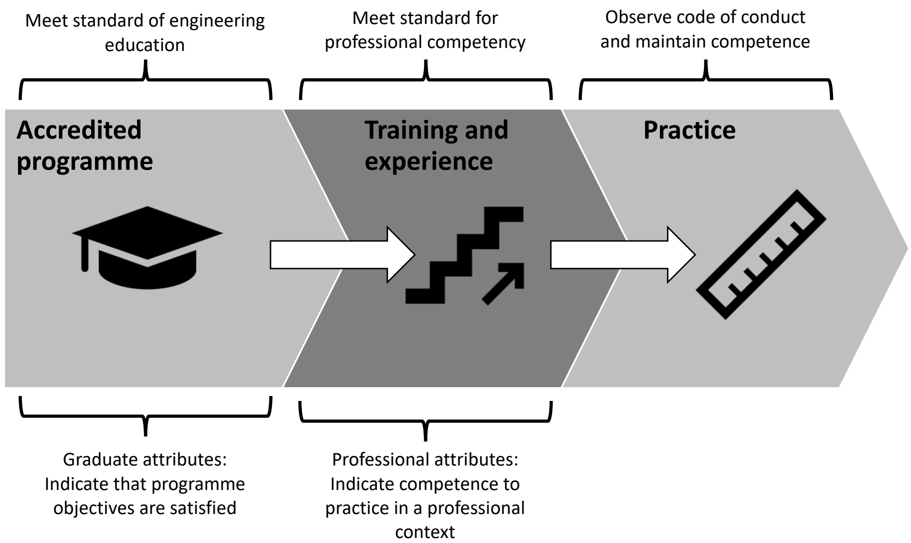

Figure 1 The route to professional practice, modified from [15]

1.1 The need for professional authority

Fire safety has a long history based around the application of building regulations. These provide prescriptive solutions which simplify the implementation of fire safety and which have come to serve as de facto performance requirements for first-principles fire safety engineering [7]. However, this prescriptive legacy undermines any claim that accredited fire safety engineers should have professional authorty on the provision of fire safety engineering services.

Practitioners such as builders, architects, building surveyors and regulators have acquired expertise in the interpretation and application of these codes. Architects have long been the primary designers of buildings, based on the implementation of prescriptive building codes, and there has been no obvious need to consult a professional with unique competence in the field of fire safety. Although it varies between jurisdictions, the fire and rescue services also often play a role in both regulation and approval of designs, based on their experiential expertise derived from, for example, fighting fires, investigating fire scenes, building inspections, etc..

The common language of these traditional fire safety practitioners revolves around the interpretation and application of the building codes (‘Codespeak’) [18]. This remains the dominant approach to fire safety, and this prescriptive legacy has provided little incentive for the development and regulation of fire safety engineering expertise. Fire safety engineering as a profession may thus struggle to establish its authority over the implementation of fire safety in the built environment because these more established practitioners also have a stake in this field.

To make the case for the professionalisation of fire safety engineering it must be clearly identified how such a profession contributes to the public good and to achieving the goal of a built environment that is safe from fire (or safe insofar as any fire risk is tolerable to all stakeholders). Core to this is the recognition that the option for first-principles fire safety engineering in many regulatory regimes poses a potential risk to the public if carried out by practitioners who lack the standards of competence and ethics that professional status should assure. In societal terms this has the potential to undermine the goal of delivering a built environment that is safe from fire. Given that the existence of practitioners without the required competence has arguably already significantly contributed to a 'race to the bottom' in terms of quality and safety [19], professionalisation of fire safety engineering is the only means of mitigating that risk whilst enabling the innovative engineering solutions that can address the need for a more sustainable and resilient built environment.

Since the current practice of fire safety engineering can (in many jurisdictions) be performed by individuals without specfic accreditation – the present situation would suggest that there is little or no value (or rather no perceived value) to society in recognising or granting such authority to the fire safety profession.

Central to the current lack of authority is the absence of a well articulated vision of how a fire safety engineer provides *necessary* and *unique* value to society by fulfilling the role for which they are given responsibility. Such a vision must be underpinned by a fully developed range of competencies – and such a vision has not been fully developed and sanctioned for practice.

Fire safety engineering can only be recognised as a profession if society accepts that such engineers are the *only* individuals capable of delivering a fire safe building using a first-principles approach. But, paradoxically, society cannot (and should not) allow those fire safety engineers to assume authority over the discipline without first demonstrating professional competence. If such a level of technical competency forms the basis of the profession, then, developing such a competency framework appears as an inevitable step to resolve this particular paradox.

Fire safety engineering today finds itself at a crossroads in its evolution [19 – 22] and strengthening its formalisation as a profession is the most important step in ensuring that as a profession fire safety engineering contributes to the public good and realises its potential.

True formalisation of fire safety engineering as a profession would require that all of the attributes that define the profession [7] are addressed. In this paper we focus on the competency related aspects of these attributes associated with the first stage of the process - admission to professional practice. In doing so, we explore variations in existing competency frameworks – and the implications that this may have for regulatory reform.

Finally, we propose a set of competencies that should be expected of fire safety engineering professionals for the entry to practice stage – i.e. the degree exit level graduate fire safety engineer. These are competencies that reflect the unique nature of fire safety engineering within the context that the profession finds itself today and that by adoption would strengthen the professional culture, status and authority of fire safety engineering.

2. Fire safety engineering and the Washington Accord

Generally, any professional competency framework will comprise various elements which include knowledge, skills and attributes. Knowledge is the understanding of fundamental principles and information about a particular field (e.g. Fire science). A skill is an ability to perform a task well, including through the application of knowledge (e.g. CFD modelling). An attribute is a quality or a feature of an individual that may be regarded as characteristic of them (e.g. ethical behaviour), but which may be attained through external influence (in contrast to a trait which is often considered to be ingrained). Competency required for practice in any professional sphere is a mix of knowledge, skills and attributes.

The competencies associated with the first stage of the accreditation process that are proposed in this article are described in such a way that they are compatible with the competency standards of the International Engineering Alliance (IEA). This is relevant and necessary because, to be recognized as valid, any competency framework defined for fire safety engineering needs to be consistent with what is expected from other engineering disciplines and with the process for professional engineering registration in the jurisdictions in which it is intended to be applied.

The IEA is the body that is responsible for the maintenance of the Washington Accord [15], an accord that enables, based on the principle of substantial equivalence of degree outcomes, the transfer and mobility of engineers between 21 signatory countries[23]. There are other accords which cover different jurisdictions or functions for engineering accreditation. For example, in addition to the different accords covering engineering education, there are a number of agreements designed to promote mobility of professional engineers between the signatory countries such as: the Asia Pacific Economic Cooperation (APEC) agreement between countries in the Asia-Pacific region [24]; and the International Professional Engineers Agreement (IPEA)[25] which is an agreement between engineering organisations in the member jurisdictions of the IEA. These accords create the framework for the establishment of an international standard of competence for professional engineering. Mobility is a key motivating factor for defining the competencies expected of fire safety engineers since the principle requires substantial equivalence of competencies between jurisdictions.

The majority of programs accredited to Washington Accord standard have a duration of 4 or 5 years post-secondary learning. This is the period of learning that is deemed to be required in order to develop all of the competencies required for entry to practice in most engineering disciplines.

The level of complexity of problems that professional engineers are expected to be able to solve is defined by the IEA as ones which are characterised by the following features[26]:

- They cannot be solved without in-depth engineering knowledge which allows a fundamentals-based, first-principles analytical approach;
- They often have a range of conflicting technical, engineering or other issues;
- They have no obvious solution and require abstract thinking to formulate suitable models for their solution;
- They involve infrequently encountered issues;
- They are outside of the scope of problems encompassed by standards and codes of practice;
- They involve diverse groups of stakeholders;
- They are high-level problems including many components.

According to the Engineering Council in the UK, in comparison, Chartered Engineers should be able to develop solutions to engineering problems using new or existing technologies, through innovation, creativity and change and/or they may have technical accountability for complex systems with significant levels of risk [27]. This is consistent with the complexity of problems that degree exit level graduates are expected to have encountered during their studies as part of a Washington Accord accredited degree.

Generally, it may therefore be summarised that a professional engineer is an individual that through their personal and professional attributes and competency is capable of using engineering knowledge and tools as input towards a design which is developed from first-principles and which defines and responds to a complex engineering problem. Attributes and skills attained in a Washington Accord degree therefore reflect a specific level of problem-solving and the level of engineering activity that is expected to be taught and assessed as part of an accredited program of study.

The Washington Accord covers just one of the different categories of practitioner: the professional engineer. Other categories of practitioner exist, including the Engineering Technologist and the Engineering Associate. The role of the Engineering Technologist and the Engineering Associate are covered by the Sydney and the Dublin accords respectively [28,29]. However these two categories of practitioners are expected to be able to apply their skills to problems of lower complexity than those of the professional engineer. This means there is scope for discussion around the possiblity of a multi-tier registration framework, but that introduces significant additional complexity in the definition of roles and is outside of the scope of this paper.

Operating on a principle of substantial equivalence, signatories to the Washington Accord recognise that the competencies possessed by graduates of accredited degree programs are largely the same, irrespective of the structure and specific approach to delivering the educational foundation. Content is therefore not specified by the Washington Accord, but rather the competencies reflecting the graduate attributes are specified in this outcomes-based approach.

The relationship between the different elements of competency is shown schematically in Figure 2, adapted from [30]. The box representing Engineering Specialism corresponds to the discipline related knowledge. There is therefore an expectation that individual engineering disciplines have also established the complementary knowledge requirements specifically associated with the discipline. This comprises the elements of the knowledge base that include engineering, natural sciences, and mathematics; and which are complemented with contextual knowledge, project management and finance as well as commmunication, teamwork and ethics. Of critical importance, the knowledge base and attributes are connected with graduate attributes in the core process of design, which must reflect the complexity of problem described above for the professional engineer. Competency in all of these areas is necessary for first stage accreditation of an individual, and the accreditation of a degree program is attestation by the accrediting body that degree exit level graduates have competence in these areas.

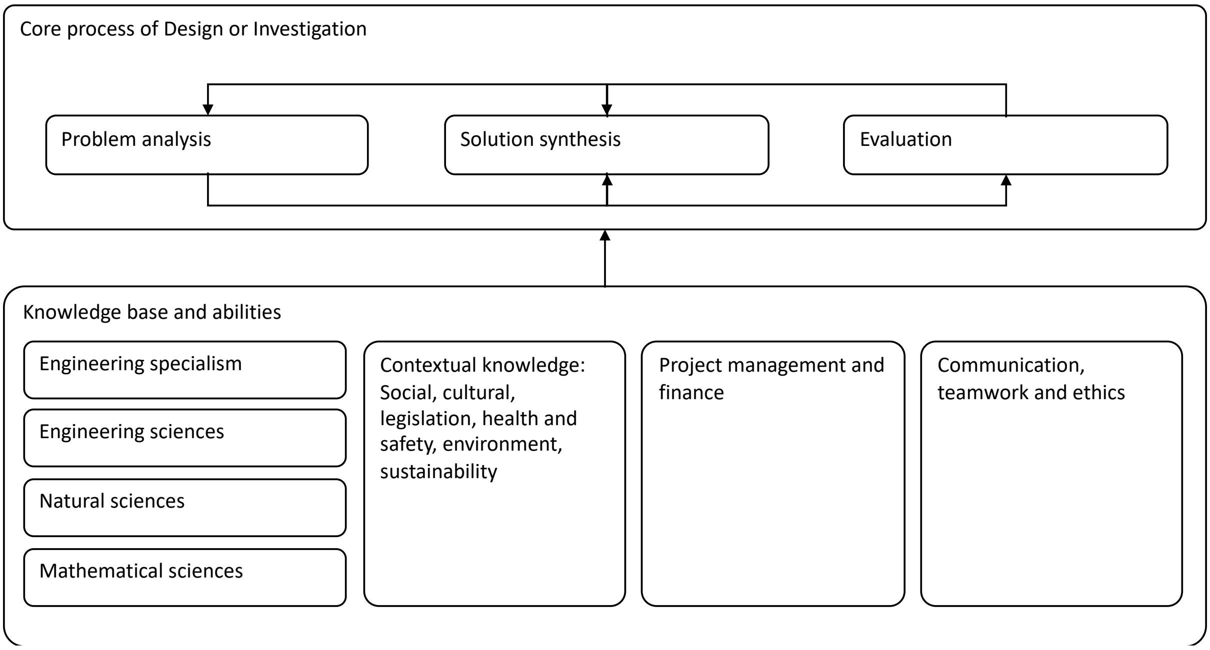

Figure 2 A conceptual model underlying the Graduate Attributes, reproduced from Hanrahan[30]

This *outcomes-based approach* to accreditation of engineering degree programs is the basis of the first stage, or career entry level, accreditation of engineers in the signatory countries to the Washington Accord. For example, for fire safety engineering it should not be an aim simply to create a curriculum that includes fire dynamics, but rather to deliver the program outcome that graduate engineers possess the capability to *apply fire dynamics principles as part of the process of the design of a fire safety strategy* and other related analysis that may be required of the profession. Any accredited degree program must therefore include appropriate assessment that enables verification of the required competency – the skill in the application of the knowledge base of the fire safety engineer to develop a fire safety strategy from first-principles (the skill in the application of the technical content to a suitably complex problem).

2.1 Expected competencies in fire safety engineering

Contrary to the focus on skill in application of knowledge explicit in the Washington Accord approach, the traditional way to attempt differentiation of fire safety engineering from other disciplines has been based on the structuring of the knowledge specific to the field - i.e. to focus on the engineering specialism, and in some instances the basic engineering knowledge that underpins this - rather than the ensemble of graduate atttributes. For example, this knowledge-based approach is seen in the 5 core modules for fire safety engineering education identified by Rasbash in 1980 [31], that were built upon by Magnusson et al. as part of the activities of the International Working Group on fire safety engineering Curricula when defining a model curriculum in 1995. This Working Group sought to 'define the subject matter that an employer can expect an employee who is a fire safety engineer to have mastered' [32]. This work was completed before many jurisdictions transitioned to a regulatory model that permitted fire safety engineering from first-principles and thus bears revisiting. Similarly, the SFPE's Recommended Minimum Technical Core Competencies for the Practice of Fire Protection Engineering [33] published in 2018 set out both BSc and MSc curricula [34, 35] that focus on the competencies associated with the technical knowledge base. Whilst this is more recent than the model curriculum developed by Magnusson et al, these competencies simply constitute a list of expected knowledge outcomes of that model. Additionally, the recently published "Setting the bar" report aimed at the UK building sector presents a list of "Knowledge headings" or technical competencies, but does not fully address the application of that knowledge, as should be expected of fire safety engineers if the failings exposed by the Grenfell Tower disaster are to be remedied [36].

The curricula mentioned above focus primarily on the body of knowledge underpinning fire safety engineering. They do not adequately address the development of skill in the application of this knowledge to complex engineering problems or any of the other personal or professional attributes that are expected of an individual seeking admission to professional practice. Therefore, none of these curricula fully satisfy on their own the requirements of an accreditation framework for fire safety engineers and must be supplemented by other aspects of general engineering education. While they provide a potential key component of a future accreditation framework, the lack of integration of all fire engineering competencies into one curriculum is a significant weakness.

Woodrow *et al* set out a framework for fire safety engineering education in response to a number of industry presentations given at a Lloyds Register Educational Trust (LRET) Global Technical Leadership Seminar on fire safety engineering [37]. This work showed that technical knowledge is not an appropriate nucleus around which to structure the education of a design oriented professional, instead emphasizing other graduate attributes for fire safety engineers. However, as with the 1995 Model Curriculum, the focus of Woodrow et al's work was primarily on education, and thus the details of the expected graduate attributes were not discussed in a sufficiently comprehensive manner to allow the development of a more complete competency framework.

This is one of the biggest issues in fire safety engineering today. While there are accredited programs, the criteria and competencies upon which this accreditation is based have a focus only on the technical content of the degree: not on the application of this content to complex problems in fire safety engineering; nor on the other attributes required for practice and which can be taught as part of a structured program of learning. Without a well-defined competency framework for fire safety engineering that meets the needs of industry today and upon which this accreditation can be based, any accreditation of fire safety engineering programs can only lead to widely varying outcomes.

A further issue to be addressed, in regards to the historical legacy of fire safety practitioners being mostly orientated to code compliance, is the current membership of the professional organisations. For example, although the Institution of Fire Engineers (IFE) was licensed by the Engineering Council in 1996 to enable it to accredit individual competence and register members with the appropriate professional status, questions remain with regards to the extent to which this registered membership are all competent to implement a first-principles approach to fire safety engineering. Variable levels of competence within the IFE, and other such organisations globally, is a critical matter because in any profession, in order to be allowed to practice, a professional has to be accredited as possessing the necessary competencies by a group of similarly accredited professional peers. As noted by Spinardi: 'In principle, peer review should uphold a coherent set of standards as regards competency and ethics, but the issue for fire safety engineering is whether the profession as it is currently composed is sufficiently homogenous to have this coherence' [38].

Furthermore, the professional institution does not operate in a social vacuum; its accreditation standards should reflect the operational requirements of the industry that it serves (and consequently provide the broader societal benefits seen to justify a monopoly of practice). Professional status is not an end in itself, and educational attainment must reflect and support industry practice. To what extent should the domain of fire safety engineering be driven by cutting edge research in specialist higher education departments as opposed to being driven by the pragmatic concerns of an industry that mostly continues to operate in a prescriptive regulatory context?

As described, following the first stage accreditation, degree exit level graduates are admitted to a second stage in the process which comprises practice under the supervision of an accredited professional. Once a suitable body of work has been undertaken, which demonstrates competence within a professional context in the application of the knowledge, skills and attributes attained during the degree program, then the individual can be fully accredited and admitted to the profession [14]. Here, again we are presented with a paradox with regards to the role of industry which must be addressed. For the accreditation mechanism to function, there must be an agreed upon definition from within the industry of what specific competencies a professional is expected to have and gain through education and supervised professional practice. The various curricula that have been proposed by those representing fire safety engineering over the years only go part of the way in achieving this.

Ultimately, competencies should match the role that a profession seeks to monopolise in society. Our agenda is therefore clear in that we aim to provide the necessary definition of competencies required to justify such authority. We suggest that those practising fire safety engineering who appreciate the value of professional recognition should advocate for a monopoly of practice in the field of fire safety engineering design on the basis of the competencies described here.

3. A competency framework for fire safety engineers

The process for developing the proposed competencies for fire safety engineering has at its foundation the proposed roles that have been detailed in the Roles Report[39] of the Warren Centre project carried out in Australia, which had as its objective the professionalisation of fire safety engineering in that country. This vision was based on a more integrated and holistic approach to fire safety design and review than is currently the norm in practice in Australia; from planning and concept design through to construction, commissioning, and handover to the building owner/manager. These roles are also consistent with the design process as described by Maluk et al. following discussions held at a subsequent LRET global technical leadership seminar to that used by Woodrow et al. to draw up their educational framework [40].

The original proposal of these competencies was based around compatibility with the Engineers Australia (EA) competency standards for first stage accreditation [41]. The proposed competency standard is therefore intended to reflect the required competency of a degree exit level engineer for entry to practice on the route to Chartered, Chartered Professional or Professional Engineer status(CEng, CPEng or PEng).

As noted earlier, the product of the fire safety engineering design process is the fire safety strategy. The optimization of the design process requires the explicit and continuous interaction of the fire safety engineer with the entirety of the design team. The objective of the fire safety engineer in meeting this responsibility is to deliver the fire safety strategy while considering all other requirements in an optimized manner. A competency framework needs to reflect the process of design of the fire safety strategy and the multiple roles and professional interactions that this development requires. The complexity of examples of fire safety strategy encountered by students as part of their university education is therefore an important indicator of the level of attainment in relation to each of the elements of competency expected of them.

Commonly, fire safety engineering is placed as a speciality within the disciplines participating in the construction process. It is important however to recognise that fire safety engineering sits at the complex interface between specialised and generalist practice. That is to say that the fire safety engineer is not only influenced by other disciplines in the design team, incorporating discipline specific drivers and constraints into aspects of the fire safety strategy, but also has the capacity to significantly influence all other aspects of the design, imposing additional drivers and constraints on other disciplines. The former is a specialist role while the latter is more generalist practice. Few disciplines have a sufficiently broad impact in design to be able to operate in both modes, with the possible exception of Architecture. While not explicit, this is recognised in the SFPE - Recommended Minimum Technical Competencies for Fire Protection Engineering [33], where the following definition is presented:

"A fire Protection Engineer is an individual who, by formal training and professional experience, carries the necessary competency, and has the skills to provide guidance and

direction to protect life, property and environment from threats posed by fire and its related mechanism.”

The generalist role can be identified as “*providing guidance*” while the specialist role as “*providing direction*.” Building on this, Figure 3 shows an idealised delivery framework which can be defined where the fire safety engineer can operate either as a specialist or a generalist. In this framework, a project manager is appointed by a building owner, developer, or client representative with the brief of coordinating the process leading to delivery of a building or infrastructure. The lead designer is appointed by the project manager to coordinate the various aspects of the design with other specialist designers. The designer liaises with approvals organisations, authorities, certification bodies and fire brigades to obtain design approval and to ensure that conformity of the design to regulatory standards is agreed. The designer also liaises with general contractors in the delivery of detailed specifications for the design. If the design is acceptable to all parties, then the details are passed to the general contractor, who manages the delivery of the project to the project manager’s client. Clearly, one or more of these parties may be the same organisation fulfilling multiple roles, but the roles are distinct.

As an example, a fire safety engineer might be a specialist in fire performance of structures, smoke control or egress. In this case, the fire safety engineer responds to the designer and is required to provide adequate solutions that optimise resources and deliver the requested functionality. In the definition of solutions, the fire safety engineer has to show awareness of the needs of other professionals. Nevertheless, the responsibility to optimise all components of the integrated design rests with the designer, who in this case may be the architect.

The fire safety engineer, however, can also play a role in an approvals process and be required to certify that the complete fire safety strategy and package of fire safety measures meet the regulatory requirements. In this case, the fire engineer has overall responsibility for the approvals process relating to a specific ensemble of related design features. A significant part of the responsibility regarding the fitness of the holistic design towards societal requirements in this case rests with the designer, who in this example is the fire safety engineer.

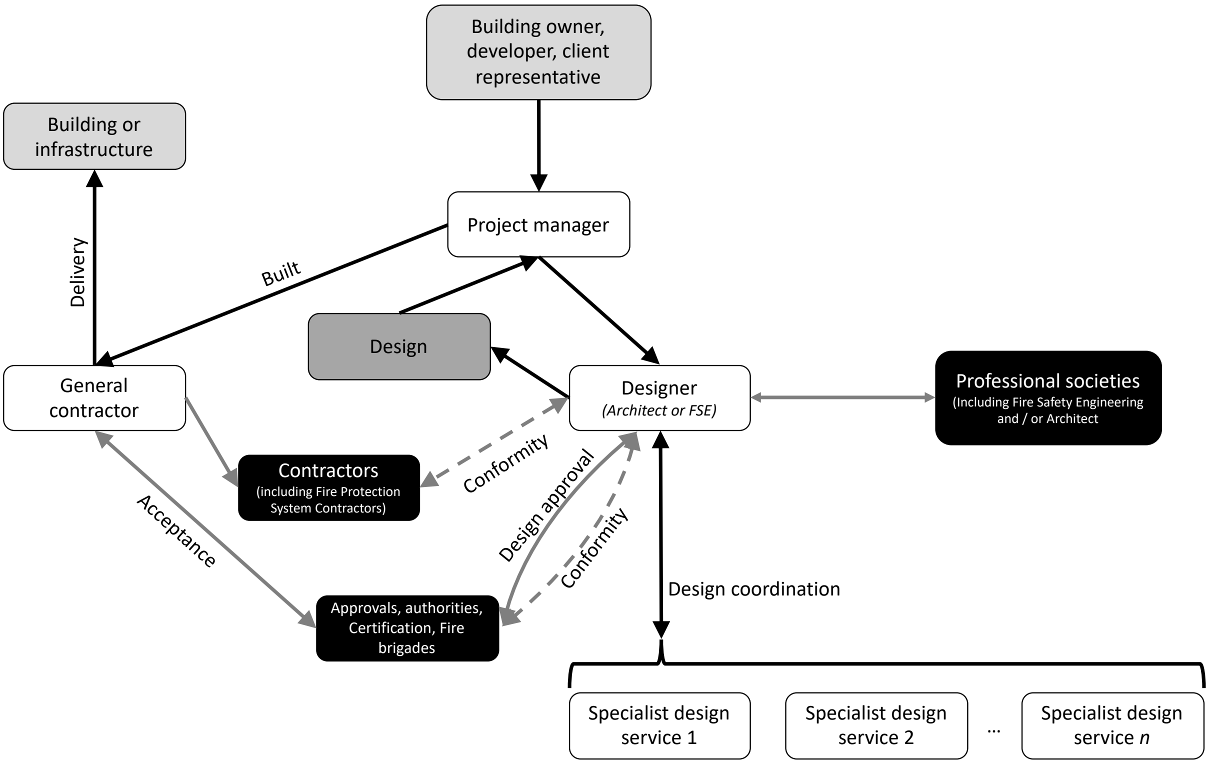

Figure 3 Idealised delivery framework (shading delineates between those external bodies who contribute to the conformity of the design or its implementation to accepted standards (black), those with a potential design role or responsibility (white), the design (dark grey) and the result to be delivered and its owner (light grey))

Fire safety engineering can also therefore have a major influence on most of the design and construction solutions implemented by other professionals, informing, for example, materials used and their configuration, the overall layout of the building, the required performance and integration of HVAC systems in the building, the building envelope design, etc. Therefore, the fire safety engineer can operate as a generalist that coordinates other disciplines around adequate fire safety solutions and integrates specialist knowledge from other disciplines (e.g. structural engineering, building services, etc.) around the design of a fire safety strategy.

In all cases, approvals are linked to the designer and the fire safety engineer needs to be able to play a part in this central role to the overall approvals process. Therefore, the competencies that are required of the fire safety engineer may also resemble those currently deemed essential for architects. Thus, in addition to using the engineering competency framework of the IEA as a source, this proposed competency framework for fire safety engineering also draws on specific aspects of the Royal Institute of British Architects (RIBA) competency framework [42] related to the design integration, delivery and approvals process.

In response to the identification of fire safety engineering as both a generalist and a specialist area of practice, a number of additional competencies have been adopted from the RIBA competency framework where these are relevant and where they were not already identifiable in the Engineers Australia competency standards. In addition, reflecting the conclusions of the earlier reports of the Warren Centre project [43, 44], we propose additional competencies beyond those set out by the IEA. In particular, a key additional competency is the need for fire safety engineers to be able to identify where developments (such as new materials, products, systems, or techniques) in other engineering disciplines could impact upon the current practice of their own profession and the application of their own specialist body of knowledge.

The entire list of competencies was presented to and commented on by representatives of the fire safety engineering industry in Australia, at a series of 3 review meetings held in the middle of 2019. Representatives of all of the organisations listed in Table 1 were invited to comment on the proposed competencies

Table 1. Overview of entities who contributed to the review of the proposed competencies.

Industry	**fire and rescue services**	**Authorities**
Arup Umow Lai Dobbs Doherty Holmes fire RED fire Engineers Warrington fire Omnii Aurecon Scientific fire services SKIP consulting	SAMFS (South Australia Metropolitan fire Service) AFAC (Australasian fire Authorities Council) New South Wales fire and Rescue Service QFES (Queensland fire and Emergency Service)	ABCB (Australian Building Codes Board) VBA (Victorian Building Authority)

The structure of the original proposal was based on the current Engineers Australia Stage 1 competency standards [41], with the elements of competency modified to reflect the integration of the generalist role and the additional competencies identified as necessary in the Warren Centre project [39]. While Australia is a signatory to the Washington Accord, the competency standards of EA have a different structure to the competency standards of the IEA and so these proposed competencies in this article have been restructured for an international context. In mapping the original proposal to the IEA competency standard, these additional elements have been integrated into the 12 Graduate Attributes of the Washington Accord [26]. The 12 resulting elements of competency are summarised in Table 2, which gives the original element of competency from the IEA framework, as well as the proposed wording of that for Fire Safety Engineering and a suggested indicator of attainment. The indicators of attainment are drawn from Engineer Australia indicators, with modification where needed and appropriate to better reflect expectations from industry of fire safety engineers seeking stage 1 accreditation.

These competencies, as an ensemble, reflect the graduate attributes, including skill in application of the knowledge obtained to complex problems, for a fire safety engineer to be expected to enter practice and perform with a degree of efficacy in relation to the expectations of that role. This is as opposed to the curricula described in the introductory sections which do not address the complexity of the problems encountered. It is also clearly distinct from the Initial Professional Development competencies proposed by the IFE in the “Setting the Bar” report which covers the expectation during stage 2 of the individual accreditation process (which is broadly the process followed in the UK, one of the signatories to the Washington Accord) [36].

The subsequent sections summarise the elements of competency against the three broad headings of: Knowledge and skill base; Engineering application ability; and Professional and personal attributes.

3.1. Knowledge and skill base

Whether the professional operates as a generalist or a specialist, the fire safety engineer is required to possess a comprehensive array of specialist knowledge. Specialist knowledge is therefore an essential component of fire safety engineering. This knowledge is unique to the profession and serves to define some of the elements of competency for the fire safety engineer. Awareness of this specialised knowledge is required from many of the other professionals participating in the design and construction process; nevertheless, none of these other professionals can serve as a substitute for the fire safety engineer. Both the SFPE's Recommended Minimum Competencies for Fire Protection Engineering[33] and the Model Curriculum [32] of Magnusson et al itemise relevant specialist knowledge in fire safety engineering that includes at least the following technical subject matters:

1. implementation of an effective fire safety strategy;
2. principles of risk assessment;
3. principles of building and infrastructure design;
4. principles of people movement, human behaviour and crowd management and the application of analytical and computational tools;
5. principles of fire dynamics, chemistry, fluid mechanics, heat transfer, combustion and the associated mathematical, analytical and computational skills;
6. principles of fire protection: design, implementation, commissioning and maintenance;
7. principles of solid mechanics, structural behaviour and the application of relevant analytical and computational tools;
8. principles of firefighting;
9. applicable regulatory framework; and
10. awareness of the needs and principles of other professions operating within design and construction.

While this list provides a set of essential technical components and can serve as guidance when defining curriculum, presentation of this list does not mean endorsement or any assessment of priority. It is therefore essential for national professional organisations to engage in a dialogue with degree granting institutions to establish how this knowledge and the related skills and attributes will be introduced into the educational process. Given that engineering education accreditation is framed within an outcomes-based approach, discipline-based knowledge also has to be placed within the same structure.

The degree granting institutions need to put forward a pedagogical model that covers the required knowledge and skills and the means to verify that the learning outcomes have been met. Furthermore, evidence that the pedagogical model encourages the development of all essential professional attributes is required. The national professional organisations have to accept that this model is appropriate.

This will deliver the confidence that the graduates of this Stage 1 process have the required knowledge, skills and attributes. By itself, and without the general attributes and program accreditation process described above, the list of knowledge areas is insufficient.

Finally, there are elements of competency (whilst incorporated in many degree programs around the world) that are sometimes neglected from curricula relating to the following key aspects:

1. Discernment of knowledge development and research directions within the fire safety engineering discipline.
2. Knowledge of developments and research directions in related areas of practice which may impact upon the fire safety engineering discipline.
3. Awareness of the needs and requirements of professional disciplines and other stakeholders within the design and construction process and an understanding of how the fire safety engineering process influences and interacts with these professional disciplines or stakeholders.
4. Awareness of the role and activities of other disciplines and stakeholders within the design and construction process and an understanding of how the fire safety engineering process is influenced by these professional disciplines and stakeholders.
5. Understanding of the scope, principles, norms, accountabilities and bounds of sustainable fire safety engineering practice

All of these specific elements are incorporated in the fire Engineering competencies proposed in Table 2 following the structure of the IEA's competency framework. These competencies also include example indicators of attainment, drawn from EA's indicators of attainment [40] but modified where appropriate for fire safety engineering. Here it must be noted that the examples given in the indicators proposed are not intended to be an exhaustive list. Fire safety engineering is multidisciplinary and not every engineer will attain fluency in the development and application of all of the examples.

3.2 Engineering application ability

In order to address the introduction of discipline based knowledge, it is essential to understand the role the engineer needs to play in the design process and the manner in which the knowledge will be applied. For example, while principles of building and infrastructure design should always be part of the technical knowledge of a fire safety engineer, for a specialist, this falls within the context of general awareness. If the fire safety engineer is expected to act as a generalist, then design principles become a core skill of the fire safety engineer.

The generalist fire safety engineer should demonstrate awareness of the needs and requirements of professional disciplines within the design and construction process but also understand how fire safety engineering influences and interacts with these professional disciplines. Integrated and iterative design, which are at the core of architectural education, therefore become the primary driver of fire safety engineering.

To introduce these attributes within the education of the fire safety engineer, some elements of technical knowledge, which have been at the core of curricula in fire safety engineering to date, need to be deemphasised in a very careful manner, whilst still being retained in the program. The generalist will therefore be required to be supported by the specialist.

In contrast, a fire safety engineer specialised in structural fire analysis will require detailed technical knowledge that creates a common base with structural engineers. The needs and requirements of professional disciplines within design and construction can be reduced and the time refocused towards the needs of structural engineers. Thus, the time released can be dedicated to developing the required discipline-based knowledge.

Through the process of accreditation of a program, a dialogue between the professional bodies and the degree granting institution will define the ultimate structure of the program. It is not unusual for most engineering disciplines to make these distinctions which can be found in any university engineering department.

The following elements are therefore reflected in the competencies proposed in Table 2:

1. Application of established fire safety engineering methods to complex fire engineering problem solving;
2. Fluent application of fire safety engineering techniques, tools and resources to the design of the fire safety strategy;
3. Application of systematic fire safety engineering synthesis and design processes; and
4. Application of the range of services offered by fire safety engineering to the conduct and management of engineering projects, including to all those disciplines being influenced by fire safety engineering, resulting the ability to deliver the necessary services in a manner that prioritises the interests of society while respecting and having regard to the client and other stakeholders.

The description and wording of the competencies given in Table 2 reflect the focus of the fire safety engineering framework proposed by Woodrow *et al*., which places the emphasis not on the solution to a problem but rather on its definition [37]. This helps to deemphasise the technical knowledge whilst requiring the exit-level graduate to demonstrate ability in its application.

This also highlights the importance of pedagogy. As discussed above and in [7], there is a need to reinforce the fire safety strategy as the artefact for which the fire safety engineer has responsibility in the design process. Demonstrating ability to apply the technical knowledge discussed in the previous section to the design of the fire safety strategy for a variety of buildings supports an approach to fire safety engineering education which is based on problem based learning. The benefits of this are demonstrated clearly by Woodrow *et al*.[44].

Further, the focus on gaining an ability to apply fire safety engineering knowledge to complex problems and to develop complex fire safety strategies from first-principles, commensurate with the competencies expected of a professional or chartered engineer, implies that education should be structured around a backbone of skill in design as opposed to the body of knowledge alone. While this approach is incorporated in some fire safety engineering degree programs around the world it is far from universal.

All of the above is connected to the importance of the experience and attributes of the academics delivering the program. Accreditation of degree programs involves some implied endorsement by the profession of the academics delivering these programs. Therefore to be able to adequately deliver such a program the relevant faculty should have themselves either achieved or be in a position to achieve the accreditation from the professional body that their students are expected to go on to. This means that at a bare minimum those academics charged with delivering an accredited degree program should possess the competencies described in this paper. While full professional accreditation is not always a pre-requisite for academic endeavour there is an argument for it to be seen as such, since it lends credibility to the taught program, in particular considering the expectations of their graduates to be able to develop a fire safety strategy for a complex building from first-principles. Indeed, engagement with the professional community constitutes an important part of the professional culture that universities should engage in, with the conduct of ad-hoc consultancy and peer-review of complex solutions often being within the remit of academics. Given a drive to fully professionalise fire safety engineering the argument for academics to be suitably professionally accredited is clear.

This argument can of course be taken further, considering the role of universities as part of the professional culture in advancing the knowledge of the discipline. This places further inescapable requirements on the faculty responsible for the delivery of a program in fire safety engineering to conduct and disseminate a significant body of original research in the field.

3.3 Professional and personal attributes

In addition to the knowledge and skill base and the engineering application ability that we argue are required for a competent fire safety engineer, there are certain other professional and personal attributes expected of a degree exit-level engineer. These professional and personal attributes should normally be obtained through the process of undertaking a substantial tertiary education, although they cannot easily be examined. Therefore we rely on the pedagogy of the program, amongst other factors, to instill these traits in graduates, including:

1. Understanding of the impact of engineering on society and the environment
2. A commitment to ethics and quality of practice – to uphold a duty and a standard of care
3. Knowledge of economics and project management
4. An ablity to work both individually and as part of a team

5. An ability to communicate concepts to various stakeholders in a range of settings - particularly important given the impact of fire safety communication skills
6. A commitment to life-long learning

Those elements above which are listed in the Washington Accord graduate attributes are, in many instances, the basis of what defines a "Global Engineer" – an engineer with a capacity to respond effectlvely to global issues such as interdependency between social and technical systems in a rapidly shrinking world [45]. These attributes should be common across all engineering disciplines and so in the competencies listed no changes are proposed, although some indicators of attainment specific to fire safety engineering are proposed in Table 4.

These graduates attributes are central to the social contract that exists between engineering and society. As noted by Chan and Fishbein [45], engineering is the application of scientific principles for the betterment of society – and is therefore by definition a service profession. This is reflected in the words of Wickenden, a former president of the Insitution of electrical engineers quoted by Dahrendorf [10], who said; *"'Professional status is therefore an implied contract to serve society over and beyond all specific duty to client and employer in consideration of the privileges and protection society extends to the profession"*

Although it is not more important in fire safety engineering than in other engineering disciplines, the commitment to life long learning is worth noting because the body of knowledge and the problems that are encountered by the fire safety engineer have a shorter life span than the typical career of the practitioner [37]. As reflected in the competencies associated with the knowledge and skill base, fire safety engineers are often responding to the unintended consequences of progress in other disciplines. Further, fire safety engineering is a relatively young discipline, and as stated by Drysdale: "…*the perception seems to be that sufficient science has been done to support the engineering, but this is a dangerous viewpoint for a number of reasons. The most significant is that it leads to the unjustified assumption that "fire safely engineering" as it is now practised is soundly and reliably based – yet it has not been practised for long enough to give us the experience to confirm this assumption.*"[46] Recognsiing these facts, means that a commitment to life long learning is the only way to ensure that the discipline is practiced ethically.

4. Conclusions

This paper argues that a first step towards professionalizing fire safety engineering in a manner that enables a first-principles approach is to define an adequate competency framework. This competency framework serves as the foundation that will enable fire safety engineering to begin the process towards achieving a professional status that grants the discipline professional authority over its field of practice.

This definition of a competency framework addresses the issues highlighted in this paper that are generated by a long history of reliance on prescriptive regulations. This history has resulted in a confusion of competency that undermines the case for fire safety engineers to demand professional authority on the application of first-principles methods.

A series of competencies for fire safety engineering that are aligned with the Washington Accord competencies are presented. This framework could be used as a basis for first stage accreditation of practitioners through accreditation of degree programs in fire safety engineering.

This implies and requires a dialogue between the national professional organisations and the relevant degree granting institutions that results in accredited degree programs. The process of accreditation should reflect that discipline-based knowledge and general knowledge are structured around a pedagogy that the profession deems acceptable. The assessment of the professional competency of staff that deliver the course is also part of the process of accreditation.

A point that emerges from the competencies and that needs to be emphasised is that discipline-based knowledge alone is not enough. The Stage 1 accreditation expects many other skills and attributes in an engineer. This is what is expected of other engineering disciplines, and the proposed competencies raise the bar of fire safety engineers to a level consistent with other engineering disciplines. The proposed indicators of attainment therefore reflect a degree exit-level fire safety engineer.

By virtue of the basis for the proposed competencies, these also reflect what a cross-section of fire safety engineering practitioners believe that a Washington Accord accredited degree in fire safety engineering should look like. Most fundamentally agreement between the profession and the degree granting institution can provide assurance that the product of the degree program possesses the competencies that the profession deems necessary to enter practice and to proceed towards accreditation under the supervision of an accredited professional. Without this agreement, accredited professionals are not empowered to demand authority over their profession. If they were to attempt to do so, others could easily challenge their competency. The proposed competencies address this.

Another benefit of the proposed approach is, therefore, that if these are the elements of competency expected from an exit-level graduate of an accredited degree in fire safety engineering then this is the benchmark for Stage 1 accreditation for those seeking admission to the profession via an alternate route.

Adoption of these competencies would therefore lead to consistency in the accreditation process. This would inevitably raise the bar to the level that industry collectively requires and will enable fire safety engineers to perform with a high degree of efficacy in their role. The proposed competencies therefore also serve the purpose of delivering a flow of adequately qualified professionals.

Finally, raising of the bar does not only apply to the individuals seeking accreditation. It also applies to the higher education institutions who produce graduates in fire safety engineering. If a higher education institution is not able to attain accreditation for their degree against the agreed graduate profile, then the responsibility is on them to adjust the program, change the staff or modify the courses that they deliver.

Having established the need to raise the bar, it follows that the profession should not let the competencies of the exit-level graduate of the existing degree programs determine the level of competency that the profession accepts. This would be the same as watering down the requirements compared with other engineering disciplines, diminishing the effectiveness and therefore the credibility of the profession. Higher Education institutions therefore need support from both industry and governments to develop the degree programs that are able to produce the degree exit-level engineer described in this paper. This is an issue for the profession globally, not only the countries represented in the authorship of this paper, and not only for those countries reflected in the list of signatories to the Washington Accord. All elements of the profession internationally should therefore contribute and collaborate to take these issues forward.

Table 2: competencies and indicators of attainment related to the knowledge and skill base for fire safety engineering

Category	**Element of competence (general)** *General element of competence as worded by IEA [14]*	**Competency description for fire safety engineering** *Element of competence as worded for fire safety engineering*	**Indicator of attainment (fire)** *Proposed indicator of attainment for fire safety engineering, based on Engineers Australia's indicators of attainment [41] for similar general competency's with modifications made to reflect the expectations for fire safety*

Engineering Knowledge	WA1: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems	This element of competence refers to the body of knowledge required of a fire safety engineer in order to practice with efficacy in the role. Mastery of the body of knowledge requires a: a) Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to fire safety engineering. b) In depth understanding of the body of knowledge pertaining to one of the specialist bodies of knowledge in fire safety engineering These specific attributes can be developed through education and represent the imparting of knowledge to a student. Evidence of an understanding of the body of knowledge can be shown through the application of established fire safety engineering methods to complex fire engineering problem solving. c) Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences as used by the fire safety engineering discipline in practice. Mastery of the mathematics that underpins the discipline can also be taught, however the most effective way to *evidence* mastery is through the ability to fluently apply it to a	a) Engages with the engineering discipline at a phenomenological level, applying a combination of knowledge in chemistry and combustion, fire dynamics, Fluid mechanics, Heat and mass transfer, Suppression and detection, Human behaviour and fire, Solid mechanics, Structural fire engineering, fluid mechanics, thermodynamics, heat and mass transfer and solid mechanics as well as engineering fundamentals to systematic investigation, interpretation, analysis and innovative solution of complex problems and broader aspects of fire safety engineering practice. b) Proficiently applies advanced technical knowledge and skills in at least one specialist practice domain of the engineering discipline, e.g. (but not limited to): - human behaviour in fire - fire risk analysis, fire risk assessment and fire risk management - structural fire engineering - smoke control - combustion - suppression and detection c) Develops and fluently applies relevant investigation analysis, interpretation, assessment, characterisation, prediction, evaluation, modelling, decision making, measurement, evaluation, knowledge management and communication tools and techniques pertinent to the engineering discipline. This may include, depending on the specialist area of competence in fire safety engineering, e.g. (but not limited to) - ability to fluently apply CFD software to a wide variety of fire safety engineering problems - ability to fluently apply zone models to a variety of fire safety engineering problems - ability to fluently apply finite element analysis software to a variety of problems in structural fire Engineering, including heat transfer problems and mechanical problems - ability to fluently apply egress models (software tools and other methods) to the study of evacuation of occupants from buildings - ability to justify the use and application of methods of analysis by reference to current literature and state of the art - ability to fluently apply compartment fire models as appropriate - ability to apply basic engineering mathematics to simple problems in fire science and which may be solved using the above - ability to fluently apply risk analysis, risk assesment and risk management techniques to problems in the field of fire safety engineering

		range of problems in fire safety engineering. The examples of applications of mathematics in fire safety engineering given in the proposed indicators of attainment are not intended to be an exhaustive list	

Problem analysis	WA2: Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first-principles of mathematics, natural sciences and engineering sciences (WK1 to WK4).	This element refers to an ability to both discern knowledge development and research directions within the fire safety engineering discipline, and to have knowledge of developments and research directions in related areas of practice which may impact upon the fire safety engineering Discipline. An understanding of knowledge developments in the field of fire safety engineering will contribute to a clear understanding of ones own competency limits, whereas knowledge of developments in other disciplines will allow fire safety engineers to proactively address the impacts of progress in other disciplines.	a) Knowledge of current and recent literature as pertaining to the fundamentals of the body of knowledge underpinning the profession b) Ability to critically evaluate and summarise state of the art in at least one specialist practice domain within the discipline c) Ability to critically evaluate fire safety engineering designs and solutions based on an understanding of the current state of the art as well as the body of knowledge underpinning the profession d) Ability to identify research needs for the progression of fire engineering practice. e) Ability to identify where developments in the built environment create additional fire safety hazards f) Ability to critically evaluate the fire safety strategy of a building accounting for the impact of additional hazards identified as a result of changes in the built environment

Design / development of solutions	WA3: Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health, and safety, cultural, societal and environmental considerations (WK5).	Responding to the need to account for interdependencies between disciplines in the construction process as well as the fire engineers role as a central part of the design team in complex projects, the fire engineer requires an awareness of (similar to architects who also maintain a central role in the design team): a) the needs and requirements of professional disciplines and other stakeholders within the design and construction process and an understanding of how the fire safety engineering process influences and interacts with these professional disciplines or stakeholders; and b) the role and activities of other disciplines and stakeholders within the design and construction process and an understanding of how the fire safety engineering process is influenced by these professional disciplines and stakeholders. This is in addition to an understanding of the scope, principles, norms and bounds of sustainable fire safety engineering practice.	a) Demonstrates awareness of fire safety as a social obligation, including the understanding of all different sectors (age groups, physical ability and degree of independence, etc.) of a population. Understanding of the sectors of a population implies knowledge of the role society attributes to the different groups in regards to the delivery of their own safety. b) Identifies and applies systematic principles of engineering design relevant to the engineering discipline. c) Is aware of the fundamentals of business and enterprise management. d) Identifies the structure, roles and capabilities of the engineering workforce. e) Engages with the overall design principles and process in the built environment; f) Engages with architectural practice; g) Demonstrates an understanding of integrated design and professional interactions in the built environment; h) Appreciates the basis and relevance of standards and codes of practice, including the Deemed to Satisfy / prescriptive solutions in the building regulations, their origin and application, as well as legislative and statutory requirements applicable to the fire safety engineering discipline. i) Demonstrated knowledge of historical literature within the field and the impact of the history and development of the practice on the practice today. j) Understands the fundamental principles of engineering project management as a basis for planning, organising and managing resources. k) Appreciates the formal structures and methodologies of systems engineering as a holistic basis for managing complexity and sustainability in engineering practice. l) Is able to demonstrate the value of engineered solutions in terms of cost, societal capacity and risk mitigation.

Table 3: competencies and indicators of attainment related to the engineering application ability for fire safety engineering

Category	Element of competence (general) *General element of competence as worded by IEA [14]*	Competency description for fire safety engineering *Element of competence as worded for fire safety engineering*	Indicator of attainment *Proposed indicator of attainment for fire safety engineering, based on Engineers Australia's indicators of attainment [41] for similar general competency's with modifications made to reflect the expectations for fire safety*
Investigation	WA4: Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.	Generally this element of competency is directly applicable to fire safety engineering and relates to the application of established fire safety engineering methods to complex fire engineering problem solving.	a) Identifies, discerns and characterises salient issues, determines and analyses causes and effects, justifies and applies appropriate simplifying assumptions, predicts performance and behaviour, synthesises solution strategies and develops substantiated conclusions. b) Ensures that all aspects of engineering activity are soundly based on fundamental principles – by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic. c) Competently addresses complex fire engineering problems which involve uncertainty, ambiguity, imprecise information and wide-ranging and sometimes conflicting technical and non-technical factors. d) Investigates complex problems using research-based knowledge and research methods. e) Conceptualises alternative engineering approaches and evaluates potential outcomes against appropriate criteria to justify an optimal solution choice. f) Critically reviews and applies relevant standards and codes of practice underpinning the engineering discipline and nominated specialisations. g) Identifies, quantifies, mitigates and manages technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline. h) Interprets and ensures compliance with relevant legislative and statutory requirements applicable to the engineering discipline.
Modern tool usage	WA5: Create, select and apply appropriate techniques, resources and modern engineering and IT tools,	This element of competency is applicable to fire safety engineering and relates to the fluent application of fire safety engineering techniques, tools and resources.	a) Partitions problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then re-combines to form a whole, with the integrity and performance of the overall system as the paramount consideration. b) Proficiently identifies, selects and applies the materials, components, devices, systems, processes, resources, plant and equipment relevant to the engineering discipline. c) Constructs or selects and applies from a qualitative description of a phenomenon,

	including prediction and modelling, to complex engineering problems, with an understanding of the limitations (WK6).		process, system, component or device an appropriate model based on fundamental scientific principles and justifiable simplifying assumptions. d) Determines properties, performance, failure modes, and other inherent parameters of materials, components and systems relevant to fire safety engineering. e) Applies a wide range of engineering tools for analysis, simulation, visualisation, synthesis and design, including assessing the accuracy and limitations of such tools, and validation of their results. f) Applies formal systems engineering methods to address the planning and execution of complex, problem solving and engineering projects. g) Designs and conducts experiments, analyses and interprets result data and formulates reliable conclusions. h) Analyses sources of error in applied models and experiments; eliminates, minimises or compensates for such errors; quantifies significance of errors to any conclusions drawn. i) Safely applies laboratory, test and experimental procedures appropriate to the engineering discipline. j) Understands the need for systematic management of the acquisition, commissioning, operation, upgrade, monitoring and maintenance of engineering plant, facilities, equipment and systems. k) Understands the role of quality management systems, tools and processes within a culture of continuous improvement.
The engineer and society	WA6: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems (WK7).	Generally there is no change to this element of competence, relating to an understanding of the accountabilities and bounds of fire safety engineering practice.	a) Is aware of the importance of competency limits of practitioners. b) Appreciates the principles of Safety Engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the fire safety engineering discipline. c) Appreciates the social, environmental and economic principles of sustainable fire safety engineering practice. d) Knowledge of the relevant legal systems, civil liabilities and the laws of contract and tort (delict); e) Knowledge of professional ethics as may be applied in the practice of fire safety engineering

Table 4: competencies and indicators of attainment related to the professional and personal attributes for fire safety engineering

Category	**Element of competence (general)** *General element of competence as worded by IEA [14]*	**Competency description for fire safety engineering** *Element of competence as worded for fire safety engineering*	**Indicator of attainment (fire)** *Proposed indicator of attainment for fire safety engineering, based on Engineers Australia's indicators of attainment [41] for similar general competency's with modifications made to reflect the expectations for fire safety*
Environment and sustainability	WA7: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts (WK7).	No change to this element of competence.	a) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline. b) Appreciates the issues associated with international engineering practice and global operating contexts. c) Is aware of the founding principles of human factors relevant to the engineering discipline.
Ethics	WA8: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice (WK7).	No change to this element of competence, which reflects an overall competence and the ability to behave with integrity, in the ethical and professional manner appropriate to their role.	a) Demonstrates commitment to uphold local ethical standards, and established norms of professional regulation, conduct and discipline pertinent to the fire engineering discipline. b) Demonstrates an understanding of the fire safety engineer's obligation to society and the protection of the environment; c) Understands the need for 'due-diligence' in certification, compliance and risk management processes. d) Understands the accountabilities of the professional engineer and the broader engineering team for the safety of other people and for protection of the environment. e) Is aware of the fundamental principles of intellectual property rights and protection.

			f) Demonstrates a capacity for autonomous working and taking responsibility within a practice context g) Demonstrates attributes of integrity, impartiality, reliability and courtesy; h) Thinks critically and applies an appropriate balance of logic and intellectual criteria to analysis, judgement and decision making. g) Demonstrates commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work.
Individual and teamwork	WA9: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.	No change to this element of competence, which reflects both: a) Orderly management of self, and professional conduct; and b) Effective team membership and team leadership.	a) Understands the fundamentals of team dynamics and leadership. b) Functions as an effective member or leader of diverse engineering teams, including those with multi-level, multi-disciplinary and multi-cultural dimensions. c) Recognises the value of alternative and diverse viewpoints, scholarly advice and the importance of professional networking. d) Confidently pursues and discerns expert assistance and professional advice.
Communication	WA10: Communicate effectively on complex engineering activities with the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.	Application of the range of services offered by fire safety engineering to the conduct and management of engineering projects; including to all those disciplines being influenced by fire safety engineering and as a result be able to deliver the necessary services in a manner that prioritises the interests of society while respecting the client and other stakeholders. Effective oral and written communication in professional and lay domains.	a) Demonstrates an understanding of types of clients, their priorities and the management of the relationship. b) Is proficient in listening, speaking, reading and writing, including: - comprehending critically and fairly the viewpoints of others; - expressing information effectively and succinctly, issuing instruction, engaging in discussion, presenting arguments and justification, debating and negotiating – to technical and non-technical audiences and using textual, diagrammatic, pictorial and graphical media best suited to the context; - representing an engineering position, or the engineering profession at large to the broader community; - appreciating the impact of body language, personal behaviour and other non-verbal communication processes, as well as the fundamentals of human social behaviour and their cross-cultural differences. c) Prepares high quality engineering documents such as progress and project reports, reports of investigations and feasibility studies, proposals, specifications, design records, drawings, technical descriptions and presentations pertinent to the engineering discipline.

			d) Demonstrates an ability for effective communication, presentation, confirmation and recording
Project management and finance	WA11: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work as a member and leader in a team, to manage projects and in multi-disciplinary environments.	No change to this element of competence, which reflects effective team membership and team leadership.	a) Contributes to and/or manages complex engineering project activity, as a member and/or as the leader of an engineering team. b) Seeks out the requirements and associated resources and realistically assesses the scope, dimensions, scale of effort and indicative costs of a complex engineering project. c) Accommodates relevant contextual issues into all phases of engineering project work, including the fundamentals of business planning and financial management d) Proficiently applies basic systems engineering and/or project management tools and processes to the planning and execution of project work, targeting the delivery of a significant outcome to a professional standard. e) Is aware of the need to plan and quantify performance over the full life-cycle of a project, managing engineering performance within the overall implementation context. f) Presents a professional image in all circumstances, including relations with clients, stakeholders, as well as with professional and technical colleagues across wide ranging disciplines. g) Takes initiative and fulfils the leadership role whilst respecting the agreed roles of others. h) Displays a capacity for team member development, motivation, supervision and planning. i) Earns the trust and confidence of colleagues through competent and timely completion of tasks. j) Manages time and processes effectively, prioritises competing demands to achieve personal, career and organisational goals and objectives.

Life-long learning	WA12: Recognise the need for, and have the preparation and ability to engage in, independent and life-long learning in the broadest context of technological change.	No change to the wording of this element of competence.	a) Demonstrates commitment to critical self-review and performance evaluation against appropriate criteria as a primary means of tracking personal development needs and achievements. b) Understands the importance of being a member of a professional and intellectual community, learning from its knowledge and standards, and contributing to their maintenance and advancement. c) Demonstrates commitment to life-long learning and continuing professional development. d) Applies creative approaches to identify and develop alternative concepts, solutions and procedures, appropriately challenges engineering practices from technical and non-technical viewpoints; identifies new technological opportunities. e) Seeks out new developments in the engineering discipline and specialisations and applies fundamental knowledge and systematic processes to evaluate and report potential. f) Is aware of broader fields of science, engineering, technology and commerce from which new ideas and interfaces may be drawn and readily engages with professionals from these fields to exchange ideas.

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