Observations on the Situation with Performance-Based Building Regulation and Fire Safety Engineering Design in Sweden and the Potential for Incorporation of More Risk-Based Concepts

Professor Brian Meacham
Worcester Polytechnic Institute
Worcester, MA, 01609, USA

March 2017

Disclaimer

The observations, discussions and opinions expressed in this document result from an investigation undertaken by Professor Brian Meacham of Worcester Polytechnic Institute (WPI) within Sweden during the month of September 2016 as part of his year-long sabbatical research into the situation with performance-based building regulations and fire safety engineering in seven countries: Australia, Japan, the Netherlands, New Zealand, Scotland, Spain and Sweden. Overall, his research is focused on understanding how the existing performance-based building regulatory systems are working, the potential for building regulatory systems to become more risk-informed or risk-based, how the existing approach(es) to fire safety engineering is working within those countries, and the potential for fire safety engineering approaches to become more risk-informed or risk-based.

The research conducted by Professor Meacham within Sweden was funded through a Fulbright Global Scholar award to Professor Meacham. It should be understood that this work was not requested by, nor paid for, by Boverket, by any Swedish fire consulting or engineering firm, or by Lund University.

While reasonable attempts were made to verify the accuracy of the information provided, referenced and summarized in this report, it is possible that errors associated with translation of complex documents, and/or of interpretation of discussion and comments exist, or that inadvertent omission or incomplete representation of facts exists. All observations, summaries, opinions, findings, conclusions or recommendations expressed in this report are those of the author and do not necessarily reflect the views of Boverket or its staff, or of the firms, entities or individuals that the author held meetings with and/or who responded to his questionnaire as part of the research and development of this report.

Overview of Research Approach

There were two primary sources of data used in this research:

a) Review of documents, written in English, which describe the Swedish building regulatory system, such as available at http://www.boverket.se/en/start-in-english/building-regulations/national-regulations/, including the Swedish regulatory hierarchy (http://www.boverket.se/en/start-in-english/building-regulations/national-regulations/regulatory-hierarchy/), the Building Regulations, BBR19 (http://www.boverket.se/en/start-in-english/publications/2012/building-regulations-bbr/), 2011 edition, an English translation of Boverket's general recommendations on the analytical design of a building's fire protection, BBRAD (BFS 2011:27), as amended by BFS 2013:12 (BBRAD 3), and the mandatory provisions on application of the Eurocodes for Structure, EKS (http://www.boverket.se/globalassets/publikationer/dokument/2015/eks-9-en-2015-01-14.pdf); and
b) Interviews and discussions with staff from Boverket, with fire engineers from several engineering consulting firms, and with faculty at Lund University.

It should be noted that while the Building Regulations (BBR19) had been updated from the 2011 version to BBR22, the English translation was not available at the time of the research visit. It is anticipated that changes from the 2011 edition, which have a bearing on the issues researched as part of this study, will be addressed in September 2017, when Professor Meacham returns to Sweden for a follow-up visit under his Fulbright Global Scholar award.

Swedish Building Regulatory System

The first objective of this research was to obtain an understanding of the Swedish building regulatory system. To facilitate this, a meeting was held at Boverket on 9 September 2016 to discuss with staff the Swedish legislative structure, the building regulatory system, the fire safety approach within the building regulatory system.

Boverket – the Swedish National Board of Housing, Building and Planning – is a central government authority arranged under the Ministry of Enterprise and Innovation. As part of its mission, Boverket gathers relevant facts and statistics in Sweden and internationally to describe, understand, forecast and make policy suggestions. They undertake evaluations and impact assessments of policy initiatives at national and regional levels, supervise town and country planning in Sweden from legislative, procedural and architectural perspectives, and issue the Swedish Building Regulations.

Of particular interest in this meeting was to obtain information regarding the roles and responsibilities of actors in the building regulatory system, how performance is expressed within the regulations, including performance objectives, criteria and means of verification, and the extent to which risk is, or may be, used as a basis to establish levels of expected performance.

In advance of the meeting, Boverket staff had provided Professor Meacham with copies of the Fire Safety provisions of the Swedish Building Regulations (BBR 19, Chapter 5) and Boverket's general recommendations on the analytical design of a building's fire protection, BBRAD (BFS 2011:27, as amended by BFS 2013:12 BBRAD 3). As noted above, the 2011 version of the BBR was the focus, as it was the most recent version available in English at the time of the study.

Professor Meacham, in turn, had provided Boverket staff with an overview of the research aims, a questionnaire for obtaining feedback from the Swedish fire engineering community, examples of similar work he had conducted in other countries, along with a copy of a manuscript, which was under review, on a potential future approach to incorporating risk concepts into performance-based building regulations.

The following summarizes Professor Meacham's interpretation of the system and related issues.

<u>Form of Law and Regulatory Structure for Buildings</u>

The Swedish legal system is of the Civil Law tradition. Otherwise known as Napoleonic or Roman Law, the term civil law tradition or system is really a shorthand method of identifying a system of law that consists primarily of legislative or administrative enactments reduced to writing in codes as the supreme law of the country for all to see (Ortwien, 2003). A fundamental aspect of a Civil Law system is that the law defines what are unlawful or unjust acts, and for each of these, the penalty. As such, anything not expressly forbidden is allowed (Ale, 2005). This places a burden on legislation (Act, Laws, Ordinances, Regulations) to adequately establish limits around what is permitted.

The limits of what are permitted with respect to buildings are largely governed by the Planning and Building Act (2010:900), the Planning and Building Ordinance (2011:338), and the mandatory provisions and general recommendations stated within the Building Regulations (BBR) and the mandatory provisions on application of the Eurocodes for Structure (EKS). It is also noted on the Boverket website that: “An EU Regulation immediately becomes a part of Swedish legislation. If Sweden were to have regulations that conflict with an EU Regulation, these would not apply. An example of an EU Regulation is the *Construction Products Regulation,* CPR.”

In addition, there is a set of general recommendations on the analytical design of a building’s fire protection (BBRAD), along with a host of voluntary standards and guidelines as developed by standards-making organizations, professional societies and others. A hierarchy of the relationships between these documents is illustrated in Figure 1.

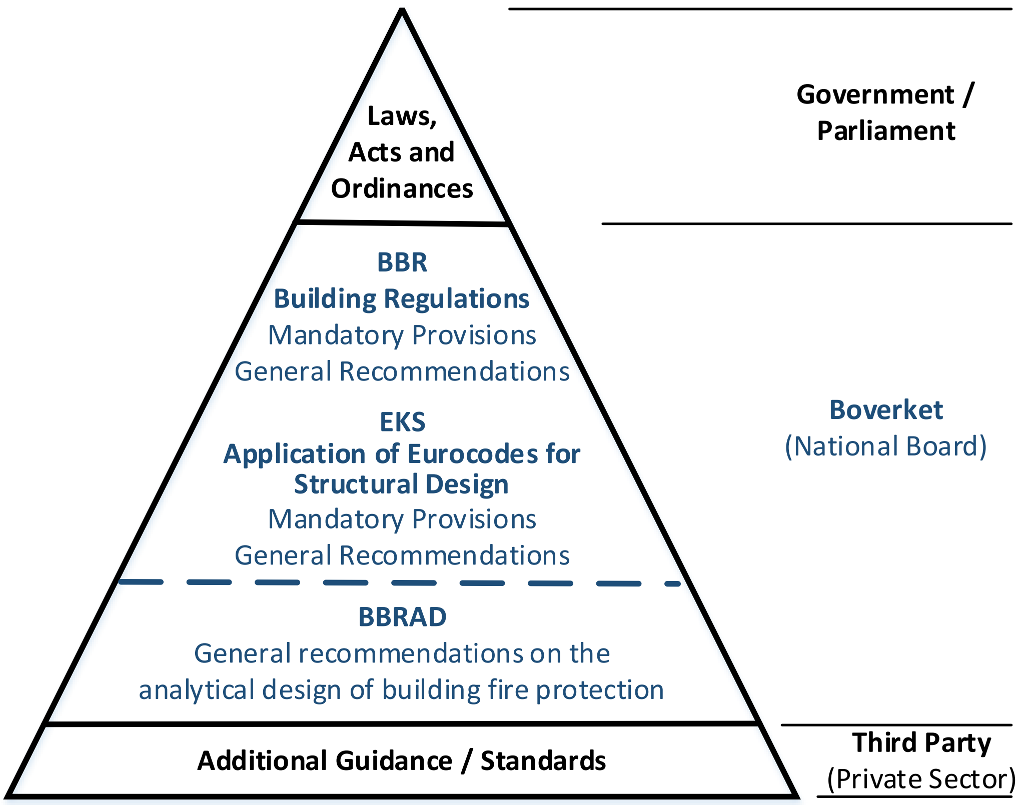

Figure 1. Swedish Regulatory Hierarchy for Building Regulations

Focusing on fire and life safety, within the Planning and Building Act, Chapter 8, *Requirements for construction works, construction products, lots and public spaces*, Section 4, it is stated that “construction works must have the technical characteristics which are essential in terms of … safety in case of fire…” From an external perspective, this can be perceived as being largely a statement to invoke the requirements of the CPR. While this is not of itself a bad thing, it is arguable whether the CPR is appropriate – on its own – as the basis for regulatory provisions for fire and life safety. The aim of the CPR is consistency in product / product approvals between member states of the EU. The aim of building regulation should be the safety of occupants. This becomes important when exploring ‘acceptable’ risk.

The Planning and Building Ordinance does provide more detail. Within Chapter 3, *Requirements for construction works*, the following is stated: “To fulfil the requirement on safety in case of fire pursuant to Chapter 8, Section 4, first paragraph, item 2 of the Planning and Building Act (2010:900), a construction works must be designed and constructed in such a way that:

1. The load-bearing capacity of the construction works in case of fire can be expected to last for a determined period of time;
2. Development and spread of fire and smoke within the construction works is limited;
3. Spread of fire to adjacent construction works is limited;
4. People present in the construction works in case of fire can leave the construction works or be rescued by other means; and
5. Consideration has been taken to the rescue team's safety in case of fire."

These requirements are largely aspirational, and to a certain extent functional, in that they address specific functional components of a building (e.g., structural stability during fire). However, they lack any measure of quantification (e.g., how long is a 'predetermined amount of time,' or what does 'limited' mean). Again, the lack of specificity is not necessarily a bad thing, as long as sufficient guidance is given somewhere within the regulatory system relative to the interpretation of these statements in the context of a building fire safety design scheme.

The Building Regulations (BFS 2011:26) provide yet another level of detail. However, these details are provided in two components: mandatory provisions and general recommendations, both of which are included in the Building Regulations. In addition, for fire safety, Boverket publishes further guidance in the form of *general recommendations on the analytical design of a building's fire protection*, BBRAD (BFS 2011:27). Furthermore, there are the requirements in the EKS to consider. Until 2011, fire safety requirements for load bearing structures within the Swedish legislation was included in the BBR. However, the fire safety requirements for structural design are now included in the EKS. As a result, compliance with the Planning and Building Ordinance involves compliance with the BBR, BBRAD and EKS.

<u>Opportunities and Challenges with the Current Structure</u>

As with any performance-based regulatory system, the concept of focusing on intended functions and performance to be achieved, rather than specifying detailed requirements for a building, can result in flexibility in design, innovation in materials, and optimization of risk and cost. However, such systems face challenges with respect to adequately defining performance measures to facilitate ease of determining regulatory compliance and allowing for suitably qualified professionals to make appropriate decisions. This balance between assuring safety as public policy, and allowing choice within the market, can be difficult to find. The requirement to adhere to two different regulatory systems – Sweden and the EU – can also introduce challenges.

Starting with the latter point, consider changes made to the Swedish regulations to incorporate the Eurocodes for structural design. Until 2011, fire safety requirements for load bearing structures within the Swedish legislation was included in the BBR. However, the fire safety requirements for structural design are now included in the EKS. While the separation may make sense for regulatory reasons, it can create to some challenges in practice. For example, the structural fire safety requirements dictated by the EKS should be included in the fire strategy report for a building, which is developed under the BBR and BBRAD3. However, the approach to performance assessment differs between the BBR/BBRAD3 approach and the EKS. The BBRAD describes different approaches and requirements for design fires than does the EKS. The criteria for performance are also different. This can make for challenges in practice when trying to apply a consistent performance-based approach, and in particular for risk-informed approaches.

With respect to flexibility and associated decisions regarding compliance, consider first the different between mandatory provisions and general recommendations. Mandatory provisions are clear –

they have to be complied with. General recommendations illustrate how one might comply with the mandatory provisions, and while legally they are not mandatory, in practice they can be viewed as such. For example, it is noted that general recommendations “state how someone can or should go about meeting a binding regulation in an Act, Ordinance or mandatory provision, but they are not required to be followed” and “a general recommendation may be seen as a toolbox presenting a method or solution. But if you choose not to do things in the manner stated in the general recommendation, you must be able to show that the binding regulations are still met” (Boverket website). For a practitioner, this wording opens the opportunity to use other methods. For an enforcer, however, a higher level of surety may be perceived if there is not deviation from the general recommendations, as they present an acceptable method or solution, and no decision on an alternate method or solution is needed by the enforcer. In fact, feedback from practitioners suggests that some local authorities significantly focus on the prescribed general recommendations, to the point where, even if alternative design can be undertaken, the resulting uncertainty in the approvals process often proves to be a deterrent to taking an alternative approach.

Likewise, there are several other benefits and detriments to having non-binding guidance, depending on one’s point of view. If complete, such guidance (e.g., general recommendations and BBRAD) can be helpful in clarifying intents (e.g., what is ‘limited’ spread of smoke, what is adequate time to safely escape a building during a fire). It can also provide a clarity in terms of how analysis should be undertaken for the defined conditions (e.g., building use groups / classifications). The provision of criteria to use in analysis (e.g., heat release rates, tenability criteria and the like) can be very helpful for achieving consistency in application and acceptance. However, such guidance can be problematic when it does not address all potential considerations (e.g., building uses, occupant characteristics, etc.), relies too heavily on ‘expert judgment’ of the user, or inadvertently restricts the use of other, equally suitable methods.

For example, ‘verification’ can be via qualitative assessment (including expert judgment), scenario-based analysis or quantitative risk analysis (QRA). With all the given parameters for ‘scenario analysis’, it is reported as being difficult to get approval of QRA approaches. This is because QRA is not well understood, typically resulting in more extensive review, longer timeframes, and uncertainty in approval, and clients ultimately view the uncertainty in approval as not worth the risk of trying. Also, while QRA is provided as an option, the Mandatory Provisions of the BBR state (5:1) “The design of the fire protection shall be based on the assumption that a fire could occur.” If one must assume a fire occurs, without considering the probability of occurrence, this limits the QRA and mitigation options (e.g., control of ignition sources, fuels, etc.). Looking ahead, this issue in particular would need to be addressed with any significant move to using risk as a basis for performance requirements.

To a certain extent, the uncertainty around acceptance and approval of non-mandatory approaches, such as risk-informed analysis and design, or even legally permitted deviations from specific scenarios and criteria, is a function of the Civil Law system and the accountability of the actors in the system. As described by Boverket staff, the Building Regulation is targeted at the person (entity) which is paying for the construction of a building, and it is this person (entity) who has the obligation for compliance. There are of course contractual arrangements between this entity and others, including the contractor, design engineers and others. However, should the building be found to be non-compliant, the entity paying for the works would be liable in the first instance. There is no particular liability of the local authority (Building Committee), so the contract would become the mechanism for determining if any others share liability.

In addition, in a Civil Law system, such as Sweden, the Courts typically have a more limited role in adjudicating differing interpretations of legislation, as compared with Common Law countries (e.g., see Meacham and van Straalen, 2017). With respect to the people of Sweden, it has been observed that generally they do not automatically think of seeking legal advice as problems arise: an attitude fostered to some extent by the way the legal system is designed as well as the cultural nature of the population (Ortwien, 2003).

These issues present a particularly challenging situation for risk-informed or risk-based analyses – even though allowed by the Building Regulations and the *general recommendations on the analytical design of a building's fire protection* via the approach of verification by quantitative risk analysis. First, there is the challenge that many people are unfamiliar and uncomfortable with risk analysis. Second, the general recommendations place restrictions on the risk analysis, which may not be fully appropriate. For example, the general recommendations state: "a quantitative risk analysis should consider either a reference building according to prescriptive design or the acceptance criteria specified in these general recommendations when assessing a satisfactory level of fire safety." However, as noted above, the prescriptive design approach (in fact the Building Regulations) say that one should assume that a fire could occur and gives options for mitigation. In a quantitative risk analysis, one should start with the likelihood or frequency of fire ignition. As such, it is not clear that comparison to a reference building based on prescriptive design is an appropriate benchmark. Likewise, if one were to choose the option of comparing to the specified acceptance criteria, it is not clear how this would be done. A quantified risk analysis (QRA) would typically consider the likelihood of exceeding some safety limit and resulting in the probability of a certain number of fatalities, or, at least, the criteria would be expressed in some form of probability of occurrence or exceedence.

In part it seems there may be a mix of concepts. One can apply risk approaches, including QRA, to look at fire scenarios of concern, or likelihood of safety barriers (fire protection systems) mitigating the fire, or the probability of safe evacuation given potential fires and reliabilities of fire protection systems, or the probability of fire fatality. Each approach is a little different, and requires different data, as they look at different outcomes. In an event tree approach, for example, one can either start with a probability (or frequency) of ignition, or start with established burning (credible initiation fire), and then assess likelihood of fire protection systems working as intended and the resulting consequences and probabilities of occurrence. While the consequences could end up similar, their likelihood of occurrence will be much different if one starts with say a probability of ignition of 10^{-3} or that a fire has occurred (probability of 1). The reviewer of a design would need to know which type of analysis they are reviewing and what the implications might be.

There is also the challenge, identified above, of the different approaches permitted by the BBR and the EKS for demonstrating compliance. In a full building fire performance analysis, it would generally be expected that the performance objectives, acceptance criteria, fire scenarios, and design fires would all align, and that the assessment of safe egress, structural performance, and other objectives, and the mitigating strategies utilized, would be demonstrated to fit together. This is difficult with two sets of regulations with different requirements and options for compliance. As structured now, the BBR allows a quantified risk approach, but the EKS does not, at least not of the same structure. Also, the Eurocodes provide for the use of a simplified 'time equivalency' approach for assessing fire resistance requirements, and it is presumed that the EKS allows this as well. If so, use of the time equivalency approach could be conflict with BBR mandatory requirements and general recommendations.

Regulatory Development and Interaction

Regulatory development is solely the responsibility of Boverket staff. They may, if they choose, use consultants for some work, and they have and do use reference groups. Questions, comments and suggestions can also be sent in from any practitioner, industry body or member of the public. However, in the end, Boverket writes and promulgates the Building Regulation.

Staff are required to undertake regulatory impact analyses, including with respect to economic impact (benefit-cost), environmental impacts, and impacts on people with disabilities. There are no set guidelines for such analysis, within Boverket or between Ministries and agencies, although efforts are undertaken to benchmark against others (e.g., Traffic Agency). Benefit-cost analysis, for example, was undertaken with respect to decisions on requirements for sprinklers.

Also, it is observed that fire safety provisions occupy much more content than other areas in the Building Regulations, yet there are only two staff members working on fire, and they may have other duties as well. This seems rather a low number of persons to develop new provisions, develop new guidance, answer questions on Building Regulation interpretations, and more (with new work items coming from Ministers, new EU regulations, …).

With respect to the regulations and regulatory development process, there seems to be little consistency across the building regulation areas, such as fire, structure, energy, and accessibility, even though all are intimately linked in terms of the end product being a useable and safe building. The need to holistically-developed and operating building regulations is widely accepted, and the types of system failures and competing objectives can be significant (e.g., see Meacham, 2010; 2016)

Because there is little coordination between areas, conflicts in how the regulations provide for demonstrating compliance exist. In particular, the differences between the BBR and the EKS are noted. As noted above, there are different criteria, scenarios and fires, and while the ability to use risk analysis exists in both the BBR for fire safety and in the EKS for structural safety, there is no consistency in approaches, even though fire is a load that structural analyses needs to consider, and fire performance of structures is something that building fire safety design needs to consider.

Finally, staff have indicated that they are open to moving to a more risk-based or risk-informed approach, at least for Fire, but given resource limitations, and the potential for new, higher priority work items from the Government, this could take years. In addition, while the appetite might be there to advance risk approaches for Fire, it is suggested that a more holistic approach should be considered. Buildings are a complex system of systems – they require architectural layout, structure, fire protection, access and egress, ventilation, sanitation and other systems to work together to achieve safe and well-performing buildings. If different areas of regulation approach each problem differently, it is not clear what the resulting overall level of safety / risk might be, or even for fire.

The point is that in general, a holistic approach is helpful, and a risk-informed approach should look at all of the hazard-related risks so as to make sure benchmarking and safety delivered is appropriate across all regulated areas.

Compliance and Enforcement

As noted earlier, responsibility for compliance with the regulations is targeted at the person (entity) which is paying for the construction of a building, and it is this person (entity) who has the obligation for compliance. There are typically contractual arrangements between this entity and others, including the contractor, design engineers and others. However, should the building be found to be non-compliant, the entity paying for the works would be liable in the first instance. There is no particular liability of the local authority (Building Committee), so the contract would become the mechanism for determining if any others share liability.

The Building Committee in a municipality assesses whether a building permit is required based on the type of project. Constructing a new building or adding an extension are measures which normally require a building permit. In Sweden, an extension is a measure by which the volume of a building is increased in any direction, either vertically or horizontally. A change of building use would normally also trigger the need for a permit. Once the permit process has ended, either with a permit being granted or once a notification being made, the construction process begins. The construction process includes a number of steps.

Works which requires a building permit or notification may not be commenced until the Building Committee has given starting clearance. In order to obtain starting clearance, the developer must be able to show that the works fulfil the requirements stipulated in the Planning and Building Act and associated regulations. For the Building Committee to make a decision on compliance, the developer must submit a proposal for an inspection and a test plan (ITP), along with the required technical documentation. The Building Committee affirms the ITP in the starting clearance.

Along the construction process, various inspections must be made. These inspectors (KA) must be certified by an accredited certification body. In cases where inspections are required, a technical consultation meeting will be held at the Building Committee, which includes discussions on how the work should be planned and organized, the proposal for ITP and general documentation. In most cases, the Building Committee will visit the site where the works are being carried out at least once during the project. The need for such a visit is decided at the technical consultation meeting. Once the works are completed, a final consultation is often held before a final clearance is issued, to review that the works have been complete as per the ITP.

In cases where the builder lacks the competence within their organization to demonstrate compliance with the building code, or does not engage an organization with this competence before the construction works starts, the Building Committee can demand that the builder engage a professional with a special certification related to competency in building regulation requirements – a SAK3 certificate – to conduct one or several specified controls, as specified in the ITP. These controls are often to check if the building is being built in compliance with the building code

However, it is reported that use the approach of requiring review by a professional with a SAK3 certificate is often used incorrectly, being demanded by a Building Committee in situations where there is not legal standing to demand review by a SAK3 certified professional, or for review of items not addressed in the ITP. It is observed that this situation should be addressed, perhaps simply through an education or training program regarding the SAK3 approach.

It is also noted that in addition to the Building Committee, the fire service may have a role in the approval process as well. The level of interactions between authorities and documentation requirements can (and reportedly does) vary by region and municipality.

It is observed that a lack of national consistency can result in varying levels of performance (safety) being delivered across the country. It also can have impacts on the market. For example, it was reported in interviews with fire safety engineers that it is up to each individual firm, and the local authorities, as to how much analysis is needed for alternative (analytical) approaches. This can range from an 'expert' saying that the difference is minor, to a requirement for an extensive analysis to be undertaken and reported.

In general, there seems to be a lack of guidance on what types of projects, or problems, deserve more attention in design and review. It was reported that some projects, including large complex ones, get little or no review; that some authorities ask for a lot of information, while others just sign off once ‘fire documentation’ is provided; that some authorities ask for detailed reports on fire fundamentals, not outcomes from the analysis, which involves significant time with questionable benefits, and that the role of the fire service can vary.

It is observed that given lack of national consistency in the review and approvals process, and given that there is an expectation of and high reliance on ‘internal’ peer review and quality control on designs (since responsibility and accountability lie with the engineer via contractual arrangements), there can be a wide range of performance being delivered. Such a high reliance on internal peer review can work well when robust quality control and quality management procedures are in place. However, establishment of robust systems for small firms can be problematic for several reasons, including resource limitations and lack of experts with appropriate experience and expertise to conduct the internal reviews. In cases where both internal peer review and external oversight is inadequate, there could be significant reason for concern. It would seem important to understand to what extent this situation exists, and how big of a concern it might be.

Feedback from Meetings with Fire Safety Engineers

The second part of this research effort focused on interviews and discussions with fire safety engineers working for a number of engineering and consulting firms in Sweden. The firms included Bengt Dahlgren Brand & Risk, Brandkonsulten, Brandskyddslaget, Briab, SWECO and WSP. Meetings were held in the engineers' offices in Stockholm and Malmo.

A summary of the feedback received from the fire safety engineering community is provided below. A questionnaire was sent to each firm in advance of the meetings. A copy is provided in Annex A. The questionnaire was provided to guide the discussion, and it was not required that each question be addressed during the discussions. As such, the headings below do not completely match the questionnaire.

The following text represents the author's interpretation and representation of feedback as received during these discussions. While reasonable attempts were made to accurately reflect the feedback obtained by the fire safety engineers in these firms, it is possible that errors associated with interpretation of discussion and comments exist, or that inadvertent omission or incomplete representation of feedback exists. All statements below, and any errors that exist, are those of the author and should not be interpreted as coming from any specific firm or person interviewed.

It should be noted that given the overlap on some of the questions in the questionnaire, some of the responses to questions may be duplicated under different headings.

<u>What is the general sense of the state of fire safety engineering in Sweden?</u>

- Generally the situation is good. There is a lot of work, and projects are going rather well.
- There were a number of 'bad actors' between 1994 and 2012, since any method could be applied, but since 2012 there has been some 'self-correction' by the market (less competent entities doing less engineering work).

<u>What is working well?</u>

- Current FSE approach as in the *general recommendations* works quite well, for qualified firms, but not clear all in the market are comfortable with it (or qualified to use it).
- System now allows PB design, in a structured manner.
- In beginning it was seen as a detriment: difficult to use, resulted in lower safety level in some cases, not clear it was needed, However, over time, it came to be seen as beneficial, providing a good framework for communication, providing a standard approach to scenarios, fires, analysis, etc. In the end it helps provide more consistency in designs / levels of safety delivered.
- There is now a system to get certified, based on criteria set by Boverket, to be able to do third party review of fire safety designs. This is good for the market, and gives authorities (and clients) some level of comfort. However, the aims are largely to look at whether the consulting firm who carried out the work has been able to achieved requirements from a legal perspective, more so than from a technical perspective.
- An entity can also ask for technical third-party review, but this is not often done. This is expected to be conducted internally.

What is not working so well?

- There is a concern with the designs from some firms. While the solutions are theoretically (technically) feasible, they are not always practical to install, and long term operation is suspect.
- There is a concern that the quality of education is going down because the universities are forced to admit less qualified persons.
- Graduates and young engineers are often focused on modeling without understanding the value of output in the context of design (e.g., estimating detector response at 68.42 seconds, when the certainty of input parameters does not justify such stated precision).
- The FSE guidance / general recommendations have created a focus on solving the stated problem, not necessarily the correct problem. Engineers are not asking as many questions as they used to, and are more often solving the problem the client wants without exploring whether it is the right (or complete) question / problem.
- Comparative analyses difficult, especially how to define ‘reference building.’ One can take the worst possible code-compliant building – and then ‘stretch’ the comparative part, so the basis is a very poor performing building.
- Big issue – approval process can be long and arduous – basically a report on fire fundamentals – not outcomes. This involves a lot of time for little benefit.
- Sustainability and fire issues are missing. Insulation, PV, timber, …
- Too much complex technology being used, without good controls and knowledge of reliability and availability when needed in fire.
- Some ‘Level 2’ criteria in Level 1 of the code (i.e., prescriptions mixed with functional), meaning no deviation possible. Example is sprinklers in hospitals. Can lead to unneeded design and cost. Should separate.
- The requirement for ‘fire documentation’ can be problematic, especially if no one actually checks or uses the documents – as is the focus is on producing a document that is compliant, not necessarily a good design.
- The way the projects are developed FSEs can work in pre-design (concept), which sets parameters, detailed design, during which strategy and implementation may change, and then be accountable to either argue to original client that changes were necessary, or go back and check all is ok, or just remain silent and sign off. While the system can work well, it also presents opportunities for problems.
- Some changes to the BBR have been interpreted such that significant cost is being added to some projects, in particular requirements around hospitals and which areas are required to have fire sprinkler protection, and how that is being interpreted as applicable to parts or all of the hospital building by different entities. Lack of guidance on what is required, under what conditions, has resulted in some hospitals requiring sprinklers if any patient rooms are in a building, regardless of the ratio of patient rooms to other spaces, while other entities require sprinklers only in patient rooms. Subsequently, it is not clear that all risks are being addressed as intended (e.g., fire in power supply for ICU could pose bigger risk to life of patients than fire in a patient room).

What percentage of projects would you estimate are: (a) direct compliance with Building Code provisions, (b) alternatives / equivalencies to Building Code provisions, (c) unique design (fully engineered from first principles), (d) some combination?

- There is really not that much 'engineering.' Some 60%-70% of market is predominantly prescriptive design, with about 20%-30% equivalencies, and less than 10% 'full' performance-based design.
- Real performance-based design, and risk-informed or risk-based design, used around power plants, transit, and related facilities, and as associated with transport of dangerous goods (near a building) and siting hazardous locations. Not really used otherwise in commercial engineering.

On what types of projects is fire safety engineering most used?

- Many types, for simple deviations. Offices, hospitals in particular.
- On facility types which have no building regulations – underground stations, power plants, etc.
- Tall, single means of escape (stairs) buildings.
- Used a lot on existing buildings, as they are renovated, expanded, etc.
- Real performance-based design, and risk-informed or risk-based design, used around power plants, transit, and related facilities, and as associated with transport of dangerous goods (near a building) and siting hazardous locations. Not really used otherwise in commercial engineering.

What are the main triggers for using fire safety engineering?

- Small alternatives to the prescriptive requirements is the main driver.
- Many facilities, like power plants, transportation hubs, etc. do not fall under the building regulation and require (or benefit from) fire safety engineering.
- Where projects are large / complex.
- Some code changes, like sprinklers in hospitals, has increased FSE solutions.

What are your views on the current formulation of the Building Code with respect to fire?

- Intents / purpose not as clear as could be. What is rational for dead end distances, or specific fire resistance rating, or…? In risk-based design, what do these mean? What is underlying risk / safety level target?
- The 2011 code revision provided more detail that the 1994 version, and indicates that if you exceed certain requirements, then must do performance-based (analytical) assessment. However, even though there are some criteria (for scenario analysis), the code is not clear on what performance one is trying to achieve, and comparative analysis can be difficult (and can be applied improperly, using buildings which are not comparative in all aspects).
- What is technical / risk justification for values in Code (e.g., HRR, smoke, …)?

- It is up to each individual firm, and the local authorities, how much analysis is needed for alternative (analytical) approaches. Can simply be expert saying the difference is minor, or could be extensive analysis (with 100-page reports than no one reads…).
- The scenario requiring failure of systems is problematic. It forces one to design as if certain systems are not there. This does not seem appropriate.
- The code has importance levels, but what does it mean? There needs to be explicit acceptance levels / safety levels / risk levels.
- There are always questions of 'how safe is safe enough' and little guidance to help answer this.
- Some facility types have no regulations – underground stations, for example – only 5 functional requirements – no code, no deemed to satisfy, … all up to stakeholders. It would be helpful to have guidance for these cases (in Code or elsewhere).
- Gap between regulation and type of buildings – regulation more complex – some ways to handle it but regulation not appropriate for complex buildings
- Sustainability and fire issues are missing.
- The intent / purpose of code provisions is lacking – more guidance is needed.

What should next step(s) with the code be?

- Next step should be a focus on buildings / facilities where guidance is lacking, underground, transit, power plants, etc.
- More refinements in categorization of building uses would be helpful. Now a small number of categories, but could break them down into more detail. Also, some missing. Will help with interpretation and design.
- There needs to be explicit acceptance levels / safety levels / risk levels.
- Intent of code needs to be clarified: life safety (and for whom, to what level), property protection (whose, and to what level), full burnout of buildings, …
- Need to review detailed provisions in light of current building practice, fire loads, etc. For example, issue with separation between floors of 1.2 m – appropriate for current fire loads and conditions?
- Need fire tests and guidance on aluminum framed façade and curtain wall systems. Tests standards on exterior flammability and flame spread, but no test for fire insult from the inside.
- Code is silent on many new technologies, like modular construction and fire protection of void spaces. Fires have occurred in this type of construction. Need at least a functional statement, and good to have general recommendations as well.
- Need more experienced people involved in development of code and guidance – existing staff good, but limited resources and experience.
- More explicit benefit-cost analysis is needed.

- Eliminate the 'fire protection documentation' requirement and focus on demonstrating that the fire safety objectives have been achieved. Currently too much focus on document on not enough on good design. (Note: This comment is focused on documentation aimed to satisfy requirements the code provisions have been complied with, not fire engineering strategies or related documentation.)

- Code does not address fire and sustainability issues – insulation, indoor air quality, tightness and overpressure due to fire, timber use, etc. Should consider these issues.

- Big push on timber – which is good – but how well is timber fire safety performance actually known, especially as buildings change over time, new technologies (e.g., CLT), etc. More guidance could be helpful.

- Lack of guidance on design of elevators for emergency evacuation. Perhaps not so much on hardening (some guidance, like firefighter elevators), but controls, situation awareness (when is lift coming, how long to wait, etc.), controls, power, etc.

- Concern with government focus on affordability – could safety be compromised? If no measure of risk / safety, how will this be assessed?

Do you think that only qualified fire safety engineers are undertaking fire engineering designs?

- It is getting better. After 1994 code and before 2011 changes, large number of former fire brigade and other persons were doing 'engineering' designs without necessarily being qualified or understanding what was required. Changes in 2011 has helped weed some of these people out. (They are fine to do code consulting, but not engineering.)

- Graduates and young engineers are often focused on modeling without understanding the value of output in the context of design (e.g., estimating detector response at 68.42 seconds, when the certainty of input parameters does not justify such stated precision).

- Question of what we are educating for: academia or engineering?

- Ethics is a growing concern. The system relies heavily on people doing the right thing, and self (or internally) checking work. More firms also taking money to do what client wants – whether it makes good sense for fire safety or not – and with no one really reviewing, …

Do you think there are enough qualified fire safety engineers in Sweden? How is 'qualified' determined?

- Most FSEs are code consultants – as such, not as many working with the engineering analysis as should have – should have some type of qualification to demonstrate competency.

- Skeptical about qualifications. You have to be a Registered Engineer in Australia, but still you see garbage from engineers who are on the register.

- You cannot have registration for software – you cannot know everything – up to the ethics at a certain point.

- Level of knowledge for engineers going downhill because lower qualifications into university – trying to get more students in – number of engineers going down, so letting more unqualified people in – maybe some certification is important.

- Courses at University focused on theory – students not prepared for dealing with reality – takes a lot of retraining. Faculty focused on development of tools – not on proper use.
- Larger companies have good internal checking systems – hard to assess quality in smaller firms, especially with no required detailed technical review.

What are your experiences with the approvals process?

- Approval process varies by region – some ask for a lot of information, others just sign off once fire documentation is provided. This can be good or bad. Sometimes fire service is involved, which can add time, but can also really help identify issues.
- Approval process can be long and arduous – basically a report on fire fundamentals – not outcomes. This involves a lot of time for little benefit.
- Have to get the right educated persons in the right location – MSB requiring FSEs to conduct plan approvals was a good changed.
- Need a more transparent and robust review process. Some projects, including large complex ones, get little or no review. This is not healthy.

Do you think more / different guidance for design is needed? If so, in what areas, and comprising what?

- Would be helpful to have better / more benefit-cost analyses to justify changes, and guidance on B-C analyses to help engineers with clients (e.g., with the hospital sprinkler issue).

What is your experience with third-party reviews?

- Seldom used. Focus on 'fire protection documentation' and firm / engineer.
- There is now a system to get certified (SAK 3), based on criteria set by Boverket, to be able to do third party review of fire safety designs for code compliance. This is good for the market, and gives authorities (and clients) some level of comfort. However, the aims are largely to look at whether the consulting firm who carried out the work has been able to achieve requirements from a legal perspective, more so than from a technical perspective (i.e., they check compliance with the code, not validity of engineering analysis).
- An entity can also ask for technical third-party review, but this is not often done. This is expected to be conducted internally.
- I have worked on a complex project for seven years, and not once has anyone asked a question about the fire engineering. While I believe I do a good job, it is very helpful to have external review, as no one is perfect, and there are always different ways to look at a problem.
- A more comprehensive and robust review process would be welcome. Only used when requested. Rely on internal review. Lot of variability. No clear understanding of level of performance / safety delivered across built environment.

What are your views on risk-based or risk-informed design?

- Should work, but not clear that it is all that practical at this time.

- There are currently too many definitions and interpretations of risk. Risk used in areas near transport of hazardous materials, hazardous facilities siting, etc. Authorities often not clear. Sometimes fire brigade just benchmarks to comparative figures.
- In some areas, like tunnels, risk is used extensively. In that area, all parties well versed in the concepts, tools and methods.
- Risk-informed approach could be beneficial for existing, particularly historical buildings – can better balance different societal objectives. Also addresses issue – should risk be the same in all buildings? If not, provide means for assessing and designing to whatever levels are agreed.
- Quantified acceptance criteria needed – now engineers have to have quantify expressions like 'low risk to life' – need a risk level that is quantified.
- Should be clear basis of performance in legislation benchmarked against society's risk tolerance.
- Code interpretations / FSE design approvals would be easier if everyone knew the risk level / criteria upon which provisions are based.
- INSTA effort a good first step, but needs to be better refined.
- Boverket should work with standardization community – hard for Boverket to keep up with limited resources.
- Better account of systems reliability is needed. Many designs today are complex technological solutions, and no one is assessing how likely they are to work when needed.
- Would be helpful to build safety management into legislation, but not possible (only construction). As such, the life cycle risk is difficult to manage.
- Risk-based design should work and would be great if we could adopt it; however, it requires that the building code be reworked so that the intents of different requirements are clearer (e.g. instead of saying that a structure should have a 90 minute fire rating, it should state that a structure should be able to with stand a full fire (with a certain probability), with the addition that this could be achieved by 90 minute fire resistance in the standard fire test.

Observations, Conclusions and Possible Steps Forward

The following reflects observations on potential activities which could be undertaken by Boverket and the fire safety engineering community to address concerns with the existing building and fire regulatory system and structure, as well as to help facilitate a more extensive and transparent use of risk as a basis for performance requirements and criteria in the building regulatory system in Sweden, should a decision be taken to move in that direction.

<u>Suggestions based on Feedback from FSE Community on Potential Boverket Work Items Regarding Fire Provisions</u>

There were a number of items identified through discussion with practitioners as to where activities might be undertaken by Boverket to clarify the current fire safety provisions and approaches in the building regulations.

- Removing prescriptive criteria from mandatory provisions, unless absolutely needed, and provide justification for why the criteria are needed (risk, scientific or policy based decision).
- Clarification of the intent of various fire safety requirements, and to the extent practicable, the risk, scientific or policy basis for the requirements / criteria that reside in the prescriptive requirements of the general recommendations (e.g., the basis of performance).
- Development of guidance on how to create appropriate engineering rationale for deviation
- Developing guidance on design of elevator systems for occupant self-evacuation (including controls, messaging (situation awareness), and hardening).
- Would be helpful to build safety management into legislation, but not possible (only construction). As such, the life cycle risk is difficult to manage.
- Focus on buildings / facilities where guidance is lacking, underground, transit, power plants, etc.
- More refinements in categorization of building uses would be helpful. Now a small number of categories, but could break them down into more detail. Also, some missing. Will help with interpretation and design.
- There needs to be explicit acceptance levels / safety levels / risk levels.
- Need to review detailed provisions in light of current building practice, fire loads, etc. For example, issue with separation between floors of 1.2 m – appropriate for current fire loads and conditions?
- Need fire tests and guidance on aluminum framed façade and curtain wall systems. Tests standards on exterior flammability and flame spread, but no test for fire insult from the inside.
- Code is silent on many new technologies, like modular construction and fire protection of void spaces. Fires have occurred in this type of construction. Need at least a functional statement, and good to have general recommendations as well.
- Need more experienced people involved in development of code and guidance – existing staff good, but limited resources and experience.

- More explicit benefit-cost analysis is needed.
- Eliminate the 'fire protection documentation' requirement and focus on demonstrating that the fire safety objectives have been achieved. Currently too much focus on document on not enough on good design.
- Code does not address fire and sustainability issues – insulation, indoor air quality, tightness and overpressure due to fire, timber use, etc. Should consider these issues.
- Big push on timber – which is good – but how well is timber fire safety performance actually known, especially as buildings change over time, new technologies (e.g., CLT), etc. More guidance could be helpful.
- Lack of guidance on design of elevators for emergency evacuation. Perhaps not so much on hardening (some guidance, like firefighter elevators), but controls, situation awareness (when is lift coming, how long to wait, etc.), controls, power, etc.
- Concern with government focus on affordability – could safety be compromised? If no measure of risk / safety, how will this be assessed?

Considerations for Moving to a Risk-Informed Approach

Some Boverket staff voiced interest in facilitating the use of risk in the Building Regulations, especially in fire safety, where there is already the ability to undertake quantified risk assessment as one of the analytic approaches as an alternative to prescriptive design. However, it is difficult to determine what the risk targets / levels should be, if regulated, and how to develop them. It is hoped that work being conducted on the new INSTA guide on probabilistic approaches to fire safety engineering design will be helpful. However, the author suggested that the guide is not currently moving in a direction which would significantly help Boverket in this regard.

There are several items which Boverket might consider should a decision be made to move towards adoption of a more risk-informed approach.

- It is necessary to decide whether the current approach in the regulations is appropriate (i.e., assume a fire has occurred) or if a 'complete' risk approach is to be used (i.e., one that includes probability and consequences), while considering those populations and situations of concern from a fire risk perspective.
- A risk characterization effort should be undertaken to characterize populations of concern, building uses / hazards of concern, whether one or more levels of risk are appropriate, and if so, whether levels are set by occupant characteristics, hazard characteristics or both.
    - Consideration should be given to whether there is one risk target for all users of buildings (e.g., residents, workers, visitors; vulnerable populations; etc.), or if different levels, or age-based relationships, etc., might better suit. It is suggested that a single value for the whole of the population may not be appropriate. Risk categories, risk levels based on national fatality rates, or other should be explored.
    - Consideration should be given to the fire hazards that a particular occupancy presents to the occupants, environment, etc., and the extent to which this is of importance to establishing risk levels.

- Consideration should be given to using broad stakeholder groups to agree whatever risk criteria / levels are developed, before implementation in regulation.
- Consideration should be given to Bayesian techniques to develop initial distributions for required parameters. Objective data can be used where available; however, one will never have a complete set of objective data, and sufficient data exist, along with expert input, using accepted methods, to develop usable distributions.
- Consideration should be given to developing detailed guidance and study cases (examples) before implementation in regulation.
- It should be considered that resulting risk targets / levels do not need to reside within the Building Regulations, but can reside in a supporting document which describes the principles and processes used to develop the risk targets / levels. This will also be helpful for interpretations which will come later.
- Consideration should be given to whether fire risk is a big enough public and political concern to go forward.
- Consideration should be given to submitting proposals to Brandforsk and/or other entities which could help resource the risk characterization process.
- Consideration should be given to adding more staff and/or utilizing more extensively outside help. It is not practicable for such an effort to be staff only, at least with the current numbers. Moving toward a risk-informed (or risk-based) approach will require significant effort to define the problem, structure the approach, collect data, consult with stakeholders, draft provisions and draft guidance. More staff would be helpful, and use of external resources seems a requirements (could be consultants, university research, etc., and should include reference groups, if not actual working groups of practitioners).

Possible Approach to Risk Characterization and Incorporation into Building Regulations

It has been suggested that building regulatory systems can be viewed as a socio-technical system (STS) (Meacham and van Straalen, 2017). The building regulatory system as an STS is reflected in Figure 2.

As presented, there are two operational environments, legal and regulatory (blue) and market (green), and an interactions environment within which decisions are made (red). Within each environment are subsystems associated with technology (Built Environment (BESS), Fire Hazard (FHSS) and Design, Construction and Evaluation (DCESS)), policy / decision making (Political, Economic and Societal (PESSS) and Policy Formulation, Implementation and Adoption (PFIASS)), and the market (Organizational Implementation Decision-Making (OIDMSS)).

In principle, the diagram shows the high-level interactions between sub-systems on each level. For example, the BESS, FHSS and DCESS interact with each other to describe/define the hazards, assessment approaches and mitigation options. The selection of regulated levels of performance, and tools and methods of analysis recognized for compliance with the regulations, are developed and agreed in the PESSS, PFIASS and risk characterization and decision environment. The policy suggestions are vetted and balanced with market options in the OIDMSS.

It is noted that the subsystems themselves are also socio-technical systems. It is also recognized that standards are developed in the private sector, and may or may not become part of the regulatory environment, as they may be used on a voluntary basis. However, the placement of standards within the DCESS reflects the role they play within the regulatory environment.

Details of the STS framework can be found in Meacham and Straalen (2017). At this point in time, the key issue is to illustrate how the building regulatory system is a socio-technical systems, and how the regulations, market, and components interact, with a particular focus on identifying components of the system that have an impact on the incorporation of risk concepts, in particular quantified risk measures, into building regulation.

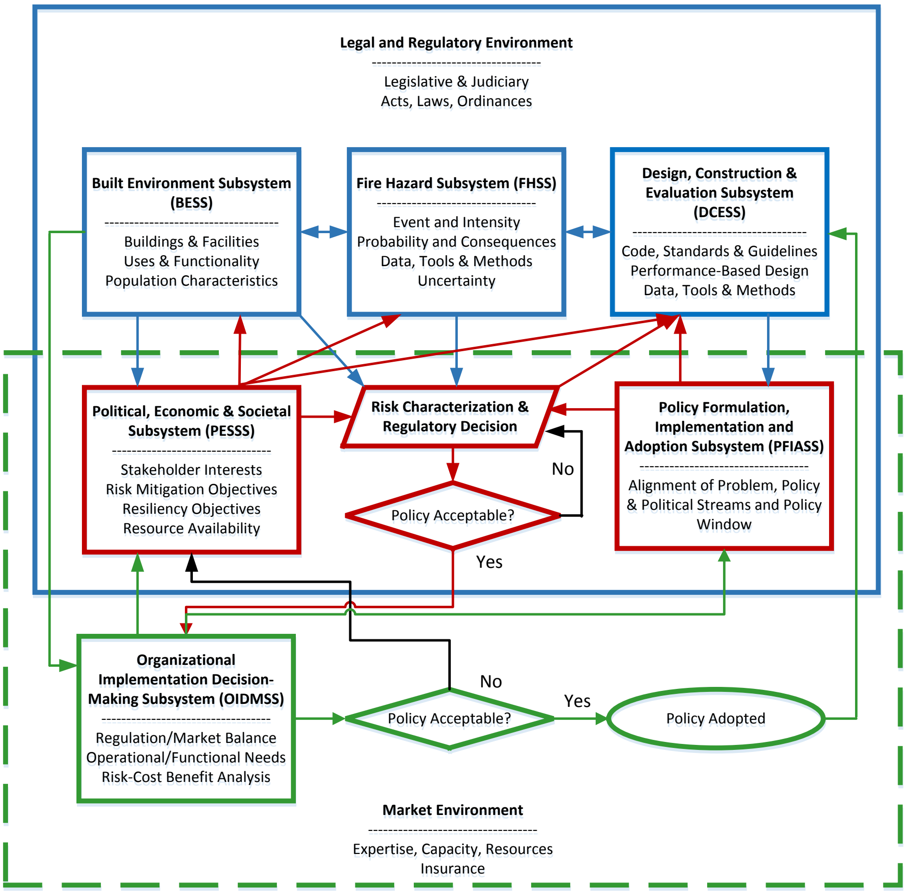

Figure 2. Building regulatory system as a socio-technical system (Meacham and van Straalen, 2017).

As to the incorporation of risk concepts into the building regulations – the risk characterization and decision component in the STS framework above – it is suggested that the approach developed by the U.S. National Research Council (Stern and Fineberg, 1996) provides a reasonable process to follow (see Figure 3).

This risk characterization process provides a framework for the integration of various aspects of risk, including identification, assessment, communication and analysis. It is the product of an analytic-deliberative decision-making process, wherein there is an appropriate mix of scientific information (from "traditional" risk assessment) and input from interested and affected parties throughout. It is a decision-driven activity, directed toward informing choices and solving problems. Since coping with a risk situation requires a broad understanding of the relevant losses, harms, or consequences to the interested or affected parties, significant interaction is required. It is very important, therefore, that the process have an appropriately diverse participation or representation of the spectrum of interested and affected parties, of decision-makers, and of specialists in appropriate areas of science, engineering and risk analysis at each step.

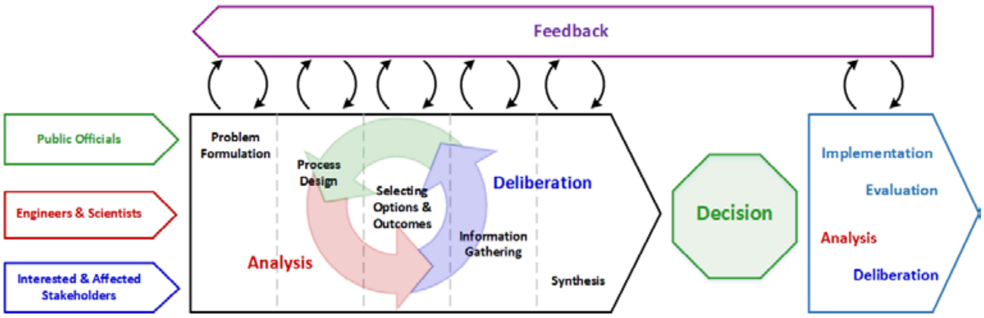

Figure 3. Risk Characterization Process (Meacham, 2010a, adapted from Stern and Fineburg, 1996)

This risk characterization process fits well within the STS framework, as it brings together the stakeholders, data, tools and methods, to develop an agreed decision on the characterization of risk, with defined policy formulation and implementation constructs. How these components come together, however, will depend in part on the legal and regulatory environment of a jurisdiction, and the issues associated with decision-making and regulatory implementation in those environments.

<u>Potential Options for Further Involvement by Professor Meacham</u>

Under the terms of the Fulbright Global Scholar Award, Professor Meacham will return to Sweden in September 2017. This presents an opportunity, if agreeable to Boverket and the FSE community in Sweden, for Professor Meacham to help facilitate addressing any of the issues identified above, and/or helping to advance the incorporation of risk as a basis for performance into the Swedish building regulations. The following are suggestions for consideration in these regards.

- Work with Boverket, and others as deemed appropriate, to help clarify the intent of various fire safety requirements – in both the BBR and EKS, to help identify and offer suggestions for minimizing conflicts between the BBR and EKS, and to help clarify, to the extent practicable, the risk / scientific / policy basis for the requirements / criteria, and develop guidance on rationale for deviation, where permitted.

- Facilitate a workshop, or set of workshops, comprised of persons from Boverket, universities, research entities, fire safety engineering firms, local building authorities, the fire service, developers, building owners, and the public, to try identify and agree means by which to characterize fire risk as a basis for establishing and justifying performance criteria to be used in the Building Regulations in the future (risk characterization process, as defined in associated documents). This effort might result in risk targets / levels, which may sit within the Building Regulations or in a support document, and should consider issues such as population characteristics (e.g., age, dependency, vulnerability), building use factors (e.g., sleeping & familiar, sleeping & unfamiliar, awake and mobile, …), building and process related hazards, fire event frequencies, and consequences of concern. This effort may also justify current criteria as well; however, the intent is to be forward looking to have a means to assess all provisions and approaches which may be implemented with respect to fire risk and risk management measures.

- Work with Boverket and/or a working group comprised of representatives of universities, research entities, and fire safety engineering firms to outline and/or develop an approach to assessing fire risk, for target populations, buildings, etc., using the risk characterizations (criteria, levels) as developed in the above activity. Whereas the above effort looks to define how risk is used in the regulation, this effort focuses on how one assesses the risk, and offers suggestions on determining acceptable or tolerable levels.

- Work with Boverket and/or a working group comprised of representatives of universities, research entities, and fire safety engineering firms to outline and/or develop guidance for undertaking risk-informed (risk-based) fire engineering analyses based on the above activities.

Acknowledgements

Professor Meacham gratefully acknowledges the time and thoughtful input from Boverket staff, in particular Caroline Bernelius Cronsioe and Anders Johansson; the time and thoughtful comments from the many fire safety engineers and managers that were interviewed from Bengt Dahlgren Brand & Risk, Brandkonsulten, Brandskyddslaget, Briab, SWECO and WSP; and time and thoughtful comments from faculty and staff of the Lund University Department of Fire Safety Engineering, as well as their gracious hospitality as his host during his research visit. I extend sincere appreciate to Professor Patrick van Hees at Lund University and to Anders Sjelvgren and Madeleine Hjortsberg for supporting my Fulbright Global Scholar Award application. I gratefully acknowledge the financial support from the Fulbright Foundation through the Fulbright Global Scholar Award.

Disclaimer

The observations, discussions and opinions expressed in this document result from an investigation undertaken by Professor Brian Meacham of Worcester Polytechnic Institute (WPI) in Sweden during the month of September 2016, which was funded through a Fulbright Global Scholar award to Professor Meacham. It should be understood that this work was not requested by, nor paid for, by Boverket, by any Swedish fire consulting or engineering firm, or by Lund University. While reasonable attempts were made to verify the accuracy of the information provided, referenced and summarized in this report, it is possible that errors associated with translation of complex documents, and/or of interpretation of discussion and comments exist, or that inadvertent omission or incomplete representation of facts exists. All observations, summaries, opinions, findings, conclusions or recommendations expressed in this report are those of Professor Meacham and do not necessarily reflect the views of Boverket or its staff, or of the firms, entities or individuals that the author held meetings with and/or who responded to his questionnaire as part of the research and development of this report, or of WPI.

References

Ale, B.J.M. (2005). "Tolerable or Acceptable: A Comparison of Risk Regulation in the United Kingdom and in the Netherlands," *Risk Analysis*, Vol. 25, No.2, pp231-241.

Meacham, B.J. (2010). "Accommodating Innovation in Building Regulation: Lessons and Challenges," *Building Research & Information*, Vol.38, No. 6.

Meacham, B.J. (2010a). "A Risk-Informed Performance-Based Approach to Building Regulation," *Journal of Risk Research*, Vol.13, Issue 7.

Meacham, B.J. (2016). "Sustainability and Resiliency Issues and Objectives in Performance Building Regulations," Special Edition – Building Governance and Climate Change: Regulation and Related Polices, *Building Research and Information*, Volume 44, Issue 5-6, DOI:10.1080/09613218.2016.1142330, published on-line 9 March 2016.

Meacham, B.J. and van Straalen, I.J. (2017). "A Socio-Technical System Framework for Risk-Informed Performance-Based Building Regulation," *Building Research & Information*, http://dx.doi.org/10.1080/09613218.2017.1299525, published on-line, March 2017.

OECD (2010). *Better Regulation in Europe: Sweden*, OECD, Paris, France.

Ortwien, B.M., 3rd, (2003). “The Swedish Legal System: An Introduction,” *Indiana International and Comparative Law Review*, Volume 13, Number 2, pp.405-446.

Stern, P.C. and Fineburg, H.V., eds. (1996). *Understanding Risk: Informing Decisions in a Democratic Society*, National Academy Press, Washington, DC.