Final Work Report

Delivery Phase 2

07-07-2021

BIM based permit procedure

Development of a software solution for the BIM based model checking service

Reach-U

Republic of Estonia Ministry of Economic Affairs and Communications

European Union European Structural and Investment Funds

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Index

1a. Juhtimise kokkuvõte

Käesoleva projekti eesmärgiks oli luua BIM-põhine ehitusloa menetlemise teenus Eesti riiklikusse Ehitisregistrisse. Veendumaks, et sellise lahenduse jaoks kasutatakse parimat tehnilist lähenemisviisi, teostati eelnevalt ka prooviprojekt kontseptsiooni testimiseks (*Proof of Concept*). Nimetatud kontseptsiooninäidise raames viidi läbi uuringuid ka teiste samas valdkonnas tehtud eksperimentide kohta maailmas, mille põhjal valiti rakendamiseks lõpuks veebipõhine mikroteenuste arhitektuur, mis kasutab nii reeglipõhist kui ka eelistatavalt algoritmipõhist lähenemisviisi ning peaks viima hõlpsasti kasutatava, paindliku ja skaleeritava BIM-mudelite kontrollimise teenuse esimese versioonini riiklikus ehitisregistris.

Eestis on BIM e-ehituse strateegia lahutamatuks osaks, loomaks tõhusamaid avalikke teenuseid ja pakkumaks avatud juurdepääsu ehitatud keskkonnaga seotud avalikele andmetele. Käesolev projekt on selles strateegias üks esimesi samme, aitamaks BIM-i juurutada ning suurendamaks ehitamisega seotud avalike teenuste tõhusust. Pikemas perspektiivis suurendab projekt BIM-i kasutamist ja ehituse digitaliseerimist Eestis, mis viib ehitise elutsükli kulude vähenemiseni. Samuti paraneb ehitise elutsükliga seotud avalike teenuste tõhusus ja kvaliteet.

Pärast esimest kolmekuulist analüüsietappi, mille jooksul uuriti põhjalikumalt esialgse ülesande teostatavust ja tegelikku rakendatavust, töötati projekti teises, kuue kuu pikkuses etapis välja riikliku ehitisregistri tegelik esimene BIM-kontrolliteenus. Arvestades projekti uuendusmeelsust ja paljusid väliseid sõltuvusi, läheneti projektile agiilselt. Ootuspäraselt selgus projekti elluviimise käigus, et nii mõnelgi juhul oli vaja alternatiivset lähenemist või mõned asjad võtsid planeeritust rohkem aega. Sellegipoolest on aga tänu heale ja tõhusale vastastikusele suhtlusele välja töötatud toimiv, paindlik ja skaleeritav esimene BIM-kontrolliteenus.

Kuna EHR-i uue menetluskeskkonna arendus ei olnud käesoleva projekti lõpuks veel valmis, ei olnud võimalik ka tegelikku juurutamist läbi viia. Seetõttu ei ole BIM-teenus lõppkasutajatele veel päris EHR-i keskkonnas saadaval. Vaatamata sellele on komponendid siiski teiste teenustega ühenduse loomiseks valmis ja BIM-moodulit on võimalik avalikustada kohe, kui need teenused on saadaval.

Eesti saab seega olema üks esimesi riike maailmas, kus ehitusloa menetlemise abivahendina on kasutuses üleriigiline BIM-teenus. Nii saavad kõik ehitusloa menetlusega seotud osapooled tasapisi BIM-iga harjuda ja BIM-i kasutamisest hakkavad senisest suuremad kasud ilmnema. Kuna BIM-i kasutatakse tööprotsessides laiemalt, suurenevad teadmised ja toetus ehitise elukaare veelgi suuremaks digitaliseerimiseks. Samm-sammult on võimalik töötada ka selles suunas, et tulevikus saaks läbi viia vahest koguni täisautomaatselt toimivat BIM-põhist loamenetlust eesmärgiga veelgi lühendada menetluse kestust ning menetleva ametkonna ehitusprojekti kontrollimisele kuluvat aega.

Käesolev projekt jõuab lõpule peale kolmandat etappi. Kolmas etapp algab augusti lõpus ja on suunatud teadmiste edastamisele ning BIM-teenuse kasutamise koolitamisele.

1b. Management summary

The goal of this project was to create a BIM based building permit checking service within the Building Registry for the Estonian government. To make sure the best technical approach for such a solution was taken, a Proof of Concept was executed prior to this project. Within this Proof of Concept, research was also conducted into other experiments in this area in the world, which ultimately led to the selection of a web-based microservice architecture that uses both - rule-based and preferably algorithm-based approach, and should lead to a first version of an easy to use, flexible and scalable BIM checking service within the national Building Registry.

In Estonia BIM is an integral part of the e-construction strategy to create more efficient public services and to provide open access to public data related to the built environment. This project is one of the first steps in this strategy and will help implement BIM in organisations and increase efficiency of public services related to construction. In the longer term the project will increase the use of BIM and construction digitisation in Estonia, which ultimately will lead to the reduction of building lifecycle costs. Also the efficiency and quality of public services related to the building lifecycle will improve.

After a first analysis phase of three months in which the feasibility and actual implementation of the initial assignment was examined more closely, an actual first BIM checking service for the national Building Registry was developed in the second phase of six months of the project. Given the innovative nature of the project and the many external dependencies, the project was approached in an agile way. As expected, during the execution of the project it became apparent that sometimes an alternative approach was needed or some things took more time. However, due to good and intensive mutual communication, a solid, flexible and scalable first BIM checking service has been developed.

As the development of the new EHR procedural environment was not yet complete by the end of this project, it was not possible to carry out the actual implementation. Therefore the BIM service is not yet available live for end users. However, all components are prepared to connect with these services, so that the BIM service can be made public as soon as those are available.

Estonia will thus be one of the first countries in the world to have a country-wide BIM service at its disposal as an aid in permit processing. In this way, everyone involved can get used to the use of BIM and the benefits of using BIM are already being reaped. Because BIM will be used more widely in the work processes, knowledge and support will increase. It will be possible, step by step, to work towards a possibly fully automatic BIM-based permit process in the future.

The final stage of this project will be reached after phase 3. Phase 3 will start at the end of August and will focus on handing over knowledge and giving training on the use of the BIM service.

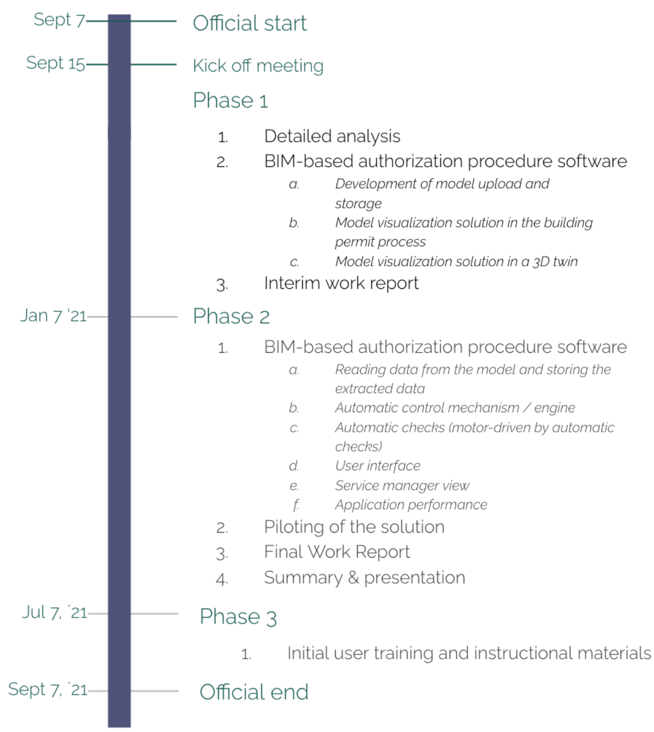
2. Introduction

In this final work report of the second phase of our project we describe the results and activities executed. The aim of this phase was to develop a software solution for the BIM based permitting procedure for the Ministry of Economic Affairs and Communications of Estonia (MKM).

In 2019 we, as Future Insight already had the honour to work on the Proof of Concept for this project. Building the first outline for a BIM based process for building permits in Estonia. A very innovative and challenging assignment, but also an assignment that fitted in perfectly with our vision and experience and which gave us the opportunity to bring this vision into practice. An opportunity to show what already is possible with BIM models and which impact this can have related to efficiency and effectiveness within the daily work environment. And not without result, the Proof of Concept was also noticed internationally and even rewarded with a 'Special Mention' during the international Buildings Smart Awards in October 2020.

We are pleased to have also won the tender for this actual first implementation of the service, for which we have entered into a close partnership with Reach-U. They also have extensive experience in carrying out innovative projects and were, for example, already involved in the development of the 3D Digital Twin proof of concept, on behalf of the ministry. Together we have all the necessary knowledge and experience available to bring this challenging project to a successful conclusion and Estonia can be one of the first countries in the world to start using a truly working online BIM-based permit checking service.

This project started in september 2020. The goal of the first phase was to analyse all the information that is in place. Regarding the proposed checks that should be executed, regarding requirements and classifications. Next to the analysis it was also the goal to get a first common understanding on the architectural setup of the software solution, the user interface and how certain functionalities could work. This was done to get a very solid common ground and understanding what will be developed in the second phase of this project and what is feasible and what not (yet).



The second phase is about the further development and design of the platform and the checks. At the same time, we also saw from the first phase that there was still enough research and choices to be made. The agile approach that was used was extremely suitable for this, whereby it was still necessary to look carefully at which developments are given priority and which are pushed back a bit further.

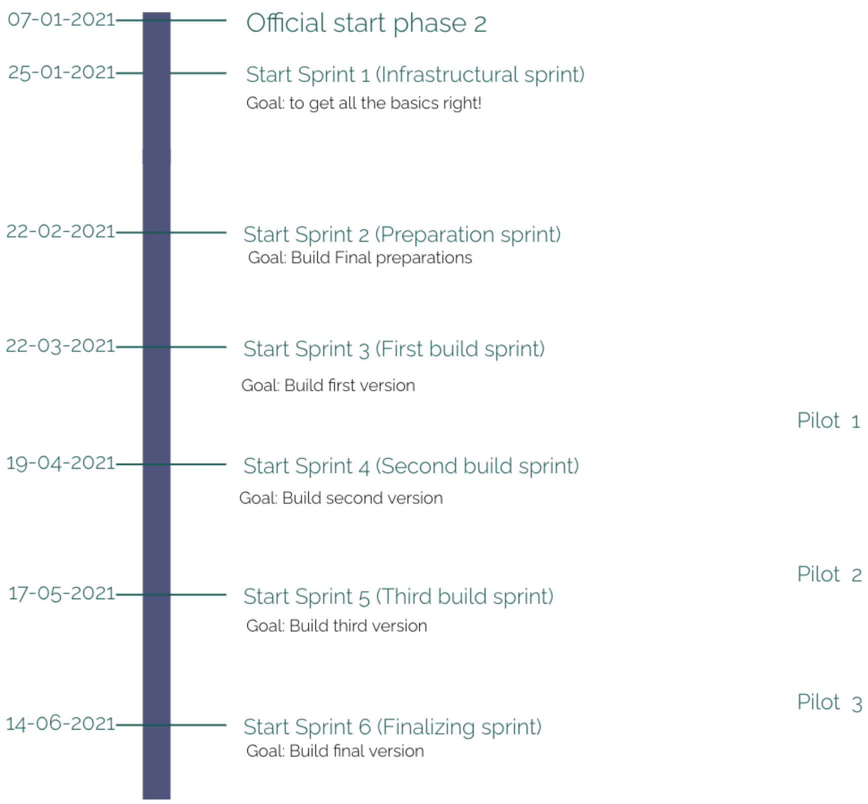
3. The approach of the development phase

3.1 Agile approach

As requested in the tender, the development phase of the project is carried out in an 'agile' manner. Although there is a clear specification of the central question in the tender, it is a very innovative project in a very dynamic environment. The specifications from the tender therefore should actually be seen as a starting point for the development. Experience shows that with these types of innovative projects, the goals and results can gradually change and the focus can shift. Certainly because there are many dependencies on parallel projects that require connection and the results of these projects that can also shift.

Such an 'agile' approach is common in software development projects and generally means working on concrete development parts in short sprints of several weeks. Depending on successful or less successful results, it is then decided in close consultation which parts will be tackled in the next sprint. This requires close coordination between client and contractor, but it provides a high degree of flexibility. This often ensures that all kinds of joint choices are made during the project, which result in a different yet better end result.

Six months were available for the execution of the second phase of the project. After a short preparation, these months were divided into six sprints of four weeks. This resulted in the schedule below:



The first two sprints were roughly reserved for general technical preparations and implementation. The BIM service had to be integrated into the new Building Registry that is still under development and which is fully based on microservices. In order to prevent that at the end of the project during the integration of the results, all kinds of unexpected problems were encountered, it was decided to start with this integration.

The last four sprints were then reserved for the actual development of the BIM service and the checks. It has also been taken into account in advance that the last sprint should actually be kept free for a completion. At the end of sprint 3, a first visible result should be ready, with which the planned pilots could be carried out.

3.2 The collaboration

Good and clear communication is very important to be able to switch quickly and effectively in such an innovative project. To this end, good agreements were made at the start of the second phase about the cooperation between client and contractor, in which full openness and modern means of communication are the key points.

Below is a brief overview of the work agreements and tools that were used during the development phase.

- Weekly meeting
  A standard general work meeting was scheduled every Tuesday afternoon. Progress was discussed here and questions could be asked and decisions made. Parallel sessions were also planned for specific topics such as the more technical organization of the BIM service and the configuration of the checks to specifically discuss these topics.
- 4 weekly delivery
  It has been agreed to work with sprints of 4 weeks. At the end of each sprint, a short overview of the results and the successes and setbacks was made. Based on this, the course was adjusted where necessary and the priorities for the next sprint were determined.
- Open activity planning in 'Monday'
  Since the planning of the activities was quite fluid due to the Agile approach and we had to work together remotely, it was important to use a clear and open tool for this as well. By keeping track of the workload on one joint board in Monday, it was easy to always get a good idea of the latest state of affairs.
- Shared working documents in Google Drive
  A shared Google Drive environment was used for working on joint documents. The client's employees were also able to work directly in this, which also made this collaboration very smooth.
- Direct communication using Slack
  In addition to email for more formal communication, a shared Slack environment has been set up for direct communication. This also worked well to achieve fast and fluid communication between all participants in the project.

3.3 The minimal result

As indicated earlier in this chapter, it is very difficult to look and plan far ahead with these kinds of innovative software development projects. At the same time, a very extensive list of requirements from the tender has been listed in the last chapter of this report. Naturally, the goal has always been to tick off as many of these requirements as possible.

At the same time, at the beginning of the second phase, the discussion was held on what should be the minimum end result at the end of the project in order for the project to be called 'successful'.

This is a useful tool for making choices during the project and when determining the content of the sprints. Which developments should be given priority and which could possibly be eliminated. The following description came out of this:

> Ultimately, it is most important to realize a stable and reliable BIM service that gives employees at all municipalities in Estonia a simple and accessible way to deal with BIM designs properly. The usability of the service and available checks are more important than the exact number of functions or checks.

4. The sprints

4.1 Sprint 1: Infrastructural sprint (25-01/12-02)

The first two sprints of the project were about getting the basics in place and integrating the components into the new Building Registry, which is completely based on microservices that communicate with each other via open APIs. This connecting project is also fairly new and still in full development. In order to connect well with this infrastructure, The core of various basic components had to be adapted. In order not to run into all kinds of surprises at the end of the project, it was decided to start this integration as early as possible in the project.

Goals

Technical:

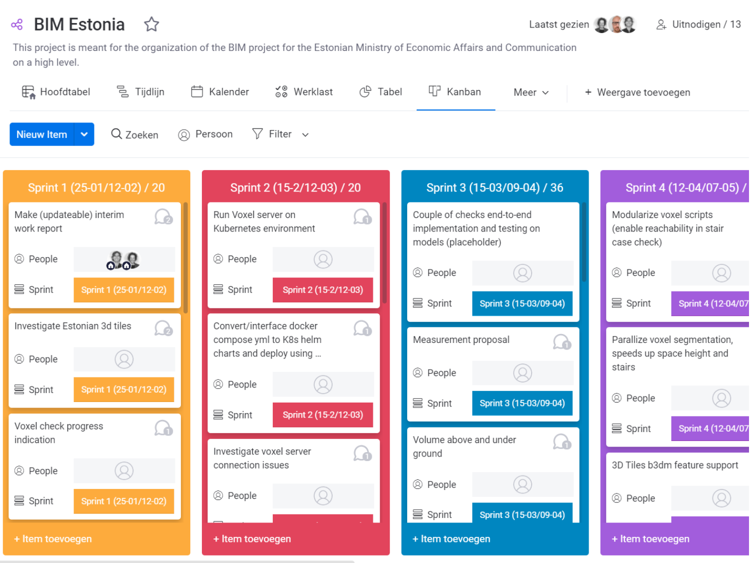
- *Add demo to staging environment MKM according to required procedures & some improvements*
- *Technical architecture clear*
- *First version BCF export*

Non Technical:

- *Design the way of working in sprints and supporting tool to keep track on activities*

Results

During the first sprint we were able to divide the total tasklist into 6 sprints. For every sprint the main goals were set. We decided to use Monday as our tool to structure all the work that needs to be done and to keep track of our progress related to the activities. All the activities are placed in the right sprint with the right owner. Everyone in the project has access to Monday, the ministry as well. In this way it was transparent for everyone what the current status was.



Next to this practical way of working setup, the first meetings took place regarding the enterprise architecture database and the wireframes. In the end we managed to:

- Finish the installation of BIM.Works on the staging environment.
- Implement the BCF export within BIM.Works.
- Improve the logging of the Voxel server.

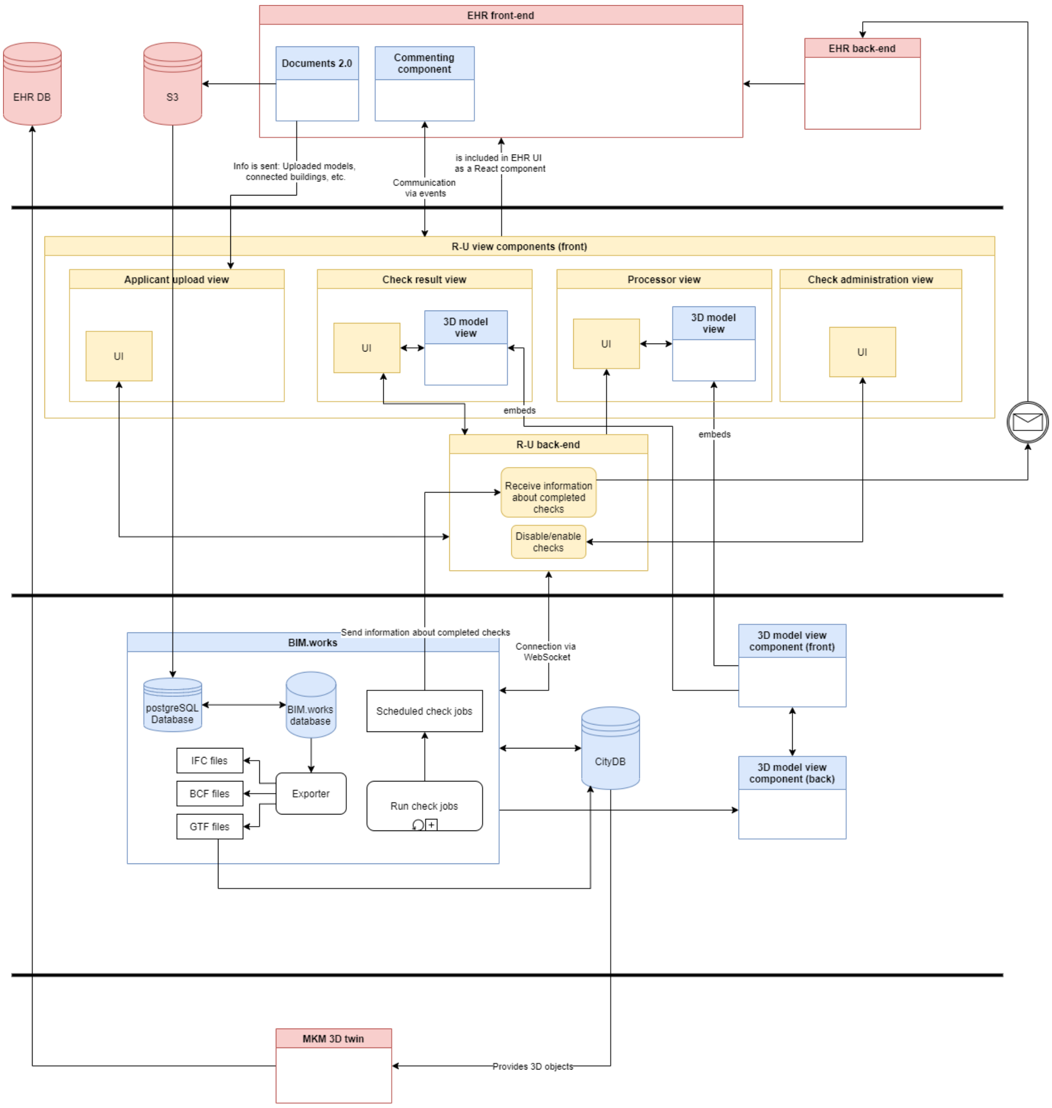
4.2 Sprint 2: Preparation Sprint (15-02/12-03)

Goals

As mentioned above during this sprint the focus was still about getting the basics in place. The Bim.Works on the staging environment needed some improvements and the testing of the deployment needed to be done. We wanted to further detail the technical architecture and have the first iteration session on the UX designs. Finally we wanted to dive deeper in the topic of extracting data regarding 3D Twin (& geo-location as well on BIM data through API.

Results

During this sprint we were able to create the overview of the technical architecture.
This helped us to get the overview on all the elements that needed development and-or integration.



Overview of BIM module elements and its relations to other EHR components and services

During this sprint we had our first iteration session for the UX design on March 9. The file upload, wish for commenting functions and switching between versions was the most under discussion and will be picked up further for the next iteration session.
Furthermore the connection with the digital twin project had been laid, Overall this sprint gave us the feeling that we really started the project

4.3 Sprint 3: First development sprint (15-03/09-04)

Goals

The goals for this sprint were about developing. Developing the first checks, developing a first working service and developing further on the UX design. Several elements are crucial for this like the building zones and spaces and the integration with the MKM environment.

Results

We found out during this sprint that there were still some topics pending. Due to this there wasn't that much to show in the front end. In the back end the progress continued. One of the pending topics was regarding the file upload function for the UX design, which needs to be integrated with another module in the Building Registry. That module was not ready yet and the desired solution couldn't be developed further. We decided to move the second iteration session to the fourth sprint. In the backend a clean and simple, but very useful measuring tool was developed, we also took care that multiple IFC models can be checked during one check. As in most cases multiple models will be uploaded during a check that are in the same environment. So one application can consist of multiple buildings, and for each of those buildings different discipline models can be uploaded.

4.4. Sprint 4: Second build sprint (12-04/07-05)

Goals

The main goal for this sprint was to get a first demo working on the MKM development environment, so we could start the piloting phase as well. Next to that the second iteration session regarding the UX design should take place and more checks needed to be developed. Finally we discussed that functions like commenting and file upload should become clear during this sprint.

Results

The main goal to have everything running on the MKM development environment wasn't completely finished. There were some last issues to be fixed in the next sprint, but most of the buttons in the BIM services are working now. Next to that a lot of progress has been made in simplifying and redesigning the solution based on the BIM requirements. Some minimal additional BIM requirements have been added which are really necessary to execute the basic checks. Furthermore, a start has been made with the development of a test BIM design according to these requirements to be able to test the developed checks. Also the possibility to hide objects from the 3D Digital Twin and get additional information from the 3D Tiles per object has been added to the 3D viewer. As the latest version of the service is every week shown and discussed we agreed to further skip the iteration sessions as these became redundant.

4.5. Sprint 5: Third build sprint (10-05/04-06)

Goals

During this last building sprint the focus was on getting everything running on the MKM development environment. We agreed to make an overview of all demands from the tender document and discuss together per point what needs to be done to finish them. The first final version of the BIM service will be built with all (most) functionality within this sprint. This way we should be able to detect issues and improvements as soon as possible and still have time in the finalizing sprint to improve them. The results will be made available in the demo environment. This way we can test both the results of the checks and the user interface and use the feedback to make improvements.

Results

The BIM service is available on the MKM development environment. The environment is a bit slower then our own development environment, This is still a work to do. The latest topics regarding the architecture and integration are discussed like the notification topic. The service manager view is developed and agreed upon. The next sprint will start with an overview of the To Do's and Not To Do's to make the expectations on the delivery clear.

4.6. Sprint 6: Finalizing sprint (07-06/07-07)

Goals

This last sprint is made very specific, what are still the to do's and the not to do's. Downunder the summary is given.

To do	Not to do
Finalise 26 feasible checks + 3 Voxel checks	IDS checks
Determine feasibility fire safety checks (5/10)	Graylog logging
Finalize exported data	Zabbix
Tasks depending on DNS/connectivity	Gitlab customizable code
Remap mouse & keyboard control (list Jaan)	Remaining checks
Implement terrain	90 degrees topic
Fix height issues	
Finalize connectivity graph	
Maleva model	
BIM module deploy to MKM	File upload integration with Files 2.0
File upload - mocked solution	Commenting by Processor
Notify users about "files ready" and "checks finished"	Detecting and deleting unnecessary files from BIM.works
Implement measuring tool	Admin: check scheduling
Switching between processing rounds	Zabbix
BCF download	Not to check the files that have not been changed between two check rounds
Commenting by Applicant	
Cancelling checks	
API endpoints	
Admin module (statuses, groupings)	

Results

In this sixth and final sprint, all developed parts were connected, the last changes were made and everything was implemented on the MKM development environment.

5. The final results

5.1 The BIM module

5.1.1 User interface

In terms of user interface the following main requirements were set by the customer:

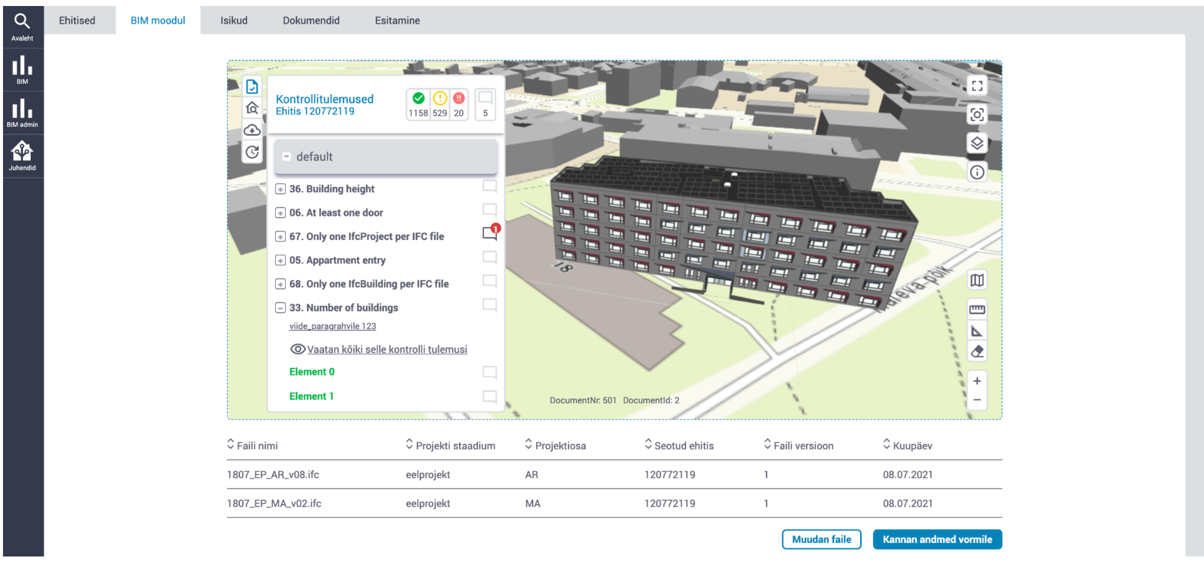
1) It must be simple, logically usable for the licensing officer who is not a BIM specialist.
2) It must comply with the e-construction style book.

In order to make the planning process of the user interface as open as possible, and to create an opportunity for operative communication, a Figma space was created already in the first phase of the project. Initially, wireframes were created to agree on a general concept, but due to the fact that there is already an existing set of clearly defined user interface elements for the EHR, it was possible to move quite quickly to prototypes based on the actual design elements. In addition to the design book, an already functioning 3D-twin user interface was an important point of reference.

The BIM module UI is located in a separate tab in the general EHR interface for applying for a building permit. The tab is created and is available only if the applicant decides to submit a BIM-based permit application. .

The BIM module view consists of a 3D viewer and a table of currently used ifc-files. What exactly can be seen and done in the module depends on the role of the user and the rights granted.

5.1.2 3D-viewer



The 3D viewer is the most important part of the BIM module. It displays and navigates models, as well as the results of the automatic checks.

A detailed description of the 3D viewer and instructions for navigation are described in the user guide document.

5.1.3 Table of files

Table of files below the 3d-viewer displays a list of IFCfiles associated with the open document. It also indicates which building ID the files are associated with and when they were uploaded.

In the current version of the module, delivered in the scope of this project, there is a possibility to mock file upload until final integration with the EHR environment is completed. To allow different situations to be played through, a number of files have been pre-uploaded to the server, parts of which form a single building (defined through the same EHR code) and some contain different disciplines. It is possible to create new applications (document) and procedure rounds (document versions) to create the various possible procedural options.

5.1.4 Data extraction

In addition to the integrated 3D BIM viewer and automatic checks, technical information of a building is also automatically extracted from the BIM models. Some examples of this information are the used area, height of the building, fire safety class and type of building. This data can be used in other places in the Building Registry to simplify the processes. For example, the automatic completion of fields in the application process, which previously had to be filled in by hand. This saves time but also prevents errors. This extracted information is directly derived from the design, which previously the applicant usually had to look up or come up with resulting in mistakes. A complete list of all extracted data is available in Annex 3.

5.1.5 Technical architecture

An important prerequisite for the BIM-module to be created was its integratiability into the overall authorization process of the EHR. This meant that both - integration to the overall structure of the EHR, and compatibility with components and services that were already available, and also with some still in development processes, had to be taken into account.

Throughout the analysis process, we worked on a separate architectural document which grew with continuous refinement of the information.

The BIM module is implemented as a microservice in EHR. The EHR UI provides the necessary information to the BIM module micro-frontend. The main principles have been integrability on the one hand and the principle of separation on the other. Throughout the analysis process, we have tried to think along about the compatibility of other related components and services, as well as to find solutions to cover the functionalities of the missing links (e.g. IFC files migration from “Documents” tab and commenting function of permit processor, which is an independent microservice), so that the BIM module can be developed as far as possible.

The detailed structure of the BIM module and its links to other parts of the EHR are described in a separate document "Architecture and integrations".

5.2 The implemented checks

5.2.1 Introduction

During the first phase, a total of 64 checks proposed by the Ministry were analyzed (Annex 1A). The proposed checks were derived from various regulations listed below.

- M85: Housing requirements
  https://www.riigiteataja.ee/akt/109072020017
- M97: Requirements for construction projects
  (https://www.riigiteataja.ee/akt/118072015007)
- M28: Special needs of people with disabilities
  (https://www.riigiteataja.ee/akt/131052018055)
- EhS Design Conditions
  https://www.riigiteataja.ee/akt/130102020006
- M62: Requirements for construction project expertise
  (https://www.riigiteataja.ee/akt/109062015025)
- M17 Fire safety requirements for buildings and requirements for fire water supply
  (https://www.riigiteataja.ee/akt/130112018012)

The conclusion of this first analysis was that **32** checks should be able to be implemented properly. For **25**, the feasibility was questionable due to complexity and additional requirements for the BIM designs used. With **7** checks it was immediately decided that they were not feasible due to the complexity, but also because some were not really checks. For all checks, assumptions have been made about the minimum availability of certain types of objects and additional properties for the execution of the checks. To avoid too much dependence on the quality and content of the BIM files, an algorithm-based approach was preferred when configuring the checks. However, practice has also shown that part of the checks will almost always be rule-based, for example to select the correct objects that need to be checked. The BIM requirements, which were set up in a parallel project, were not yet available during the analysis phase, so that they could unfortunately not yet be taken as a starting point.

5.2.2 Rule based & algorithm based checking approach

The most commonly used way to perform BIM checks is the rule-based method. Selections are made and values are checked on the basis of properties that are linked to BIM objects. The disadvantage of this is that these properties are often entered manually by the modeller and such a check is therefore very error-prone and not very intelligent. It is important that all these properties are always named and classified in the same way by the different modellers in order to get the same results. A typo or a different spelling of a certain object can already lead to false positives or negatives. Moreover, it is necessary to draw up extremely extensive and detailed BIM specifications, in order to be able to perform extensive rule-based checks, which in turn must be complied with by designers and developers. Experience from various initiatives in recent years shows that it is very unlikely that this will succeed. At the same time, it is also clear that a minimal use of rule-based checking will be required when implementing checks.

A newer and less used way of checking is the algorithm based check approach. This is based more on the pure geometry of the BIM design and smart calculations and analyzes are used to perform the checks. As a result, there is less dependence on the pure input of the modeler and the quality of the check results is higher. It also becomes possible to perform new types of checks, which are not possible in the traditional way, like calculating the escape routes. The algorithm-based checks can take all kinds of forms, such as Artificial Intelligence and Machine Learning from various suppliers. It can be connected via the microservice architecture. In the configuration of the checks for this project, the Voxel server has already been used in a number of places, just like during the PoC. The Voxel server is an external service that communicates via a standard interface with the central BIM service and performs purely geometric voxel-based checks. For example, the escape routes and minimal headroom checks are done in this way. To make this possible, it is all the more important to continue to maintain and further intensify the use of open standards and APIs. This will create an increasingly intelligent and reliable checking ecosystem, with smart checking services from different suppliers.

It will be a constant and structural consideration to see how checks can be constructed smartly from rule and algorithm based components. Taking into account minimal impact on the expansion of the BIM requirements and maximum reliability of the result.

5.2.3 The implementation of the checks

However, when the final BIM requirements became available in the second phase of the project, much of this data was not available in the BIM models that were available for piloting. Therefore a new approach had to be defined for most of the checks. Although the design of the checks has been based on an algorithm-based approach as much as possible, most checks still require a rule-based part. For example, to select the right rooms that need to be checked. A correct classification of the objects is crucial here. The ifcZones that were required for many checks were not present in the models and it is also unrealistic to expect them to be added from practice in the short term. That 's why during this process, a set of minimal BIM requirements were specified that are necessary for the currently developed checks to work properly. These requirements are a selection of the general BIM requirements and are detailed in Annex 1. It is of course better if all BIM requirements are met, but these are the minimum for the current check to function properly. This only concerns adding specific properties to objects, assuming that the BIM models are modeled according to the coding and guidelines of Building Smart[1]. Ultimately, this new round of analysis led to a total of **48** checks actually being implemented and **25** checks not being realised. A list with a description of the checks is attached in Annex 2

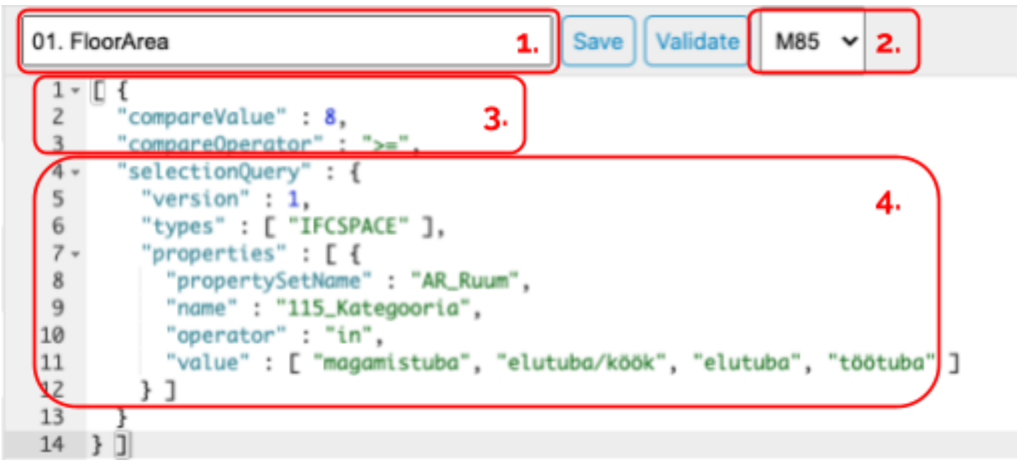
One of the already expected risks, the incorrect classification of the supplied IFC designs, made us decide to develop a number of extra checks that check the quality of the supplied data. For example, an extra check has been added which checks whether the geo-location has been added correctly and one that displays ifcProxy objects (which are not desired). The challenge is that when incorrect data is supplied, the checks will produce incorrect results (false positives or negatives). It is therefore very important to first get an idea about the quality of the data, to also get a good understanding about the quality of the check results. Since only limited requirements can be imposed on the BIM model to be delivered in a first step such as this, it is not yet feasible to check the regulations fully automatically. The current check service should be seen more as a tool for permit assessors to deal with BIM models and to gain quick insight through the checks. In the longer term, the service can be expanded further and further, eventually becoming a true fully automatic service. For this, however, not only the technology but also the BIM requirements, legislation and other frameworks and regulations will have to be further digitized.

[1] https://standards.buildingsmart.org/IFC/RELEASE/IFC2x3
https://technical.buildingsmart.org/resources/ifcimplementationguidance/

5.2.4. Configuring the checks

To ensure that a scalable and flexible service is created that can grow with developments and needs, we made it possible to expand or adjust the checks. The design of the BIM service broadly consists of two parts. The checks themselves are configured and performed in the BIM.Works service. They can be switched on in the 'service manager view' of the BIM service on the e-Construction platform and linked to the correct check procedures.

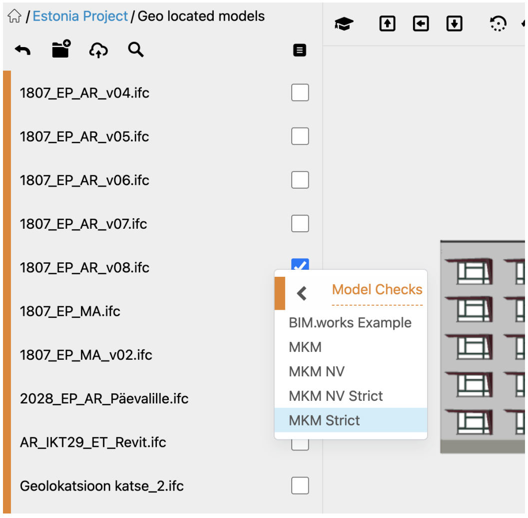
To explain how the configuration of these checks work, the setup of the first check is explained in some more detail.



1. When a new check is configured in BIM.Works, a 'basic' function is first selected. In this case this is the 'FloorAreaCheck' which calculates the area of a space based on the actual geometry of the design and therefore does not assume a specified value. All developed functions are available in this way and can be reconfigured to define 'new' checks.
2. Also a 'trigger' can be specified, for this check this is the M85 regulation. In this case it means that this check is only performed on buildings with a certain function (KAOL code) which is supplied as an extra property with the building object. These 'triggers' can be configured and reused separately as a special check.

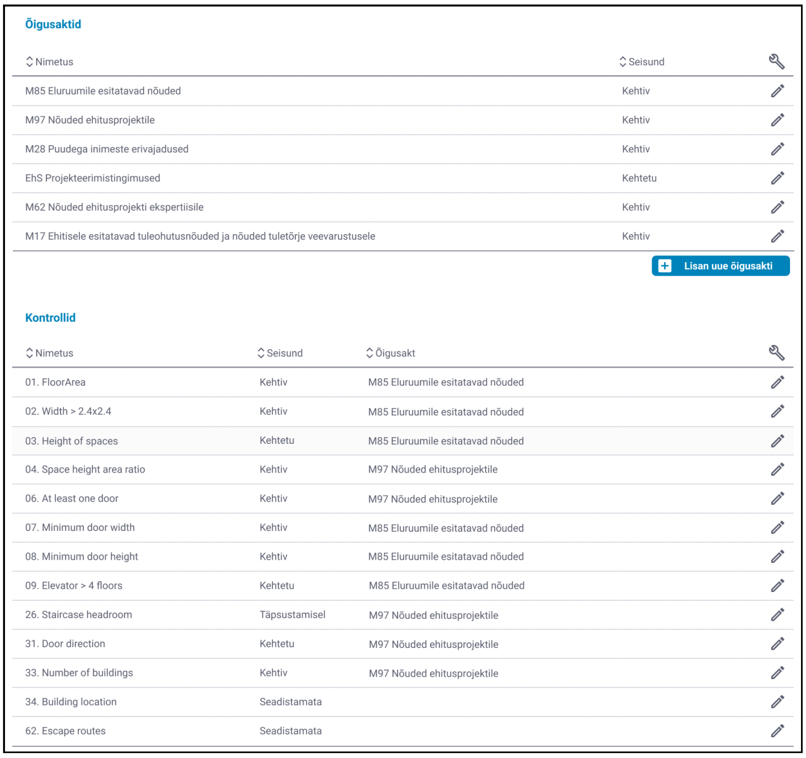
3. The checks are configured by entering a simple piece of Json code, with a fairly standard structure. First, the values that the objects must meet are specified. In this case, the room must be at least 8 (m2) in size.
4. It is then specified to which objects this check applies. In this case, all 'Spaces' with propertySetName 'AR_Ruum' where the properties of '115_Kategooria' are 'magamistuba' (sleeping room), 'elutuba/köök' (living room / kitchen), 'elutuba' or 'töötuba (working room)'.

The check can be tested from the BIM.Works environment by opening a BIM model and executing the appropriate check set. The 'MKM strict' set is the one which is used by the central BIM service.

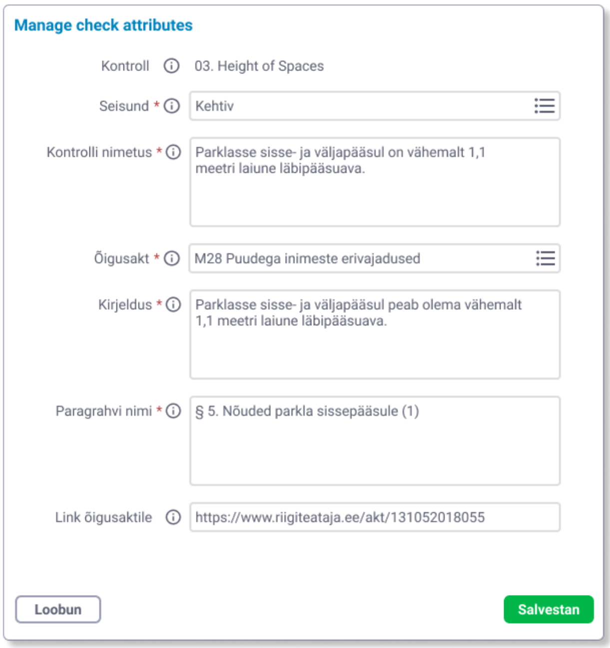


5.2.5. The 'Service Manager View'

When the configuration of the check is ready, it can be 'enabled' through the 'service manager' module of the BIM service on the e-Construction platform. From the total list of checks the new check can be edited and for example be added to the regulation group that is.



The additional information, for example error description can then be entered for each check. Only after the check has been configured here, it will be automatically executed in the relevant processes.

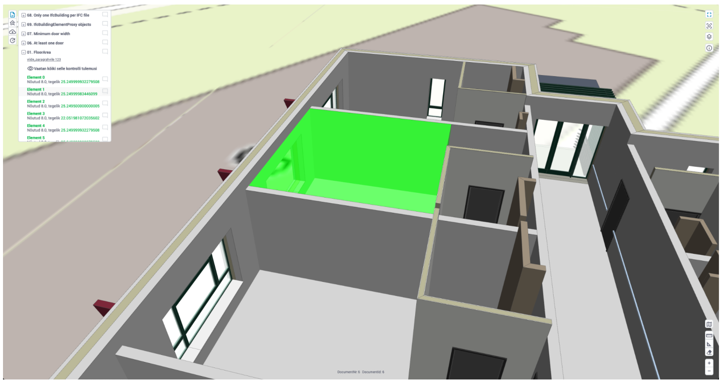


5.2.6 Type of results

A check can yield different types of results with associated visualizations. Below is an overview of the different options.

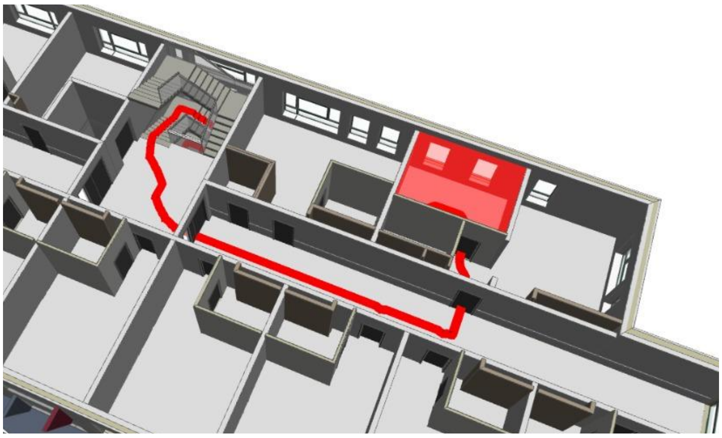
Results linked to geometrical objects

When a check result can be linked one-to-one to an object from the BIM model, it will be visualized in this way. In check 1, for example, it is checked whether the surface of certain rooms is at least 8m2. The result is visualized by coloring the corresponding Space object green (good) or red (wrong). When a result is selected in the list, all objects on the floors above this object will automatically be turned off in the viewer and the view will zoom in on this object.



Results with new geometry

In the case of a voxel check, new geometry is created. In the example on the right you see the result of the 'fire escape route check'. The method to just highlight existing objects no longer works and a new geometry is generated. In this case this is the line showing the escape route. Projecting this geometry in the model creates a good picture of the results of the check.



Results with general information

Finally, there are a number of checks that retrieve or calculate more general information from the BIM file, such as the building height, the building function, or the maximum number of users of the building according to the design. This information is displayed and can be input for the permit issuer, but cannot be visualized in the model.

6. Lessons learned

- A lot is already technically possible, but there are many organizational and legislative dependencies to realize a real conclusive solution. To get the checks really 100% correct, additional information is often needed from other systems that are not yet available digitally. For example, the allowed building height from a zoning plan or required noise insulation in relation to the local traffic situation. Also, in order to come to the result that a check can be performed fully automatically, the complete organizational chain must be viewed as a whole and all different stakeholders must be involved to ensure the required quality and the necessary support.
- Conclusive, simple and well-communicated BIM requirements are an important precondition for a successful implementation. The exact opposite is often achieved with too extensive and unclear BIM requirements. It scares people off, they don't get it and no longer want to cooperate. A strategy in which a link is made with the check to be implemented with the most impact, the required minimum BIM requirements and an associated implementation plan are important instruments.
- The microservice architecture works but is also still very new and laborious. It takes quite a bit of extra time to understand the dependencies and to connect to this environment, especially when there are many related services developed in parallel. This is not a problem, but it needs to be kept in mind when planning new developments.
- Another lesson learned is that the services developed within this project are a lot heavier in terms of performance than the usual services. In order to ensure reliable and fast operation, further attention will have to be paid to this in terms of infrastructure setup and availability in the future. Currently BIM.Works is already running on it's own server and it would be good to do the same for the Voxel server.
- It is not always possible to translate existing legislation one-on-one into a conclusive check. It seems sensible to look closely at the purpose of a rule and openly look at a smart way to check it. Capturing the existing rule one on one in a digital check often leads to unnecessarily complex check configurations and associated BIM requirements.
- It would have helped a lot if there was a clearer overview of the expectations for business logic between BIM-module and the rest of the EHR environment and related components from the beginning of the project. It took a lot of time and energy to understand the needs and logic of expected behaviour.
- When planning to order new modules and functionalities, it is important to think in advance which existing (or planned) parts of the EHR it should be related to and analyze whether all the necessary inputs are available. That would also help to define the expectations more clearly.

7. Recommendations

- Keep it simple, set realistic goals and take small steps forward.
  The coverage of all the great developments and sales pitches from technology suppliers makes it seem like the most insane things are technically possible. That is partly true, only to implement it really successfully, broadly and scalable in a daily work process takes a lot of effort. So be careful not to go too fast, but take the time to properly connect and integrate the innovative techniques into the organization.
- Use an integral agile 'development' approach.
  A lot is possible in terms of setting up automatic checks. At the same time, it has also been found that there are many dependencies to make the checks really useful and practical. In addition to the possibilities of technology, it is important to look critically at the legislation, the specifications in terms of BIM requirements and support and impact among stakeholders. Try to design the checks step by step seen from the chain as a whole, involving a larger group of multidisciplinary stakeholders. This may sound cumbersome, but it ultimately gives the fastest and best results.
- Invest in good, realistic and widely supported BIM requirements that can be introduced step by step. Support users as much as possible with, for example, training and central facilities such as a central data dictionary (bSDD)[2] and 'quality checking service'. A generic and unambiguous structure of the BIM models is crucial for the successful further expansion of the service.
- Connect with the international openBIM developments and share experiences.
  Estonia is a forerunner, but certainly not the only one that is actively involved in BIM based permit checking. More and more initiatives are emerging in other countries. Also the Building Smart strategy and the development of their open standards connect well to the developments. By using and stimulating these international openBIM standards and sharing practical experience, the approach will be more generically applicable. When more countries start working with these developments in more or less the same way, it will eventually become faster and easier.

[2] https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/

8. The tender requirements

In this chapter an overview is given where or how the results of the expected deliverables and tasks can be found. This is done by the given tasks listed in Annex 1, technical description from the contract. For the functionality / specifications of the software developed in this second phase of the project, we have taken the requirements from section 2.2 of this annex as a basis.

8.1 Uploading and storing of BIM Models

- The solution created by the developer allows BIM models in IFC format to be uploaded and stored in a machine-readable form in a database (BIMserver solution or similar).
    - As offered in the project proposal the BIM.Works solution is used for this purpose. This solution is not open source, but for this project a perpetual license has been granted. Additionally an integration with the new EHR "file upload service" has also been developed.
- The solution to be created must link several IFC models to one object according to the disciplines (for example, architecture, building structures, different technical systems, etc.) and create an integrated model that can be visualized and analyzed. Automated checks must take into account all models associated with the object and visualize the results in an aggregate model.
    - It is possible to merge multiple BIM models into one using BIM.Works as a base for executing checks. Currently the file upload service on the EHR is under development. Therefore we now only support the architectural and the site model. Once the file upload service developments are finished all disciplines will be supported.
- The BIM model database must also allow data exchange with other EHR / e-construction services via the API.
    - The list of endpoints provided by the BIM module is given in the chapter "3.4 Swagger API endpoints provided by the BIM module" of the architecture document, and each item in the list is referring to technical specification in the corresponding chapter. Each of the endpoints will also be available on MKM Swagger,
- If changes need to be made to the existing EHR database together with this development, the Developer will make proposals for the corresponding changes to the database.
    - The BIM module is database-independent from the rest of the EHR, and no changes have been made to any of the existing databases. All needs of the BIM module are covered by separate databases, which are documented as required.

8.2 Reading data from the model and saving the extracted data

- Reading data from the model

- The contractor is developing a solution that allows reading (extracting) from the BIM model the data necessary for carrying out permitting checks.
    - The BIM repository used on the backend (BIM.Works) is an open, microservice based solution, making all data and functions available using an API.
- The data in the EHR data set is read from the BIM model and stored together with the EHR building permit application procedure data. The Client shall provide the developer with a description of the database in Enterprise Architect format.
    - As agreed during the project, an endpoint is provided by the BIM module and the transmitted data can be stored on the EHR side. Therefore database description in the context of this project is not relevant.
- The data composition to be read from the Model shall be specified by the Developer in cooperation with the Client in clauses 2.1 and 3.3. the result of the detailed analysis discussed.
    - This data definition has been defined together with the customer and is made available through the API
- If, in the future, the addition / change of controls necessitates the addition of data / data readings from the model, this must be feasible (see section 3.4.4). Automatic control mechanism).
    - This is feasible, when new fields become available, those can be added to the export

- Saving / copying extracted data to the EHR database:
    - Based on the BIM models, the data of the Building Register are supplemented, and when storing the extracted data in the EHR database, the structure of the EHR database must be taken into account. The data storage process will be specified during the detailed analysis.
        - The extracted data is provided using an API call to another EHR service which stores the data in the EHR database and manages database integrity.
    - Data not included in the EHR data set, but required for BIM checks, model display, or other reasons, is extracted into PostGRes data tables outside the EHR registry. The format and data model of the data tables shall be approved by the Developer with the Client.
        - Extra data which is required for the BIM checks is stored outside the EHR data set in the BIM.Works database. This way it remains available for later use.
    - The developer creates an opportunity to store the last verified IFC format version of the same project in the EHR environment controlled by the building permit applicant. Older versions must be automatically deleted as a result of development work to minimize the amount of data that can be saved. Once the applicant for a building permit has submitted the verified BIM model to the competent authority for processing, he must not be able

to resubmit the same construction project, unless the construction project has been returned by the applicant for improvements.

- If more than one version of the application has been submitted for processing, both the applicant and the person conducting the proceedings will be able to see the previous version of the model in addition to the version being supplemented / processed. All the check results and comments of the previous version are saved and can be used as a reference. The version already submitted (previous) cannot be modified or supplemented by the applicant, but can only be used as background information.

8.3 Model visualization solution

- Visualization of the model in the building permit process:
    - The visualized BIM model is a detailed solution, similar to that in PoC.
        - The same BIM viewer component (BIM Surfer) has been used as in the PoC. The layout and style is slightly different though because the EHR stylebook has been used.
    - The visualized BIM model must be observable on a floor-by-floor basis (floors can be added and removed) and can be cut from the desired location.
        - It is possible to turn floors on and off and also the section plane function is still available (CTRL LMB), as during the PoC
    - The visualized BIM aggregate model must be divided into engineering-disciplinary sub-models (architecture, building structures, different technical systems, etc.)
        - For an active model, if more than one discipline is available, it is possible to see the list of disciplines and switch them off and on. When a discipline is deselected, it is not shown in the 3d-viewer.
    - The developer creates a "walk-through" option in the visualized environment to look around in the WASD + mouse style model
        - The WASD mode has been added to the open source BIM surfer functionality and has been implemented.
    - The model must be visualized with the surrounding 3D environment available from the 3D Twin service in CityGML and / or 3D Tiles format.
        - The functionality to add 3D Tiles layers has been added to the BIM surfer viewer. Since it's still a BIM viewer only one tile will be loaded. Several 3D layers from the 3D twin service have been added to the BIM service which can be switched on and off. Also it has been made possible to show 2D WMS map layers within the BIM viewer.
- Visualization of models in 3D twin:
    - The building model must be visualizable in a 3D twin with the most accurate external geometry (LOD3) possible, showing all the details visible from the outside of the building (incl. Windows, doors, chimneys, external stairs, terraces, etc.).

    - After a BIM file is uploaded to BIM.Works automatically an glTF version is made available to show in the 3D Twin service. The API endpoints have been made available. The real integration in the 3D twin service will be executed in another consecutive project.
  - The solution to be developed must automatically perform the necessary simplifications of the model (remove internal details that are not visible from external observation) and convert the model to a format suitable for visualizing the 3D twin, which is expected to be 3D Tiles or CityGML. The 3D twin is visualized using a Cesium free solution.
    - The generated glTF only consists of all the exterior objects of the BIM file. This exterior detection is performed in BIM.Works on the basis of all actually visible objects and therefore does not make use of the IsExternal property, which is usually not reliable.

8.4 Automatic control mechanism / engine

- Automatic, easily renewable, technical inspection mechanism ("engine").
  - BIM.Works was used as a central BIM repository and check engine. It has been installed according to the conditions on the central MKM environment based on a perpetual license.
- The control mechanism must be divided into separately modifiable blocks in accordance with the legislation.
  - As described in chapter 5.2.3, the checks can be extensively configured in BIM.Works and can be divided into various legislation via the service manager view.
- The developer must document a description of how the data read from the model can be supplemented in future developments.
  - Most checks can be configured by updating the JSON of a check definition. Any IFC property, field or classification can be used to extract this data by changing the check definition. New checks can also be defined and can use other properties than have been used in the current checks.
- The mechanism to be created must be able to operate at a reasonable, non-disruptive speed, even after the addition of additional controls by the Contracting Authority.
  - As demonstrated during the various demos during the development phase, the service runs quickly and smoothly on an average computer. The performance mainly depends on the underlying infrastructure and network on which the various components are installed. Given the heavy graphical processes and analyzes which are performed, this is an important and permanent point of attention in the further implementation and scaling of the service.

8.5 Automated checks

- The automatic inspections must correspond to the description of the inspections determined on the basis of the detailed analysis (supplemented table of automatic inspections of the authorization procedure (Annex 1a)).
    - As described in chapter 5.2.2, based on the eventually available BIM requirements for many of the checks, the chosen approach from the analysis phase turned out to be unrealistic. In close consultation, a more practical and robust approach was therefore chosen for most checks. An overview of the final analysis and results can be found in annex 2.
- All defined automatic checks can be performed / input through the automatic control mechanism.
    - All configured checks, when relevant, are performed automatically when instructed by the user.
- The results displayed to the user of the checks must be differentiated according to PoC:

    1. The check has been passed successfully (green result);
    2. Verification of comments (yellow result - this is a potential error, but the legislation leaves open the possibility of different interpretations or the control mechanism does not allow false positive / false negative results to be completely ruled out due to technological capabilities);
    3. The inspection has completely failed (red result). - As agreed with the customer during the project, applications with red results can be submitted, but all the red results must be commented by the applicant before submitting).

    - Based on success level, the check results are visually differentiated as green-yellow-red, and it is also possible to filter the results accordingly.
- The results of the inspections are displayed by legislative block in three columns - "is in the project"; "Is required" and "link to request".
    - As agreed with the customer during the project, check results are not displayed in columns, but nevertheless the results are grouped by legislation and also contain additional information that can be configured in the admin module.
- The inspection report must also be issued in BCF format (more information in PoC).
    - It is possible to download BCF file(s) of the currently active version.
- It must be possible to change the status of the controls in the control mechanism (control is valid / expired / needs clarification / etc.) - clarification in section 3.4.7 a.
    - Status of the controls can be set in the admin module. Available statuses are Kehtiv (Valid), Kehtetu (Invalid), Täpsustamisel (Needs clarification) and Seadistamata (Not configured).

8.6 User interface

- Create a visualized mapping of user paths (UX interaction flow) based on the user function of the application (administrator, processor, building permit applicant).

   - Throughout the project, a Figma file has been used, on the basis of which both the user interface planning by the developer and communication with the customer has taken place.
- In the case of prototypes / samples, functionality is important, but given the number of feedback providers, it is expedient to compile them in a way that is sufficiently reminiscent of the final design. The method may involve the combined use of a prototype and samples.
   - To get the best understanding of the final solution, elements from the existing EHR style guide were used to create the prototypes.
- Must be integrated with the EHR process and user interface. The user interface must comply with the e-construction style book (Appendix 5); in the absence of the necessary components in the style book, the corresponding component must be created or the existing ones must be supplemented in cooperation with the style book project. The ideal guideline in UC is UX interaction flows, but the primary guideline is the e-construction style book.
   - The EHR style book was used and in some cases also additional elements were added by the client according to the needs of the BIM project (for example for a measurement tool). Also the already existing 3d-twin application was used as a reference.
- The user interface must be simple, logically usable for the licensing officer who is not a BIM specialist.
   - The aim has been to create a solution that is as convenient and understandable as possible. Also customer's wishes and guidelines have been taken into account, as they have a better understanding of the needs and (technical) capacity of the end users.
- During the prototyping of the user interface and the preparation of instruction materials, at least 3 iterations must take place, in which the Customer's team is involved as a provider of feedback.
   - During the planning and development, there has been constant communication with the customer regarding the appearance and structure of the user interface. As the instruction materials are still being created, no communication has taken place in this regard.
- During the iterations, the Client may ask for opinions from additional organizations or invite additional parties to provide feedback by notifying the Developer. It is recommended to perform more iterations with the Client's team, but it depends on the method chosen by the Developer.
   - This was indeed our starting point in the first place. Throughout the project we came to understand that this was not the time to engage a wider audience because there was still so much to discover and develop. We can well imagine that this will add a lot of value in the next phase towards implementation and further development

8.7 Service manager view

In addition to the user views covered in the PoC, the Developer must also create a manager view with the corresponding functionality that:

- Allows you to turn controls on/off and change their status. The statuses will be specified during the detailed analysis, but at least 3 different statuses must be taken into account (valid / expired / needs to be specified);
    - Status of the controls can be set. The statuses were specified and agreed with the customer and are: Kehtiv (Valid), Kehtetu (Invalid), Täpsustamisel (Needs clarification) and Seadistamata (Not configured).
- allows to manage the classification of automatic controls, ie to group controls according to functionality (eg legislative basis, engineering-technical functionality, BIM functionality [IFC elements]) and to add / remove groupings;
    - As agreed with the customer, only one type of grouping is available and not to switch between several types of groupings. It is possible to add new groups and manage attributes (name, status) of the existing groups. Groups cannot be deleted, but it's possible to turn them unusable by setting status to "invalid".
- is as simple as possible for the user - a minimalist solution.
    - The existing ehr UI components were used to create the user interface and the functionalities will hopefully be logical for the administrators.

Annex 1: Minimal BIM requirements current checks

General				
One BIM file should only contain one ifcBuilding				
The BIM file should be geo-located according to the Estonian L-EST97, epsg:3301 coordinate system				
Also an elevator shaft should be modelled as a (one) space (AR_Ruum) with the correct 115_Kategooria property				
AR_Hoone/ifcBuilding				
Attribute	ifcReference	Data Type	Content	Example
040_Kõrgus	TotalHeight	ifcLenghtMeasure	Height	25,1
045_Hoonealune_pindala	SiteCoverage	IfcAreaMeasure	Underground surface (above ground) ACTUAL UNDER CONSTRUCTION	8000,1
056_Kasutajate arv	OccupancyNumber	ifcInteger	Max number of people	55
058_Kasutusotstarbe kood	OccupancyType	ifcLabel	KAOL code	11222
059_Eripõlemiskoormus	FireLoad	ifcInteger	Heating load	599
060_Tuleohutusklass	FireSafety Class	ifcLabel	Fire safety class	TP1
061_Sügavus	TotalDepth	ifcLenghtMeasure	Depth	5,1
???_Kasutusotstarve		ifcLabel	Intended use	Other residential building with three or more apartments
AR_Ruum/ifcSpace				
110_Tüüp	Reference	ifcIdentifier	Room type selection	Üldkasutatav pind / Public Area
115_Kategooria	Category	ifcLabel	Pick category from list	elutuba / living room töötuba / working room magamistuba / sleeping room rödu / balcony wc / toilet

				lodža / loggia köök / kitchen vannituba / bathroom parkla / car park lift / elevator
126_Köetav pind		ifcBoolean	Heated surface	True
127_Ruumitemperatuuriga pind		ifcBoolean	Room with surface temperature	True
128_Korteri number		ifcLabel	Apartment number	2
AR_Tsoon/ifcZone (when one building exists of multiple functions, instead of in the ifcBuilding)				
056_Kasutajate arv	OccupancyNumber	ifcInteger	Max number of people	55
058_Kasutusotstarbe kood	OccupancyType	ifcLabel	Kaos code	11222
059_Eripõlemiskoormus	FireLoad	ifcInteger	Heating load	599
060_Tuleohutusklass	FireSafety Class	ifcLabel	Fire safety class	TP1
080_Tähis	IfcZone.Name	IfcLabel	Fire compartment section symbol	TTS-1
085_Tuletõkkesektsioon	IfcZoneDescription	IfcLabel	EI30	Fire resistance of the fire compartment
???_Kasutusotstarve	IfcZoneGroupName (?)	ifcLabel	Intended use	Other residential building with three or more apartments
???_Evakuatsioonitee		ifcBoolean	This is an escape route (TRUE) or an exit route (FALSE)	True
AR_Korrus/ifcFloor				
065_Korruse_number	ifcBuildingStorey.name	ifcLabel	Floor number	-1
066_seaduslik korrus		ifcBoolean	Legal floor	True
070_Maapealne	AboveGroun	ifcLogical	Is it a ground	True

	d		floor?	
AR_Sein/ifcWall				
330_Tulekindlus	FireRating	ifcLabel	Fire resistance	REI120
500_Kandev	LoadBearing	ifcBoolean	Bearing	True
AR_Uks/ifcDoor				
330_Tulekindlus	FireRating	ifcLabel	Fire Rating	EI30
335_Välispiire	IsExternal	ifcBoolean	Isexternal	True
370_Evakuatsiooniväljapääs	FireExit	ifcBoolean	Fire Exit	True
AR_Vahelagi/ifcSlab				
330_Tulekindlus	FireRating	ifcLabel	Fire resistance	REI120
500_Kandev	LoadBearing	ifcBoolean	Bearing	True

Regulation	Check number	Check description	Executed	Planned phase 1	Classification		Description	Requirements
					Feasibilty	Usefullness		
M85	3.1	The area of each living room, study and bedroom is at least 8 m2	Yes	Yes	High	High	Select the spaces with the matching properties from the 115_category property ('magamistuba' (sleeping room), 'elutuba/köök' (living room / kitchen), 'elutuba' or 'töötuba'(working room)) and measure if they are larger than 8m2	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M85	3.2	The width of each living room, study and bedroom (distance between opposite walls) shall be at least 2.4 m	Yes	Yes	High	High	Select the spaces with the matching properties ('magamistuba' (sleeping room), 'elutuba/köök' (living room / kitchen), 'elutuba' or 'töötuba' (working room)) from the 115_category property and a 2.4x2.4 diameter circle should be able to be fitted within the room	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M85	3.3	The height of each living room, study and bedroom in the dwelling is at least 2.5 m, in the case of a dwelling with one apartment at least 2.3 m.	Yes	Yes	High	High	Select the spaces with the matching properties ('magamistuba' (sleeping room), 'elutuba/köök' (living room / kitchen), 'elutuba' or 'töötuba' (working room)) from the 115_category property and a 2.4x2.4 diameter circle should be able to be fitted within the room Dwelling with one appartement: 11101, 11102 Dwelling with more appartments: 11200,11210,11212,11221, 11222	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M85	3.4	In a room with sloping walls on the attic, the minimum height is guaranteed at least to the extent of half the area of the room, whereas only those parts of the room where the height of the room is at least 1.6 meters are taken into account when calculating the area.	Yes	Yes	High	High	For all spaces we check whether usable area (any place higher than 1.6m) is at least 0.5 * the total area.	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in
M85	3.5	The dwelling has a separate entrance from the other dwellings through a door	Yes	Yes	Medium	High	The IfcSpace property AR_Ruum.128_Korteri number is used to identify all IfcSpace objects of the same appartment. Consequently the entrance door(s) are determined by looking at connectivity to non-appartments spaces (Korteri_number is missing, empty or "-").	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in - ifcSpaces (AR_Ruum) property AR_Ruum.128_Korteri number (appartment number) needs to be properly filled in
M85	3.6	There is at least one door in each living, working and sleeping area and in the kitchen	Yes	Yes	High	High	First the eligible spaces are identified by looking at the AR_Room.115_kategooria property, it should be either "töötuba", "elutuba/köök", "elutuba", "magamistuba" or "köök". Then we determine the amount of doors by looking at the connectivity graph.	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M85	3.7	Subject to the requirements of another legal act, the minimum width of the door illuminating surface shall be: 900 mm for the external door, 700 mm for the interior and balcony doors (whole building); 600 mm for the bathroom and toilet door;	Yes	Yes	High	High	This check has 3 stages. First we look at all external doors based on the Pset_DoorCommon.IsExternal property, each should be wider than 900mm. Then we look at all the remaining doors that have a 115_Kategooria of "vannituba" or "wc", those should be 600mm wide. Then we look at all the remaining IfcDoor objects, those should all be 700mm wide.	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M85	3.8	Subject to the requirements of another legal act, the minimum height of the door illuminating surface shall be 1950 mm	Yes	Yes	High	High	All doors should have a minimum opening of 1950 mm heigh	- ifcBuilding (AR_Hoone) needs property 058_Kasutusotstarbe kood (OccupancyType, KAOL code) properly filled in

M85	3.9	In a building to be erected, the connection between the dwelling and the entrance to the building is ensured by means of an elevator if the dwelling is located on the fourth floor or higher than the entrance to the building.	Yes	Yes	Medium	High	First we select all ifcBuilding (AR_Hoone)Storey objects with property AR_Korrus.066_seaduslik korrus = true. Then we determine the appartments (see 3.5). Then we determine the appartment doors (3.5). Then we determine all building exits by looking at Pset_DoorCommon.IsExernal. Then we calculate routes between all the appartment doors and the building exits and see whether it crosses an elevator (which are determined by AR_Ruum.100_nimi == "LIFT")	- ifcBuilding (AR_Hoone) needs property OccupancyType (KAOL code) properly filled - ifcSpaces (AR_Ruum) need property 115_categooria (Category) and 128_Korteri number properly filled in - ifcSpaces (AR_Ruum) from the elevator needs to be modelled as one spaces covering all available floors - ifcStorey ((AR_Korrus) needs 065_Korruse_number properly filled in
M97	3.10	When applying for a building permit, drawings are submitted in the section of the construction plan of the construction project, which reflect the location of the building on the plot.	No	Yes	High	High	Too complicated	- The building plot should be available somewhere - ifcSite for direct designed surroundings always available - Geo-location should be stored accoreding to chapter 5 of the BuildingSmart definition: https://www.buildingsmart.org/wp-content/uploads/2020/02/User-Guide-for-Geo-referencing-in-IFC-v2.0.pdf
M97	3.11	When applying for a building permit, the architectural solution of the building is presented in the architectural part of the construction project	Yes	Yes	Medium	High	The discipline is taken from the filename and stored in BIM Module. When a check is being run, it simply checks whether there is at least one architectural model present.	- File name should meet the MKM file naming conventions - New file 2.0 service needs to be implemented
M97	3.12	When applying for a building permit, requirements and solutions ensuring compliance with the requirements have been submitted to ensure mobility opportunities arising from the special needs of disabled people;	No	No			Double	
M28	3.13	The Regulation on Requirements for the Special Needs of Disabled Persons applies to a building or a part thereof where a service intended for the public is provided.	Yes	Yes	Low	High	Always run all M28 disbaled persons checks to raise awareness for the topic	
M28	3.14	The regulation on the requirements arising from the special needs of disabled persons has been applied to a building or a part thereof which, according to the plan or design conditions, must meet the requirements arising from the special needs of disabled persons.	No	No			`Double	
M28	3.15	The car park has at least one percent of all parking spaces for a disabled person's vehicle, but not less than two spaces; In a parking lot with less than 20 parking spaces, there is at least one place for parking a disabled person's vehicle.	No	No	Medium	Medium	Too complicated regarding BIM requirements in relation to check	
M28	3.16	The entrance and exit to the car park have an entrance opening at least 1.1 meters wide.	No	No	Medium	Medium	Option was to start generic voxel check to measure 1.1 m width everywhere, but this give other issues because not all spaces need to be 1.1 m wide	
M28	3.17	The longitudinal slope of the pledge is up to 6 percent. If it is not possible to comply with the requirement due to the peculiarities of the building, the longitudinal slope of the pledge may be up to 10 percent.	Yes	Yes	Medium	Medium	For all IfcRamp elements in the model, geometry is converted into a boundary representation. The upwards pointing face is selected and the normal N of the that face surface is sampled. The percentage follows from the surface normal and is actuall tan(arccos(N.z)) x 100%.	- ifcRamps need to be specified as such
M28	3.18	In the case of a longitudinal slope of more than 5 per cent, the length of the embankment shall be at least 1.5 meters in the case of a straight embankment and at least 2 meters in the case of a twisted embankment after each rest period of up to 6 meters. The length of the twisted mateme is measured from the inside.	No	No	Low	Low	Too specific and complicated with a lot of additional requirements to the BIM model to be able to check this	

M28	3.19	If the longitudinal slope of the pledge is more than 5 percent, there are handrails on both sides of the pledge. Pandan's handrails continue uninterruptedly at resting places.	Yes	Maybe	Low	Low	Are there handrails on both sides for any ramp with a slope of > 5%	- ifcRamps need to be specified as such - Handrails should be modelled as IfcRailing - The uninterrupted check will be done based on the triangulated geometry (it should be one mesh, compensated with a delta) - There should be 2 handrails per slope
M28	3.20	Plaster with a longitudinal slope of 5% or less must be limited to a border 50-70 mm high. (? See Notes column)	No	Maybe	Low	Low	Too specific and complicated	
M28	3.21	There is at least 2.3 meters of free space above any sloped object	Yes	Yes	High	Medium	Geometry of the entire building model is voxelized. Above IfcRamp voxels a new voxel volume is constructed that starts at the top of the ramp and runs upwards to any voxel unit encountered (operation extrude until). This volume is then again flattened downwards (operation collapse count) storing the count of collapsed voxels as the new cell value. Cells with values under the passed threshold are coloured red and result in an error.	Any sloped object needs to be specified as an IfcRamp
M28	3.22	The minimum width of a straight pavement with one-way traffic is 1.1 meters and with a two-way one 1.8 meters. The widths of the twisted pile are the same, but at full turn the width is not less than 3 meters.	No	No	Low	Low	No provisions in IFC for this, and not something we have seen in IFC files	
M28	3.23	A staircase is an ascent of three or more steps. ?	Yes	Maybe	Medium	Medium	Voxel checks looks for everything with steps that looks like a stair	Any furniture should be classified as such so that we can ignore them in this check
M28	3.24	Stair steps shall be at least 270 millimeters wide and up to 160 millimeters high in the case of a stairway enclosure and a covered external staircase; in the case of an open external stairway, not less than 400 millimeters wide and not more than 130 millimeters high	No	No	Low	Medium	Lots of issues with naming, where to measure the width etc.	
M28	3.25	The staircase between two floors has at least one landing	Yes	Yes	Medium	Medium	The landing is described by it's length, it needs to be 1.5 meters. This check starts from the voxelized flow field. Starting from the external doors the walkable surfaces of the model are traversed. Then this flow field is converted to a graph using the Medial Axis Transform. This results in a directed graph that follows the exact geometry of the model. The nodes of the graph are labelled with the building storey they belong to. For every 2-combination of building storey nodes on adjacent floors the simple paths in the graph are enumerated. If this path does not contain any other nodes from those stories then it is a stairs that connect those two stories. In this path, the horizontal and vertical edges are segmented. The horizontal edges longer than the supplied threshold are considered landings.	All staircases should be modeled as such, and also the flights
M28	3.26	There is at least 2.3 meters of free space above the stairwell	Yes	Yes	High	High	See 3.21 but then considering IfcStairs and their decomposing elements	Should be defined as IfcStair
M28	3.27	There is also a continuous handrail on both sides of the stairs	Yes	Maybe	Low	Low	See 3.19	Should be IfcRailing/IfcStair
M28	3.28	The handrail shall be 900 mm above the front edge of the steps and the duplicate handrail at a height of 700 mm and at least 45 mm from the wall or enclosure and shall be contrasting	No	No	Low	Low	Too specific and complicated	
M28	3.29	There is a stepless rise to the entrance level of the building by means of a pledge or other equivalent solution	No	Yes	Medium	Medium	Too specific and complicated	- Surrounding design of building is also included as ifcSite - If there is a slope it should be an IfcRamp

M28	3.30	There is a free horizontal movement space of 1.5 times 1.5 meters in front of the entrance door of the building	Yes	Yes	Medium	Medium	A three-dimensional solid is positioned facing outwards from the external doors. Any intersection of building element geometries with this volume (excluding space and opening) result in an error.	- Doors should have the 335_Välispiire (IsExternal) property
M28	3.31	The door opens in the direction of escape and at least 90 degrees. ~~The requirement does not have to be complied with when renovating an existing building if the door cannot be positioned properly.~~	Yes	Yes	Low	Medium	The voxelized flow field (3.25) is sampled on both sides of every door. The field represents the distance to the exterior, so in the direction of the opening of the door, the values for this field should decrease. An error is raised when this is not the case.	- Escape route should be calculatable (3.62) - Doors should be modeled as IfcDoor and have the correct IFC door opening direction/hinging properties
EHS design conditions	3.32	The purpose of use of the building corresponds to the purpose of use specified in the design conditions.	Yes	Yes	Medium	High	We extract the KAOL code from the ifcBuilding (AR_Hoone) property AR_Hoone.058_058_Kasutusotstarbe kood. This code is also converted to the Estonian translation via a user-defined mapping (initially taken from the excel sheet KAOL tabel.xlsx	- The ifcBuilding (AR_Hoone) should contain the 'OccupancyType (058_Kasutusotstarbe kood)
EHS design conditions	3.33	The number of buildings on the site does not exceed the maximum number of buildings on the site as determined by the design conditions	Yes	Yes	Medium	High	For now we simply export how many buildings there are in the model check. For each building we output the name of the building.	- ifcBuilding (AR_Hoone) should be defined properly - GeoLocation should be defined properly
EHS design conditions	3.34	The location of the building corresponds to the location specified in the design conditions	Yes	Yes	Medium	High	In the export the format is simply a list of x/y values in L-EST97 of the building outline (not the bb). As a check result this just shows the lat/lon in L-EST97. The location is assumed to be stored in the localplacement of the IfcSite object in L-EST97	- ifcBuilding (AR_Hoone) should be defined properly - GeoLocation should be defined properly
EHS design conditions	3.35	The area under construction does not exceed the maximum area under construction permitted by the design conditions	Yes	Yes	Medium	High	Just the area of the floorplan is calculated as information. The floorplan is a projection of all objects as see from the top.	- ifcBuilding (AR_Hoone) should be defined properly and should contain 045_Hoonealune_pindala - GeoLocation should be defined properly
EHS design conditions	3.36	The height of the building does not exceed the height allowed by the design conditions	Yes	Yes	Medium	High	Height is taken from the ifcBuilding (AR_Hoone) property AR_Hoone.040_Kõrgus	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus (height) property - GeoLocation should be defined properly
EHS design conditions	3.37	The depth of the building does not exceed the depth allowed by the design conditions	Yes	Yes	Medium	High	Depth is taken from the ifcBuilding (AR_Hoone) property AR_Hoone.061_Sügavus	- ifcBuilding (AR_Hoone) should be defined properly and should contain 061_Sügavus (depth) property - GeoLocation should be defined properly
EHS design conditions	3.38	The location of the building required for the servicing of buildings located on land or water corresponds to the possible location determined by the design conditions	No	No	Low	Low	Too specific and complicated	

M62	3.39	An examination of a construction project has been performed if it includes the erection, construction, reconstruction or extension of the following buildings in which more than 50 people can be present at the same time: 1) buildings of welfare institutions; 2) a dormitory; 3) accommodation buildings; 4) catering buildings; 5) office buildings; 6) commercial buildings; 7) service buildings; 8) terminals; 9) parking house; 10) entertainment buildings; 11) museum and library buildings; 12) educational and research buildings; 13) hospitals and other medical buildings, except for the hospital of the place of detention; 14) sports buildings; 15) cult and conventional buildings; 16) sports and recreation facilities.	Yes	Yes	Medium	Medium	The number is people is determined by taking the AR_Hoone.056_kasutajate arv property from ifcBuilding (AR_Hoone). The type of building is taken from the KAOL code (AR_Hoone.058_058_Kasutusotstarbe kood). The check configuration stores all the KAOL codes that are appliccable. Check returns whether an examination is required or not.	- The ifcBuilding (AR_Hoone) should contain the 'OccupancyType (058_Kasutusotstarbe kood) and OccupancyNumber (056_Kasutajate arv) properties
M62	3.40	A construction project which involves the erection, construction, reconstruction or extension of a building with a conventional design and where the height according to the construction design of that building is more than 30 meters above the ground or a depth of more than 5 meters has been subjected to a construction examination.	Yes	Yes	Medium	Medium	Height and depth taken from respectively AR_Hoone.040_Kõrgus and AR_Hoone.061_Sügavus. Two results are given for both values.	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus (height) and 061_Sügavus (depth) properties - GeoLocation should be defined properly
M17	3.41	The fire safety use of the building has been determined in accordance with Annex 1 to this Regulation.	Yes	Yes	Medium	Medium	060_Tuleohutusklass?	- ifcBuilding (AR_Hoone) should be defined properly and should contain 058_Kasutusotstarbe kood
M17	3.42	The fire safety use of the building has been duly determined in accordance with Annex 1 to this Regulation.	Yes	Yes	Medium	Medium	060_Tuleohutusklass?	- ifcBuilding (AR_Hoone) should be defined properly and should contain 058_Kasutusotstarbe kood
M17	3.43	The area under the building is calculated according to the list of technical data of the building M57 and is presented separately in the fire safety requirements control kit.	Yes	Maybe	Medium	Medium	The area of the floorplan is calculated. The floorplan is a projection of all objects as see from the top.	- ifcBuilding (AR_Hoone) should be defined properly and should contain 045_Hoonealune_pindala
M17	3.44	The closed net area of the building is calculated according to the M57 Building Technical Data List and is presented separately in the fire safety requirements control kit.	Yes	Maybe	Medium	Medium	All spaces with AR_Ruum.115_Kategooria of "rõdu", "lodža" or "terrass" are excluded. Per space the floor area is taken from the BIM.works calculated value. All are added together and form the total net area.	- ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M17	3.45	The height of the building is calculated according to the list of technical data of the building M57 and is presented separately in the fire safety requirements control kit.	Yes	Maybe	Medium	Medium	Taken from ifcBuilding (AR_Hoone) property AR_Hoone.040_Kõrgus	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus (height) property
M17	3.46	The number of floors of the building is calculated according to the list of technical data of the building M57 and is presented separately in the fire safety requirements control kit.	Yes	Maybe	Medium	Medium	All ifcBuilding (AR_Hoone) storeys are taken into account that have AR_Korrus.066_seaduslik korrus set to true and that have a AR_Korrus.065_Korruse_number value that is numeric.	- ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties
M17	3.47	The number of users of the building (in terms of fire safety) is presented correctly	Yes	Yes	Medium	Medium	Value is taken from ifcBuilding (AR_Hoone) property.AR_Hoone.056_kasutajate arv	- ifcBuilding (AR_Hoone) should be defined properly and should contain (056_kasutajate arv (number of people) property

M17	3.48	The fire safety class of the building has been submitted and duly determined	Yes	Maybe	Low	Medium	Number of people taken from ifcBuilding (AR_Hoone) property AR_Hoone.056_kasutajate arv. Building height taken from ifcBuilding (AR_Hoone) property AR_Hoone.040_Kõrgus. Combustion load taken from ifcBuilding (AR_Hoone) property AR_Hoone.059_Eripõlemiskoormus. KAOL code taken from ifcBuilding (AR_Hoone) property AR_Hoone.058_058_Kasutusotstarbe kood. Provided safety class taken from AR_Hoone.060_Tuleohutusklass. All values are being fed to the firesafety calculater (a port of the python code). and so the TP value is calculated. It is also compared with the given value and a warning is shown when the calculated value is lower than the given one.	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus, 056_kasutajate arv, 058_Kasutusotstarbe kood, 059_Eripõlemiskoormus and 060_Tuleohutusklass properties - ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in
M17	3.49	The fire resistance of the load-bearing structures of the building is presented and meets the requirements	Yes	Maybe	Low	Medium	The previous description is used for calculating the TP value. Subsequently we query all objects with AR_Sein.500_Kandev = true. For each object, if it has AR_Sein.330_Tulekindlus. it is compared with the required value, otherwise a warning is shown that the property is missing.	ifcWall (AR_Sein) should be defined properly and contain the 330_Tulekindlus (Fire resistance) and 500_Kandev (bearing) properties" - ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus, 056_kasutajate arv, 058_Kasutusotstarbe kood, 059_Eripõlemiskoormus and 060_Tuleohutusklass properties - ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in"
M17	3.50	The fire resistance of the fire protection sections of the building is presented and meets the requirements	Yes	Maybe	Low	Medium	TODO	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus, 056_kasutajate arv, 058_Kasutusotstarbe kood, 059_Eripõlemiskoormus and 060_Tuleohutusklass properties - ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in"
M17	3.51	The boundary area of the fire protection section of the building is presented and meets the requirements:	Yes	Maybe	Low	Medium	TODO	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus, 056_kasutajate arv, 058_Kasutusotstarbe kood, 059_Eripõlemiskoormus and 060_Tuleohutusklass properties - ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in"
M17	3.52	The fire sensitivity of the walls and ceilings of the interior surfaces of the building is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.53	The fire sensitivity of the floors of the interior surfaces of the building is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.54	The fire sensitivity of the external surfaces of the external walls of the building is presented and meets the requirements	No	Maybe	Medium	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.55	The fire sensitivity of the external surface of the ventilation slot of the building is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.56	The fire sensitivity of the inner surface of the ventilation slot of the building is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.57	The fire sensitivity of the building insulation system is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	

M17	3.58	The fire sensitivity of the walls and ceilings of the technical rooms of the building, including the partitions of the storage rooms, is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.59	The fire sensitivity of the floors of the technical rooms of the building is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.60	The fire sensitivity of the boiler room floor of the building is presented and meets the requirements	No	Maybe	Low	Medium	Will not be done. The parameters aren't put into the BIM files properly	
M17	3.61	The building has a fire lift if required	No	Maybe	Medium	High	Will not be done. The parameters aren't put into the BIM files properly	- Fire lifts should be identifiable as such by means of a property/classification
M17	3.62	The building has the required number of firesafety doors.	Yes	Maybe	Medium	Medium	Based on the outcome of the firesafety calculater (based on number of floors, number of people, kaol code and closed net area), there should be either - At least one door that is wider than 1200 - At least one door that is wider than 1200 and at least one door that is wider than 900 Also there can be the additional requirement that the total width of both doors is larger than a given value (Math.ceil((input.getNumberOfPeople()-120) / 60) * 400 + 1200)	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus, 056_kasutajate arv, 058_Kasutusotstarbe kood, 059_Eripõlemiskoormus and 060_Tuleohutusklass properties - ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in""" - ifcDoors (AR_Uks) should have the 335_Välispiire (IsExternal) and the 370_Evakuatsiooniväljapääs (FireExit) property
M17	3.63	The length of the fire escape route meets the requirements	Yes	Maybe	Medium	Medium	Using the directed geometric connectivity graph (3.25) the nodes are labelled with the spaces they are contained in. Also, nodes at fire exits are labelled. For every space, all 2-combinations of space nodes and fire exit nodes are considered. The farthest point in the space is used and the closest fire exit is used. This results in a three-dimensional path that is further broken down into segments at the place of interior fire doors. The length of each of these segments is checked against the configured value. In case a segment is longer, that segment is coloured red and the space is flagged as an error.	- ifcBuilding (AR_Hoone) should be defined properly and should contain 040_Kõrgus, 056_kasutajate arv, 058_Kasutusotstarbe kood, 059_Eripõlemiskoormus and 060_Tuleohutusklass properties - ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties - ifcSpaces (AR_Ruum) need property 115_categooria (Category) properly filled in""" - ifcDoors (AR_Uks) should have the 335_Välispiire (IsExternal) and the 370_Evakuatsiooniväljapääs (FireExit) property
M17	3.64	The graphic presentation of the fire protection sections of the building meets the requirements	Yes	Maybe	Low	Low	Show all the individual IfcZone objects and allow the user to see the object details of the zones when clicking on it. Also show all the IfcZones with button.	- ifcStoreys (AR_Korrus) should contain 065_Korruse_number, 066_seaduslik and 070_Maapealne properties -ifcZones (AR_Tsoon) should contain the 080_Tähis property
	3.65	There can only be one ifcBuilding (AR_Hoone) in one IFC file (discussed with Christopher, multiple files and thus buildings in one check is possible)	No	No				
	3.66	Fall detection	Yes	No			The fall detection is used to detect stairs with missing railings or other safety barriers. This works by overlaying the voxelized flow field with areas where persons can fall down more than a configurable amount. If the reachable area is connected to the areas where one can fall down an error is flagged.	
	3.67	There should be 1 and only one IfcProject	Yes	No			Gives an error when there are less then or more then 1 IfcProject in a model	
	3.68	There should be 1 and only one ifcBuilding (AR_Hoone)	Yes	No			Gives an error when there are less than or more than 1 ifcBuilding (AR_Hoone) in a model	
	3.69	Are there any ifcBuilding (AR_Hoone)ElementProxy in this model?	Yes	No			Gives a warning for each ifcBuilding (AR_Hoone)ElementProxy object, because it can indicate that other checks are failing because of no type information	
	3.70	Are the geo coordinates in the model and are they in Estonia	Yes	No			Gives an error when there either are no geo coordinates in the model, or when they are not in Estonia (not in the EPSG:3301 bounds)	

	3.71	IDS style check on all required properties/classifications	No	No				
	3.72	Check whether the amount of appartments (as identified by unique appartment numbers on the spaces) matches with the given KAOL code on the ifcBuilding (AR_Hoone) object (or later Zones)	No	No				
	3.73	Object does have 330_Tulekindlus code but is not load bearing -> Warning. Object does not have 330_Tulekindlus but is load bearing -> Also warning. Could also just be check 49	Yes	No			Show all the object that don't have the load bearing (500_Kandev) property	ifcColumn, ifcRoof, ifcSlab, ifcWall and ifcWallStandardcase should contain 500_Kandev property
	3.74	Each door where you go from one zone to another, should be an evacuation door when both of the zones are an evacuation zone, this door should also be > 1200m wide. Also when crossing from non evacuation zone to evacuation zone, the door should not be an evacuation door.	Yes	No			Each door where you go from one zone to another, should be an evacuation door when both of the zones are an evacuation zone, this door should also be > 1200m wide. Also when crossing from non evacuation zone to evacuation zone, the door should not be an evacuation door.	070_Maapealne, AR_Tsoon.???_Evakuatsioonitee, AR_Uks.370_Evakuatsiooniväljapääs

Description	More info	Code	Example	Description	Requirements
Name of building		ifcName	Name of the building	IfcBuilding.Name field	IfcBuilding.Name field
Long name of building		IfcLongName	Long name of the Building	IfcBuilding.LongName field	IfcBuilding.LongName field
Unique ID		ifcGuid	2gri1HAZUjd7LMlfPHhdfq	IfcBuilding.GlobalId field	IfcBuilding.GlobalId field
Area under construction (m2)	§ 19. Area under construction	areaUnderBuildingM2	5.99	Takes the 045 value from the IfcBuilding object	properties.AR_Hoone.045_Hoonealune_pindala
Area under the building, calculated		calculatedAreaUnderBuildingM2	5.99	Calculated area of the projection of the building	Actual 3D geometry in the model
Ground area (m2)	§ 19. Area under construction (3)	areaUnderAboveGroundM2	5.99	Calculated area of the projection of the building	Actual 3D geometry in the model
Number of floors above ground	§ 18. Floor	numberOfFloorsAboveGround	3	Only IfcBuildingStoreys are counted that have 066 set to true and have 065 set to an integer value. The value of 070 determines whether the storey is above or below the ground	properties.AR_Korrus.070_Maapealne properties.AR_Korrus.066_seaduslik korrus properties.AR_Korrus.065_Korruse_number
Number of underground floors	§ 18. Floor	numberOfFloorsBelowGround	0	Only IfcBuildingStoreys are counted that have 066 set to true and have 065 set to an integer value. The value of 070 determines whether the storey is above or below the ground	properties.AR_Korrus.070_Maapealne properties.AR_Korrus.066_seaduslik korrus properties.AR_Korrus.065_Korruse_number
Absolute height (m), extracted	§ 30. Height of building	absoluteHeightM	6.27	Height of the bounding box of the building	Actual 3D geometry in the model
Absolute height (m), calculated	§ 30. Height of building	calculatedHeightM	20	The maximum value of the bounding box	Actual 3D geometry in the model
Height (m)	§ 30. Height of building	heightM	0,001	Takes the 040 value from IfcBuilding	properties.AR_Hoone.040_Kõrgus
Length (m)	§ 32. Length of structure	lengthM	59.79	Takes the footprint of the building, and then determines a minimum bounding rectangle. Of this rectangle the longest side is reported.	Actual 3D geometry in the model
Width (m)	§ 33. Width of building	widthM	5.97	Takes the footprint of the building, and then determines a minimum bounding rectangle. Of this rectangle the shortest side is reported.	Actual 3D geometry in the model
Depth (m), extracted	§ 31. Depth of structure	depthM	0,3	Takes the 061 value from IfcBuilding	properties.AR_Hoone.061_Sügavus
Depth (m), calculated	§ 31. Depth of structure	calculatedDepthM	1	The minimum value of the bounding box	Actual 3D geometry in the model
Closed net area (m2)	§ 22. Closed net area	closedNetAreaM2	50,31	All IfcSpace objects are traversed, the categoria is extracted and balconies, loggias and terraces are discarded. Then the floorArea is calculated based on the geometry. Only the areas where the height is higher than 1.6 meters is used. All the areas are summed up	properties.AR_Ruum.115_Kategooria
Heated area (m2)	§ 28. Heated surface	heatedSurfaceM2	50,31	All IfcSpace objects are traversed, the categoria is extracted and balconies, loggias and terraces are discarded. Then the floorArea is calculated based on the geometry. Only the areas where the height is higher than 1.6 meters is used. For heated spaces then, only space with 126= true are summed up	properties.AR_Ruum.115_Kategooria properties.AR_Ruum.126_Köetav pind
Volume of the above-ground part (m3)	§ 34. Volume of structure	volumeAboveGroundM3	267,77	Uses the voxel server to calculate the volume above ground	Actual 3D geometry in the model
Volume of the under-ground part (m3)		volumeUndergroundM3	18,09	Uses the voxel server to calculate the volume below ground	Actual 3D geometry in the model
Total volume (m3)	§ 34. Volume of structure	totalVolumeM3	285,86	The sum of volumeAboveGroundM3 and volumeUndergroundM3	See volumeAboveGroundM3 and volumeUndergroundM3
Common area (m2)	§ 27. Public space	publicSpaceM2	50,31	All IfcSpace objects are traversed, the categoria is extracted and balconies, loggias and terraces are discarded. Then the floorArea is calculated based on the geometry. Only the areas where the height is higher than 1.6 meters is used. For public spaces then, only space with 110 = "Üldkasutatav pind" are summed up	properties.AR_Ruum.115_Kategooria properties.AR_Ruum.110_Tüüp

List of extracted data

Description	More info	Code	Example	Description	Requirements
Technical area (m2)	§ 26. Technical surface	technicalSpaceM2	50,31	All IfcSpace objects are traversed, the categoria is extracted and balconies, loggias and terraces are discarded. Then the floorArea is calculated based on the geometry. Only the areas where the height is higher than 1.6 meters is used. For technical spaces then, only space with 110 = "Tehnopind" are summed up	properties.AR_Ruum.115_Kategooria properties.AR_Ruum.110_Tüüp
Number of lifts		numberOfLifts	0	Counts the number of IfcSpace objects where the	properties.AR_Ruum.100_Nimi
Dwelling entrance floor		entranceFloor	3	The floor number the apartment is on	properties.AR_Korrus.065_Korruse_number
Living space (m2)	§ 23. Area of room and § 24. Area of dwelling	surfaceM2	20	Total area of all spaces linked to this appartment	properties.AR_Korrus.065_Korruse_number
Heated area of the dwelling (m2)	§ 28. Heated surface	heatedSurfaceM2	12	Total area of all spaces linked to this appartment that have the 126 set to true	properties.AR_Korrus.065_Korruse_number properties.AR_Ruum.126_Köetav pind
Room temperature (m2)	§ 28. Heated surface	roomTemperatureSurfaceM2	8	Total area of all spaces linked to this appartment that have the 127 set to true	properties.AR_Korrus.065_Korruse_number properties.AR_Ruum.127_Ruumitemperatuuriga pind
Number of rooms in the dwelling	§ 17. Types of premises	numberOfRooms	2	The number of IfcSpace objects linked to this apartment	properties.AR_Korrus.065_Korruse_number
Number of kitchens in the dwelling	§ 17. Types of premises	numberOfKitchens	1	The number of IfcSpace objects linked to this apartment that have 115 set to "köök"	properties.AR_Korrus.065_Korruse_number properties.AR_Ruum.115_Kategooria
Number of open kitchens in the dwelling	§ 17. Types of premises	numberOfOpenKitchens	0	The number of IfcSpace objects linked to this apartment that have 115 set to "elutuba/köök"	properties.AR_Korrus.065_Korruse_number properties.AR_Ruum.115_Kategooria
Area of balconies and loggias of the dwelling (m2)	§ 29. Surface of balcony and loggia	balconiesAndLoggiasAreaM2	0	Total area of all spaces linked to this appartment that have the 115 set to either "rõdu", "lodža" or "terrass"	properties.AR_Korrus.065_Korruse_number properties.AR_Ruum.115_Kategooria
Outer bound coordinates, in GeoJSON		outerBoundsGeoJson	coordinates	The outer bounds are calculated by projecting all objects to a horizontal plane. The resulting geometry is subsequently converted to L-EST-97 and formatted as GeoJSON	Actual 3D geometry in the model
Outer bound coordinates, in GeoJSON at z=0		outerBoundsGeoJsonLevelZero	coordinates	The outer bounds are calculated by slicing the model at height z=0. The resulting geometry is subsequently converted to L-EST-97 and formatted as GeoJSON	Actual 3D geometry in the model
Live link:	https://bimbase.notion.site/Export-38d06b1524cc431b96452a69db162d65				