Integration of 3D BIM Models in a Web GIS for Life Cycle Asset Management

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November 2018

TU Delft

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Integration of 3D BIM Models in a Web GIS for Life Cycle Asset Management

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TU Delft

November 9, 2018, 13:00h, Room P,
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Overview

Overview

1. INTRODUCTION

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1.1. Problem Statement

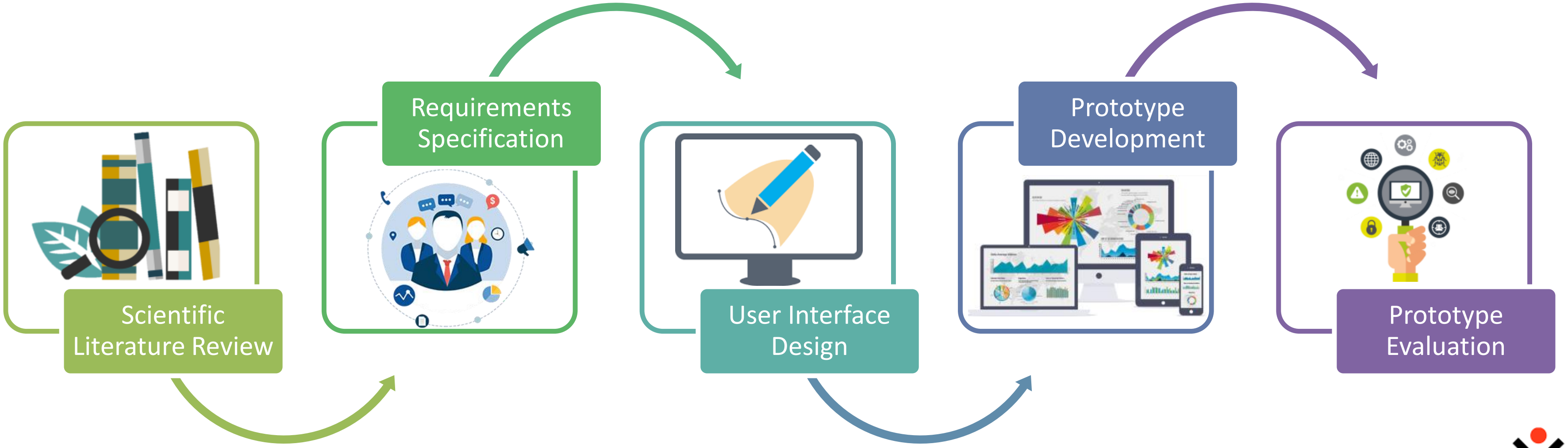
- Life Cycle Asset Management (LCAM) for improving the decision making in each phase of the life cycle of infrastructure assets
- Geographic Information Systems (GIS) optimize the administration of infrastructure assets through advanced modelling, analysis and visualization
- Growing necessity for 3D geoinformation in infrastructure management to provide a more realistic representation of the built environment
- Building Information Modelling (BIM) facilitates the generation of multi-dimensional models to describe the physical and functional characteristics of built objects

1.2. Research Objective

Integrating 3D BIM models of civil structures in a Web GIS system for optimising dynamic and complex processes in the maintenance phase of LCAM

Research questions:

1. What is the current state of data visualization in LCAM and how can it be improved?
2. What are the requirements for the development of the 3D prototype?
3. How can 3D models be processed for effective utilisation in condition monitoring?
4. How can 3D models be integrated in a Web GIS?



2. THEORETICAL BACKGROUND

2.1. Life Cycle Asset Management

Figure 1: Phases in LCAM, adapted from Too [2008].

2.1. Life Cycle Asset Management

Condition Monitoring

- Defines current condition and capacity of the assets
- Enabled through visual inspections and physical checks of the assets

NEN 2767-4 Standards

- National standards for inspection and maintenance
- Determine the condition of the public infrastructure
- Facilitate maintenance planning, budgeting, and prioritisation

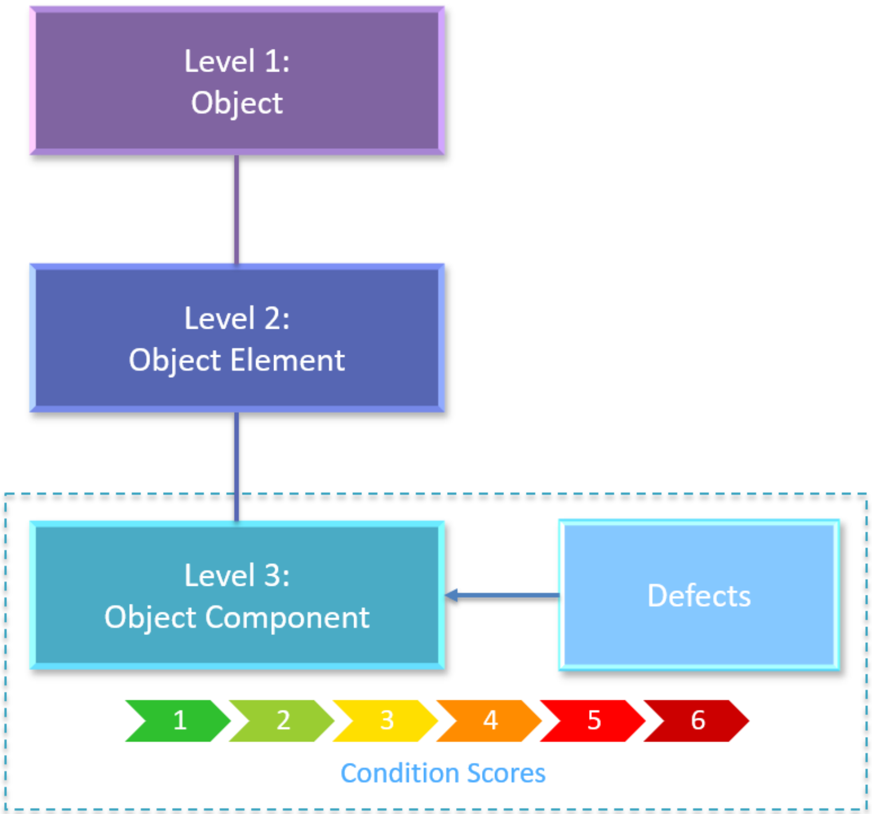


Figure 2: NEN levels for the infrastructure assets, adapted from Boanca [2014].

2.1. Life Cycle Asset Management

Table 1: Advantages and disadvantages of semantic 3D models in LCAM

Advantages	Disadvantages
More realistic and detailed representation of the built environment	More powerful hardware and software necessary for 3D modelling and rendering
Powerful tool for visualizing subsurface assets like pipelines and cables	Efficient data storage for interoperability and database integration
Better understanding and interpretation by experts and non-experts at different stages	Staff training for the deployment of new technologies in the work processes
More convenient data updating through data interoperability and compatibility	

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2.2. Web GIS

- Improves the availability and dissemination of geoinformation
- Interactive data representation through dynamic maps generated directly from spatial DBs
- Based on client-server architecture for easier access to the DBMS

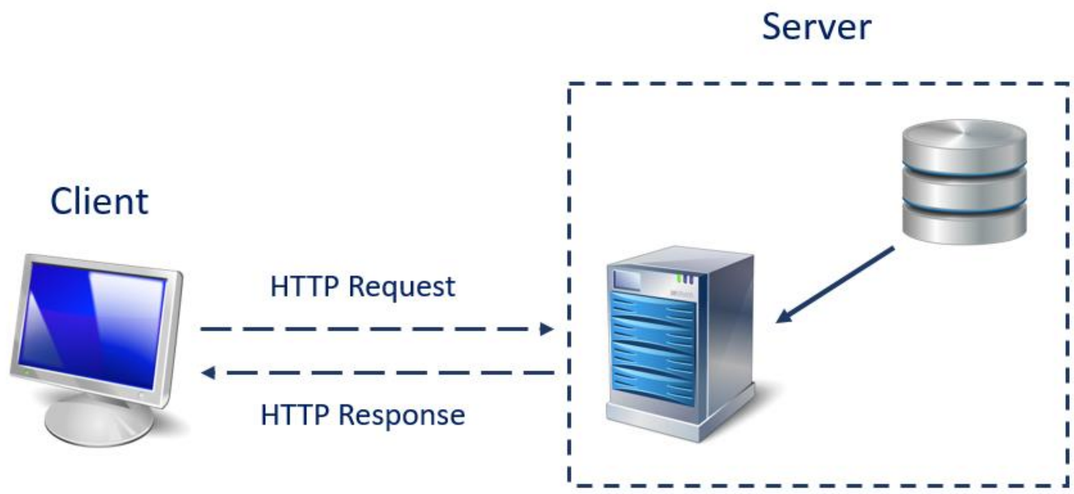
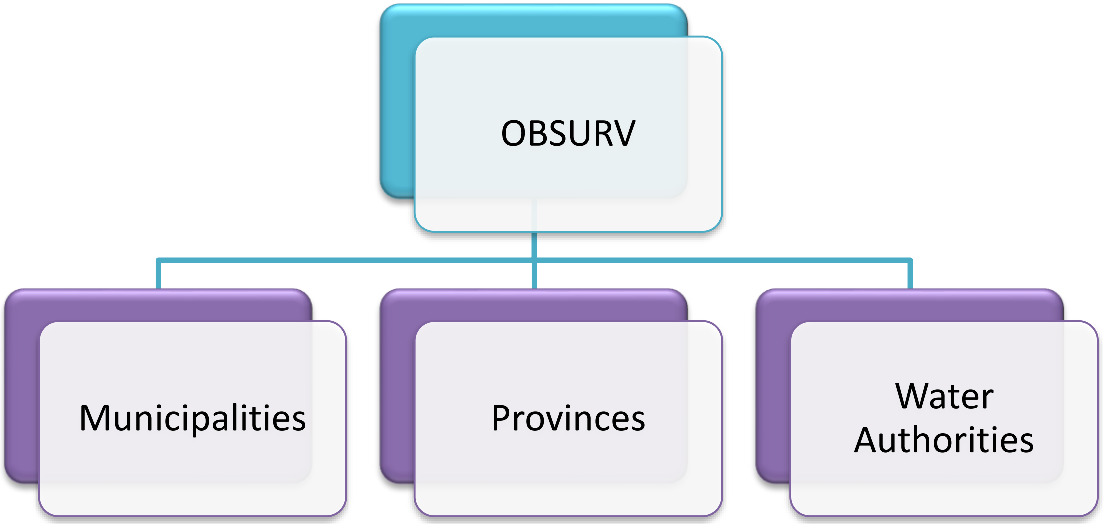


Figure 3: Client-server architecture, adapted from Alesheikh et al. [2002].

2.2. Web GIS

OBSURV

- Web GIS for public infrastructure management developed by Sweco
- Enables asset managers and decision makers to view and manage their assets
- Data representation in a tabular form and base map comprised of several layers



2.2. Web GIS

OBSURV

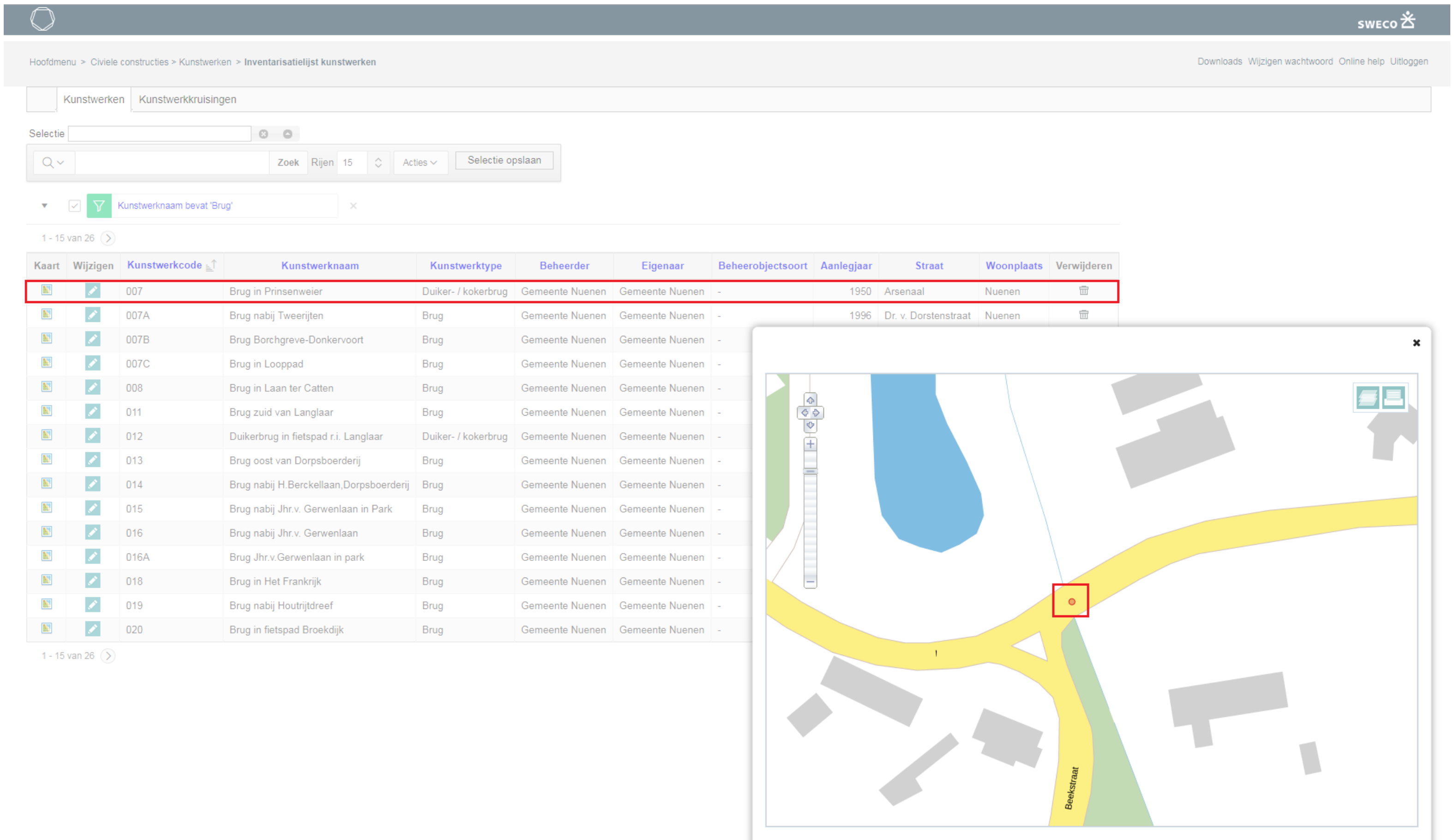


Figure 4: Current data representation in OBSURV.

2.2. Web GIS

OBSURV System Architecture

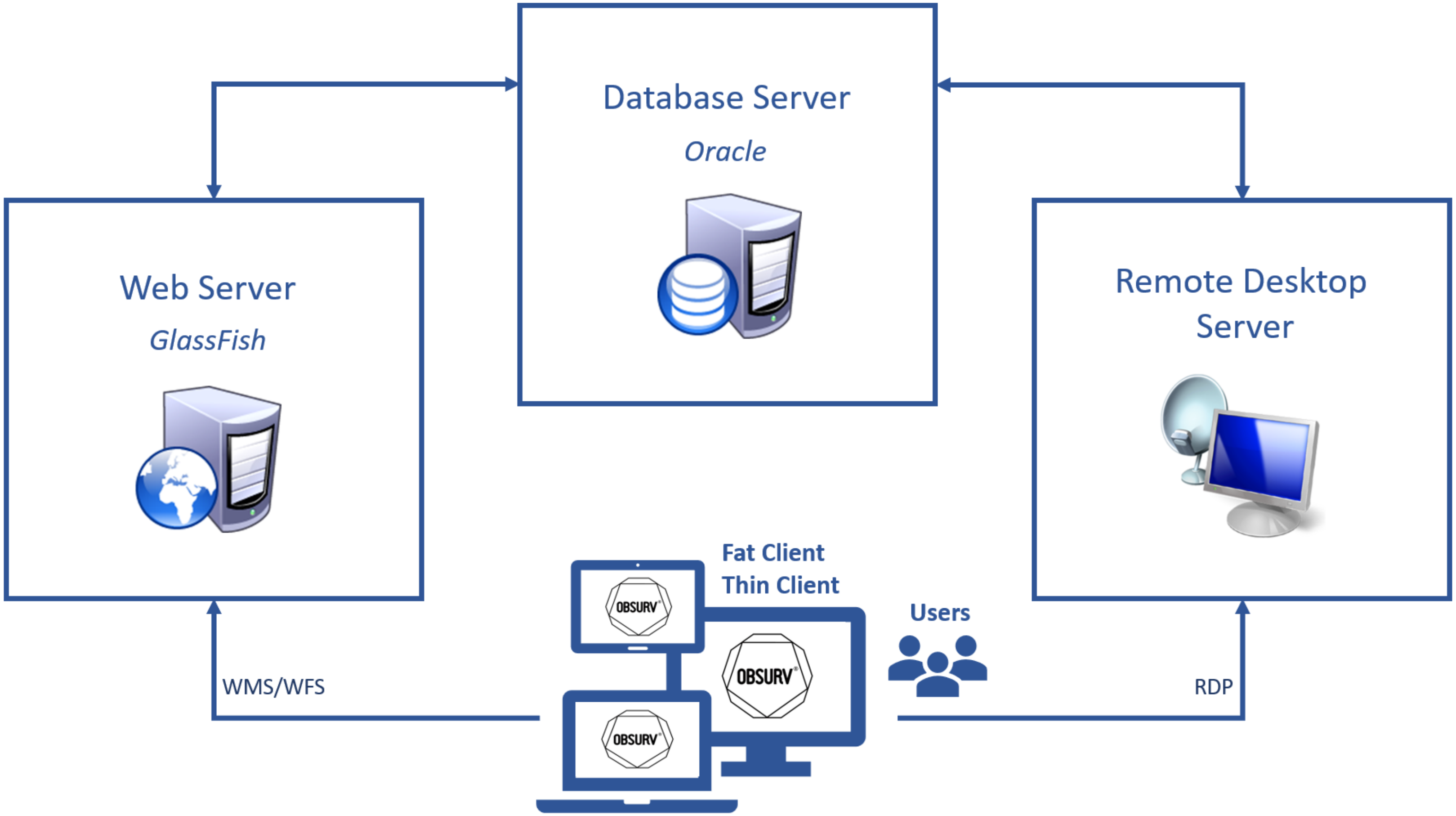


Figure 5: Multi-tier client-server architecture of OBSURV, adopted from Tepas [2014].

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2.3. Semantic 3D Models

Building Information Modelling

- Combination of organisational solutions and technologies to increase the productivity and efficiency in the construction industry
- Provides details about the design, construction, management, maintenance and operation of objects
- Parametric modelling to generate multi-dimensional models

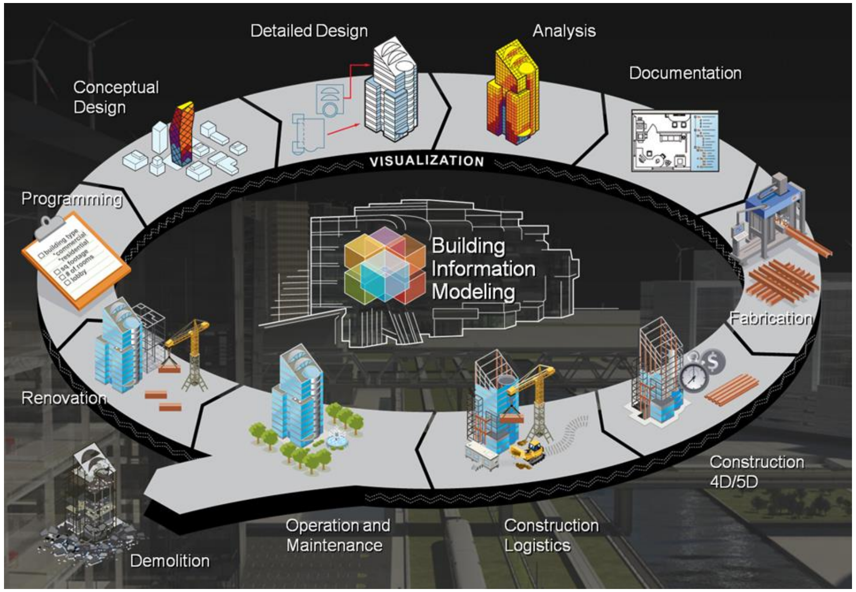

Figure 6: BIM implementation in the building life cycle [Dispenza, 2010].

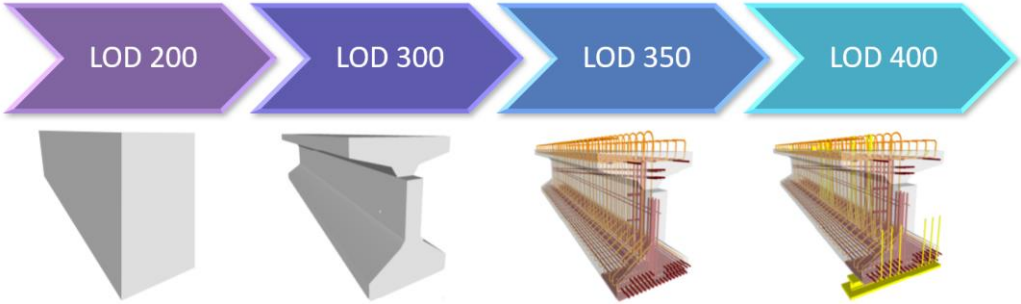

Figure 7: LOD in the BIM technology specified by BIMForum [2016].

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2.3. Semantic 3D Models

CityGML

- OGC standard for the storage and exchange of 3D geoinformation
- Used for creating virtual 3D city models (e.g. Berlin, Potsdam, Rotterdam, Helsinki)
- Semantic – geometric modelling for the combination of graphical and semantic information about urban objects

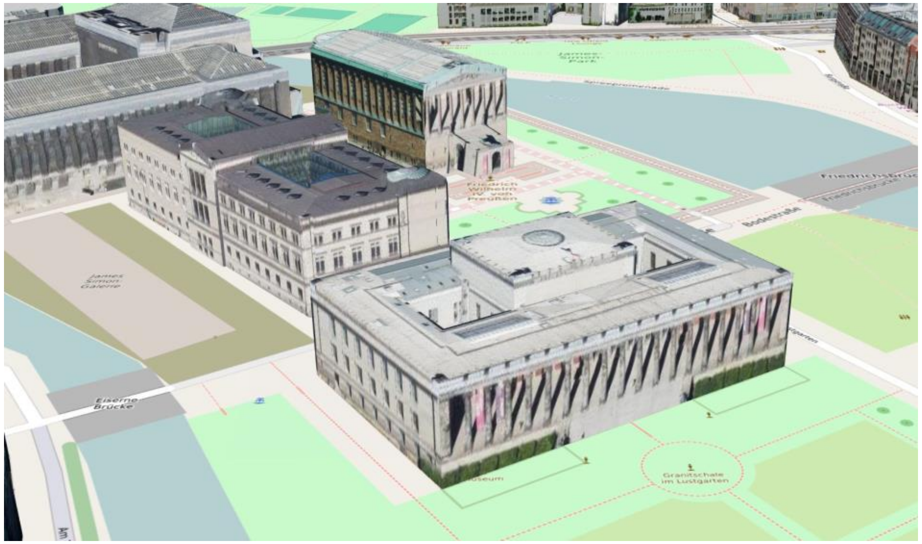

Figure 8: Semantic 3D city model of Berlin [3DCityDB, 2017].

Figure 9: LOD in CityGML [Biljecki et al., 2017].

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2.4. Related work

Web visualization of semantic 3D models

Figure 10: 3D city model of Berlin [Schilling et al., 2016].

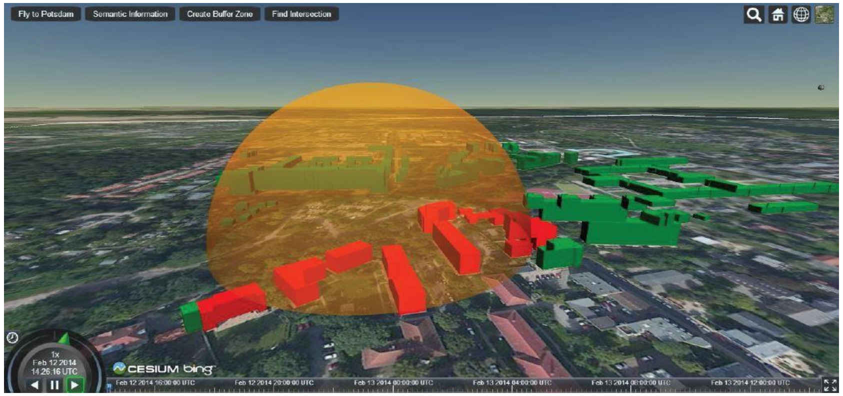

Figure 11: Web platform developed by Chaturvedi [2014].

Figure 12: 3D city model of Rotterdam [Prandi et al., 2015].

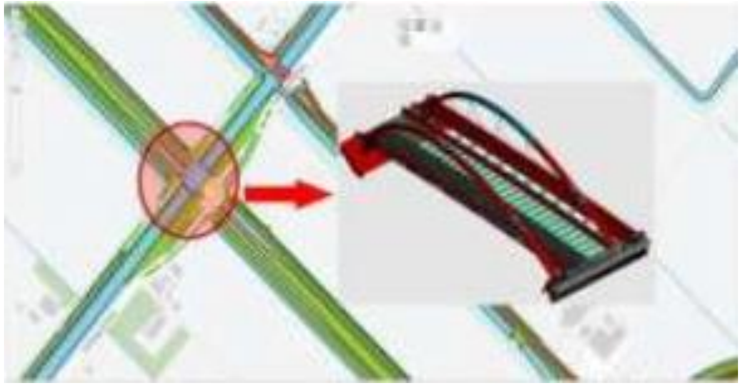

Figure 13: Integration of BIM model in OBSURV [Boanca, 2014].

2.4. Related work

Methods for georeferencing of 3D models

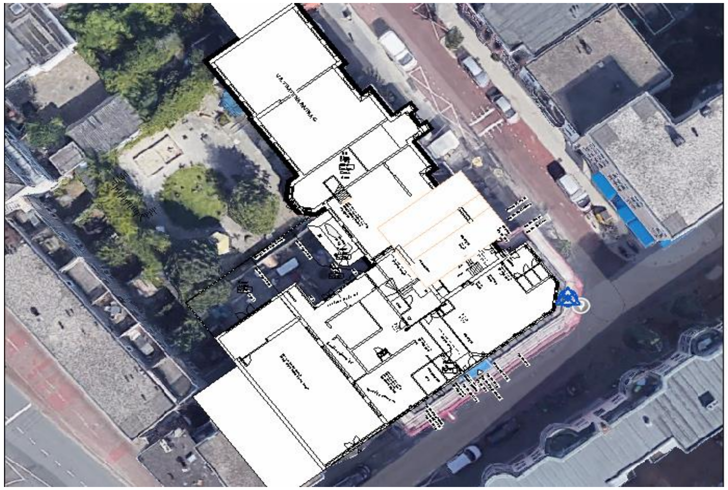

Figure 14: Georeferenced BIM model of a building in The Hague [Diakite, 2018].

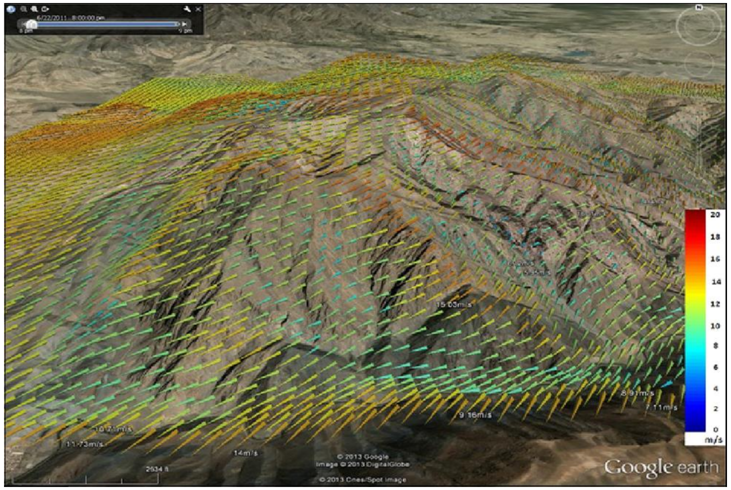

Figure 15: Meteorological model integrated in Google Earth [Wang et al., 2013].

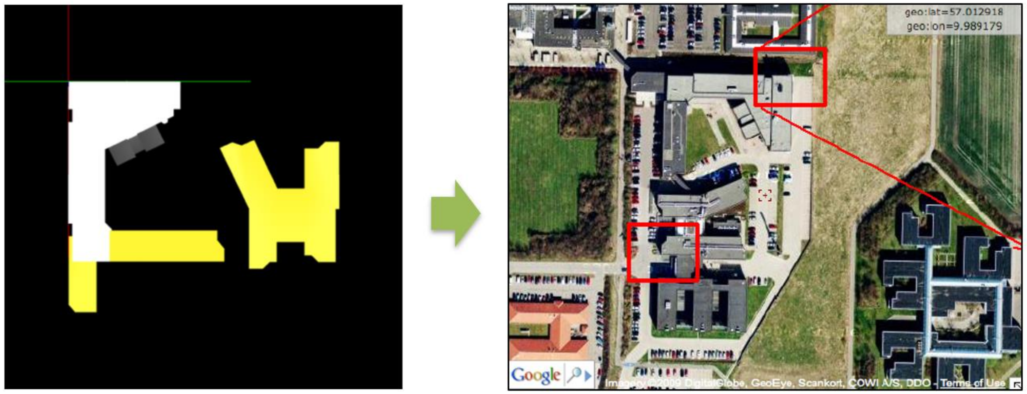

Figure 16: Georeferenced 3D model of a building by Kolár and Wen [2009].

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3. PROTOTYPE DESIGN

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3.1. Requirements Specification

Table 2: Interviewees participated in the graduation project.

Municipality of Rotterdam	Sweco Netherlands
Jan de Jong *Project Leader OBSURV*	Hilbert Davelaar *Product Manager OBSURV*
Joris Goos *Manager Digital Management & Building*	Henri Veldhuis *Manager Business Development*
Helmer Heijden *Asset Manager*	Marijn van den Berg *Asset Management Advisor*

3.1. Requirements Specification

1. Data collection, processing and visualization

- Acquisition of BIM models of civil structures in Rotterdam
- Decomposition of BIM models according to NEN 2767-4 standards
- 3D viewer integrated in OBSURV
- Assignment of different colours to the distinct bridge elements based on the inspection data
- Selection of bridge elements and display of related information

2. Base map and animation

- Integration of base map to visualize the surroun-ding environment of the bridge
- Rotate, zoom and pan capabilities for a better navigation of the view port
- Explode function to improve the visibility of the distinct bridge ele-ments

3. Additional functionalities

- Integration of switcher to allow the users to control the visibility of the bridge elements
- Include previous inspe-ctions to keep track of any changes in the condition of the bridge elements

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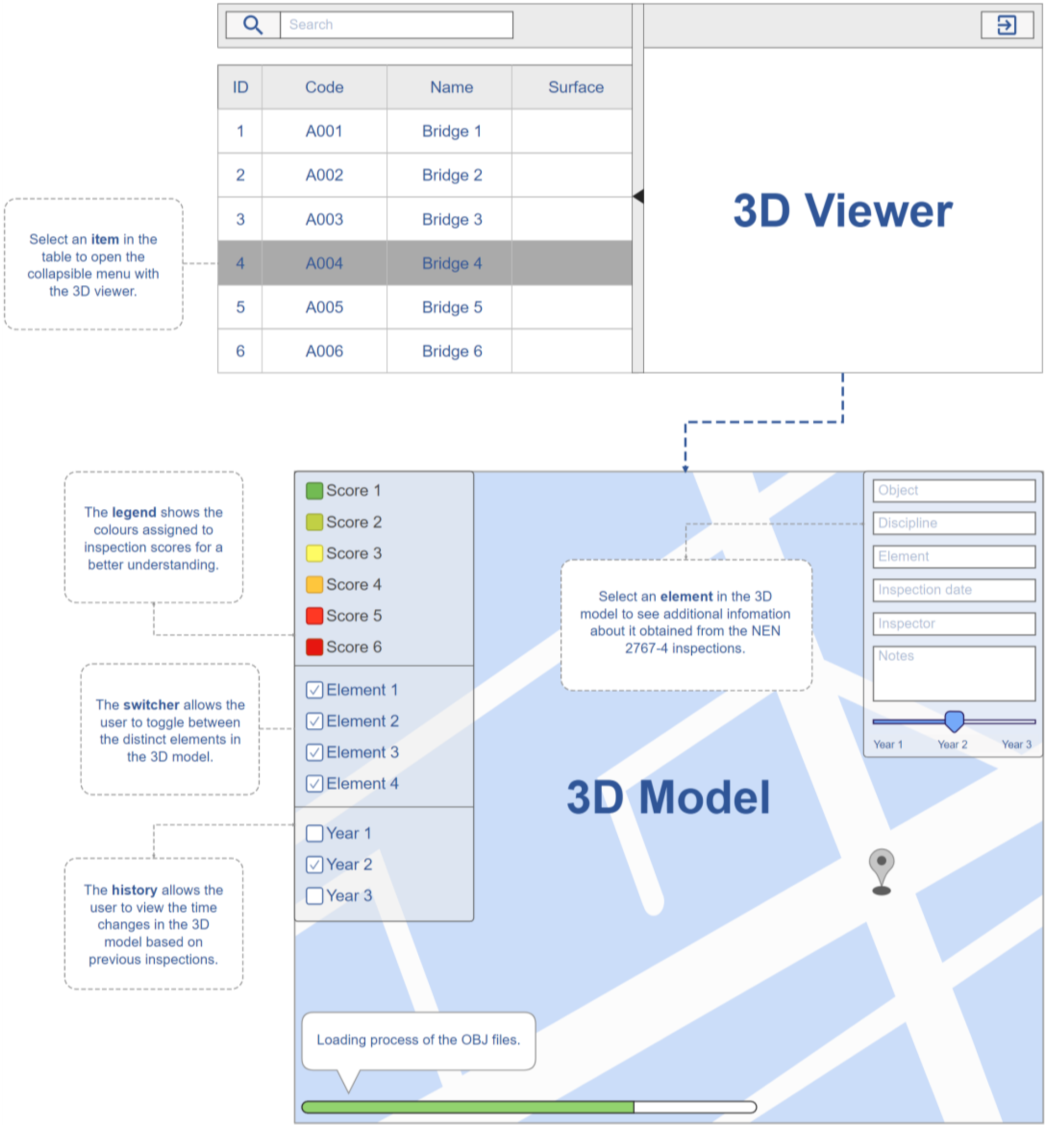
3.2. User Interface Design



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3.3. WebGL Frameworks

WebGL

- Technology for displaying and interacting with complex 3D graphics and animations
- Traditional built-in functionality supported by all modern web browsers
- Developed based on Open Graphics Language (OpenGL)

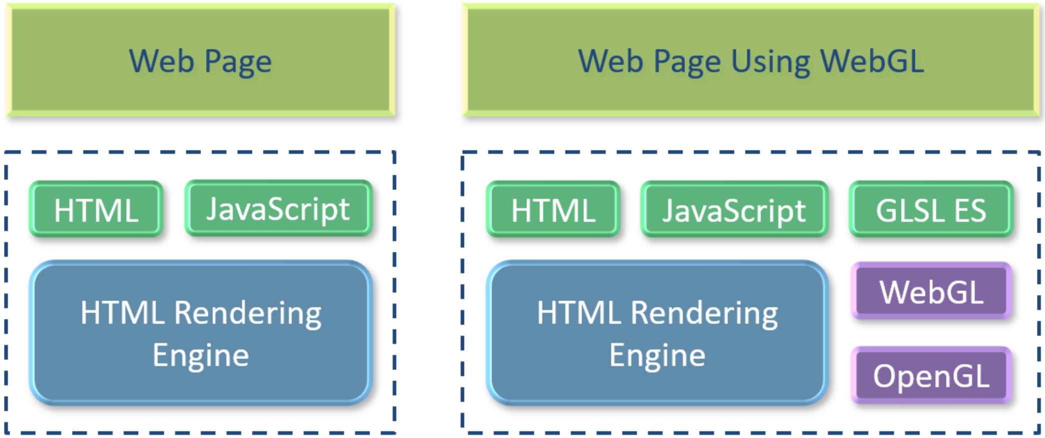

Figure 17: Software architecture of dynamic web pages and web pages using WebGL technology, adapted from Matsuda and Lea [2013].

3.3. WebGL Frameworks

Three.js

- Object-oriented library for 3D graphics and animations
- Supports loading of diverse 3D BIM models in different file formats
- Detailed documentation and various sample applications

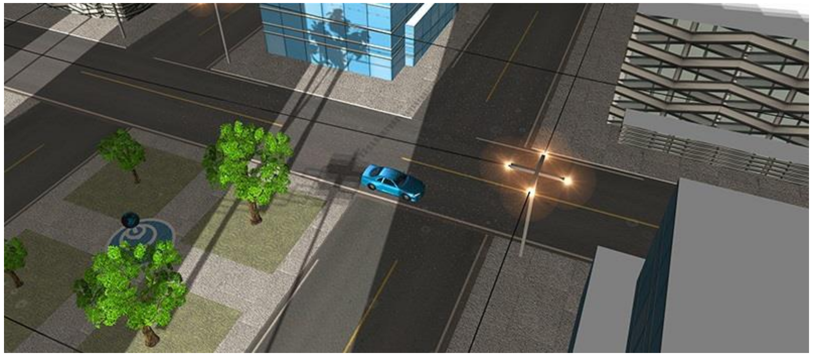

Figure 18: City car driving application built on Three.js [Poppe, 2017].

iTowns

- Library for 3D geospatial data visualisation based on Three.js
- Enables advanced interaction functions like annotation, 3D measurements, simulations, AR

Figure 19: Application for extruded buildings based on iTowns [iTowns, 2017].

3.3. WebGL Frameworks

Cesium

- Application for creating 3D globes and maps
- OGC compliant for creating virtual 3D city models
- Uses 3D Tiles for rendering BIM and other 3D models

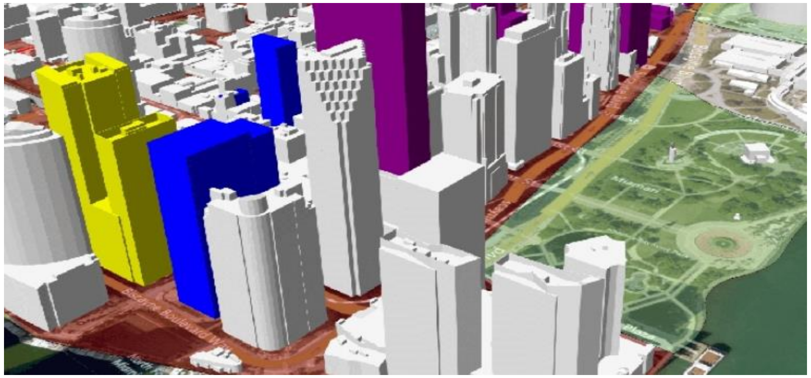

Figure 20: CyberCity 3D buildings visualized in Cesium [Cesium, 2018].

OSM Buildings

- Application for the visualisation of 2D and 3D OSM building geometries on interactive maps
- Classic version: 2.5D + Leaflet
- Modern version: 3D + Mapbox

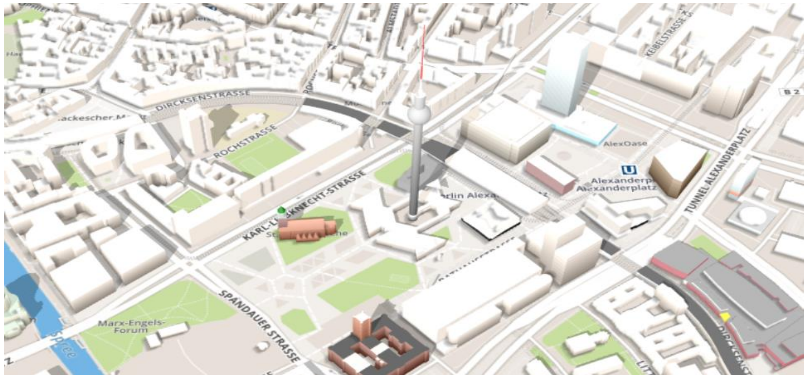

Figure 21: 3D buildings visualized in OSM Buildings [OSM Buildings, 2018].

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3.4. Frameworks Comparison

Table 3: Comparison of the studied WebGL frameworks.

	Three.js	iTowns	Cesium	OSM Buildings
BIM Formats Support	✓	✓	✓	✓
Dynamic Colour Assignment	✓	✓	✓ (grey)	✓ (grey)
Subsurface View	✓	✓	✓ (grey)	✓ (grey)
Object Selection	✓	✓	✓	✓
Georeference Tool	✓ (grey)	✓	✓	✓
Rotate, Zoom, Pan	✓	✓	✓	✓
Layers Control	✓	✓	✓	✓
Lightweight API	✓	✓	✓ (grey)	✓ (grey)
High Loading Speed	✓	✓ (grey)	✓ (grey)	✓ (grey)

4. BIM MODEL PROCESSING

4.1. BIM Dataset

Koninginnebrug

- Built in 1929 as a double bascule bridge
- 3D BIM model created in Autodesk Inventor
- Point cloud dataset available

Figure 22: Location of Koninginnebrug.

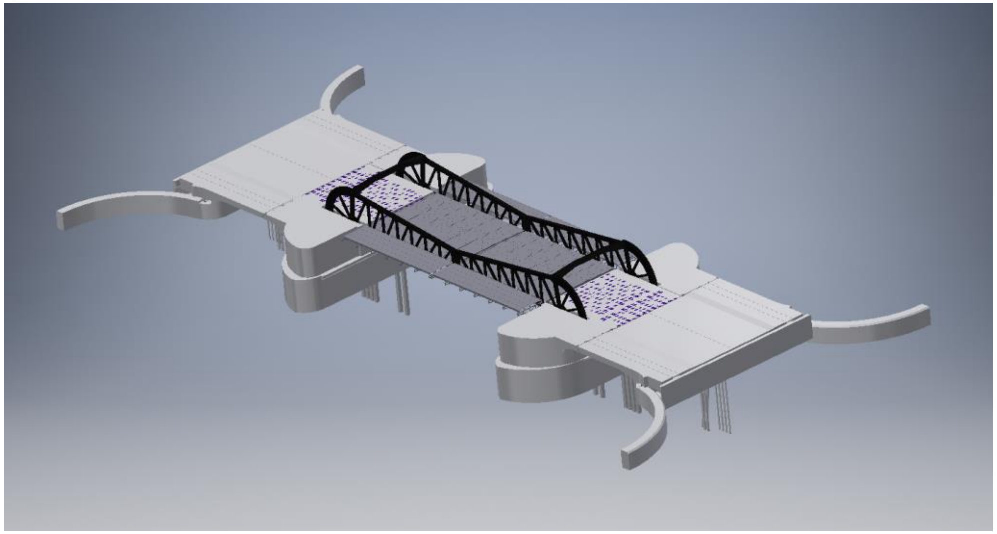


Figure 23: 3D BIM model of Koninginnebrug created in Autodesk Inventor.

4.1. BIM Dataset

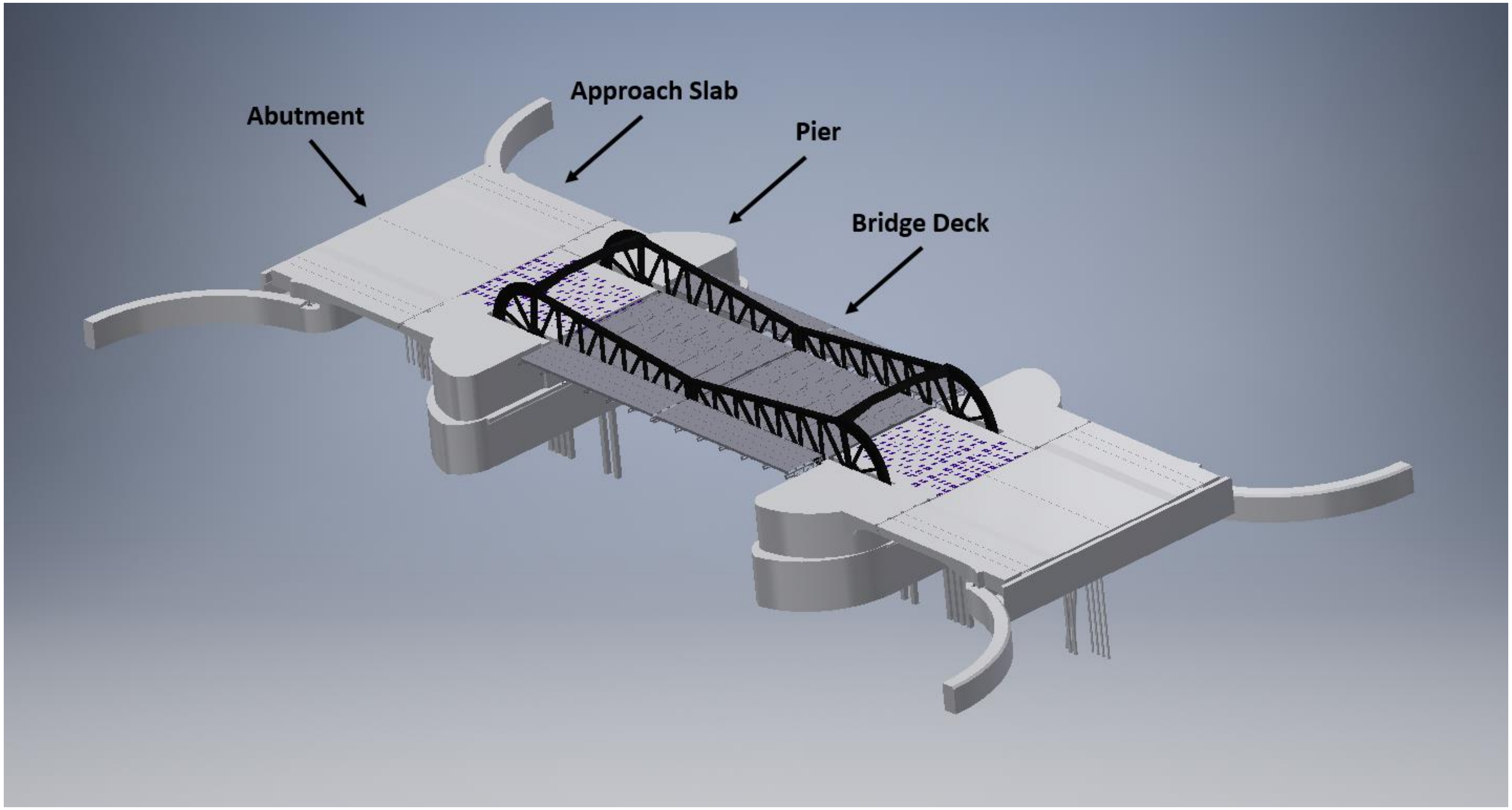


Figure 24: Composition of the 3D model of Koninginnebrug.

4.2. BIM Decomposition

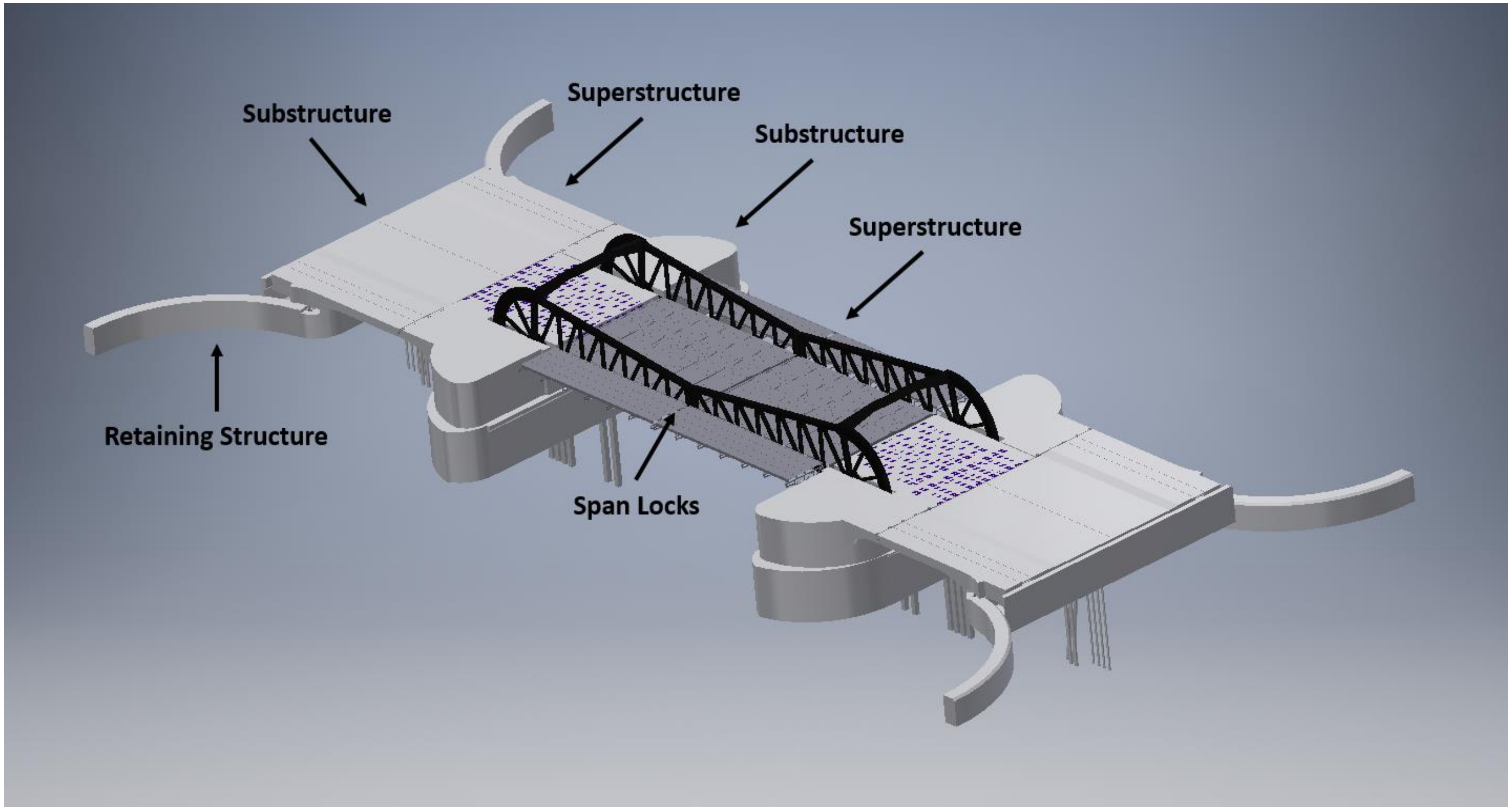


Figure 25: Decomposition of the 3D model of Koninginnebrug.

4.2. BIM Decomposition

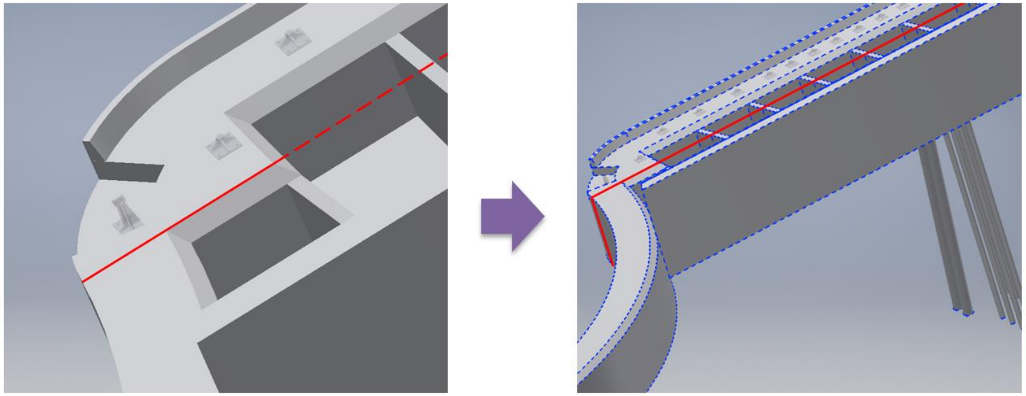


Figure 26: Decomposition of the bridge abutment in Autodesk Inventor.

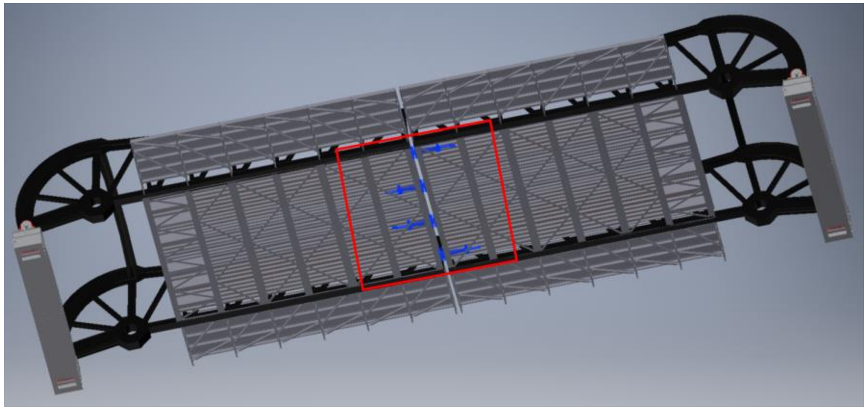


Figure 27: Decomposition of the bridge span locks.

4.2. BIM Decomposition

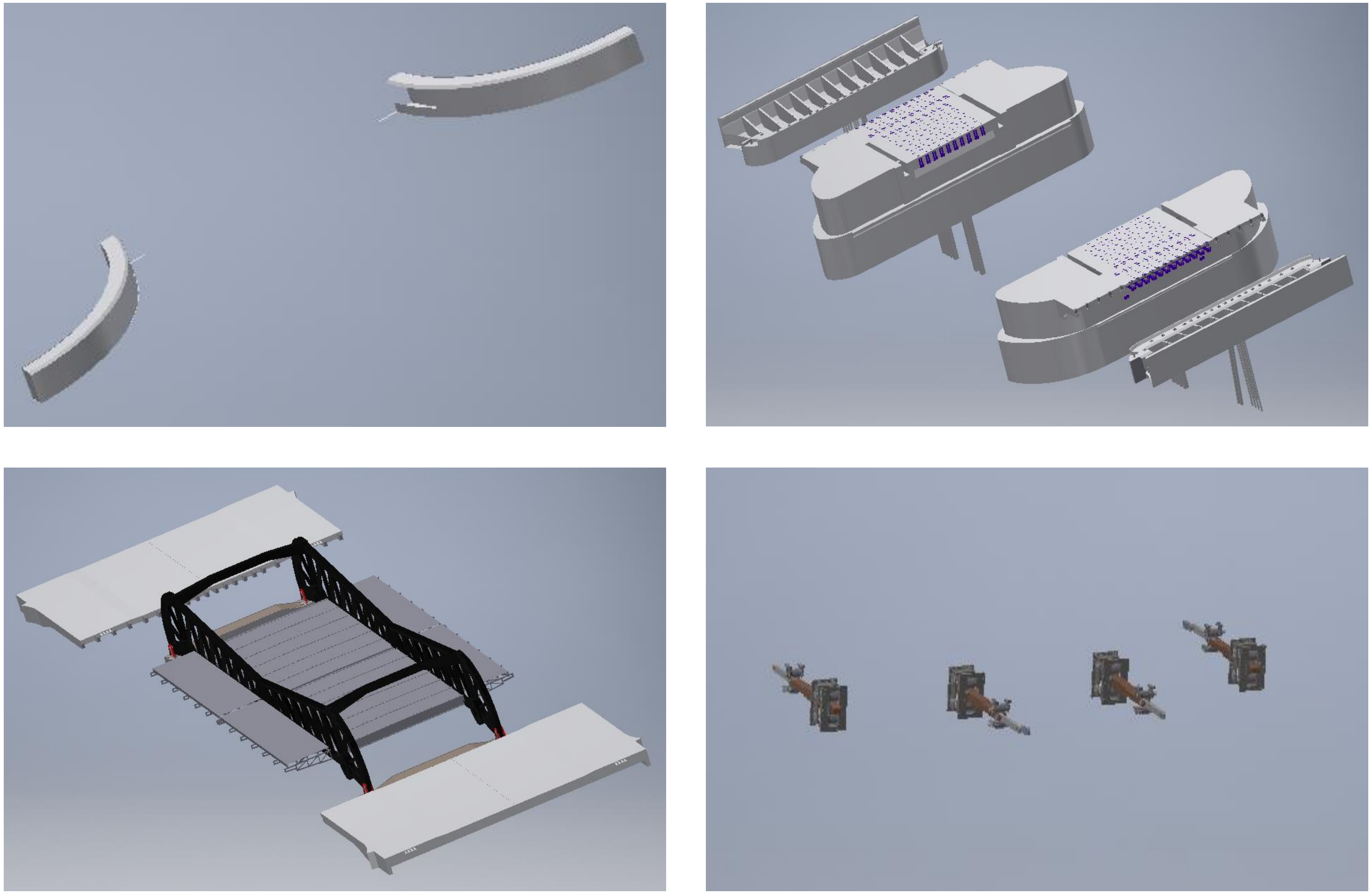
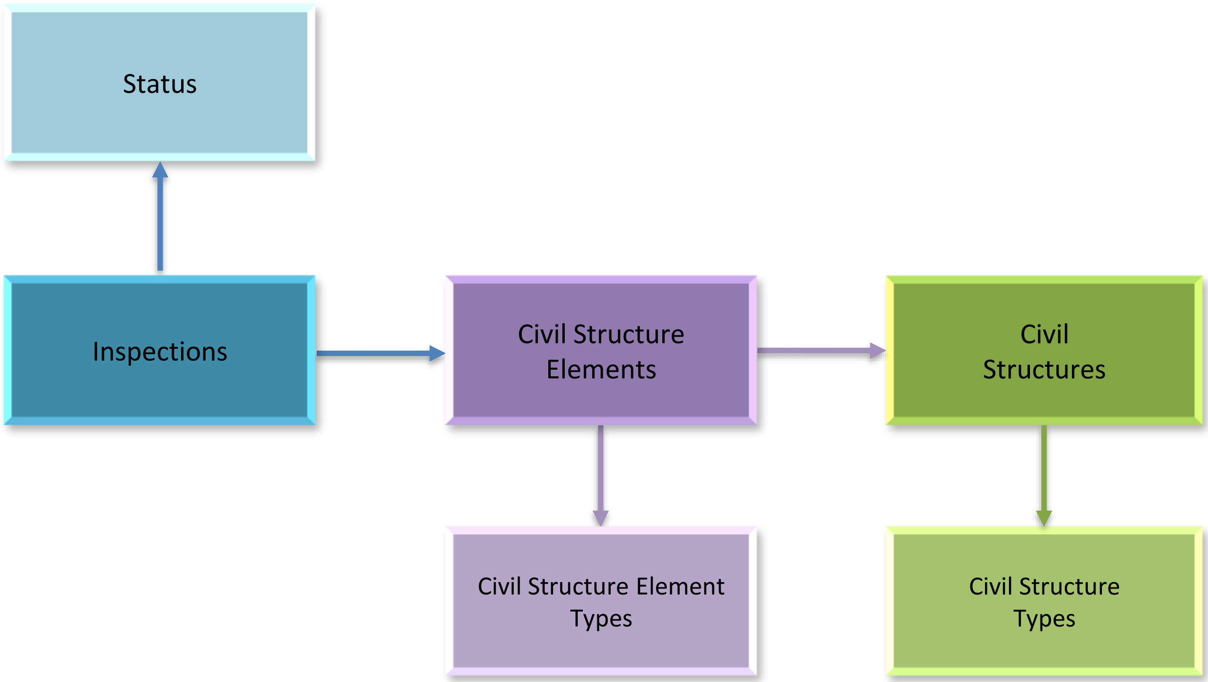


Figure 28: Results from the 3D model decomposition.

5. PROTOTYPE DEVELOPMENT

4.3. Test Environment Preparation

Database Structure



5.1. Test Environment Preparation

Home Page Configuration

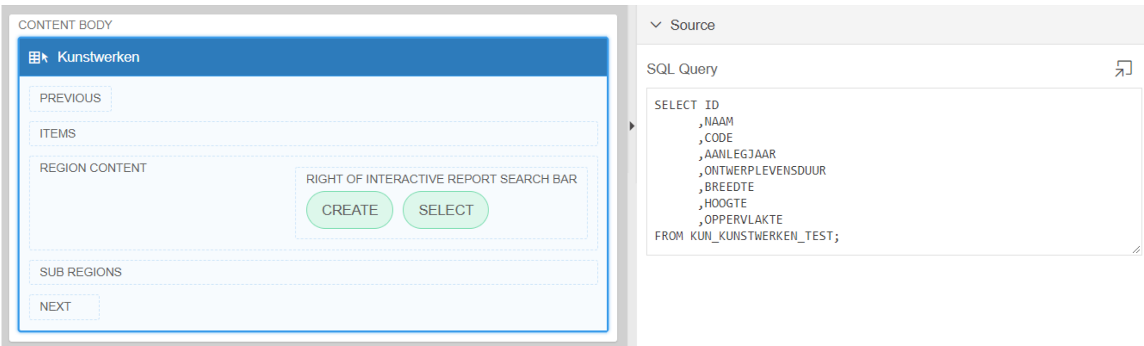


Figure 29: Configuration of the interactive report.

Go | Rows 50 | Actions | Nieuw | Selecties

1 - 7 of 7

Id	Naam	Code	Aanlegjaar	Ontwerplevensduur	Breedte	Hoogte	Oppervlakte
1130	Binnenhavenbrug	A001	1993	70	21.3	2.1	501.34
1132	Erasmusbrug	A040	1996	70	33.8	12.5	29828.33
1137	Piekbrug	A010	1988	70	20.1	2.7	665.38
1139	Nassaubrug	A014	1983	70	10.75	2.5	324.92
1897	Spoorweghavenbrug	A026	1995	70	14.34	2.4	3207.29
1898	Willemsbrug	B001	1981	70	33	65	15833.67
2162	Koninginnebrug (Rijksmonument)	A008	1927	70	49.34	3.7	5060.21

1 - 7 of 7

Figure 30: Interactive report with several bridges in Rotterdam.

5.1. Test Environment Preparation

Associating 2D Objects with 3D Models

ID	Code	Name	Surface
1	A001	Bridge 1	
2	A002	Bridge 2	
3	A003	Bridge 3	
4	A004	Bridge 4	
5	A005	Bridge 5	
6	A006	Bridge 6	

OBJ Files

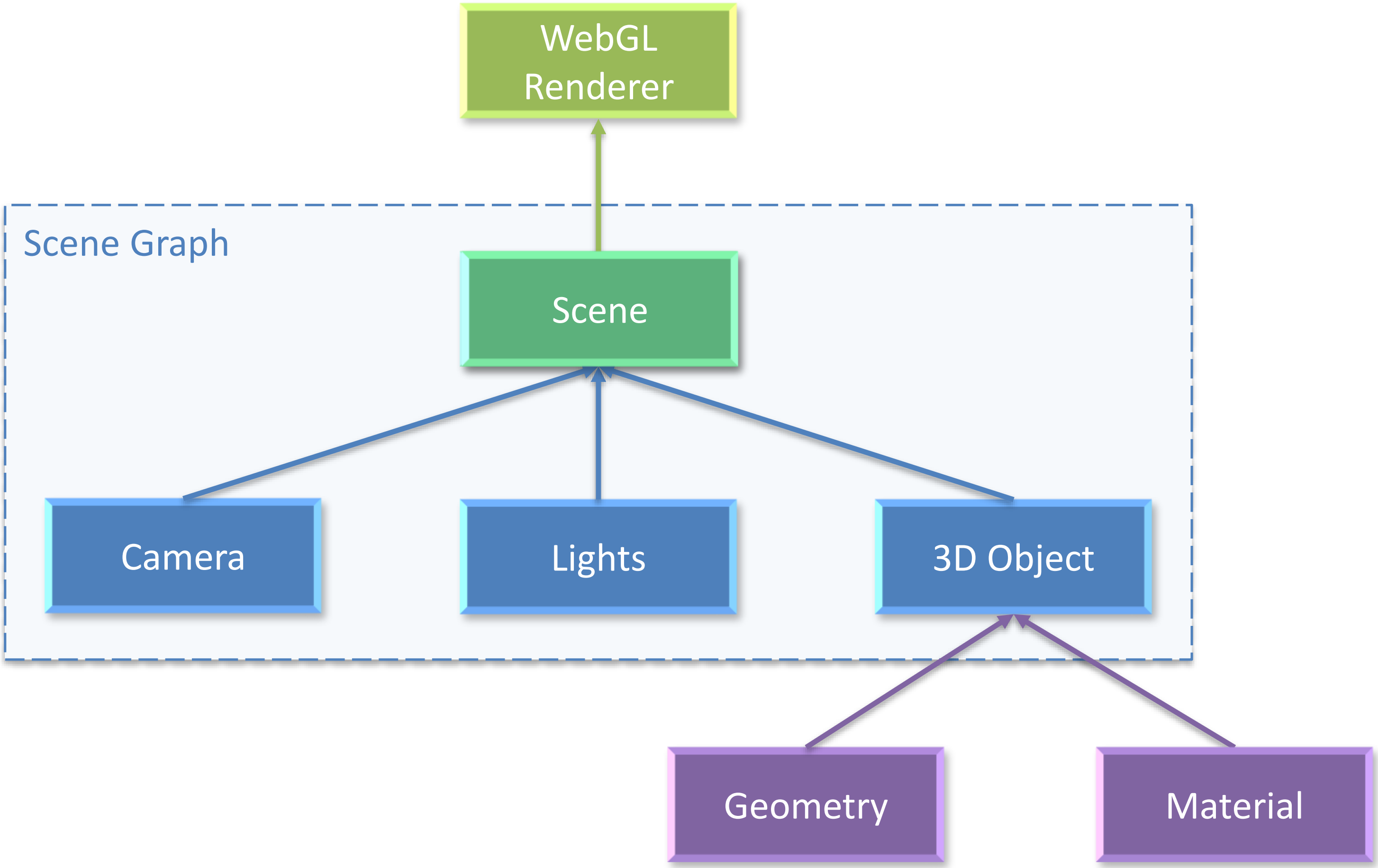
- 4_Object Element.obj
- 4_Object Element.obj
- 4_Object Element.obj
- 4_Object Element.obj

HTTP Status 200: Files exist

HTTP Status 404: Files not found

5.2. 3D Viewer Configuration

WebGL Rendering



5.2. 3D Viewer Configuration

Scene Creation

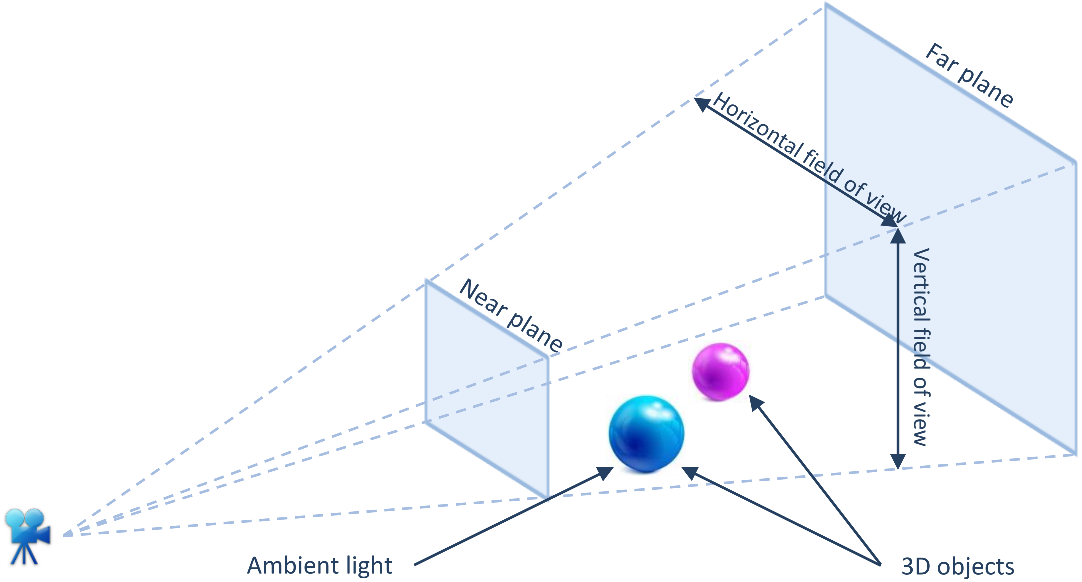
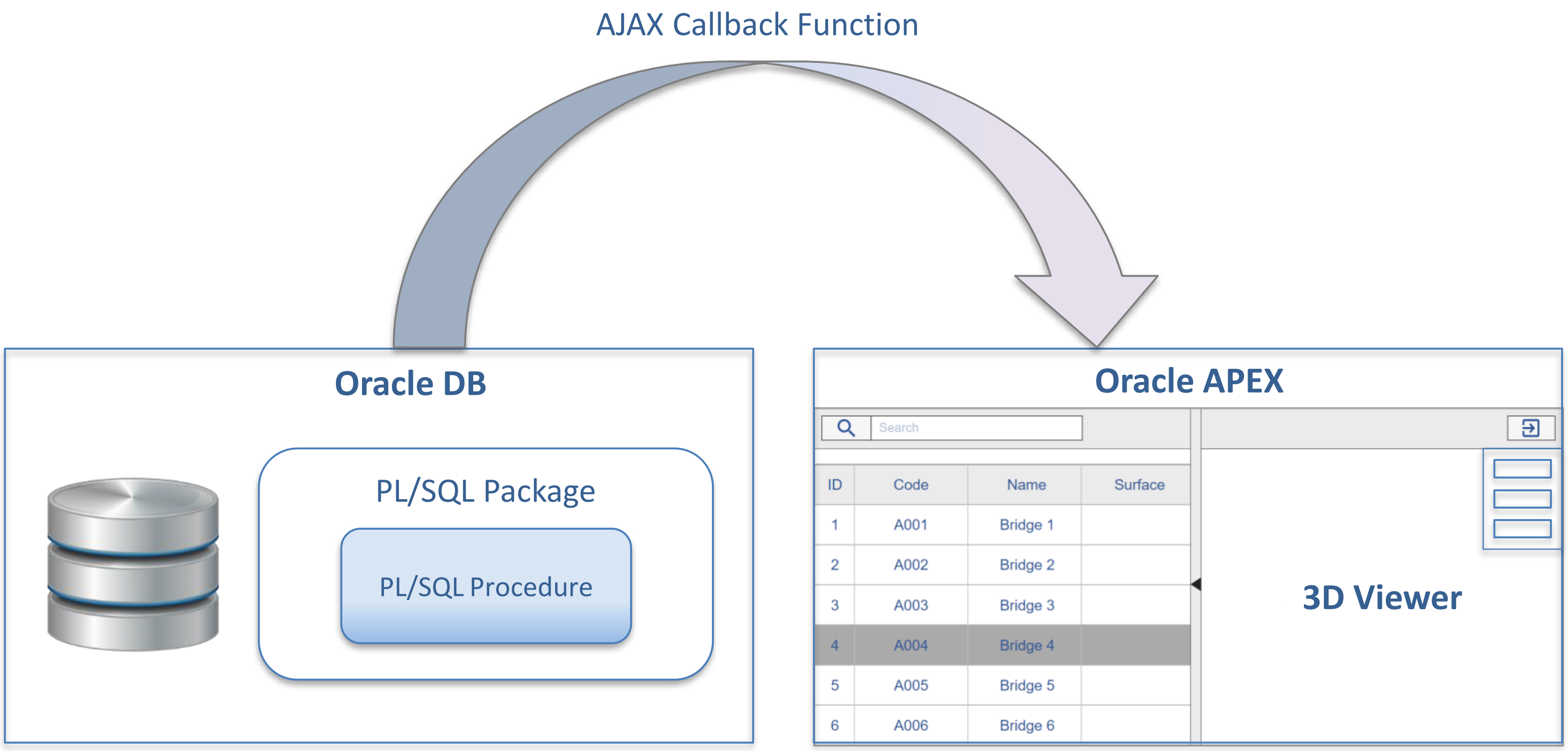


Figure 31: Main rendering parameters, adapted from Dirksen [2013].

5.2. 3D Viewer Configuration

BIM Model Loading



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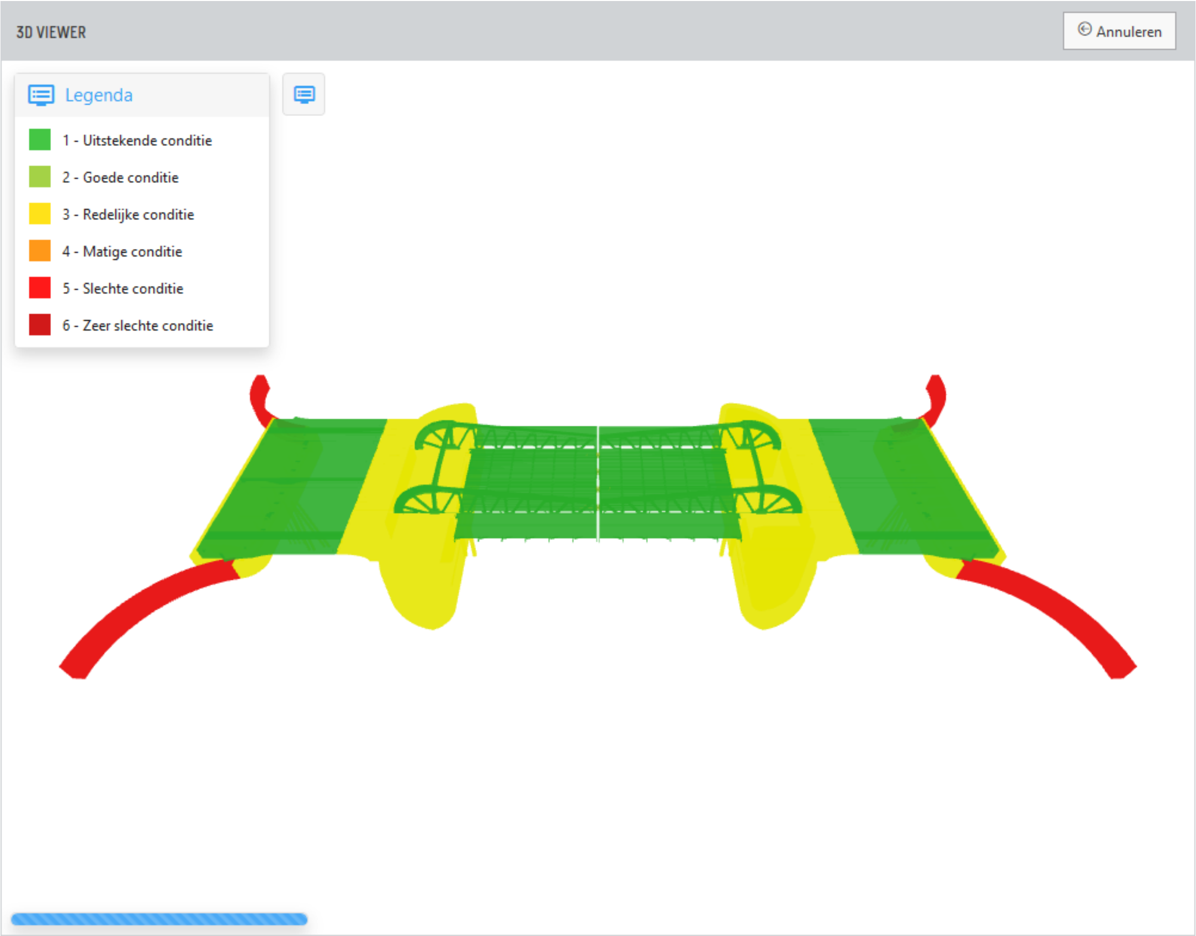
5.2. 3D Viewer Configuration

BIM Model Loading



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5.2. 3D Viewer Configuration

Base Map Configuration

- Ground plane with image of area of interest as texture
- WMS request sent to PDOK to retrieve topographic map

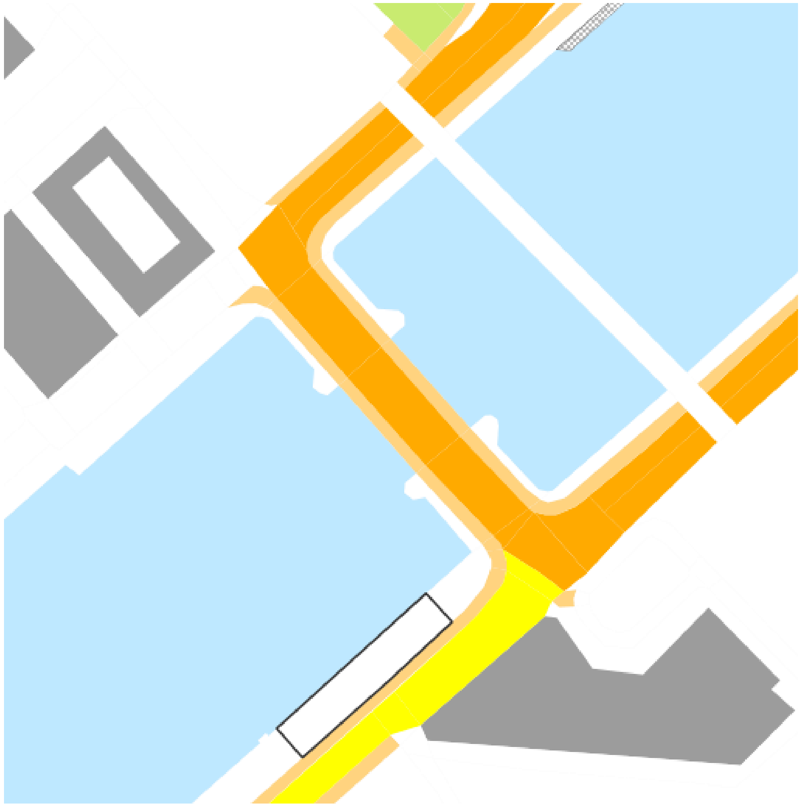
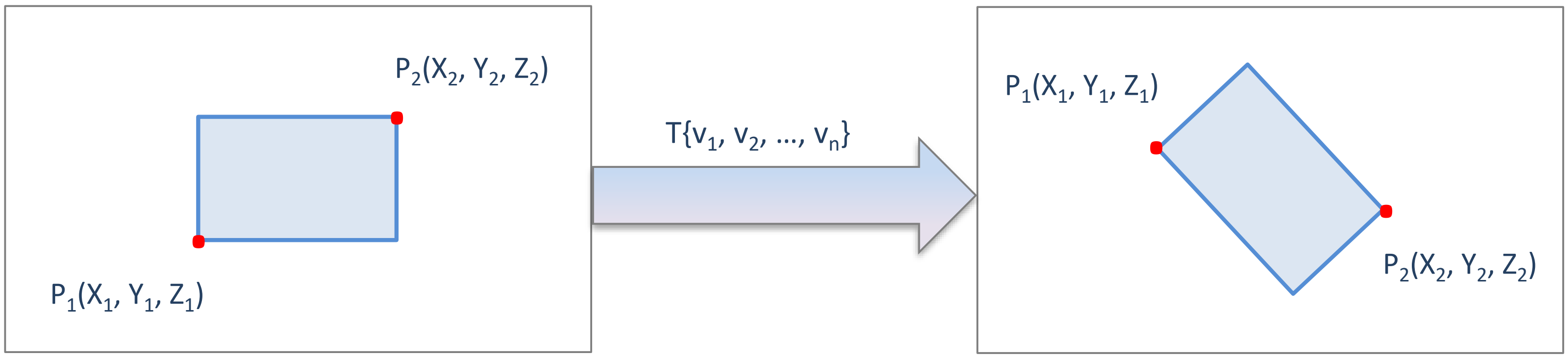
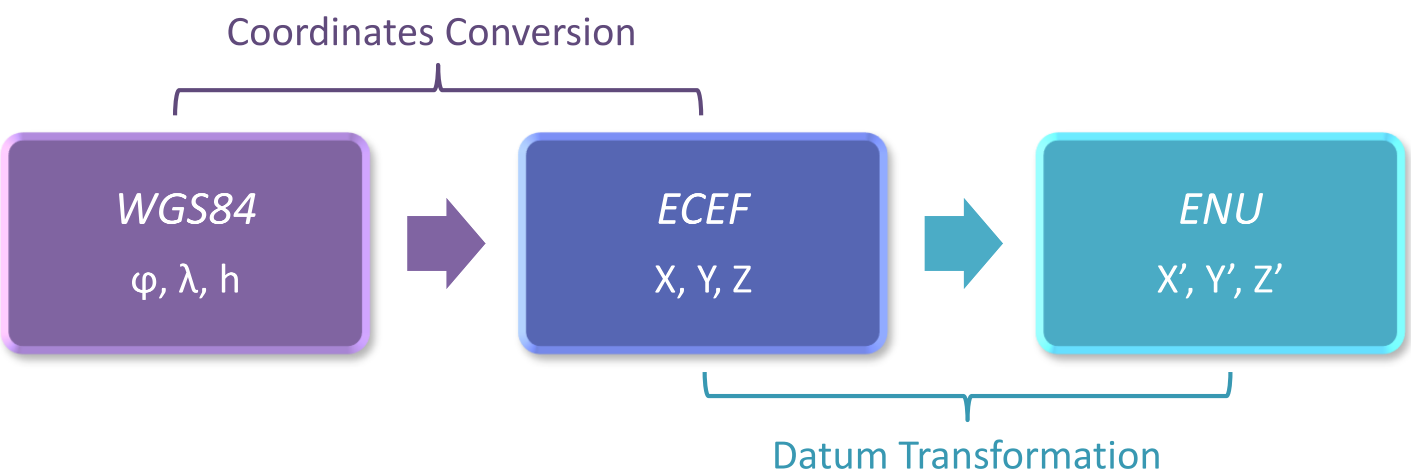


Figure 32: Image of the area of interest, obtained from WMS request.

5.2. 3D Viewer Configuration

BIM Model Georeferencing





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5.2. 3D Viewer Configuration

BIM Model Georeferencing

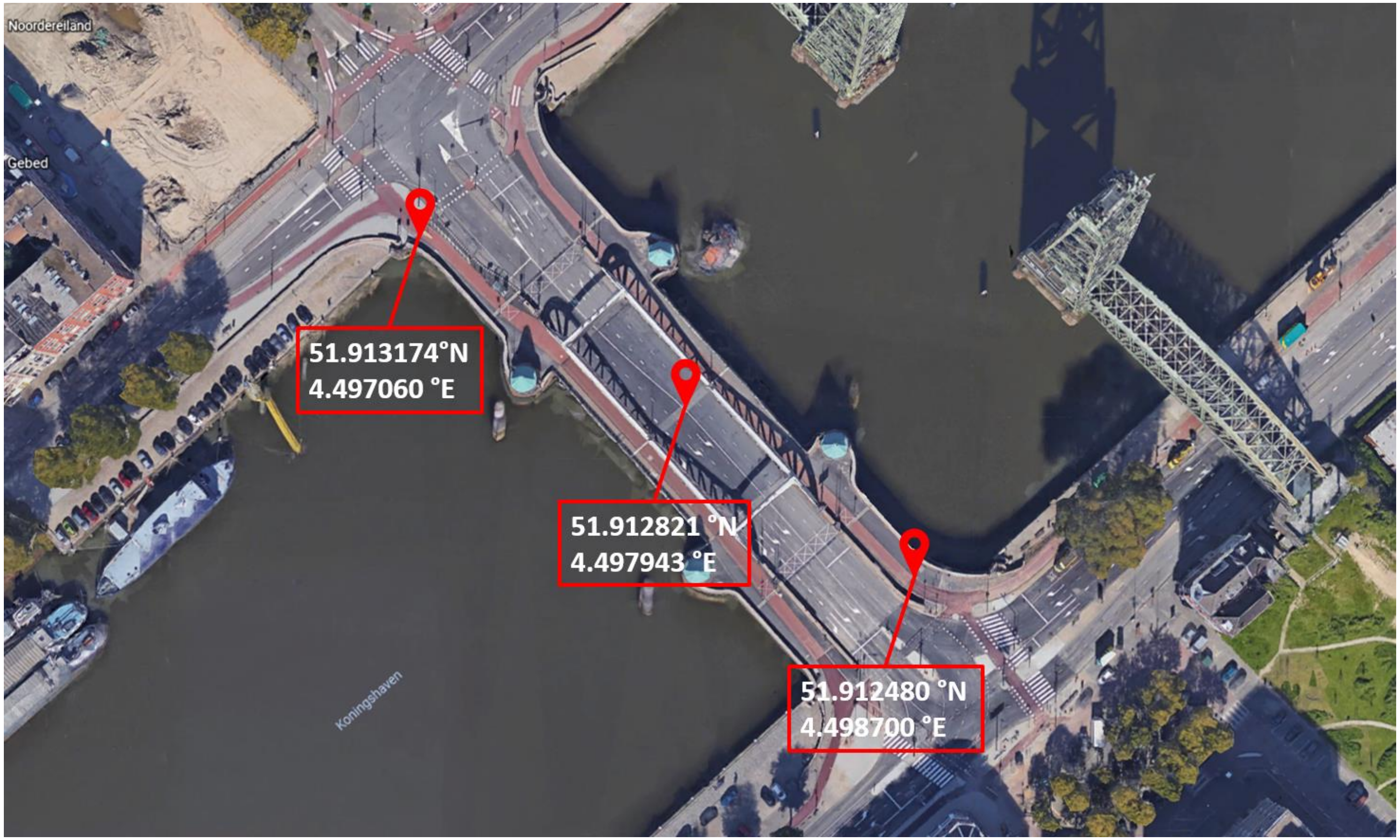

Figure 33: Reference points and their coordinates obtained from Google Earth.

5.2. 3D Viewer Configuration

BIM Model Georeferencing

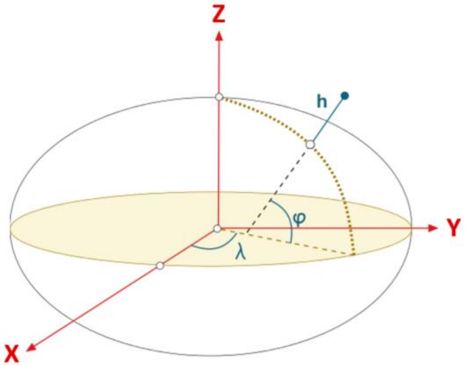

Figure 34: WGS84 and ECEF coordinates, adapted from Sanz Subirana et al. [2011].

$$f = \frac{a-b}{a} \qquad e^2 = 2f - f^2 \qquad \bar{N} = \frac{a}{\sqrt{1 - e^2 sin^2 \varphi}}$$

$$X = (\bar{N} + h)\, cos\varphi\, cos\lambda$$

$$Y = (\bar{N} + h)\, cos\varphi\, sin\lambda$$

$$Z = (\bar{N}(1 - e^2) + h)\, sin\varphi$$

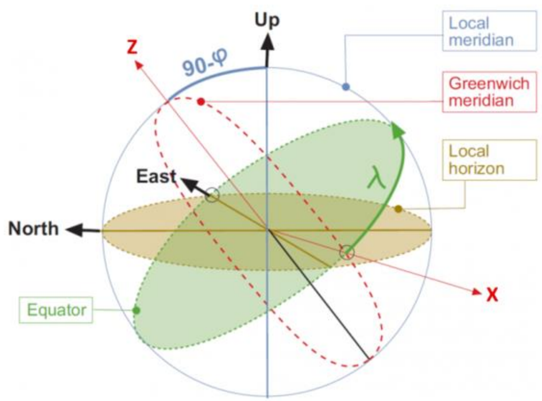

Figure 35: ECEF and ENU coordinates, adopted from Sanz Subirana et al. [2011].

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = (1 + \mu) \cdot R(\Omega_x \Omega_y \Omega_z) \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \cdot \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix}$$

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} -sin\lambda_0 & cos\lambda_0 & 0 \\ -sin\varphi_0 cos\lambda_0 & -sin\varphi_0 sin\lambda_0 & cos\varphi_0 \\ cos\varphi_0 cos\lambda_0 & cos\varphi_0 sin\lambda_0 & sin\varphi_0 \end{bmatrix} \cdot \begin{bmatrix} X_P - X_0 \\ Y_P - Y_0 \\ Z_P - Z_0 \end{bmatrix}$$

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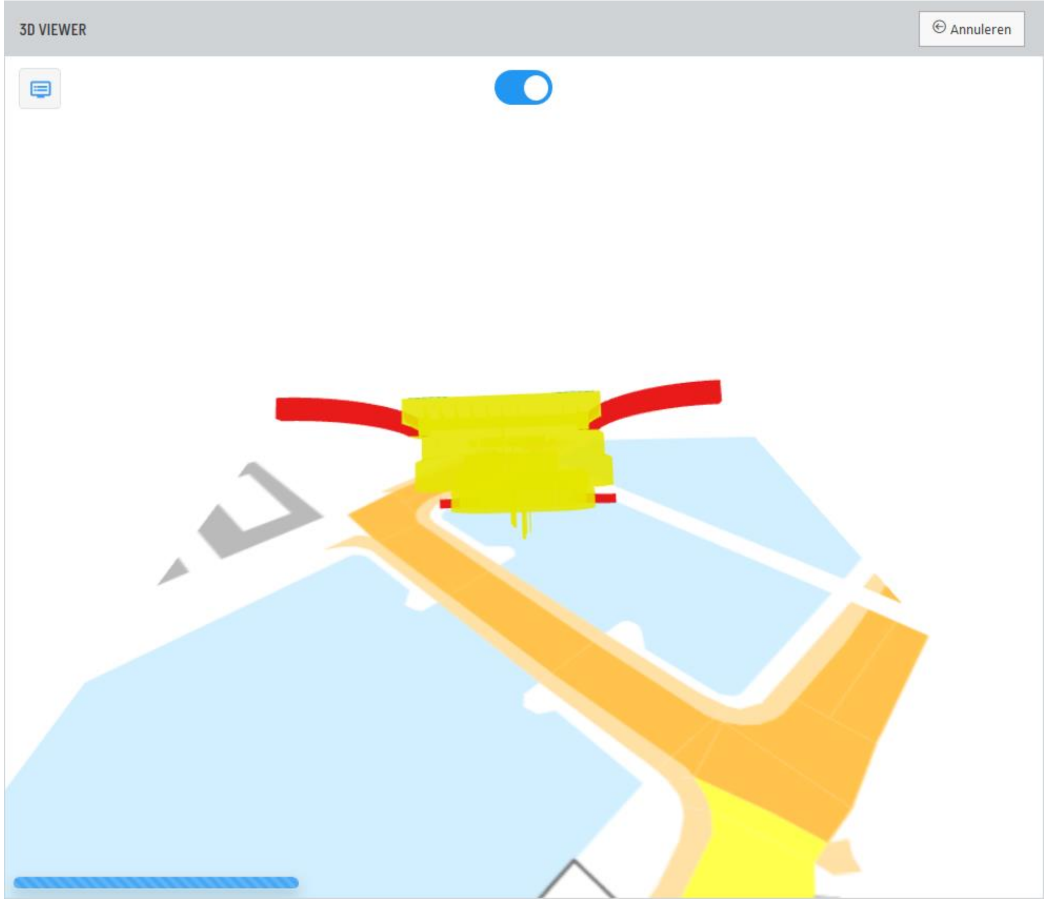
5.2. 3D Viewer Configuration

BIM Model Georeferencing



5.2. 3D Viewer Configuration

BIM Model Georeferencing

- Transformation matrix generated by CloudCompare
- Translation of BIM model to fit the WMS image
- Rotation of BIM model by approximating the location

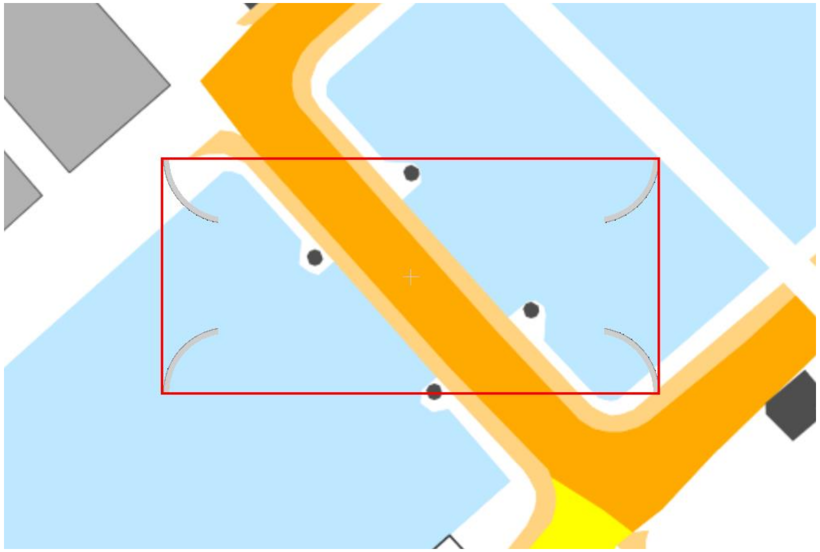


Figure 36: Translation of the BIM model in CloudCompare.

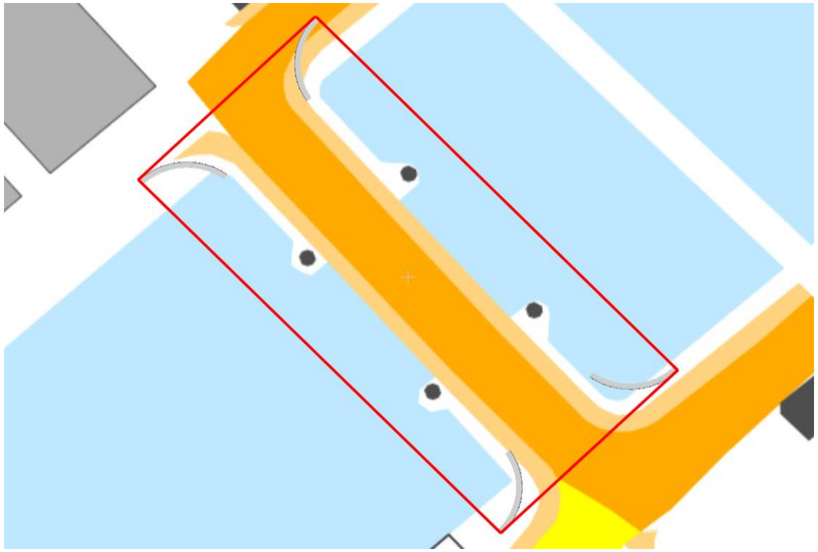
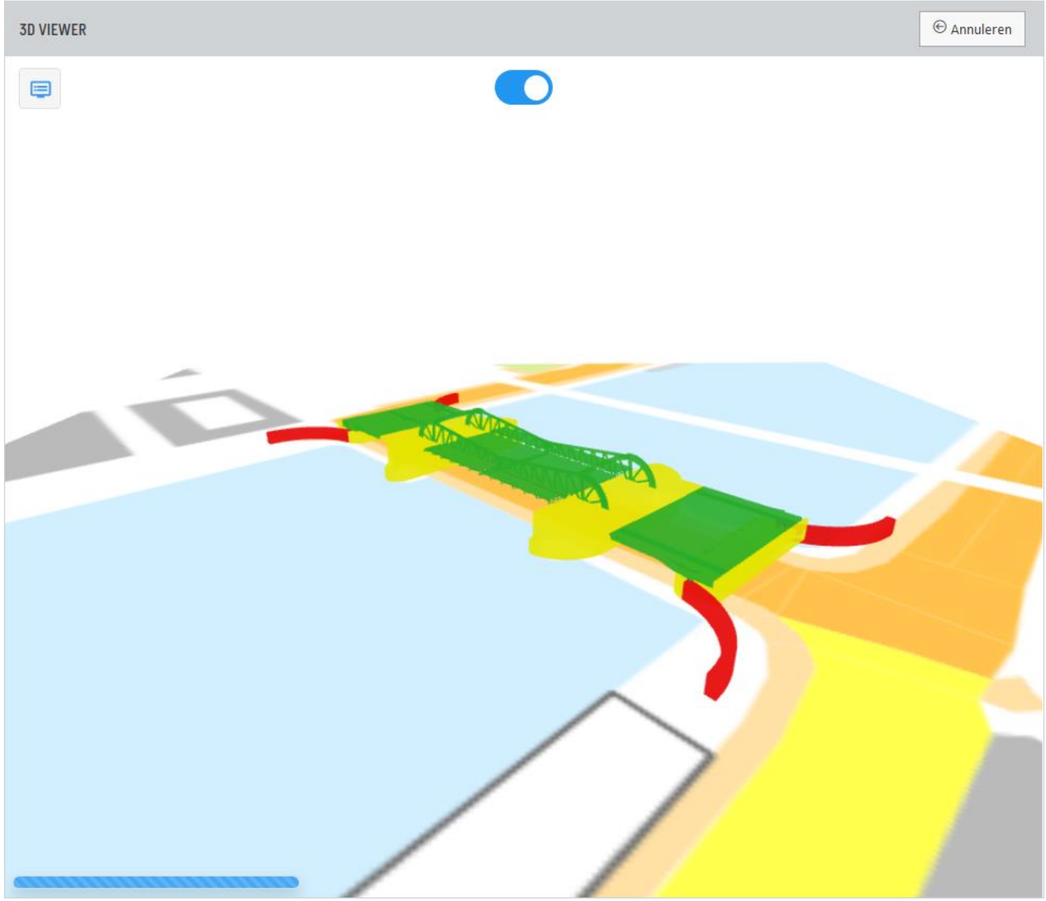


Figure 37: Rotation of the BIM model in CloudCompare.

5.2. 3D Viewer Configuration

BIM Model Georeferencing



5.2. 3D Viewer Configuration

Object Selection

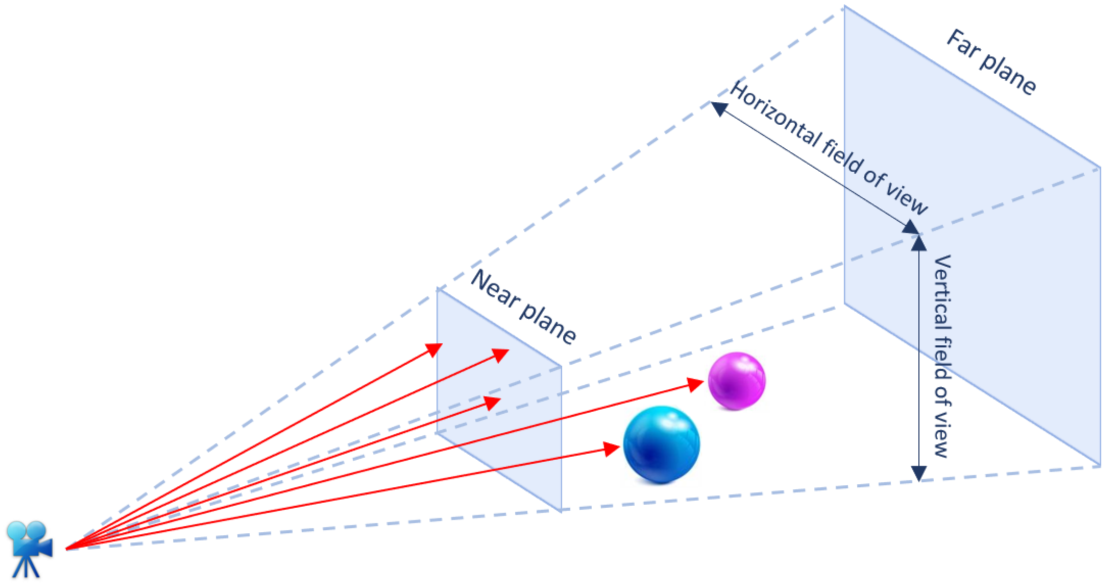


Figure 38: Ray casting model, adapted from Dirksen [2013].

5.2. 3D Viewer Configuration

Object Selection

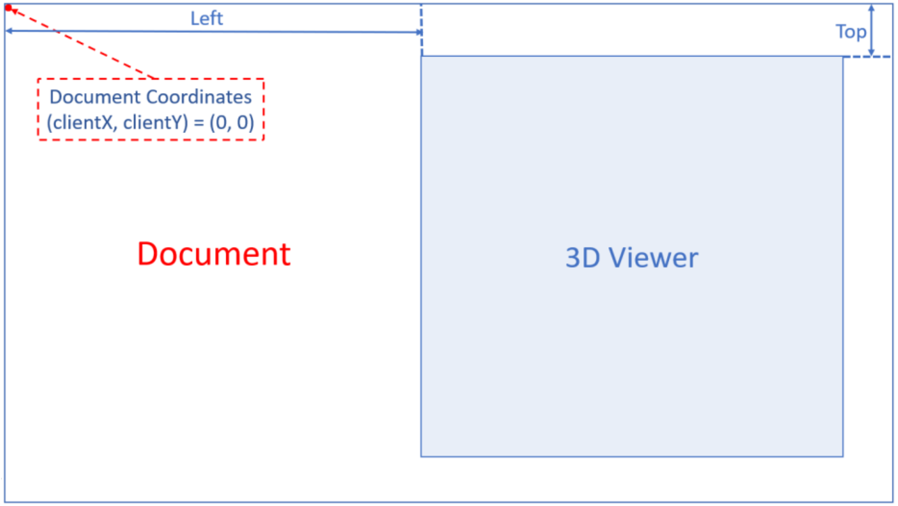
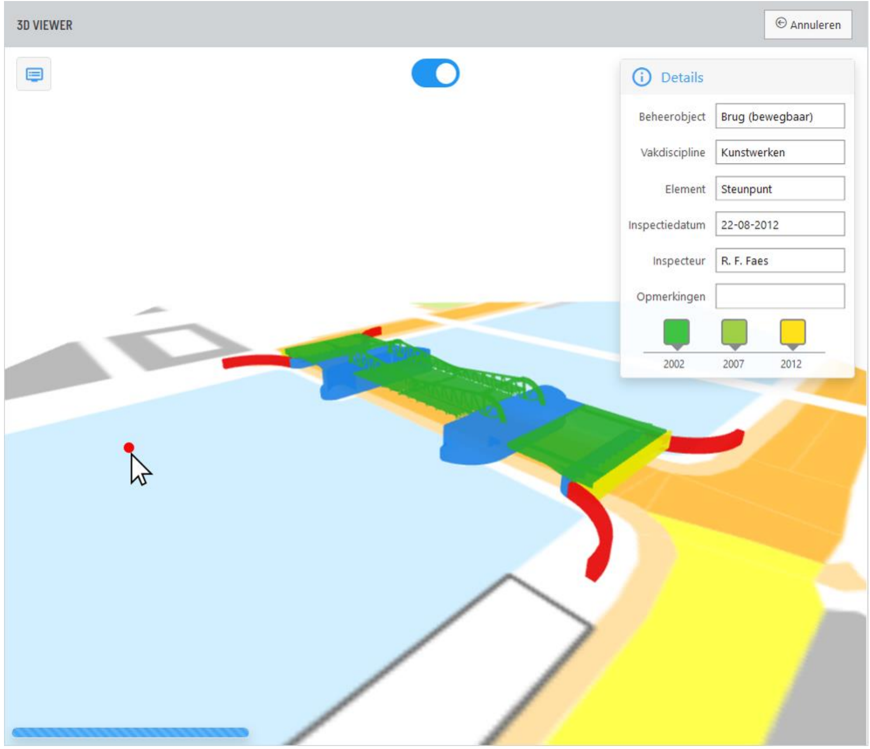
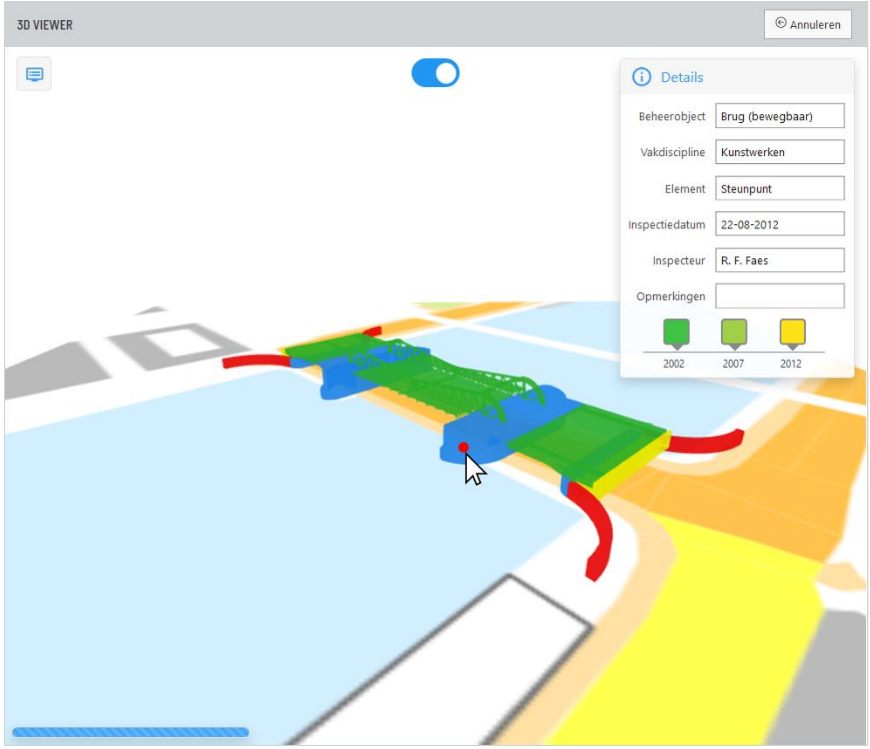


Figure 39: Specification of the mouse position according to the document and window coordinates.

5.2. 3D Viewer Configuration

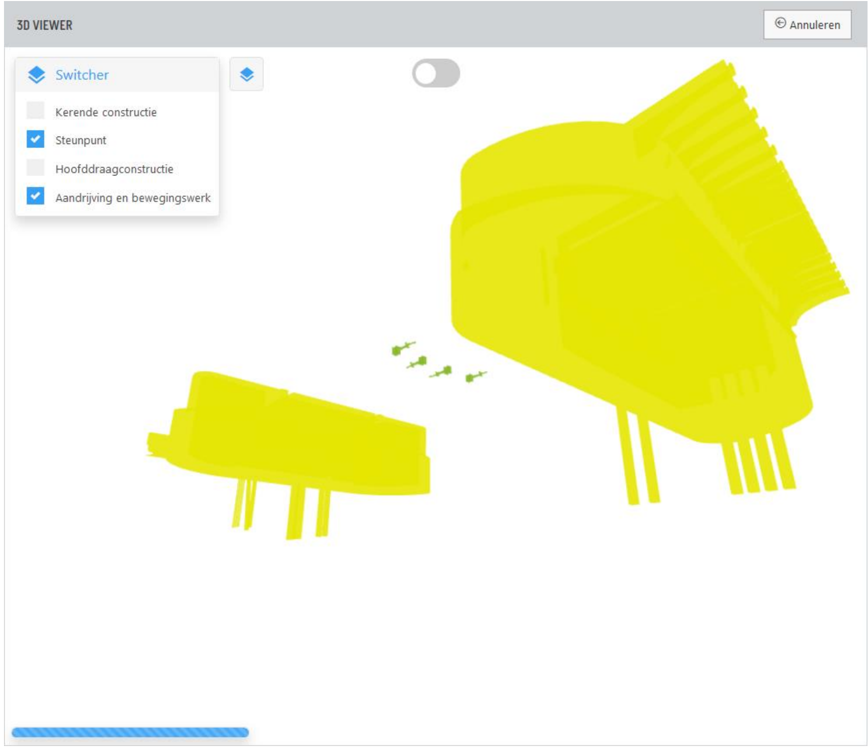
Object Selection

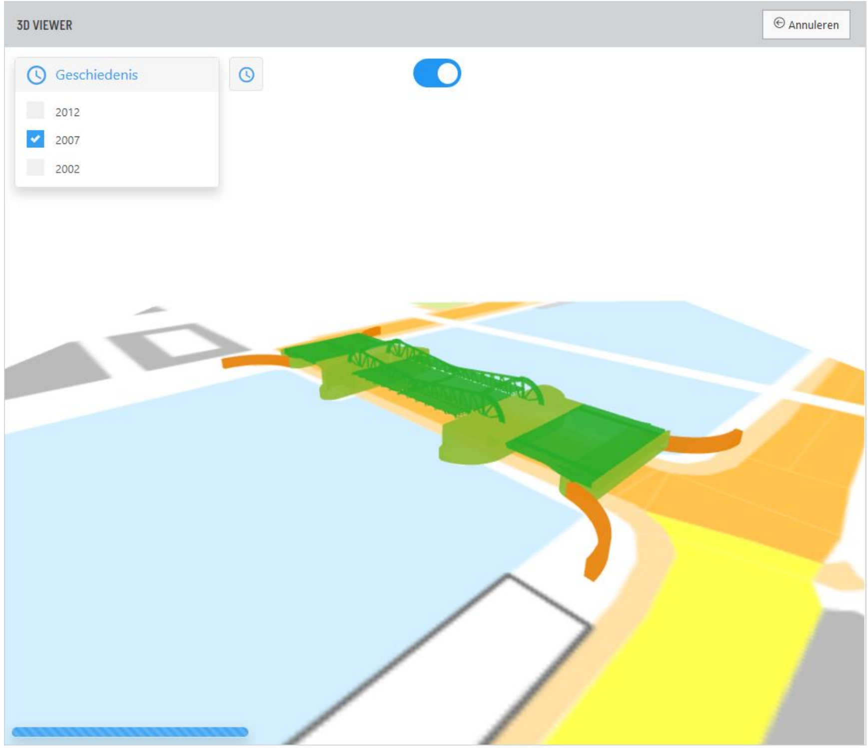




5.2. 3D Viewer Configuration

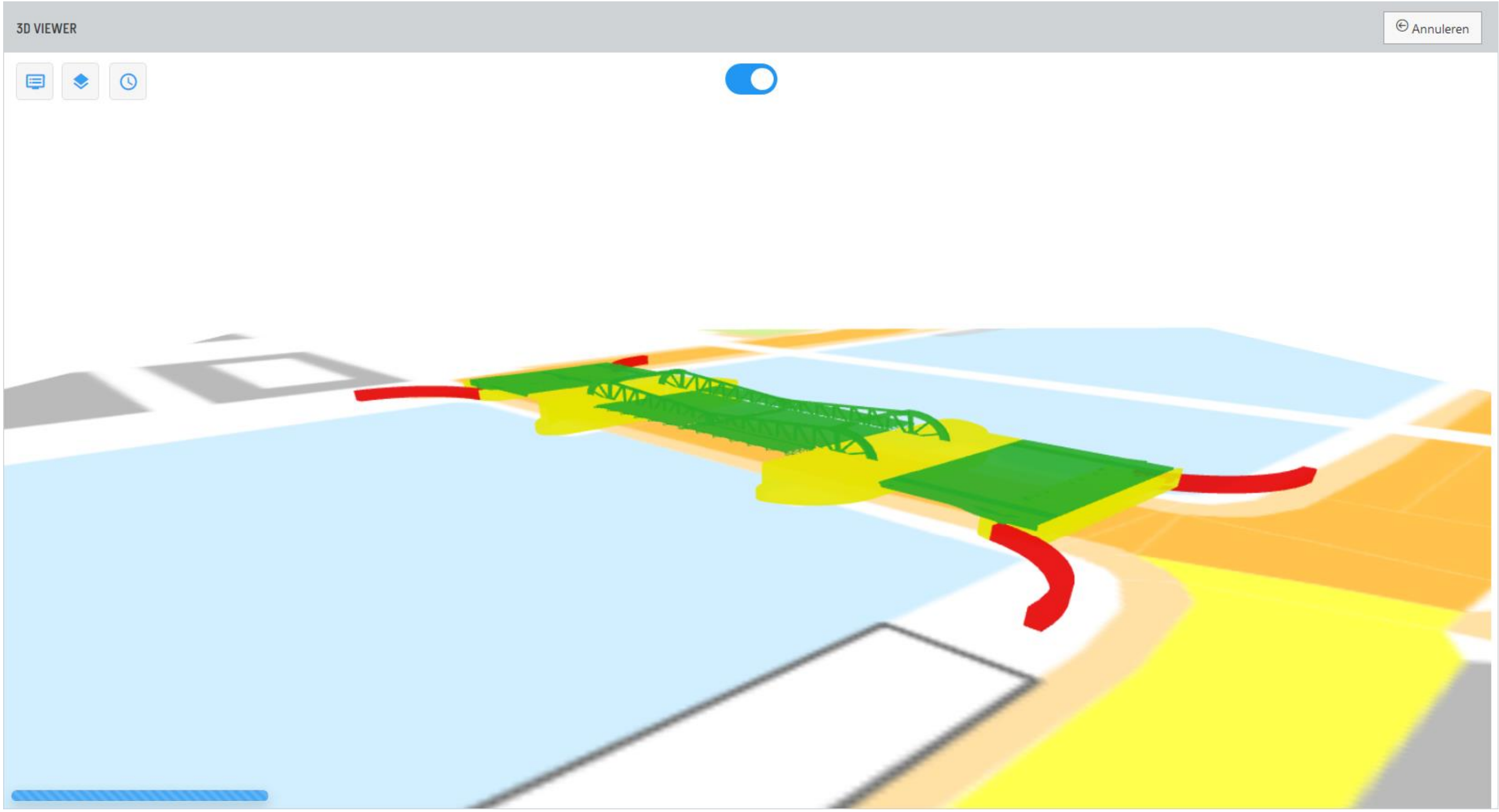
Additional Functionalities





5.2. 3D Viewer Configuration

BIM Model Rescaling



6. PROTOTYPE EVALUATION

6. Prototype Evaluation

Usability Testing

- Research tool that enables the users to assess a product or a prototype
- Qualitative testing based on findings by UX experts to assess the UI and ease of use of a system
- Quantitative testing of the users performance on a given task

Survey Research

- Quantitative method to gather information on the opinions of a large number of people
- Provides accurate, reliable, and valid data for descriptive and explanatory statistics

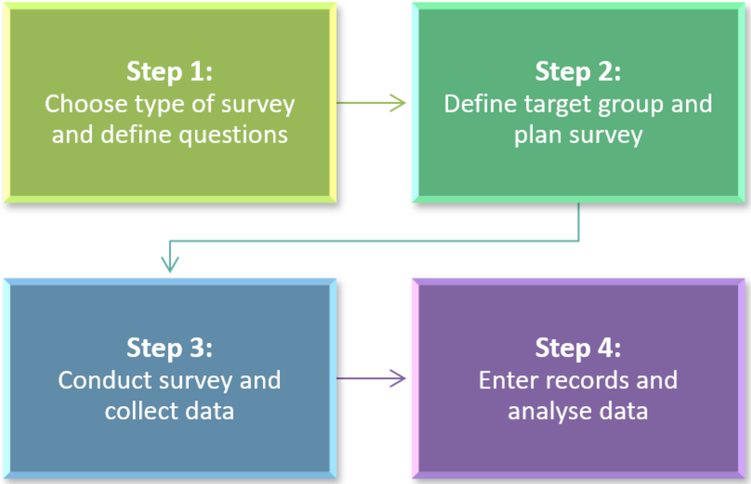


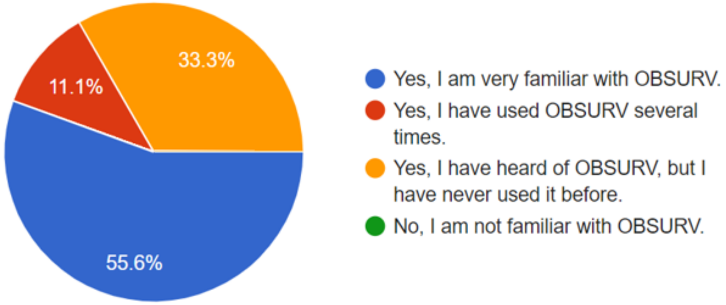
Figure 36: Steps in the survey research process, adapted from Neuman [2014].

6.2. Survey Research

Survey Results

Occupation Fields	Responses
Asset Management Civil Structures	2
Waterway Construction	1
Infrastructure Design	1
Civil Engineering	1
3D / VR Development	1
Business Development	1
Consultancy	1
Product Management	1

Familiarity with OBSURV



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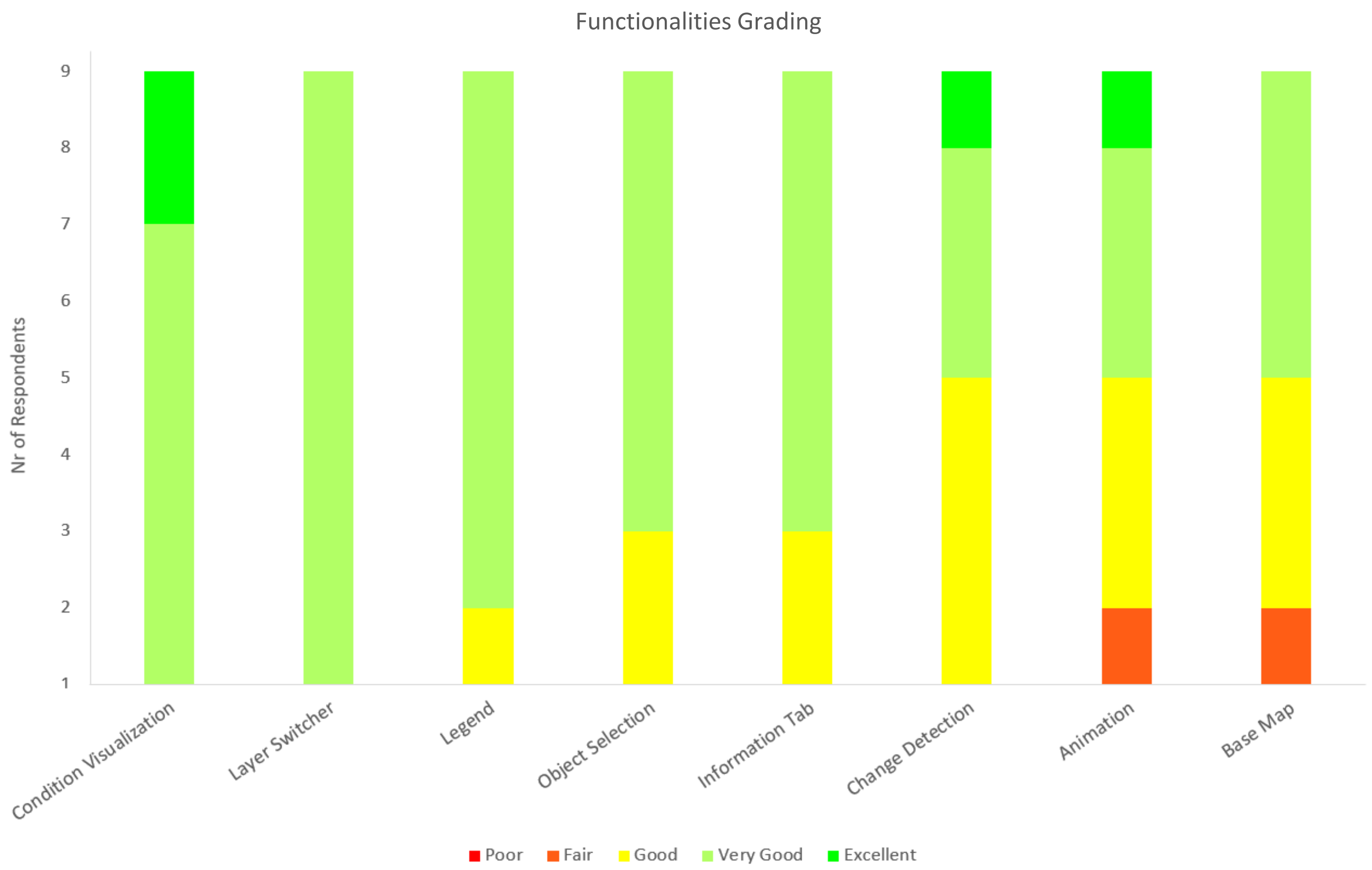
6. Prototype Evaluation

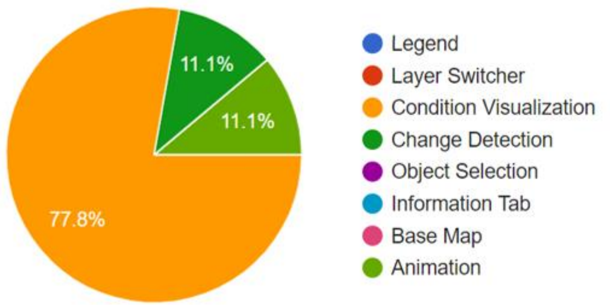
Survey Results



6. Prototype Evaluation

Survey Results

Most useful functionality



Main usability issues:

- Lack of BIM models of infrastructure assets in public institutions
- Rendering of multiple 3D objects in OBSURV due to the large size of BIM models
- Visualizing object elements instead of object components
- Not enough information about the objects and their inspections available

Further Improvements

- Replacing the condition score with risk analysis
- Adding more electromechanical components of the civil structure
- Combining with design information for linking different LCAM phases
- Switching between maintenance status and normal view
- Using larger infrastructure models of roads and railways for construction and engineering
- Graphical improvements

7. FUTURE WORK

7. Future Work

- Adding or updating records of the NEN 2767-4 inspections in the information tab in the 3D viewer
- Implementing the explode function for better visibility of the asset elements
- Finding other public infrastructure assets suitable for 3D visualization
- Decreasing the LOD and reducing the file size of BIM models in case of integrating multiple models
- Connecting the 3D viewer and the design platform for the creation of the BIM model
- Including risk analysis for more detailed information about the asset condition
- Displaying design information about the asset elements
- Further investigation on the BIM georeferencing techniques
- Adding AR for better visualization and user interaction with the BIM model

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Thank you for your attention!