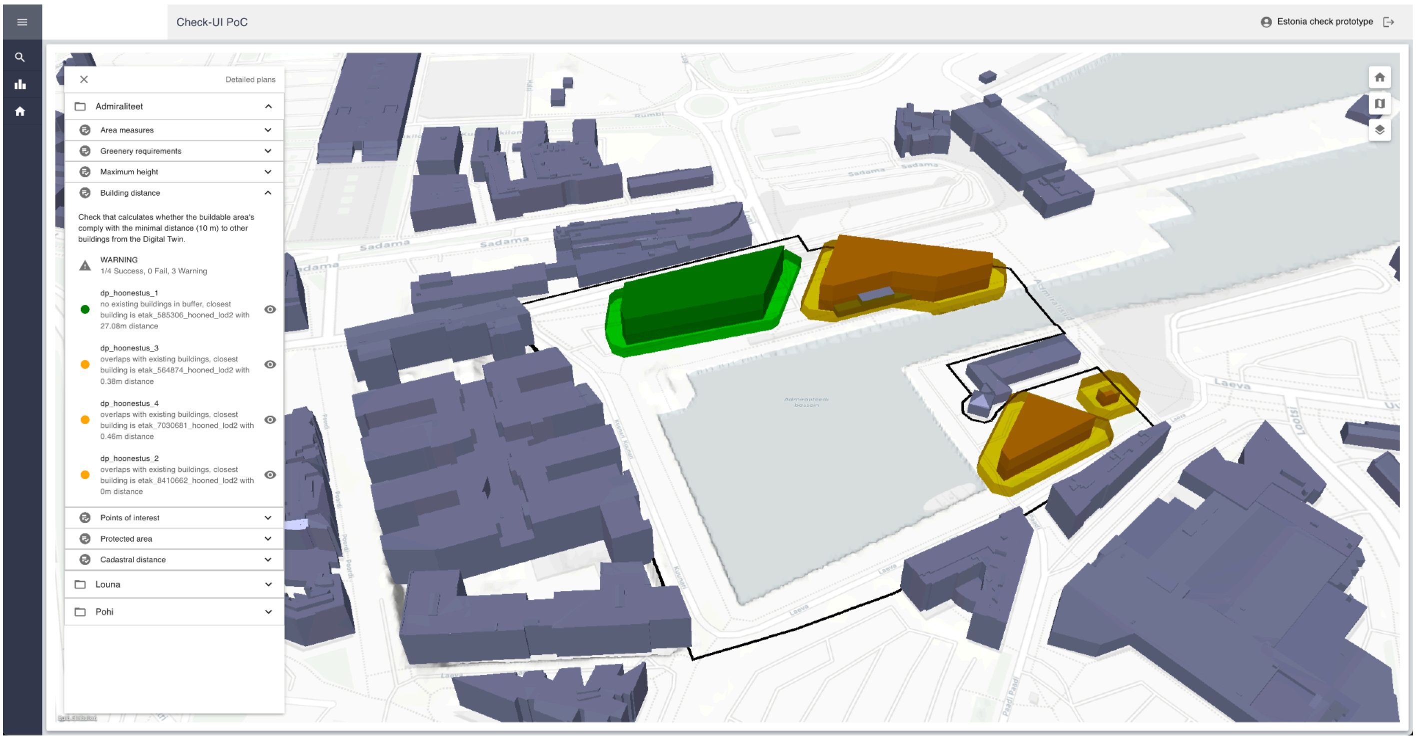
# Detailed analysis of the use of the information model of the plan and creation of a prototype solution

# Final Work Report





Future Insight Group B.V.



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# 1a. Juhtimise kokkuvõte

Eesti on uuendusmeelne riik, kes on tuntud oma digiambitsioonide poolest. Tänu siin loodud nutikatele e-lahendustele kulub ettevõtte käivitamiseks vaid paar tundi ja maksude deklareerimiseks minuteid. Riik on idufirmade arvult elaniku kohta Euroopas üks parimaid riike ja WEF-i ettevõtlusindeksis esikohal. Eesti kodanikud on harjunud oma asju veebis korraldama tänu väga arenenud digi-ID-le, millega saab ligi kõigile avaliku sektori teenustele e-formaadis.

BIM kasutamise arendamine on avaliku sektori jaoks tähtsal kohal. Eesti valitsuses on sellel oluline roll e-ehituse platvormi tehnilises kaasajastamisel. Käesolev aruanne annab ülevaate PlanBIM projekti lähenemisest ja tulemustest. Selle projekti eesmärk oli välja töötada veebipõhise tööriista prototüüp, mille abil saab detailplaneeringute infomudeleid kontrollida üldplaneeringute ja nõuetele vastavuse osas..

Projekti esimeses etapis viidi läbi uuring, et mõista praegust planeerimisprotsessi Eestis, saada aru, kuidas planeerimise infomudelid töötavad, milliseid andmeformaate nende mudelite sees kasutatama peaks ning milline on rahvusvaheline parim praktika selles valdkonnas. Seda tehti erialalise kirjanduse analüüsimise, ekspertidega konsulteerimise, huvirühmade intervjueerimise ja valitsuse dokumentidega tutvumise teel. Järeldus oli, et ühest küljest toimub selles protsessis rahvusvaheliselt vähe innovaatilisi arendusi, kuid teisest küljest on protsessi kiiruse, läbipaistvuse ja selguse osas palju võita. Muutes detailplaneeringud standardiseeritumaks ja infomudeli vormis kättesaadavaks, lisades ka 3D mahtusid, muutuvad need kõigile kaasatud osapooltele selgemaks ning neile saab peale ehitada automatiseeritud kontrollmehhanismi.

Projekti teises etapis töötati välja töötav veebipõhine prototüüp, milles teostati seitse automatiseeritud kontrolli, näiteks hoone maksimaalne kõrgus, minimaalne nõutav haljastuse protsent. Prototüüp on täielikult üles ehitatud olemasolevate avatud standardite ja veebikomponentide alusel, mis ühtivad riikliku e-ehituse platvormi arhitektuuriga. See tagab, et edasiarenduse skaleeritavus ja paindlikkus on realistlikud.

Projekti lõppjäreldus on, et automatiseeritud 'PlanBIM' kontrolliteenuse arendamine on nii kasulik kui ka teostatav. Projektiga seotud Eesti avaliku sektori spetsialistid kui ka projekti vältel kaasatud lõppkasutajad tunnistavad selle lahenduse potentsiaali ja on selle rakendamiseks avatud. Selle realiseerimiseks on vaja lisaks tööriista väljatöötamisele ka selged kokkulepped riiklikul tasandil planeeringute alusandmete standardiseerimiseks ning infomudelite kasutamiseks planeerimise töövoos.

# 1b. Management summary

Estonia is an innovative nation known for its digital ambitions. Thanks to the smart e-solutions created here, it only takes a few hours to start a business and minutes to declare taxes. The country is one of the best countries in Europe in terms of the number of start-ups per capita and ranks first in the WEF Entrepreneurship Index. Estonian citizens are used to organising their affairs online thanks to the highly developed digital ID, which allows access to all public sector services in e-format.

The development of the use of BIM is important for the public sector. In the Estonian government, it plays an important role in the technical modernization of the e-construction platform. This report provides an overview of the approach and results of the PlanBIM project. The aim of this project was to develop a prototype of a web-based tool that can be used to check the information models of detailed plans for compliance with general plans and requirements.

In the first stage of the project, a study was conducted to understand the current planning process in Estonia, to understand how planning information models work, what data formats should be used within these models, and what are the international best practices in this field. This was done by analysing professional literature, consulting with experts, interviewing stakeholders and reviewing government documents. The conclusion was that, on the one hand, there are few innovative developments in this process internationally, but on the other hand, there is much to be gained in terms of speed, transparency and clarity of the process. By making the detailed plans more standardised and available in the form of an information model, including 3D volumes, they become clearer to all parties involved, and an automated control mechanism can be built on top of them.

In the second phase of the project, a working web-based prototype was developed in which seven automated checks were performed, such as maximum building height, minimum percentage of required greenery. The prototype is fully built based on existing open standards and web components that align with the architecture of the National e-Construction Platform. This ensures that the scalability and flexibility of further development is realistic.

The final conclusion of the project is that the development of an automated 'PlanBIM' checking service is both useful and feasible. Estonian public sector specialists involved in the project as well as the end users involved during the project recognize the potential of this solution and are open to its implementation. In order to realise this, in addition to the development of a tool, clear agreements on the standardisation of basic planning data and the use of information models in the planning workflow are also needed at the national level.

## 2. Introduction

Estonia is one of the world's forerunners when it comes to BIM based permit checking. The first version of such a service, developed in recent years in Estonia, is seen around the world as a good example of how such a system should be set up. A first version of the service is currently available nationwide for everyone applying for a building permit.

This project examines the next important steps to see whether and how the approach can be applied one step earlier in the process, specifically when submitting and offering detailed plans. These designs cover larger areas and therefore probably require different techniques and types of data.

This final report describes the results of the project. In phase 1 of the project various stakeholders from the Estonian practice were interviewed and other global initiatives were examined through the desk research. The results were analysed to develop recommendations. A value case was constructed on the input of the interviews and desk research. A detailed description of these results is available in the interim work report.

This final report  primarily focuses on the design, development and implementation of the planBIM online working prototype, which executes 7 automated checks for detailed plans using all kinds of information made available for this project. Additionally, it describes the lessons learned and provides recommendations from the execution of the project.

## 2.1 Abbreviations

| | |
|---|---|
| **API** | Application Programming Interfaces |
| **BCA** | Building and Construction Authority |
| **BEITM** | Built Environment Industry Transformation Map |
| **BIM** | Building Information Modelling |
| **BRISE** | Building Regulations Information for Submission Involvement |
| **CHEK** | Change Toolkit for Digital Building Permit |
| **CityGML** | City Geography Markup Language |
| **CORENET** | Construction and Real Estate NETwork |
| **CP** | County Plan |
| **DP** | Detailed Plan |
| **EHR** | Estonian Building Register |
| **GIS** | Geographic Information System |
| **IDD** | Integrated Digital Delivery |
| **IDS** | Information Delivery Specification |
| **IFC** | Industry Foundation Classes |
| **KOV** | Local government |
| **MKM** | Ministry of Economic Affairs and Communications |
| **MP** | Master Plan |
| **NP** | National Plan |
| **PBL** | Swedish Planning and Building Act |
| **PLANIS** | Planning Procedure Information System |
| **PLANK** | Spatial Plans Database |
| **RAM** | Ministry of Finance |
| **REM** | Ministry of Regional Affairs and Agriculture |
| **SEA** | Strategic Environmental Assessment |
| **SEIA** | Strategic Environmental Impact Assessment |
| **TalTech** | Tallinn University of Technology |
| **TLV** | Tallinn City Government |

| | |
|---|---|
| **UI** | User Interface |
| **UX** | User Experience |
| **VDC** | Virtual Design and Construction |

## 2.2 Estonian terminology in English

| **Estonian** | **English** |
|---|---|
| Üleriigiline Planeering | Nationwide Plan |
| Maakonna Planeering | County Plan |
| Üldplaneering | Master Plan |
| Detailplaneering | Detailed Plan |
| KSH | SEIA |

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# 3. The project

In this chapter, the project and its background will be described. The project consists of two stages, the first stage was executed during Q3 and Q4 of 2023. In Q1 and Q2 of 2024, the second stage was completed, of which this report will provide the results.

The chapter will start with the methodology and results of the first stage, after which the goals and methodology of the second stage will be stated.

## 3.1 Methodology of the first 'detailed analysis' stage

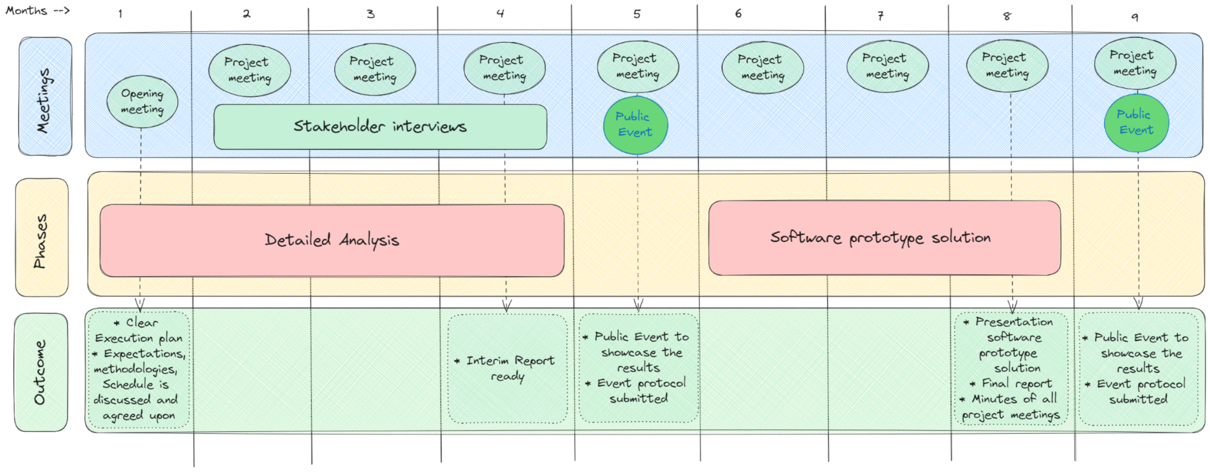


*Figure 1: Complete planning of the project.*

The project consisted of two stages, the detailed analysis stage and the software prototype solution stage. The complete project planning is shown in Figure 1. In the first stage, the existing state, challenges and bottlenecks of the Estonian planning process was researched. Besides that, the value proposition of the prototype solution was outlined. This stage served as input for the subsequent software prototype solution stage, where a prototype was developed based on the findings of the analysis. The extended Interim Work Report about this stage is available here.

The main research question was: "What are the most prominent bottlenecks in the current Estonian planning process and how can they be improved using automated checks based on Planning Information Models?"

To address this, multiple steps were included in the methodology. The overview of these steps can be found in Figure 2. First, desk research was conducted to understand planning information models, data formats, the current planning process in Estonia, and international best practices. This step included reviewing publications, consulting experts and examining government documents.

At the same time, interviews were conducted to gather practical insights and identify perceived challenges from various stakeholders. Interview materials included a consent form, a list of questions, and a list of potential interviewees. The main goal of the interviews was to reveal the interests of different stakeholders in the planning processes. This included questions about the market readiness for the introduction of planning

information models, bottlenecks in the current planning process regarding legislation and effectiveness and bottlenecks in the use of software.
All interviews were recorded, transcribed, and summarised to identify bottlenecks, potential checks, and recommendations. Based on the interviews, a list with possibilities for automated checking was made. This list was analysed based on the criteria clarity, feasibility, value, and 3D advantage, out of which a subset of check possibilities came that would be achievable for the second stage.

The next step was to analyse the results from the desk research and interviews together to form the value case and solution design. This included determining suitable (open) data formats for the planning information model, learning from current and previous systems and incorporating international best practices. The resulting summary of this step can be found in Chapter 3.2.

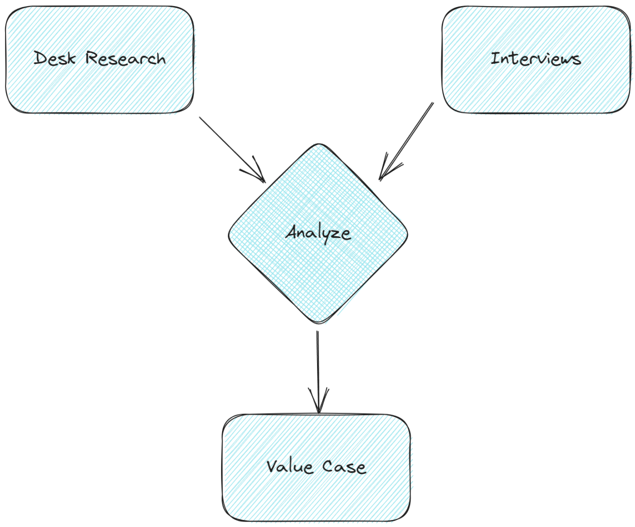


*Figure 2: Methodology of the detailed analysis stage.*

The first stage was finalised with a value case outlining the challenges and bottlenecks of the Estonian planning process and proposing a prototype solution.
This included a user experience flow, a TO-BE process diagram and a shortlist of the check possibilities to automate, all aligned with the national e-construction platform. In Chapter 3.3, this value case can be found.

In the second stage of this project, the software prototype was realised. The methodology of this stage can be read in Chapter 3.4.

## 3.2 Summary of the first 'detailed analysis' stage

To summarise the current state of the planning process in Estonia, findings from both desk research and interviews were incorporated to create a solid foundation for the value case.

The lack of standardisation is a key bottleneck causing disruptions in the data flow, reducing the data quality, and impeding effective comparison between the different plan

types and versions. Recognizing the need for greater public participation, there is a clear demand for 3D tools to better visualisation and understanding of the plans.
Moreover, the reliance on manual checks introduces a risk of human error, which makes the introduction of automated systems necessary for greater accuracy. The current planning process consists of time-consuming approvals from different stakeholders, underscoring the need for improved and smarter collaboration. Efforts to do so are crucial to break down silos and foster a more cohesive planning approach.

Embracing efficiency and digitalisation is paramount, and the strategic (re)use of 3D data is emerging as a promising solution to address these challenges, offering a path to a more streamlined and effective planning approach in Estonia.

In the 11 interviews conducted, several bottlenecks in the current planning process were identified. It is shown that Estonia is working towards a central e-construction platform, from which we conclude that the solution proposed in this research should fit into that. This means the solution design should be integrated or should have the ability to be integrated into the e-construction platform,
The introduction of uploading spatial plans in PLANK[1] has created a starting point towards this integrated platform idea and this was also the start for standardisation throughout the planning process. PLANK includes validation checking on the submitted plans and although this is a start with introducing automated checks, it only applies to 2D and validation checks. Because there is a shift in using more 3D in the planning process,Because there is a shift in using more 3D in the planning process, there is a need for a check mechanism being able to handle both 2D and 3D data and automatically check on regulations for both data types. Additionally, plans are currently only registered in PLANK at the end of the planning procedure. Based on the interviews we determined a need to have (detailed) plan data available earlier in the planning process. In this way, the detailed plan data could be validated against requirements earlier in the process. This will help the designer adapt the plan to applicable requirements for certain areas.

The interviews provided insights into the types and usage of data in the spatial planning process. We found that data formats include PDFs, CAD files, and GIS data. While some data adheres to data regulations as provided on a national level[2], this is not always the case. Desk research also revealed data usage practices in other countries.
The use of BIM is increasing, with IFC being the most commonly used format. Our recommendation is to develop a standardised IFC protocol in Estonia specifically for spatial planning and establishing requirements for master plans, detailed plans, and designs. This will facilitate automated checking and address current issues in data flow, quality, and comparison. In Finland, the adoption of IFC standard as legal archivable format has significantly improved the efficiency and reliability of data in the building permitting process[3]. Applying a similar approach to spatial planning in Estonia by introducing IFC standards could yield comparable benefits, ensuring that data used in planning is consistent, high-quality, and easily comparable.  Additionally, the required

[1] https://planeerimine.ee/digi/plank/
[2] https://www.riigiteataja.ee/akt/121102022001
[3] https://kirahub.org/en/rava3pro-en/

level of detail for BIM should be clear and consistent. This will be further analysed in the second stage of this research.

Stages in the planning process where 3D has a prominent value, based on the interviews, are with the public's involvement and in comparing the detailed plan versus the master plan.

Based on the outcome, we can conclude that the interface of the prototype has to be user friendly. As several stakeholders need to be able to use the prototype, it should be taken into account that no specific knowledge or experience is needed in order to automatically check the plans. Another point of attention is that proper training should be given, in order to make the acceptance as high as possible and it will be properly used.

This applies especially to smaller municipalities with less human resources and access to the right software and hardware. They can achieve great benefits from the implementation of automatic checks as it would save time and resources for them. Therefore, their opinion and experiences should be taken into account, next to those of other stakeholders in the planning process. A concern of those smaller municipalities was that 3D tools are too expensive and the proposed solution would therefore not be feasible for them. This highlights it's important to propose a solution that includes availability for each stakeholder in the process and not only the ones with the most resources.

Another concern that came out of the interviews was regarding the level of detail that 3D visualisations often have. When talking about the detailed planning stage, details are not needed to convey necessary information. Just a simple 3D visualisation, like a 3D block in a 2D environment could be enough for this stage. Although this is something to further define in the second part of this research, we can already conclude that the amount of information used in 3D in the design stage is not needed. This should be made clear to the users when implementing the prototype, as it will determine a large part of the will to adopt the solution design by the stakeholders. When creating the standard used for the automated check, the practitioners should be involved as well to make sure that it suits the reality and not only the theory.

## 3.3 Value case

A study conducted in 2018 showed that there were approximately 15,000 detailed plans valid in Estonia[4]. At that time, 34% of the letters were still on paper and 30% of the drawings were on paper (see Figure 3). In 2018, there were still municipalities that did not use information systems nor prepared their plans digitally. With the introduction of PLANK, a new way of working started which has helped digitising the planning practice and therefore digitalizing the detailed plans created after 1.11.2022. The Ministry of Regional Affairs and Agriculture plans to digitise all enforced detailed plans by 2026.

4 https://planeerimine.blogi.fin.ee/wp-content/uploads/2021/05/2018_0083_DPde-hulk-ja-andmekandja_aruanne_20190403.pdf

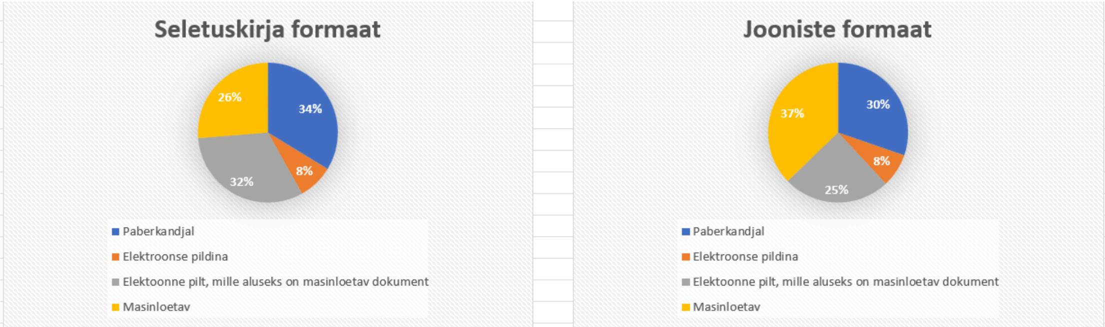


*Figure 3: Division of file formats in the detailed plannings in 2018*[5].

With the implementation of our proposed solution design, value is added in various places in the current planning process. We would like to name specifically:

**Standardisation**

The recent introduction of spatial planning regulations improved the way new plans are structured. This increased the standardisation as well. Nevertheless, the lack of standardisation of already enforced plans remains and because the regulations are quite new, there is not yet enough feedback on how the regulations can be improved. With the introduction of a standardised way of using 2D and 3D plan data in the planning process, the overall cooperation will run more smoothly and will be improved. It will not only have an impact on the ability to be able to run automatic checks, it will also improve the overall planning process by being able to quicker compare plans, digitalise data and use data over different software products.

For 3D data, this project focuses mainly on IFC format. The IFC format is an open standard, already well known in the AEC industry, has a rich data representation, and concurs with the principles of BIM, including life cycle thinking. IFC as an open standard has made it possible to exchange (building) data among different disciplines and phases, which is visible in a variety of software packages supporting reading and exporting to IFC. These software packages concur with well known software packages creating CAD-drawings, which could aid the adoption of the use of IFC in the planning process. IFC has a rich data format, firstly it supports 3D geometry, which adds a 3D dimension opening possibilities for more complex checks, and an enhanced visualisation. Next to geometry however, IFC includes a rich semantic model of (building) elements, extendable by common or user-defined property sets. The elements are relational, meaning the relationships between different elements are stored.

Although IFC is not the only open data standard available for 3D data, the choice has been made to use it for this project as it is in live with the building permitting checks. Also CityGML has been considered, but IFC has been chosen because of the reason above.

**3D Visualisation.**

5 https://planeerimine.blogi.fin.ee/wp-content/uploads/2021/05/2018_0083_DPde-hulk-ja-andmekandja_aruanne_20190403.pdf

By using more 3D plans, the public will be able to understand the proposed detailed plans as well. The current drawings are often technical, which makes it hard for someone without technical knowledge to understand what is being pointed out. The transparency of the plans in the living environment will therefore increase. The 3D renderings used in the existing process are presenting only one perspective of the plan area and they are not interactive.

**Automated checking**
Running checks automatically on a 3D plan will prevent human errors when looked at manually. There is always a chance that details are missed when checked manually, but with the introduction of an automatic check mechanism this will be excluded.

**Time savings**
A bottleneck often referred to in the interviews was that the current detailed planning process can take quite some time as different departments have to approve and criticise a plan. By introducing automatic checks in this process, the estimation is that less work has to be done by the individual departments. For example a department that checks the greenery requirements for a certain plan and calculates that manually. This will result in a reduction of human resources needed, which is especially important for municipalities with not enough human resources available.

**Interoperability and re-use of data**
By already using 3D data in the planning process, this data can be reused for automatic checking later in the building permitting process or in the visualisation of the country in the digital twin. This will increase the overall efficiency and digitalisation of Estonia.

As shown by these value points, the proposed solution design will not only have an impact on its own part of the planning process, but will improve the overall planning process of Estonia.

## 3.4 Methodology of the second 'software prototype solution' stage

In the second stage of the project, the 'software prototype solution', a working detailed plan checking solution, was developed based on the principles as defined as output of the first stage of the project.

An agile approach has been adopted, in which there is a clear interaction between setting up the basic technology, preparing the required data and setting up the checks.

The stage starts by analysing how the basic infrastructure should be set up and making a plan for that. In the meantime, the 10 checks that resulted out of the first stage were analysed to see which data would be needed to execute the check. Schemes were made for each check with which checks to take and which data would be included in these steps. After that, the needed data was collected and the necessary functionalities were tried out. This resulted in 7 checks that were possible to execute in the scope of this project.

While the basic infrastructure was set up, the interface for the prototype was sketched. This related to both the part where the map would be introduced for 2D and 3D data as the part where the check results would be shown.

Of those 7 checks, a first version was created to see if the output was in relation to what was expected. When the output of the check was what was agreed on with the client, the check was integrated into the prototype interface. In case the output was not yet what was wanted, the check was further developed into the needed result. After integrating all 7 checks into the prototype interface, all checks were discussed in the project team and further fine-tuned. The stage ended with writing all conclusions and recommendations down in this final report.

Like in the first stage of the project, close coordination was sought with the client. This was very important given the innovative nature of the project. Because many things were not yet completely clear in advance and unexpected results were more the rule than the exception, choices had to be carefully coordinated. In an agile process in which the customer was involved in the results every two weeks, the prototype was developed over the past four months, broadly in accordance with the schedule as can be seen in Figure 4. In addition, there was a structural communication line in a shared Skype group, which allowed for quick and effective communication between stakeholders.

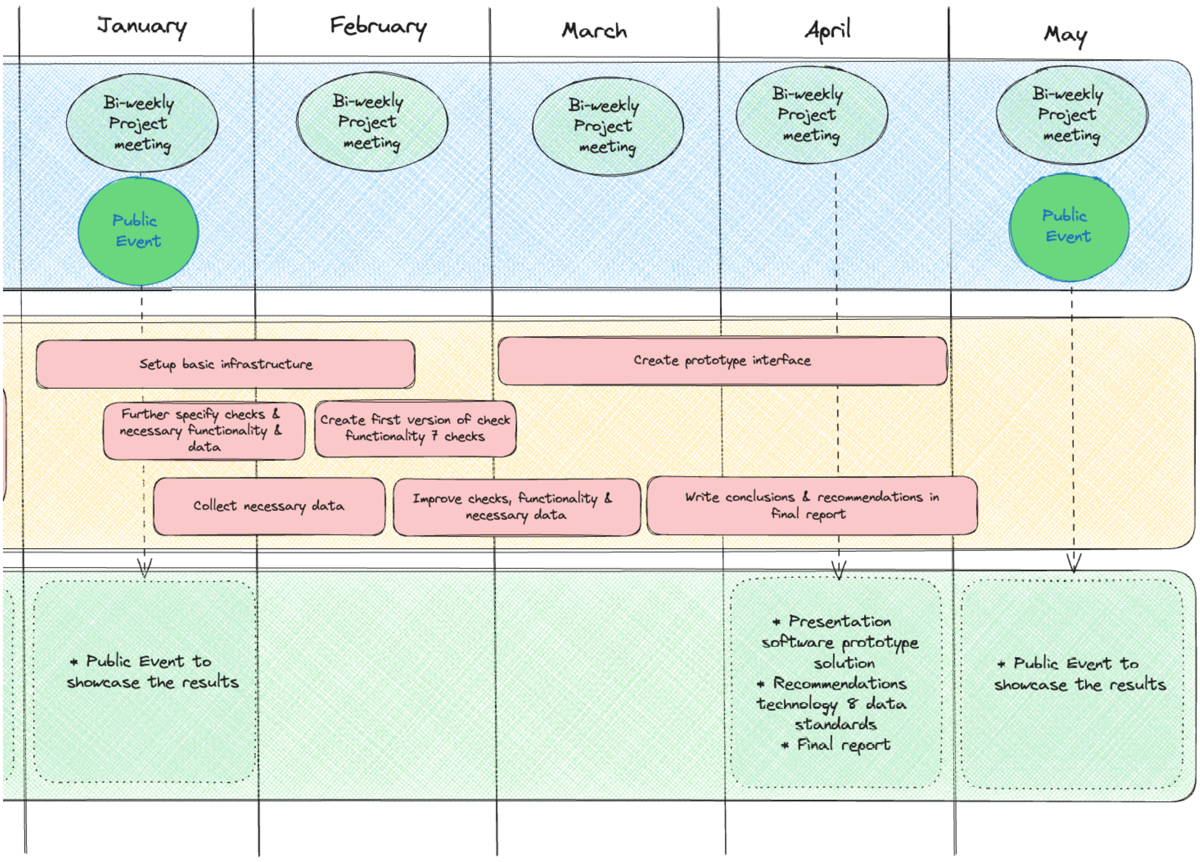


*Figure 4: Methodology and planning of the 'software prototype solution' stage.*

# 4. The prototype solution

This chapter describes the methodology of the software prototype solution stage. The goal of this stage was to create a prototype in which checks are executed on BIM models to simplify and speed up the Estonian detailed planning process. This prototype is based on the results of the desk research and interviews.

The products that are delivered in this second stage are:

- A prototype solution based on existing software
- Seven checks that can be used within that prototype
- Clear direction for the planning data to be standardised to be used for automatic checking

The solution direction for the prototype solution came forth from stage one, the detailed analysis stage. In the second stage we set up the basic technology, prepared the required data and set up the checks. A shortlist of ten possible checks was agreed upon, from which seven checks were developed. Scalability of the prototype was considered throughout its development.

Based on the three products, we identified the following activities to be executed:

- Prototype solution
    - Setup basic infrastructure
    - Specify necessary functionalities
    - Create prototype interface
    - Implement checks in interface
    - Recommend how to implement real solution
- Checks
    - Specify checks to be executed
    - Collect necessary data
    - Create first version of the check functionality of seven checks
    - Implement checks in interface
    - Recommend improvements for further development of checks
- Standardising planning data
    - Collect necessary data
    - Investigate which data and properties are needed to perform checks
    - Recommend improvements for data standardisation

Every component will be discussed in a subchapter, together with the actions taken, lessons learned and recommendations. First, the starting points are described, thereafter the technical infrastructure of the prototype is shown, followed by a description of the developed checks and data requirements.

## 4.1 Starting points

Several requirements were set for the development of the software prototype, based on which the final solution is made. This included the following points:

The prototype should:

- Be web based, have a simple user interface and follow [the style book of the e-construction platform]
- Include 3D visualisation of planning information models.
- Use only open data formats (including IFC for detailed plans)
- Display different layers used in the information models, such as buildable areas, greenery, transport area, etc. The layers should be put on and off by the user of the prototype.
- Display information/attributes added to the layers.
- Display the result of automatic checks of compliance with the requirements of the planning information model to the software users, similar to the automated checks of the BIM-based building permit procedure..
- It should be piloted with at least 3 detailed planning information models.

Based on the existing systems, the location of the prototype has been determined just before the PLANK system, in which established detailed plans are registered in 2D. The position of the solution is shown in Figure 5. When carrying out the automated checks, it will mainly have to be able to use available 2D & 3D geo information such as master plans, thematic plans, other policy maps or asset management information. At the same time, the new 3D detailed plans can also be used later on to test architectural designs when applying for a building permit.

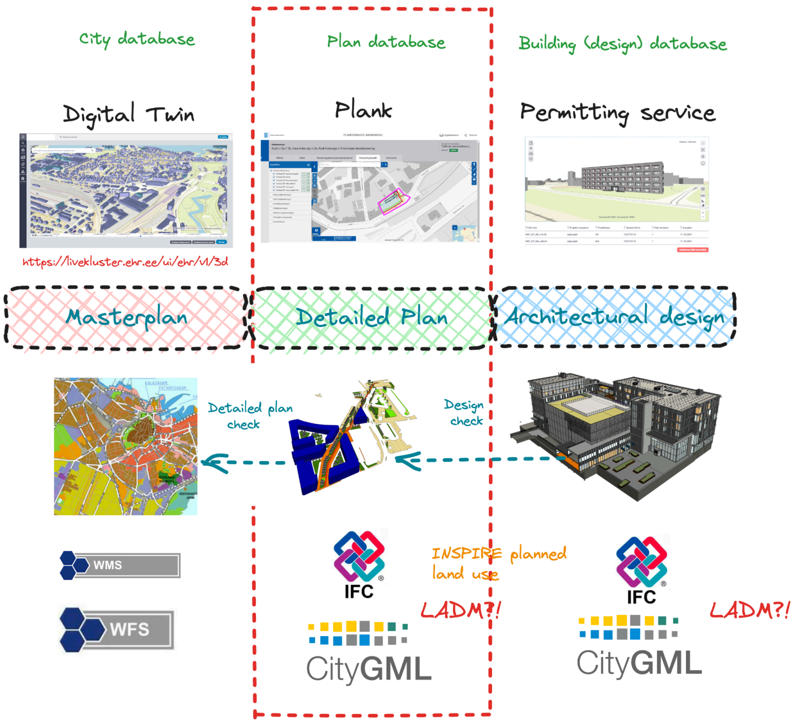


*Figure 5: The phases of the Estonian planning process together with the IT and data (standards) used.*

## 4.2 Technical Infrastructure

Based on the results of the research phase and our previous experiences, a proposal has been made to base the solution on an online microservice architecture using international open standards. This is also in line with previous initiatives, the design of the e-construction platform and other international initiatives that have been investigated, such as Accord[6] and CHEK[7]. At the same time, it also appears that there is still very little experience with standardising and automatically checking detailed plans, which means that there are actually no operating examples available yet.

The basic components for this approach are already available in the [Clearly.Hub](). This is Future Insights digitally connected ecosystem that anyone can connect to. From one central facility, data and apps are made available in a secure manner for various applications using various international standards and openAPIs. Sensor, 2D, 3D and BIM data and functionalities are already supported by the ecosystem. In the Clearly.Hub, data, functionality and apps are completely and strictly separated and by connecting them using open standards and protocols, an open and flexible digital ecosystem is created that is scalable, flexible and sustainable. Figure 6 describes  a general idea of how this works.

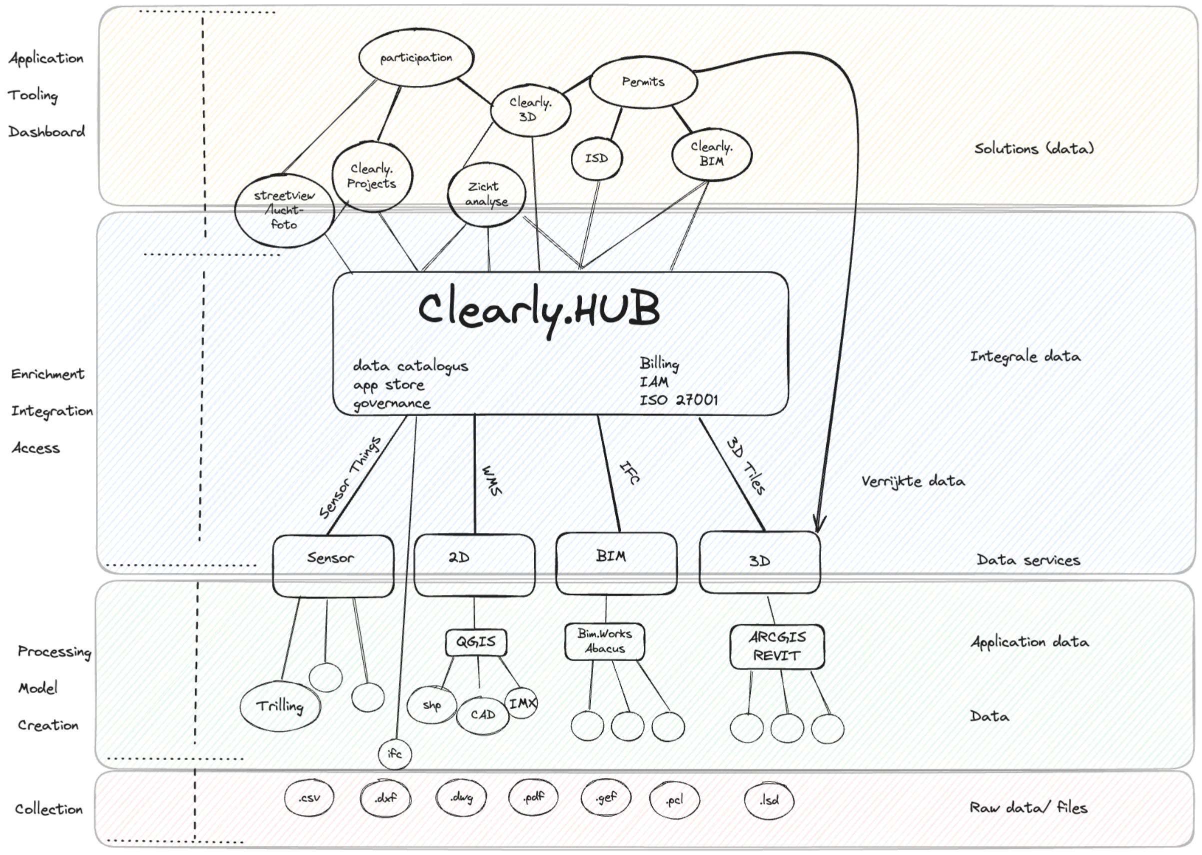


*Figure 6: Overview of the technical infrastructure of the prototype solution.*

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[6] https://accordproject.eu/wp-content/uploads/2023/09/ACCORD_D1.2_ACCORD-Framework-and-User-Requirements-Specification.pdf

[7] https://chekdbp.eu/

### 4.2.1 Components and standards used

An important part of the solution is organising the implementation of the checks. To ensure that this is done as flexibly and openly as possible, we started using a so-called orchestration service. With this service it should be possible to combine different online analysis services. This principle is also part of the ACCORD target architecture, for example, but there is little experience with it yet. How the orchestration service is an integral service in the technical infrastructure of Accord is shown in Figure 7.

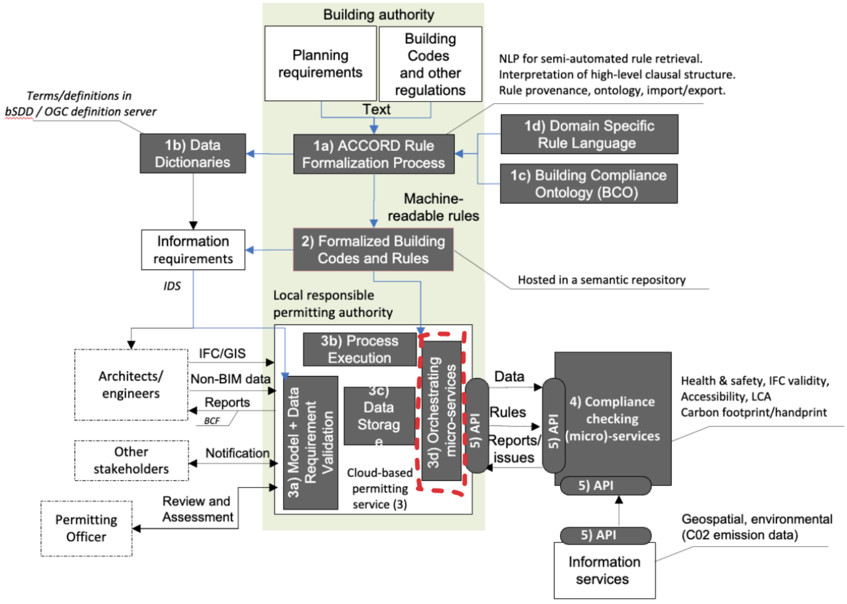



*Figure 7: Overview of the technical infrastructure of Accord.*

Various open and closed solutions are available for this, such as: Netflix Conductor, Apache Airflow and Microsoft Logic Apps. For this prototype we chose FME Flow given the knowledge already available in the community and within the organisation, the flexibility, the extensive available geo-functionality and broad support. A more detailed description of how exactly the checks are set up is detailed in Chapter 4.3.3.

Furthermore, Clearly.Hub plays an important role in the operation of the prototype. Many relevant components in terms of open standards and protocols that are required for the operation of the prototype are already present, making it possible to develop a high-quality, scalable and flexible prototype relatively quickly and easily. In general, there are roughly three steps required for the prototype to function:

**1. Collecting and organising required (source) data.**

A crucial initial step is to collect and organise necessary source data from a variety of origins. Preferably, this data is available as standardised data so that it is scalable, and available for the pilot area. Therefore, data from the PLANK database has the preference, as this data follows a standardised structure. In case the data for the pilot area is not available in PLANK, the secondary preference is to make use of open data, available in an open standard. Examples of such open data are the national 3D Digital Twin of Estonia[8], which is available in CityGML and 3D Tiles, and a dataset containing points of

[8] https://3d.maaamet.ee/kaart/

interest such as fire hydrants and other facilities, which are available in WMS and WFS. A more detailed overview of all data resources used per check can be found in the description of the checks in Chapter 4.3.2.

For the 3D detailed plans, IFC files are collected. They must be available online. The reason why IFC is used in this project as standard for 3D data, can be read in Chapter 3.3. More information about the requirements for IFC data can be found in Chapter 4.4.1.
Finally, the detailed plan to be checked must be available online in IFC. All this (source) data has been organised and made available in a structured manner in the Clearly.Hub as a basis for the prototype and possibly other applications such as the BIM-based permit checking service.

**2. Perform planBIM checks in the orchestrator based on available data and make results available again.**
The various checks configured in the orchestration service are executed. Naturally, the available data and the supplied detailed plan are used, but the results of the checks carried out are also described and made available using a standard structure in 3D Tiles in the Clearly.Hub. An important advantage of this is that the results are not only available for the prototype developed for this project, but also for any other web service, such as the BIM-based permit checking service.

**3. Make standardised results available in the online PlanBIM prototype.**
The developed prototype is a relatively simple web service based on the open source Cesium JS component, which connects to the Clearly.Hub via a standardised and open source OAuth component. The technical infrastructure of the Clearly.Hub in relation to this project can be found in Figure 8. All map layers that have been made available will automatically become available as a map layer in the prototype. For each check you can configure which map layer contains the check results with the associated standardised description and which map layers should be shown as a reference to clarify the result. At the same time, this data can also be used in any other web service, such as the BIM-Based permit checking service, making the infrastructure very flexible, scalable and future proof.

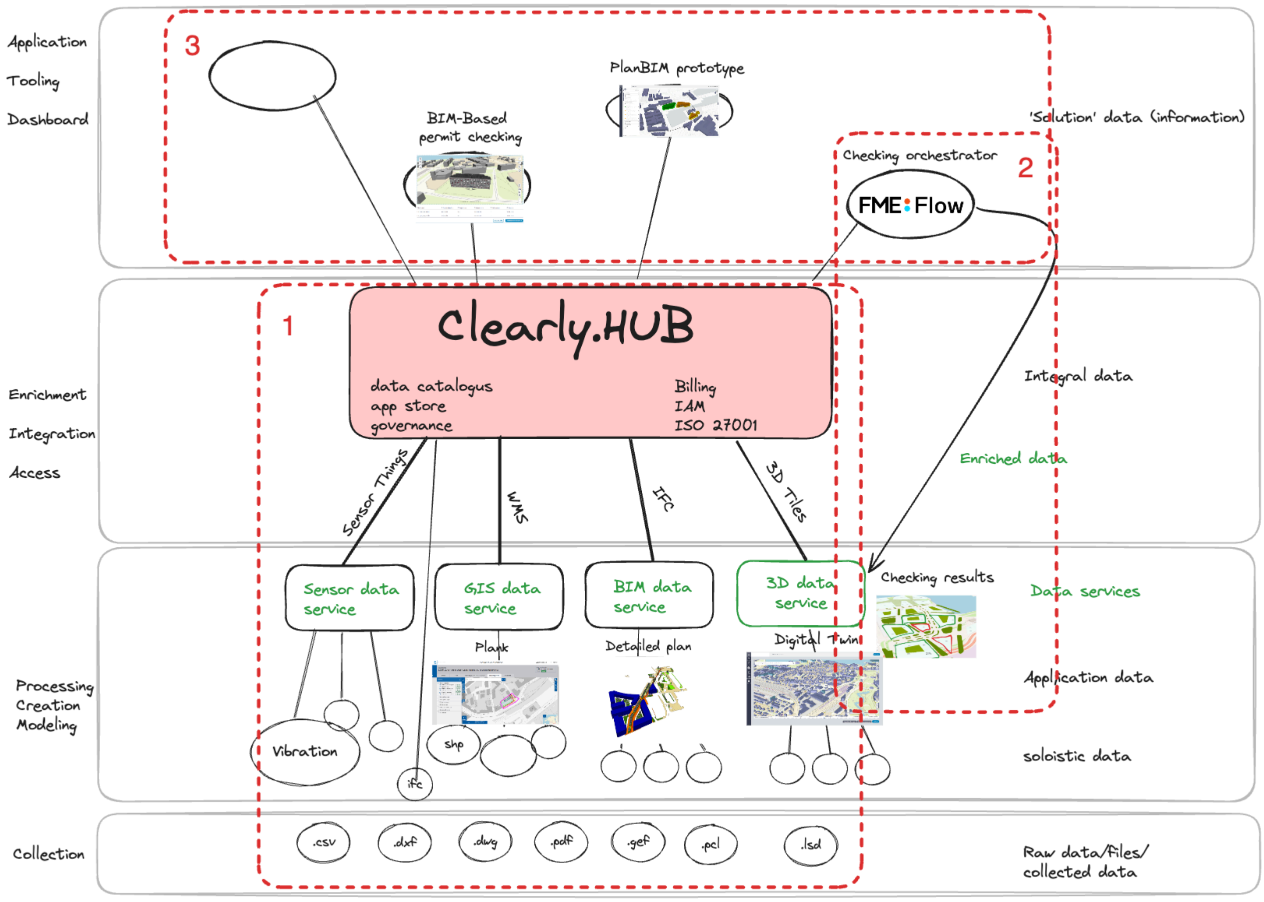



*Figure 8: Overview of the technical infrastructure of the Clearly.Hub for this project.*

## 4.2.2 LADM

To build a scalable and future-proof solution, it is important to use international open standards whenever possible. This ensures that it is easy to connect and learn from other international developments that also use this standard. The most relevant standard available for this topic is LADM, the Land Administration Domain Model[9].

The Land Administration Domain Model (LADM) established as an ISO standard (ISO 19152:2012) provides a shared ontology, defining a common terminology for Land Administration. Since the vote of its first edition as an ISO standard in 2012 numerous countries have adopted LADM to develop or modernise their Land Administration System.

Currently, its second edition is under development, including extended functionality to support valuation, taxation, spatial planning and zoning. The LADM Edition II will be published as a multi-part series that has resulted in the development of six standards backwards compatible with Edition I.

[9] van Oosterom, P., & Lemmen, C. (2015). The land administration domain model (LADM): Motivation, standardisation, application and further development. Land use policy, 49, 527-534.

LADM Part 5 - Spatial Plan Information (ISO 19152-5) aims to integrate land registry and planned land use information on the same conceptual model and allow shared usage of both datasets. It supports planning hierarchy, organises plan units in a plan block, provides extensible code list values for the spatial (sub) functions of the plan, supports permit registration related to the relevant plan unit and allows open dissemination and clear 2D and 3D visualisation of plan information. An overview of LADM Part 5 can be found in Figure 9.

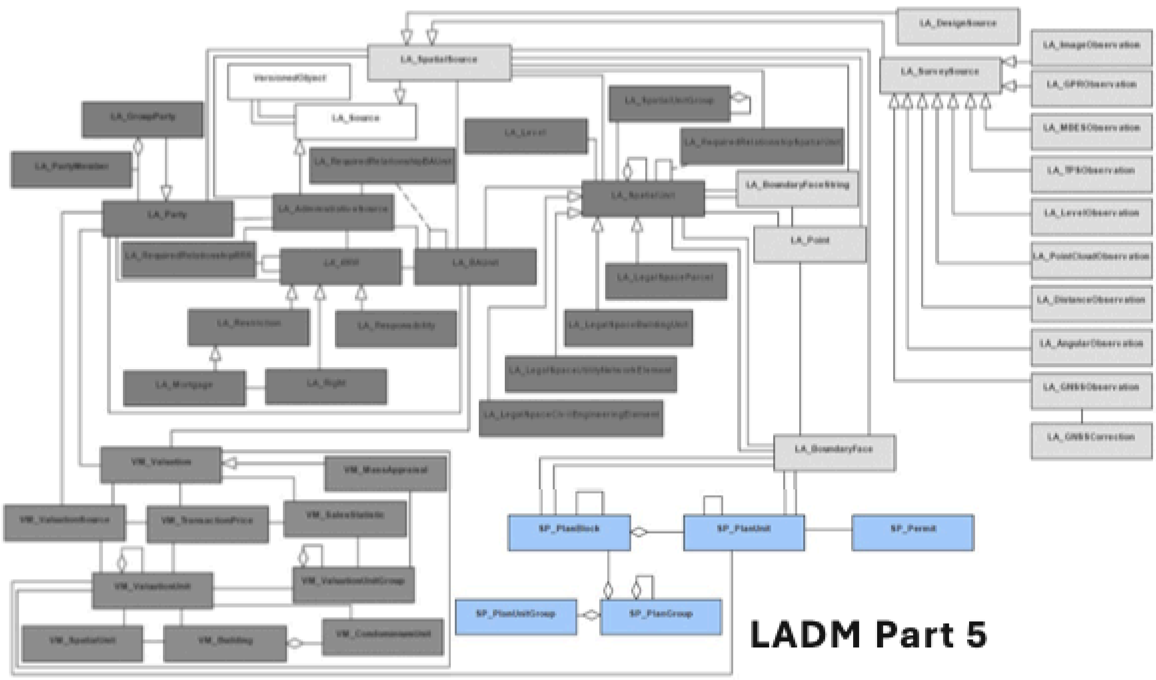



*Figure 9: Overview of LADM Part 5.*

Part 5 will contribute to the need for a clear way to store the urbanistic rules and make them available for processing. Integrating LADM into the Estonian planning process would be a strategic solution to the possible limitations of the application. This integration can provide seamless validation of one spatial plan against another plan (e.g., a detailed plan against a master plan), and LADM itself can contribute by being a consistent data standard throughout the spatial life cycle rather than the creation of new, unstandardized data in every phase. Finally, using LADM in the pipeline would foster interoperability and enhance communication within different LAS modules, which LADM provides for the project's future development.

In the context of the project, an LADM Part 5 country profile for Estonia has been developed[10]. The first step was to map the LADM Part 5 basic classes with the layers of spatial plans in Estonia, as presented in Figure 10.

[10] Proceeding paper for the [12th International FIG Workshop on LADM & 3D LA 24-26 September 2024, Kuching, Malaysia]: Batum, S., E. Kalogianni, M.A. Broekhuizen, C. Raitviir, K. Mägi & P. van Oosterom. (2024). Leveraging BIM for the registration of spatial plans and permit checking in Estonia based on LADM Part 5 - Spatial Plan Information; appendice d

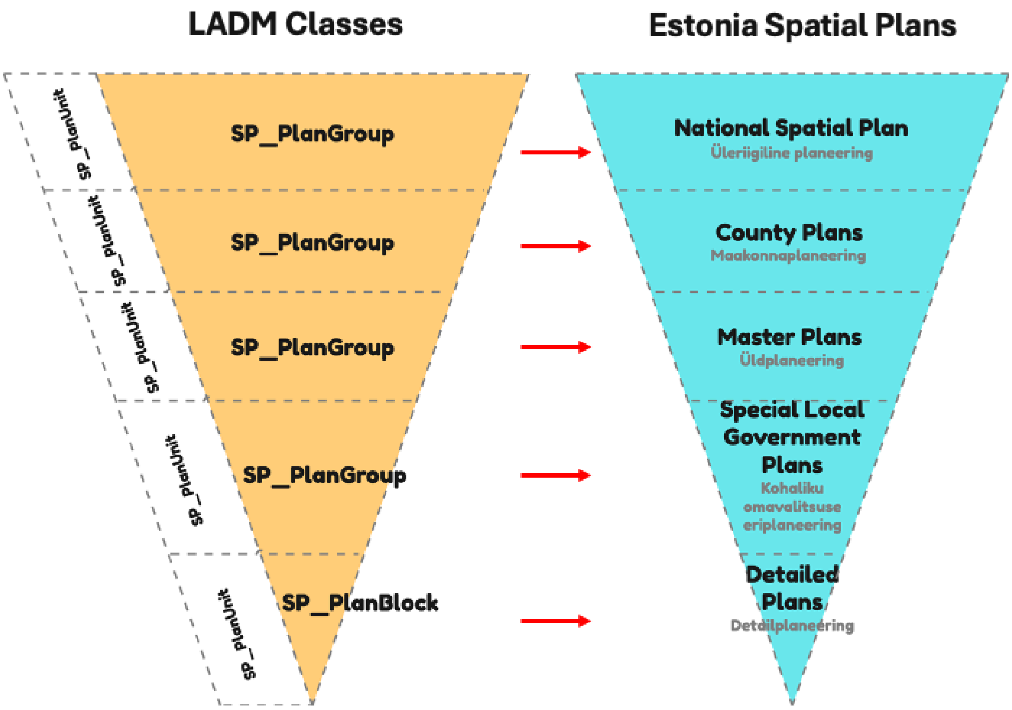



*Figure 10: Overview of the LADM classes in relation to the Estonia Spatial plans.*

It contains three main classes: SP PlanningBlock, SP PlanningUnit, and SP PlanningGroup. SP PlanningBlock and SP PlanningGroup were associated with the different plan types (e.g. Detailed plan, Master plan, etc.) and a new Estonia class, respectively to the different plan types was made containing these LADM classes. Each mapping level also has its own specific SP PlanningUnit class, which represents focused areas in that specific plan. For example, the Detailed plan, which is represented by EST_Detailed_Plan in the final model has an EST_Detailed_Unit class associated with it. EST_Detailed_Plan can represent the whole detailed plan data while EST_Detailed_Unit can offer more information about focused units in the Detailed Plan.

### 4.2.3 User Interface Design

As required in the tender the UI should be simple, based on the style book of the e-construction platform and work similar to the automated checks of the BIM-based building permit procedure. The developed prototype is available online at [https://estonia-poc.clearly.app/](https://estonia-poc.clearly.app/). A general login to get access is available using [estonia@futureinsight.nl](mailto:estonia@futureinsight.nl) and password **Ar3ac#eck**. As visible in Figure 11 and 12, the PlanBIM prototype and the BIM-based permit service they look very similar despite different technologies used in the background:

- The service is integrated into the e-construction platform, making it easy to reuse at relevant places in the process.
- A 3D viewer is the central part of the service and shows the plan in the clearest and simplest possible way.
- On the right side of the screen are a number of control buttons with which map elements can be operated.
- On the left side of the screen is a menu showing the check results. More information is provided about these results per check and the viewer automatically zooms in on the selected object.

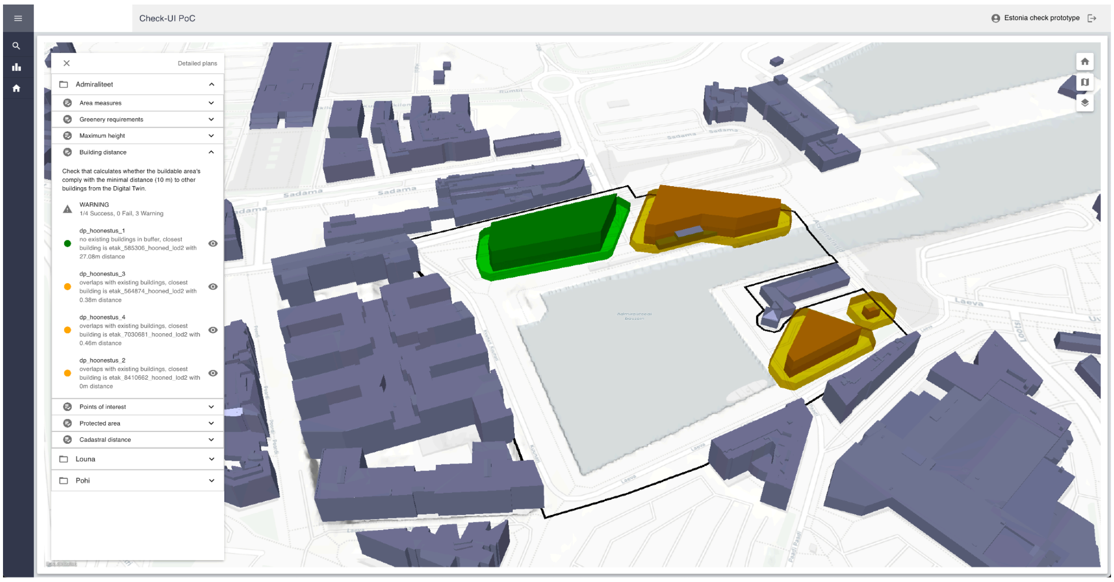



*Figure 11: Interface of the new PlanBIM prototype service.*

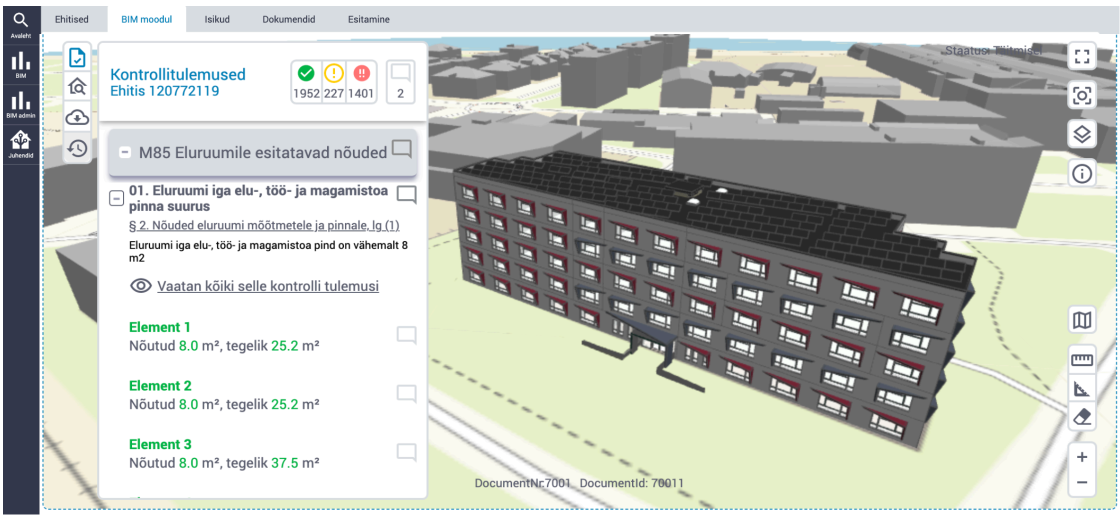



*Figure 12: Interface of the current automated BIM-Based permit checking service.*

### 4.2.4 Key lessons learned & Recommendations

During the development of the prototype solution, several lessons were learned that resulted in recommendations:

- Due to the fact that drawing detailed plans in 3D is not yet the standard and automatic checks on this data type are still new, several agreements still need to be reached regarding central availability and standardisation of such data.
- The precise interpretation of regulations is currently under extensive discussion. A lot of time and attention will have to be spent on this to really translate the rules properly into a supported and conclusive automatic check. Significant time and attention will be required to accurately translate these rules into a robust and definitive automated verification process.
- Visualising results tends to get complicated quickly. Try to keep the visualisation as simple and standardised as possible and stick to the core of the message. Otherwise it will not become easier, but more difficult.
- Make very clear agreements about the standardised delivery of check results. For example, that they always contain the columns ID, description, result and that they are delivered in 3D Tiles or added to a CityGML database. This creates a generic approach that is consistent, scalable and flexible.
- Use common associations when using colour and keep it simple. Green (pass), Yellow (warning) and Red (fail) are associations that users already have, for example, and that are logical. Also keep the colour of the reference layers calm, so that the check result stands out clearly.
- By using a streaming file format such as 3D Tiles, it is now possible to zoom in only on check results. They cannot be turned on and off individually, which would make the results even clearer. To make this possible, a direct connection could perhaps be used in the future, for example a CityGML database and use of the OGC API standard.

## 4.3 Implemented checks

### 4.3.1 Introduction

In the first phase of this research, several interviews were conducted that delivered a total of 18 unique check possibilities. These checks were analysed against the criteria clarity, feasibility, value and 3D advantage which resulted in ten check possibilities being taken into consideration. After analysing the data and technical possibilities, seven checks were developed and implemented in the prototype solution.

In this subchapter, the seven implemented checks are described. This includes a short description of the check, a description of the data needed to execute the check and a technical description of the check. Additionally for each check remarks, recommendations and future improvements are noted, which are summarised at the end of the subchapter, and are also input for the data requirement analysis in Chapter 4.4. The checks below were ultimately selected and developed in close consultation with the client.

| Nr. | Short name | Detailed Description |
|---|---|---|
| 1 | Check area measures | Calculate the area per land use type, such as the building area, to give an overview. |
| 2 | Greenery demands (%) | Calculate the percentage of greenery area in the plan area, to compare to the requirements of the master plan. |
| 3 | Maximum building height | Check if the height of the buildable area is within the maximum building height requirements. |
| 4 | Building distance | Calculate the distance of buildable areas against buildings in the digital twin. The distance between buildings has to be compliant with minimum distance according to fire requirements. |
| 5 | Fire hydrants | Calculate the distance of buildable areas against fire hydrant data from the digital twin. The distance from the buildable area to fire hydrants has to be compliant with minimum distance according to fire requirements. |
| 6 | Protected area requirements | Check if the detailed plan overlaps with protected areas, such as protected heritage areas or flood areas, and give a warning or error if their is overlap. |
| 7 | Cadastral border distance | Calculate the distance of buildable areas against its cadastral border. The distance from the buildable area to cadastral border has to be compliant with minimum distance according to fire requirements. |

Next to the seven checks, a check orchestrator is implemented, to run all checks at once, and gather and process the check results for the user interface. This orchestration is described in Chapter 4.3.4

### 4.3.2 Data analysis for automated checks

For the execution of the checks, data of the detailed plan and the master plan is needed. Data for the detailed plan in this prototype are BIM models, in the open standard IFC. This differs from the currently often used 2D geodata in CAD or .shp format. Additionally, it is not (yet) an official format to be used in spatial planning according to the regulations and therefore for PLANK. During the development of the prototype the use of IFC's representing detailed plans as input for automated checks was investigated. For the current prototype, the following data requirements are stated for detailed plan IFC's:

**IFC requirements**

For the IFC model of the detailed plan, the following data requirements apply:

1. The detailed plan file(s) are IFC
2. The objects in the IFC are IFC entity IfcBuildingElementProxy or IfcAnnotation
3. The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the following list (concurrent with the regulations and PLANK):
    a. dp_arhVoistlus|dp_avalik|dp_haljastus|dp_hoonestus|dp_juurdep|dp_KKTingimus|dp_KOVLoodus|dp_krunt|dp_krundiSihtotstarve|dp_maapar|dp_servituut|dp_sund|dp_tehno|dp_tingimus|dp_transp|dp_vaartloodus|dp_vaartMiljoo|dp_vaartPollum
4. The property sets contain attributes according to the mandated attribute list described in the regulations[11].
5. The IFC(s) should contain exactly one plan boundary, identified by the propertyset dp_plan_ala, and modelled as line in the IFC entity IfcAnnotation
6. The IFC(s) should contain one or more plot boundaries, identified by the propertyset dp_krunt and modelled as line in IFC entity IfcAnnotation
7. The objects of the IFC cover the entire planning area
8. The objects of the IFC do not overlap with each other
9. The IFC(s) contain a correct georeference and are modelled in EPSG:3301

### 4.3.3 Functional elaboration of the checks

In this subchapter, a functional elaboration for each of the seven checks can be found. Each elaboration starts with an analysis of the four criteria: clarity, feasibility, value and 3D advantage. The scale of these criteria is as follows:

| Symbols used | Meaning |
|---|---|
| VV | Very positive/very high |
| V | Positive/ high |
| X | Negative/low |
| XX | Very negative/very low |

[11] https://www.riigiteataja.ee/akt/121102022001, appendice C

1. Check area measures

| | |
|---|---|
| **Clarity**<br>XX / X / V / **VV** | **Feasibility**<br>XX / X / V / **VV** |
| **Value**<br>XX / X / V / **VV** | **3D Advantage**<br>XX / **X** / V / VV |

**Description:**
Show an overview of the area measurements per land use type within the detailed plan boundary. The check is informative, the results can be judged by the user.

**Necessary source data:**
IFC model(s) representing the detailed plan

**Data requirements:**

IFC model(s):
- See general requirements for IFC model(s) in Chapter 4.3.2., specifically:
    - The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the list concurrent with PLANK.
    - The IFC(s) should contain exactly one plan boundary, identified by the propertyset plan_ala, and modelled as line in the IFC entity IfcAnnotation
    - The IFC(s) should contain one or more plot boundaries, identified by the propertyset dp_krunt and modelled as line in IFC entity IfcAnnotation

**Technical description how check is executed (steps taken):**

Input:
- The IFC(s) of a detailed plan

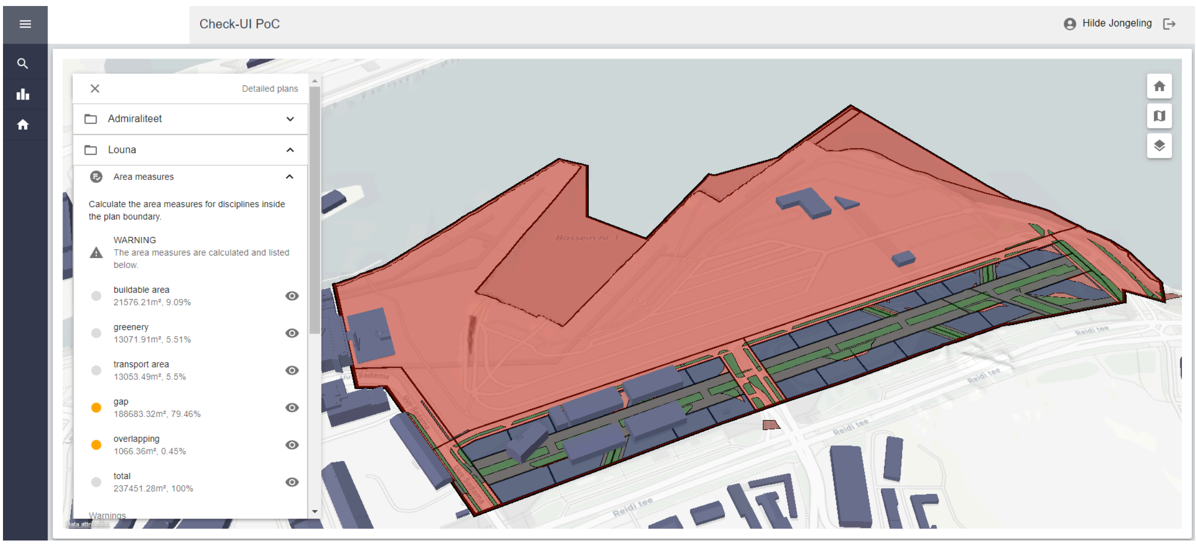
1. The IFC files are read
2. As described in the data requirements objects in the IFCs have to be assigned a propertyset whose name represents the discipline. The name of these propertyset is limited to a list of propertyset names concurrent with layer names defined in PLANK.
   The objects in the IFC files are read, and it is tested if they contain one of the property sets required. If objects do not have a propertyset from the defined list, they are logged as warning and ignored in the rest of the progress.
3. Based on the previous step it is verified that the IFC(s) contains at least the following disciplines (i.e. objects with a propertyset named accordingly):
    - dp_plan_ala
    - dp_krunt
   These disciplines are required both by PLANK guidelines, and are also necessary for input in this check and following checks. Therefore if they are not present, the check is terminated.
4. The (3D) geometries of objects are validated
5. The 3D geometries are converted to 2D surfaces
6. A distinction is made between:
    - The planning boundary (dp_plan_ala)
    - The plot boundary (dp_krunt)
    - Other discipline layers
7. The discipline layers are clipped with the plan boundary. If any parts of the discipline layers

are outside the planning boundary, this is invalid. The results is:
   - Discipline objects within the plan boundary, they continue in the process
   - Discipline objects outside the plan boundary, they are logged as warning.
8. An overlap analysis is made. In this analysis it is assessed if areas are unique, or if two or more discipline areas are overlapping. The result is:
   - Areas which are unique, they continue in the process
   - Areas which are overlapping, they are logged as warning. Since they can not count towards any discipline, the discipline name is replaced with 'overlapping'
9. A gap analysis is made to see if all objects/area cover the entire area within the plan boundary. The result are:
   - Gap areas. They are logged as warning. A discipline name is assigned: 'gap'. They continue in the process.
10. The area in m2 is calculated for the plan boundary
    - An attribute to the plan area is added: area_m2, which contains the area in m2.
11. For each area, the area is calculated
    - An attribute to every area is added: area_m2, which contains the area in m2.
12. For each area, the relative area compared to the plan area is calculated
    - An attribute to every area is added: area_rel, which contains the area in % compared to the plan area

Outcome:

- Result:
  - Overall result (Success, Warning)
  - List of disciplines with area in m2 and area %
  - The total plan area in m2
  - List of warnings, containing:
    - Objects without a valid discipline name
    - Objects outside the plan area
    - Overlapping areas
    - Gap areas
- Geojson of plan boundary
- Geojson of plot boundaries
- Geojson of plan footprint

**Check visualisation and interpretation**



The result of the check is an overview of land use type in percentage and square metres.

In the checkbox, an overview of the land use types is given. This includes per land use type a percentage and a m2. Besides the land use types given by the disciplines in the IFC model, the overview will also include percentages and m2 for the gaps and overlaps.

On the map, the different land use types are grouped and visualised with different colours. Clicking on the land use groups will give more information about the group.

Gaps and overlap areas are logged as warnings and visualised in red. Additionally objects outside the plan boundary are visualised in red. These areas should be further investigated, as they are invalid parts of the detailed plan.

**Diagram**
The diagram of this check can be found in Appendix B2.

**Reliability**
During the validation, warnings can be generated for the model if some requirements are not met. When they are not met, the overview is still generated. Since the outcomes of these checks are used as input for other checks, this impacts the results of other checks.

A good example of this is the greenery check, which uses the outcome of this check. For example, in the "Põhi" detailed plan greenery is present, but it overlaps with buildable area and is therefore presented as 'overlapping', this results in fails in the greenery checks, whereas if there was no overlap they would be successes.

**Possible future improvements / recommendations**

**Lessons Learned**

1. Overlapping polygons can result in double-counting or underestimation of certain land cover types, leading to misleading conclusions. Therefore an overlap analysis is needed to prevent unreliable check results in further checks.
2. Since areas are aggregated per discipline, overlap within a discipline is less problematic.
3. Although we run a validation on the IFC model(s), we still continue when the model gives a warning. We do this to be able to show more results. However, in practice invalid detailed plans cannot be checked reliably.
4. The trees that occurred in the IFC models are tree models which are hard to convert to a reliable surface area. Therefore, they are not taken into account in this check.
5. In earlier versions of the detailed plan IFC models plan and plot boundaries were modelled as 3D solids. Even though this allows for a clear 3D visualisation, for the processing of boundaries a more accurate geometry was needed. Therefore a new version of the detailed plan IFC's included the boundaries as line in the IFC entity IfcAnnotation. This proved to be better usable and give more accurate results. However, it should be further investigated if the use of annotation lines is the optimal solution.

**Recommendations**

1. Validate and don't continue with the check if the validation results in an error.

**Future improvements:**

1. Find a way to include trees in the calculation of the area measurements. Since trees contribute to the greenery in a detailed plan, the results of area measures will greatly differ

depending if the area of the trunk or crown of the trees are calculated. For now, we only calculated the footprint, so the volume or items on the model were out of scope. To give a more precise result, the volume of trees and other objects should be taken into account as well. Alternatively, the current area measures analysis is quantitative, however the quality of the greenery is not taken into account, as this is difficult to measure objectively.

2. Next to trees, in general the handling of 3D objects is not described in the current standards. This description can be made, including allowed (3D) geometry types per discipline, and how to process them both in 3D as in 2D.

| 2. Check greenery area | |
|---|---|
| **Clarity**<br>XX / X / V / **VV** | **Feasibility**<br>XX / X / V / **VV** |
| **Value**<br>XX / X / V / **VV** | **3D Advantage**<br>XX / **X** / V / VV |

**Description:**
Check whether the greenery area in the detailed plan is sufficient according to the requirements stated in the master plan.

**Necessary source data:**

1. The geojson created in the first check contains the area measures of the detailed plan.
2. The geojson created in the first check containing plot boundaries
3. Greenery requirements for the area of the detailed plan. Currently, we use map layers called "Masterplan_greenery_demands". These map layers are available in WMS and WFS and provide percentages for the different areas in Tallinn. Ideally, there should be plan data from the central PLANK database with a national level of greenery.

**Data requirements:**

IFC:
- The check 'Check area measurements' has successfully run. Therefore the IFC requirements of 'Check area measurements' apply.

Geojson:
- The geojson plan_footprint.json, containing land use types should not contain warnings. For the execution of this check, this requirement is ignored so results are visible.

Greenery requirements:
- WFS service with greenery requirements
- In the data, geometries are expected with a percentage attribute that has a numeric value that represents the greenery percentage from 0 to 100.

**Technical description how check is executed (steps taken):**

Input:

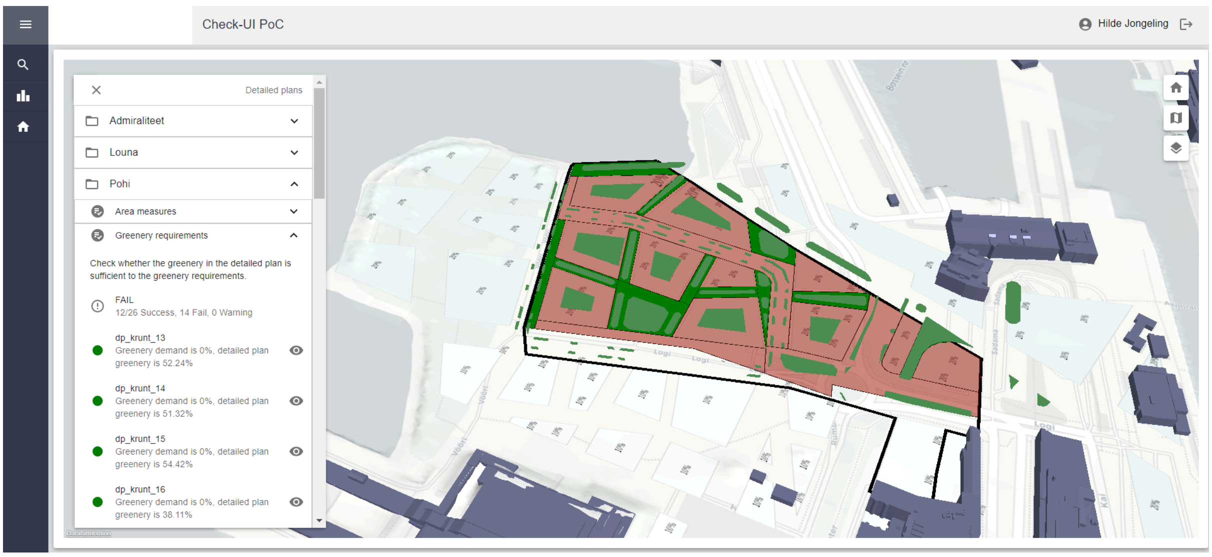
- Geojson of plot boundaries (Created in area measures check)
- Geojson of plan footprint (Created in area measures check)
- Greenery requirements WFS

1. Read plot_boundary geojson
2. Read Greenery Requirements WFS
3. Perform an overlap analysis for the detailed plan plots and the greenery requirements. The results can be:
    a. Single overlap - the greenery requirement of the detailed plan plot is according to the overlapping greenery requirement from the master plan area
    b. Multiple overlap - the greenery requirement of the detailed plan plot is according to the overlapping greenery requirement from the master plan area with the highest greenery requirement. A warning is given.
    c. No overlap. The greenery requirement of this plot is 0%
4. Assign greenery requirement value per plot based on above overlap analysis
5. Read the plan_footprint geojson, containing the area measures per land use type
6. Filter the greenery areas. The origin of these areas are objects in the detailed plan with discipline dp_haljastus
7. Calculate the greenery area % per plot, using the greenery areas from the plan_footprint geojson
8. The calculated greenery area % is compared to the greenery requirement
    - If the calculated greenery area % is equal to or bigger than the greenery requirement, it is a success.
    - If the calculated greenery area % is smaller than the greenery requirement, it is a fail.

Outcome:

- Result:
    - Success / Warning / Fail
- Results geojson for visualisation

**Check visualisation and interpretation**



The result of the check should be an overview of the different plots in the detailed plan and whether they meet the greenery requirements or not.

In the checkbox, the overall result is given based on the individual plots. If all plots meet the greenery requirements, the result is a success. If one of the plots fail the requirements, the result is a fail.

On the map, the plots in the detailed plan turn green when they meet the requirements and red when they don't. When clicking on a plot, individual information is given for that plot about the check result and the corresponding value. The value states what the greenery requirement for that plot is and what the actual greenery value is.

**Diagram**

The diagram of this check can be found in Appendix B3.

**Reliability**

In the validation, we also let models continue with warnings and errors in the validation. If greenery is not recognized, the check is still executed and will give an error as result.
Dp_haljastus is not specifically needed, as it can also occur that a detailed plan does not have greenery included in the plan.

**Possible future improvements / recommendations**

Lessons learned during execution:

1. There is no national standard available regarding greenery requirements in the national regulations for spatial planning. Therefore, we used Tallinn data to execute this check.
2. The plots from the IFC model do not correspond to the areas in the Greenery requirements WMS provided by Tallinn. For now, we can provide a validation message warning for this incongruence, but for a more reliable outcome it is recommended that the greenery requirement areas are congruent with plot boundaries.
3. Some plannings do not contain any greenery at all and some do not contain greenery for the plots given by the greenery requirements, while there is greenery placed somewhere else.
4. What if there is no data available for the detailed plan area? Does this mean the result is always a success?

Recommendation:

1. We recommend to arrange greenery requirements formally on a national level. These should be used and made available as data fields in the national regulations as well. For this data requirements, we recommend the following:
    a. WFS
    b. Geometries with attributes.
2. Make the plots in the greenery requirements dataset and the plots from the IFC model the same. If the plot area's from the greenery requirements and the plots from the IFC model of the detailed plan (dp_krunt) are the same, the check can be simplified and the output can be made more stable, faster and reliable. This could for example be done by providing plotid's.
3. Also include areas in the data with percentage zero. The data only included plots with percentages, but in between the plots, there was no value given. To increase the reliability of the check, the data should provide a percentage for all area's.

Future improvement:
1. Expand the check with checking the other land use types regarding their requirements. When the requirements are available, this expansion could be realised in an easy way.

3. Building height requirements

| Clarity<br>XX / X / **V** / VV | Feasibility<br>XX / X / **V** / VV |
|---|---|
| **Value**<br>XX / X / V / **VV** | **3D Advantage**<br>XX / X / V / **VV** |

**Description:**
Check whether the maximum height of the buildable area in the detailed plan is equal or less than the maximum building height described in the master plan for the buildable area in the plot.

**Necessary source data:**
1. IFC model(s) representing the detailed plan.
2. Building height requirements. Currently we use the Tallinn service as input, but ideally this should be plan data from the central PLANK database. The dataset we use is called 'Masterplan_height' and available as WMS and WFS.

**Data requirements:**

IFC model(s):
- See general requirements for IFC model(s) in Chapter 4.3.2., specifically:
- The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the list concurrent with PLANK.
- The buildable area is identified by the propertyset 'dp_hoonestus', and should contain at least the attributes 'objectid' and 'korgus', with a value higher than 0.

Building height requirements:
- Building height data of the master plan should be available.
- For the maximum building height dataset, WFS data is required.
- In the data, geometries are expected that represent the plots. These plots should have a numeric value that represents the maximum building height for that area.
- The height should be given in a numeric value in metres, in order to be able to compare.
- The geometries of the building height dataset should be within the planning boundary of the detailed plan.

**Technical description how check is executed (steps taken):**

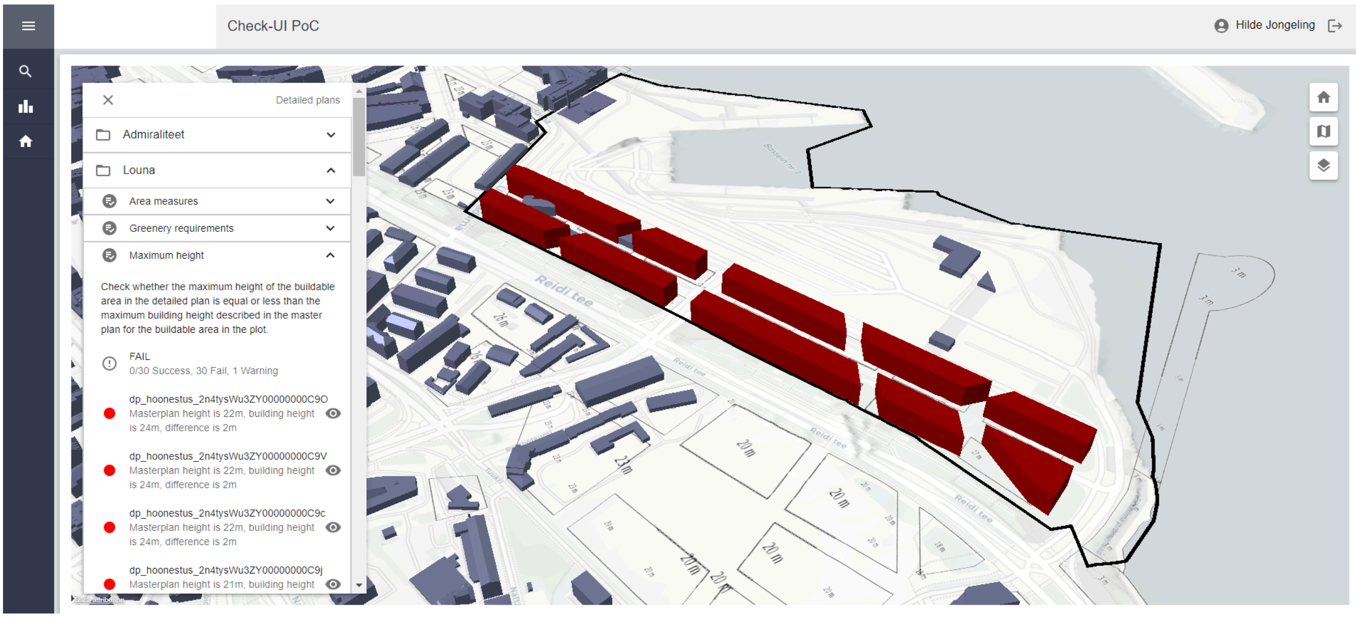
Input:
- IFC(s) of detailed plan
- Building height requirements on plot level

1. The IFC files are read

2. The buildable area solids are filtered (dp_hoonestus). Only buildable areas are used for this check.
3. Validate if the building height attribute 'korgus' exists, and if it is bigger than 0.
    a. Buildable areas with a valid height attribute bigger than 0 continue
    b. Buildable areas with an invalid attribute are logged as warning
4. Read the areas with maximum building height requirements from the WFS service
5. Using an overlap analysis, determine which building height requirement applies to which buildable area. If a buildable area overlaps the plot boundary, a warning is given.
6. Compare the values of the buildable area height and the masterplan height requirement
    a. If the buildable area height is smaller or equal to the masterplan height requirement, this is a success.
    b. If the buildable area height is larger than the masterplan height requirement, this is a fail.

Outcome:
- Result:
    - Success / Warning / Fail
- Results 3D Tiles of buildable areas for visualisation

**Check visualisation and interpretation**




The check gives as result for the detailed plan which buildable areas are compliant to the height requirements.

In the checkbox, the overall result is given with a success, fail or warning message. When one or more buildable areas do not comply with the requirements, the output of the check is a fail. For each buildable area, the height and the requirements are stated.

On the map, the buildable area is coloured green when the check has success as a result, orange when it's a warning and red when it's a fail. Clicking on an individual buildable area will open an information box with the object id, the result and the output value.

**Diagram**

The diagram of this check can be found in Appendix B4.

**Reliability**
During the execution of the check, we do not take the height of the terrain into account, since the height of the plots from the master plan are unknown. This makes the output of the check less reliable in case the maximum height requirements do take the height of the ground into account.

**Possible future improvements / recommendations**
Lessons learned during execution:

1. The building height is often described in stories rather than exact metres. Stories properties are only for Tallinn specific dp_hoone - "korrus_mpe" (stories above ground) and "korrus_mal" (stories below ground).
2. The detailed plan IFC's also contained the discipline 'dp_hoone', representing more detailed buildable areas. However these were not used, since they are not official disciplines from the spatial planning regulations.

Recommendations:

1. Create a national standard value for the building height. Whether this is metres or stories do not matter, as long as it is always the same.
2. Record the maximum building height on a specific location and in a specific field in master plans on a national level and make this a standard.
3. To get results to show, we included objects in the output that had warnings as well. For a more reliable result, the buildable areas that generate warnings should be excluded after the validation.

Future improvements:

1. To improve the reliability and the output of the check result, the height of the ground should be taken into account.
2. In the development of the check analysis based on 3D geometry has also been performed and shows potential. Using calculated heights additional to the value given by the plan designer improves reliability.

## 4. Building distance

| | |
|---|---|
| **Clarity**<br>XX / X / **V** / VV | **Feasibility**<br>XX / X / **V** / VV |
| **Value**<br>XX / X / V / **VV** | **3D Advantage**<br>XX / **X** / V / **VV** |

**Description:**
Calculate the distance of buildable areas in the detailed plan against buildings in the digital twin. The distance between buildings has to be compliant with minimum distance according to fire requirements.

**Necessary source data:**

1. IFC model(s) representing the detailed plan
2. Digital twin data in CityGML. For this check, the LoD2 buildings of the Digital Twin of Tallinn were used.

**Data requirements:**
IFC model:
- See general requirements for IFC model(s) in Chapter 4.3.2., specifically:
- The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the list concurrent with PLANK.
- The buildable area is identified by the propertyset 'dp_hoonestus', and should contain at least the attribute 'objectid'.

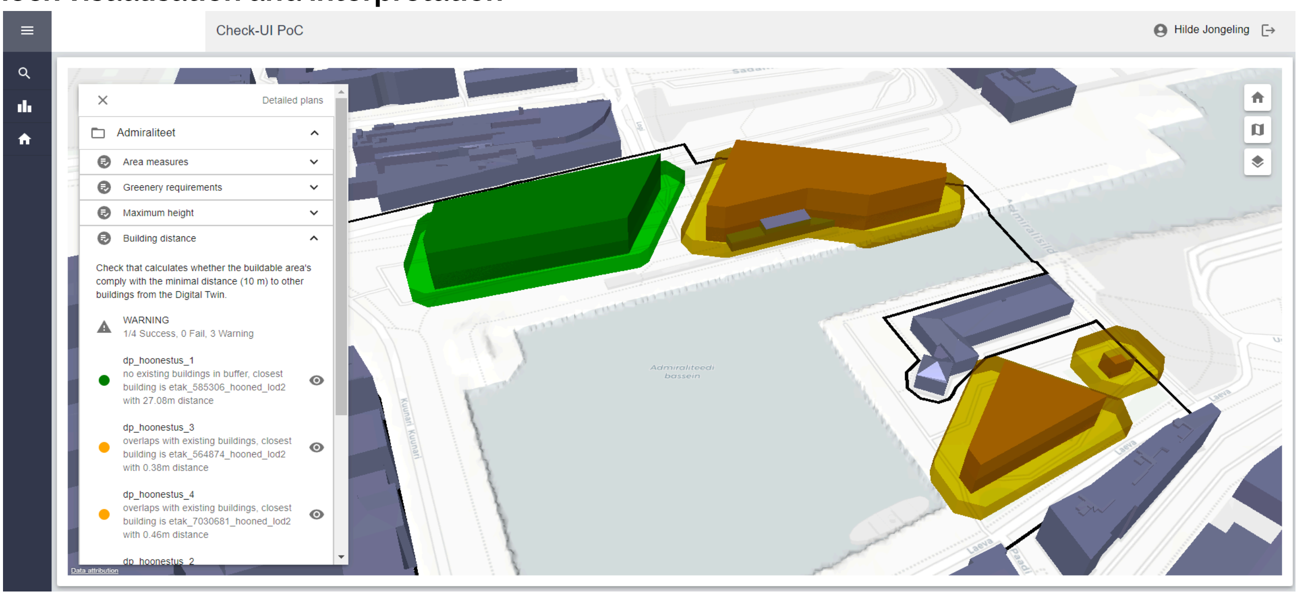
Digital twin:
- The data of the digital twin should be available in CityGML.
- It should contain 3D buildings in the neighbourhood of the detailed plan.
- It is recommended that the input of a digital twin is consistent, and not varying per city.

**Technical description how check is executed (steps taken):**
Input:
- IFC(s) of detailed plan
- Digital twin
- Minimal building distance in metres (numeric)

1. The IFC files are read
2. The buildable area solids are filtered (dp_hoonestus). Only buildable areas are used for this check.
3. All Digital Twin buildings within the plan boundary + the buffer distance are read.
4. Around the buildable area(s), a buffer of Xm(minimum distance) is drawn. The result is:
    - A 3D volume, the buildable area buffer
5. A 3D overlap analysis between the digital twin buildings and the buildable area + buffer is made. The result is either:
    - No overlap. This is a success.
    - Overlap: This is a warning.

Outcome:
- Result:
    - Success / Warning
- Results 3D Tiles of buildable areas + Buffer for visualisation

**Check visualisation and interpretation**



The result of this check will be insight into which buildings from the digital twin dataset are located within 10 metres from the buildable areas of the detailed plan.

In the checkbox, the overall result is given with a success or warning message. When one or more buildable areas have other buildings within a range of 10 metres, the output of the check is a warning. When no buildable area has a building from the digital twin within 10 metres, the result is a success. For each buildable area, the closest building is stated together with the amount of metres.

On the map, the buildable area and the 10 metres range are visualised. They are coloured green when the check has success as a result and orange when it's a warning. Clicking on the buildable area will open an information box with the object id, the result and the output value.

**Diagram**

The diagram of this check can be found in Appendix B5.

**Reliability**

The reliability of the check depends on the quality of the 3D buildings against which it is checked. The higher the level of detail is the more precise the result will be. For this check, LoD2 was used but when using a higher level of detail, more details of the buildings can be taken into account.

**Possible future improvements / recommendations**

Lessons learned during execution:

1. Some buildable areas in the detailed plannings include buildings from the digital twin. It could be the case that these buildings will be removed or renovated, but when executing the check this information is not available.
2. 3D tiles (in which the digital twin of Estonia is provided) can not be used by FME to read the 3D buildings. To execute the check, CityGML files of the same city model were used. For further automated checking, the CityGML files should be stored or preferably read from a 3D CityDB.

Recommendations:

1. Consider adding a data requirement for the digital twin that states something about the minimum level of detail of the 3D data. The outcome of the check depends partly on the quality of the digital twin.
2. The minimum distance for regulations is not nationally named. Therefore, a standard input of 10 metres was used but this value might differ per region.

Future improvement:

1. The range for the minimum distance for buildings could be a numeric value that can be changed by the executor of the check, preferably in the interface. At the moment, a numeric value is given as input for the check in FME but can not be changed in the interface of the POC.
2. Now, the building distance of fire requirements was taken into account, but other requirements might state minimum distances to objects in the area as well. Future improvements of this check can focus on expanding the check with different distances and different objects besides the buildings in the area.

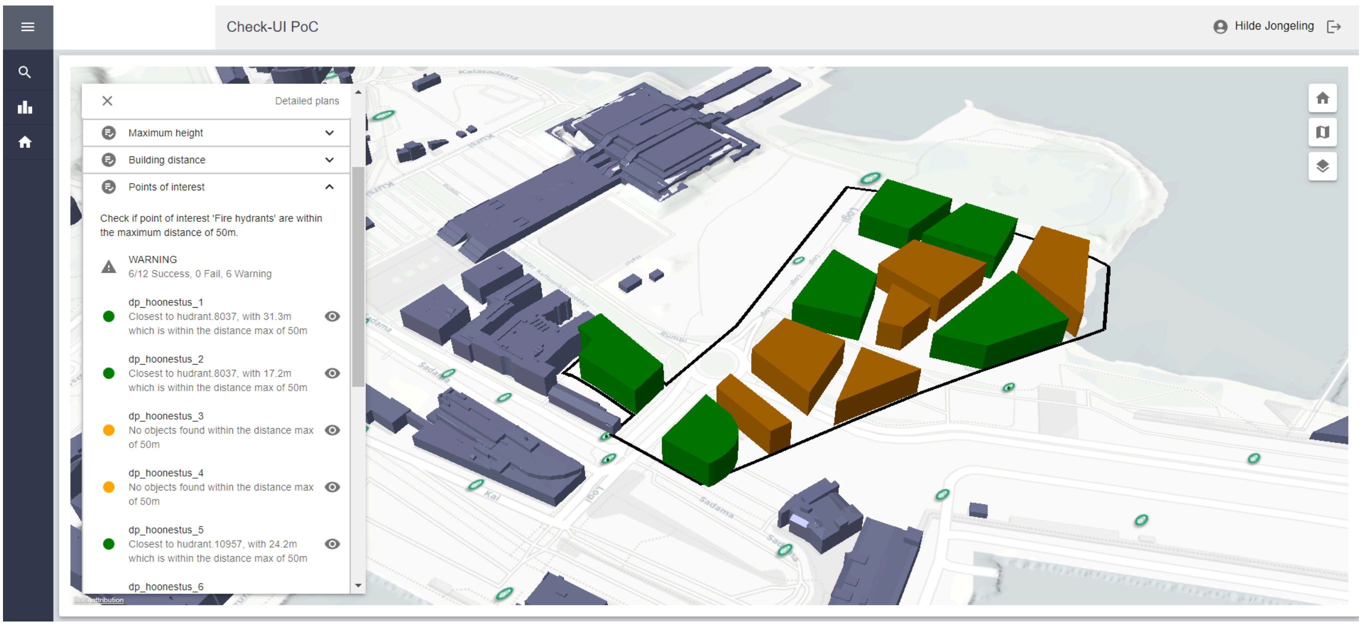
|  |
|---|
| 3. Buildable areas present the volume in which it is allowed to build, rather than the actual shape of the planned building. The check can be expanded to check the building distance in a later stage, when the design of the building is more detailed. |

| 5. Points of interest | |
|---|---|
| **Clarity**<br>XX / X / V / **VV** | **Feasibility**<br>XX / X / **V** / VV |
| **Value**<br>XX / X / V / **VV** | **3D Advantage**<br>XX / X / **V** / VV |
| **Description**<br>Calculate the distance of buildable areas against point of interest data. The distance from the buildable area to these points of interest has to be compliant with a minimum distance according to regulations. For this execution of the check, we measured the distance from buildable areas to the closest fire hydrant to check if this is compliant to the fire regulations. | |
| **Necessary source data:**<br>1. IFC model(s) representing the detailed plan<br>2. The WFS layer 'hudrant' in a dataset with Estonian points of interest located at https://gsavalik.envir.ee/geoserver/huvipunkt/wms?&version=1.3.0&request=GetCapabilities. The map service displays points of interest collected from public data sources. The points of interest are entered on the map (automatically geocoded) based on the addresses given in the source register. | |
| **Data requirements:**<br><br>IFC model:<br>- See general requirements for IFC model(s) in Chapter 4.3.2, specifically:<br>- The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the list concurrent with PLANK.<br>- The buildable area is identified by the propertyset 'dp_hoonestus', and should contain at least the attribute 'objectid'.<br><br>Fire hydrant:<br>- Contains the location of fire hydrants as point data, available as WFS. | |
| **Technical description how check is executed (steps taken):**<br><br>Input:<br>- The IFC(s) of detailed plan<br>- Fire hydrant data<br>- Distance (numeric) | |

1. The IFC files are read
2. The buildable area solids are filtered (dp_hoonestus). Only buildable areas are used for this check.
3. All Points of interest (Fire hydrants) within the plan boundary + the buffer distance are read.
4. Per buildable area solid the closest POI is sought, and the distance between the buildable area solid and the closest point of interest is recorded.
5. The recorded distance of the closest POI is compared to the maximum distance.
    a. If the distance of the closest POI is smaller or equal to the maximum distance, the result is a success
    b. If the distance of the closest POI is larger to the maximum distance, the result is a warning

Outcome:
- Result:
    - Success / Warning
- Results 3D Tiles of buildable areas for visualisation
- Results 3D Tiles of Fire hydrants

**Check visualisation and interpretation**




For all buildable areas in the detailed plan, a result is given whether there is a certain point of interest in a certain distance. In this case, it is calculated whether there is at least 1 fire hydrant within 50m of the buildable area. If that is the case, the buildable area colours green on the map and the result is a success. If there is no object found within 50m, the result is a warning and the buildable area colours orange on the map.

The overall result of the check is a success if all buildable areas have the point of interest within the given distance. If that's not the case, the result of the check is a warning. Clicking on the individual buildable areas on the map will give information about the specific distance for that buildable area.

**Diagram**

| |
|---|
| The diagram of this check can be found in Appendix B6. |
| **Reliability:**<br><br>As the dataset used covers the complete country, the distance to the closest fire hydrant could be measured for any detailed plan. |
| **Possible future improvements / recommendations:**<br>Lessons learned during execution:<br>1. Besides checking the distance from the buildable area to the fire hydrants, this check could be easily expanded by checking the distance to other points of interest.<br><br>Recommendations for the data:<br>1. The requirement for the maximum distance from buildable area to fire hydrants is unknown, and can not be derived from the master plan. If the maximum distance requirement would be added as a requirement in the master plan as a standardised attribute the requirement could be read from the master plan data.<br><br>Future improvements:<br>1. When the result is a fail, calculate the distance to the closest fire hydrant and visualise this.<br>2. The distances to the fire hydrants could be visualised with lines with the values connected to them.<br>3. Expand the check with an option to select to which point of interest you want to measure.<br>4. Expand the check with an option to fill in the maximum distance to the point of interest.<br>5. Further in the future, several of these maximum distances could be predefined based on different regulations. For example, if the master plan states that a fire hydrant for a certain area should be in a 40m zone, this value could be automatically used when selecting the fire hydrant as point of interest. |

| 6. Protected area requirements | |
|---|---|
| **Clarity**<br>XX / X / V / **VV** | **Feasibility**<br>XX / X / V / **VV** |
| **Value**<br>XX / X / V / **VV** | **3D Advantage**<br>XX / **X** / V / VV |
| **Description**<br>Check if the detailed plan overlaps with protected areas, such as protected heritage areas or flood areas, and give an error in case of overlap. For the execution of this check, we checked against a railway and its contact zone. | |
| **Necessary source data:**<br>1. IFC model representing the detailed plan<br>2. Data of the protected area. For the execution of this check, the following was used:<br>    a. Railway plan data of the harbour area, which is provided as WFS and WMS.<br>    b. Railway contact zone data of the harbour area, provided as WFS and WMS as well. | |
| **Data requirements:**<br>IFC model:<br>- See general requirements for IFC model(s) in Chapter 4.3.2, specifically:<br>- The objects in the IFC contain a propertyset, whose name represents the discipline. The | |

name of these propertyset is limited to the list concurrent with PLANK.
- The buildable area is identified by the propertyset 'dp_hoonestus', and should contain at least the attribute 'objectid'.

Railway contact zone data (protected area):
- Area around the railway plan data
- Polygon data from a WFS service

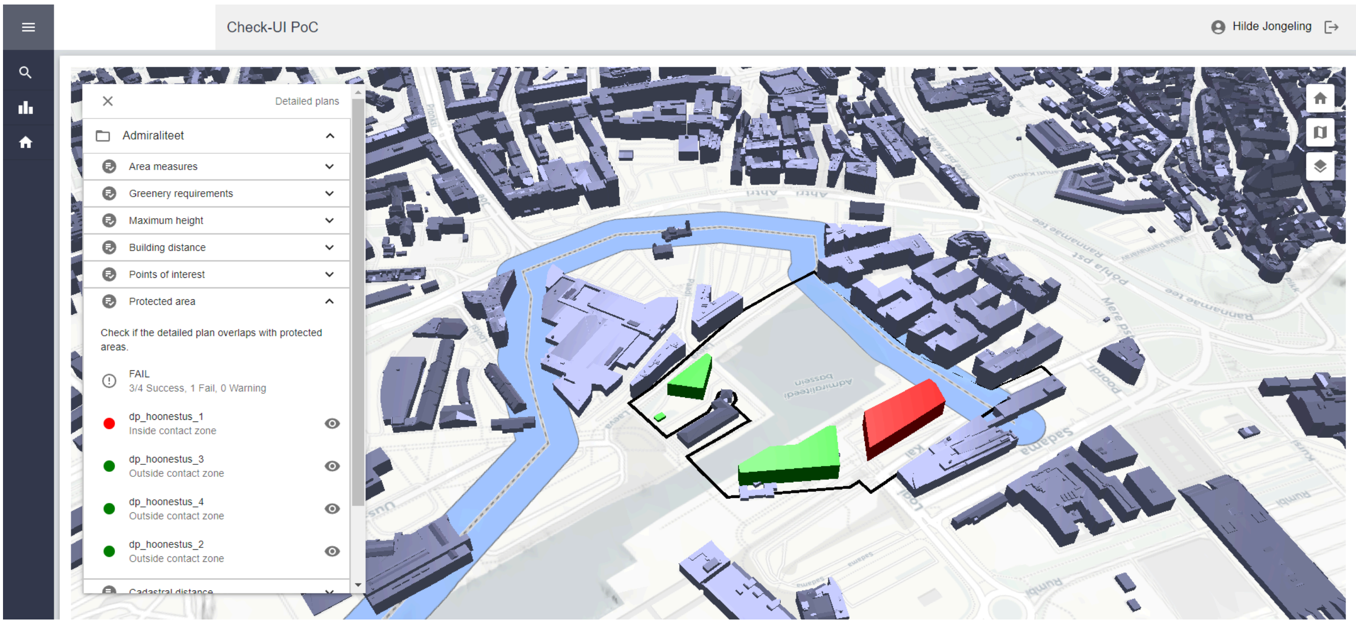
**Technical description how check is executed (steps taken):**

Input:
- IFC(s) of detailed plan
- Railway contact data
- Planning boundary (from dp_plan_ala, created in check 9)

1. The IFC files are read
2. The buildable area solids are filtered (dp_hoonestus). Only buildable areas are used for this check.
3. The railway contact data is read
4. An overlap analysis is performed with the buildable area solids and the contact zone.
   a. Overlapping objects are logged as error
   b. Non-overlapping objects are logged as success

Outcome:
- Result:
  - Success / Fail
- Results 3D Tiles of buildable areas for visualisation

**Check visualisation and interpretation**




The check should give as result if the detailed plan overlaps with protected areas, in this case the railway and its contact zone. The contact zone is visualised as a blue buffer in the picture above.

In the checkbox, the overall result is given. This is a success if there is no overlap at all with the protected area and a fail if there is for at least one buildable area overlap with the protected area.

On the map, the buildable areas of the detailed plan are visualised in green if they don't overlap with the protected area and red if there is overlap with the protected area.

**Diagram**

The diagram of this check can be found in Appendix B7.

**Reliability:**
With a planning boundary, the reliability of the check is quite high for this type of check (railway zone). In case of other types of protected area zones, standardisation of the input will make the output of the check more reliable.

**Possible future improvements / recommendations:**

Lessons learned during execution:

1. Depending on the type of protected area, not all objects have to be tested. In the comparison with the railway contact zone, only buildable areas were checked for overlap, since buildings are not allowed in this protected zone.

Recommendation:

1. For this type of protected area requirements (railway), the check is simple as there can be no overlap at all with buildable areas. For some other protected area types, it might be that overlap can happen but it will mean that certain regulations will apply. There should be thought of a way to standardise the input of the protected area so it can be made clear whether overlap is allowed and if so, what rules are connected to this.
2. This check uses an example from the city of Tallinn protected area, however it could be expanded to use layers from the master plan and county plan according to the PLANK database. In the attachments of the spatial planning regulations  specific layers, i.e. 'Valuable green area' or 'Flood area' are defined. The use of this for nationwide automatic checking can be further researched.
3. This check only applies to buildable areas, since for this specific protected area other disciplines, such as transport are allowed in the area. However, the check can be adjusted per protected area to also include or exclude different disciplines.

Future improvements:

1. Expand the check with checking other protected area zones, especially ones that allow some overlap but will bring regulations to the table. Examples of these types can be flood areas, nature areas or heritage areas.
2. Show as output which objects from the IFC model are within the overlap and for how many percentages this is. This output can then be made clickable in 2D or even 3D as well.
3. When expanding the check with new protected area zones that don't specifically forbid overlap but rather bring new rules to the detailed plan, a next check could be developed to check on these regulations as well. Although the implementation of this depends on the type of regulations, in case of the named examples (flood, nature and heritage areas) some next checks can be thought of.

| 7. Cadaster border distance | |
|---|---|
| **Clarity**<br>XX / X / V / VV | **Feasibility**<br>XX / X / V / VV |
| **Value**<br>XX / X / V / VV | **3D Advantage**<br>XX / X / V / VV |

**Description**
Check if buildable areas are located in a plot, and calculate the minimum, mean and maximum distance to the plot boundary.

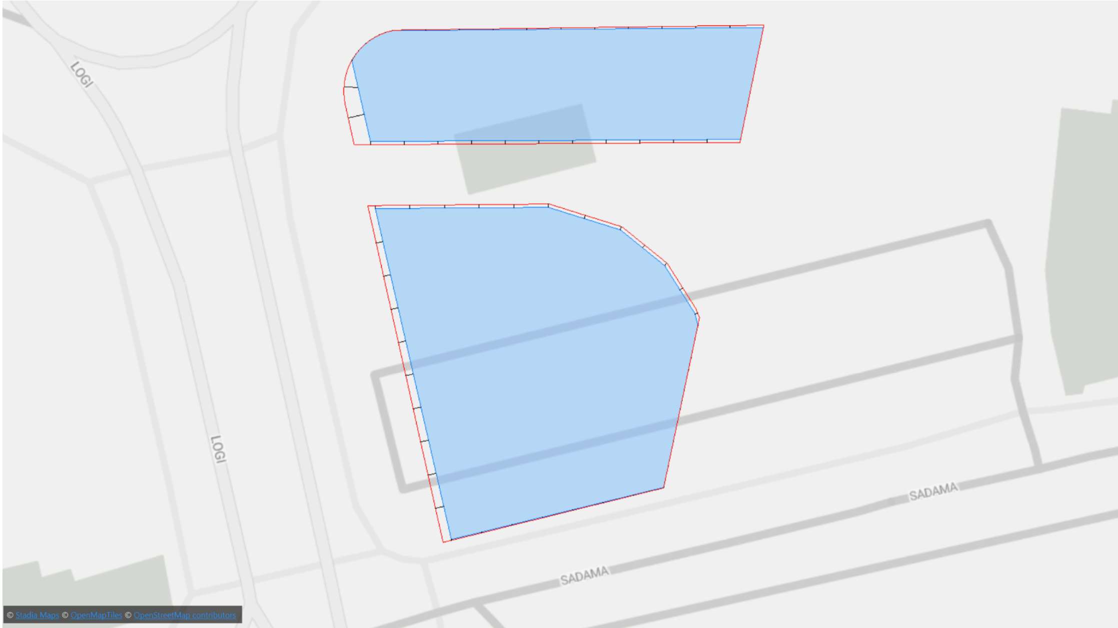
**Necessary source data:**
- Detailed plan (IFC model)
- The geojson created in the first check containing plot boundaries

**Data requirements:**
IFC model
- See general requirements for IFC model(s) in Chapter 4.3.2, specifically:
- The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the list concurrent with PLANK.
- The buildable area is identified by the propertyset 'dp_hoonestus', and should contain at least the attribute 'objectid'.
- The plot boundaries are identified by the propertyset 'dp_krunt', and are preprocessed in the check 'Area measures''.

Geojson
- The plot boundaries are identified by the propertyset 'dp_krunt', and are preprocessed in the check 'Area measures''.

**Technical description how check is executed (steps taken):**
Input:
- IFC(s) of detailed plan

1. The buildable areas are read (dp_hoonestus)
2. The plot boundaries are read (dp_krunt)
3. First an assessment is made which buildable areas and plots can be linked. The assumption is that one buildable area belongs to one plot. To do this, for the buildable areas, the centerpoints are extracted. Using these centerpoints, it is assessed in which plots the centerpoints are located. The result is
    a. Plots which can be linked with a buildable area
    b. Plots which do not contain a buildable area
    c. Buildable areas which can be linked with a plot
    d. Buildable areas which cannot be linked with a plot, this is logged as fail
4. For the plots and buildable areas which can be linked, first it is assessed if the buildable area is within the plot boundary, using a clipping analysis. The result is:
    a. Buildable area within the plot, these features continue
    b. Buildable area outside (crossing) the plot boundary, these are logged as warning
5. After this, an analysis is made to calculate the minimum and maximum distance between the plot and the buildable area (using the Hausdorff method)
   No check is performed against the distance.

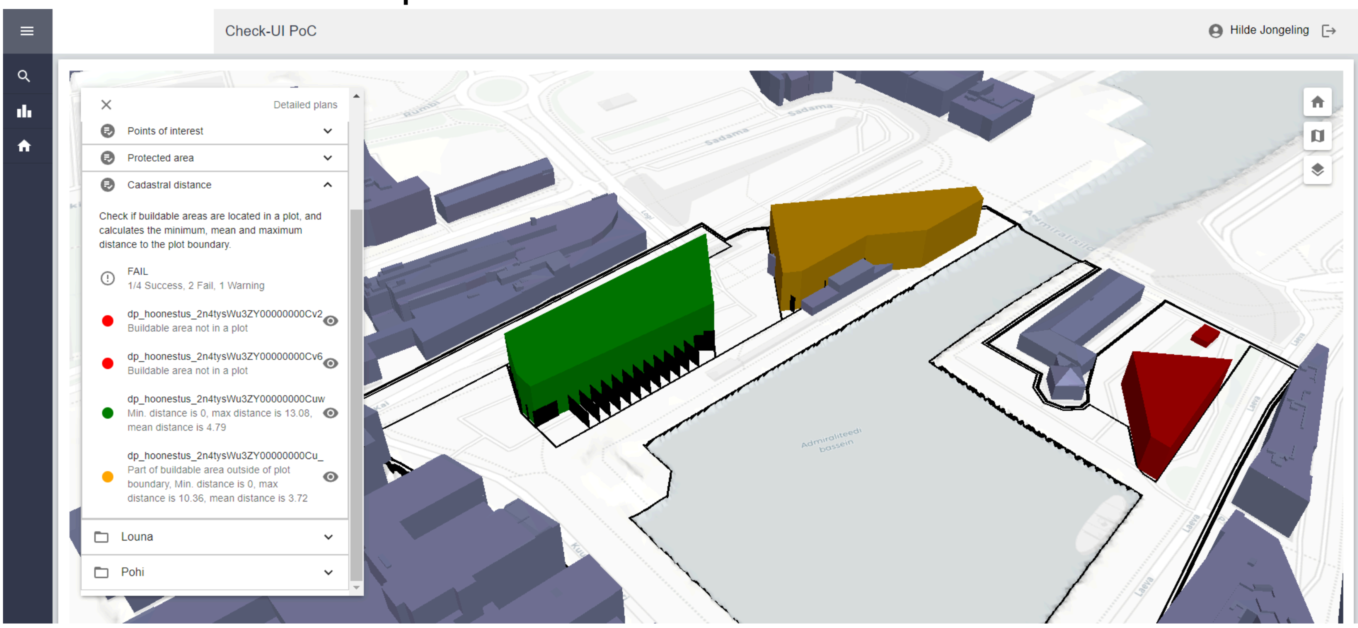



*Distance calculation showing buildable areas (blue), plot boundaries (red) and calculated distances (black)*

Outcome:

- Result:
    - Success / Warning / Fail
- Results 3D Tiles of buildable areas for visualisation

**Check visualisation and interpretation**




The result of the check is a success if all buildable areas in the detailed plan are within plots. If one of them is not inside a plot, the result is a fail.

In the checkbox, an overview of the buildable areas in the detailed plan and their results are given. For every buildable area, the minimum, mean and maximum distance to the plot boundary are calculated. If the buildable area fits completely in a plot, the result is a success. Otherwise it's a fail.

| |
|---|
| With a button, you can look at the distinct buildable areas on the map.<br><br>On the map, the buildable areas are visualised green (success), yellow (partly fail) and red (fail) on the map. By clicking on them, an information box with individual information will open. Black walls visualise the distance to the plot boundary. Clicking on them will give individual information about the exact distance. |
| **Diagram**<br>The diagram of this check can be found in Appendix B8. |
| **Possible future improvements / recommendations:**<br><br>Lessons learned during execution:<br>1. The distance between the plot boundary and buildable area can be calculated, but does not result in one value. It should be further specified which distance is relevant, and how to measure that. Despite this, a calculation and visualisation of the distances from the buildable area to the plot boundary can already give more insight.<br><br>Recommendation:<br>1. Determine from which point the distance should be calculated, i.e. entrance from the plot or the closest boundary to a public road.<br><br>Future improvements:<br>1. Buildable areas present the volume in which it is allowed to build, rather than the actual shape of the planned building. The check can be expanded to check the distance in a later stage, when the design of the building is more detailed. |

### 4.3.4 Implementing the checks in the interface

The detailed plans and the check results are shown in the prototype interface, together with basic data such as base layers, the digital twin data and other landboard data. The results used in the prototype consist of structured text data (json), 3D-tiles and geojson. They are structured so that the results are consistent and predictable for each check.

The check results are generated by starting a check orchestrator which runs all developed checks per detailed plan at once. The implemented check orchestrator executes all checks, collects and processes the check results for the user interface. The order of the process is shown in Figure 13.

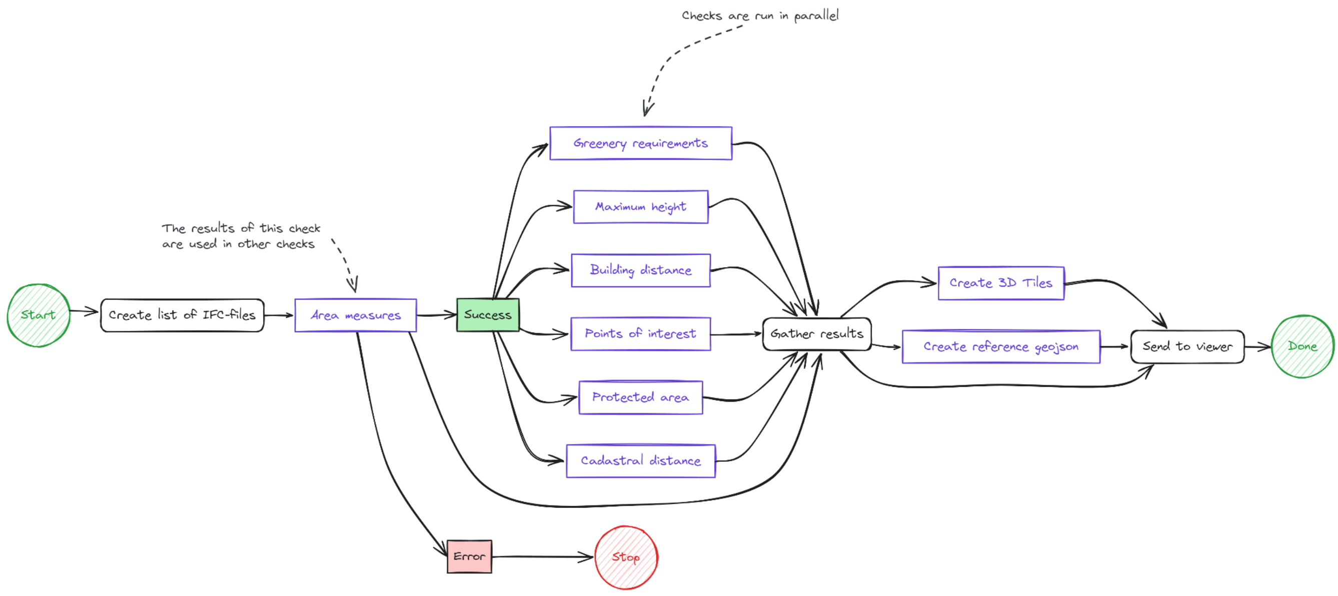
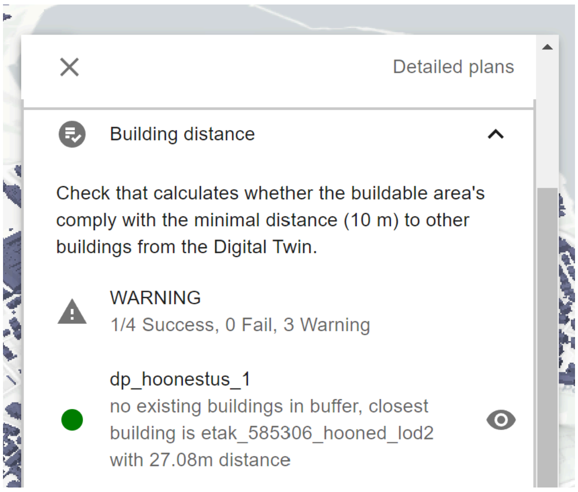



*Figure 13: Process of the check orchestrator.*

First, a list of all IFC-files belonging to a specific detailed plan is made. This list serves as input for the checks. Then, the first check: 'Area measures' is run. While most of the implemented checks can run independently and in parallel, this check has to run first since the outcome of this check is used as input for the other checks. Therefore, if this check fails, the entire process should be stopped. It is worth noting that, in the current prototype solution, an error does not lead to process discontinuation.

Second, after the 'Area measures' check has run, the other six checks are executed in parallel. The result of every check is structured as follows: a json-file, containing the general outcome. This file is used to present the check result in the left window in the prototype. An example of this can be found in Figure 14. Using the same structure to present the results makes the prototype scalable to expand with additional checks. Additionally a 3D tiles and/or a geojson file are generated for the visualisation in the prototype.





```
{
   "order" : 4,
   "title" : "Building Distance",
   "description" : "Check that calculates
whether the buildable area's comply with
the minimal distance (10 m) to other
buildings from the Digital Twin.",
   "RESULT" : "WARNING",
   "summary" : "1/4 Success, 0 Fail, 3
Warning",
   "results" : [
      {
         "objectid" :
"dp_hoonestus_2n4tysWu3ZY00000000Cv2",
         "result" : "WARNING",
         "message" : "overlaps with
existing buildings, closest building is
etak_564874_hooned_lod2 with 0.38m
distance"
      },

[...]
```


*Figure 14: Example of the data structure of a check.*

To present the detailed plan in the prototype, an additional process 'Create 3D Tiles' is run, to convert the IFC files into 3D tiles. This includes the attributes according to the spatial planning regulations, which are also included in the 3D tiles. Parallel another process is run: 'Create reference geojson'. This is a file needed to be able to zoom in to features referenced in the check result. In the last step, the results are made available for the prototype viewer.

### 4.3.5 Key lessons learned & Recommendations

Based on the implementation of the seven checks in the prototype solution, several lessons are learned based on which recommendations can be made.

- Before executing the check, validate and only execute the check with validated objects. Now the results of the checks are less reliable, as validation was done during the check. The designer of the IFC model can check with the validation if the model meets all the data requirements, so checks will give the optimal results and discussion around results are prevented.
- For the development, the cooperation with the designer of the IFC model was positive. It has proven beneficial that if it was discovered during the development of  check that the check would improve by altering the input data, this was possible. This cooperation also gave valuable insights in possible requirements to state for IFC models of detailed plans.
- The outcome of a check is very closely related to how a rule is interpreted. This must be clear before a check can be put together. By iterating together with the project team through the checks, we came to a common understanding of the different check outputs.
- Currently the PLANK database contains spatial plans, including master plans. In these plans it is possible to state requirements for underlying plans, for example

detailed plans. However, there is little standardisation on how these requirements are defined. It can be either a string of text, a link to a document or file, or municipality specific. Constraints can be set in separate plan layers, however there is no specific layer or attribute regarding greenery requirements, building distance requirements, requirements for the maximum distance to points of interest and protected area requirements. If these would be values available in the master plan, they could be derived automatically for each detailed plan in the checking solution.

- Align plots in needed datasets. In several checks, plots from the IFC model and plots from WMS services were combined to create check results on. The reliability of these checks is at the moment lower than it could be due to non-matching plots.
- ObjectID - The ObjectID is a required attribute in the spatial planning regulations, and is now required to be unique at least in its own discipline/layer (i.e. dp_hoonestus). However, in the current data the ObjectID is not always unique. Since the ObjectID is used in checks to uniquely identify objects, as well as in the viewer to report results and zoom to the objects, the uniqueness is an important requirement. For the current data, a workaround is used by using the GlobalID of the IFC objects if ObjectIDs are not unique. Additionally, it can be considered to assign a global unique identifier, i.e. a unique identifier for objects which are unique for the entire plan, or even the spatial planning regulations. This prevents mistakes in identifying objects for humans, but also the automated checks. For example, in the current situation an object in a greenery layer (dp_haljastus) and an object in a buildable area layer (dp_hoonestus) can both have ObjectID '1'. In the poc the objectID is prefixed with the discipline, i.e. dp_haljastus_1.

## 4.4 Data requirements analysis

### 4.4.1 IFC Requirements

For the execution of the checks data of the detailed plan and the master plan is needed. Data for the detailed plan in this prototype are BIM models, in the open standard IFC. This differs from the currently often used 2D geodata in CAD or .shp format. Additionally it is not an official file format used in the spatial planning regulations and therefore in PLANK. During the development of the prototype the use of IFC's representing detailed plans as input for automated checks was investigated. This includes an analysis if the IFC file format fits in the current regulations and the PLANK database, noting IFC can be an addition and not an exclusive file format to be used. Next to the compatibility, an overview is given of IFC requirements which are recommended to install in order to be used in the automated checks. Lastly, the findings are concluded in a table with an overview of recommendations to integrate IFC in the current systems.

**Compatibility of IFC with regulations**

The "Requirements for the formalisation and structure of a plan"[12] states legal regulation for the content and design of planning documents and files. The IFC file format can adhere to this regulation, with the following notes:

- The regulation itself does not require specific file format,it only states that the file has to be digitally available, machine readable, and can be viewed in non proprietary software and web browsers (§2). IFC is a digital machine readable format. Since it is an open standard there is open source software available to investigate the IFC file. However they are not web-based. In order to show IFC online a web viewer has to be implemented, and/or a conversion can be made to the open standard 3D tiles, so that it can be shown in a web viewer.
- The plan must be presentable in the correct location (§5). The IFC format makes use of a local coordinate system. However there are options to include georeferencing attributes in the IFC in order to present objects in the IFC on the correct geographic location. Therefore in the IFC requirements it is required that this georeferencing option is applied (8).
- To identify different layers and objects there must be different layers, with different attributes, as described in the regulation attachments. IFC offers the option to assign layers, and assign custom attributes in propertysets. Therefore in the IFC requirements it is required to assign property sets to objects according to the regulation (2, 3)
- Of these different layers and attributes, some are optional and some are mandatory. Therefore in the IFC requirements it is stated which of these layers are mandatory (4, 5).

**Compatibility of IFC with PLANK**

All spatial plans according to the regulation can be stored in the PLANK system[13]. This consists of documents and drawings, but also a database containing geometric representations with attribute information of spatial plans. This database is made available as a OGC WFS data service. However, a large portion of spatial plans are not yet stored in the database. Even though the IFC file format can be added in the PLANK system as an attachment, it is not yet possible to import IFC data into the PLANK database. Currently GIS and CAD files can be uploaded, validated and imported into the PLANK database. To make it possible to integrate IFC detailed plan data into PLANK 3D geometries have to be added in the PLANK database. Additionally validation based on the IFC requirements have to be added.

**Recommendations based on development**

During the development of the checks the use of the IFC detailed plan pilot data is analysed, based on that the development process the following recommendations are made:

[12] https://www.riigiteataja.ee/akt/121102022001
[13] https://planeeringud.ee/plank-web/#/planning

- The use of the IFC entities IfcBuildingelementproxy and IfcAnnotation are suitable for this prototype. It is for now the best option since there are no suitable entities in IFC which represent to be planned zoning objects. However, it should be further explored if in the future IfcEntities which are more specifically meant for planned spatial objects are added to the IFC schema.
- Different objects are currently distinguished by the name of the propertyset. Sometimes further distinction can be beneficial, for example distinguishing trees in greenery layers, or distinguishing different transport layers.
- Part of the requirements for the IFC's refer to the PLANK standards. The PLANK standards are based on 2D geometries, while IFC uses 3D geometries. It is possible to alter standards so that IFC can be included. The changes needed are concluded in this paragraph.
- For 3D data it should be assessed which 3D geometries are (also) allowed. For buildable areas (dp_hoonestus) it is recommended to allow 3D solids. For other disciplines, such as transport and greenery, 3D surfaces are suitable.
- Plan_ala and dp_krunt in current requirements only allow polygons. In the detailed plan IFCs, first they were modelled as 3D-lines, (building proxies) which was unsuitable. Thereafter they were modelled as annotations, line features, which are used in the current prototype. What geometry is best suitable for these objects? And how to put that in requirements? 2D geometries might still be best, but it is unclear how to model that in IFC optimally.
- In the list of disciplines of PLANK 'dp_hoone' is not stated. However in the detailed plan IFC's for the prototype dp_hoone was included, since the city of Tallinn makes use of this discipline in their current process. Dp_hoone represents a more detailed form of buildable areas. The checks do not use this discipline since it is not an official discipline, however the use of these could result in different check results. The use of dp_hoone can be further investigated as part of the planning regulation. Additionally, then it should be specified if checks are based on dp_hoonestus or dp_hoone.
- The IFC's are currently validated for the use of the checks. This validation can be extended. In a production environment invalid validation should result in a halt for further checks.
- Next to IFC other 3D formats for the use of modelling detailed plans can be further explored, for example the open standard CityGML or LADM. Potential use has been investigated in theory, a possible next step is to investigate the use in practice. Extending possible file formats can increase use of 3D data for actors less familiar with BIM. However, a risk is that additional file formats require additional validation and development.
- The IFC files are now used directly. However, an alternative flow to be explored is importing the IFC files into a PLANK or LADM database after validation. The checks can then run from the database, and results can be stored in a database rather than file-based. This improves being able to save detailed plan history, version comparison, and scalability.

**IFC requirements**

For the IFC model of the detailed plan, the following data requirements apply, based on the planning regulation, the PLANK standard and findings during the development of the checks:

1. The detailed plan file(s) are IFC
2. The objects in the IFC are IFC entity IfcBuildingElementProxy or IfcAnnotation
3. The objects in the IFC contain a propertyset, whose name represents the discipline. The name of these propertyset is limited to the following list (concurrent with PLANK):
    a. dp_arhVoistlus|dp_avalik|dp_haljastus|dp_hoonestus|dp_juurdep|dp_KKTingimus|dp_KOVLoodus|dp_krunt|dp_krundiSihtotstarve|dp_maapar|dp_servituut|dp_sund|dp_tehno|dp_tingimus|dp_transp|dp_vaartloodus|dp_vaartMiljoo|dp_vaartPollum
4. The property sets contain attributes according to the mandated attribute list described in the regulations[14].
5. The IFC(s) should contain exactly one plan boundary, identified by the propertyset dp_plan_ala, and modelled as line in the IFC entity IfcAnnotation
6. The IFC(s) should contain one or more plot boundaries, identified by the propertyset dp_krunt and modelled as line in IFC entity IfcAnnotation
7. The objects of the IFC cover the entire planning area
8. The objects of the IFC do not overlap with each other
9. The IFC(s) contain a correct georeference and are modelled in EPSG:3301

**IFC recommendations**

As stated in the IFC requirements the objects in the IFC must contain a propertyset according to the regulations, of which part are mandatory. Below is an overview of layers and attributes used in the developed checks. If they are not yet mandatory, it is recommended to make these attributes mandatory since they are needed to perform the checks.

| Base layer | Attribute | Required for | Current status | Recommendation |
|---|---|---|---|---|
| plan_ala | - | 1. Check area measures | Mandatory, only surface geometry | Keep mandatory, allow IfcAnnotation line geometry |
| dp_krunt | - | 1. Check area measures | Mandatory, only surface geometry | Keep mandatory, allow IfcAnnotation line geometry |
| All layers | ObjectID | All checks | Mandatory, Unique within the base layer at least | Keep mandatory, make unique for the entire plan |
| dp_haljastus | - | 2. Check greenery area | Not mandatory, point, line and surface geometries allowed | Not mandatory, as a detailed plan is allowed to have no greenery.<br><br>Only (3D) surface geometry is usable for area |

[14] https://www.riigiteataja.ee/akt/121102022001, appendice C

| | | | | |
|---|---|---|---|---|
| | | | | calculation. |
| dp_haljastus | jaotuskiht (classification layer) | 2. Check greenery area | Not mandatory | Make mandatory, to distinguish which greenery objects should be taken into account. The allowed names should be specified (i.e. muru, puittaim) |
| dp_hoonestus | - | 3. Building height requirements<br>4. Building distance<br>5. Points of interest<br>6. Protected area requirements<br>7. Cadaster border distance | Not mandatory, surface geometry allowed | Not mandatory, as a detailed plan is allowed to have no greenery.<br><br>Allow 3D solid geometry. |
| dp_hoone | - | none | Not allowed | Allow, as it can give a more detailed calculation of for example the building distance to other objects. |
| dp_hoonestus | korgus, korgusAbs | 3. Building height requirements | Conditionally mandatory (either korgus or korgusAbs is required) | Make both mandatory, so that they both can be used in checks |
| dp_hoonestus | | 7. Cadaster border distance | | It is required that the buildable area is inside the plot |

### 4.4.2 Master Plan data requirements

Data for the master plan and of existing objects (i.e. buildings, fire hydrants) used in this prototype consists of different WMS and WFS services, provided respectively by the city of Tallinn and the Land Board of Estonia[15].

**Master Plan data used in the prototype**
The master plan data provided by the city of Tallinn are made by and for the city of Tallinn. Similar data is not found in the PLANK database. This is because 1. Not all master plans of the city of Tallinn are in the PLANK database, 2. Even though in the PLANK database there is room to state constraints and requirements, there is no specific place for specific requirements (i.e. greenery percentages or building height). Therefore at this point the checks are less scalable. as that would require finding and processing different data sources representing similar requirements. Standardising these specific

[15] https://geoportaal.maaamet.ee/

requirements in the regulation, and consequently the PLANK database, will improve scalability of the automated checks. The PLANK database stores spatial plans according to the regulations on a national level. A benefit of this is that spatial plans are stored in one location, in the same way. Another benefit of the PLANK database is that it is available as a WFS service. The current format allows for easy data integration in the automated checks, if specific requirements are further standardised. In conclusion, for the use of master plan data in the automated checks the following recommendations are made

- The use of national or internationally standardised data is recommended, rather than municipality specific. Use of the PLANK database is recommended as input data for master plans, as this is based on national legal requirements.
- The availability of spatial plans as open data, in the open standard WFS, makes it possible to use as input in automated checks.
- The PLANK database is relatively new (2022) and does not contain all spatial plans. Not all spatial plans are digitised and/or set up according to the regulation. If master plans are not stored in the PLANK database, they can not be used as input for automated checks. Therefore it is recommended to invest in filling the PLANK database with more spatial plans, either by digitising and/or making existing data suitable.
- Also, no specific place for specific requirements. Specify this. Further analysis of this is made in table below, based on developments
- Standardisation for plan data is needed to make automatic checking possible. The development of the PLANK standard is a good step. However, an extension of the data model is needed as input for the developed checks. Recommendations of possible extensions are made in this report.

**Master Plan data recommendations**

For check *2. "Check greenery area"* it has to be clear which greenery requirement is valid where. To use this the data should be available as:

- Polygons
- An attribute containing the greenery requirement percentage as numeric value between 0 and 100
- An OGC WFS service

A possible implementation in the regulation is recommended:

| Base layer | Attribute | Value | Type | Recommendation |
|---|---|---|---|---|
| yp_tingimus (master plan condition) | jaotuskiht (classification layer) | *haljastuse nõue (greenery requirement)* | tekst | Require standard value for existing attribute |
| yp_tingimus | *value* | *0 - 100* | *numeric* | Add attribute containing a numeric value between 0 and 100 representing the required greenery in percentage |

For check *3. "Building height requirement"*, it has to be clear which building height requirement is valid where. To use this the data should be available as:

- Polygons
- An attribute containing the maximum building height as numeric value representing metres, for absolute height
- An attribute containing the maximum building height as numeric value representing metres, for relative height
- An OGC WFS service

A possible implementation in the regulation is recommended:

| **Base layer** | **Attribute** | **Value** | **Type** | **Recommendation** |
|---|---|---|---|---|
| yp_tingimus (master plan condition) | jaotuskiht (classification layer) | *hoone kõrguse nõue Abs (Absolute building height requirement)* | tekst | Require standard value for existing attribute |
| yp_tingimus | *value* | *Above 0, representing metres* | *Numeric* | Add attribute containing a numeric value representing the maximum absolute building height |
| yp_tingimus (master plan condition) | jaotuskiht (classification layer) | *hoone kõrguse nõue Rel (Relative building height requirement)* | tekst | Require standard value for existing attribute |
| yp_tingimus | *value* | *Above 0, representing metres* | *Numeric* | Add attribute containing a numeric value representing the maximum relative building height |

An alternative is adding another layer, i.e. yp_buildingheight, containing multiple attributes representing maximum building height, corresponding to the height attributes in dp_hoonestus (korgus, korgusAbs, etc.)

For check *6. "Protected area requirements"*, the location of the protected area, and its implications on the detailed plan should be known. Therefore this data has to be available as:

- Polygons, lines or points
- An OGC WFS service

Currently, the regulation offers multiple layers with protected areas. They can be used as input for the automated checks. However, for these layers it should be known:

- What disciplines are to be tested for overlap with the protected area (i.e. buildable area, transport, greenery, all)

- What is the consequence of the overlap (i.e. a warning stating the regulation, a fail since it is not allowed, etc.)

For example:

| **Base layer** | **Attribute** | **Value** | **Type** | **Recommendation** |
|---|---|---|---|---|
| yp_vaartrohe (master plan valuable green) | tingimus (condition) | dp_hoonestus forbidden | tekst | Require standard value for existing attribute |

For check 7. *"Cadaster border distance"*, the maximum distance from the plot boundary to the building has to be defined. This does not necessarily have to be a requirement from the master plan, but could also be defined on a national level. Additionally the point from where to measure the distance from the plot boundary to the building has to be defined. This has to be available as a single point of entry, or a line representing a side of the plot boundary from which the plot will be accessed from the public road. Since with the designing of a detailed plan, new transport areas and plot boundaries can be defined, it is recommended that the designer of the detailed plan also states its intended access to the plot. This can be used as input for an automated check.

| **Base layer** | **Type** | **Recommendation** |
|---|---|---|
| dp_juurdep_krunt_boundary | Point, line | Add sublayer, representing a point or line, consistent with dp_krunt, which indicates the point from where to measure distance from the plot boundary |

### 4.4.3 Data output needed

For the visualisation of the check results in the prototype, the following open standard data formats are used: 3D-tiles, geojson and json. These file formats are non-proprietary and make it possible to also use in other applications. The attributes in these files are advised to be kept similar as much as possible. This allows for possible future checks to be integrated. The main attributes for every object are: objectid, result (success, warning, fail) and message. The colours used are also similar. For every result, success is green, warning is orange, and red is fail. This simple colour scheme makes the results intuitively interpretable.

3D Tiles are used for visualising 3D objects, and geojson is used to display 2D object. Displaying 2D objects in a 3D environment proved to be a challenge, as terrain data has to be taken into account. Geojson allows objects to be presented on a terrain surface. However, the geojson file format becomes more inefficient especially presenting larger areas, and no style can be stored in a geojson.

For future development, a similar file structure can be used. Next to a file-based structure, a database can be considered. Storing results in a database allows for scalability. Additionally, 2D results can be better processed from a database, to for example a WMS service which allows for better visualisation.

# 5. Lessons learned

- Although IFC seems to be a logical standard to be used for storing the detailed plans, the added value of existing BIM solutions is limited, because the objects and properties used are different. For example, the automated extrusion of the 2D footprint of a BIM design is now mainly based on the selection of exterior walls. In the detailed plans wall objects aren't used, resulting in the algorithm not properly working. This is the case of a lot of standard BIM functions which are designed for use for building designs. The functions should be made configurable to be re-used but this is certainly not yet the case by default.
- 3D data is also different to process than 2D geodata. Combining 3D data and 2D data is possible, however challenges arise. For example how and if to consider terrain, converting from 3D data to 2D data and vice versa, and the visualisation of both 3D and 2D data effectively.
- The flexible design of the spatial checks via a so-called 'Orchestrator' service works well. It provides a flexible and easily adaptable design of the checks that can easily be adapted and reused.
- Technically a lot is already possible. However there are also organisational and legislative issues to be addressed to be able to realise a suitable solution. To implement the checks correctly other information can be needed from systems that are not digitally available, or not available as standardised data. For example, the PLANK database does not contain every spatial plan, not every plan is available digitally and/or adherent to the relatively new PLANK standard.
- Next to a standard in data, it should be further explored what to check, and how this is presented in regulations. Even though similar checks are performed across municipalities the methods or source data can differ. For example, building heights and greenery requirements are wanted checks, however it is difficult to refer these checks to national regulations.
- Having detailed plans available online digitally and in 3D creates new possibilities. Not all information needs to be shown at once, unlike an analog drawing or PDF. Depending on the position in the process and the relevant user, it can be determined which information is relevant, after which only this information can be shown. This is therefore an extra step that must be consciously considered during the design of the service.
- It is very important to present the results of the automatic checks as simply and clearly as possible. This quickly turns out to be very complicated, especially for a less technical end user. Use commonly used colour associations, such as green (pass), yellow (warning) and red (fail) and be consistent here.
- The requirements stated in 4.4 are a start for BIM requirements for detailed plans. They can be extended, but it is important to keep the requirements conclusive and simple.

# 6. 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 organisation.
- Just 3D visualisation is already a big win
  The basic principle alone that detailed plans are easily shown in a standardised manner in a clear online 3D viewer is already a major advance. The fact that all kinds of smart things can then be done with it, such as checks, is even more beneficial.
- 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 data 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 data standards and 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)[16] 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 and openGIS 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 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.

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

# Appendices

**Overview of appendices**

**a. Check tender requirements**
**b. Check diagrams**
**c. PLANK English translation**
**d. LADM Part 5 country profile for Estonia.**

## a. Check tender requirements

An overview of all the tender requirements has been discussed to get an overview of work to be done before the end of the project and make sure all boxes are checked by then.

| Status | Requirement | Action |
|---|---|---|
| **Detailed analysis** | | |
| ✅ | The tenderer must conduct an interview with market participants involved in the planning process, including representatives of the Estonian Planners' Association, the Estonian Architects' Union and the Estonian Landscape Architects' Union; with a minimum of 5 local government representatives (including the cities of Tallinn and Tartu); With representatives selected by the contractor of the Land Administration, RAM and MKM, and at least 3 representatives of private companies involved in the preparation of plans. The procurer can add up to 5 more interviewees to the list. As a result of the interviews, it must be revealed as a minimum: | Done |
| ✅ | - The readiness of the market for the introduction of the planning information model. | Done |
| ✅ | - The most used software for creating plans (general plan and detailed plan). | Done |
| ✅ | - The bottlenecks of the current process from the point of view of the legislation and the effectiveness of the process. | Done |
| ✅ | - The bottlenecks in the introduction of planning information models and the changes necessary for introduction from a technological, organizational and legislative point of view. | Done |
| ✅ | - The bottlenecks of the three-dimensional visualization of detailed plans and possible solutions in publicizing the plans and involving interested parties | Done |
| ✅ | - What kind of compliance checks are the most time-consuming in the procedural process of detailed planning and the most potential for human error during the check. | Done |
| ✅ | The tenderer must familiarize himself with the pilot projects of planning information models made in Estonia (for example, the property at 21 Gonsiori St. and 14 F.R. | Done |

| | | |
|---|---|---|
| | Kreutzwald St. and the detailed plan of the surrounding area[17]) and analyze the possibility of reusing the information obtained from these projects when creating a prototype solution. | |
| ✅ | In a detailed analysis, the provider provides an overview of international best practice regarding the use of planning information models in a minimum of 5 countries. Priority should be given to the achievements of Singapore, the Netherlands, Denmark, Sweden and Norway in this field. If, to the bidder's knowledge, greater progress has been made than the aforementioned in other countries, the bidder will consider them in the analysis. | Done |
| ✅ | In the detailed analysis, the provider must take into account the requirement to use open data formats, such as IFC and CityGML, and as a result of the detailed analysis, offer the most reasonable open data format for use in the various processes of the planning information model to create a prototype solution, based on the results of the interviews and the best international practice. | Done |
| ✅ | The provider analyzes the implementation of automatic checks in the procedural process of the plans and the resulting time gain and the increase in the quality of the process. During the analysis, the provider, in cooperation with the supplier, selects a minimum of 7 automatic checks, which the provider implements in the prototype solution. The selected checks must provide the greatest possible added value to the procedural process | Done |
| ✅ | The provider analyzes the regulation "Requirements for planning formalization and structure"[18] and the appendices of this regulation and during the analysis makes suggestions as to what kind of data is necessary to carry out automatic checks starting from the initiation of the plan and what kind of additional data is needed that is not covered in the currently valid regulation. | Done |
| ✅ | The provider deals with the use of the planning information model in the state established in the detailed analysis in the BIM-based building permit procedure[19] As a basic document of a BIM-based construction project and uses the results obtained during the analysis in a prototype solution. | Done |

[17] Detailed plan of the property and the surrounding area at 21 Gonsiori st. and 14 F. R. Kreutzwald st. in the Tallinn plans registerhttps://tpr.tallinn.ee/DetailPlanning/Details/DP045040 and the pilot of the 3D information model of the plan https://tallinngis.maps.arcgis.com/apps/webappviewer3d/index.html?id=16a84d6c12d34a41b75be71a06de2f49

[18] Regulation of the Minister of Public Administration "Requirements for formalization and structure of planning"https://www.riigiteataja.ee/akt/121102022002 Appendices 1-9 of the regulation can be found in the lower part of the regulation.

[19] BIM-based building permit procedurehttps://eehitus.ee/timeline-post/bim-pohine-ehitusloa-menetlus/

| | | |
|---|---|---|
| ☑ | In the detailed analysis, the provider submits the user experience flow in the procedural process of the planning information model use plan (*UX flow*) and the TO-BE process diagram, which also include the automatic checks created in the prototype solution and the integration of the comments submitted in the disclosure process with the prototype solution. When creating the user experience flow and TO-BE process diagrams, the provider takes into account the integration of the process with the national e-construction platform[20], including the planning processing information system under development PLANIS (input information from CGI analysis[21] and from Nortal's analysis[22]) and the Tallinn Planning Register[23] .The provider indicates possible integration points. | Done |
| ☑ | The provider presents the results of the detailed analysis as an interim report and organizes a public event (physically with up to 100 participants with webcast and recording) to introduce the results of the detailed analysis discussed in the report to market participants in Estonia. | Done |
| **Prototype solution** | | |
| ☑ | The provider must create a prototype software for planning information models that enables: | Done |
| ☑ | - The user can upload planning information models and building information models (BIM) in open data formats (including IFC). | Done |
| ☑ | - Three-dimensional visualisation of the information model(s) files of the detailed plan(s) uploaded by the user in the software created by the provider. | Done |
| ☑ | - Selecting the elements of information models and displaying the information added to the corresponding elements. | Done |
| ☑ | - Display of element layers used in information models (for example, building area, landscaping, transport area, etc.) and switching on and off by the software user. | Done |

[20] The user interface of the e-construction platform building registerhttps://livekluster.ehr.ee/ui/ehr/v1/

[21] Final report of the CGI study "Preliminary and business analysis of interfacing the planning procedure with the design and procedure system of public services and the e-construction platform"https://planeerimine.blogi.fin.ee/wp-content/uploads/2021/05/mkm_rm_planeeringud_menetlus_arianalyys_l6pparuanne.pdf

[22] Nortal's preliminary analysis "Analysis of the functional requirements of the planning procedure information system and the definition of reuse possibilities of e-construction components"https://planeerimine.ee/wp-content/uploads/Nortali_analyys.pdf

[23] Register of Tallinn planshttps://tpr.tallinn.ee/

| | | |
|---|---|---|
| ✅ | - Displaying, filtering and switching on and off the basic data (general plan, thematic plan, other current map applications) in the area of the detailed plan(s). The basic data remaining in the area are transmitted via the WMS/WFS service (for example, PLANK services[24]). The prototype solution to be created must be able to receive them. | Done |
| ✅ | - Displaying the result of automatic checks of compliance with the requirements of the planning information model to the software users. | Done |
| ✅ | The provider must perform a minimum of 7 automatic checks in the prototype software in accordance with the information model of the detailed plan with the basic data (for example, the general plan). The exact content of automatic checks is agreed upon with the supplier during the detailed analysis. | Done |
| ✅ | The results of the automatic checks performed in the prototype solution must be visualised in the user interface as similar as possible to the automatic checks of the BIM-based building permit procedure. | Done |
| ✅ | Prototype software must be web-based (*web based*).Prototype software must have as simple a user interface as possible (*simple* UI) and follow the style book of the e-construction platform | Done |
| ✅ | Prototype software must use open data formats (for example, IFC, CityGML, etc.) and not convert open formats into closed formats. | Done |
| ✅ | The prototype software must be piloted with a minimum of 3 detailed planning information models and a minimum of 1 construction project information model. The information models to be piloted will be delivered by the procurer to the tenderer no later than 1 week after the tenderer has fulfilled the requirements discussed in point 4.9. | Done |
| ✅ | The provider submits a final report, which discusses the new knowledge gained during the preparation of the prototype solution compared to the interim report discussed in section 4.9, the technical architecture of the prototype solution, proposals to the procurer for the next development stages, and recommendations for the implementation of the process. | Done |
| ✅ | The provider organises a public event in Estonia (physically with up to 100 participants with webcast and recording) to present the results of the prototype software and the final | Done |

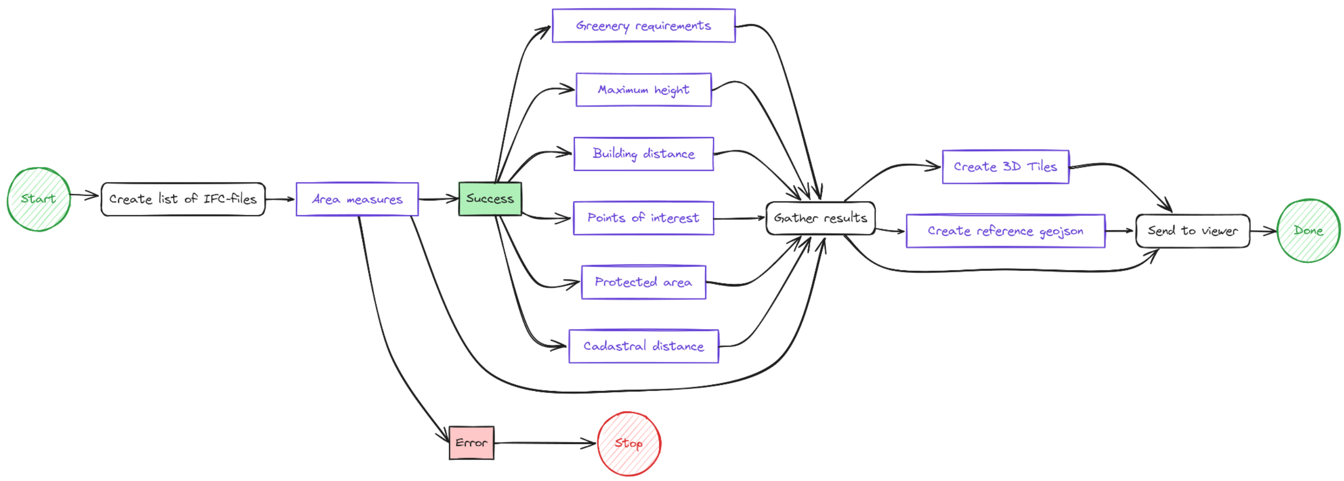
[24] PLANK WMS and WFS serviceshttps://planeerimine.ee/digi/plank/plank-juhendid/planeeringute-andmekogu-wms-ja-wfs-teenused/

| | | |
|---|---|---|
| | report. The provider will prepare presentation presentations in PPTX format and at least one demo video showing the main features of the prototype. | |
| ✓ | The provider hands over the prototype software to the supplier and assists the supplier in solving technical issues that accompany the installation of the software in the supplier's IT environment. The delivered prototype software must fulfil the functionality corresponding to the requirements given to the software, at least in the volume of piloted models. The purpose of the procurer is to use the prototype software at conferences and in other presentations introducing the created process and as a basis for the procurement of the subsequent software development stage. The volume to be transferred by the provider must enable the client's goals to be met. | Done |

## b. Check diagrams

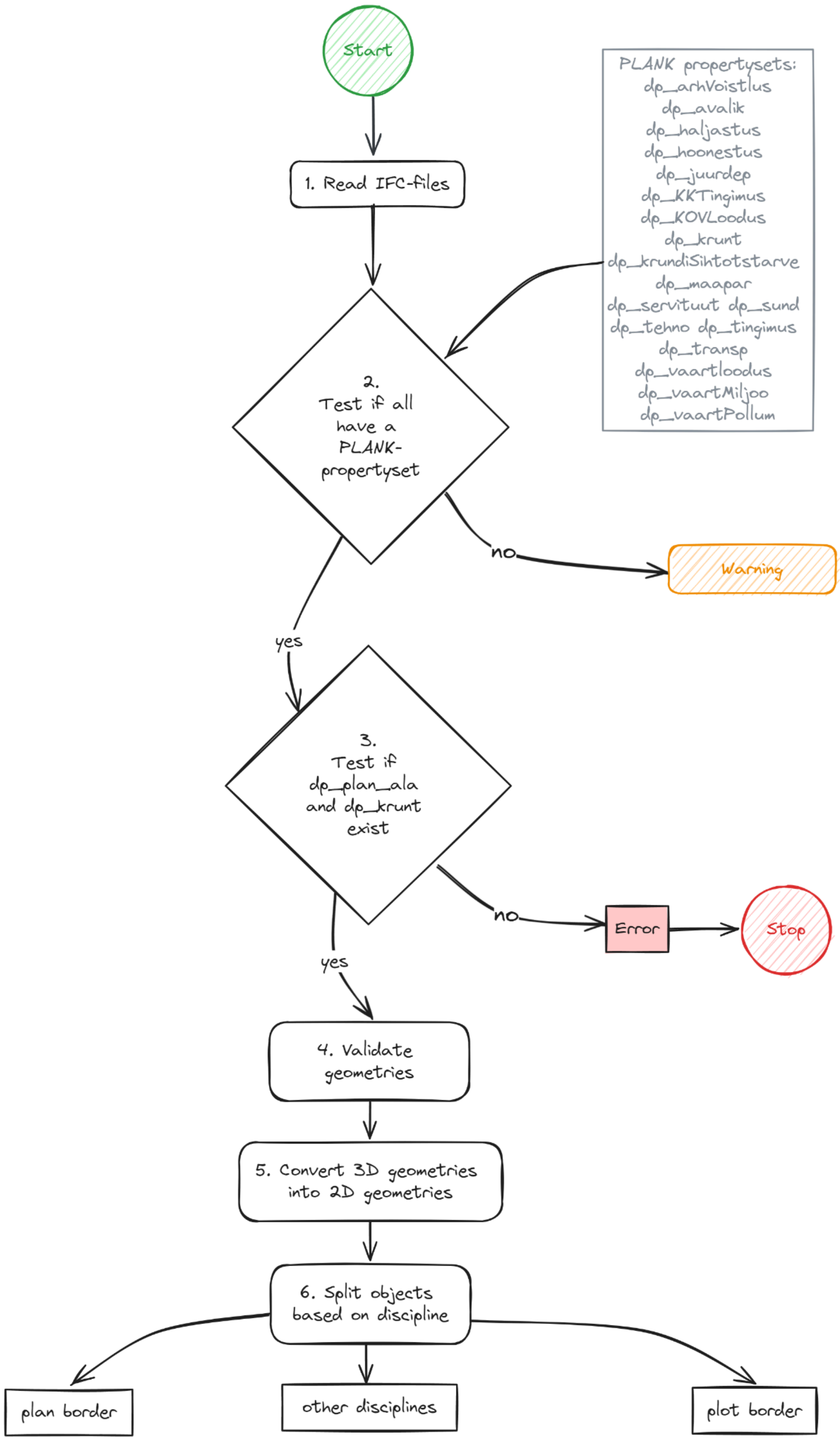
A schematic overview of the execution of the developed checks.

### 1. Master Flow

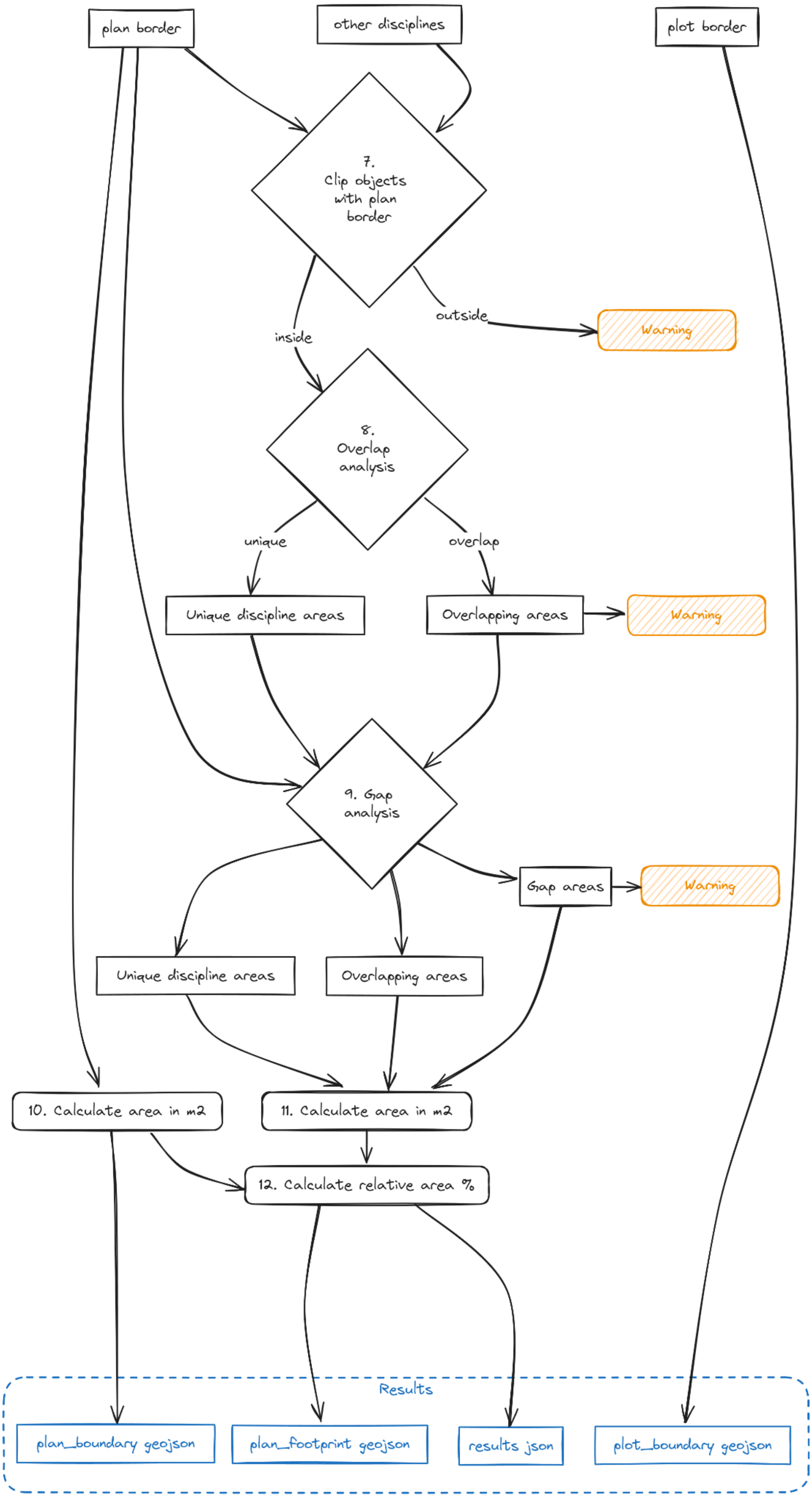


## 2. Area measures

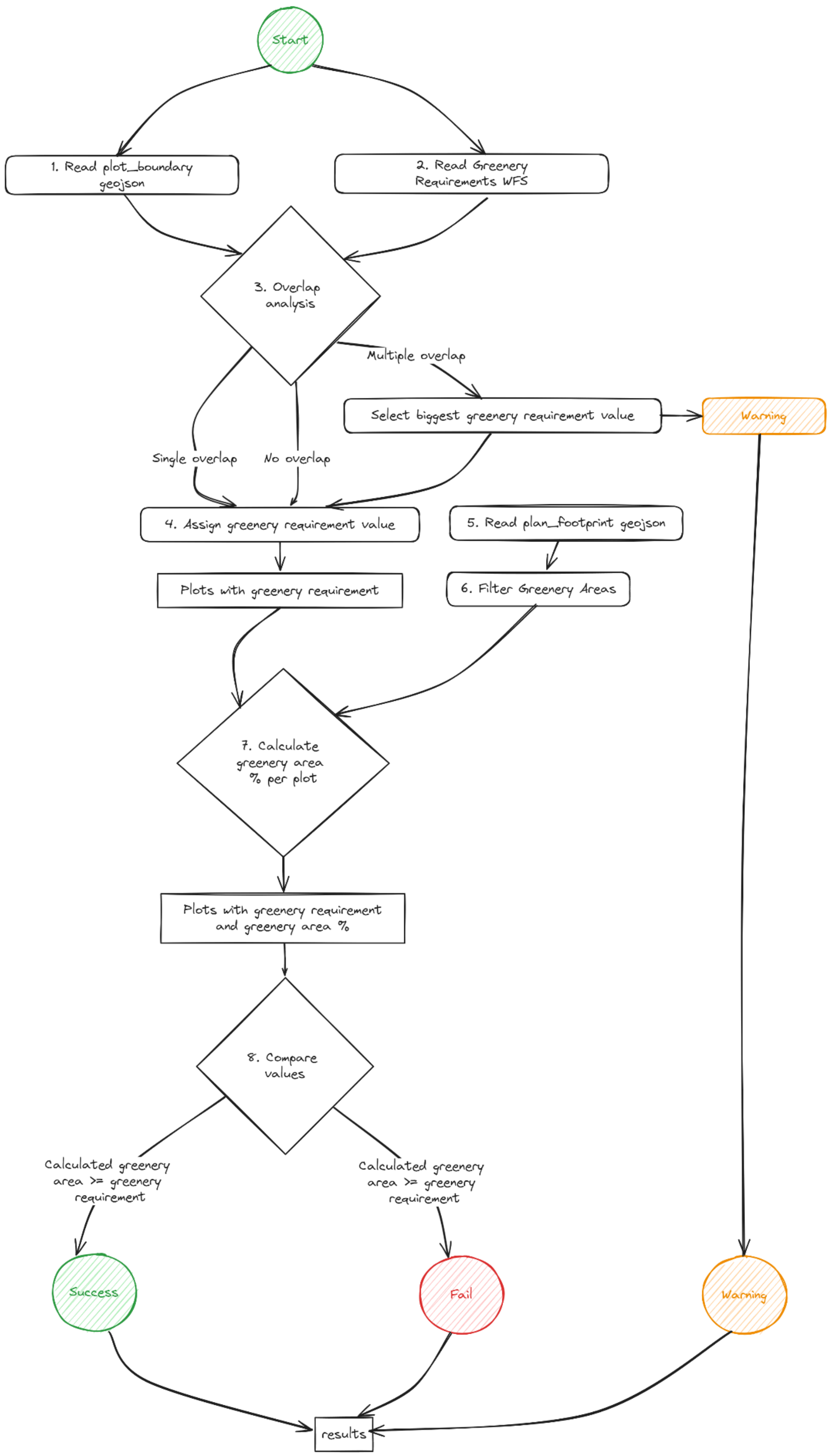
**(1/2)**



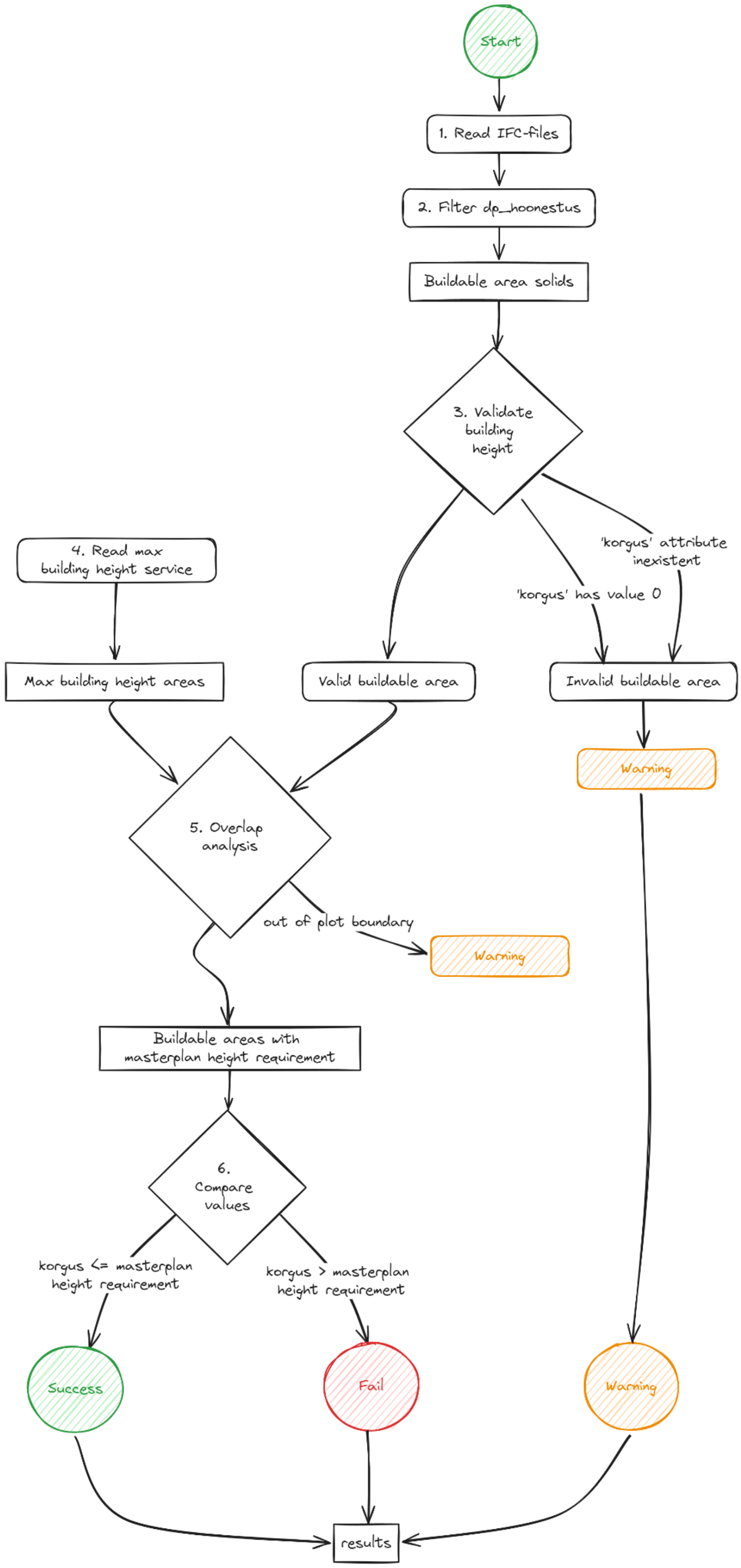

**Area measures (2/2)**


plan border
other disciplines
plot border
7.
Clip objects
with plan
border
outside
Warning
inside
8.
Overlap
analysis
unique
overlap
Unique discipline areas
Overlapping areas
Warning
9. Gap
analysis
Gap areas
Warning
Unique discipline areas
Overlapping areas
10. Calculate area in m2
11. Calculate area in m2
12. Calculate relative area %
Results
plan_boundary geojson
plan_footprint geojson
results json
plot_boundary geojson

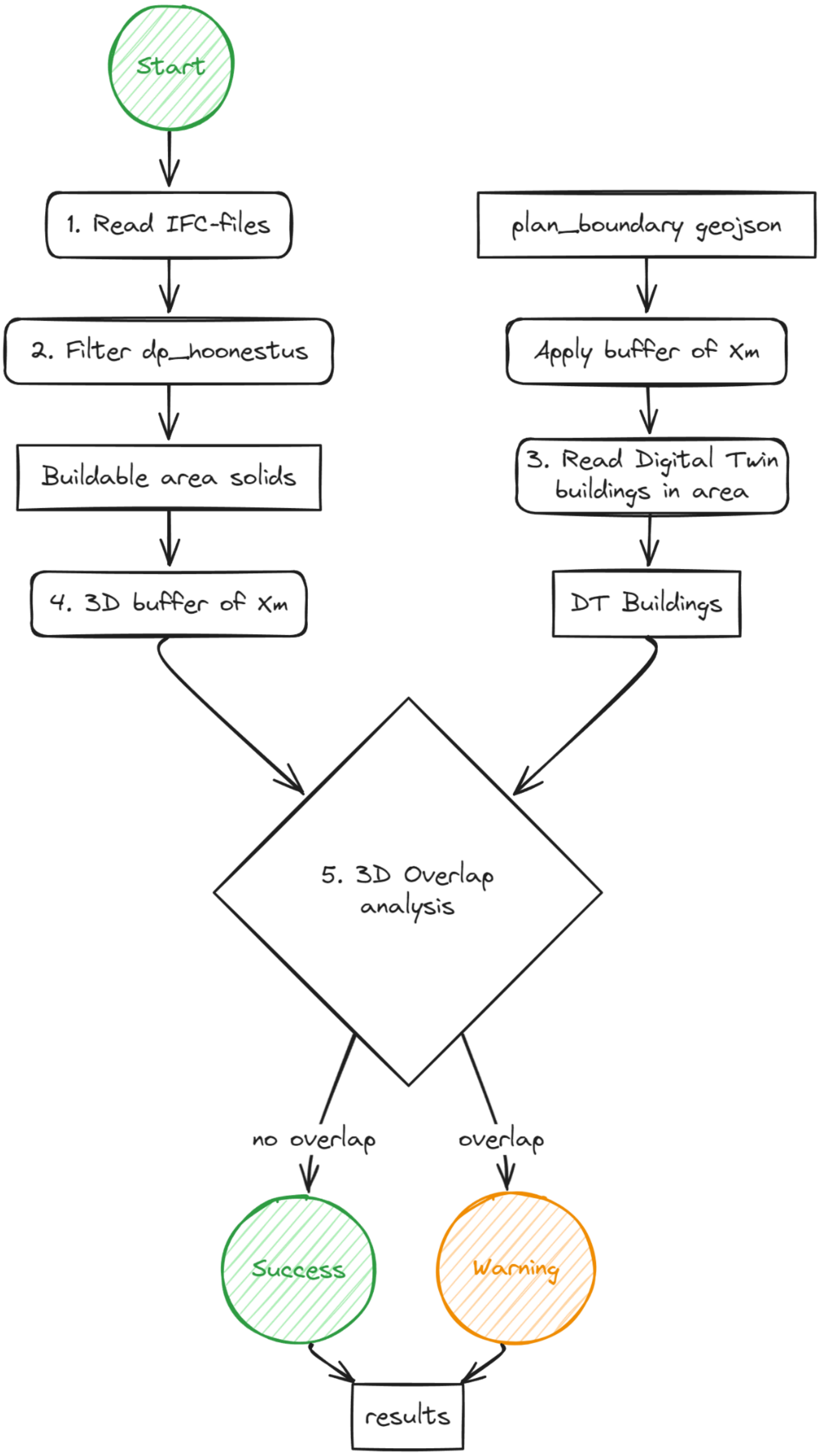
## 3. Greenery requirements



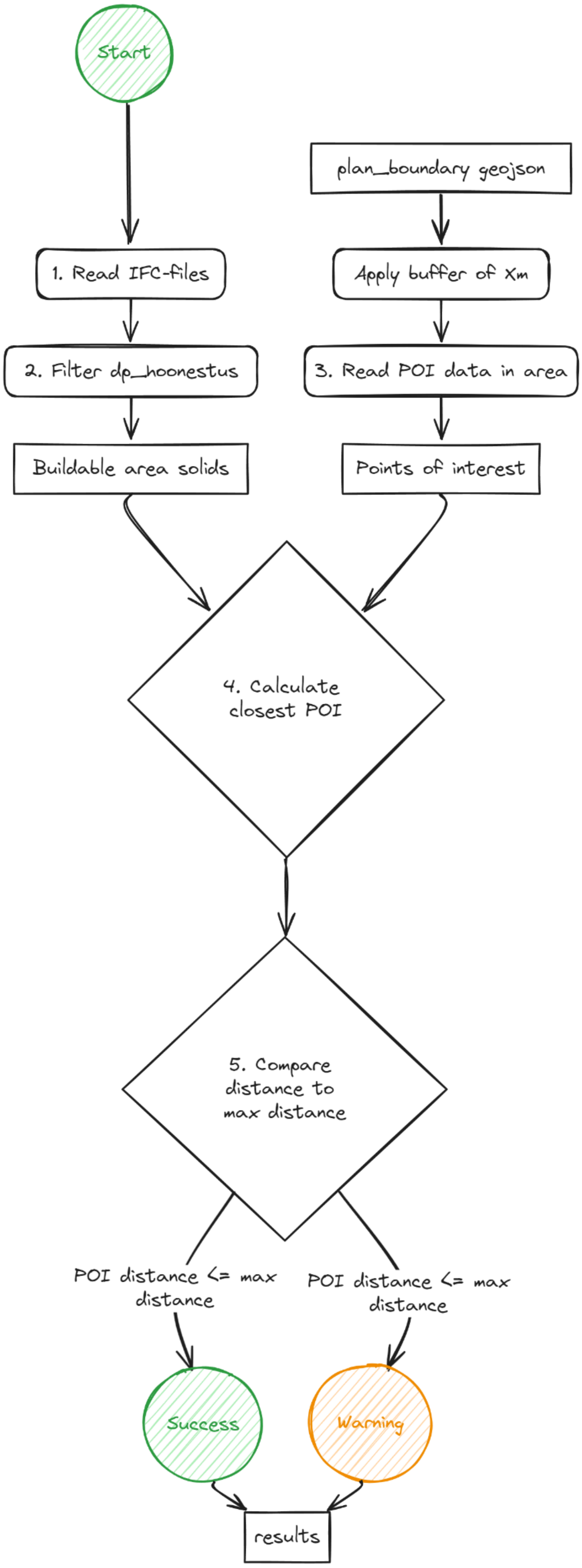
## 4. Building height requirements



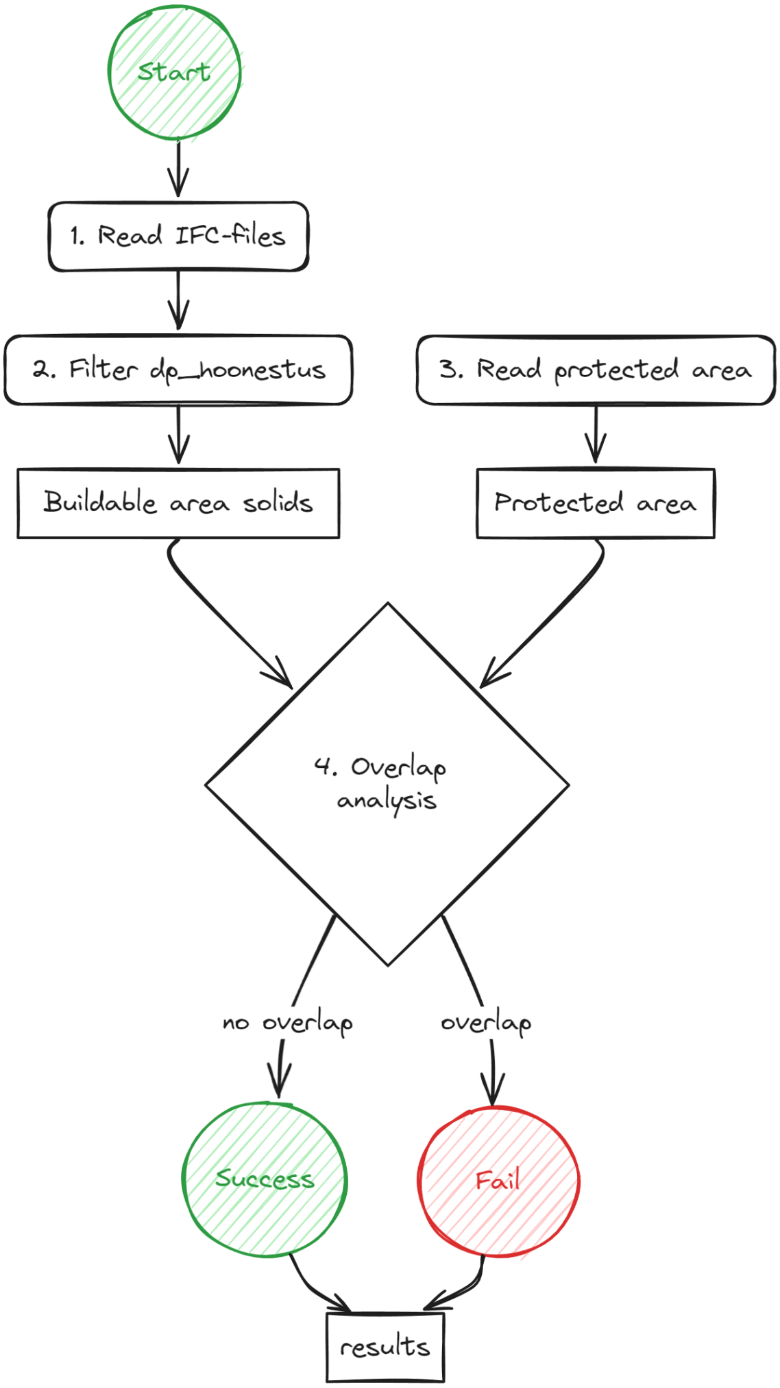
5. Building distance



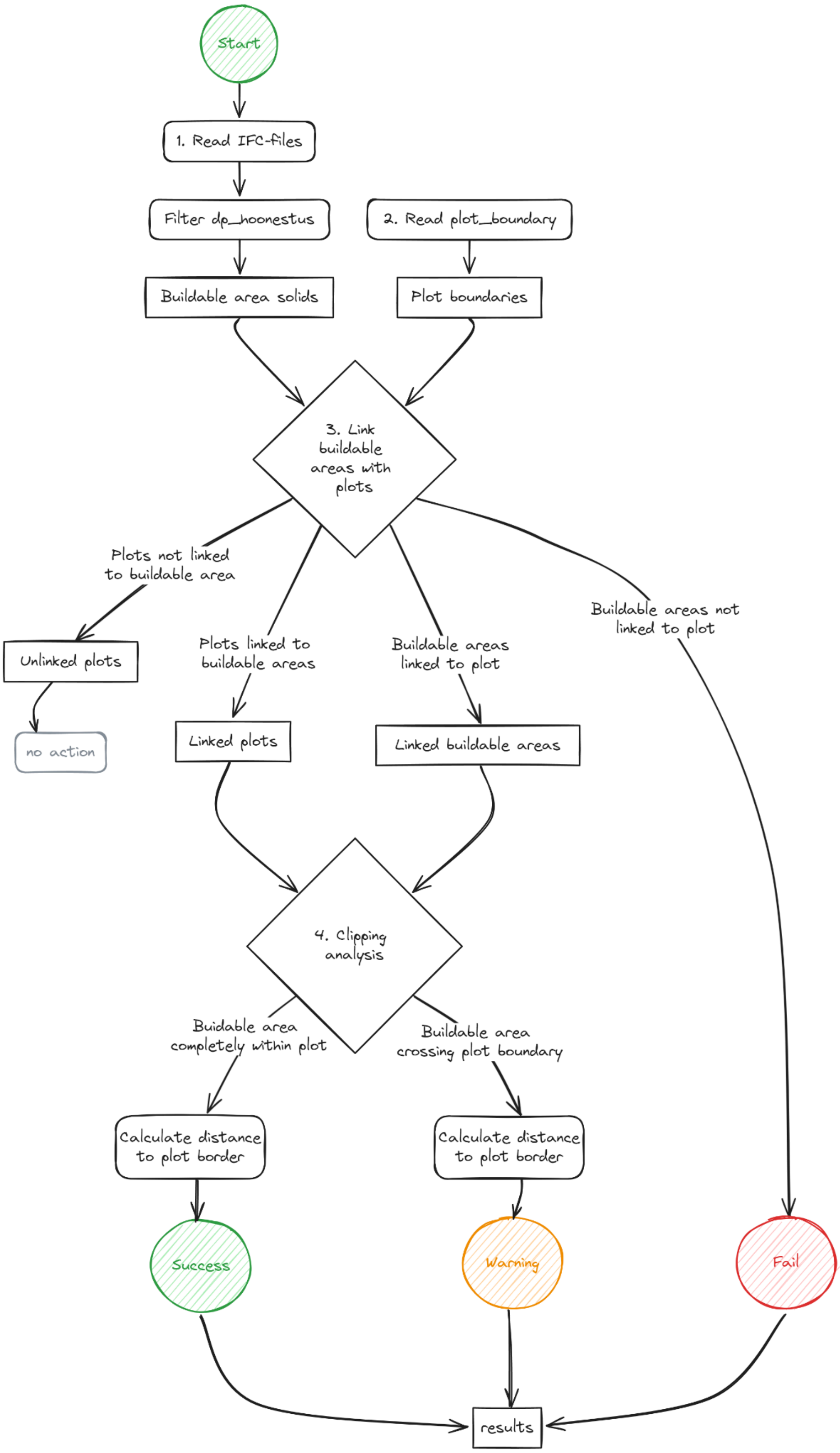
## 6. Points of interest



## 7. Protected area requirements



## 8. Cadaster border distance



## c. PLANK layers english translation

The original PLANK requirements are stated in Estonian. For the development of the prototype the following translation of the PLANK requirements to english are used:

### NATIONAL PLAN

| Plan Type | Core Layer Name | Name | Division Layers | Mandatory | Spatial Data Requirements | Smart Data *(Tärkandmed)* | Point | Line | Surface |
|---|---|---|---|---|---|---|---|---|---|
| 40 | plan_ala | Planning Area | - | Mandatory | - | Mandatory | - | - | Allowed |
| 40 | yrpmsp_ehitis | Structure Not Permanently Connected to the Shore | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 40 | yrpmsp_kaitse | Conservation Area | Allowed | - | - | - | - | - | Allowed |
| 40 | yrpmsp_kalandus | Area Necessary for Fishing Operations | Allowed | - | - | - | - | - | Allowed |
| 40 | yrpmsp_maavara | Area Affected by Mineral Resource Utilization or Mining | Allowed | - | - | - | - | - | Allowed |
| 40 | yrpmsp_muinsusk | Object Necessary for Ensuring Heritage Conservation Values | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 40 | yrpmsp_puhke | Recreational Area | Allowed | - | - | - | Allowed | - | Allowed |
| 40 | yrpmsp_riigikaitse | Area for Defense Purposes | Allowed | - | - | - | - | - | Allowed |
| 40 | yrpmsp_sadam | Port | Allowed | - | - | - | Allowed | - | Allowed |
| 40 | yrpmsp_tehno | Energy, Gas, and Telecommunication Networks | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 40 | yrpmsp_tingimus | Area with Conditions Set by the Plan | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 40 | yrpmsp_veeliiklus | Area Necessary for Water Traffic | Allowed | - | - | - | - | Allowed | Allowed |

### COUNTY PLAN

| Plan Type | Core Layer Name | Name | Division Layers | Mandatory | Spatial Data Requirements | Smart Data *(Tärkandmed)* | Point | Line | Surface |
|---|---|---|---|---|---|---|---|---|---|
| 10 | plan_ala | Planning Area | - | Mandatory | - | Mandatory | - | - | Allowed |
| 10 | mp_jaade | Regional Waste Management | Allowed | - | - | - | Allowed | - | Allowed |
| 10 | mp_keskus | Network of Centers | - | - | - | - | Allowed | - | Allowed |
| 10 | mp_kultparand | Cultural Heritage | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_linnaline | Urban Area | - | - | - | - | - | - | Allowed |
| 10 | mp_maavara | Deposit and Mine | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_MSP | Marine Planning | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_puhke | Recreational and Leisure Area | Allowed | - | - | - | - | - | Allowed |
| 10 | mp_riigikaitse | Defense Area | Allowed | - | - | - | - | - | Allowed |
| 10 | mp_rohev | Green Network Area | Allowed | - | - | - | - | - | Allowed |
| 10 | mp_suunis | Area with Planning Guidelines | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_tehno | Infrastructure | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_transp | Transportation Network | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_vaartPollum | Valuable Agricultural Land | Allowed | - | - | - | - | - | Allowed |
| 10 | mp_vaartRohe | Valuable Natural Habitat | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 10 | mp_veeala | Public Water Bodies Area | Allowed | - | - | - | - | - | Allowed |

# MASTER PLAN

| Plan Type | Core Layer Name | Name | Division Layers | Mandatory | Spatial Data Requirements | Smart Data (*Tärkandmed*) | Point | Line | Surface |
|---|---|---|---|---|---|---|---|---|---|
| 20 | plan_ala | Planning Area | - | Mandatory | - | Mandatory | - | - | Allowed |
| 20 | yp_arhVoistlus | Area with Mandatory Architectural Competition for Detail Planning | Allowed | - | - | - | Allowed | - | Allowed |
| 20 | yp_DPKoKo | Area with Mandatory Detail Planning | - | - | - | - | - | - | Allowed |
| 20 | yp_EKV | Construction Prohibition Zone Increase or Decrease | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_jaade | Waste Management | Allowed | - | - | - | Allowed | - | Allowed |
| 20 | yp_juurdep | Access | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_kaldaehitis | Water and Shore Construction | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_kallasrada | Shore Path Closure and Modification | Allowed | - | - | - | - | Allowed | Allowed |
| 20 | yp_KKTingimus | Area with Environmental Condition Set by Master Plan | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_KOVKultparand | Local Cultural Heritage or Heritage Conservation Object | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_KOVLoodus | Local Government Nature Conservation Proposal | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_maakas | Land Use Purpose | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_maapar | Land Improvement Systems | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_maavara | Restriction from Mineral or Mining | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_ORME | Construction with Significant Spatial Impact | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_puhke | Recreation and Leisure Area | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_rand | Beach | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_rohev | Green Network | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_strateegia | Strategic Principle Areas | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_sund | Need for Expropriation in Public Interest | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_tehno | Technical Construction | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_tiheas | Dense Settlement Area | - | - | - | - | - | - | Allowed |
| 20 | yp_tingimus | Condition Set by Master Plan | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_transp | Transportation Construction or Area | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_vaartMaastik | Valuable Landscape | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_vaartMiljoo | Valuable Milieu | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_vaartPollum | Valuable Agricultural Land | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_vaartRohe | Valuable Green Area | Allowed | - | - | - | - | - | Allowed |
| 20 | yp_vaartVaade | Valuable Views | Allowed | - | - | - | Allowed | Allowed | Allowed |
| 20 | yp_veehaare | Water Intake | Allowed | - | - | - | Allowed | - | Allowed |
| 20 | yp_yleujutus | Flood Area or High Water Limit | Allowed | - | - | - | - | Allowed | Allowed |

| Layer Name | Attribute (Column Name) | Data Type | Explanation | Mandatory | Condition for Mandatory |
|---|---|---|---|---|---|
| yp_EKV | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |
| | nimetus | text | Object name. | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Conditions. | - | - |
| yp_jaade | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |
| | nimetus | text | Object name. | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Conditions. | - | - |
| yp_juurdep | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |
| | nimetus | text | Object name. | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Conditions. | - | - |
| yp_kaldaehitis | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |
| | nimetus | text | Object name. | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Conditions. | - | - |
| yp_KOVKultparand | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |
| | nimetus | text | Object name. | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Conditions. | - | - |
| | voond | integer\|fraction | Width of the protection zone. | - | - |
| yp_KOVLoodus | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |
| | nimetus | text | Object name. | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Conditions. | - | - |
| | voond | integer\|fraction | Width of the protection zone. | - | - |
| yp_maakas | objectID | integer\|text | Object identifier. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - |

| Plan Type | Core Layer Name | Name | Division Layers | Mandatory | Spatial Data Requirements | Smart Data *(Tärkandmed)* | Point | Line | Surface |
|---|---|---|---|---|---|---|---|---|---|
| **30** | **plan_ala** | Planning Area | - | Mandatory | - | Mandatory | - | - | Allowed |
| **30** | **dp_arhVoistlus** | Area Requiring Architectural Competition | Allowed | - | - | - | - | - | Allowed |
| **30** | **dp_avalik** | Area Planned for Public Use | Allowed | - | - | - | - | Allowed | Allowed |
| **30** | **dp_haljastus** | Landscaping and Maintenance | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_hoonestus** | Building Area | Allowed | Mandatory | Building area must be entirely within the plot connected to the annotation data | - | - | - | Allowed |
| **30** | **dp_juurdep** | Access | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_KKTingimus** | Environmental Condition Area | Allowed | - | - | - | - | - | Allowed |
| **30** | **dp_KOVLoodus** | Local Government Nature Conservation Proposal | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_krunt** | Plot | - | Mandatory | The spatial shape of an object cannot be a collection of surfaces. At least one geometry per layout. | Mandatory | - | - | Allowed |
| **30** | **dp_krundiSihtotstarve** | Plot Purpose | - | Mandatory | - | Mandatory | - | - | - |
| **30** | **dp_maapar** | Land Improvement System | Allowed | - | - | - | - | Allowed | Allowed |
| **30** | **dp_servituut** | Easement Need | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_sund** | Need for Acquisition in Public Interest | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_tehno** | Technical Construction | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_tingimus** | Condition Set by Plan | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_transp** | Transportation Construction or Area | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_vaartloodus** | Natural Value | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_vaartMiljoo** | Milieu Value | Allowed | - | - | - | Allowed | Allowed | Allowed |
| **30** | **dp_vaartPollum** | Valuable Agricultural Land | Allowed | - | - | - | - |  | Allowed |

| Layer Name (Worksheet) | Attribute (Column Name) | Data Type in Column | Explanation | Filling Rules | Mandatory | Condition for Mandatory |
|---|---|---|---|---|---|---|
| **dp_vaartPollum** | objectID | integer\|text | Object identifier | Unique within the base layer at least | Mandatory | - |
| | jaotuskiht | text | Distribution layer for GIS formats | - | - | - |
| | tingimus | text | Description of conditions | - | - | - |
| **dp_vaartMiljoo** | objectID | integer\|text | Object identifier | Unique within the base layer at least | Mandatory | - |
| | jaotuskiht | text | Distribution layer for GIS formats | - | - | - |
| | nimetus | text | Object name | - | Conditionally Mandatory | Mandatory if distribution layers are not used |
| | tingimus | text | Description of conditions | - | - | - |
| **dp_vaartLoodus** | objectID | integer\|text | Object identifier | Unique within the base layer at least | Mandatory | - |
| | jaotuskiht | text | Distribution layer for GIS formats | - | - | - |
| | nimetus | text | Object name | - | Conditionally Mandatory | Mandatory if distribution layers are not used |
| | tingimus | text | Description of conditions | - | - | - |
| **dp_transp** | objectID | integer\|text | Object identifier | Unique within the base layer at least | Mandatory | - |
| | voond | integer\|fraction | Width of the protection zone | Unit: meter | - | - |
| | jaotuskiht | text | Distribution layer for GIS formats | - | - | - |
| | kujaTing | text | Conditions of the corridor, such as spacing | Unit: meter | - | - |
| | nimetus | text | If all road and street elements are presented on one layer, it is mandatory to indicate which object it is | - | Conditionally Mandatory | Mandatory if distribution layers are not used |
| | tingimus | text | Description of conditions | - | - | - |
| **dp_tingimus** | objectID | integer\|text | Object identifier | Unique within the base layer at least | Mandatory | - |
| | jaotuskiht | text | Distribution layer for GIS formats | - | - | - |
| | nimetus | text | Object name | - | Conditionally Mandatory | Mandatory if distribution layers are not used |
| | tingimus | text | Description of conditions | - | - | - |
| **dp_tehno** | objectID | integer\|text | Object identifier | Unique within the base layer at least | Mandatory | - |
| | korgus | integer\|fraction | Relative height above ground | Unit: meter | - | - |
| | korgusAbs | integer\|fraction | Absolute height | Unit: meter | - | - |
| | maxKorgAbs | integer\|fraction | Maximum allowed absolute height | Unit: meter | - | - |
| | maxKorgus | integer\|fraction | Maximum allowed relative height above ground | Unit: meter | - | - |
| | maxSygavus | integer\|fraction | Maximum allowed depth in meters is relevant for buildings or significant public interest facilities | Unit: meter | - | - |
| | minKorgAbs | integer\|fraction | Minimum allowed absolute height | Unit: meter | - | - |
| | minKorgus | integer\|fraction | Minimum allowed relative height above ground | Unit: meter | - | - |
| | minSygavus | integer\|fraction | Minimum allowed depth in meters is relevant | Unit: meter | - | - |
| | sygavus | integer\|fraction | If depth in meters is relevant | Unit: meter | - | - |
| | voond | integer\|fraction | Width of the protection zone | Unit: meter | - | - |
| | jaotuskiht | text | Distribution layer for GIS formats | - | - | - |
| | kujaTing | text | Conditions of the corridor, such as spacing | Unit: meter | - | - |
| | nimetus | text | Object name | - | Conditionally Mandatory | Mandatory if distribution layers are not used |
| | tingimus | text | Description of conditions | - | - | - |

| Layer Name (Worksheet) | Attribute (Column Name) | Data Type in Column | Explanation | Filling Rules | Mandatory | Condition for Mandatory |
|---|---|---|---|---|---|---|
| **dp_haljastus** | objectID | integer\|text | Object identifier. | Unique at least within the core layer. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - | - |
| | nimetus | text | Object name. | - | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Description of land use and building conditions. | - | - | - |
| | kujaTing | text | Corridor conditions, e.g., spacing. | Unit: meter | - | - |
| **dp_juurdep dp_KKTingimus dp_maapar dp_KOVLoodus dp_arhVoistlus** | objectID | integer\|text | Object identifier. | Unique at least within the core layer. | Mandatory | - |
| | jaotuskiht | text | Classified distribution layer for GIS formats. | - | - | - |
| **dp_servituut dp_avalik dp_sund** | nimetus | text | Object name. | - | Conditionally Mandatory | Mandatory if no distribution layers are used. |
| | tingimus | text | Description of land use and building conditions. | - | - | - |

## d. LADM Part 5 country profile for Estonia.