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New technologies: application and use in fire safety

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NEW TECHNOLOGIES: APPLICATION AND USE IN FIRE SAFETY

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1. Introduction

This research has been a collaborative project carried out by the University of Tampere and the Finnish Rescue Association. The project has been funded by the Finnish Fire Protection Fund. The work is based on previous studies and projects in which SPEK has acted as a guiding and coordinating body in cooperation with other parties. In the analyses, the fire safety development possibilities have been examined from the perspectives of both new technologies and smart construction. This research investigates solutions for design and implementation of fire safety systems.

The research was launched in 2019 to meet the challenges and problem areas that arose in previous research projects and to find new solutions and develop fire safety in construction projects. These previous studies deal with the utilization of IoT technology in the development of fire safety in buildings (Pylkkänen 2018) and the approach that consider fire safety in modern smart constructions (Malaska, Aaltonen, Lehto 2018).

To illuminate this uncharted area, research is needed to deepen the knowledge of previously identified challenges in the implementation of fire safety systems and modern smart construction. The purpose of this work was to identify new technological opportunities in the market and to describe their added value from a fire safety perspective. In addition, the work comprehensively examined various administrative challenges as well as development opportunities related to fire safety.

2. Results

Based on an extensive interview and analysis of the questionnaire, it was possible to form an overall picture of the administrative problems of fire safety systems and development needs related to design, implementation and maintenance covering the entire life cycle of the building. The results and conclusions consisted of describing, explaining, and reflecting on the various problem areas found. When collecting information, development proposals were also created that could improve the described problems and the management of fire safety systems. Some of the suggestions came from interviewees and some were created through the analysis of the results and by applying the operating models presented in the literature. Development ideas were developed through interviews and surveys.

This chapter presents the main conclusions of Janne Mäkelä's diploma thesis (2020) divided into the main themes that emerged through the analysis of the results. At the beginning of the report, the technologies identified in the study are presented, which offer new opportunities for developing and improving the fire safety of buildings. This is followed by a review of the roles, responsibilities, and tasks of the key parties in the construction project that emerged from the research project, which, according to the results, require clarification or which should be added as new roles to existing project organizations. The roles that were considered to require special attention include the project coordinator, the system coordinator, and the fire safety authorities and inspection bodies. In addition, the role, needs and involvement of the end user have been considered. The key themes that have emerged from the point of view of the design, procurement, implementation, and maintenance of fire safety systems, as well as the related findings and development opportunities, are examined in the chronological parts of the system project life cycle. This study also highlighted that the value of fire safety is not fully understood, and fire safety is often not seen as part of the overall safety of a building. This theme has been addressed in the conclusions.

2.1 New technologies in fire safety development

The research interviews highlighted many simple hardware technologies that would already be available if a design process approach and a unified operation plan were created for them at the beginning of the construction project. The plan would include information about where and how the data is collected and who would be allowed to use the information in different scenarios. It has also emerged that, especially in more demanding construction projects, large-scale centralized control rooms have been implemented, which can also be used remotely. These capabilities can be used to monitor the conditions and operation of the property's premises and to assess the need for system maintenance. This also makes it possible to use other measurement data to detect and identify issues caused by lack of maintenance.

Currently, buildings have a lot of equipment and sensors monitoring the real-time environmental conditions which include temperature, humidity, pressure and, for example, the amount of light that can be used to assess whether smoke has accumulated in the room or whether the room is dark. Particularly, smart lighting systems, security systems and sound-analyzing entities emerged in this research. However, the potential of different technologies is not yet known to all designers. The ideas of equipment suppliers and the needs of the end user should also be more closely integrated in connection with the initial mapping.
Sensors in lighting systems can produce significant information about the conditions of the space where fire occurs. For example, in a fire situation, activities can be concentrated, and lighting directed to where it is needed or where something is happening. Lighting can also be used to influence how people behave and guide their movements and activities in a safe direction.

Sound recognition makes it possible to assess the development and spread of fire or to assess human behavior in different situations. The level of sound can tell a lot about the conditions of a fire situation as well as whether the person or people are distressed. It can also be used to confirm if there are sound in locations where people are believed to be in based on other data collected and analyzed from the building. The overall picture, supplemented by this information, will allow a better assessment of emergency services' needs.

The overall picture could also be complemented by other existing solutions, such as motion detection and monitoring of locks and doors. This information can be used, for example, to assess the number of people in the event of an emergency exit situation, or other threatening or exceptional event. These could also be used to analyze people's behavior in a state of emergency. Information about the direction where people are moving in the building can inform if they are moving towards safety, or if there are people exposed to immediate danger.
The data generated by camera surveillance can also be used to develop information about people's behavior or the development of conditions. Camera surveillance can be used to assess and identify temperatures, smoke, conditions, and movement. It operates as a preventative factor and detection can act similarly to traditional safety solutions where unusual activity or repetitive motion can be identified. In addition to motion and frequency, modern technology enables

identifying the size of the moving target and general conditions in the monitored space. The importance of cameras in forecasting and supporting other building technologies was seen to be emphasized in the future.

Often there is an explanatory feature in a fire event that can be identified and reacted proactively before the fire risk materializes. It is fundamental to recognize any unusual activity and conditions. The timing of the observation can also be significant and can be used in estimating if the observation is usual considering the normal activity of the monitored space or if it is something that should be reacted to.

This research provided evidence that IoT, that is used to monitor the use and conditions of the premises, provide opportunities that are beneficial particularly in actualizing predictive measures during the maintenance and building life cycle. However, the opportunities provided by IoT have not been considered in projects; utilization of this type of technology is often based on individual needs. The technology is often implemented for only one specific monitoring purpose and other potential application and use providing additional value are currently not recognized in projects. However, there are several operatives on the market that could solve and implement the monitoring needed in properties in a more versatile way than with current methods. If the knowledge and expertise of different operators were utilized in the early stages of the planning process, there would be great potential for new innovations to actively identify and prevent incidents. A good example of innovative, integrated fire safety solutions are appliances used in Sweden and Germany, in which elevators stop only on those floors which are detected to have smoke free conditions. There are also solutions that can be used in inspection activities. However, these solutions require human input, so they do not fully extend to the concept of IoT.

The preliminary design and needs assessment in IoT solutions are highly significant. When designing multiuse digital sensing solutions, it is important to know at an early stage what information is wished to be collected from the building. At the present time, the end user often recognizes these needs during the construction process or when the construction has already finished. In this case, it is often found that it is impossible to connect the systems retrospectively or that the agreements between the various parties involved in the management of the information significantly limit the possibilities.

According to the international questionnaire results, the respondents believe that the opportunities provided by IoT technology are identified and known at the design level. However, the designers do not have similar knowledge of fire safety related technology. All the respondents agreed that fire safety would be better considered if safety features were integrated in other solutions provided by IoT technology. In addition to this, it was believed that IoT will increase in the use of fire safety and buildings by 2025. Regarding new technologies, it was seen that current standards for fire safety and fire protection systems could limit implementations and make the use of new technologies challenging.

Information collected from IoT equipment was considered to have the greatest benefit in the development of rescue services' operations, in more efficient inspection activities and in the remote use of fire-fighting technology. Regarding the use of the building, it was seen that the greatest benefits emerge in ensuring safety and continuity, as well as in preventing damage. On the other hand, maintenance and its facilitation are also areas for future development.

The main reason why IoT technology has not yet been more widely used was the cost of the new technology. Other reasons that emerged were risk avoidance and the lack of case studies and information about new technologies. Some interviewees felt that the standards for fire safety and fire safety systems limited implementations and made the use of new technology challenging. The biggest threats were identified as information security issues and cyber threats. Reliable connections were also seen as one challenge. In addition, human user and then human error became one of the threats.

2.2 Role of the party engaging in a building project

This research provides evidence that the party responsible for the procurement of a technological system that supports fire safety, i.e. the person undertaking the building project, does not always have sufficient understanding and competence to successfully procure the system. Therefore, there is a need for additional information and support for the parties engaging in a construction process. This would ensure that buildings have a functional system that improves fire safety and that can be fully maintained and remain operational during the building life cycle.

Based on this research, a to-do has been created to clarify the role of the person initiating a construction project. The to-do list consists of the following sections:

- Acquires, if necessary, a system coordinator at the beginning of the project to support and interpret
- Familiarizes and understands the possibilities and added value of fire safety
- Conducts a risk assessment
- Defines the criticality classes for safety-related subsystems
- Defines the desired functionalities of the system package
- Maintain discussion and negotiate with system suppliers

In a platform orientated model, tender out the system providers that can offer the desired functionalities and other requirements that enable the platform solution and

- Ensures that all information required by project processes is available to ensure quality
- The party engaging in a building project must have a competent organization or external support around them to carry out the above tasks. The premise is that the party engaging in a building project knows what they want.

2.3 The system coordinator supports the implementation of fire safety

This research clearly indicates that fire safety system planning, execution, and maintenance, as well as the system integration project management, require significant expertise. The project should have an allocated party who coordinates the operation, is able to discuss with different operators, and understands the effects of different decisions in fire safety. Regarding fire safety and system integration projects, the role of system coordinator was developed as part of this research project. The purpose of the system coordinator is to support those parties engaging in a building project and act as a support and translator in different stages of the project. They would act as a party who takes the responsibility for controlled forming of the system package. The role and its associated tasks were developed and defined in interviews, workshops and questionnaires conducted in this research project.

The resulting to-do list consists of the following sections:

- Responsible for ensuring that end-user needs are consulted at the beginning of the project.
- Ensures that the risk assessment is conducted in the beginning of the project
- Supports the construction project in making the necessary specifications.
- Contribute to the emergence of an efficient and reliable system for the entire life cycle of the system
- Helps the party engaging in a building project with choosing a system platform that meets the desired requirements
- Can describe the benefits of systems
- Ensures that different operators understand what interfaces is required for the systems they provide

- Facilitate dialogue between operators and ensure that functionalities through integration are implemented as designed
- Divides the system package in controlled sections to facilitate the competitive tendering in the acquiring stage
- Ensures there are no overlaps between different systems during the implementation stage
- Monitors the integration testing of the system package, including individual system interfaces, final functionalities, fault situations and recovery from fault situations
- Participates in the testing and commissioning process and ensures with the checklist that joint tests and equipment specific self-inspections have been carried out properly
- Monitors that changes, upgrades, maintenance, and extensions to the system are conducted and documented in the service manual and operating instructions.
- Inspects the authenticity of the equipment and their compliance with the plan during their interchange
- Prepares a technical implementation orientation plan for the party responsible for the maintenance of the site.

As part of the discussions, it was proposed that the role of system coordinator could be undertaken by the designer, system vendor or other party that have the required specialization to fulfill these tasks. System coordinator should be part of the design teams as early as possible in the pre-design phase.

2.4 The role of the authority in the fire safety system project

During the investigation, it emerged that there are conflicting and erroneous interpretations of the roles and responsibilities of building control and rescue authorities. Therefore, the aim of this study was to clarify the roles and responsibilities described in the legislation of the various parties to the project and in the guidelines of the authorities.

During the investigation, it became clear that the role of the rescue authority in fire safety system projects is not always fully understood by all stakeholders. In addition, the proposals made by the rescue authority in the pre-planning phase have not always ended up in the building permit phase plans. It was considered that that the designer may have pruned the proposed solutions for cost reasons and replaced them with solutions that meet the minimum requirements of the law. However, it can be also explained with the designers poor understanding of the overall fire safety.

Based on the interviews, the experience of the industry is that a clear unified alignment and appropriate timing would be needed for the regulatory control and for the discussions with the authorities. A type of public forum was raised as a development idea. This would enable discussion of problems and the development of common solutions.

Digital technology provides new opportunities for the rescue authority to develop fire safety monitoring and maintenance work. For example, digital information collected from the building provide new opportunities for the development of predictive fire safety. Also, the data could be utilized more widely, for example in fire investigation. In the results, a digital maintenance book was emerged as a development idea. This would include matters relevant to maintenance, such as the state and maintenance of the building's firefighting and prevention technology, the fulfilment of designing, self-preparedness, and site-specific planning of operations. Platform solutions can also facilitate these needs, and the platform solutions should take better account of the authorities' perspective.

Requirements instructed and required by law

According to the Land Use and Building Act (1999/132), responsibility for the construction project is on the one initiating the project and they must ensure that the building is constructed in a fireproof manner as required by the intended use. Compliance with the requirements is reviewed and stated in the planning documents during the building permit procedure. The scope of the planning documents will be assessed on a site-by-site basis. The scope and extend of the system depend on how much the applied loads, design solutions and design criteria differ from the regulations in force. The plans must be made in accordance with the regulations and instructions of the Ministry of the Environment.

If automatic fire extinguishing system is installed in the building or its fire compartment, it may be permitted to mitigate the maximum floor areas of the building, the number of persons, load-bearing structures, compartment sizes, compartmental building parts, internal surfaces, exterior surfaces of the outer wall and ventilation box, the lengths of the passageway, and the number of exits (Jantunen 2017). Therefore, fire safety systems are not based on official requirements, but their need arises from site-specific, e.g. architectural or functional, objectives and solutions for the premises. In some cases, this issue is not clear to all operators, and it may be believed that fire safety systems would be implemented as a specified requirement.

The task of the building control authority is to ensure that the construction is guided and advised and to ensure that the regulations and orders are complied with in the construction. Building control decides and formulates the terms of building permits. Depending on the complexity of the construction project the building permit documents may require a fire safety plan and report and specific fire safety designs and justifications. The fire safety plan demonstrates how the requirements set out in the existing provisions have been implemented. During the processing phase of the building permit, the building permit authority may, if necessary, request statements from the rescue authority. These statements define fire and personal safety and the possibilities for rescue personnel to act in the event of an accident, among other things.

The legislation does not directly oblige the rescue authority to be involved in construction projects, although in practice it has been found useful. During the design phase of the building, the rescue authority acts as a guiding body, expert, and opinion-giver, addressing the definition of operational needs. It is not the rescue authority's responsibility to interfere with the placement and implementation of fire safety systems. If necessary, the building control authority consults the rescue authority, which will then consult the inspection bodies on technical details if needed. The justification for fire safety planning is approved by the rescue authority. Upon request, the implementation protocol of system design and plans are presented to the local rescue authority for supervision. For example, in early stages of fire detection system projects, the holder's representative compiles, delivers, and presents the basic specifications, operational requirements and other requirements mentioned in the fire detection system implementation protocol of system design to the local rescue authority. The rescue authority may also comment on the justification of the fire extinguishing system plan. They can also make a statement on the smoke and heat removal plan, the sign and safety lighting plan and the building automation plan (Topten Steering Group 2020).

The building control authority or rescue authority does not inspect the plan, but only ensures its validity and legality. The responsibility for the validity of the design is held by its author (Turunen 2012, 15). The international questionnaire revealed that other countries compared to Finland operate in very similar ways and therefore direct operating models cannot be introduced. As in Finland, the respondents submitted that, in the case of technical solutions, the rescue authority may have required the compiled plans to be presented before the start of the contracting, but then with a targeted perspective related to operational activities based on previous responses. These areas, which required the perspective of the rescue services, were presented as issues such as an attack, fire extinguishing and rescue routes, access to water for fire-fighting and the facilities needed for the rescue services' vehicles and equipment. The role of the rescue authority was also considered to include regular inspection of the implementation of the fire safety of the site. Technical inspections are the responsibility of inspection bodies as a third party.

At the construction pre-start meeting, in accordance with the Land Use and Building Act (1999/132), the party engaging in the building project negotiates the starting points for the construction plan with the building control authority, and the minutes of the meeting include, among other things, the tasks of regulatory oversight and the number of inspections required. The task of regulatory control is mainly to determine through inspections whether the measures and inspections and the necessary investigations have been carried out, and whether the measures required based on the shortcomings and deficiencies identified have been carried out. If required by the Building Control Authority, the rescue authority may, if necessary, provide guidance on the implementation of practical solutions to fire safety. However, responsibility for the details of implementation lies with the system designer and installation company (Turunen 2012.15). The commissioning inspection of the building and the decision on the commissioning of the building are always made by the building control authority. The rescue authority will conduct a special fire inspection if the building control authority, acting on a proposal from the rescue authority, has required it in the permit conditions or in the minutes of the opening meeting. The special fire inspection will result in a statement, that states whether the conditions for rescue operations and personal safety, for example in the case of fire safety equipment, have been considered and implemented as required by the building permit and plans. For fire extinguishing systems and Fire Detection Systems, the commissioning inspection is executed by the person who installed them and the verification inspection by the inspection body.

In connection with commissioning, periodic inspections and system changes, the inspection body is responsible for verifying the suitability of the system for the site and to determine to what extent the system meets the requirements of the standard or meets the design criteria presented in the data. The inspection body creates a record of the inspection and based on the inspection, issue correction notice. The inspection record will be submitted to the building control and rescue authority. The inspection body is obliged to report any serious deficiencies it has identified to the rescue authority. The rescue authority monitors compliance with repair orders as part of fire inspections and carries out documentary surveillance. The owner of the fire alarm is responsible for complying with the requirements of the system that facilitates firefighting and rescue operations. In any problems occurs, the rescue authority may also obtain additional information from inspection bodies. However, the building control authorities and the rescue authorities are not responsible for supervising and evaluating the inspection bodies; the responsibility belongs to Tukes, the Finnish Safety and Chemicals Agency (Topte Steering Group 2020); Order A:60 1999 of the Ministry of the Interior). During operation and maintenance, the rescue authority will continue its work to maintain the fire safety of the building throughout its life cycle by monitoring factors such as the condition of accident prevention and damage prevention equipment, the functionality of the site's safety system and the training and attitude of the crew.

2.5 The role of the inspection bodies in the fire safety system project

The inspection bodies are approved and supervised by Finnish Safety and Chemicals Agency (Tukes). Their task is to carry out commissioning, verification, and periodic inspections, as well as condition assessments for critical fire safety systems in buildings, in accordance with defined principles. Inspection bodies may also carry out third-party quality control during design and construction. The inspections are covered by Rescue Services Act 10/2007 and are based on the regulations SM 1999 440/Tu33 for the fire detector and SM 1999 967/Tu33 for the fire extinguishing system. The inspection ensure that the system meets the requirements set for it, is suitable for its intended purpose, operates in a technically designed manner and is maintained in accordance with the maintenance programme. A certificate of inspection is conducted and submitted to the equipment operator and rescue authority. The inspection bodies also have a cooperation meeting model in place to uniform the inspection practices of inspection bodies. The third-part working group for interpreting standards and instructions of fire extinguishing systems participates in the cooperation meetings.

Inspection bodies have often had to inspect incomplete projects in commissioning inspections. This mainly results from overly strict schedules and installments. Furthermore, after these inspections, changes can still be made to the building that are relevant to the assessment. Depending on the challenge of the site and the scheduling pressures, the inspection of the property can be divided into parts to ensure that the inspections are carried out properly and that the systems are operational.

During the interviews, it was pointed out that the inspection bodies have made errors of interpretation. In new solutions and conditions, interpreting standards can be challenging. Also, key shortcomings have been identified in completed system packages, while the inspection body considers that the technical requirements have been met. Consequently, it has been considered problematic that the authority might prefer to listen the inspector over the designers' point of view. It was stated in the interviews that the inspection body does not take responsibility for the entirety and they may not document their decisions properly. The interviews also proposed an option that a third-party designing consult would be responsible for the task and role currently carried out by the inspection bodies.

2.6 Development of the system integration project pre-design

There are several key operations and decisions required in the project pre-design stage, including system functionalities, integrations, platform solutions and different system definitions. End-users and owners should also be included in defining these specifications. Proposed key topics in this theme are:

- Developing the definition of risks and functionalities
- Platform solution as the basis for an integrated system
- Integrating critical systems and new technological solutions into the platform
- Including property owners and end-users in the project preplanning
- Sufficient consideration of system life cycle in the preplanning stage

Developing the definition of risks and functionalities

Pre-planning should be started with a need's assessment, accompanied by a risk analysis. This study revealed that the responsibility for carrying out a risk analysis is sometimes unclear and the value it produces cannot be properly measured. This could be clarified if the party engaging in the building project carried out a risk analysis with the assistance of the system coordinator.

The desired safety level for the building can be determined based on the organization's business operations and the identified risks. Those starting a construction project together with the end users select the functionalities and criticalities of the project that meet the defined safety objectives and are in line with the intended use of the premises. The description of the functionalities must be comprehensive to make the level of implementation of the systems clear. A system description that is sufficient for the procurement and implementation of the design should be created early in the project. The needs for system integration should also be identified based on the planned functionalities. Clear modelling of functionalities was seen to have a significant impact on the trouble-safe deployment of the integrated system. In the early stages of the need's assessment, the existing fire safety services and solutions should also be assessed. System-specific guides would support this work. Also, the operational model for the need's assessment should ensure that the screening covers the latest technology, and it should be able to present the improved fire safety and cost benefits provided. With the support from the system coordinator, could be better ensured that the discussion involves the right and sufficient technical experts and that those starting construction projects can execute the above definitions in a sufficiently accurate and comprehensive manner.

This study examined the views and position of different parties in relation to the risk classification that guides the requirements of systems and system integrations. According to the results, the concept of risk rating was welcomed. The responses highlighted that the risk assessment should be sufficiently comprehensive, and it should consider the critical nature of the systems in terms of operation, operational reliability, fire resistance requirements and the operating environment. The current relatively comprehensive standardization and a high level of requirements of fire safety systems was also highlighted in the responses.

Platform solution as the basis for an integrated system

In the questionnaire, the respondents were asked to define the roles, functions and parts of platforms utilized in the building systems. The results indicate that the platform is a system containing interfaces that enables user friendly integration between different technologies, systems, and buildings. The platform gathers information from different systems, is open and modular and enables the independent operation of related systems. The platform is a constantly evolving product with new features and interfaces added as needed. The integrated system can be designed and implemented on the system platform. Platforms consist of components such as code, database, user interfaces, and control boards. The components can be integrated or linked to the platform on a case-by-case basis. The platform itself is not physical, but it involves several physical devices and parts. The platform can serve several properties and the property can serve several systems. Platform can also have several different tasks. These include various system controls, common user interfaces, visualizations, remote maintenance and monitoring, data collection and reporting. The platform enables the aggregation of comprehensive information. Through the user interface, system usage can be managed both automatically and manually. The main advantages of the platform are remote monitoring of the operation and condition of the systems, partly remote implementation of pre-corrections and fault repairs, and reports on the state of different systems and properties. At its best, the platform is not only a product integration platform, but also offers an opportunity for third parties to connect their own services.

Based on the international questionnaire, platform-driven projects are not yet common in other countries either. In construction projects, when fire safety is considered, it is emphasized that the needs of the customer and end user should be considered at the very beginning of the project. The identification of system interfaces should also be developed, and training increased to ensure there are enough fire safety experts in construction projects. However, in an international comparison, such design models for the construction project had not been found frequently or at all, although the importance of them is understood. The decision on whether to design and implement an integrated system on the system platform should be made during the pre-design phase. If the project is decided to be executed using a platform-based model, the first action is to acquire a platform supplier, who can reliably provide an environment of desired functionalities. Operators are interviewed and the implementation possibilities are negotiated with them. The interviews will examine how open the interfaces are to the accession and competitive tendering of different systems and services, among other things. The study provided strong evidence that, in the aim of pursuing a reliable and compatible platform solution, sufficient time must be reserved in the procurement of the platform for consultation rounds between platform suppliers and the party engaging in the building project. The starting point for successful negotiations is sufficient requirement documentation for the construction project and separate statements on the interfaces of the platform supplier's platform solution. A platform-based solution further increases the importance of pre-design.

The system coordinator was considered the appropriate party to lead the discussion on the choice of platform solution. They would support those starting the construction project by helping them interview platform suppliers and choose the solution that best meets the desired functionalities. The system coordinator would be required to have extensive knowledge of platform solutions on the market, which, on the other hand, may make it difficult to find a person with sufficient expertise. However, it is crucial that the system coordinator is platform supplier independent.

The result of the study also indicates that the use of platform solutions and the integration of systems are also likely to lead to the need to update regulations.

Integrating critical systems and new technological solutions into the platform

After selecting the system platform, the systems and operators that are connected to the platform are selected. These technical solutions will provide the defined functionalities. There are many different technical systems, but this study focuses on critical systems that are essential for fire safety, such as systems related to evacuation and personal safety. There are also various technical solutions that complement fire safety. These are often smaller and complementary technologies that do not participate in the functioning of the critical system, and do not hinder it, but are built around it.

The integration of systems critical to fire safety into the platform requires special care, as this part of the technical systems is regulated and controlled by legislation and many standards. Critical systems are verified as independent of the circumstances and should operate reliably even if the connection to the system platform is lost. Critical system control is still implemented in an integral manner, meaning locally installed. Due to operational security requirements, it is not possible to rely on cloud services or internet connection as a primary activity of control. However, the platform can provide functionalities that complement and support critical systems, such as hardware condition and maintenance monitoring. The platform connection also provides better use of information generated by critical systems in other systems and services.

Those who start a construction project, or end users, may want special additional services as part of the system, such as a new functionalities, tools, or user interface. This may include improving fire safety with new solutions for sound or video analysis or lighting control. Solutions can include both devices and services. Bringing these technologies into integration requires expertise from those initiating the project, as well as project-specific cooperation between system developers. Also, the integration of these technical solutions typically requires interaction and joint development work between the platform vendor and the associated system vendor or developer. This study indicates that technical solutions for platforms have not always been sufficiently considered and that more development cooperation between system vendors would be needed. The interviewees pointed out that co-operation between the system platform and the supplier of the related system is best when the interfaces of the systems are as open as possible, when there is a clear need for development and the developers can find a common financial interest. Combining different systems into a larger entity and ecosystem offers new functional opportunities that add value to the customer. This way operators can also market new products together. Planning for the integration of systems in the platform should commerce in the project as early as possible so that developers can agree about the implementation. In this case, implementation schedules can be managed, and functionalities can also be tested properly.

Cooperation between system vendors requires a business model that benefits all parties. For example, the information produced by the system vendor connected to the platform can be exported to the platform vendor's user interface, whereby the user receives all services from one place. In this case, the user could pay the supplier, for example, a small monthly fee for the information produced in the user interface.

In this study, examples were identified where design or contracting practices, or insufficient human and time resources, have served as a barrier to the selection of new technology solutions. These restricting circumstances keeps the old solutions in use.

The interviewees experienced that the time for the technologically old and commercially closed model is over. Solutions must apply transparency and interfaces that allow documentation and data transfers. Commonly agreed and standard interfaces also prevent problems with functionalities such as upgrades to integrated systems. Transparency is based on established and transparent data transfer protocols. The interviewees also pointed out that there may be room for maneuver within the protocols, so that they alone cannot guarantee compatibility.

Involvement of property owners and end users in pre-design

End users of the building and the systems have often not been involved in the pre-design of the project at a sufficiently early stage. This study clearly indicates that the end user should be involved in the project as early as in the project planning stage, provided the user is known. Involving end-users in the development of specifications at an early stage of the project will help ensure that the desired system functionalities are met. However, end-user knowledge of fire safety or fire safety systems is often not seen as sufficient. It has also been found that the end-user may not always be interested in safety issues. The property owner should also have sufficient understanding and interest in security and safety issues. Under those circumstances, the end user and owner would benefit from expert support related to fire safety and technical systems in defining the desired functionalities. The system coordinator could also act as an expert supporting the end-user, ensuring that their needs and perspectives are adequately addressed in the pre-design. The coordinator would act as an interpreter for end-users and ensure that they have a sufficient understanding of the added value of fire safety and the different technological possibilities available. When evaluating technologies, important issues from the end user's point of view are the life cycle, availability, transparency, modularity, and lifecycle service capabilities of the systems. The system coordinator, together with the end-users, would conduct a functional description, which should also consider the specific issues related to the use of the space and the nature of the activity, the diverse use of the facilities and possible exceptional circumstances.

Adequate consideration of the system life cycle in pre-design

When making choices related to fire safety systems, the effects of solutions and decisions should always be considered throughout the life cycle of the system. In addition to the acquisition costs of the system, the operating and maintenance costs of the systems must be considered. In this study, adaptability emerged as an essential aspect of the system's life cycle operation. Adaptability is the capacity of a system to effectively accommodate the evolving demands of its context thus increasing the efficiency of the premises. Previous projects have shown that the one initiating the construction project, or the owner, often does not understand how fire safety systems affect the building's adaptability. For example, changes in the division of the premises or they use may lead to more demanding fire safety requirements, in which case systems dimensioned to the previous situation may not be able to meet these requirements and the desired new functionality of the premises will not be possible. The modularity and maintenance-free nature of the systems are seen as factors that promote conversion flexibility. In some situations, the challenging conditions of a building can guide the technological choices of systems so significantly that the goals of conversion flexibility cannot be fully met and, as a result, a compromise of different requirements must be accepted.

2.7 Development of the system design process

This study revealed that there are challenges relating to the design and quality management of fire safety systems. The results indicate that there is room for improvement in design, for example in communication, information exchange, standardization, design independence, definition of design contracts, competence, design boundaries and coordination of the design entity.

This study highlighted the following key aspects:

- Needs of communication, information, and standardization in design
- Brand-independent design
- The importance performance specifications in procurement
- Development of long-term planning and design
- Considering the entire life cycle of the system in design
- Clarification of design boundaries between disciplines
- Management and coordination of the design entity.

Needs of communication, information, and standardization in design

There have sometimes been differences of opinion and contradictions between fire safety and architectural design. Different architectural choices can have the effect of increasing the fire safety requirements of a building. Such choices may be, for example, the large size of the fire compartments in relation to the regulations, the exceeding of the maximum floor area, the excessive number of persons or the too small number of exits. The effects of these exceedances will have to be compensated by other solutions that improve fire safety, such as an automatic fire extinguishing system for the building. The discussion on options called for an open dialogue between the parties and a better emphasis on the added value of fire safety. The development of training for architects in the field of fire safety was also seen as an opportunity to improve the situation. Designers find it difficult to find objective information about new technology. Designers should be provided with better means of obtaining design input and more efficient methods for sharing it to other parties. System supplier experience that they have knowledge, expertise, and insight that could be utilized more in design. A common discussion forum should be developed for designers and system vendors where information and experience could be shared.

Standardization is seen as a clarifier of responsibilities and a creator of common rules of conduct. The development of standards was considered important to avoid them to become an obstacle to other developments, for example for various new platform solutions.

Brand-independent design

In the interviews, it was seen important that the design is technically sufficiently independent and, to improve independence, plans should focus on system characteristics rather than brands. By favoring feature definitions, it is also possible to reduce the obsolescence of technology choices during long project processes. On the other hand, it may also be that excessive emphasis on individual features in plans limits too many potential brands to meet the requirements. The customer's needs specifications for the design work were seen to strongly guide the design of the system, so it is necessary to invest in their quality as well. The technical independence of the systems also contributes to creating the conditions for the most transparent and equitable procurement of the system.

The importance of performance specifications in procurement

Any changes in the design input or use of space, especially at a late stage of the project, have been perceived as problematic for the design work. These problems have been caused by incomplete or incorrect source data and changes in user requirements. Changes often result in the need for redesign and update of plans, which can lead to scheduling pressures. If this risk has not been considered in the design contracts, additional disputes are easily created in the payment arrangements for plan updates. In the worst case of scenario, changes in design may not be made, causing major uncertainties for the functioning of the final system. For this reason, particular emphasis should be made on the quality of requirement specifications when drawing up design contracts.

Development of long-term planning and design

The tight competitive situation of design agencies can lead to the elimination of tedious design options, which means that new technology options and opportunities can remain unexploited. The potential benefits of more extensive design work and the added value of the solution cannot be demonstrated or justified clearly enough so that people would be willing to pay for them. The situation easily leads to short-sighted assessments, which do not necessarily lead to sensible solutions from the point of view of the needs and costs of the entire life cycle of the system. As a descriptive example, the design of integration between different systems, in which cross-system data transfer is planned to be carried out through a single common field path instead of several separate cables. This integrated solution can minimize overlaps and over-volume cabling, as well as the fire load caused by them. The adaptability of the system will also be improved, as system changes can be implemented programmatically and centrally instead of wider physical changes. Consequently, the cost of the system will also decrease over the life cycle of the system. Design subscriber and designers should be familiar with technological possibilities and understand the cost impacts of their use. This objective could be supported by further training of designers.

Considering the entire life cycle of the system in design

Situations during maintenance can be significantly influenced already at the planning stage. For example, designing modular systems enables maintenance of different parts of the system at different time. Clear definition of communication dependencies and interfaces between different systems also facilitates the management of updates during the maintenance phase. The definition aims, among other things, to avoid breaches of other systems during updates and the emergence of unclear liability issues in connection with the repair of defects. The study revealed that the lifecycle of the systems has been considered in varying degrees. To improve the situation, it was proposed that sufficient resources should be allocated to the specification and report negotiations at the initial stage of the project, as they contribute to the design of features relevant to the life cycle of the system, such as adaptability, fault tolerance and updatability. In addition, there must be sufficient information on the life cycle and availability of different technologies.

Clarification of design boundaries between disciplines

According to this study, safety planning and building design boundaries have often remained unclear. Traditional design boundaries are often poorly linked to the boundaries of different system packages. This often leads to the involvement of several designers in the design of a single system, which can cause communication outages and ambiguities. Fire safety systems is a good example. Fire extinguishing system and fire detection system relatively new entrants to construction. Traditionally, designers have had little knowledge of them, so they have not been able to be planted in the implementation methods or culture traditionally used in connection with other systems. They have therefore formed their own limited sub-sector. Thus, the responsibility has also been decentralized among the various designers. For example, fire extinguishing system has been its own implementation, while FDS has been a part of its own alongside or outside electrical design. To ensure the smooth implementation of the integrated system, it was considered important that the responsibilities of designers are clearly defined. It would also be useful to examine the development needs of existing design boundaries and to assess how to better meet the need created by new technologies and systems.

Management and coordination of the design entity

Excessive fragmentation of the design package has been considered to complicate the management of the whole and increase disagreements. Fragmentation often leads to the need to produce a lot of plans for many parties in a short space of time. Information updated on a hardware-by-hardware basis also challenges designers in managing the whole. The overall picture of the design was considered to remain clearer if the design packages were kept larger.

It would be possible to improve the management of the design package with the so-called technical system design coordinator. The coordinator would be able to take responsibility for coordinating the technical systems as a whole and for linking the different parts of the components. The coordinator would review the plans of the systems objectively and promote dialogue between the designers. The coordinator could be a kind of master planner of technical systems, as well as a supervisor of designers of specific areas. They are required to have a wide range of general understanding and the ability to perceive entities. The interviews concluded that this role of design coordinator could be performed by a fire engineer or safety planner with sufficient expertise, who would in the best case have both a system supplier and design experience. However, finding a person with such a broad experience was considered challenging. There was a debate as to whether the coordinating body should be one person or a coordinating body or group. The coordinator should be selected and involved in the organization of the project at a very early stage, for example during the pre-design phase of the project.

Internationally, it was investigated how the system integration and compatibility, including fire safety, is maintained during construction projects. The answers indicate that practices in different countries vary.

In Sweden, it was found that one process was in place, such as Fire Detection Systems, while in Germany there is an expert focusing on fire safety systems during the design and construction phase and another expert performing quality assurance during building use. The latter example is similar to the approach that has emerged during this research. However, instead of one coordinator, two supervisory experts are found necessary. It may be advantageous for the project that during construction phase there is a person on site who is also responsible for the maintenance of the integrated system during its use. This would ensure the commitment to meet the needs and requirements of the end user and the operational functionality during the building use.

When the respondents to the international survey were asked who the necessary coordinator could be, consultants emerged as an option, as in domestic interviews. Another option that emerged was a specially trained expert, which was also mentioned in the responses to a question related to system-level management. This specialist role would be in line with the system coordinator discussed in Section 2.3.

In addition to the above areas, the respondents argued that in the construction projects, all the installed systems must be considered as an entity and in a modern building system a single area cannot be dismissed. However, In Sweden, the decentralization of entities is often considered a viable implementing process, whereas in Germany the links between fire safety and other safety systems and building technology was highlighted more. In Germany, as in this research, it was seen that concept of fire safety of a modern construction project must consider account design, installation, and maintenance as an entity.

2.8 Development of the system procurement process

The aim is to divide the integrated system in a controlled manner into defined parts appropriate to the procurement to maintain the predictability of the operations when the system is complete. Different forms of competitive tendering can contribute to the success of procurement. However, broader, and better consideration of qualitative criteria in procurement materials and decisions will require further development.

The key development areas include:

- Controlled splitting of a system for the procurement methods
- Forms of procurement of the system and qualitative criteria for procurement documents

Controlled splitting of systems for procurement and purchase

One of the key problems with system projects is the uncontrolled splitting of the system package during the procurement process, resulting in operational problems with the implementation of the systems and later during operation. The problems are caused, for example, by a lack of understanding of the compatibility conditions between different devices and systems. As a result of fragmentation, the project costs and predictability of the final system will be lost. The implementation of a functional and cost-effective system package would require that the package be divided in a controlled manner into sub-packages suitable for equipment procurement, without jeopardizing the implementation of the functionalities of the planned system package. The division according to functionalities was considered suitable for tendering, in which the subassemblies would consist of parts belonging to fire safety, alarms, and movement. The best timing for the partitioning is in the early stages of the planning process or immediately after the scope of the project is known with sufficient accuracy.

To ensure the smooth implementation of the integrated system and to avoid confusion between the various parties involved, it is important that the specifications of the tenders are sufficiently precise. The definition of procurement parts requires system-level expertise, so the previously presented equipment and system independent system coordinator would be a potential person responsible for sharing and defining the system package. In the interviews, the platform supplier and end user were seen as potential parties to perform the partitioning of the system.

Any modifications to the system components or design during the procurement process should be approved by someone who is able to explain and justify the impacts of the proposed changes on to system performance and on performance requirements set by the owner and end user. The changes can have negative effects on the performance of the integrated system entity, system properties, and life cycle costs. This person could be the system coordinator. The role of the system coordinator could be to inspect the final procurement plan of the main contractor before tendering. It was also pointed out in the interviews that those initiating a construction project should take greater responsibility for technological procurement.

Procurement methods and qualitative criteria for procurement documents

In this study, the possibilities of various tendering methods presented by the Finnish Procurement Act (2016/1397) was also considered to develop the procurement of fire safety systems. In addition, it was examined how different qualitative criteria appear in procurement materials and how they are considered in procurement decisions. According to this study, a restricted procedure has often been used in procurement. A negotiated procedure and tendered negotiation procedure have been used relatively often too.

The results indicate that the increased use of the negotiated procedure would improve the quality of procurement. For the success of the procurement procedure, it is important that the desired functionalities and performance are defined with sufficient precision and that the purpose of the building and premises are clearly stated. The study also revealed that in the procurement of fire safety systems, technology and the commissioning of the systems should be split into two separate tasks. Issues that are often resolved after the procurement include comprehensive testing of the integrated system, detailed issues affecting technical functioning, and sometimes additional wishes of the end user. For this reason, sufficient time and resources should be reserved for procurement and related system design, which would also improve the quality of the outcome.

In general, the inclusion of qualitative criteria in procurement has been incomplete and procurement does not always follow the instructions given. There have also been shortcomings in the availability of procurement data. The procurement materials have lacked items such as the conclusions of risk assessments, the requirements set by the platform, and the descriptions of the integration, system control entities, and interconnections between systems. The baseline data have also lacked mass lists of systems. Also, there have been shortcomings in the qualitative content of critical systems acquisition documents, such as in equipment diagrams. The control packages of the systems have not always been presented in depth and with sufficient accuracy. The documents may also have over-limited the implementation model to a specific technical solution. Moreover, the documents do not take sufficient account of the vulnerability and reliability of the systems. As solutions to these challenges, more detailed specifications of requirements, adequate report negotiations and verification and updating of operating models were presented.

The different quality criteria presented by the Finnish Procurement Act have been considered in procurement to varying degrees. The cost-effectiveness of the system is best considered. The delivery and implementation time, maintenance, delivery date and functional and aesthetic characteristics of the system have been considered moderately well. Accessibility, user requirements, operating costs and lifecycle services have again been considered rather poorly. The technical merits have received the least attention.

According to these findings, the quality, scope, and availability of procurement materials must be developed. Too much weight in the purchase price in assessing the procurement can lead to a poor outcome. It was also highlighted in the interviews that technologies that have not met the qualitative criteria for procurement materials, but which have been the lowest in terms of offer price have been selected. Qualitative deficiencies are usually highlighted in the later stages of the project. The correction of the problems they cause entails additional costs for the one initiating the project, owner of the property or the end user. However, the opportunities to influence the correction of deficiencies in procurement materials was considered good.

This study indicates there are shortcomings in procurement oversight and monitoring. The administrator may not understand all the operational possibilities of the system and can therefore focus too much on managing the details, leaving the larger entity disregarded. The supervisor should have sufficient expertise and resources to execute their supervisory work properly.

2.9 Development of the system implementation and deployment

The finalization, handover and reception of the project include quality assurance of implementation, verification, and implementation of final documentation of the system, testing and documentation of system functions, preparation of operating manual, agreement on operational training, final financial statement, and preparation of the completion certificate. Problems related to fire safety systems have been identified both during the implementation phase and in commissioning. Deficiencies have also been identified in the installation of systems and inspections. The observations emphasize the importance of quality assurance. Short duration of the test phases of different systems has been identified as one clear problem area. In addition, there has not always been sufficient guidance for testing. As a result, System Integration Testing may not be performed correctly, and functionality authentication is not successful in deploying the system. The tests may also lack documentation. Conflicts and overlaps between systems also create problems with deployment.

According to the international questionnaire, most of the challenges related to implementation have been related to schedules. In addition, the system interfaces of the various operators have not been sufficiently clear, which has reduced the effectiveness of their operationality. As part of the international survey, the respondents were asked what kind of challenges or problems they have encountered in implementations that consider integrated systems and that has been coordinated. The respondents considered that most of the challenges facing projects are schedule related. Moreover, the system interfaces are not sufficiently clear for operators and the challenges identified above affect the efficiency of the various operators, which is not at an adequate level. The solutions proposed include more guiding material, standards for managing the control systems, and more regulatory monitoring for the project period. The potential coordinator must be given sufficient time and training to emphasize the importance of the task.

According to the results of the study, there is a clear need for a responsible party to ensure that the self-checks and inspections of the system and the integration testing have been carried out properly. The responsible party would ensure that integration operators understand what interfaces are required for the systems they provide and that the requirements and functionalities are implemented as planned within the planned timeframe. Their task is to facilitate dialogue between operators and to ensure that there is no overlap between the systems. The system coordinator described earlier could have sufficient expertise to play this role.

During the study, the role of so-called fire technology manager was raised as a development idea. They would monitor and be responsible for the functionality of the entity and controls at the site until the building is commissioned and guaranteed. They would also ensure the adequacy of the documentation of fire safety systems and ensure that the necessary matters related to fire safety are recorded in the building's maintenance book. In Germany, an expert focusing on the implementation of fire safety is involved in the installation phase. In Sweden, it was considered that there was no need for such a neutral operator during implementation, but consultants are included in many different stages of construction.

Successful scheduling and keeping to schedule are considered as a key factor in the deployment of the integrated system. The safety contract also depends on other contracts, so it is important for the outcome that other contracts proceed according to schedule. In addition, it must be possible to clarify any additional planning needs in an appropriate time and it must be possible to verify the delivery times of the systems to ensure that there are no additional delays in the schedule.

2.10 Development of the system operation and maintenance

Deficiencies in the operation and maintenance of fire safety systems have been identified in relation to the operation, maintenance and updating of the systems. Also, there have been challenges in data management and in changes of responsibility in maintenance.

In the case of fire safety systems, the problems relating to maintenance have focused especially on emergency alarms and smoke extraction systems connected to the fire detection systems. The maintenance of fire detection systems has been of relatively high quality. Smoke extraction appliances do not have an equivalent regulatory background for inspection and maintenance as water extinguishing systems or fire detection systems do. The problems in smoke and heat extraction equipment have been caused by the lack of knowledge, which in turn may be due to the fact that there is less regulations covering this topic. In the future, it could be considered whether the alert and smoke removal systems should also be subject to the same more detailed maintenance regulation as the automatic fire detection and water extinguishing systems. The results highlighted challenges in the controlled takeover of fire safety systems in connection with the change of owner of the property or operators during the building life cycle. The results highlighted challenges in the controlled takeover of fire safety systems in connection with the change of owner of the property or operators during the building life cycle. A new procedure was proposed where, in connection with the change of owner or maintenance operator, the safety coordinators of the owner organizations would review the integrated system structure and relevant life cycle operations together and ensure that up-to-date documentation of the system exists.

Shortcomings in the management of the documentation of technical systems have been identified. In some cases, the location of the documentation is unknown, and the existence of those documents is not certain. In addition, changes to system may not be documented. The documentation of the system package and its timeliness must be ensured. Up-to-date documentation facilitates the use and maintenance of safety systems and the tendering and procurement of maintenance services. The interviewees also highlighted the importance of recording and compiling all maintenance measures taken in a shared maintenance book, where all parties involved in maintenance will be able to find this information. This will also prevent the maintenance of systems from being based on the knowledge of only a few people. Maintenance book and operational manual must be up-to-date, and compliance with them as well as updating must be controlled. The training of maintenance personnel must be ensured throughout the life cycle of the building. The system coordinator was considered as a potential resource to oversee system maintenance and related documentation management. The respondents from the reference countries of this study pointed out that a fire safety expert is responsible for assuring the quality of fire safety of the buildings during its use. It would certainly be justified for this responsible party to be involved during the commissioning phase of the building, so that they can ensure, on behalf of the end user, that the objectives set are considered and achieved.

There are already electronic maintenance book systems and other solutions that compile information in a single user interface, which enable maintenance, property owners and users to improve the predictability, transparency, and productivity of their operations. The systems include tools to ensure appropriate maintenance, monitor the operation of the systems and produce reports describing the situation. It should be possible to better demonstrate the effectiveness and importance of these systems to those responsible for maintenance, such as property manager. The use and generalization of systems would bring added value to users and residents through accelerated operations and greater use of real-time information.

2.11 Value of fire safety

This study clearly indicates that perception and branding associated with fire safety should be developed. Moreover, the economic added value of fire safety has not been sufficiently clearly and concretely described or perceived. The situation can be improved by increasing and developing skills and training in the field.

Perception and brand development

Fire safety should be visible and understood as a key part of the overall safety and management of the property. The industry should further clarify that fire safety is much more than fire detectors and fire extinguishing equipment. In the interviews, the industry's own weakness was perceived to be the invisibility of the operations and the promotion of fire safety was considered old-fashioned. However, Finnish people were seen as receptive to the possibilities of new technology. The development and updating of fire safety-related imagery requires information and training that can be absorbed and utilized by various parties.

When fire safety is seen as part of an entity that is considered important, the related work is considered important. During their life cycle, buildings may face a wide range of crisis situations involving simultaneous internal and external threats. Fire safety solutions help to prepare for these situations. The customer must see how different systems and services improve their safety while ensuring the continuity of operations. As a visible added value, fire safety inspires the investor, owner, and end user to seek and demand information about services on the market.

The interviews revealed that the investor, subscriber, and end-user are generally unable to assess whether the outcome meets the functionality objectives set at the initial stage of the project. They are often satisfied as long as the regulatory approval for the systems is obtained during the commissioning phase. They should be able and better equipped to assess the achievement of the quality of added value for safety during the implementation phase. They should also have the opportunity to decide whether to accept implementation with minimum requirements, or whether they want to stick to value-added functionalities.

Services, user interfaces, and tools can be programmed into system platforms to present and visualize different issues related to fire safety to the client and end user. These can be presented, for example, in 3D views. In addition, these can be pre-programmed system test and maintenance routines or data model-based safety data sheets. Demos implemented with VR/AR technology are perceived as a good way to help people understand what fire safety in a building is and to get them interested in the opportunities it provides in creating overall safety.

Added economic value

Improved fire safety cannot be perceived as a sensible investment or a cost saving accumulated during the building's life cycle. As the value of better fire safety is not recognized, no development work is carried out to improve operational efficiency or to highlight innovations. For end-users, added value is provided by better safety and ease of use. It is also essential for the customer or the end of the user that safety solutions and services support the company's business and business continuity. Other aspects of the investment culture, such as the effects of fire safety on economic certainty, business continuity, flexibility, and adaptability have not been communicated to investors sufficiently. In terms of fire safety, it is also possible to examine the effectiveness of operations in a manner that is similar to that of the industry. In this case, the maintenance time, the operational pauses caused by maintenance and fire damage, and the costs of business disruptions caused by evacuations will be included in the review. At the present, the goal is often that the systems work only in case of a fire. However, the systems should be connected to a service that updates the system. Maintenance contracts, remote monitoring and maintenance are considered as a new, evolving, and interesting opportunity for fire safety. Property owners' time and money are saved when the system can be connected remotely from a computer, tablet, or smartphone, and all the items being maintained are seen in one informative view. As a result, system management tasks can be linked to each other and handled with the same resources. The system database is located in the cloud and by analyzing the data, it is possible to assess the need for maintenance by studying, for example, the trend curves of sensor or detectors dirtiness. The systems can be inspected remotely without interrupting running production lines, which also saves time for the persons who is testing or inspecting the systems. An Internet-connected system can also streamline installation and commissioning, reducing operational resource requirements. This may increase contractor interest.

According to the interviews, the smart system does not cost more than the traditional system if cost reviews consider the impact of alternative solutions on the whole system as an entity. For example, wireless solutions reduce the amount of cabling and thus the fire load. The new technology also enables the use of fire safe and multifunctional premises, which is a significant added value for the customer. These benefits should be better demonstrated than they currently are. Based on the information received from the interviews, approximately 15 per cent of the lifecycle costs of the equipment are its acquisition costs and 85 per cent are maintenance costs. Based on the cost distribution, the system should not be designed and implemented solely for the transfer of the property. The entire life cycle of the building must be included in the reviews and decision-making process. Service sales that cover the whole lifecycle are not yet common, but the capacity for this already exists. The model includes, among other things, financing, installation service and maintenance. When the system is delivered as a lifecycle model, the price per square meter of the safety solution is different from that of system only. Subscribers have not yet identified the need for such service, but lifecycle solutions are considered as an opportunity to strengthen attractiveness.

The technology sector has value promises in place, which serve as an assurance that the investment made will be returned to the customer within a certain period as savings generated by the investment. The costs of the entity implementing the jointly agreed maintenance price are evenly distributed over a certain period and savings are made for both parties during the contract period. This requires the subscriber to be ready to share the direct savings achieved.

The design and implementation of the system must ensure that the user receives the required level of safety and avoids retrospective repair costs. Updating the systems and modifications at a late stage of the project are very expensive. When designing a system that works during the installation phase, it may be expired by the time the building is completed. When designed for a longer period, the system is likely to become of a higher quality and has also considered maintenance and sufficient capacity of the equipment for possible changes in the life cycles of the building and the system.

The use of building information models (BIM) is increasing rapidly. Building information models can be used to achieve added value by improving the efficiency of design and the management of the design information and documentation. This increases cost benefits and releases resources to provide better fire safety. Building information models would also help utilizing the new technological opportunities in designing and to improve the information sharing and coordination during projects and through the building process. The wider use of data models during the use phase of the building is considered as a significant opportunity for the future.

Based on the international questionnaire, the use of data models in fire safety implementations is still low. The examples that emerged were related to the use of data models in risk assessment, needs assessment, coordination of fire safety systems, and as a quality control tool in connection with plan updates.
The responses revealed that, in current practices, data models are used to some extent in risk assessment and in defining needs. One of the respondents was unable to comment on the subject or have not encountered it in the projects. One respondent commented that data models are used in some projects, but not very often.

During this study, it became evident that data management and the services created around it will be the cornerstone of safety and security business in the future. This was also raised by several parties. Modern technology already has the potential to add value by collecting and utilizing data measured from the building and its systems. Safety of the building can be improved, for example, by anticipating and preventing fires, improving the situational picture of the accident, and facilitating the maintenance and updating of systems and systems. However, the utilization and implementation of new functionalities and services requires clarification of common policies and the development of standardization of fire safety systems so that there is room for new solutions to develop. Solutions and services must always ensure the operation of a critical system in all situations. For example, it may never depend on the functionality of an internet connection.

To be manageable, the information collected from the system during implementation should be compiled in the system information portal. This can be, for example, a service provided to the subscriber to ensure that the added value of the information is maintained. The interviews revealed practices that have already been implemented in industry, which require that all required documents related to components, materials, and approvals must be stored on the portal before permission is granted for implementation. During operation, the product and procurement information of different subcomponents can be quickly found on the portal. Ownership of data and access rights to data from different systems can be defined in connection with the design of the system architecture. The organization must be obliged to delegate the responsibility for maintaining the system to the future owner or holder to ensure systematic takeover in the event of a change of ownership. Information on all new equipment purchases must be taken to the portal and it must be possible to ensure that the information is transferred to other implementing parties, the property, and the maintenance company. How the person responsible performs their duties and how things are maintained should be measurable.

Knowledge

The results of both national and international surveys revealed that there are differences in the identification of current smart construction and system integrations. Many parties also considered the amount of fire safety expertise and the number of trained professions to be insufficient to ensure the quality of firefighting technology implementations.

The international survey revealed that in Germany, regulations enforce quality assurance, and this is supported by the general insurance guidelines in force in the country. In Sweden, the quality of industry and system suppliers is ensured through certification and quality assurance. The competence of the approved companies was at an adequate level and standardization and internal quality control were considered effective methods for ensuring the quality of installations. As in Finland, in the countries that responded to the international questionnaire the monitoring of operations is based on third-party inspections and maintenance obligations set out in regulations, as well as on the supervision of contractors 'own work and self-inspection of the system installations.

The interviewees experienced that the time for the old technologically and commercially closed model was over. Functionalities and ecosystems should be developed and marketed to customers together. It was also highlighted that acquiring sufficient fire safety expertise for the various parties to the project requires extensive training. The operating models of training must also ensure the continuous maintenance of the level of competence of various parties.

The industry must also develop its own practices so that designers and various system operators remain more aware of the new services and products on the market. Based on the interviews, system manufacturers still want to protect the knowledge, technology and product development related to their new systems, and to manage the system by limiting the information provided for design. Effective cooperation requires that the parties can find a common economic interest that benefits all of them. These business models were considered to evolve when the customer starts ordering larger ecosystems and services. Cooperation can offer new functional opportunities and thereby increase the added value for the subscriber.

3. Conclusions

Due to the results of the research work and the challenges and needs raised in previous studies, it is difficult to find a single way or method to address the shortcomings identified in construction projects or planning processes. Also, the problems are not combined in one party, but the findings must be viewed and solved by target groups.

Throughout the research, the challenges of cooperation and information and sharing have arisen. There are several different factors that complicate the development and integration of smart fire safety solutions in rest of the building environment. For example, if the practices and operations covering the whole building life cycle are missing, if the authorities, planners, maintenance, and end users do not get information about the systems easily, if the information is not easy to interpret, and if there are no prominent cases about the cost savings and benefits. This study highlighted the clear need to better define the objectives set for the fire safety of the building and to manage the implementation of reliable fire safety as part of the integrated property safety system.

The production of neutral objective information for the various parties involved in the construction project has been considered particularly important. The present findings confirm that designers and those initiating the construction project need more information and support in construction projects to successfully implement and manage fire safety technologies and to ensure that fire safety meets the needs of the end user. The results provide evidence that it would be possible to improve the situation by defining the tasks of the various parties in more detail and by creating new roles to support and coordinate the design and implementation of the systems. Many of the problems raised in the study were caused by a lack of a clear responsibility, and therefore as part of this work, a new so-called system coordinator role is proposed. The coordinator would support the system integration process for those initiating the construction project and act as an interpreter when needed.

When addressing the various challenges raised in the research, it was clear that traditional fire safety systems have been excluded from other building technology and automation implementations, due to both fragmented design and implementation processes. For many of these challenges, such as for those relating to the implementation coordination, information management and system hierarchies, there are already existing quality management practices and instructions that can be extended to fire safety system projects. However, these guidance materials may be considered partly self-evident in the industry and may not be applicable to building technology implementations, leading to large variations in project management and quality realization.

Sometimes the designer can also have a very broad job description that requires multiple parts of the area to be managed simultaneously. In this case, the technological opportunities provided by the various fire safety systems might not be known well enough. For example, there is a great deal of qualitative development to be done in procurement processes. The results indicate that legislation is relatively well complied with, but in the case of individual systems, procurement may often be so called header level procurement, where the decision is based on price and not on qualitative criteria. In this case, too, the regulations are identified, but their guiding content is ignored.

Tools for quality management

A potential solution for the quality management issues highlighted in this research could be a handbook for building owners and developers. The handbook would help the project participants and different disciplines better understand the possibilities, benefits and value of fire safety and fire safety systems when the building is in use. This would enable better evaluation of the qualitative starting points for the input data regarding preplanning and designing process, particularly from the end users' and achievable savings point of view. At the present time, the value in the construction project is based on the original value of an individual system at the time it was purchased.

Value of fire safety during the use of the building

Development is also needed on how fire safety is sold and what new forms activities such as those relating to services could offer. Forms of marketing that complement economic efficiency of safety as a concept, and fire safety, should be developed so that the significance of the issue would be better highlighted and in a form that is understood by different parties. Similarly, as cities seek visibility through their good health services, they can develop their own safety image through fire safety.

System development and integrations

The integration of building technology in the development of systems is leading to a scenario where systems, and the information collected by them, will in future be collected on a shared platform. However, current practices and system-specific guidelines do not adequately or necessarily address this issue at all. Similar to the findings of previous studies, there is a general perception among different operators in this study that the coordination and technical implementation of the systems is not understood, and that information on other building services systems may often be incomplete for the subsystem implementation operator. Definitions of ownership of information generated by systems and platforms do not always enable the integration of information from integrated systems. In some cases, the information is not made available to all relevant parties. Also, old design and procurement methods may be an obstacle, if they are fragmented into specific planning and designing processes. Furthermore, these methods do not consider the coordination needs of existing systems. The lack of common practices creates challenges and problems that need to be addressed during the implementation processes.

Previous studies provide evidence that the uncontrolled fragmentation of the integrated system package create challenges, when small parts must be acquired and implemented separately. Deficiencies in the quality management of the entity lead to the challenges in timeliness of documentation and in time management. It has also been found that later during the contracting, the parts of the system package can no longer be implemented as a complete system. Neutral design is seen to facilitate the acquisition of open system subassemblies.

New technologies in the development of fire safety

At present, buildings have a large stock of condition-sensing equipment that can be used to transmit real-time snapshots of prevailing conditions. Often there is an explanatory feature in a fire event that can be identified and reacted proactively before the fire risk materializes. It is fundamental to recognize any unusual activity and conditions. The timing of the observation can also be significant and can be used in estimating if the observation is usual considering the normal activity of the monitored space or if it is something that should be reacted to.

Many newer demanding construction projects have implemented large-scale centralized property control rooms, which can also be used remotely. Measured and monitored condition data include temperature, humidity, pressure and, for example, the amount of light that could be used to assess whether smoke has accumulated in the room or whether the room is dark. Monitoring and measurement data can also be used to monitor the conditions and activities of the premises of the property, assess the need for maintenance of the equipment, and identify data deviations due to negligence in maintenance. The interviews highlighted many unique hardware technologies that would already be available if a model was created for their use at the beginning of the construction project, as well as definitions of how and where the data can be collected and who is allowed to use the data in different scenarios.

The opportunities provided by different technologies are not known to all parties and designers. Therefore, the development ideas of system suppliers and the needs of the end user should be identified and analyzed more comprehensively during the initial mapping of the project. In particular, smart lighting systems, security systems and sound analysis units were strongly emphasized in the research.

Lighting can be used to guide people's behavior towards a safe direction. In the event of a fire, lighting can be directed to where it is needed and where something is happening. In addition, sensors in lighting systems can provide significant information about the conditions in the space where the fire occurs. Sound recognition can be used to assess the development and spread of fire or to assess human behavior in different scenarios. The sound level can convey a lot of information about the fire and whether people are panicking. The overall picture of the rescue operation can be strengthened by investigating if there are sounds in locations where people are suspected to be in based on other data collected from the property.

The data generated by camera surveillance can be used to develop situational information about human behavior or evolving conditions. The camera can detect temperature, smoke, movement, frequency of movement and the size of the moving object. The importance of camera surveillance as a supporting forecasting feature to other building technologies will be emphasized in the future. It is possible to supplement the situational picture with other existing solutions, such as motion detection and monitoring of locks and doors. This information can be used, for example, to estimate the number of people and to analyze people's behavior when they are leaving the space where the emergency occurs or in another exceptional situation. Information about the direction of movement in a building can tell if people are moving in a safe direction away from danger or if people are exposed to immediate danger.

This research strongly highlighted the opportunities of the IoT in monitoring the use and conditions of facilities and in producing proactive information. This enables the proactive actions during property maintenance that can ultimately limit the materialization of risks. These possibilities are currently not considered in the projects, and the utilization of the technology is based on the need for an individual control task, and other value-added uses have usually not been identified or integrated into the activity.

There are many operators on the market who would be able to provide the supervision needed for the property in a more diverse way than it has been implemented by current methods. Greater use of the know-how of these actors at an early stage of the design process would certainly produce new innovations. Especially in the case of IoT solutions, the importance of pre-planning is emphasized especially if the sensoring is designed to serve several needs. However, the end user often recognizes these needs after the design and implementation phases, during the use of the property and building. In many cases, the retrospective connectivity of new functionalities is expensive or sometimes even impossible. Information management agreements between different parties can also reduce the opportunities significantly.

Building information models (BIM) in fire safety

Fire safety is a part of the building automation system and the implementation of building technology, and, therefore, the same quality assurance methods and procedures as applied to the maintenance of the automation systems could be used for the fire safety systems. Information collected from the building must meet the relevant standards, so that it can be analyzed and visualized in a way that the user can easily understand it. The information can be presented, for example, by using data models for buildings. The building information models would also help in utilizing digital twins which are able to assess data produced by different systems and this way make it possible to test system integrations already during the planning and designing phase. The implementation and planning of the fire safety of the site can be improved by linking the system data and inspection protocols related to the maintenance and monitoring of fire safety to the information model available to the authorities and other parties carrying out the monitoring. The digital twin of the building is one possible tool for managing, analyzing, and modifying the large amount of data generated by sensors. This can facilitate the modification of information in a format that can be easily understood by the user. The shared platforms of buildings and systems modeled by the same rules enable a parallel comparison of buildings, which could improve the efficiency of the use of resources and highlight potential risks and supervisory needs before damage becomes concrete.

The growing demands related to the adaptability of buildings and rapid changes in work will increase the importance of quickly available and up-to-date system information. In addition, ensuring an acceptable safety performance in the event of changes requires a rapid exchange of information between the various parties involved, as well as sufficient information on the adaptability of the system to the necessary changes. Reliably archived system information facilitates the deployment of building and its systems and equipment. It also contributes to solving the qualitative and scheduling challenges identified in the integration. Well-instructed data modeling provides a tool for this.

Opportunities provided by integrating systems in developing the situational picture for rescue services

Modern integrated building technology implementations and information from the building would make it possible to find out what and where has happened and help with monitoring the development of the situation and people's activities. This would ensure safe exit from the building and it would support with assessing the necessary actions required by the rescue services. The data received will enable the rescue services to carry out a rapid assessment of the situation based on the information. For example, in larger buildings, the challenges include the management of large numbers of people, the creation of the situational picture required to perform extinguishing and rescue operations as quickly as possible, and activity management. When the rescue services can respond to potential risk factors earlier, the extend of the damage is smaller. Information collected from buildings during fires can also help rescue authorities to develop their own work. There is sensor technology suitable for collecting data in buildings, but there are no tools or services for collecting, archiving, and analyzing data.

Future research

In the future, the development of rescue services and the development of the maintenance of the building will increasingly be linked to information on the use of the building. Data models and functional platform solutions play a key role in this development and their use and application potential in fire safety should be investigated before other development targets identified in this study can be effectively taken forward. Data modelling has been used as a design tool and various digital environments and virtual reality have been utilized to improve maintenance efficiency. In this research and the master's thesis, the topic was seen to be so multidimensional that the work has only been viewed thematically as an opportunity. The subject would require a separate study to take all the necessary starting points into account. Further research should examine how data models have been used in modern smart buildings and what practical models could be used to model fire safety systems and functionalities.

The findings and development opportunities made in this study must be deepened throughout the construction project, so that the quality manual that was presented as a solution can be created. These factors include the baseline information for the construction project and design, risk management, quality control, design and procurement, implementation process, delivery, and maintenance. Data models and the digital twin for the building were also seen as one of the technical solutions for building lifecycle management. The significance of these was recognized, but their use was considered challenging due to current practices. The main challenges are the lack of uniform design criteria and guidelines, and the production of common practices adopted by different operators. The digital twin has also been used in Finland, but both in Finland and in the reference countries of this research, the digital twins of the buildings are still rare and have mainly been used in larger projects, not in individual small properties.

Managing the system and meeting fire safety objectives throughout the life cycle of the building requires a lot of expertise and knowledge from the parties engaging in the building project. This study clearly indicates that the lack of information and the challenges in understanding the integration of systems concretized in the definition of functionalities and platforms. In the future, this would require its own design process to ensure that the necessary features and interfaces are actualized, and that procurement processes do not change these features during the construction project. The operating model must be able to ensure the compatibility of the systems throughout the process up to the maintenance phase of the building. During this study, a designated system coordinator was presented as one solution to this.

This research has highlighted the need to produce methods for construction projects and designers to increase the reliability of the control of different systems and their connections that effects the fire safety in whole. In addition to platforms, data models and digital twins of the building have been highlighted in interviews as a development opportunity and a quality management tool. This study, together with previous research, highlights that there are significant regional differences in the supervisory role of the rescue services and in the operations during construction projects. In the future, supporting the operations of rescue services with new technology requires a more detailed targeted study assessing the possibilities of the technology from the perspective of rescue services. Planners and parties engaging in a building project should be provided with more specific information about the legislation and legislative procedures and practices should be available to support the risk assessment and performance specification at the early stage of design. Regional dialogue is important in order to produce an approach accepted throughout Finland. In this case, those coordinating the construction project and the design of the system package would be able to operate on the same starting points throughout the country. This would also clarify the role of rescue services and support the consolidation of operations.

4. Summary

The purpose of this work was to explore new technological opportunities on the market and to describe their added value from the point of view of fire safety. In addition, the work comprehensively examined the various management challenges and development opportunities involved in the design, procurement, implementation, and maintenance of fire safety systems. The four key areas of the research work were: improving operational reassurance, preventing accidents, providing rescue authorities with real-time information, and utilizing the condition censoring of building technology.

This work provided a timely overview of the technologies and new technological opportunities on the market and sought to illustrate the added value of these. Different platform solutions currently enable the implementation of more integrated fire safety, which means that the system package can integrate technology that analyses sound, light, and video, introducing completely new ways to improve fire safety. This study investigated what kind of information or tools are needed to support the fire safety planning and implementation of projects. The results and conclusions of the study also provided a comprehensive description of the numerous other problems raised in the study and their possible solutions. As early as in the construction stage, it would be important to coordinate all the technology integrated in the building and see fire safety as part of it. If fire safety technology, solutions affecting fire safety and regulatory requirements could be considered already during the design phase of the building, the extension of contracts and additional costs would be avoided. Based on this study, a specialized system coordinator is suggested as a viable solution to this problem. This coordinator would be familiar with the operational procedures in the fire safety industry, and they would coordinate the fire safety aspects from the beginning to end of the construction process. The study also confirms that the end users and owners of the building should be more strongly involved in the initial phase of the building project.

The result of this study indicates that research, development, and training programs are needed in several different areas. Consequently, the contributions of expert work should therefore be transferred to the transmission of information and the development of attitudes. These results will be able to guide research and development projects in more specific areas and for the right target groups. Fire safety has been identified in construction projects as a difficult entity to manage and awareness needs to be raised both among users and those involved in design and implementation. Data production must be increased in the context of other developments, so that fire safety remains involved in the development of integrations, platform implementations and data models.

The work clearly highlighted three key areas for further research: the use of data models and the digital twin to improve fire safety, the management of the system and the operating model of the system coordinator, and the quality manual for the system project.

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SPEK TALKS

There is a need for objective information and guidance material on fire fighting and prevention technology to develop fire safety system implementation processes.

New technologies are often seen as enablers, but existing methods and lack of knowledge often limit the scope for innovative implementation or the use of new technologies in buildings, with the result that old methods are retained in both design and contracting during construction projects.

Under these circumstances, there is a need for research that can deepen the previously identified challenges to the implementation of fire safety systems and the challenges of modern smart constructions. The purpose of this work was to identify new technological opportunities in the market and to try to describe their added value from the point of view of fire safety. In addition, the work comprehensively examined various administrative challenges as well as development opportunities related to the design, procurement, implementation, and maintenance of fire safety systems.

This research work has been a collaborative project carried out by the University of Tampere and the National Rescue Association SPEK, and the work was funded by the Finnish Fire Protection Fund. The project aims to highlight new options that can be used in general for the development of fire safety technology. The project also aims to provide information.

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