ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

FAKULTA STAVEBNÍ

FIRE ALARM IN BUILDING INFORMATION MODELING

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Závěr

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ČERNÝ M. a kol. 2013. BIM Příručka. Praha 6: Odborná rada pro BIM. ISBN 978-80-260-5296-8.
Vyhláška č. 499/2006 Sb., o dokumentaci staveb. 2013. Praha: Ministerstvo vnitra České Republiky. ISSN 1211-1244.
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FRIDRICH, Ing. arch. Ing. Jan a doc. Ing. Karel KUBEČKA, PH.D.,. BIM a jeho implementace v oblasti požárního rizika. In: Tzb info [online].
PROFESNÍ KOMORA POŽÁRNÍ OCHRANY. 2013. Jednotné doklady ke stavbě: z hlediska požární ochrany. Praha.

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Datum převzetí zadání Podpis studenta(ky)

Declaration

I am declaring that I was working on this work independently with professional supervisor prof. Ing. František Wald, CSc. Sources of information for this work are listed in the end of the work.

In Aveiro 13th of December 2020 David Kaplan

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Abstract

This master thesis is focused on information building model with focus on fire alarm during the entire building life cycle. In the first part there is a summary of fire alarm topic in general. Strong focus is on legislation and fire alarm during its entire life cycle. Also, there is topic summary of certificates of fire protection, documentation of fire protection and building information modeling in general and with focus on fire safety solution. In the second part, there is concept for working with fire alarm in building information modeling. This drawn concept is touching three areas. Firstly, it lay down and algorithm which automatically place fire detectors to given floor plan. Secondly it simulates building life cycle with simulated events which will occurs to fire alarm during life the building life cycle. Lastly simulation also covers documentation of fire protection and its events and document management.

Key words

Building information model; BIM; Fire safety solution; Fire alarm; Uniform documents for fire safety devices; Fire protection documentation; Fire detectors placement

Abstrakt

Tato diplomová práce se zabývá informačním modelem budovy, se zaměřením na požární elektrickou signalizaci v průběhu životního cyklu budovy. V první části práce je shrnuta problematika elektrické požární signalizace. Důraz je kladen na legislativu a životní cyklus systému elektrické požární signalizace. Do této části práce je také zakomponovaná dokumentace o provozuschopnosti elektrické požární signalizace, dokumentace požární ochrany a úvod do informačního modelu budovy. Druhá část této práce je zaměřena na vývoj softwaru, který simuluje práci s elektrickou požární signalizací v informačním modelu budovy. Tato simulace se dotýká třech oblastí. Jako první popisuje algoritmus, který automatizuje rozmístění požárních hlásičů do daného půdorysu. Druhá část simuluje životní cyklus elektrické požární signalizace s ukázkami událostí, které mohou v průběhu životního cyklu nastat. Poslední část simulace

pokrývá problematiku organizace a dodržování dokumentace požární ochrany a událostí z ní vyplývající.

Klíčová slova

Informační model budovy; BIM; požární bezpečnostní řešení; jednotné doklady ke stavbě; dokumentace požární ochrany; rozmístění požárních hlásičů

Symbols

Sb.	Legal Code
ČSN	Czech Legal Standard
S	Area
S_{max}	Maximal Area
Kg	Kilogram
m	Meter
h_p	Fire Height
OB	Civil Building
F_o	Ventilation parameter
CAD	Computer Aided Design
2D	Two-dimensional Space
3D	Three-dimensional Space
BIM	Building Information Modelling
CO_2	Carbon Dioxide
MEP	Mechanical, electrical and pluming
IFC	Industry Foundation Classes
GUI	Graphical User Interface
m^2	Square meter

Introduction

This master degree thesis is introducing building fire safety solution in building information model. This work is touching on three areas of building life cycle. Firstly, it looks at the design phase when it is mandatory to design fire alarm. It introduces algorithm which is placing fire detectors automatically to given floor plan. Secondly, it describes a concept on how to manage fire alarm in building during its life cycle - from alerting operating staff about regular revision all the way to generating mandatory documents. Thirdly, the work focuses on fire protection documentation. Fire protection documentation is important part of building fire safety. It needs to be kept up to date with regular revision and regular staff training. And it needs to be under regular revision and the staff must be informed about system and fire guidelines during regular staff training. Overall, this master degree thesis is exploring these three areas and designs concept on how they can be used and put together in building information modelling.

1. State of Art

1.1. Fire Safety of Buildings

Fire safety solution of the building is collection of fire safety measures. There are cooperation measures, technical measures, and construction measures. All together it has an objective to prevent fire or explosion with following fire to protect people, animals and property in case of the fire emergency. In case of fire emergency, safety measures must keep building construction stable, prevent fire spreading for determined time by fire safety solution documents. Next objective is to ensure safe evacuation for building's residents and safe access for the fire brigade to fight the fire. All these objectives are clearly reflected in the fire safety solution documents [1].

1.1.1. Legislation

Fire safety solution design is one of the main parts of any building's design. From the very beginning of the project to its very end there are fire safety measures which are taken into an account. In standard law NO. 499/2006 Coll., about building documentation is stated that fire safety solution design and its documentation is indivisible part of any building development project. Fire safety documents are needed for issuing permission for building or facility, documentation for common land decision and building permit, documentation for selection construction reports, revisions and supplemented with documentation for construction work [2].

The main standard for fire safety design is standard law NO. 246/2001 Coll., about fire prevention. In this standard law there is a detailed documentation description and documentation requirements. Fire safety engineer or fire safety technician produced the fire safety documentation. Both the fire safety engineer and fire safety technician must have special authorization according to standard law NO. 360/1992 Coll. During the fire safety planning process there are many legal rules (legal provisions, legal decrees, legislative measures), and Czech technical standards (designing standards, subject standards, test standards, classification standards), European technical standards (Eurocodes) and many others. Most important are standards ČSN 73 0802 for non-production buildings and ČSN 73 0804 for production buildings.

Another very important standard is ČSN 73 0810 which is creating a relationship between European standards and other Czech standards [3], [4].

1.1.2. Fire Safety Solution Documentation

Fire safety solution design is based on requirements from special legal decree, from standards requirements and requirements based on urban sprawl. Fire safety solutions documents contains

a) conceptual design of fire safety solution based on building design and the use of the building. Solutions are based on the height of the building, building construction, building placement based on fire safety distance, details about building technologies and the use of the building, technological process, or stored materials,
b) solution for access roads, boarding area for the fire brigade equipment, ensuring enough amount of fire water or different fire extinguishing substance,
c) evaluation of suitable conditions for fire intervention or in special cases ensuring fire brigade in the facility or preventive fire watch,
d) graphical visualization of building placement with fire safety distance assumptions, eventual safety distance, access road and boarding area for fire brigade equipment, connection to technical wiring etc.

Fire safety documentation is an integral part for any building design documentation according to special standards and it contains:

a) List of dated documents used for the design;
b) Brief building description in terms of building construction, building height, use of the building, description and evaluation of building operations, building placement in relation to the surrounding development;
c) Division of the building into the fire compartments;
d) Fire risk assessment, economic risk assessment, degree of fire safety and size of the fire compartments;
e) Designed building constructions and passive fire protection assessment in terms of its fire resistance;

f) Evaluation of construction products and material (fire classification, burning droplets, flame spread rate, toxicity etc.);
g) Evaluation fire intervention condition, evacuation of people, animals and property, and establishing evacuation routes and their descriptions, capacity, equipment and used materials;
h) Establishment of building fire safety distance, eventual safety distance and establishment of fire danger area, evaluation of building fire safety distance, eventual safety distance in relation to the surrounding development, neighbourhood property and open warehouses;
i) Solution for fire water storage including collection points for both exterior and interior, eventually ensuring right amount of different extinguishing media in case of building operation where using water is not possible;
j) Establishment of the fire intervention routes for fire brigade and its technical equipment, measures to ensure safety of people performing a fire intervention and safety works, evaluation access roads, eventual boarding areas for fire brigade equipment;
k) Establishment of amount, kind and placement of fire extinguishers, eventual other kinds of fire safety protection or fire safety equipment;
l) Evaluation of technical, eventually technological building equipment (pluming, ventilation system, heating etc.) in terms of fire safety design;
m) Establishment of special requirements for increased fire resistance or reduction flammability of construction materials;
n) Evaluation of requirements for building security with fire safety devices;
o) Range and placement of warnings, safety signs and tables including evaluation of needs for designated areas with fire safety equipment and fire safety devices; [3]

The fire safety design documentation has an objective to protect and minimalize the damage on human health, animal health and minimalize the lost of property. This documentation is complex and it is the key part for any building development during its entire life cycle. From the first design to the building demolition there are fire safety requirement which are being

considered by the fire safety engineers. Due to its complexity, there are many government decrees, legal provisions and standards which must be taken into count during a fire safety design. Most common way of dealing with fire safety design is with help of many tables and standardized processes in Czech standards. There is also performance-based design which is based on complex fire modelling and computing. In this scenario fire safety engineer can overcome borders of the standards and used modelling and computing to design more efficient, economical and more suitable solution [1].

1.2. Fire Alarms Solution

Fire alarms systems are the central brain for most of the fire safety devices. It is usually the first system that will react in case of fire. The primary goal of fire alarms is to quickly detect fire in the beginning phase. There are two main parts of fire alarm project. First is the fire alarm design and the second is the fire alarm construction. Person who is responsible for both part of the project needs to have professional certificate according to decree NO. 246/2001 Coll., about fire safety prevention and law NO. 360/1992 Coll. [3,4,5].

Alarms systems varies a lot in terms of complexity. There are quite simple solutions with couple smoke detectors, an alarm siren, and a master box. On the other hand, complex building fire alarm system can control entire building safety service. Master box can control not only fire alarm, but it can also indicate in what part of the building the fire started, can operate the sprinkler system, close doors, block elevators and control any other fire safety device. Fire alarm system helps fire brigades as well. In many cases it contains a master key which open every door in the building, it can keep the necessary electricity running and much more.

1.2.1. Legislation

The entire fire safety design is affected by many legal standards due to its importance. Fire alarms follows many legal standards which help fire alarms engineers to design a working system which is safe, economical, and robust. All the design is based in standard NO. 246/2001 Coll., about fire safety prevention. This standard consists of the most important definition with the most basic rules for fire safety designs. There is a basic definition of fire alarms as part of definition about fire safety devices according to §2 paragraph (4) Types of Fire Safety Devices. This standard also states the standard procedure and other legal standards which has to be taken into an account during design process as well as construction [3].

There is also legal decree NO. 23/2008 Coll., about technical condition of building's fire safety. This standard expands safety requirements for individual building operations. For many kinds of buildings, it imposes an obligation to design a fire alarm. For example, buildings with great historical value are required to have fire alarm. Moreover, this decree is listing more legal standard which are obligatory to use in fire safety design. Especially for fire alarm systems there

are standard norms ČSN 73 0875 determination of requirements for alarm systems in the meaning of fire safety solution and ČSN 34 3710 Fire alarm – Design, construction, usage, operation, controls, service and maintenance. Equally important is a list of legal standards according to which it is obligatory to have fire alarm in the building [6].

Firstly, there is the legal standard ČSN 73 0810 Common Provisions. These are rules for fire safety in general and it contains the topic of fire alarms only a little. There are mostly requirements to design other fire solution systems. For example, there are some specific cases when having sprinklers in the building also leads to having fire alarm system which will control the sprinkler system. Main paragraph is about coordination of safety devices. There is also a clear description of many fire devices and how it should be coordinated [7].

Secondly, there are legal standards ČSN 73 08XX. Each legal standard from this set is focusing on different kind of building. From non-production building across production building, hospitals, apartment building all the way to farms and storages. Every fire safety design is based on one or more of these standards and this is where requirements for fire alarm usually originates.

Based on the requirements from legal standards mentioned above there are legal standards ČSN 73 0875 and ČSN 34 2710. ČSN 73 0875 is listing that it is obligatory to install fire alarm when,

a) according to the legal decree (legal decree NO. 23/2008 Coll.);
b) according to the legal standard for relevant buildings (legal standard ČSN 73 0802, ČSN 73 0804, ČSN 73 0831, ČSN 73 0833, ČSN 73 0845 and other legal standard from set of ČSN 7308xx);
c) according to requirement in this legal standard;
d) based on property owner requirement, operator requirements or requirements of other subjects involved in the project;
e) according to fire safety design (for example in terms of controlling other fire safety device) without needs of fire alarm requirement based in different legal standard. [8]

According to point c) of previous article there are requirements formed in this legal standard as well. Fire alarm is required when,

a) in cases where total area S of fire compartment is bigger than $S > S_{max}$ in 5. – 7. group of production and storage operations buildings. Also, if amount of random fire hazard is greater than 50 kg x m^{-2};
b) in production and non-productions fire compartments where there is according to different legal standards requirement for sprinkler system;
c) fire compartment in production and non-production operations with more occupations according to ČSN 73 0818 than 50 people with height level $h_p > 30$ m (excluding buildings group OB2 according ČSN 73 0833) assuming that area of these fire compartments is greater than 0.3 x S_{max} and at the same time random fire hazard is greater than 15 kg x m^{-2};
d) in fire compartment of production and non-production operations with area $S > 0.3$ x S_{max} which are in 3rd or lower underground floor with amount of people according to ČSN 73 0818 greater than 50, if parameter for ventilation (according to ČSN 73 0804) in fire compartment is $F_o < 0.035$ $m^{1/4}$;
e) in production and non-production fire compartments where there is not specified use of these compartments and if area of these compartments is greater than 0.3 x S_{max};[8]

Finally, there is a legal standard ČSN 34 2710 which describes fire alarms designing rules. In this standard we can find detailed description of each part of fire alarm system as well as rules where to place it and how. Most importantly, it describes how to put fire alarm into operation, what kind of testing and maintenance is required as well as service and periodic checks. Everything which is written in this legal standard is also in a line with set of standards EN 54-xx. Every part of EN 54-xx is describing different part of alarm system. Legal standard EN 54-xx was develop with an objective to have a common legal standard in fire alarms across Europe [9].

1.2.2. Fire Alarm Devices

As was mentioned above, fire alarm systems varies form very simple system with couple smoke detectors and one master box to very complex and sophisticated systems containing hundreds of detectors, master box with graphical representation of the system, with supporting master boxes, complicated wiring and many other safety devices.

In general, we can divide whole fire alarm systems into two segments. The first one is quite simple, and it is called unaddressed system. Basically, it means, that during the fire, alarm will only signal that there is a fire, but it will not indicate, where exactly in the building the fire occurs. The second one is used for more complexed buildings. The system is called addressed system. In comparison to the unaddressed system is much more sophisticated. Master box in addressed system can do much more. During a fire alarm it will clearly state in which part of the building the fire occurs.

Master box is the centre of every complex fire alarm system. Master box is responsible for evaluating different signals from many possible smoke detectors. Addressable systems with master box can control extraordinarily complex operations. Firstly, the whole system is constantly checking itself. Master box is sending signals to detectors all the time. If there is not answer from the detector the master box will detect a breakdown and person who is responsible for safety control can take necessary actions. Secondly, master box can work with many time dimensions. For example, once it receives alarm it can only alert responsible person. Responsible person can check if the alarm is valid and run full alarm. This measure can make building maintenance much cheaper due to less false alarms. Finally, it is responsible for coordinating individual fire safety devices. There are specific rules and processes on how individual devices should work together. This measure ensure that devices does not interfere each other [9].

Coupled with a mater box are the detectors. Detectors are produced in many forms. Devices varies in their time of response. There are different detecting technologies in the detectors. Detectors can be with a build in warning siren. It can be wired or wireless. Overall, there are many options of detectors to choose from. According to legal standard ČSN 34 2710 there are special ways and rules on when to use specific kind of detectors and how to place them.

There are couple ways how we can classify detectors. There are three construction differences. Firstly, there are point detectors. Point detectors usually cover dedicated area according to a producer technical sheet. It is the most used detector as they are used widely for civil building. Mostly, it uses ionization detection based on radioactive element placed in the detector. It is also possible to use optical detector, which is detecting smoke particles traveling through the heart heard of the detector. Also, there are thermal detectors based either on maximum reached temperature in the detector or the speed of temperature rise. Secondly, there are linear detectors. For the most part it is a tube with either heat sensitive vires or a sealed tube with heat expansion gas. In general, when temperature rises around the detector the wire bends and cause electric disturbance which will cause an alarm. For the gas variation expanded gas will break the tube and the pressure drop will cause the alarm. This kind of detector is often used in the big open areas. The alarm reaction is not the most sensitive one, but it is robust against false alarms. Finally, there are optical beam detectors. Beam detectors are composed of two devices and an optical beam. The basic idea is having a device on each side of the room. One emits the optical beam and the second receives it and evaluate it. When the beam is obscure the indicator will start the alarm [9].

Both master box and detectors are part of wiring systems. Nowadays there are system which run partially wireless. Usually there is a receiver which is collecting information form detectors in specific area. Detectors can be wireless. This technology is mostly used in places where additional wiring is expensive or where it can damage the interior. Receiver is usually wired to other part of the system. There are requirements on wiring and cabling as well. Slow fire, which is spreading in wiring system is quite common, dangerous and very hard to detect. Due to that there are requirements across all the legal standards which were mentioned (ČSN 73 80xx, ČSN 73 0875, ČSN 34 2710 and EN 54 – XX) for wiring placement and security [9].

Fire alarm system can contain many more devices. From one single device like transmission to local fire brigade all the way to the complex sprinkler system. Each of these devices has its own requirements and own legal standards. The most common devices appearing in fire alarm systems are voice siren, emergency lights and ventilators. Quite common devices are remote doors. Due to fire rules fire compartments need to be sealed in case of fire and hold

the fire on one place for determined time. Doors are always the week point. Especially on busy hallways it is not practical to have close doors. This problem is easily overcome by fire alarm. Fire alarm can remotely close the door in case of fire and make the fire compartments functional.

To sum up, fire alarms system can be extraordinarily complex systems with many features. Due to its complexity and responsibility for whole system of devices there are many legal standards which puts requirements and limitations on fire alarm engineers. The whole system can contain many devices from detectors and doors to the complex ventilations or sprinkle systems. For purpose of this work, it is important to identify individual devices in the system, because each device will have its own life cycle. On the top of that there is a coordination aspect between fire alarm and other systems operating the entire building.

1.3. Fire Protection Documentation

Fire protection documentation is not mandatory for every building. Fire protection documentation is mandatory only for legal or physical entities which operates with increased or high fire hazard. Fire protection documentation is collection of rules, procedures, safety activities and requirements which are obligatory for entities to follow. Fire protection documentation is regulated by law NO. 133/1985 Coll., about fire protection and in legal decree NO. 246/2001 Coll., decree about fire safety prevention. According to this decree the fire protection documentation can be produced only by fire safety technician or other professionally trained individual. Documentation is legalized by legal authorities before it can be put into operation. There must be regular revisions of the documentation. Usually documents revision takes place during regular fire inspection. Regular fire inspection takes place at least once a year. Inspection interval can be set shorter by fire safety documentation. Fire inspection is focusing on fire safety devices, fire alarm and all documentation related to building fire safety and protection. Documentation is always accessible for employees whose jobs are regulated by this documentation. Entire documentation can be put together from many parts. Sometimes the situation is not clear so authorities will ask for additional documentation above the standards written in decree about fire safety prevention. Standard documentation is built from these documents.

a) Documentation about categorizing of operations according to fire hazard
b) Validation of fire hazard
c) Stating and organization of fire protection
d) Fire rules
e) Fire alarm procedures
f) Fire evacuation plan
g) Documentation of fire intervention
h) Rules for fire alarm station
i) Documentation about staff training
j) Fire book
k) Documentation about work and ability to act of fire brigade or fire watch

Each of the documentation needs to be checked and keep up to date on regular bases. Keeping the rules set by fire protection documentation is making big difference in fire safety of entire building [3, 10, 11].

In validation of fire hazard there is a description of potential influences on the emergence of fire and its spreading. Also, it describes the risk of human harm, animal harm and potential property damage. Additionally, it contains the possibilities for fire intervention and its possible consequences. There are fire protection strategies which focus to lower probability of the fire emergences, fire spreading and its impact on human harm, animal harm and property damage. It states proposal for measures and its period for finishing [12].

Other documents as fire rules, fire alarm procedures, fire evacuation plan, documentation for fire intervention, documentation about work and ability to act of fire brigade or fire watch and rules for fire station must be prepared before to building can be put into operation. All together they have one common goal to make the building safe from fires and fires consequences. In fire rules there are descriptions of performed work and how it can potentially cause fire. It regulates employees' behaviour on the workplace, it contains potentially dangerous materials and its limited amount. Also, it regulates responsibilities of fire watch. Fire alarm procedures simply describes actions to take when fire emerges. There are listed people who are responsible for certain actions during the fire emergency and ways of announcing fire emergency to employees. Fire alarm procedures are always placed on visible point where it is accessible to everybody. Fire evacuation plan is based on fire alarm procedure. It is additional and more detailed fire alarm procedure. It focuses more on evacuation itself. It contains information about evacuation corridors, about places where people will gather after evacuation, about the way how evacuation is going to be organized and other details about evacuation process. Documentation for fire intervention has two part. One part is text which describes the object for intervention. There is information about water resources, fire safety devices and dangerous technologies in the building. It contains tactical information which are helping fire brigade to plan fire intervention with more efficiency. Also, the intervention is safer for the fire brigade when they have more information. Second part is graphical representation of the building with its water resources and places for fire brigade technology. This kind of document is created when the

building has difficult conditions for fire brigade to fight the fire and it has high fire hazard. There are also rules for fire station and documentation about the fire brigade ability to act and the fire watch. Rules for fire station are for the service of fire station. It regulates how to receive the fire alarm and what actions to take when it happens. It contains important telephone number and other contacts which has an impact on fire intervention or building fire safety. Documentation about fire brigade ability to act and fire watch regulates procedures for the fire brigade and the fire watch. It describes the obligations of the fire watch. More rules and description on fire brigade operability are in legal decree NO. 247/2001 Coll., about organization of fire brigades. There are documentations which are obligatory for the fire brigades to keep up to date like fire watch book, regular inspections, tactical procedures and documentation about training and education [3], [10], [13], [14], [15], [16].

Additionally, there are documentation about staff training and their professional preparation and the fire book. Training documentation contains education curriculum with timetable for employees and management team and records about executed trainings. Also, it contains education plan for staff responsible for regular fire watches, in house fire technicians and other employees. In general, it contains education plan with timetable and records for last trainings. Finally, there is a fire book. Fire book records everything which is happening in the building in context of fire safety and protection. There is a description of what kind of records and who is responsible for keeping the book up to date on fire rules. Fire book is quick overview of what has happened with the building fire safety and its devices. It has records about fire inspection, staff training, fire watch training, fire emerges, fire safety devices damage, documentations revisions and others. So special fire safety devices also have their special book like operation book for fire alarm [3], [10], [13], [17], [18].

In general fire protection documentation has one common goal. It helps the building to be safer in manner of fire emergencies. It lays down ground rules for working processes to lower the fire emerge probability. It describes materials which are on workplace and how dangerous it is and what is the safe limited amounts of certain materials. Also, it helps in case fire emerges. With evacuation plans and procedures it is easier to safe people. For fire brigade it provides important information about the building safety devices, potential danger, and water sources.

This combined helps to terminate fire faster with less consequences and more safety for people in the building and as well as the fire brigade.

1.4. Fire Alarm Life Cycle

In general fire alarm life cycle starts during the design phase. Fire alarm is mentioned firstly in the fire safety design. At first, fire safety engineer creates a request for the fire alarm in the building. However, the request to design and install fire alarm in the building comes from different place. The first place where the requirement for fire alarm can origin is legal standard (ČSN 73 08xx). Also, the designer has possibility to request fire alarm to lower the fire risk in the specific fire compartments. Finally, there can be special requirement made by investor, insurance company or legal authorities. In a nutshell, the life cycle starts at the very beginning of the fire safety design.

From the most general point of view the life cycle is described in the legal decree NO. 246/2001 Coll., about fire safety prevention. Most basic description of fire safety designing in general is in §5. In this paragraph one can find requirements and additional legislative documents which designers must take into count. There are also rules about coordination of the system with more than one kind of fire detection device. There are rules about construction in §6. This paragraph states that company and responsible person for constructing fire alarm must do so according to fire safety design documentation. In §7 there are most important basic rules about the life cycle itself. There are descriptions of steps, which needs to be taken before the system can be used in a real traffic. For the system itself there is a construction check. Construction is checked according to the fire alarm design. First, there is a description about what kind of tests need to be done before the fire alarm can function. More details about these tests are in legal standard ČSN 73 0875 and especially in legal standard ČSN 34 2410. Also, in this paragraph there are procedures on how to fix the system and how to change specific part of the system. Designer always follows the requirements in this legal standard, in the fire safety design and producer documentation. When the system does not pass the test, building cannot be put into operation before the error is fixed and system passes the tests. There are also some specifications for fire alarm safety devices. These specifications are written in §8. Besides standard test before fire alarm is put to operation there is a periodical testing on monthly bases for master box and its additional devices too also every six months detectors test and test for other devices which are

controlled by fire alarm system. These periods are managed by legal standards, but the designer of the fire safety device or the producer can define shorter periodical check-ups [3].

Second legal standard which adjust fire alarm life cycle is standard ČSN 73 0875. In the most part this standard is focused on requirements for alarm itself. One can find the cases and building operations where it is mandatory to have a fire alarms system. From life cycle point of view there is a description of coordination test for fire alarm system and its devices [8].

Finally, there is a legal document ČSN 34 2710. The focus of this legal standard is on fire alarm itself. There are paragraphs about documentations, designing, the test descriptions and procedures on how to act in certain situations. For this chapter it is important that there are rules for construction, operability test, passing the system from the producer to the responsible subject for building operation, maintenance, documentation and service. [9].

1.4.1. Construction

In general, the construction is aligned with approved design documentation legalized by building authority. In case, when there is any change in the design during the construction the change is approved by the designer of the system. In case of major changes, the documentation is again approved by building authority. During the construction there is extraordinarily strong surveillance on placing detectors in the right positions. Special attention is given to wiring. Wiring is crucial part of the whole system. During the construction wiring is put in placed with a great attention because this part of the system is extremely hard to check and fix after the construction is finished. Fire alarm technicians need to have a proper training and authorization before they can install fire alarm systems. After the construction is finished there are several documents submitted for approval.

a) certificate of installation;
b) electric installation report;
c) certificate of functioning or certificate of coordination test;
d) guidelines for service and maintenance each part of the fire alarm system;
e) warranty card;
f) certificate of service staff training;

g) completed drawing design documentation of real status with fire alarm block scheme;
h) ready to use operation book;

1.4.2. Put into Service Test

After the installation process there are complex checks and tests before the system can be run during the regular traffic. Before the testing of the whole system can take place there must be checks of the specific parts of the system. Checking a wiring as was mention in previous chapter is done by legal standards ČSN 33 2000-6 and ČSN 33 1500. These standards are about checking process and electric wiring regulations. Details are not particularly important for topic of this work. However, important is that electrical wiring checks is a first step in the testing process. There are also couple more checks which are mandatory [9].

Firstly, responsible technician who did the installation, do the visual check to make sure that everything is according to standardize process and documentation. Next, he makes sure that installed devices work correctly. Major focus in terms of functionality is given to,

a) smoke detectors and button alarms;
b) information given by master box are correct and it is corresponding with fire safety solution;
c) entire connections with fire alarm station or station for receiving and false reports are functional, and reports are correct and clear;
d) all the functionality is active and signalized properly;
e) all required documents and guidelines are prepared and available;
f) fire alarm system is meeting all fire safety functionalities (in the meaning of functional tests);

As a part of finalizing the test and check there is a document which must be filled and sign to confirm that the test was finished, and was successful [9], [19].

In a case, fire alarm system has sub-systems and additional devices it is mandatory to do coordination test. Coordination test is making sure that each individual device will not disrupt any other part of the system. For example, sprinkler systems, cannot be turn on before the people

leave the impacted area. In the other words there is some delay which will give people time to leave specific area before the sprinkler will start pouring water. This delay time is ensured by the fire alarm system. During these tests, technicians make sure that testing signals will not do any accidental damage. It is necessary to avoid any accidental release of water or other extinguishing medium [9], [19].

1.4.3. Evaluations and System Receiving

Before putting a fire alarm system into full traffic there is a trial period. During that period system is very closely monitored for any suspicious behaviour. There are several steps to pass the system from its producer to building operation staff.

a) verification about having all necessary documents according to legal standard ČSN 34 2710, including operation book for fire alarm system and all other controlled devices;
b) perform a visual check including all test results, which can be done. Making sure to evaluate that system matches the specifications;
c) random checks of correct function behaviour; [9]

1.4.4. Final Authorization

Fire alarm system is evaluated as finished and ready for use not before there is a legal verification from building authority. In the process there can be a third party which can have a specific requirement for testing. It can be an investor, insurance company, building operation company etc. Below there is a list of documents which needs to be available and ready for evaluation.

a) proof of compatibility assessment of system components;
b) evaluated design documentation for building permit or actual executed installation documents;
c) certificate of fire alarm system installation;
d) certification of functioning test or coordination test;
e) certificate of default revision and revision of fire alarm system;
f) approved of remote transmitter system (if it is included in fire alarm system);
g) documentation from producer or distributor including fire alarm operation book;

h) certification requested by authorized organization (declaration of conformity, certification protocols etc.) [9]

1.4.5. Operations

Operation is mostly about responsibilities and documents. Responsibility in general for fire alarm system will be discussed in the last chapter of this part of work. In this paragraph the responsibility in manners of operation stuff is covered. There is always a responsible person or even more people, which are responsible for the system. Their main responsibility is to use the fire alarm system in the way it was designed. Operation stuff do not have any authority to change or develop the system in any way. Although one of the responsibilities is also to keep the system in the working conditions. Operation stuff have set of procedures on how to act during different kind of alarms, warnings and any other events indicated by the system. Also, they are trained to operate the main box. Responsible staff are making sure that there are not any obstacles blocking potential smoke from detectors. Another responsibility is to keep the fire alarm operation book up to date. In this book is written every major event which includes fire alarm system. In the operation book the staff keeps track of every finished tests, controls, revisions, services, and maintenance of the system. Staff is required to provide a service in given interval period by legal standard or system producer. In case of a failure the responsibility is to contact a service company and fix the problem as soon as possible [9].

1.4.6. Maintenance

To ensure that the fire alarm is functioning properly regular checks and service is necessary. There must be a legal contract between a building operations and fire alarm system producers about staff training, service, repairs, and maintenance. This contract must be specific in the way that it allows producer company to have an open access to the building when dealing with possible problems. Quick contact is always available for fire safety alarm staff [9].

Operation checks are done in regularly according to the legislation and producer documentation. Operability checks are done once a year according to legislation. This process is the same as mentioned in previous chapters. Next to the regular operability checks there are also other more frequent ones.

a) Once a month there is a functionality check for the master box and its complementary devices.
b) Every six months there is a functionality check of fire detectors and other devices which are controlled by the fire alarm system.

Operation checks are executed by authorized technician and the test is described in operation check document. This document contains:

a) company information, name, address of the provider of fire safety solution and identification number;
b) building address where the operation test was executed if it is not the same as in point a);
c) placement, type, producer name, labelling type, identification number if it is needed for specific identification of the device;
d) result of the operation test check, detected issues including a way and time of elimination and the result of operation test;
e) date of the test and date of the next one;
f) and certification according to legal standards;

If there are any plans for changes in the system these are announced to the owner with the time limit to execute these changes. During the prevention tests technicians are making sure that there are no accidental water releases or releases of different type of extinguishing medium.

During the life cycle there are events which will force owners to do service and the whole cycle of system testing again. These events are clearly listed in legal standard ČSN 34 2710.

a) any kind of fire;
b) any unusual kind of false alarm;
c) expansion, change or building adjustment;
d) changes in use of the building;
e) changes in the volume level in the area which can affect sound alarm;
f) any kind of change in controlled or complementary devices;

g) sudden system activation before finishing construction of the building and passing it on the staff responsible for building operation; [9]

1.4.7. Changes or System Extension

Changing anything in the functional system is not a simple process. Operation staff is not allowed to do any changes to the system. In the general, system changes are in line with approved fire system design documentation. In case of any changes are being made in the system, there is a general rule which applies every time. The changes to the system cannot make the fire system less secure. There is a possibility to change detectors, but those detectors must provide better or at least the same level of security as the old detectors [9].

1.4.8. Responsibility

In the last sub chapter about the fire alarm system, it is necessary to at least touch upon the topic of responsibility during the life cycle. In the first place there is always a fire safety engineer or technician who is designing the system and putting together all the necessary documentation for construction process. These people must have a legal certificate issued by responsible authorities for this specialized area of expertise. In general, it is safe to say that designer is responsible for the design documentation. It is his or her responsibility to follow every legal requirements and measures. After designing phase there is the construction. Construction is done by companies or technicians who are professionally train for this particular job. During a construction they must strictly follow the design documents. When the construction is finished, the system is checked whether it corresponds with the design. So, during the constructions the company and their technicians are responsible for the quality of work. There are also the producers of the devices themselves which are responsible for the quality of the product. In the field of fire safety solutions, it is quite common that the company, which constructs the fire alarm is also the producer of the devices. After the construction and after all the tests are finished then the fire alarm is passed to the responsible staff. The building operation company takes over the responsibility. Their responsibility is to make sure that they are using the fire alarm in the way it was designed. They are keeping necessary documents like an operation book or a fire book. In case of an accident the investigation starts. Looking for a party or person who is responsible. The

investigators will take each part of responsibility chain and check if the job was done properly according to laws and legal standards [9].

To sum up, the life cycle in fire alarms system is complex and complicated. There are many documents, tests and checks which must be finished before the fire alarm can be used properly. This layer of protection is understandable because fire alarm system is the building crucial line of defence against fire. If the fire alarm fails, there is a big probability that other safety devices will fail as well, and the damage from fire will be much greater.

1.5. Electronic Documents for Fire Safety Devices

As was mentioned many times the fire solution system design is needed during the whole life cycle of the building. For each part of fire safety product there is a warranty certificate. Each product is tested according to the product testing legal standards. Legal standards describe process on how to test these products. Very same situation occurs with fire safety devices. Fire safety devices is tested according to legal standards and it gets a certificate of functioning. Process from design to functioning fire alarm is long and it requires many device certificates, tests, and checks. Due to this complex process and occurring problems with recurrent work with document filling the main fire department, the standardize documents are being prepared electronically [20].

In the core of the electronic documents are web-based applications based on simple idea. Online application will speed up work for many people, it will avoid many accidental mistakes made by human error and it will speed up the logistical process of sending the documents for approval. In general, it is a kind of 'fire card' for a building. In the system there are all information about devices which were used with certification to every device. There are all checks and tests which were made before the system was put to operation. Above all that it contains information about checking period of every devices. Due to this simple aggregation and utilizations of documents it is much easier for building operations and fire department to cooperate and find many errors in the systems before it can cause any damage. Since the documents are all together and the application can check if some certificates are not done properly it contributes to increased buildings fire safety [20].

The application is open for every person who is responsible for any part of fire solution system. Suppliers can have their product listed in the application with verified certificates. This fact helps designers with choosing the right devices for the whole system. For building operations, it is much easier to collect necessary documents for the devices because all the documents are united and stored at one place. It is very easy for fire department to provide feedback on the documents. The applications can also report many errors by itself and errors

which are found by the fire department are handled to the provider instantly with no logistic delays [20].

1.5.1. Fire Alarm Documents

Below is a list of test documentation which is needed to put fire alarm system into work as well as documents needed to maintain the fire alarm system.

a) installation certificate of fire safety device;
b) electric installation report;
c) certificate for responsible technician to install fire safety devices;
d) certificate of functional test for fire safety device;
e) warranty card for each device;
f) declaration of conformity;
g) certificate of operability for fire safety device including coordination test;
h) certificate of functional test for fire safety device;
i) certificate of service staff training;
j) guidelines for service and maintenance each part of the fire alarm system;
k) ready to use operation book; [9]

1.5.2. Uniform Documents

Model of uniforms electronic documents were made by main fire department in cooperation with the Czech Ministry of Internal Affairs and Administration. Modelled documents are listed below:

a) installation certificate of fire safety devices;
b) certificate for responsible technician to install fire safety devices;
c) certificate of operability for a fire safety device;
d) certificate of functional test for a fire safety device;
e) certificate confirms required a fire safety device property;
f) declaration of conformity of a product property;
g) declaration of conformity;
h) certificate of fire extinguishers placement

i) certificate of overall functional test and operability test of all fire safety devices according to the design. [21]

Uniform documents are big step forward to simplify the whole design and testing process. Making this process electronical is an additional step which made it even easier and faster. Since the documents are now unified and electronic, they can be used even for fire alarm process from design all the way to operations, maintenance, service, and system development. As we can see from listed documents above, most of the documents needed for fire alarm system are already included in electronic application documents. Although there are improvements which can be made. For example, having electronic operation book can be a benefit for operation staff which can make entries fast and fire department can have instant access to them and check important buildings on regular basis. There is even a potential for the system to be more automatic. Simple error entry with specific device application can find a producer and automatically contact him with a service request.

1.6. Standard Way of Fire Alarm Design

Standard way of alarm designing and building designs in general is with paper documentation and standard 2D drawings. Drawings are either done by hand or with a help of software (2D CAD etc.). This approach has many advantages, but also some great disadvantages.

1.6.1. Advantages

Using standard method of designing which was describe about is generally good enough with smaller and not complicated projects. Designer can do only specific drawing they need to finish the project. In general, there is no need to do 3D model of the building when working on a small family home. Designers will draw each discipline separately and since the project is not overly complicated there will be an easy communication between engineers and there will be no errors due to lack of discipline coordination. In this kind of method all information is contented in drawings by tables, dimensions, and hatches. Description of construction process is described in technical report. Another advantage is that the software which is much more accessible and affordable than software working with BIM technology.

1.6.2. Disadvantages

Building projects which are taking longer time and are more complex will often run into quite common following situation. Investor wants some changes to the design. When this happens the team of designers and engineers is in a tight spot. Firstly, engineers must do the change. In multiple level building even a slight change to the windows position can take couple hours to fix. Fix must be done on every drawing and there is no logical relationship between the drawings, so fixes are made by hand in each separate drawing. When the fix is finished, engineers from other disciplines must check if the change has any influence over their discipline and the chain continue. In a complicated project this can be very time consuming and can cost a lot of money. In a nutshell the hard part of standard design process is coordination. Each discipline is making their own project documentation with little knowledge what is going on in disciplines which can be closely related. It is complicated to keep every discipline up to date with current version of documentation. Collisions, data lost and lack of last versions of documentations are almost unavoidable. Another difficulty is that the standard design process is counting only with

designing phase and construction. Life cycle of the building is much longer than that. There is operation, maintenance, renovation, and demolition. Specially for operation phase it is important to have the last version of documentation, which can be extremely hard to obtain since there are usually several versions of documentation.

To sum up, standard way of documentation still has its place in civil engineering industry, but it is getting less common. In the future the standard way of designing will play smaller and smaller role. It has more disadvantages than advantages and in a long run it is more expensive. If civil engineering industry wants to able to compete with other industries, it needs to increase work productivity rapidly. Design phase must take much shorter time, construction coordination must be clear, and we have to consider entire building lifetime cycle from the very beginning of the project to its very end.

1.7. Building Information Model

With the growth of global technology network and internet there are new opportunities also for the civil engineering industry. There are signs that standard way of designing is slowly drifting away and there will be totally new way of thinking about construction. During last couple of years new working technology called BIM entered the market which has looked like a huge step from standard design process. And lately really BIM (Building Information Modelling) is on the rise among new projects. It is particularly important to know and understand that the concept of BIM is far more than just 3D model of a building. Yes, for building designer the 3D model visual representation of his work is very important aspect for the result of his/her work. But it is better to think about this concept not as a model but as a central database with information about the building. One can demonstrate the advantage on an example of a building designer. In more complex and complicated designs there are many different designers. Each of the designer is working on different part of the building. Thanks to centralized model everybody can work on the same model and see the progress made since their last change. Another common miss understanding about this technology is that it is only for buildings. BIM can be used for variety of constructions from houses to roads all the way to detailed assembly line of modern factory. The centre of this technology is database with everything connected to the project. From the very begging, when designing the first concepts, every detailed is stored in the database. Over the building life cycle every stage is clear and in one place. Every involved subject is using BIM database to store their data, designs and documentation. It is much easier to have an overview of the documentation and design phases thanks to this approach. Having a centralized building model has even more advantages. With detailed building model engineers can run series of different analysis like dynamic building movement, the impact of the object on the environment, building certification, CO2 impact and many more [22], [23], [24].

With the exploration of the new term Industry 4.0. there will be even bigger demand of BIM technologies and entire environment of supporting software. Connected to the general term Industry 4.0. the new term has emerged recently, Construction 4.0. Currently the civil engineering industry is the least digitized industry of all. Since the work production and development in civil engineering field is growing terribly slow, there is a great potential that BIM

can help with this significantly. However, growth of the civil engineering industry is very slow to various reasons. One of those reasons is a great complexity of the buildings. Much more technologies are now running new buildings than it was a case ten years ago. Thanks to IoT industry, more complex electronics there is a great potential for development. Also, there are many regulations from the government including safety standards, environmental standards and logistic standards which are making developing big project even more challenging [25].

There three main key gains when using BIM technology. It is coordination, communication, and collaboration. Coordination is widely discussed during the design phase of the process. When there is only one main model on which all the designers are working on, it is easy to resolve potential issues. In a field of MEP (mechanical, electrical and plumbing) engineering field errors can occur very easily. Pluming, electricity, and other disciplines are running through the entire building. With the main model every designer is working at the same time and can see potential clashes. Central model is putting all the information at one place. Designer do not have to send updated designs to the entire team. Team members can see the progress immediately and built on the progress. In this scheme the communication aspect of managing the building design become much easier. In the majority of cases, there are many subject working on the design, construction and the maintenance. Collaboration between those external subjects is the key for successful project and due to the central database, it becomes much easier. External subjects are usually using different software. That used to cause many problems and many mistakes which take time and money to fix. Overall one can see that with BIM there is a positive development in the right direction [26].

As was said before BIM is not a software. It is more of a designing process which using central information database. To make the whole system work there must be some standards in accessing the information from database, naming convention and processes. There is standard format IFC (Industry Foundation Classes) which is now spreading internationally to help with this process. IFC is carrying all the necessary information about the building model. It has information about geometry and object information. In collaboration with this format there is a standardize data dictionary. This dictionary is carrying all the information about terminology, entities, properties, and classification. The information is particularly important for software collaboration

and for new software development. This is key for successful BIM coordination. There is a library following these standards with Czech localization called Standardized Non-graphic Information of 3D Model (SNIM). It collects information about building elements and its properties used in BIM. This database is under development and for now it is focusing only on building construction [27], [23], [28].

1.7.1. BIM for Building Life Cycle

In general, it is necessary to look at the bigger picture during the building design, in order to see the advantages of BIM. To run a successful BIM design which will make sense for the investor, design team and the building operations, we need to think about the project from the

view of building's entire life cycle. Each project during its existence will go through each phase in the cycle.

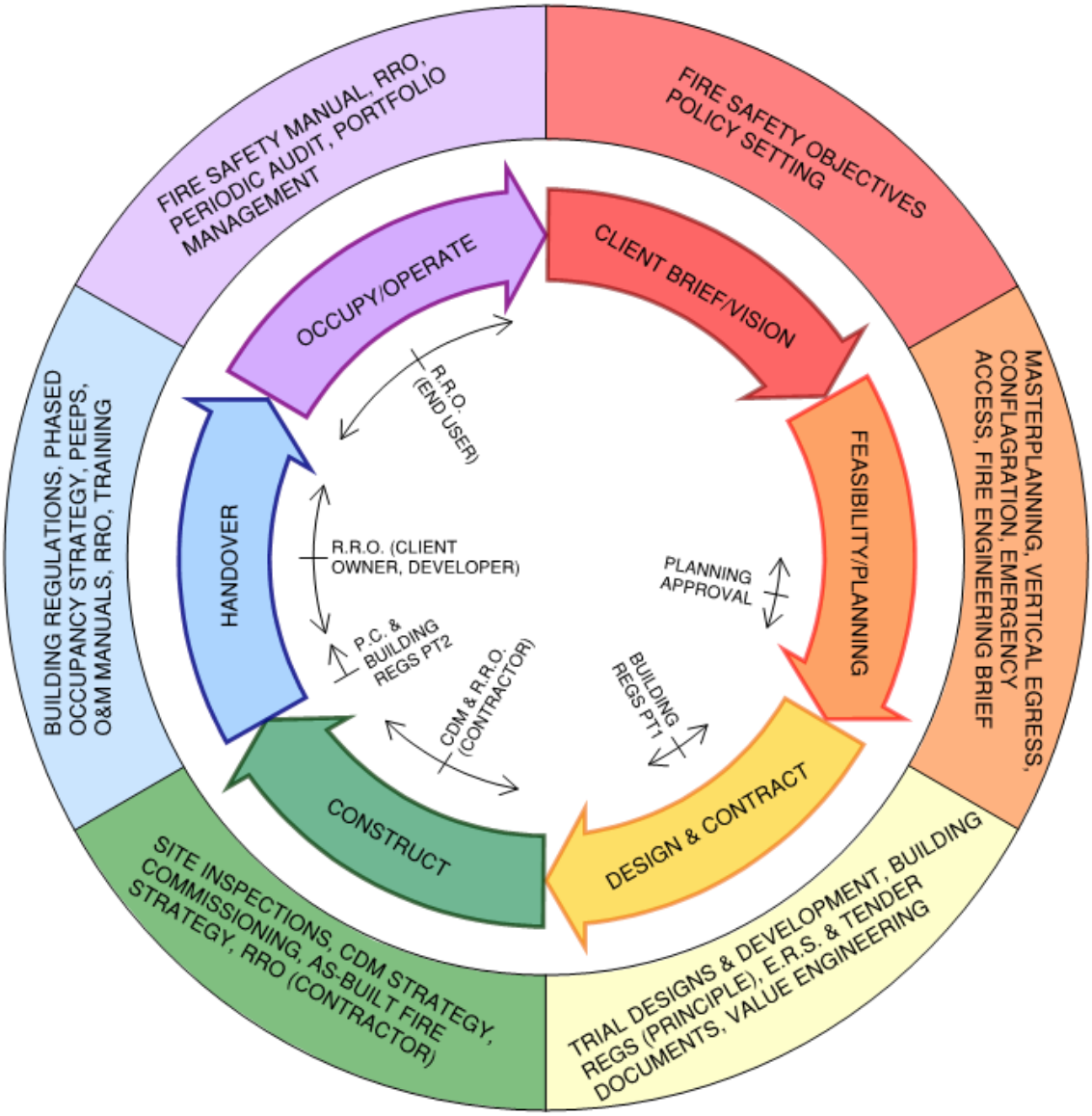


Figure 1 – Building life cycle representation [24]

The design phase is the most difficult and the most time-consuming phase during the project when using BIM technology. It is due to its demands on engineering know-how, software and collaboration since each involved subject should use BIM otherwise the whole idea of BIM is losing its advantages. Also, modelling complex building is complicated so the design is usually more costly when using BIM than the standard design process. Having a central model pays off

in a long run during other phases of the building life cycle. It all starts in planning and construction. Construction planning is much easier since managers can have a visual representation of the building. With the visual orientation it is easier to see the construction context. Also, construction companies can gain from using BIM more and have much more accurate prefabrication. Prefabrication usually speed up the construction process. After the construction is done there is an operation and maintenance phase. Building manager is using central model with its updated information for planning service and reconstruction work. Authorities can use the central database to access updated documentation to make periodical inspections. In case of the demolition phase central model is useful for information about construction, types and geometry [29].

In fire safety solution BIM has great potential. Many errors can be avoided with automatic calculations and warnings. Model can be used during entire building life cycle. During the design phase, during an evaluation of real status and during a periodical inspection of fire safety devices. Shared documentation between building operation subject, fire department and service company can have a positive impact on building safety. Many errors can be avoided. Detailed model can be extremely useful during a fire intervention. Fire brigade commander can have clear visual representation of the building with all information he might need including information about position and amount of safety devices, main gas shut-off valve, master box the fire brigade respond can carry on with much more precision and speed then before. Those little details can make a great difference in a real-life fire situation.

1.7.2. Information Modelling in the World

In last couple of years, there has been very steep development in BIM implementation on the country level. Main change occurs in a software development which can take advantage of BIM technology. On the international level there exists a leading organization called buildingSMART. This organization is promoting digitization of building industry in the word. They are behind project called openBIM which is helping to digitized the industry and help with collaboration across the entire industry [29].

First country who has started cooperating with building industry on BIM level is Finland. Since 2001, Finland is working on integration BIM modelling into civil order projects. The government demands to have BIM solution in every public procurement placed order with using standard IFC format. The reason behind this decision are advantages connected with having design in BIM. Finns specially focused on building time management and money cost in maintaining public buildings. In 2007 the authorities in cooperation with many companies, cities and developers published first document which standardized BIM designing in the country. Between years 2016 and 2018 progress continued to the road construction [23].

There are many great examples of countries in Europe which are integrating BIM to their processes very effectively. Norway was also one the first countries which started integrating BIM. The demand was similar. BIM help government to reduce cost and work effort in maintaining public buildings. In Norway there is particularly good position for BIM because not only government, but also a private sector is pushing hard for implementing BIM. They are using BIM even for smaller projects and even smaller companies emphasizes advantages of this technology [23], [28].

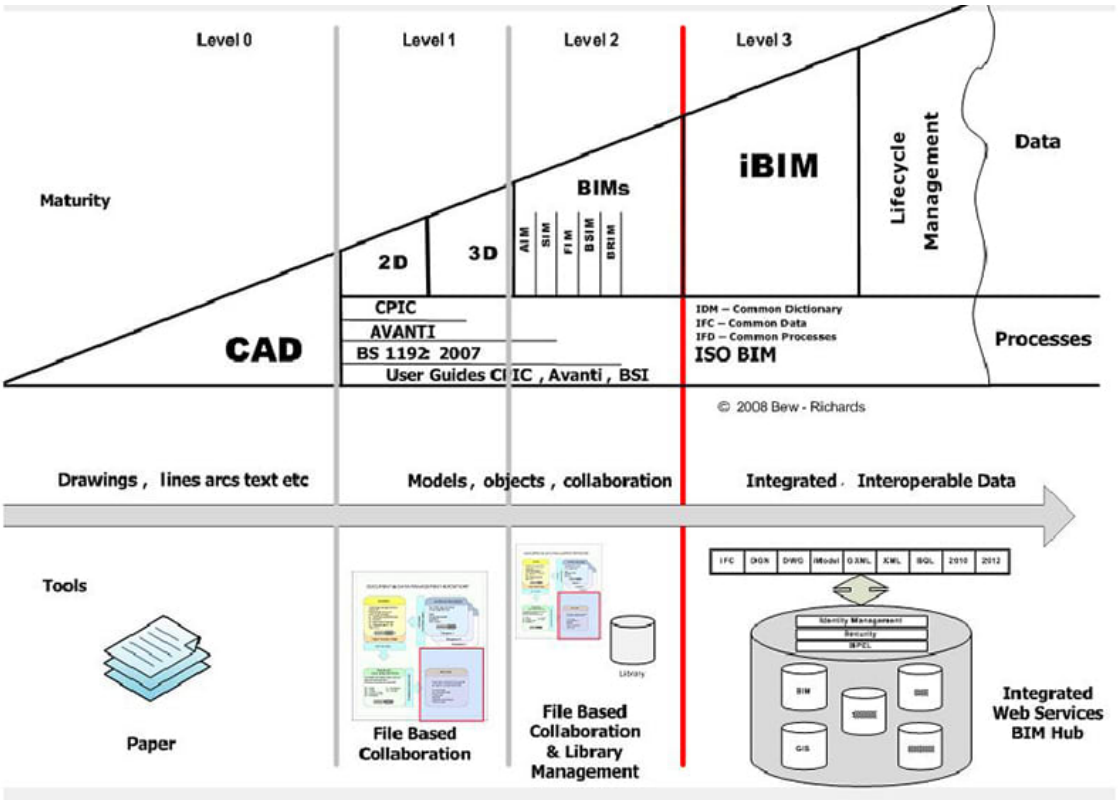


Figure 2 – Representation of BIM complexity [30]

Other countries with BIM program are UK, Netherlands, Denmark, France and Germany. The most interesting are Germany and Denmark. Both of those countries are seeing biggest potential in public procurement. They are aiming for much more transparent system of public procurement. There is a potential to have more precise public procurements in terms of cost, efficiency and speed of the whole construction. In Denmark there are clearly written criteria when BIM is a must for certain project. Those criteria are based on the estimated cost of the construction and share of involved state investments [23], [28].

In every country there is a common procedure. There is always a government organization which is working to implement BIM into the infrastructure as efficiently as possible. In Finland it is Senaatti, in Norway it is StattsBygg and in the Czech Republic it is Odborná rada pro BIM (czBIM). All of these organizations are setting the rules when it is necessary to use BIM technology, creating technological standards for designs and educating commercial sphere about BIM technology and its advantages [23], [28].

1.7.3. Information Modelling in Czech Republic

As in the other parts of the world there is a progress made in BIM solutions in Czech Republic as well. The greatest deal on this progress is thanks to the organization called Odborná rada pro BIM (czBIM). Odborná rada pro BIM was established in 2011. This organization is working with international organization buildingSMART and was able to bring openBIM program into the Czech Republic. OpenBim is a program which offers open and available standards for BIM software. With opneBIM companies can evaluate and get certification that their BIM solution is according to the international standards and that it will cooperate with other BIM software. This platform is addressing needs of building designers, suppliers, investors and other stakeholders. Odborná rada pro BIM is also working on their own activities including legislative standards and project of Standardization non-graphic information of 3D model [25], [31].

In 2017 Czech government accepted a legal bill about Conceptual implementation of BIM technologies in the Czech Republic. The plan was prepared by the Czech Ministry of Industry and Trade as they have supervisory position on implementing BIM technologies. The main goal is to start looking on building projects from bigger perspective. Using BIM usually means higher cost for building design, because using BIM is more demanding on designer's know- how, but in a long run it lowers the cost. It is important to look on the building entire life cycle. There are expectations of high expenses from first visualizations until the deconstruction and even that BIM will higher the cost in the design process. However, it will actually make the building cheaper and faster to build during construction. During a maintenance phase the cost will be also lower due to the fact, that all necessary information is on the same place and easily accessible. In the conceptual documents it is stated that the biggest challenge we are facing is a lack of knowledge and education system about BIM. There is also a problem with lack of standards which would help to connect software and work across the building life cycle. Until 2017 BIM was used occasionally in the projects. Mostly it was used only partially during at the building life cycle so the potential benefit for BIM was not fully discovered. The year 2022 will be key year for the Czech Republic. By that year public procurement of certain value will have to use BIM for documentation and for construction if the one of the stakeholders is the state [25].

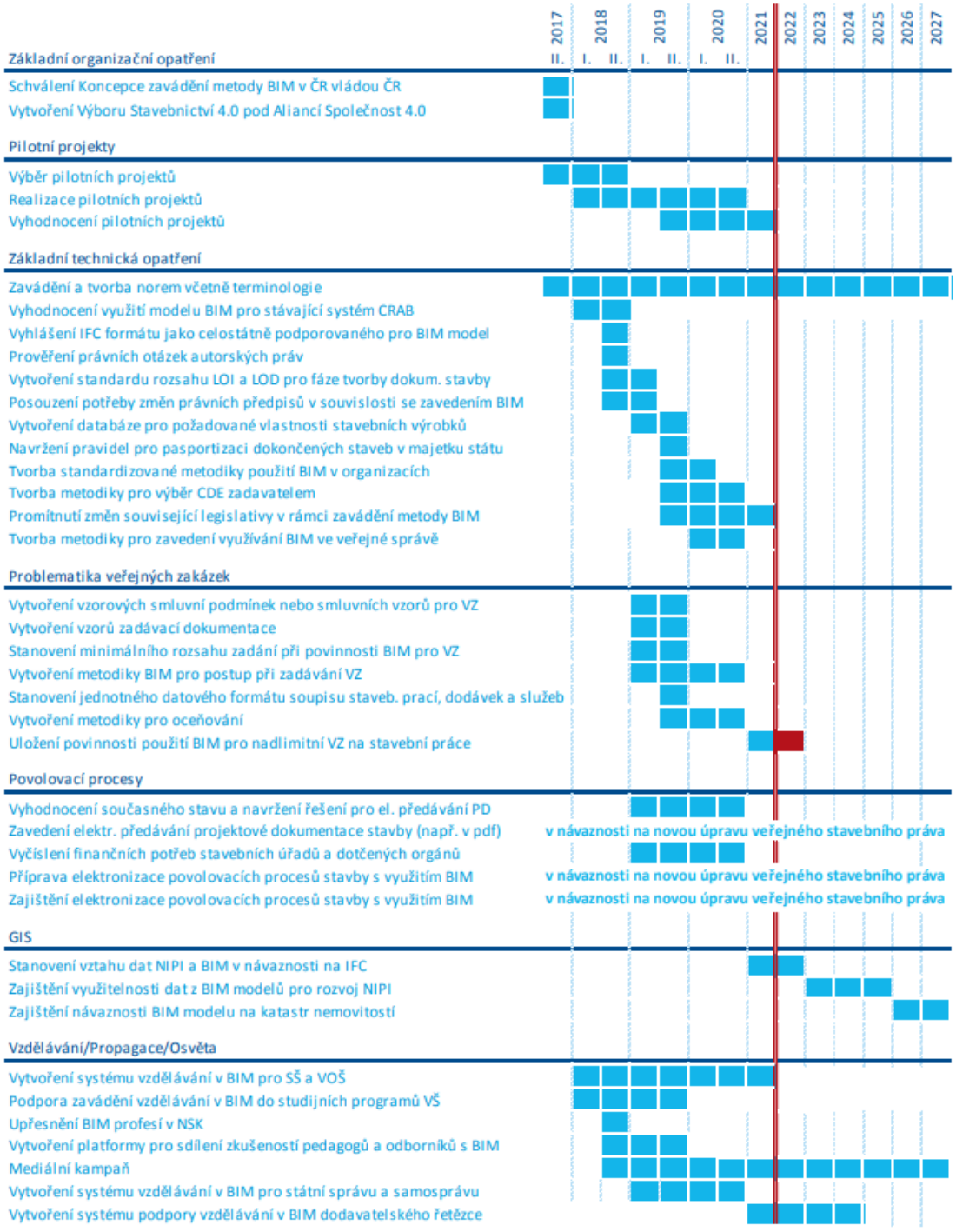


Figure 3 – Strategy for BIM implementation

1.7.4. BIM for Fire Alarm Solution

In general BIM can be extremely useful for fire design solution from the start of design phase all the way to the building demolition. Fire safety engineer can use clear information from building model, automatic calculations and control from BIM software. For example, software

can count fire risk for each room or check if the fire compartments designed by designer are not too big.

There is also great potential for fire alarm designers as well. In general fire safety solution fire alarm design also starts in design phase of the building and terminates during the building demolition. During the designing BIM model is of significant help for the designer. Visual representation of the building helps designer to place the right amount of fire safety devices and at the right places. Specially for alarm system design when the system is drafted, software can automatically assign network addresses to the devices, calculate voltage drops and prepare a battery calculation. Placing devices themselves is a needle picking job which can take hours or even days. With detailed building design this can be done automatically. Wiring can also be difficult to perform without the knowledge of plumbing and wiring placement. Resolving errors and clash detection is much easier with central model and visual representation. And it does not end with the design. After the construction is finished there is a testing phase. Each system is going through series of tests to evaluate its functionality. For fire alarm and other fire safety devices regular inspections and check-ups are scheduled. Software can easily alert operation staff that the inspection is coming soon, so they can prepare the necessary documentation. Service of this system can be much easier as well. Company responsible for service can have access to the building model and can see the needed fix without physical inspection on the building site. This is saving unnecessary trip for technicians [32].

1.7.5. Pros

The advantages are truly clear and there are many of them. Most of them were described already above. This process is different from the standard process in the general usage and information workflow. It strongly builds on cooperation, communication, and collaboration. Architect can share the building model already in the first design phase with structural engineers and building engineers. In a later stage where the model needs more details the multiple discipline engineers will get into process and work on electricity and pluming. During all these stages the fire protection engineer is overlooking the design and fixing potential errors. From investor point of view there are also running analysis for environment causes, timetables and

financial aspect of the whole project. The best way how to describe cooperation on the project among different disciplines is on the picture below.

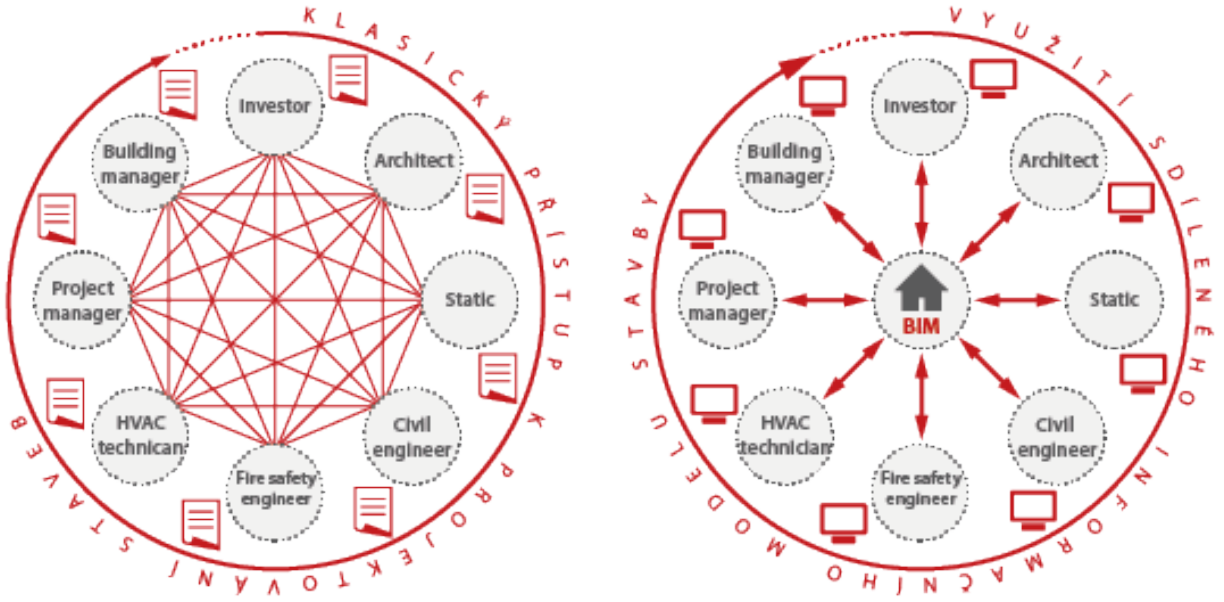


Figure 4 – Difference in communication with BIM and with standard design process [33]

The complexity of communication and cooperation during the building life cycle is very clearly demonstrated. The central model is also carrying information about each material, component, and its cost. Also, with visual representation it is easier to do time planning for the construction. This process sounds perfect in a theory, but there are some major obstacles which needs to be overcome in the future.

1.7.6. Cons

With many theoretical and practical advantages there are also many disadvantages. The transition from standard design process and BIM design process can be long, can cost a lot money and can be accepted badly across the designing team. To start with BIM software is usually more expensive than standard drawing software. To finish, complete BIM solution, there is a need to use more kind of specific software because there is not a perfect software for every kind of work. BIM solution is demanding on the designing team as well. It requires complete change of thinking about the building design. After many years designing in certain way there is often lack of will to change the standard procedure. There is also lack of education in field of BIM. Only recently the

university level educational institutions have started putting BIM technologies into their curriculums.

The other problem is private know how. Companies have their products, libraries, and principles private. It cost them great effort and money to develop this private know-how. With central model system all the know-how is shared. It is understandable that there is a scepticism on their side.

Sharing knowledge is one thing but also having a properly working and operational software is a challenge. There is also big challenge in cooperation software between dominant companies like Autodesk, BuildingSMART or Archibus. Software is usually compatible only with other software, which is made by the same company. It is therefore hard for companies, which are cooperating on the design to find a proper software to work with. Without collaborating software BIM is losing its advantage and it becomes a burden. Also, this can lead to dominant position on the market for couple companies which will make their software compatible only within its own software products. The only way to make the cooperation better is to use format IFC and openBIM standards. Unfortunately, also the IFC format is not the best deal. Data are often lost when exporting a model in to IFC format. After loading it to another software the original model is hard or impossible to edit. In the usual scenario IFC format can carry only information about geometry, but not the information about the elements and relations. Without solving this problem, using BIM across multiple platforms is losing its advantage.

There are the legislative problems as well. Most of the countries have different approach to building design and constructions. These are based deeply in history, cultural customs and available resources. There were attempts to create general legislative standards across the EU but so far, we are still in the beginning of a long process [23], [25].

To conclude as with anything in the world, there are advantages and disadvantages to BIM technology as well. Right now, we are still in the beginning, but there is a great potential in BIM. With better collaboration in the software, among designers and constructers we can make civil industry better competitor in rapidly digitalized industry. Without greater involvement of technology in civil engineering, the industry will not be able to compete on the market.

BIM models are carrying more information about the building than standard electronic drawing. There is a completely different approach in thinking about building design than standard process. Central building model is better for cooperation, communication, and collaboration between all the subject involved in the process. Model is also carrying information about the stages which come when the design is finished. It helps to plan the construction stage, to count construction cost with more accuracy and to count the time estimation for constructions. During the operation phase it serves a great deal to the subject who is maintaining the building. Overall, it provides more complex overview of the entire building life cycle.

2. Objectives

The main objective of this work is to prepare a conceptual scheme and design process for fire safety solution in building information model with the focus on fire alarm system, its design automation and maintenance.

Partial goal is to give a detailed and complex summary for topics of fire safety solution, fire alarm design and its legislation, fire protection documentation, uniform certificates for fire safety devices and overview of building information modeling and its development.

The next part of this work will showcase a solution scheme in flowcharts and its application for automation in a design tool.

Software will be developed for practical part. It will simulate fire alarm life cycle. During the design phase it will present algorithm which will help designer with fire detectors placement. During rest of the life cycle, software will simulate events which trigger fire alarm and simulate document and records management for both fire alarm and fire protection documentation.

3. Fire Alarm System in Building Information Model

3.1. Fire Safety in Building Life Cycle

Each building goes through life cycle which starts with the first idea about a construction of a building all the way to its demolition. During the entire way we can use centralized building information model with its database. When there is a central space where to store and maintain all the documentation it is much easier for people working on the project to share information and cooperate better. Since building model in not some simple drawing there is a potential for new tools which can help designers during the designing phase of the building.

From the fire design point of view the centralized database can be also used during the entire building life cycle. Building information model can be particularly useful for determination of fire risk, evaluating dimensions of fire compartments or calculating a fire safety space around the building. There is already a plug-in with this functionality made for Revit software. Plug-in BIMfire was design according to the Czech legislation to help fire safety engineers with designing process. This software can calculate fire safety distance, evaluate evacuation times or determinate fire risk in fire compartment. Additionally, it has fire devices components build in which can be used for further works when placing it to the model.

During a building operation phase building information model can be used for storing and maintaining necessary documentation. Having up to date documentation is crucial for building management. During the building life cycle there are regular revisions and not only for fire safety devices. Staff needs regular training. Fire safety procedures needs to be kept fresh and up to date. It is a lot of documentation, certification and reports to maintain. With a proper software and BIM model there is a big potential for process automation which will results in fewer cost for a building operation, better building fire safety and easier operation process in general.

In case of emergency units like fire brigade, rescuers or police can use detailed documentation. Detailed model of building can help those teams to prepare tactic plans before they even arrive to the building. This is especially useful for bigger and more complicated buildings. Key information for the planning can be store inside a building model. Building model can highlight fire safety devices, evacuations corridors or dangerous areas of the building. Having

more information can safe valuable time during the intervention and also make the whole process safer for emergency teams.

3.2. Fire Alarm Design Flow Chart

Fire alarm is a part of fire safety solution. Since most of the requirements for fire alarm are based and set-in fire safety design, job of fire alarm designer is to work with the alarm itself. Key for a good fire alarm design is to have clear goal on what fire alarm should do in the building and what role it is going to play. This clear vision and goal are of a key importance for good system design. Fire alarm can be quite simple with master box, siren and couple detectors and it will work perfectly for small apartment building. But on the other side there are large systems which are controlling key devices for fire safety especially in production buildings like factories. Fire alarm is playing its role during the entire life cycle. Flow chart below on Figure 5 is focused on the fire alarm life cycle.

The goal of the flow chart below is to show how the fire alarm is developing and operating during a building life cycle. As we can see in the flow chart fire alarm design has some specific documentation. In the flow chart there are highlighted sections which are developed into software concept later in this work. In the flow chart there is a fire alarm in phase of installation when most of the necessary documents are created by construction company. Those documents are then check by building operation staff and when all revisions and first tests are approved the fire alarm is taken into the operations. From this point all events are divided into two segments. First segment is about regular events. Regular events are events which are planned in advanced. For fire alarm it means mostly regular revisions of its devices. Once a year operability revision with fire inspection, once in six months revision of fire detectors and other devices which are controlled by fire alarm. Once a month also master box revision with additional device working alongside the master box. These are the most visible and common regular events. Regular events which are less visible but can also be included in building database are emergency and operation procedure which needs to be done be operation staff and operation staff training program. Both of those are also part for fire alarm life cycle and needs to be done on regular bases. Simple reminder to operation company about regular revision, documentation updates and staff training can make the building safer and can reduce a cost of running the building.

Secondly, there are irregular events. Events which can occur on any day and operation staff needs to have proper knowledge and tools to handle those evets. Irregular events can vary from a small system damage to a fire emergency or it can be some change in the use of the building. During smaller irregular events like change of the acoustic environment (warning siren needs to be adjusted) is usually enough to call service company. Service company will do the necessary fix (and proceed the operability test). This is another area where automation can be made. System can determinate which devices are damaged, how many devices are needed and where devices can be found. The software can call service company with those details. With that the service company will save time to examine what is needed for the service. When the irregular events occur, there is an obligation to update a fire alarm operation book (fire book if it is obligatory to have it). Updates needs to be made after the adjustments are finished as well. Fire emergency is specifically listed in legal standard ČSN 34 2710 as event after which the service is mandatory. Service company needs to check devices expose to the fire and check their functionality. Same procedures can be automated same as in case of system damage [9].

Little bit more complicated process occurs during the change of use of the building. Even though this does not happen often it can arise during a building life cycle. During the change in the use of the building there is a need to design new fire safety solution. New fire safety solution can have different requirements on the fire alarm which will put fire alarm at the very beginning of the entire design process. During these situations it is obligatory again to take the necessary steps to put fire safety alarm into operation.

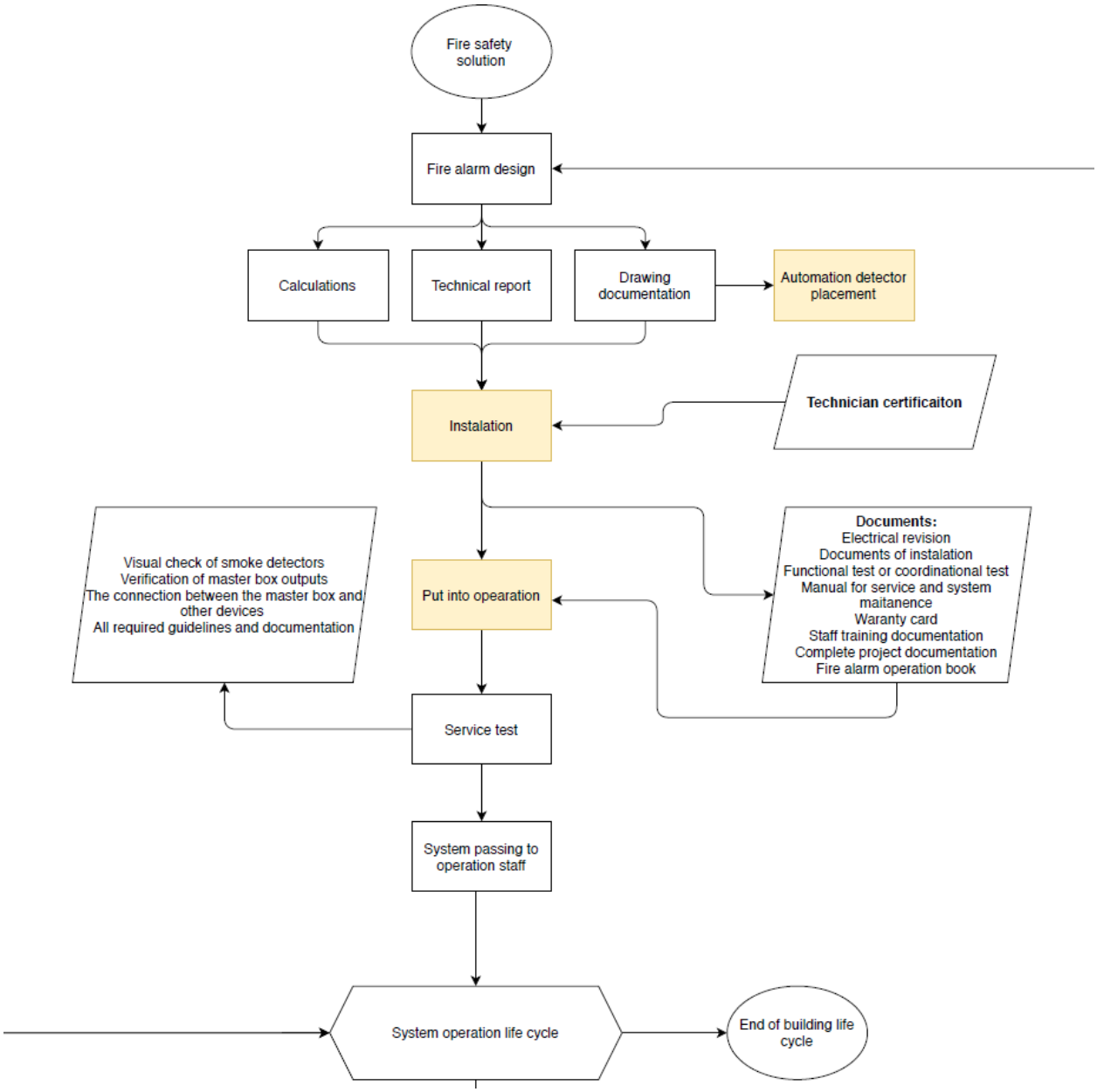


Figure 5 - Fire alarm design flow chart part 1

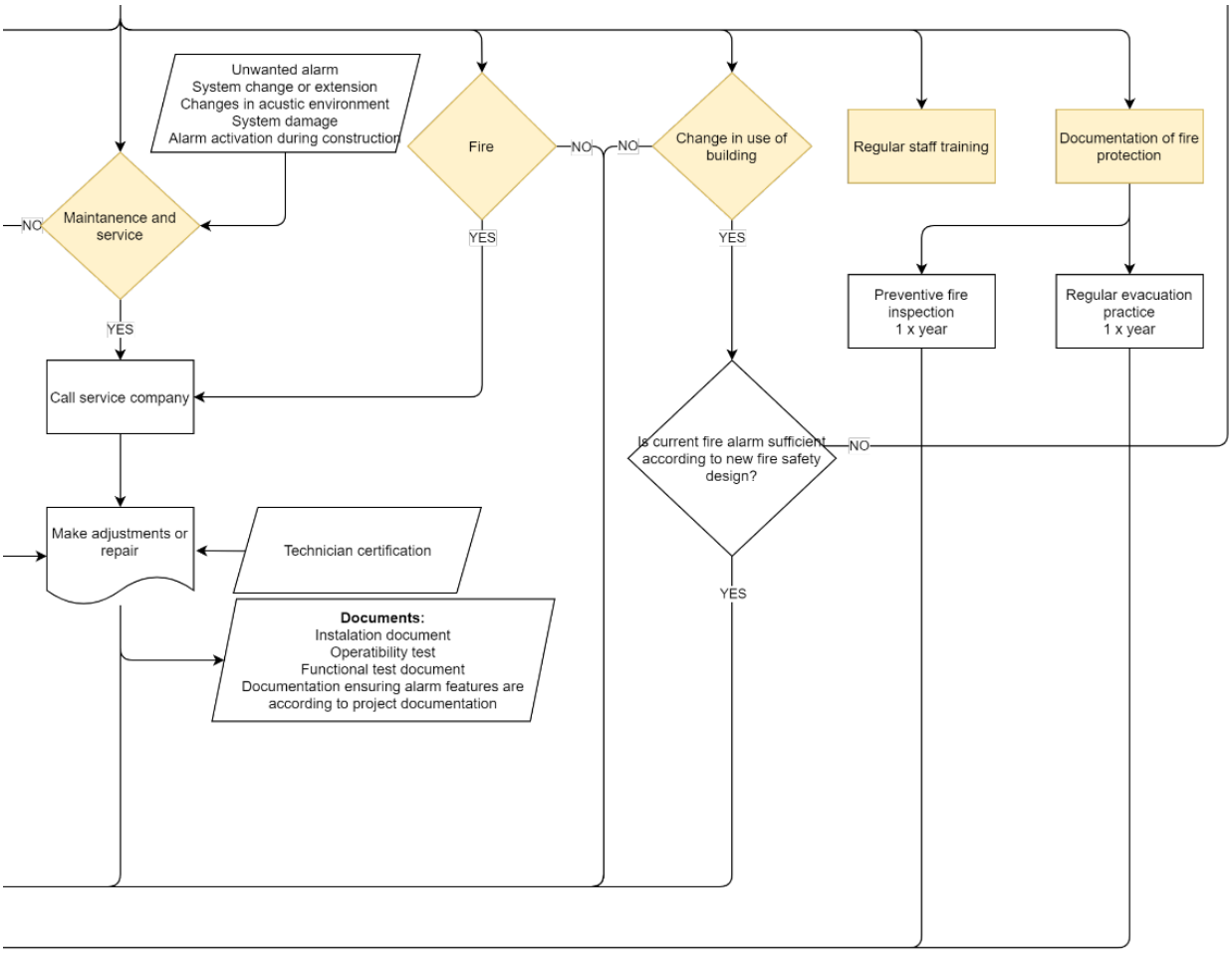


Figure 6 - Fire alarm design flow chart part 2

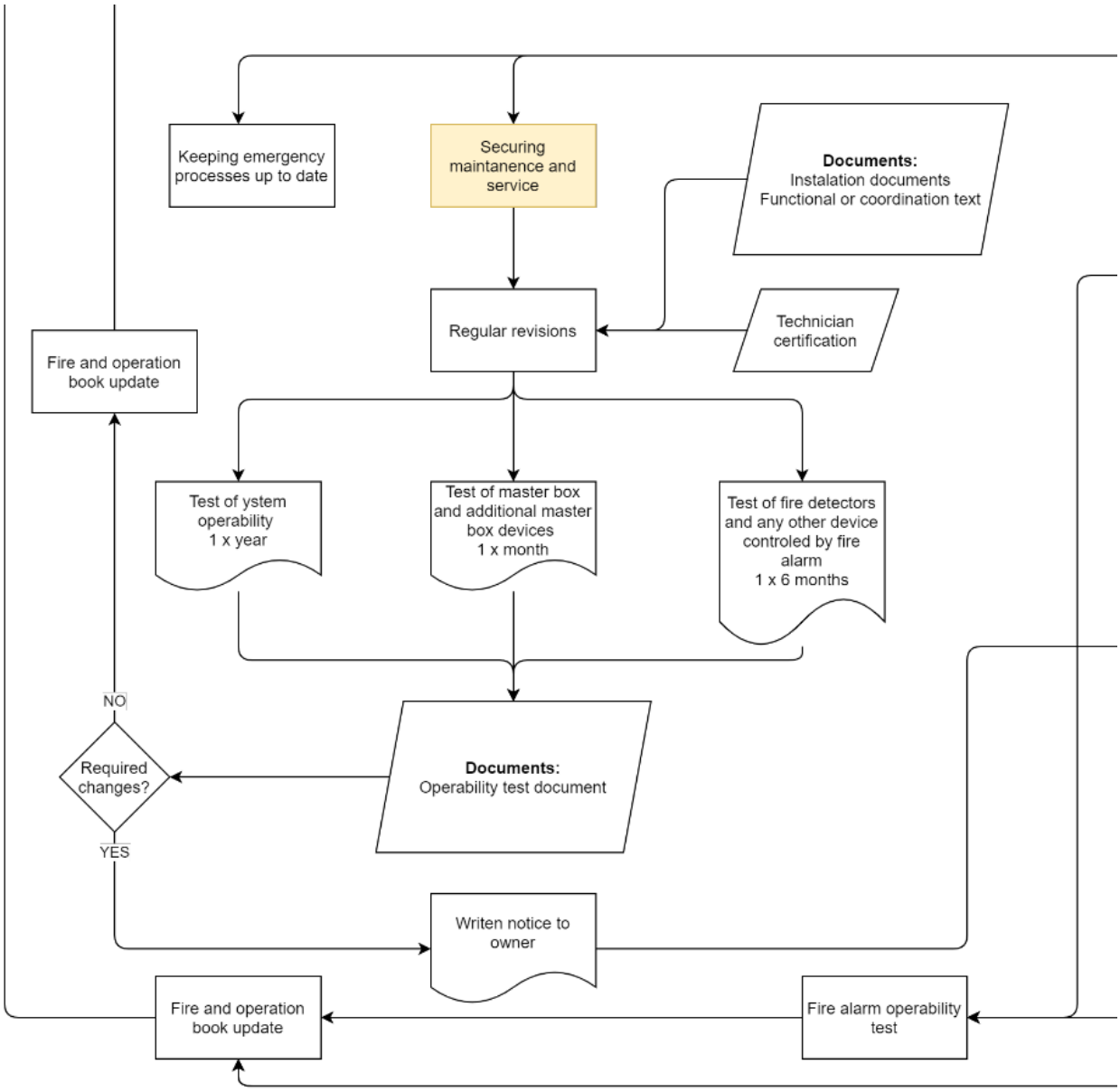


Figure 7 – Fire alarm design flow chart part 3

3.3.Software

Developed software is a simulation of building life cycle. As was already mentioned many times, during the building life cycle there are many areas where automation and use of the proper software can help with reduction cost, cooperation, and communication.

Application is developed in python (python 3.9.0) programming language. Python was chosen for its variability. Python is a great language for building an application prototype since there are a lot of technical details which are being taken care of when developing in python. Python has many built-in libraries. For graphical representation there is a library called Tkinter, which offers basic GUI (graphical user interface) option which is suitable for this kind of prototype [34], [35].

Software is built as a prototype to represent ideas and to present vision and possibilities which are worth considering in the future. Overall, the software touches three main areas. Area of fire alarm designing process, fire alarm life cycle and fire protection documents management. In all mentioned areas there is a focus on concentrating all information in one place, which is easily accessible. Focus is also on easier meeting requirements for maintenance and service of the building.

Firstly, the fire alarm design process is very tightly bind to a fire safety solution documentation. One of the many prerequisites for developing proper alarm system in BIM is a library of needed fire devices. Fire detectors are the most represented fire protection device in the entire fire alarm system. Overlooking many fire detector variations and placing manually each detector can take exceptionally long time. Although modern designing software offers various technics for copying and making patters how to place detectors, there is a potential for more automation. Presented software can place detectors automatically on the given floor plan. However so far, the algorithm works only for simple cases. But with further development it has potential to be applicable for any given floor plan.

Secondly, the focus is on fire alarm life cycle. When fire alarm design is finished there is an installation phase. Also, during installation BIM model can be used for fast system overview, working verification or quick listing of needed devices, their types and needed amount. After

installation, proper software is helpful with system installation documents generation and documents storage. There are many documents needed to properly verify fire alarm installation. After installation there is a phase of regular and irregular events. Regular service, revision, irregular fires, unwanted system alarms, system extension and other. This life cycle is simulated by this software with focus on documents management and alerting operation company about regularly happening events.

Thirdly, the focus was on fire protection documentation. Documentation is mandatory only for certain type of building. This documentation is crucial for building staff and operation. There three main regular events which are connected to this documentation. These areas are regular fire inspection, regular practice alarm and staff training. Given software is simulating these three areas in time and alerting user when events are coming up. It is also giving great overview of needed documentation.

Overall, this kind of software can be built and connected to the central building database. However, it puts great responsibility on quality of the building design. In order to automate fire detector placement, there must be proper room description. Aldo the fire compartments needs to be recognized in the model and corridors, ceilings and many more details needs to be done properly for algorithm to work. Other areas require great discipline from staff operating the building. Before any change in the real word the change needs to be put into building model. With lack of training and processes the model would soon be driven away from reality and lose its value.

3.4. Functionality

Software functionality is subordinated to the fact that the main goal of software is to make prototype which can represent the fire alarm lifetime. In this state software is ready to simulate a building life cycle and show operations which will be required during the system life cycle. According this fact all inputs are chosen according to the program functionality. There are parameters in the program which are prepared for simulation and user does not have power to change it even though it would be necessary in a real-life scenario. For example, fire alarm system which is later used in verification test is chosen in advance and user can not choose which devices will be used in the system. Also, all the documentation was only made for presentation purposes. During the lifetime simulations new documents are not generated in order to keep the simulation short and clear.

Firstly, software processes the given floor plan. Automatic distribution for any given room shape is not an easy task for the algorithm. For detector placement every room in the given floor plan, is computed individually. In the present software can determinate four room scenarios. Algorithm iterates through every room and evaluate if room is small enough to place only one detector to the middle for protection or if the room is bigger than area which one detector can cover. Based on room size and room coordinates algorithm determine number of fire detectors needed for each room. After this determination software calculate coordinates for each detector for a given room. Detectors are placed in such a pattern that there is not any unprotected area in the room. In the picture below there is a presentation of different room sizes and how the algorithm place the detectors to these rooms. For this version there is a prerequisite that there is full ceiling covering the whole room. And that there is no ventilation system installed in the rooms. Software is using default smoke detector which can cover up to 80 m^2 of area when celling hight is between 6 and 12 meters from the floor. Detector placement algorithm is represented below on the Figure 8.

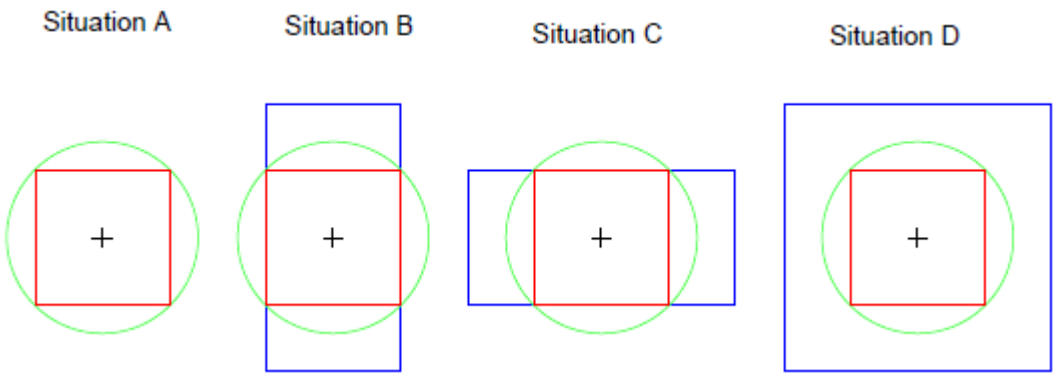


Figure 8 – Placement room situation

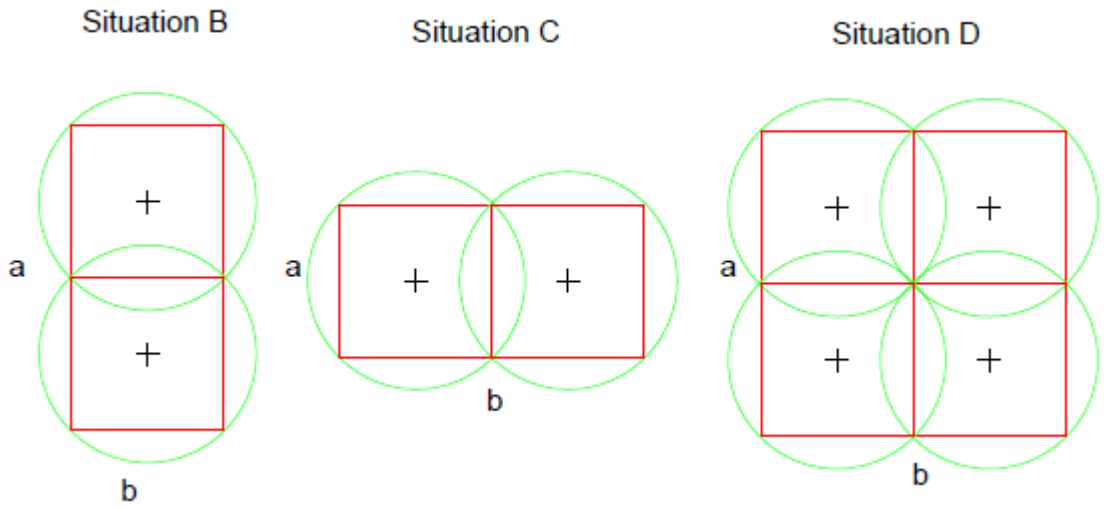


Figure 9 – Detector placement for room situation B, C, D

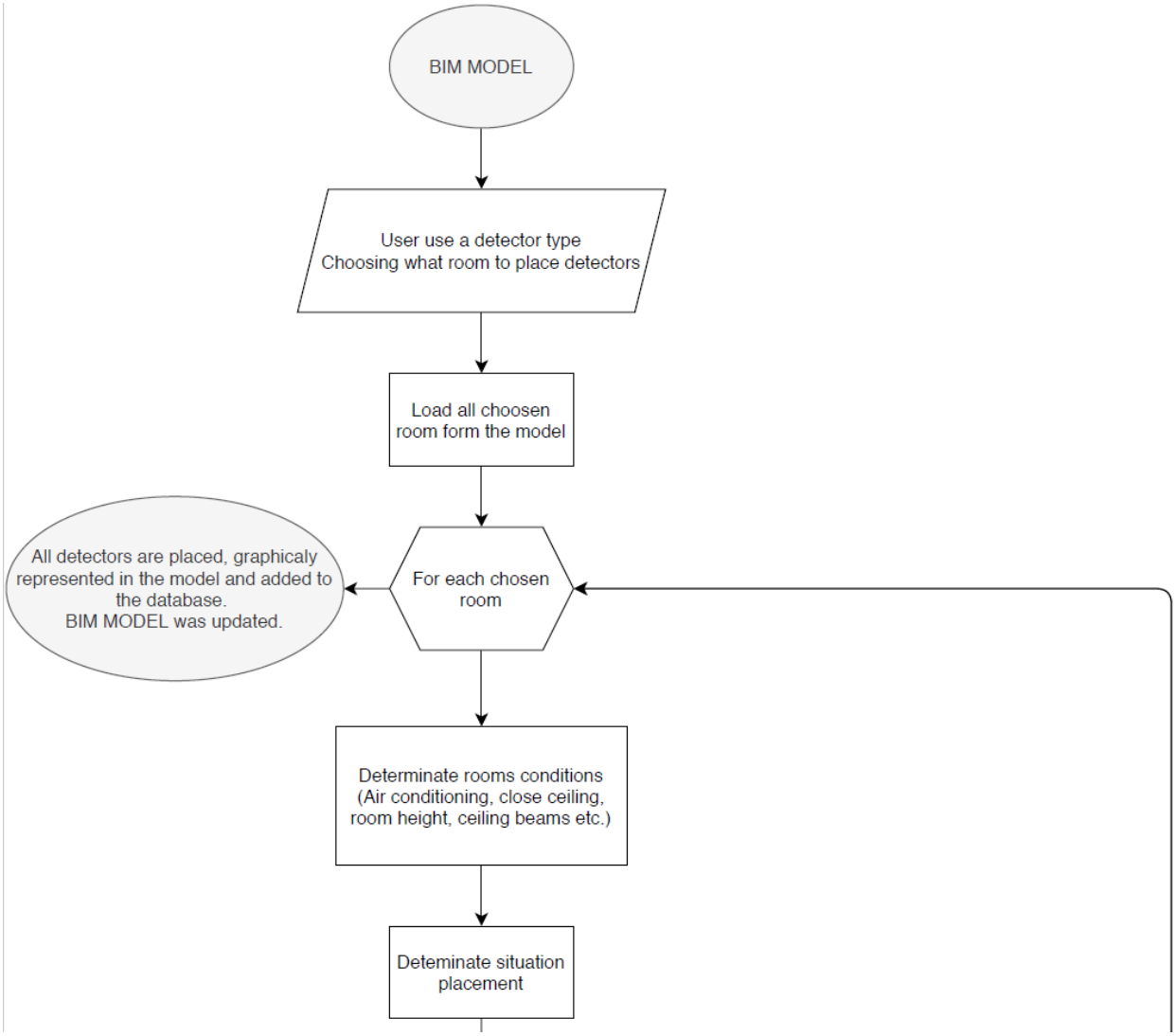


Figure 10 – Algorithm for detector placement flow chart part 1

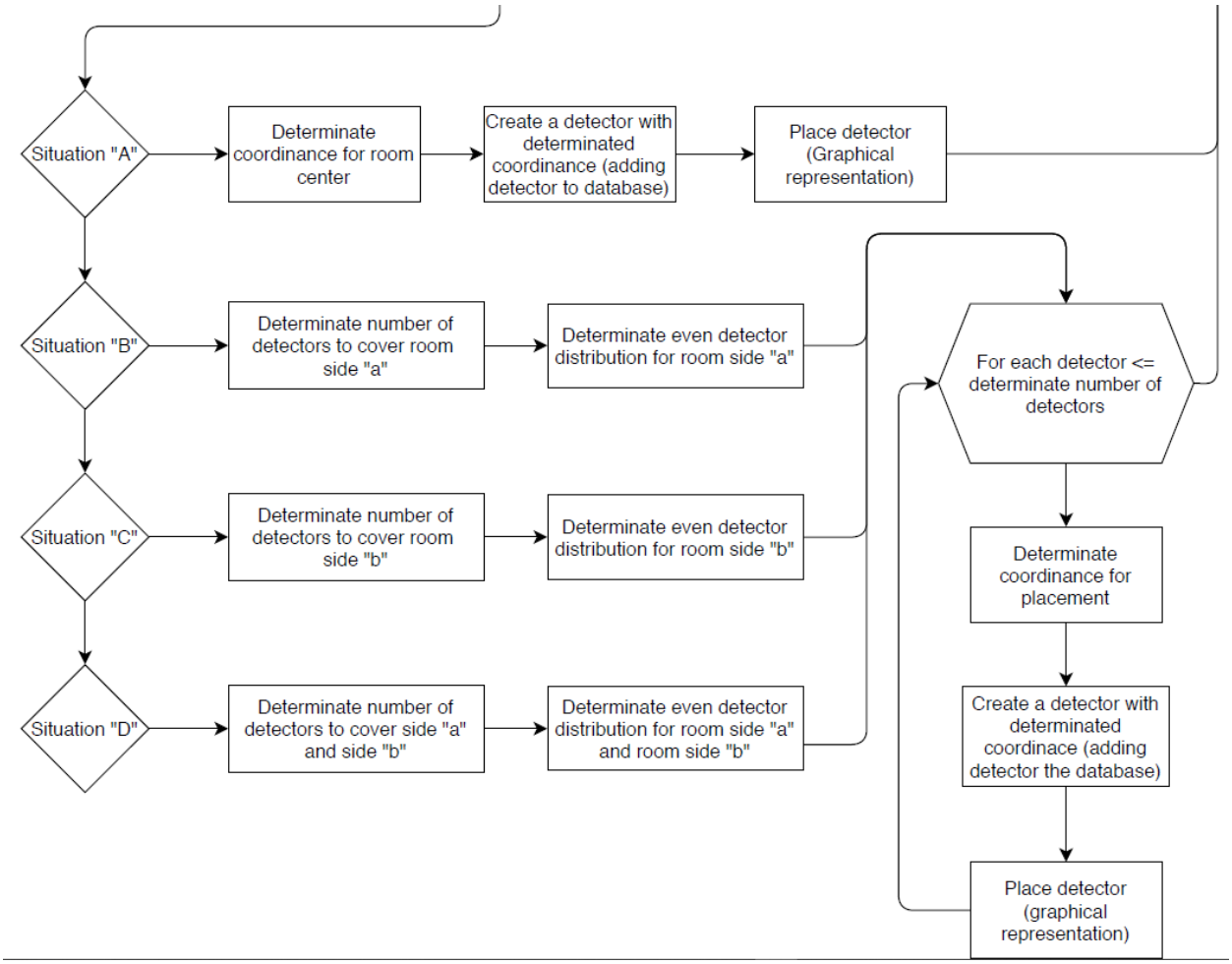


Figure 11 - Algorithm for detector placement flow chart part 1

Detector placement is at the begging of the time simulation. After the detectors are placed, the software considers fire alarm as installed and ready to put into operation. User can view the share folder with installation documentation. Folder contains all documentation needed for fire alarm installation. This folder also contains fire protection documentation. This folder is always available for the system user. All documents generated by the system or user will be centralized to this folder to keep all documentation at one place. User can also list all devices which are contained in the fire alarm. For each device there are important information about its placement, last revision date and when the next revision is coming up. By clicking button Taking alarm into operation software assumes that all the documentation is verify and correct and fire alarm is ready for traffic.

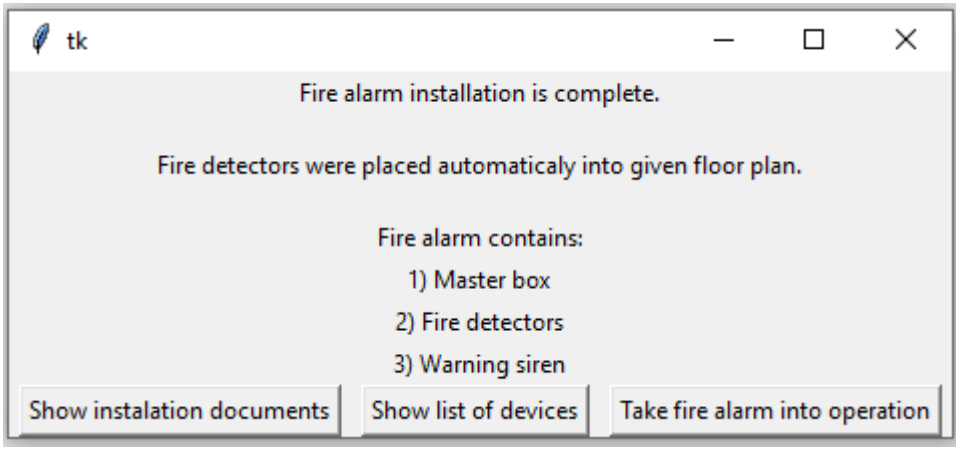


Figure 12 – Fire alarm installation window

After finishing a fire alarm installation there are many events which can occurred. After the installation is finished many buttons appears in the main toolbar. Main tool bar is divided into two sections. Top ribbon is used for action buttons and bottom ribbon is used for informative buttons. Top buttons activate events for example starting timer or make a system change. Start timer button starts running clock which represents building life cycle. System change, building environment change, building change in use are user options, which make adjustment to the fire alarm system. Below there are options for showing information about the program itself, its inputs, assumptions or information about the rooms and its coordinates. Rest of the buttons are there to help user to have good overview about the system. There is an easy access to documents about the system and access to devices which are part of the alarm system. Last two choices are operation book and fire book. These options will show current state of operation and fire book for quick overview about what actions and events occurred during the system life cycle.

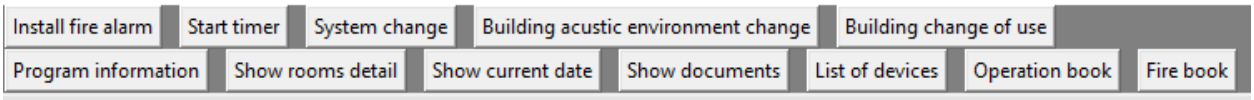


Figure 13 – Main tool bar

Since developing a software running on multiple core threads is complicated and it exceeds possibilities of used libraries there are two main stages in the program. One stage where the clock is running and second stage where clock is stopped. Also, stopping clock by user by pushing a button is complicated since Tkinter graphical library supports only single thread

applications. In the other hand Tkinter is always checking for user input (clicking a button, hovering etc.). By checking for user input Tkinter is taking one thread for this process. And since clock running is also thread process there is not a simple way to do it simultaneously. For that reason, it is more convenient to separate program into two stages. When the clock is stopped (in other words building life cycle is temporary terminated) user have multiple options. User can take multiple actions. Events options are aligned with real world possibilities, which can happen to the system. By starting a clock user starts virtual running calendar which will check every day if there is any event which needs attention. Software is giving user regular reports on coming up events. One of the possible evets are regular fire alarm revisions. More precisely monthly revision of master box and its additional devices, once in six months regular revision of fire detectors and other devices which are controlled by fire alarm and yearly fire alarm operability test.

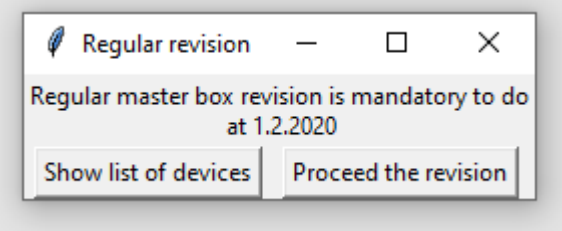


Figure 14 – Master box regular revision window alert

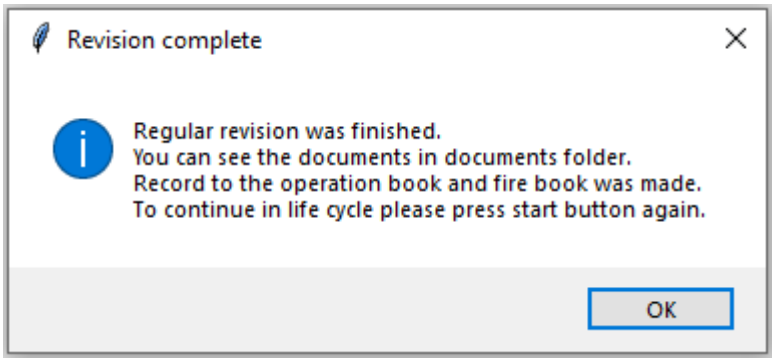


Figure 15 – Regular revision compete message

These are regular events which can occur in connection with the fire alarm itself. With considering the documentation about fire protection there are three more events implemented. With yearly alarm operability test there are also regular fire inspection. Next event is practical alarm which needs to be execute at least once a year. Last implemented regular event is staff

training. Staff training does not have to be regular but since it is a planned event it is classified as regular event for this simulation. Amount of staff training is directly dependent on fire protection documentation and its frequency can vary.

After regular event occurs, user have opportunity to open list of devices. In this system overview system will highlight devices which needs revision.

Room	Description	Last revision	Next revision	Current date	Documents
N01.1.	Fire Alarm	6.2.2020	6.2.2021	7.3.2020	Instalation Documents
N01.1.	Master Box	6.3.2020	6.4.2020	7.3.2020	Instalation Documents
N01.1.	Warning Siren	6.2.2020	6.8.2020	7.3.2020	Instalation Documents
N01.1	Fire Detector	6.2.2020	6.8.2020	7.3.2020	Instalation Documents
N01.1	Fire Detector	6.2.2020	6.8.2020	7.3.2020	Instalation Documents
N01.1	Fire Detector	6.2.2020	6.8.2020	7.3.2020	Instalation Documents
N01.1	Fire Detector	6.2.2020	6.8.2020	7.3.2020	Instalation Documents
N01.1	Fire Detector	6.2.2020	6.8.2020	7.3.2020	Instalation Documents

Figure 16 – List of devices with highlight device for revision

After proceeding revision user will be alerted that revision was complete. Highlighted devices are changed to default state and system will update date when next revision is needed. After the revision process is finished program will generate document about revision to shared document folder, update the fire alarm operation book and update the fire book.

So far descriptions only for regular or expected events which will happened during the system life cycle were described. In order to have simulation as close to real life as possible there are also irregular and unexpected evets which can occurs. For this simulation there are three unexpected events which can happened. Handling events is simplified for sake of this simulation. One of the cases is fire emergency. When fire occurs in the building the system will alert user. Program will highlight devices which were hit by the fire. User has the option to automatically call the service company. Program will send the noticed to service company which is assigned to service the fire devices. Software will take highlighted devices and send the list to the service company. This step is crucial for the service company. Contractors will know exactly what devices are needed for services even before they will come to the building. Software will also make automatic records to the operation book and the fire book and generate needed documents.

There are two more irregular events. One is system damage and other is unexpected alarm. Both events are listed in legal standard ČSN 34 2710 as events when fire alarm system needs to go through service. These events are handled similar as fire event. Service company can be called automatically with devices which need service. Records to operation and fire book are made and necessary documents are generated [9].

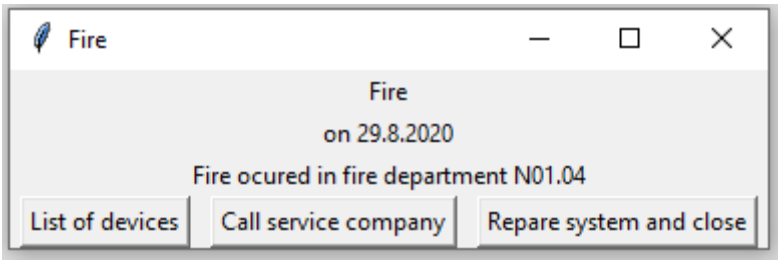


Figure 17 – Fire emergency alert window

Figure 18 - System damage alert window

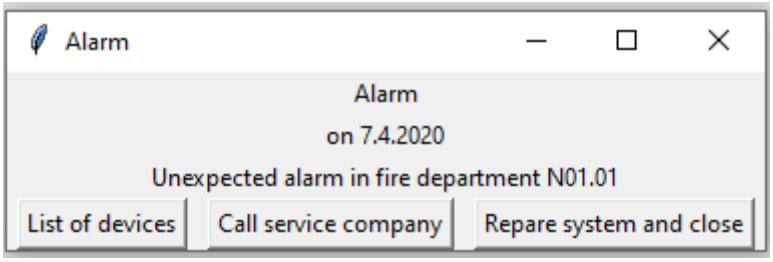


Figure 19 – System unexpected alert window

When the timer is stopped, user has options which were described above in Figure 13. First is system change or extension. When this option is chosen, program assumes that building operation staff needs to make changes or extensions to the alarm system. Program will simulate the beginning and the end of this process. When the change is pushed, forward system will generate documents about system change. Also, new operability test needs to be finished in order to have alarm system functional again. Program will automatically make records to the fire

book and operation book. In general, since the program is only simulations it logically skips some process steps. The process of making system extension needs more time and work of third-party company to prepare the extension design or system change. In real situation it will take time but in this simulation this action is processed instantly.

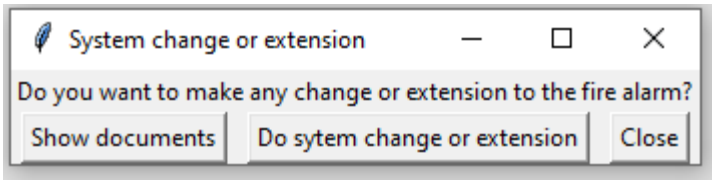


Figure 20 – System change or extension option window

Process of changing acoustic environment is described legal standard ČSN 34 2710. There are listed conditions when alarm system needs to go through test and evaluation. One of those is change in acoustic environment. This kind of change is also simulated by the program. Program will adjust the siren accordingly the change, generate necessary documents and make records in the operation book and the fire book [9].

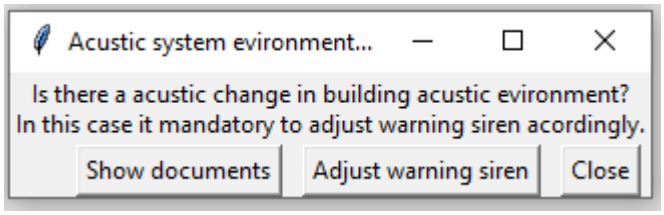


Figure 21 – Change in acoustic environment option window

Last user option is taking into the account the possible change in the use of the building. This is probably the most complex process to handle. In many cases new fire alarm design needs to be completed. Again, for simulation purposes the process is simplified. By clicking change the building use program assumes that the whole process was already completed, and it generates necessary documents and make records to the operation and fire book.

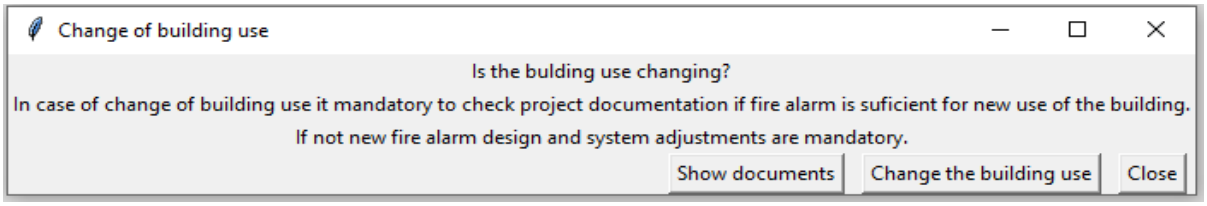


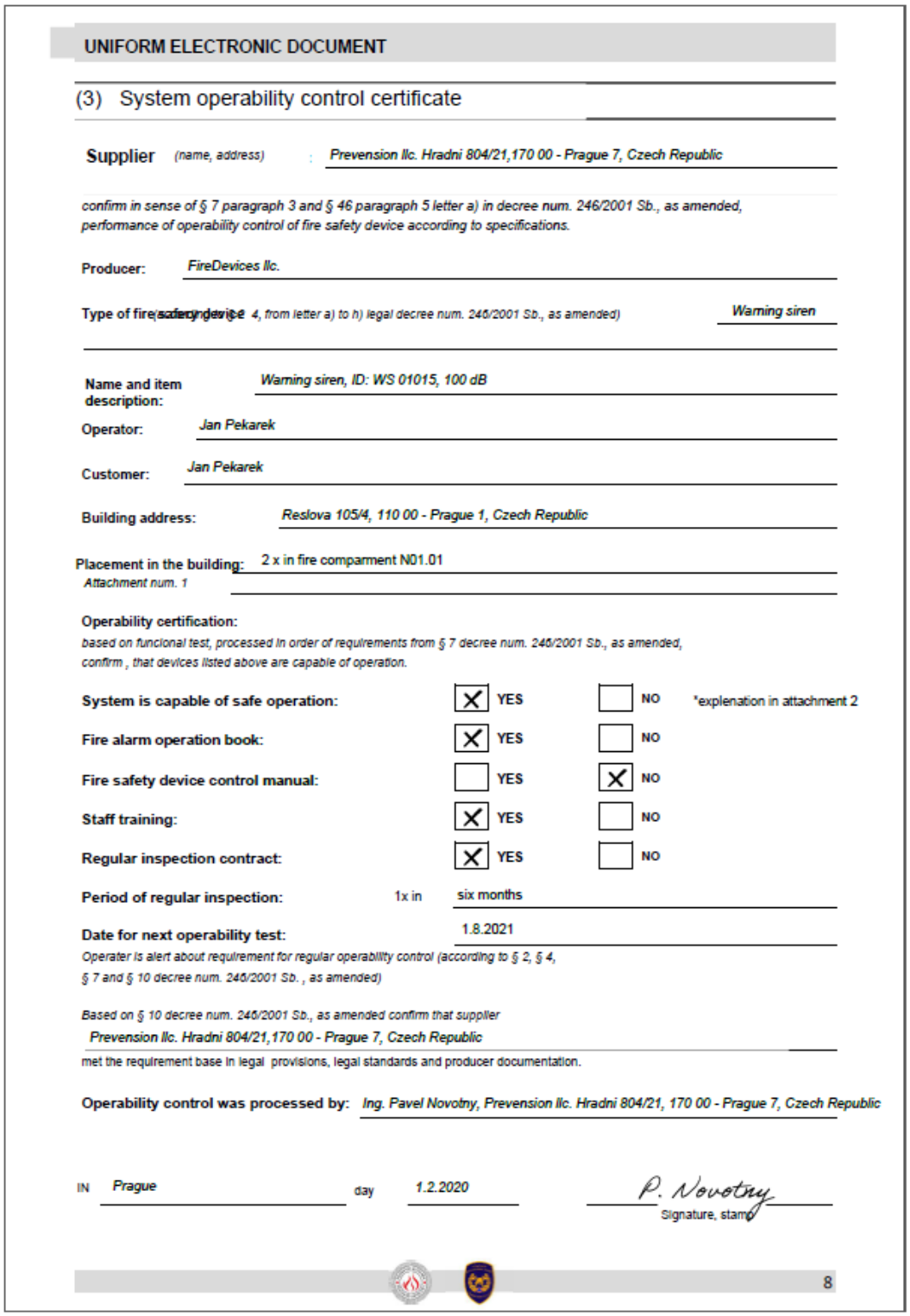
Figure 22 – Change in building change of use option window

One of important information buttons is the list of devices. List of devices is showing every device which is installed in the fire alarm system. It contains information about device placement, about last revision, coming up revision and current date. There is also a quick access to the shared folder with system documentation.

Room	Description	Last revision	Next revision	Current date	Documents
N01.1.	Fire Alarm	5.6.2020	5.6.2021	21.8.2020	Instalation Documents
N01.1.	Master Box	5.8.2020	5.9.2020	21.8.2020	Instalation Documents
N01.1.	Warning Siren	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.1	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.2	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.3	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.3	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.3	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.4	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents
N01.4	Fire Detector	5.6.2020	5.12.2020	21.8.2020	Instalation Documents

Figure 23 – List of devices overview window

Through showed documents user can access one single data storage where all information about system fire alarm and documents of fire protection should be stored. At this point just a little work with sharing the documents to the third-party cloud-based service has been done, but it can be presented like shared folder in private company servers or fire department servers. Example of listed document is in Figure 24.



UNIFORM ELECTRONIC DOCUMENT

(3) System operability control certificate

Supplier *(name, address)* : *Prevension llc. Hradni 804/21,170 00 - Prague 7, Czech Republic*

confirm in sense of § 7 paragraph 3 and § 46 paragraph 5 letter a) in decree num. 246/2001 Sb., as amended, performance of operability control of fire safety device according to specifications.

Producer: *FireDevices llc.*

Type of fire safety device *4, from letter a) to h) legal decree num. 246/2001 Sb., as amended)* *Warning siren*

Name and item description: *Warning siren, ID: WS 01015, 100 dB*

Operator: *Jan Pekarek*

Customer: *Jan Pekarek*

Building address: *Reslova 105/4, 110 00 - Prague 1, Czech Republic*

Placement in the building: 2 x in fire comparment N01.01
Attachment num. 1

Operability certification:
based on funcional test, processed in order of requirements from § 7 decree num. 246/2001 Sb., as amended, confirm , that devices listed above are capable of operation.

System is capable of safe operation:	[X] YES	[ ] NO	*explenation in attachment 2
Fire alarm operation book:	[X] YES	[ ] NO	
Fire safety device control manual:	[ ] YES	[X] NO	
Staff training:	[X] YES	[ ] NO	
Regular inspection contract:	[X] YES	[ ] NO	

Period of regular inspection: 1x in six months

Date for next operability test: 1.8.2021

Operater is alert about requirement for regular operability control (according to § 2, § 4, § 7 and § 10 decree num. 246/2001 Sb. , as amended)

Based on § 10 decree num. 246/2001 Sb., as amended confirm that supplier
Prevension llc. Hradni 804/21,170 00 - Prague 7, Czech Republic
met the requirement base in legal provisions, legal standards and producer documentation.

Operability control was processed by: *Ing. Pavel Novotny, Prevension llc. Hradni 804/21, 170 00 - Prague 7, Czech Republic*

IN *Prague* day *1.2.2020* *P. Novotny*
Signature, stamp

8

Figure 24 – Example of uniform electronic document

Fire alarm operation book is a book with records about everything what is happening with the system. Operation book is prepared by operation company after in the end of installation process. Records about events are made automatically by the application. After a year life cycle there will be at least records about regular system revisions and operability test.

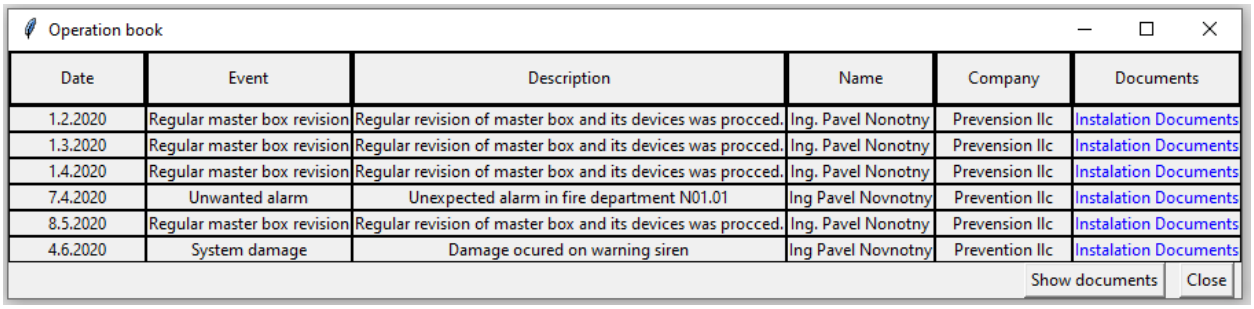


Figure 25 – Operation book window

Alongside fire alarm operation book there is also a fire book. By law fire book is not always necessary in the operation. It is assigned to keep it by fire department. Fire book is very similar to operation book. It can also automatically make records about events happening in the building. Next to recording what is happening to the fire alarm system, there are also records about practical alarms, staff training and regular fire inspections. Combination of records in fire book and valid documentation is enough to prove that the system is evaluated and working.

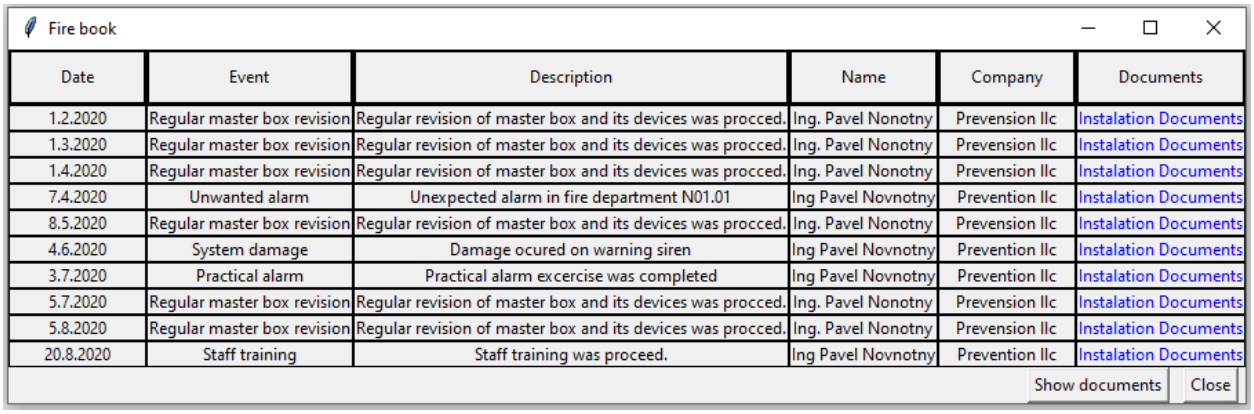


Figure 26 – Fire book records window

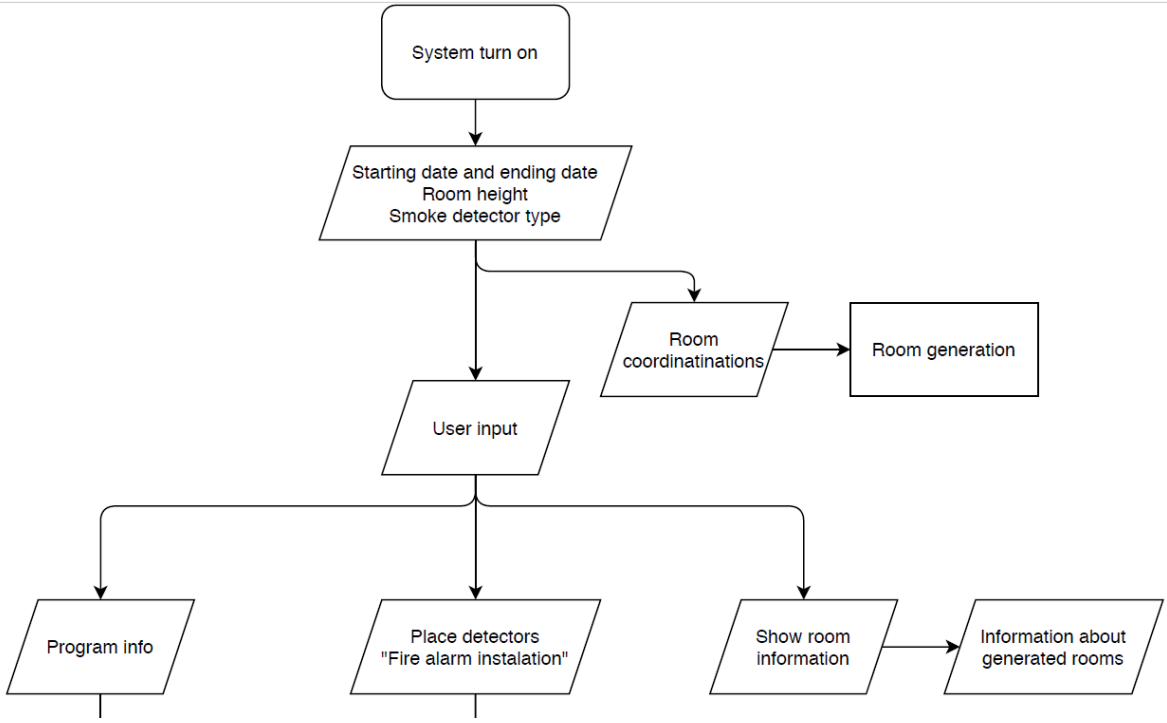


Figure 27 – Software functionality flow chart part 1

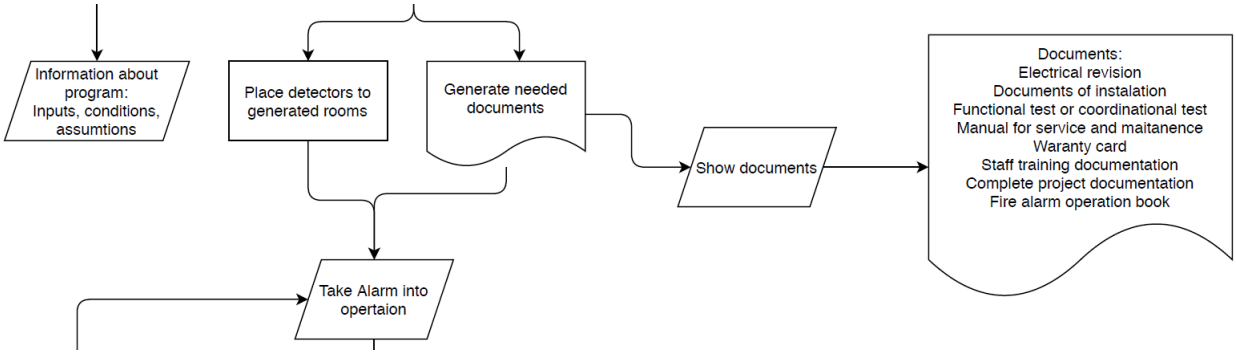


Figure 28 - Software functionality flow chart part 2

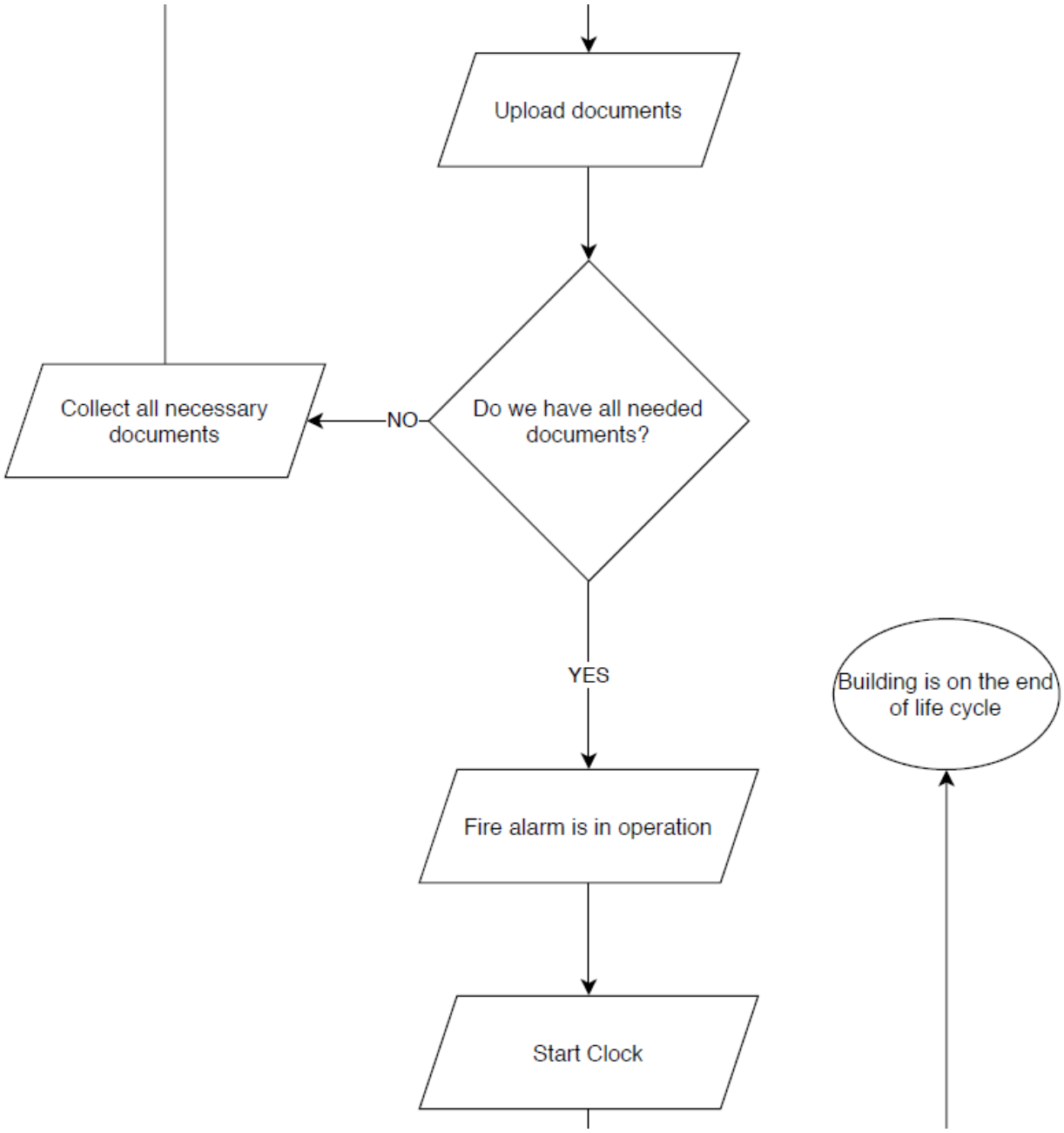


Figure 29 - Software functionality flow chart part 3

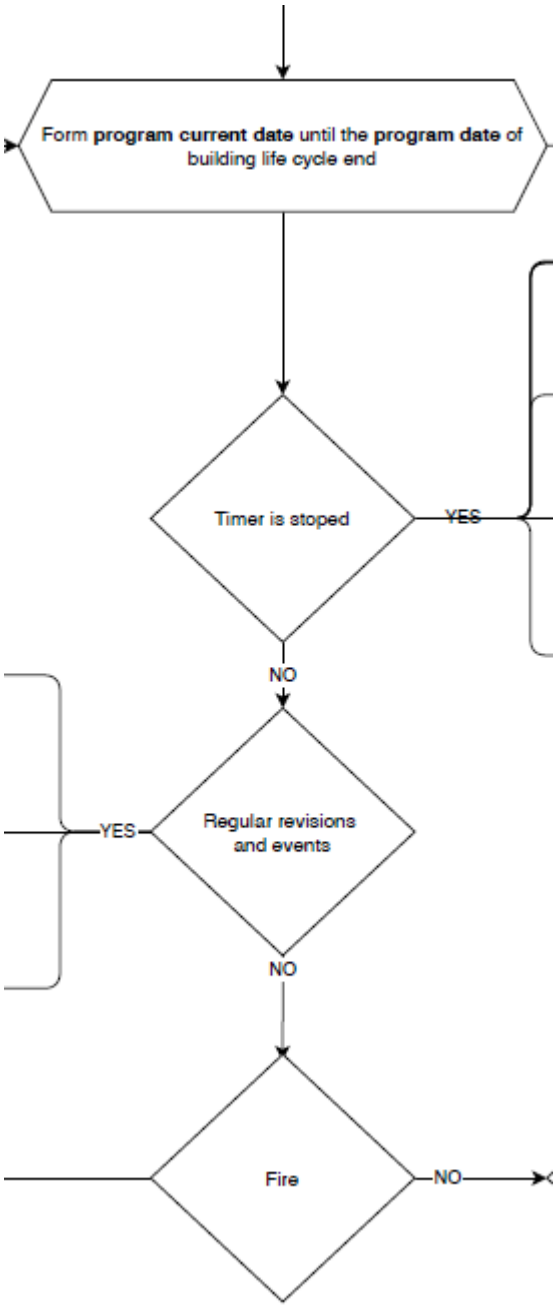


Figure 30 - Software functionality flow chart part 3

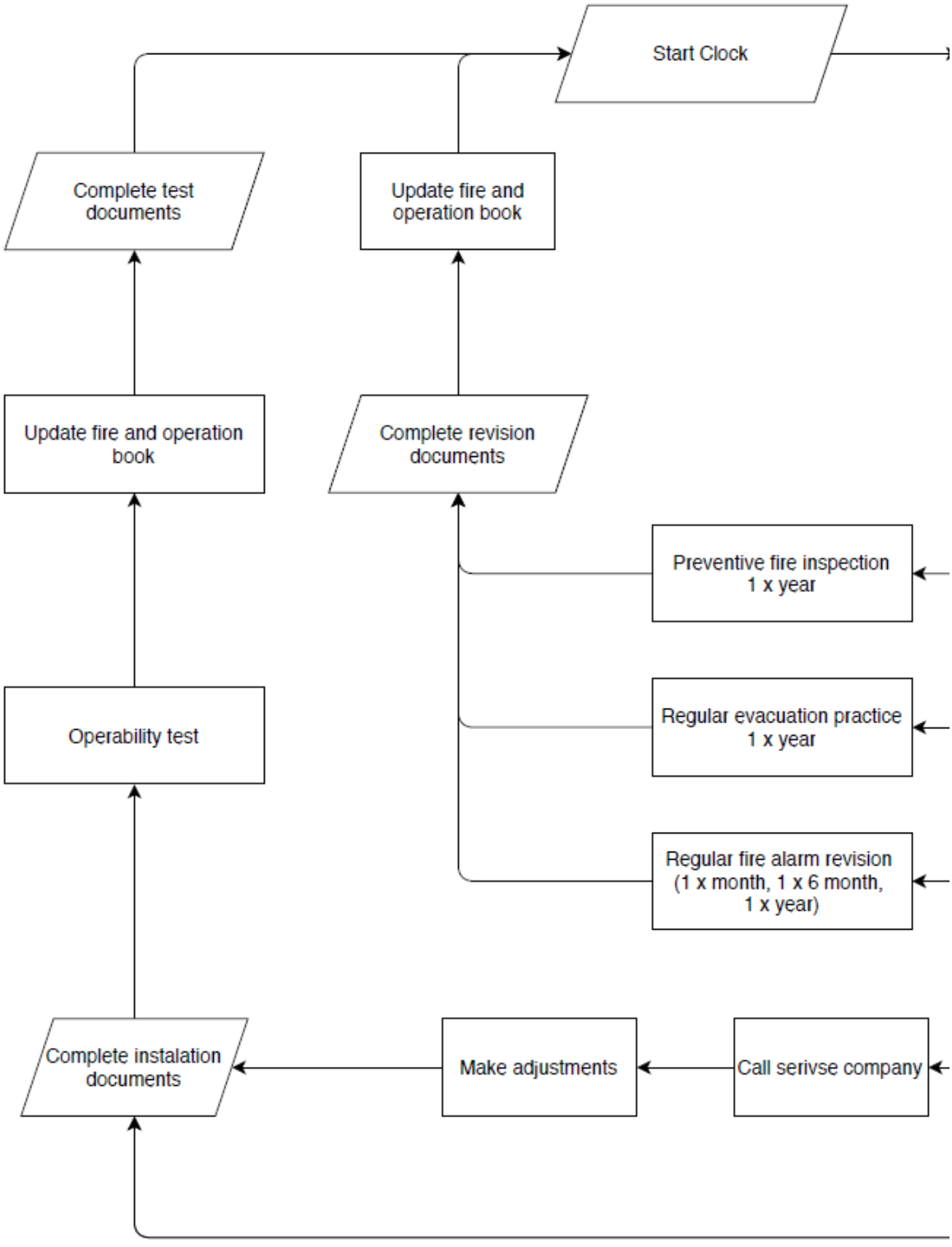


Figure 31 – Software functionality flow chart part 4

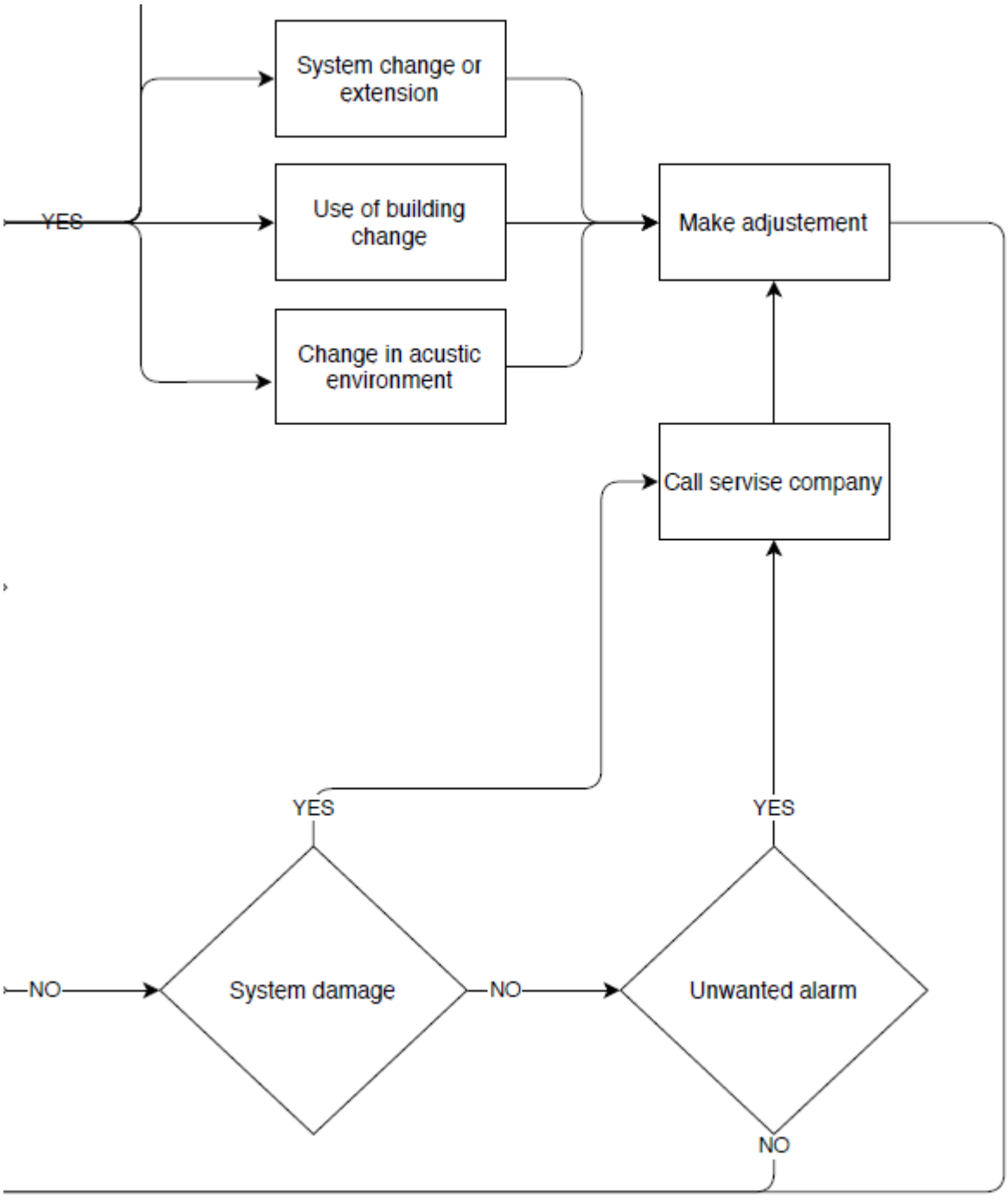


Figure 32 - Software functionality flow chart part 5

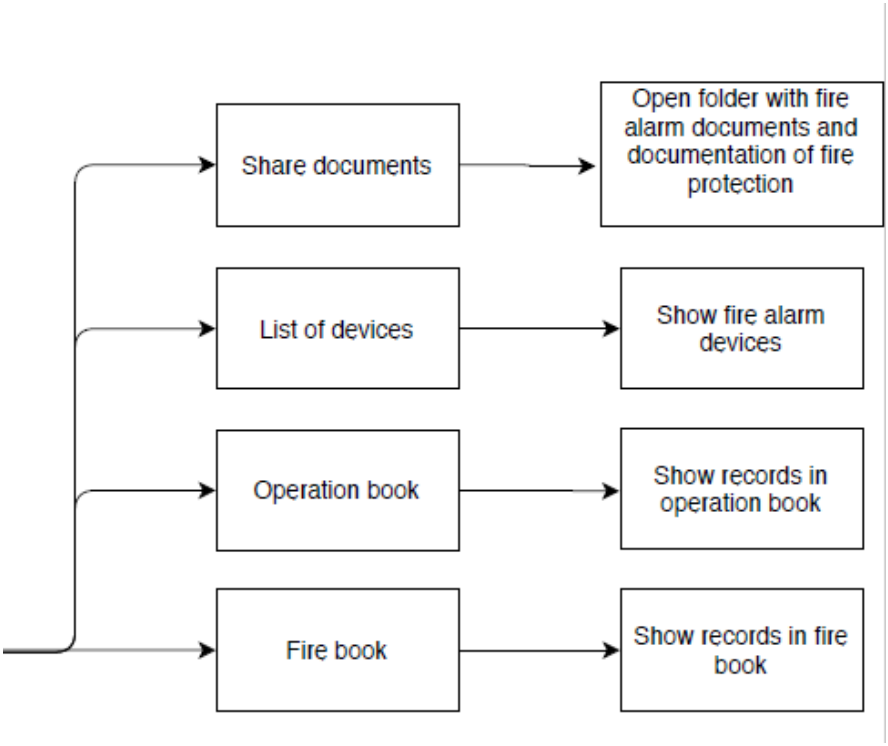


Figure 33 - Software functionality flow chart part 6

Overall, this building system simulation is developed to introduce and explore potential of BIM in area of fire alarms and its maintenance. This software concept is developed with focus to help fire alarm designer to automate his work. By clicking a placement button algorithm can place detector to the given floor plan. Also, it shows potential in automation of work of building managers and operation staff. Software helps with document management and reminders when regular revisions are needed, as well as the staff training and managers responsibilities. There is also a potential in better cooperation and communication with local fire brigades and the fire departments. Proper documentation, training and well design processes are great benefit for building fire safety. In this stage of development there are some programming shortcuts in order to make this prototype possible. Since it is a simulation of real events there is a clear determination when some of irregular events going to occur. Overall, this is an idea concept and fundamentals for more development.

4. Application

4.1. Verification Example with Simple Floor Plan

For application example a simple floor plan was created. Floor plan was designed to represent all four situations cover by algorithm. During the simulation all possible events occur. In general, conditions were chosen so the algorithm can work properly. All rooms have full ceiling. Height of the rooms are less than 12 meters and greater than 6 meters. There is not air conditioning in the rooms. Detectors are placed in such a way that there is not any unprotected space in the room. Software is using smoke detector according to ČSN EN 54-7. According to legal standard ČSN 34 2710 this kind of detector in described conditions can cover up to 80 m^2 of space. Also records and documents are simplified in order to keep simulation simple. In the other words the important part is that the software can automate certain tasks. It is not that important how the documents are processed or how exactly the record in fire book looks like. It is only a matter of preference and future work on the system can make visual and contextual adjustments [9], [36].

4.2. Inputs

Floor plan contains three rooms and a corridor. Each room is an individual fire compartment. For verification purposes each room has a requirement to have a fire detector. Floor plan is drawn in centimetres. For demonstration purposes fire alarm was chosen with one master box, one siren and smoke detectors. Number of detectors is determinate by the software according to floor plan dimensions. Putting more devices would not make big difference because all the devices will be revised in a same time as a fire alarm. Also, most of the adjustment of devices follow the same process as for fire alarm. In order to present every possible regular and irregular event there is a chosen date when irregular events will happen. During simulation time every regular and irregular event will happen. Also, all system adjustment which can be made by user will occur.

Figure 34 – Input floor plan

4.3. Outputs

Software starts with loading a floor plan. When taking in consideration every assumption from above then everything is ready for fire alarm to be installed.

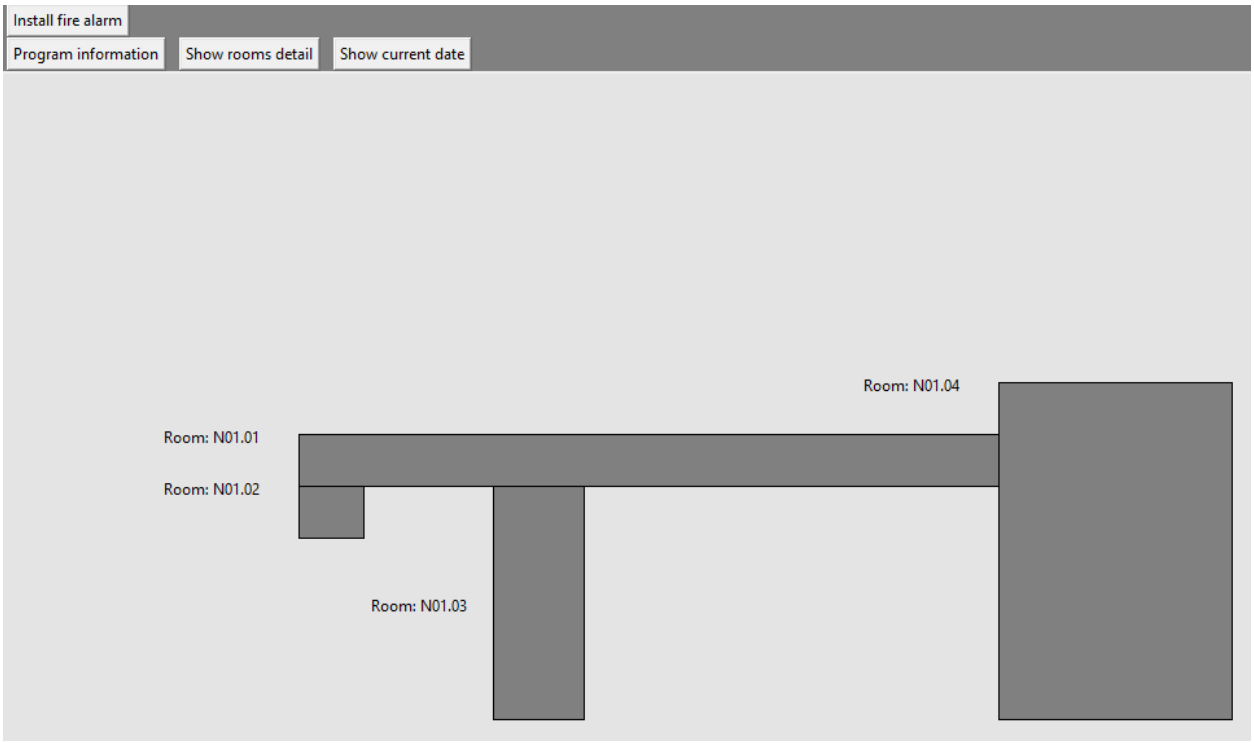


Figure 35 - Default software window

After installation a fire alarm software detects and iterate through each room. Algorithm determinates room by size and place detectors accordingly.

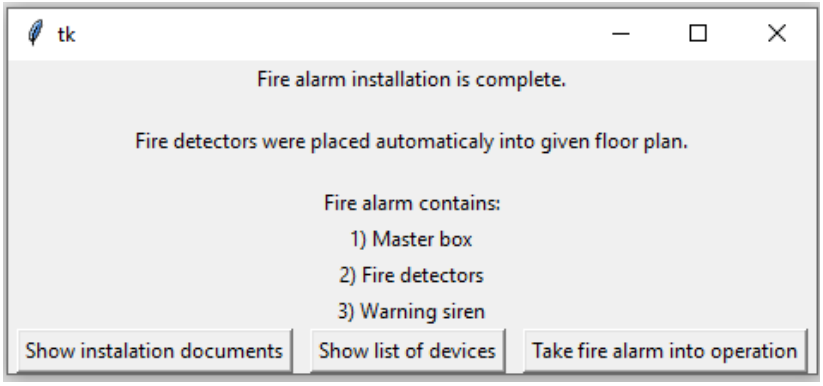
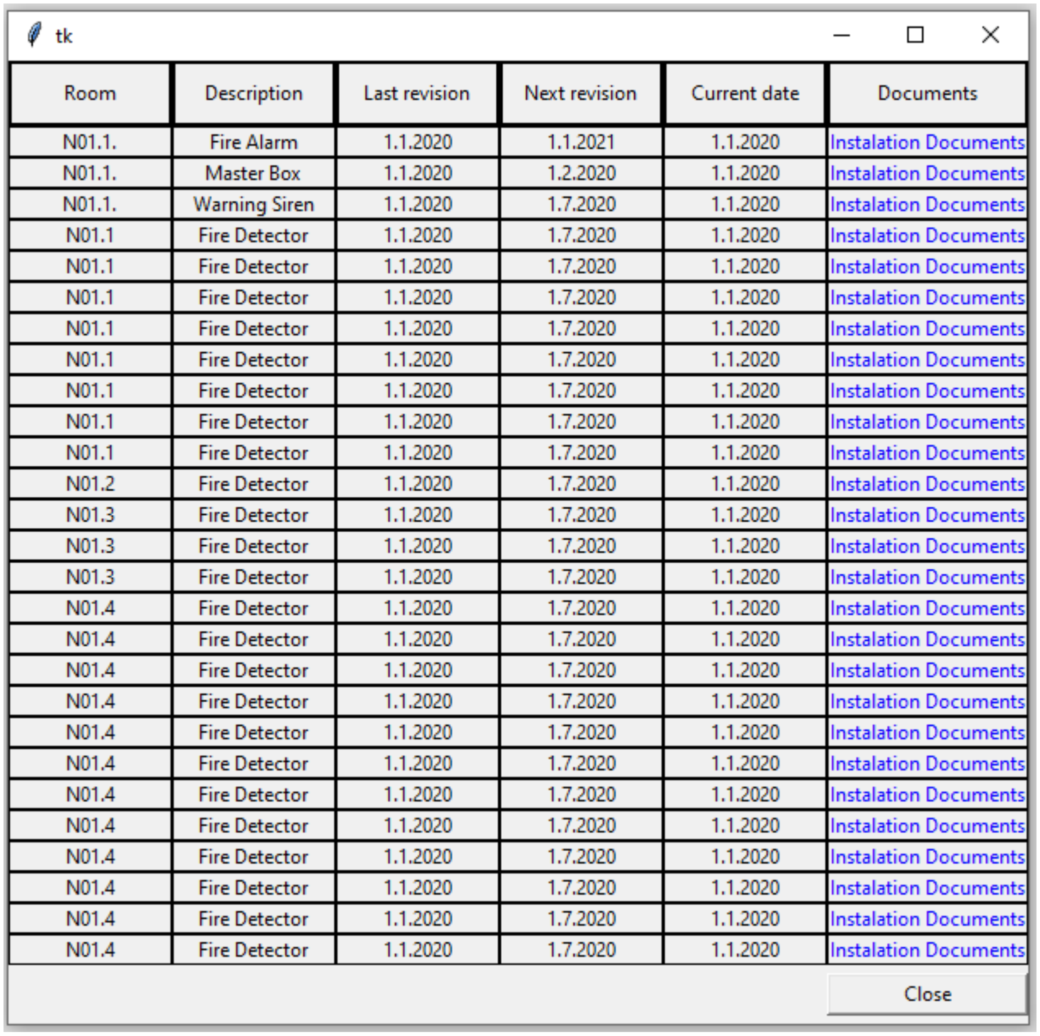


Figure 36 - Fire alarm installation complete window

When detector placement is finished, installation window appears. With possibility to display list of devices or fire alarm installation documents.



tk

Room	Description	Last revision	Next revision	Current date	Documents
N01.1.	Fire Alarm	1.1.2020	1.1.2021	1.1.2020	Instalation Documents
N01.1.	Master Box	1.1.2020	1.2.2020	1.1.2020	Instalation Documents
N01.1.	Warning Siren	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.2	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.3	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.3	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.3	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents
N01.4	Fire Detector	1.1.2020	1.7.2020	1.1.2020	Instalation Documents

Close

Figure 37 - List of devices window

Name ↑	Modified	Members	
Certificate_for_Responsible_Technician.pdf	Just now	Only you	•••
Certificate_of_Functional_Test.pdf	Just now	Only you	•••
Certificate_of_Operability.pdf	Just now	Only you	•••
Certification_of_Functional_Test_and_Operability.pdf	Just now	Only you	•••
Complete_Design_Documentation_of_Real_Installation.pdf	Just now	Only you	•••
Contol_Manual.pdf	Just now	Only you	•••
Electrical_Wiring_Revision.pdf	Just now	Only you	•••
Installation_Certificate_of_Fire_Safety_Device.pdf	Just now	Only you	•••
Operation_Book.pdf	Just now	Only you	•••
Staff_Training_Documentation.pdf	Just now	Only you	•••
Warranty_Card.pdf	Just now	Only you	•••

Figure 38 - Shared document folder

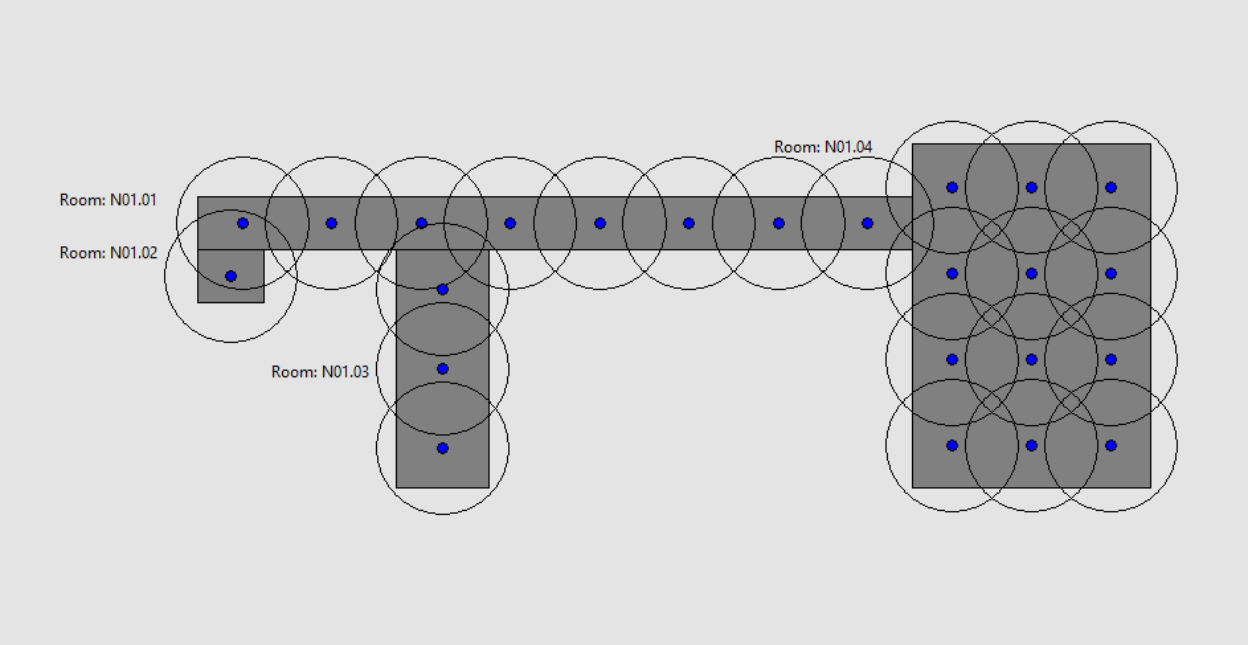


Figure 39 - Result of automatic detector placement

After starting the life cycle first regular revision of master box happens which is set for 1st of February 2020. This revision will from that date on appear every month.

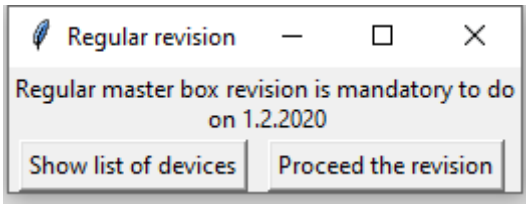


Figure 40 - Regular revision alert window

When the provision is procced, new documents are generated in share folder and the devices are highlighted in the list of documents.

Room	Description	Last revision	Next revision	Current date	Documents
N01.1.	Fire Alarm	1.1.2020	1.1.2021	2.2.2020	Instalation Documents
N01.1.	Master Box	1.2.2020	1.3.2020	2.2.2020	Instalation Documents
N01.1.	Warning Siren	1.1.2020	1.7.2020	2.2.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	2.2.2020	Instalation Documents
N01.1	Fire Detector	1.1.2020	1.7.2020	2.2.2020	Instalation Documents

Figure 41 – List of devices window with highlighted device for revision

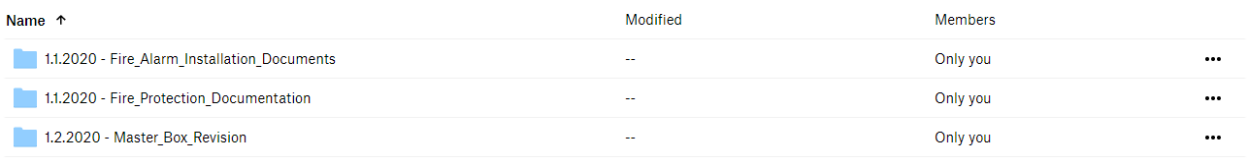


Figure 42 – Shared folder documentation

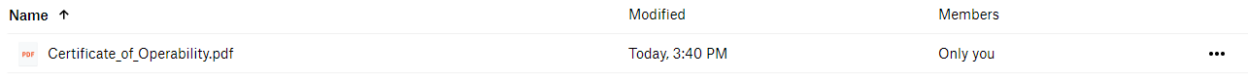


Figure 43 – Generated document after master box revision

Unexpected alarm was detected by system on 5th February 2020. User will get an alert about this fact. User have different options what to do. There is an option to call service company, proceed with service, or close the window. Also, one can show list of devices with highlighted device which reported unexpected alarm and need service.

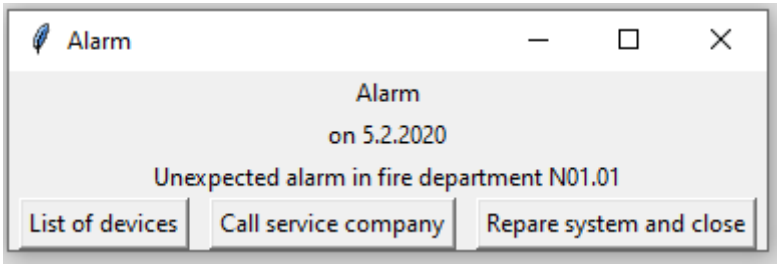


Figure 44 - Unexpected alarm alert

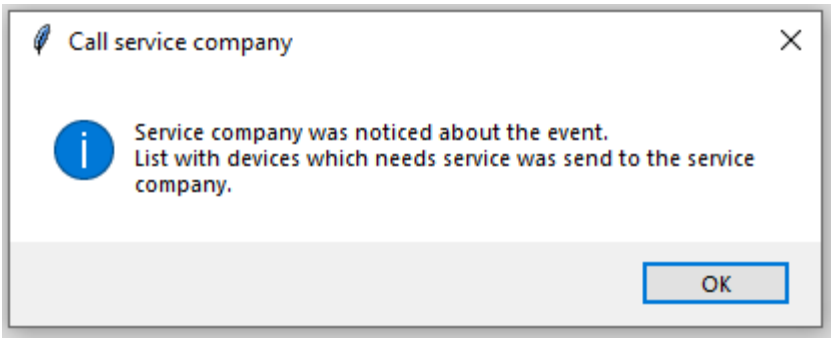


Figure 45 - Automatic service company calling message

Practical alarm for staff and employees is planned for 3rd July 2020. Software will alert user about the practical alarm and help with administration. When the practical alarm is finished software generates records to the fire book, operation book and generate all the needed documentation.

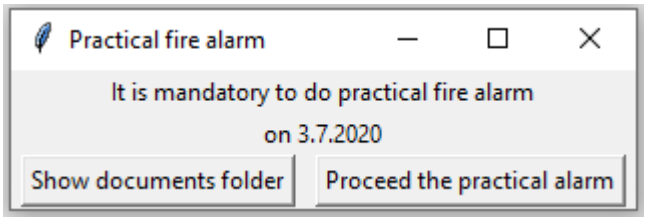


Figure 46 – Practical fire alarm alert window

System damage was reported by fire alarm on 15thJuly 2020. System damage requires device services. List of devices for services are highlighted in list of devices. Also, service company can be called automatically.

Figure 47 – System damage alert window

Staff training was planned for 20th August 2020. Staff trainings are regular events which repeats every year. Repeating period varies on many details and can be very different in every building. When this event appears software will alert user a give him options on what to do.

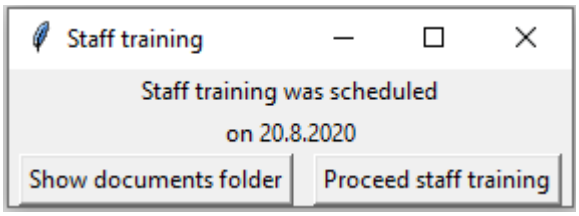


Figure 48 – Staff training announcement window

Fire emergency was reported by the fire alarm. Fire was reported on 17th November 2020. When fire is reported in the building, it is mandatory to do services of devices which were hit by fire. All devices are highlighted in list of devices, again there is a possibility to automatically call service company and make system repair. Also, when fire happens all operation test of system and documentation needs to be finished. Before the system is put into operation again, fire inspection will do the last system check.

Figure 49 – Fire alert window

N01.1	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.1	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.1	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.1	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.2	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.3	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.3	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.3	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents
N01.4	Fire Detector	16.7.2020	16.1.2021	18.11.2020	Instalation Documents

Close

Figure 50 – List of devices after fire. Highlighted devices with need of service

On 19th February 2021 change in the system or extension is taking place. System change requires operability test and revision. Also, it requires to do the fire inspection. Software will generate documents to the folder and make record to the operation and fire book.

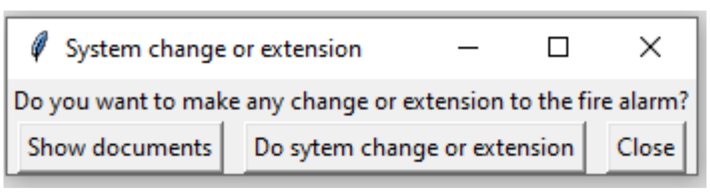


Figure 51 – System change or extension option window

On 19th August 2021 system reported that regular revision for fire detectors and other devices which are controlled by fire alarm is coming up. Again, there are highlighted devices in list of devices or option to proceed with the revision which will make records and generate documents.

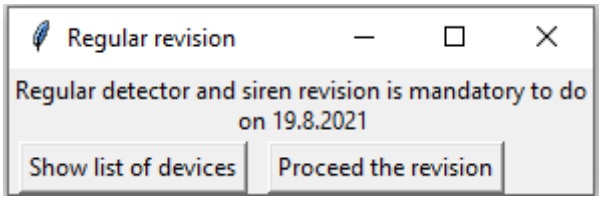


Figure 52 – Detector and other fire alarm devices revision window

Fire alarm revision and fire inspection is mandatory to do on 19.2.2022 according to software. Standard fire alarm revision comprises, operability test, test of master box and fire alarm devices. Fire inspection checks the fire alarm system and additionally it controls every fire protection device which is in the building as well as documentation of fire protection.

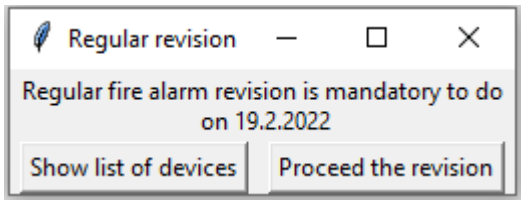


Figure 53 – Regular fire alarm revision window

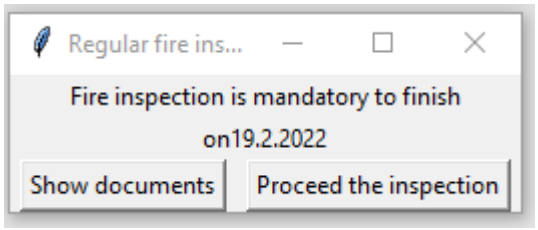


Figure 54 – Regular fire inspection alert window

When acoustic change in building environment happens software will simulate situation. Change in acoustic environment is connected to warning siren. In case of the acoustic level goes up there is requirement to adjust warning siren accordingly. Software will generate documents and make proper records to the fire and operation book.

Figure 55 – Acoustic environment change option window

Finally, there is a change in the use of the building in the software. Changing a building use can be very long and complicated process. For simulation it is simplified. When the building change is chosen software will generate new documentation for the fire alarm, documentation for installation of new fire alarm and make proper records to the fire and operation book.

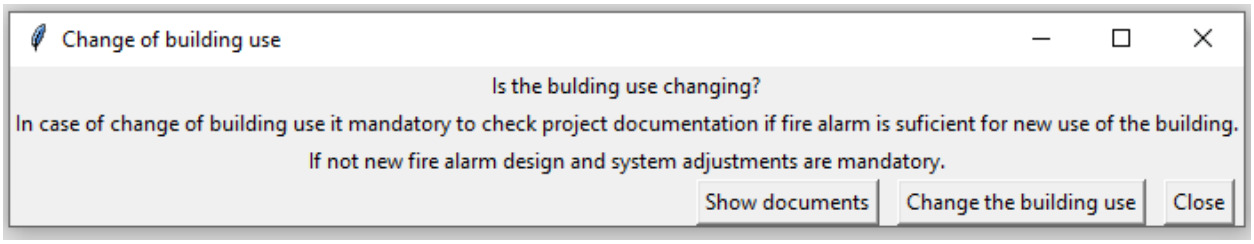
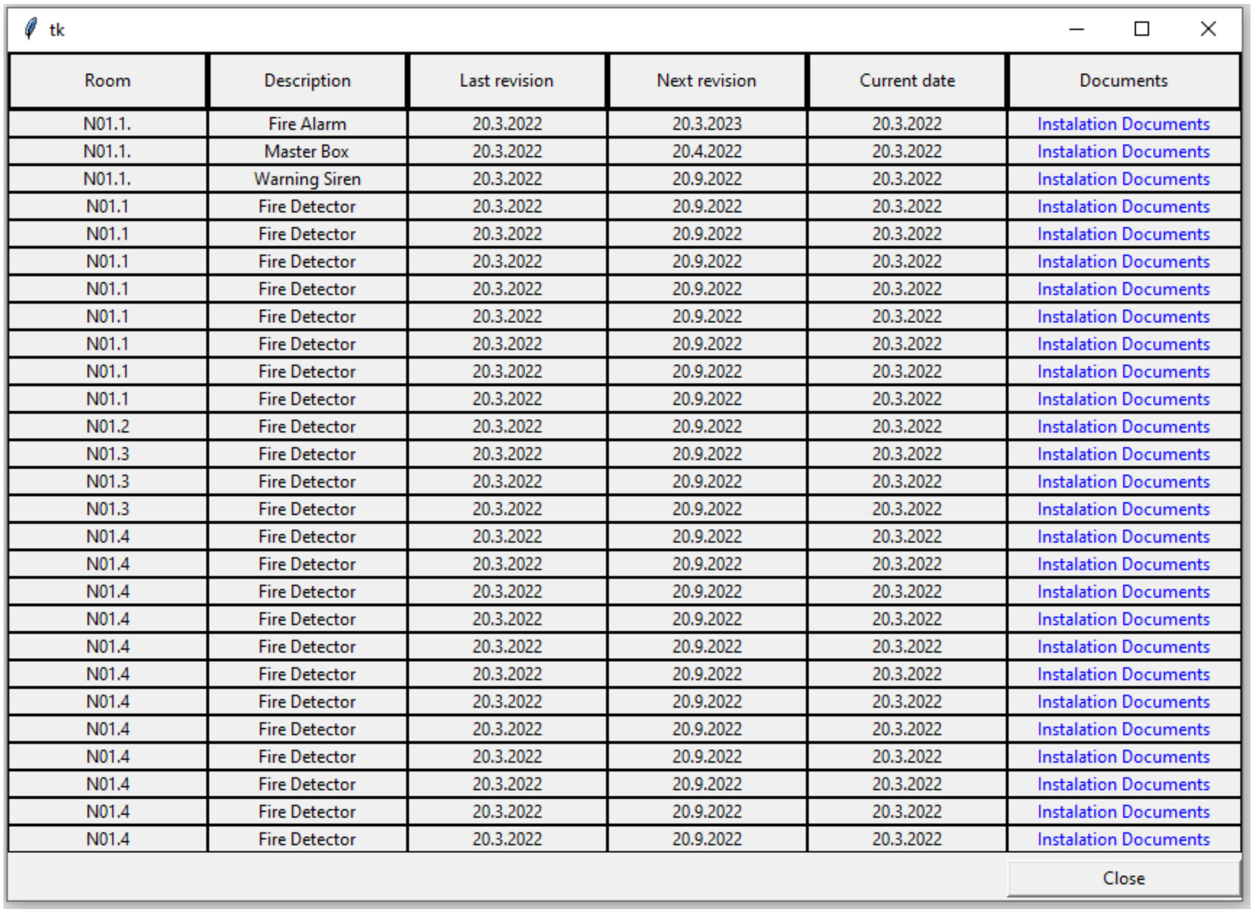


Figure 56 – Building change of use option window

To sum up, it is important to show windows with list of devices, operation book and fire book. List of devices is keeping track of every device in the system. It shows last and next revision and highlight devices in case they need revision or when they are damaged. Operation book is keeping track of every event which is important directly to the fire alarm system. All revisions, damages, unwanted alarms, changes, and other events are recorded. Fire book is up to date with everything which is happening around building fire safety. It records same events as operation book. On top of that there are records about the fire inspections, staff training and practical alarms.



tk

Room	Description	Last revision	Next revision	Current date	Documents
N01.1.	Fire Alarm	20.3.2022	20.3.2023	20.3.2022	Instalation Documents
N01.1.	Master Box	20.3.2022	20.4.2022	20.3.2022	Instalation Documents
N01.1.	Warning Siren	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.1	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.2	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.3	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.3	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.3	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents
N01.4	Fire Detector	20.3.2022	20.9.2022	20.3.2022	Instalation Documents

Close

Figure 57 – List of devices window on the end of simulation

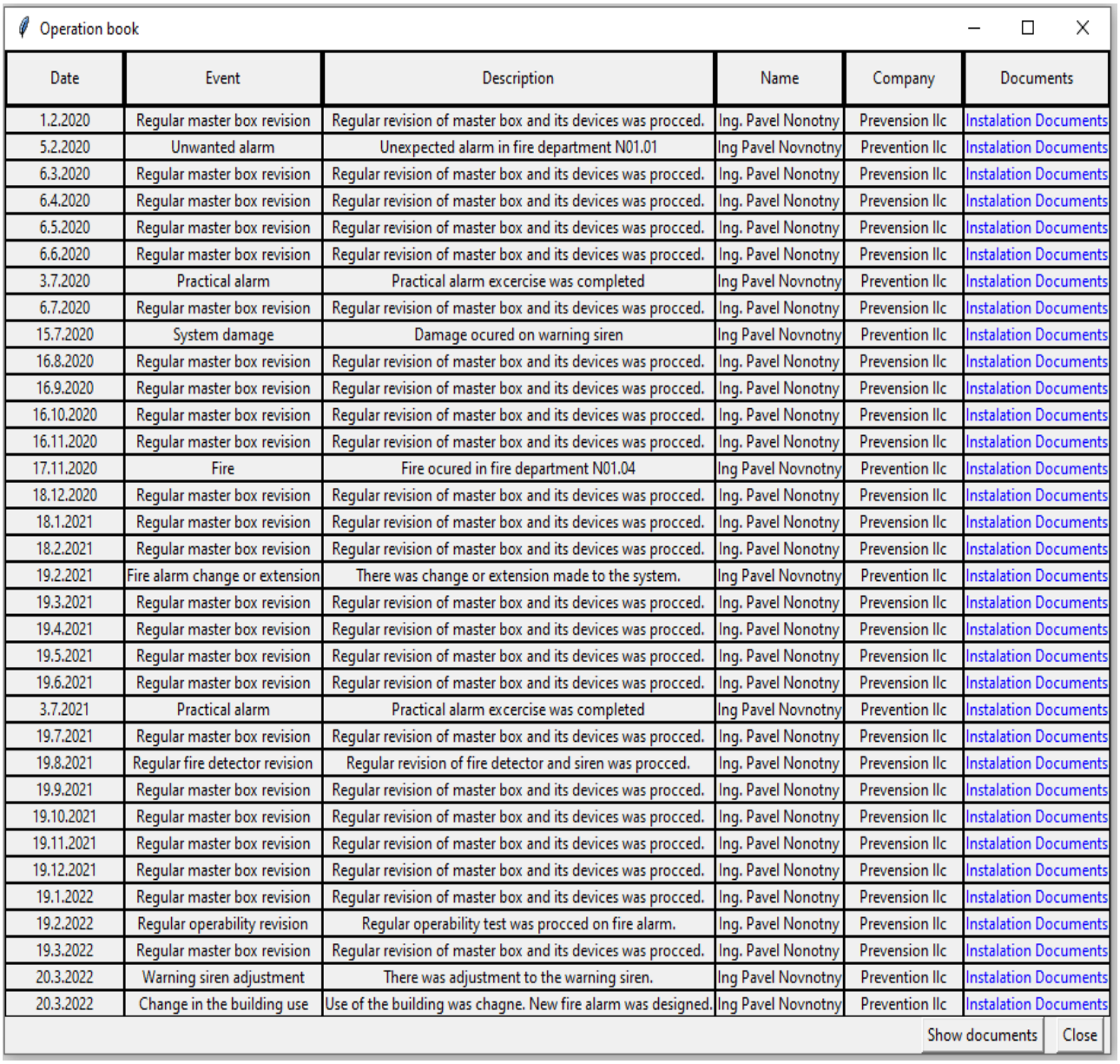


Figure 58 – Operation book on the end of simulation

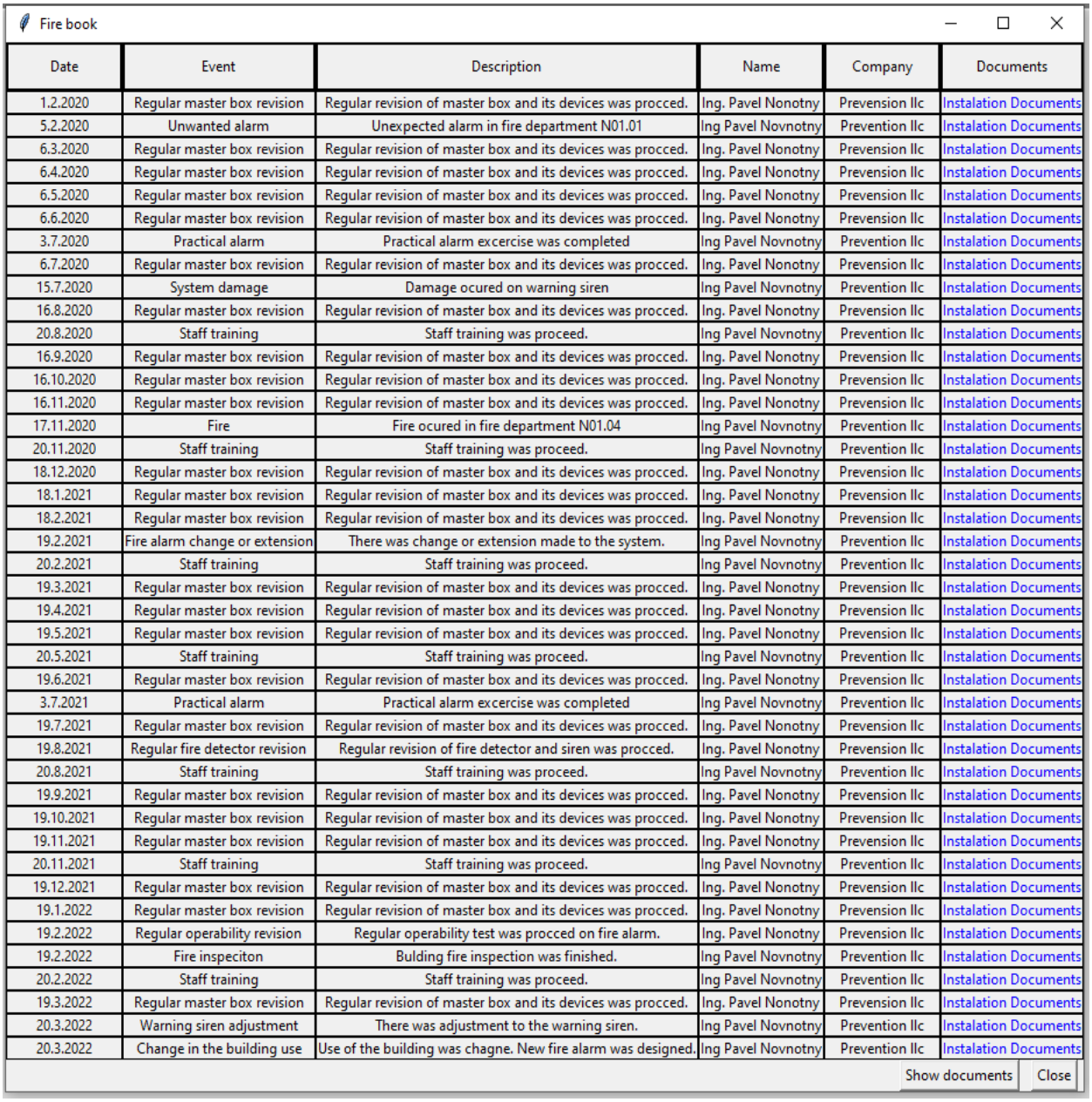


Figure 59 – Fire book on the end of simulation

In general, this example showed in Figure 34 was developed to verify the software concept and the idea. In the present the software is not ready to tackle more complex tasks. Since it was built from ground up it will need more development before putting up with more complex jobs.

Overall, this simulation give user an idea how can software cooperation with model automate certain tasks and simplify work for building operation staff. With connection to fire

department it can also help fire department with keeping up current documentation and revision process. In the end it will make the fire protection in the building better.

5. Summary

Building information modeling was used in this work as a key element. Entire work focuses on automation and work simplification with help of central building model and database. In the first part of the work, necessary theoretical fundamentals were laid down. There is description and summary of topic in fire safety solution, fire alarm with focus to legislation and life cycle. Also, there is a summary of documentation for building fire protection. Following the topics mention above there is a chapter about uniform electronical documents which unifying process of evaluating fire safety devices. In the end everything is connected in chapter about building information modeling and its development and implementation in the Czech Republic and in other European countries.

The developed software is touching three important areas in building life cycle and its fire safety devices and documentation. In the begging it simulates designers work and it automate the task of fire detector placement to the model.

This software feature can load floor plan and iterate through rooms and place fire detectors to each chosen room, so every space is protected by alarm. In the present the software is not ready to tackle complex tasks. Since it was built from ground up it will need more development before dealing with more complex jobs.

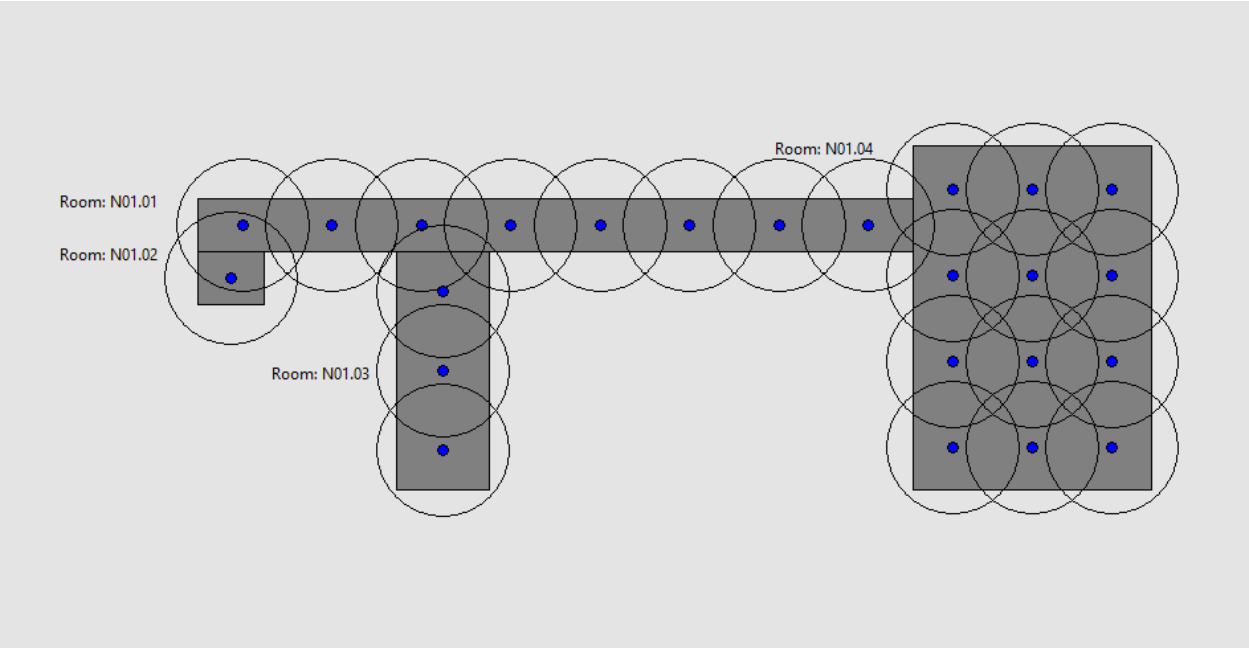


Figure 60 – Automation of fire detector placement into given floor plan

In the second part of simulation there are regular and irregular evets which happens during the building life cycle. Every event is handled by software.

Software tool alert about the event, leads user through process how to handle the event and generate necessary documents for processing the event. Also, it can simulate changes and extension for alarm system.

Software uses simplified processes for handling those kinds of events with alert, revision updates and documents generation. Last area is documentation of building fire protection. Keeping updated documentation, performing staff training and proceed regular inspection is the cheapest way for better building fire protection. Software simulates events which are usually part of fire protection documentation like fire inspection, staff training and practical alarms. On Figure 61 and 62 there is presented example for future displaying a coming up events and its handling.

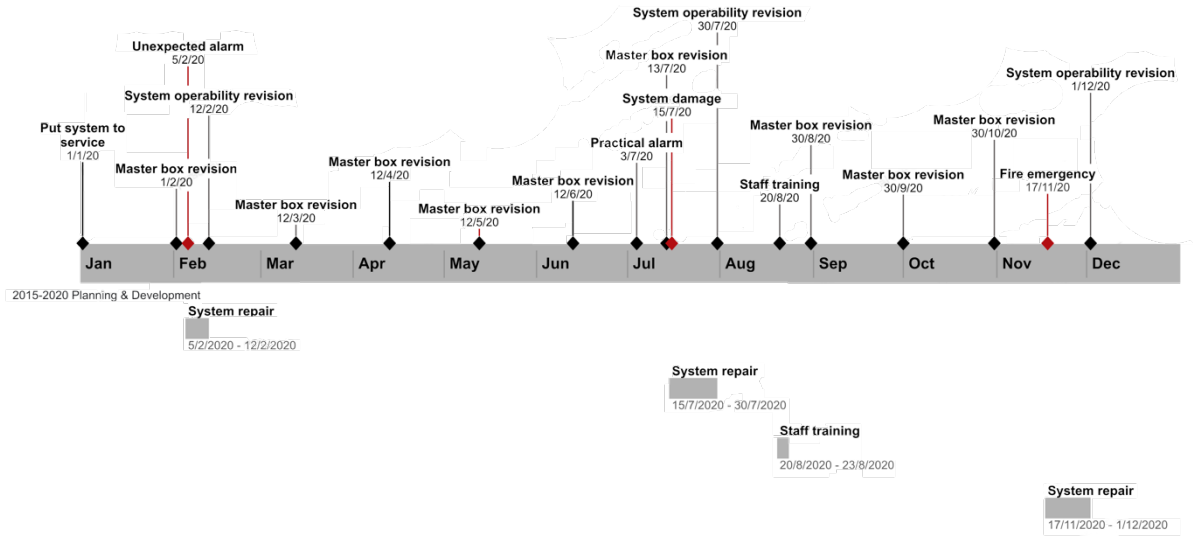


Figure 61 – Building life cycle and future events processed by software

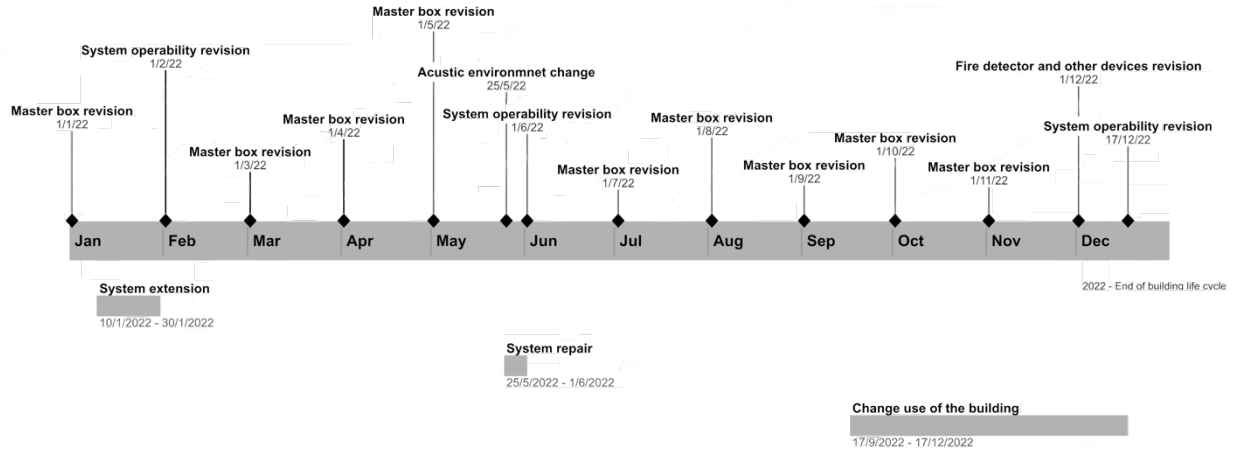


Figure 62 - Building life cycle and future events processed by software

Developing a software which can handle everything mentioned above with good user interface, all possible scenarios and great deal of automation is a complex task. Automation of

design process can be very complicated topic. There are edge cases which are not clear in legal standards. For example, it is not clear precisely what kind of revisions and test are necessary after simple system service or how exactly the test is processed and so on.

For further development the MVP (minimal valuable product) would contain clear and well-organized documentation storage system, which will be shared with fire department. Storage system will contain all needed documentation about systems, devices, and revisions. Documents will be generated automatically with opportunity for user to add details and descriptions. This all is possible with an assumption that authorities will use electronic signatures and certifications of documents.

6. Future Works

In the next work, it would be possible to prepare:

Detector placement algorithm improvement and more exploration in the fire alarm design process automation.

Building information model extension for fire brigade. Highlighting fire safety devices, showing information about corridors and about dangerous areas in the building.

Building information model extension for sprinkler system design.

Exploring possibilities in automation for fire inspection and fire safety device revisions.

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