ABSTRACT
A new Nordic guidance document for fire safety engineering and control in the building process, is being developed. The aim of the guidance document is to facilitate verification of building solutions including innovative and sustainable solutions and to harmonize the process for control within the field of fire safety engineering within the Nordic countries. The focus for the guidance document has been on a general level for review and control, independent of national regulatory requirements in the Nordic countries, with a primary focus on defining procedures within the planning and building process. But the process has also, to some extent, given guidance on how the fire safety engineering process can be a normal part of the overall control and review of the building process. The different steps within the planning and design phase, construction phase and operational and maintenance aspects that may be important to consider, to ensure the fire safety within a building’s lifespan, have been defined and the different kinds of review and controls have been clarified for these phases.

BACKGROUND
In 2014 a new three year research project entitled “fire safety engineering for innovative and sustainable building solutions” commenced under the leadership of SP Technical Research Institute of Sweden. The project consortium has 15 members in total from Denmark, Finland, Iceland, Norway and Sweden representing academia, building regulatory bodies, construction companies, engineering consultants, research institutes and standards bodies.

The project had been in response to a call from Nordic Innovation which sought projects where new standards are created or implemented as a main driver for innovation within a specific sector. The project addresses a number of challenges that face the construction sector in relation to sustainable and innovative building solutions. The environment for the introduction of technological solutions that differ from conventional options is challenging. Generally the building industry is conservative and slow to adopt change. There is constant pressure to reduce cost in the face of increasing regional and international competition and a trend to expect more for less. There is a need to cater for changing demographics, particularly an aging population and hence universal design. At the same time there are strong drivers to build sustainably, particularly with a focus on energy conservation. In addition, climate change is occurring and extreme weather events are becoming more common.
With the backdrop of these environmental conditions, significant barriers to trade exist for the construction sector in the Nordic region. One particular area of the market, and the focus of the project, is fire safety engineering. While all the Nordic countries have introduced performance-based building codes, their implementation with regard to fire safety has been ineffective and inefficient due to a lack of standardized fire safety engineering/verification methods. This is the case at both a national and regional level. Within individual jurisdictions, designers continue to rely on pre-accepted solutions as the path of least resistance, and the authorities having jurisdiction continue to question whether performance-based designs actually deliver the level of fire safety required by the performance-based code.

At the transnational scale, differences in regulations, verification methods and control procedures amongst neighboring Nordic countries are causing significant barriers to the trade of products and services. The ultimate outcome would be to have a single unified Nordic construction market.

The concept of this project is therefore to develop two new INSTA standards that could be used throughout the Nordic region; one new standard that will provide a specific technical method for the verification of innovative and sustainable solutions, and a second new standard that defines a standard process to review and control fire safety engineering in building projects.

Concurrently, the project has developed a preliminary standard entitled Fire Safety Engineering – Control in the Building Process. The document provides guidance on review and control in the building process relating to the planning phase (conceptual design, the fire safety strategy, detailed design, and consent), the construction phase (building and construction, and approval) and the service life phase of the building (inspections, maintenance and service, staff education, and drills) and this paper will focus on developed guidance document and highlight interesting findings from the work and present defined procedures for a Nordic context.

GENERAL

The aim of the guidance document is to facilitate verification of building solutions including innovative and sustainable solutions and to harmonize the process for control within the field of fire safety engineering within the Nordic countries.

The focus for the guidance document has been on a general level for review and control, independent of national legal matters in the Nordic countries, with a primary focus on defining procedures within the planning and building process. But the process has also, to some extent, given guidance on how the fire safety engineering process can be a normal part of the overall control and review of the building process and define eligibility criteria for those doing the control.

The first part of the specification describes an overall process regarding an ideal planning and building process with a corresponding review and control process for fire safety aspects within the building process. The different steps within the planning and design phase, construction phase and operational and maintenance aspects that may be important to consider, to ensure the fire safety within a building’s lifespan, are described in more detail in separate chapters. In each section we have tried to define when, how and why to perform different reviews and controls.
There are many different types of guidelines and standards used today for fire safety engineering in the Nordic countries. The new guidance document regarding control in the building process, however, mainly focuses on the concept and method rather than detailed guidance. The adoption of nationally determined parameters is also significant for the new specification. Since regulation of fire safety is a national matter the specification will give options to have nationally chosen parameters and processes, but the specification shows the direction with certain recommendations. The chosen approach is similar to the system used earlier for INSTA/TS 950 - Fire Safety Engineering – Comparative method to verify fire safety design in buildings [1, 2]. The Nordic countries may harmonize approaches by using the recommendations, but may also maintain flexibility by using national options. This is important in connection to the different legal systems within the Nordic countries.

**Fire Safety design within the Nordic countries**

To understand the proposed process for review and control regarding fire safety aspects, a short presentation regarding fire safety design within the Nordic countries is needed. Within all Nordic countries two principal methods are available when designing fire safety in a building:

- **Prescriptive-based design** based on pre-accepted solutions;
- **Analytical design** based on fire safety engineering methods.

Prescriptive-based design uses general recommendations and approved documents to establish the fire safety design. The design method does not allow for deviations from these recommendations and documents, and the need for verification is limited. The designer must ensure that the proposed building and its intended use fits in the regulatory system for prescriptive design by considering architectural design, occupant characteristics and relevant fire safety objectives. A number of design alternatives are usually allowed within the scope of prescriptive-based design and these are well described in the general recommendations in the building regulations. If there is a need for deviations from the prescribed solutions, the engineer needs to verify that the proposed design meets all relevant performance criteria, which can be fire safety engineering methods. The objective for the designer is to verify that the building meets the performance criteria.

The fire safety features of a building within the Nordic countries are commonly designed using a mix of pre-accepted solutions and those verified by the use of fire safety engineering methods. Due to this, there is a need for an overall understanding of the fire safety design process and the relationship between the pre-accepted solutions and the fire safety engineering design approach, through the planning and design phase within the overall building process.

A number of publications, [3, 4, 5] provide information about the fire safety design process. But, these guidelines primarily focus on fire safety engineering principles. The guidelines do not describe the relationship between the pre-accepted solutions and fire safety engineering approach which is commonly used within the Nordic countries. Due to this the process described by Nystedt [6] is a more realistic way of describing the process within the Nordic countries. The process is outlined in Figure 2.
THE PLANING AND BUILDING PROCESS

The defined ideal design and construction process can generally be described as outlined in Figure 1 with different stages and steps. For the different stages in the process the need for different kinds of control and review for fire safety aspects varies depending on the complexity of a project. A combination of the different types of control is often the most effective in each step as described in Figure 1. Figure 2 gives a short description of each phase.

Figure 1 – Description of an ideal planning and building process with different phases and different review and control aspects for fire safety aspects within each phase.

Design phase

The design phase includes two main steps

Design concept and fire safety strategy

In this first phase the overall fire safety strategy and design concept is laid down. When it comes to fire issues it is important for the fire safety designer to be involved in the process as early as possible. The main issues in this stage are:

- What is the general purpose and use of the building? Are there any restrictions in the building’s use, number of persons, type of activities, fire load, etc.?
- What are the main features, or main restrictions of the building, main areas for movement of people, are there any open spaces and atria, etc.?
- What are the building design parameters that affect the fire safety design (e.g., structural material)?
- If the building should be designed with fire safety engineering methods of any kind or mainly pre-accepted solutions.

After these questions are answered a general fire safety design brief can be produced which make up the basis for the continuing phases and stages in the building process.
**Detailed design and building permit**

In the second step, the actual design process and detailed solutions are chosen. In this phase, the key players are not only the owner of the building and the architect but also the entire consultant team, such as electrical, structural and water and heating consultants.

It is important to explain the main features of the fire safety strategy to other disciplines with the process. Since the drawings and documents produced by the other technical consultants are the ones that are used for construction, it is essential to make sure that the fire safety solutions from the fire safety design documentation are incorporated into these drawings and documents.

In order to start the actual building activities, a permit from the local authority is normally required within the Nordic countries. Whether the building authority checks the specific design or just the building organization’s competence and control system, varies in different countries. In some countries, the fire department could also check the fire safety design documentation as a separate decision from the building authority.

**Construction phase**

In the actual construction phase, the fire safety design specifications are integrated into design documents of other technical disciplines. The documents and drawings from other technical disciplines are used as a basis to do the actual construction works. However, during the construction phase, it is common that alterations are made in the building’s layout, in technical solutions or in details of technical systems. In that case, it’s important to be able to go back to the fire safety design documentation and redesign a solution that fulfills the fire safety concept.

In order for the building to be occupied and used, some kind of decision from the local building authority is normally required within the Nordic countries. This could be based on checking if the builder’s inspection scheme has been followed and by onsite inspections by the building authority. Often, a combination of the two is used and to ensure that the fire-related aspects are fulfilled, it is usually one of the most important aspects for the approval.

**Operation and maintenance phase**

When designing the building, it’s of great importance to consider how the fire safety systems should be maintained during the building’s service life. The most important step is to pass on the knowledge of the fire safety systems, how they work, and how they should be maintained, to the owner and the manager of the building. If this is not done, there is a risk that the fire safety features will not work in the future.

**REVIEW AND CONTROL IN THE PLANNING AND DESIGN PHASE**

The process for review and control in the planning and design phase of a fire safety engineering design is divided into two processes; initial design control and detailed design control.

In the initial design control issues such as, peer-review, the choice of a reviewer, the scope of the review, and the documentation of the peer review are highlighted. The focus for control and review within the detailed design is mainly to ensure that the fire safety strategy is implemented, important design aspects are documented, and the strategy is meeting/fulfilling the performance criteria described in the fire safety design brief and also to ensure that the detailed design is sufficient as the basis for the construction phase.
Initial design review
The defined procedure for initial design review is based on the SFPE Guidelines for Peer Review in the Fire Protection Design Process [7] and the Guidelines for Independent Control from Direktoratet for byggkvalitet [8], and is adjusted to fit the process in the Nordic countries. Typically a peer review is sought to provide a second opinion regarding the design’s likelihood of achieving the stated objectives. A peer review may be conducted on any or all components of a design, such as the conceptual approaches (trial design), application or interpretation of code requirements, the fire safety design brief and the fire safety verification. Within the Nordic countries the initial design review can also be used as a basis for surveillance performed by the local building authorities (or AHJs).

As a basis for the proposed procedure, the peer review should be limited to only the technical aspects of the design documentation. The peer review should not evaluate the education, experience or other aspects of the person or company that prepared the design. The peer review should examine both the internal and external appropriateness of the design. External appropriateness considers whether the correct problems are being solved. Internal appropriateness considers whether the problems are solved correctly.

Whether the scope of the peer review is the complete documentation of a project or some specific aspect of it, the peer reviewer should consider the following, as appropriate to the design being reviewed:

- Performance criteria;
- Acceptance criteria;
- Assumptions made by the designer (e.g., design fire scenarios, material properties used in correlations or models);
- Technical approach used by the designer;
- Choice of verification method;
- Appropriateness of models and methods used to solve the design problem;
- Applicable codes, standards and guidelines;
- Input data to the design problem and to the models and methods used;
- Appropriateness of recommendations or conclusions with respect to the results of design calculations;
- Correctness of the execution of the design approach (e.g., no mathematical errors or errors in interpretation of input or output data).

For peer-review of specific technical disciplines (e.g., CFD-simulations, design of structural fire resistance or active fire safety systems) the reviewer is encouraged to seek specialized literature on agreed best practice for the relevant discipline, preferably, as product-specific as possible such as for example the Swedish chapter of SFPE’s (BIV) or the Danish Best practice group guidance on CFD analysis [9, 10] or Briab’s guideline documents regarding smoke control and evacuation [11, 12].

When to conduct a peer review – the process
The decision as to whether or not to conduct a peer review is up to individual stakeholders. The motivation may be a desire to have a better understanding of the quality, completeness or the scientific bases of the design. The decision to conduct a peer review may also be made by a stakeholder who has resource limitations and/or lack of competencies and wishes to bring in
outside assistance to evaluate the fire safety features of the design. It is recommended that a peer reviewer is involved at four different steps of the fire safety design process - see Figure 2. The scope of each review is described in Figure 3.
Choosing the level of control
Not all construction projects require the same level of control. The choice of appropriate level has to be chosen based on the complexity of the building, the composition of occupants (number and physical capabilities) in the building and the complexity of the verification tools used. The proposal to choose different kind of controls is presented in Table 1 and is based on work by Lundin [13].

Table 1– Levels of peer review due to complexity. 1 = the designer in charge of the design and verification controls his/her own work; 2 = In-house peer review and 3 = Third-party peer review.

<table>
<thead>
<tr>
<th>Complexity of the construction</th>
<th>Composition of occupants</th>
<th>Verification method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Simplified verification methods such as qualitative arguments, simple and well known hand calculation methods.</td>
</tr>
<tr>
<td>Simple</td>
<td>Low risk</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>High risk</td>
<td>2</td>
</tr>
<tr>
<td>Medium</td>
<td>Low risk</td>
<td>2</td>
</tr>
<tr>
<td>High</td>
<td>High risk</td>
<td>3</td>
</tr>
</tbody>
</table>

1 Low risk: Few occupants with good mobility, high risk: Large number of occupants or occupants with low mobility.

Review and control of the detailed design process
Within the detailed design phase, the fire safety strategy must be considered to identify any special circumstances or conditions that affect different stakeholders. This includes details that experience shows are not designed adequately, not designed in sufficient detail, or details affecting different disciplines. Due to the fire safety designer’s overall influence on the entire consultant team, it is important that he/she, as a part of the builders’ control and inspection scheme, also controls the requirements in the fire safety design document that have been incorporated in their drawings and documents. This can be done by, e.g., participating in joint review meetings.

Ideally the fire safety designer who has carried out the fire safety design should be part of the detailed design process. At least the fire safety engineer should review construction documents to determine compliance with the intent and requirements of the fire safety design documentation.

It is also essential to verify that each discipline (e.g., architect, electrical, structural and water and heating consultants) confirm that they fulfil all requirements in the fire safety design document. When designing the fire safety by engineering methods, the transformation of the concept design into a construction document is of critical importance.
CONTROL AND REVIEW DURING THE CONSTRUCTION PHASE
The defined procedure and process for verification of compliance of fire safety during the construction phase is based on the SFPE Engineering Guide to Performance-Based Fire Protection [7] and the guidelines for verification of fire safety within the building process by the Swedish Chapter of SFPE, (BIV) [14] and is adjusted to fit the process in the Nordic countries.

Inspection and testing plan (ITP)
Prior to the construction phase, and as a part of the documentation of the fire safety concept, an inspection and testing plan (ITP) needs to be defined. The ITP is the link between the fire safety design/construction phase and the building in service, and it is important to ensure that the stakeholders understand and approve the proposed ITP. Within some Nordic countries, the ITP may be a part of the builder’s control and inspection scheme, and will then also need to be approved by the AHJ.

The ITP should specify the required commissioning procedure, measurement techniques and required results for the validation and also acceptable tolerances for the performance metric. In the ITP, the division of responsibility for different inspections and tests should be clarified. With regards to the inter-dependency of several fire safety design systems to ensure the defined fire safety strategy, a coordinated inspection protocol should be defined.

When to conduct a review within the construction phase
The proposed process for verification of compliance in the construction phase is described in Figure 4. The process is intended to be used as guidance during the construction of the building and to ensure that all fire safety measures that are needed are built as described in the fire safety documentation and construction documents. While the process is described as a step-by-step procedure, the process may in reality be iterative.

![Figure 4 – Process for verification of compliance within the construction phase.](image)

Consultation with the builder and local authority
The one doing the control should participate in the consultation with the builder and the local authority to clarify which documents should be used for the control and inspection of the fire safety measures, in which phases the fire safety measures should be controlled and inspected and to define what controls to perform by each contractor and also clarify when they should be performed. During the joint consultation the procedure within the project for identifying and
documenting field changes and deviations from the defined fire safety concept should also be defined.

**Start-up meeting with construction management**
When the building management has been chosen, a startup meeting between the controller and a representative from the building management company should be held. During the meeting all fire safety documents should be reviewed and uncertainties sorted out, controls and inspections should be planned and uncertainties sorted out and the construction project organization should be clarified for the controller.

**Normative controls**
It is important that the controls include parts of the execution where experience shows that errors often occur. Examples are the installation of fire doors and glass structures. If the design has deviations from the pre-accepted solutions, execution of the performance-based measures should be the focus of special controls. Control of the execution includes control of the documentation for construction products.

**Field changes and deviations**
When deviations from the fire safety design documents and construction documents occur during the construction phase, the fire safety designer responsible for the design needs to be notified. Evaluation, assessment and reporting of the deviations need to be carried out. If the fire safety design is based on fire safety engineering methods, all deviations that exceed the predetermined design tolerances must be evaluated in the context of the overall design to ensure that the defined level of safety is met. All deviations should be reported in the fire safety design document. Any impact that may occur on the commissioning and testing procedures, as defined in the ITP, should be incorporated in a revised version of the ITP.

**Final control**
A final control is always required before the building, or a part of the building, is occupied and used. The control should be performed together with a representative from the construction management and the contractor’s controls and routines should be documented.

*Integrated system testing*
During the final control, integrated testing of fire safety and life safety systems should be conducted. The scope of integrated system testing is the verification of the completeness and integrity of the building construction, ensuring that individual system function, operation and acceptance as required in applicable installation standard tests, and to ensure the completion of pre-functional tests of integrated systems. Integrated testing should demonstrate that the final integrated system installation complies with the specific design objectives and the aspects defined in the fire safety design document, constructions documents and the ITP. Further guidance on integrated system testing is given in NFPA 4: Standard for integrated Fire Protection and Life Safety system testing [15].

**Verification of compliance statement and as-built documentation**
The Verification of Compliance Statement declares that the fire safety design (both fire safety engineering design and pre-accepted solutions) have been met. The Verification of Compliance
should be based on inspections and commissioning reports, as well as first hand observations throughout the construction process.

In preparation of the Verifications of Compliance documentation as-built documentation should be prepared. Furthermore, as-built drawings must be updated when any change occurs to accurately reflect the current conditions in the building. To ensure continued compliance with the constructed fire safety throughout a building’s service life, the fire safety designer should include provisions in the as-build documentation regarding a process by which the facility may be assessed and monitored for change and a procedure for addressing those changes to ensure continual compliance.

**OPERATION AND MAINTENANCE**

The success of a fire safety design requires adherence to the design aspects throughout the service life of the facility. The service life involves operation and maintenance as well as changes in a facility. The changes can involve changes in individual stakeholders; such as owners, facility tenants and maintenance staff, as well as changes in the facility configurations and occupancy. It is critical that these changes are managed through recognition and adherence to facility maintenance manuals and established procedures for the national process of approval and documentation of facility alterations.

In the guidance document the link between the planning and building process is described in brief, but the link is of major importance to ensure the intended level of fire safety during a building’s (or facility’s) service life. The ability to ensure that facility modifications meet the original fire safety design objectives relies directly on the amount and accuracy of existing design and construction documentation as well as facility commissioning, inspections and maintenance reports. This documentation is the basis for evaluation of any proposed changes or modifications in the facility.

**DISCUSSION AND CONCLUSIONS**

Many of the existing fire safety engineering guidelines and standards focus on technical aspects, and less on the process to reach a sound fire safety engineered building. In the future, it will be important for those involved in building projects to focus on the design and construction process in itself as well. In that effort, it will be important to decide what the role of the fire safety engineer is in respect to others in the construction process, and what is needed to successfully achieve a fire safe structure.

The Nordic collaboration on fire safety engineering reaches a new level with the creation of new common technical specifications and standards. Hopefully the new guidance document regarding control and review for fire safety design that is the subject of this paper will strengthen the collaboration and reduce the barriers to trade for the construction sector in the Nordic region and be another step towards a single unified Nordic construction market. But to be able to reach this goal an important aspect in the ongoing work will be to adapt the guidance document to something practically applicable in the Nordic context. So, the next step in the development process is field testing where the guidance document is used for actual building projects as a comparison to current verification or quality control procedures.
ACKNOWLEDGEMENTS
We’d like to acknowledge the whole group of Nordic participants who made this guidance document possible and who have provided significant in-kind self-funding contributions to the project. Also, we would like to thank the external funders for the project; Nordic Innovation, the Norwegian building regulator DiBK, and the Swedish construction industry development fund SBUF.

REFERENCES
[10] Best Practice gruppen CFD Best Practice, Copenhagen, 2009. [In Danish]