Saimaa University of Applied Sciences
Technology, Lappeenranta
Degree Programme in Civil and Construction Engineering

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RE-ENGINEERING BIM IN BRIDGE DESIGN

Bachelor’s Thesis 2019

ABSTRACT
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The objective of the study was to examine problems encountered when using BIM during the project cycle, if it became necessary to change the software, and to test and describe re-engineering process variants. The practical part is carried out through the example of bridge models in Autodesk Revit and Tekla Structures. In addition, another goal was to review cloud-based platforms for using BIM: Trimble Connect and Dalux.

This study was commissioned by Pöyry Finland Oy.

Although IFC is considered as the main format for interoperability between different software applications, it is still unstable in many cases. This work showed that for such often geometrically complex structures as bridges and, therefore, modeled in most cases with non-standard tools, acceptable transfer of information from one software to another through the considered format is impossible. In this regard, an alternative solution was the use of 3D dwg format.

Nowadays there is a rapid development of BIM tools. The construction industry is becoming more advanced in sense of information technologies: any application can be customized through using API, augmented and mixed reality is no longer an unreal future, nowadays it finds application on a construction site.

Keywords: Re-engineering, BIM, IFC, 3D dwg, Tekla Structures, Autodesk Revit, Trimble Connect, Dalux.

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LIST OF DEFINITIONS

API (Application Programming Interface), in computer programming, is a description of methods (a set of classes, procedures, functions, structures, or constants) by which one computer program can interact with another program (1).

AR (Augmented reality) is an interactive experience of a real-world environment where the objects that reside in the real-world are "augmented" by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory (2).

ARCore is a software development kit developed by Google that allows for augmented reality applications to be built (3).

ARKit (Apple ARKit) is Apple’s augmented reality (AR) development platform for iOS mobile devices (4).

BIM (Building Information Modelling or Building Information Model) is an intelligent 3D model **or** intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure (5).

DWG (from **drawing**) is both a technology environment and .dwg files, the native file format for Autodesk’s AutoCAD® software (6).

ERP (Enterprise resource planning) is the integrated management of core business processes, often in real-time and mediated by software and technology (7).

IFC (Industry Foundation Classes) are the open and neutral data format for openBIM (8).

Macro, in computer science, is a rule or pattern that specifies how a certain input sequence (often a sequence of characters) should be mapped to a replacement output sequence (also often a sequence of characters) according to a defined procedure (9).

MR (Mixed reality) is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time (10).

.NET Framework is an integral Windows component that supports building, deploying, and running the next generation of applications and Web services. It provides a highly productive, standards-based, multilanguage environment for integrating existing investments with next generation applications and services, as well as the agility to solve the challenges of deployment and operation of Internet-scale applications (11).

1 INTRODUCTION

The adoption of BIM processes is gaining ground not just because of popularity, it becomes imperative and often mandatory at all stages of the building's lifecycle: from design to construction and during operation and maintenance.

In some cases, re-engineering BIM is required. Re-engineering is creating a new object with similar functionality as an existing one. Besides functionality, re-engineered BIM should possess all the features and attributes attached to the original one. Re-engineered BIM can actually contain additional information in attributes and therefore be more functional than the original one.

The need for re-engineering is generated from two major reasons. The first one occurs when the restored native format is no longer compatible with a newer version of a software or a significant part of features and attributes is lost during input process. Even a more recognized reason, which is pretty commonplace for the cycle of infrastructure design, is the change of designer and software used for the design work over the course of the project, for example, when a project phase changes.

The purpose of this thesis is to identify challenges arising in the process of using BIM-model in one software, provided that it was created in another. The softwares on which it was implemented are Autodesk Revit and Tekla Structures. The described process has been performed on models of parts of bridges using various output forms and import options, such as IFC, 3D dwg and use of extensions designed for the chosen programs.

An additional goal was to compare two cloud-based platforms for using BIM: Trimble Connect and Dalux, allowing to facilitate the process of data sharing and improve collaboration of multiple participants in a construction project.

2 BUILDING INFORMATION MODELLING SOFTWARES

This chapter provides an overview of two BIM softwares used to accomplish one of the objectives of this study.

2.1 Tekla Structures

Tekla Structures (or Tekla) is a software product belonging to the class of BIM solutions, demonstrating maximum efficiency while accelerating production and improving the quality of documentation on the structures. Tekla Structures works with all materials and with the most complex structures (12).

2.1.1 Interface

Figure 2.1 shows the Tekla Structures interface.

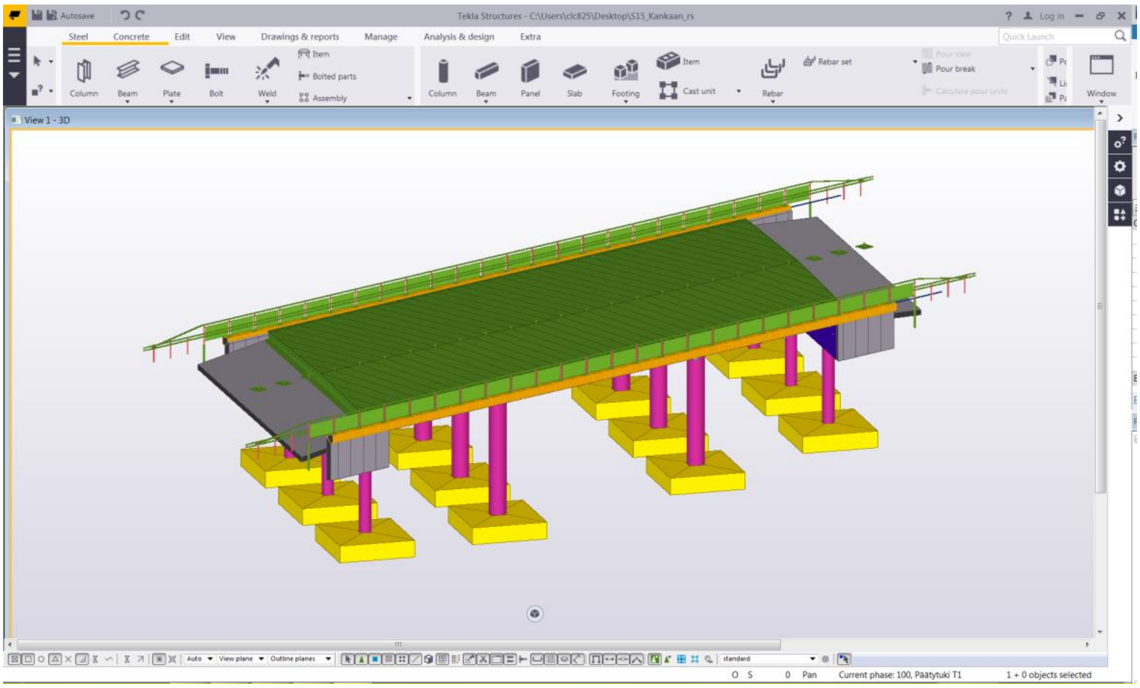

Figure 2.1 Tekla Structures interface

Below there is a description of the functions of the main tabs (13):

- “Steel” and “Concrete” tabs are designed for modelling different relevant structures like columns, beams, plates/slabs, etc. and different fasteners;
- “Edit” contains commands for editing objects and construction geometry;
- “View” tab includes commands for views, clip planes, work planes, rendering and navigation;
- “Drawings & reports” tab is for creating drawing lists, properties and for making reports;
- “Manage” has commands for categorizing and managing model information, object properties, clash check and other tools;
- “Analysis & design” tab represents calculation related commands (loads, their properties etc.).

It is also possible to add your own tabs for commonly used commands.

2.1.2 Supported file formats

File formats and industry standards supported by Tekla are indicated in the table that is shown in Appendix 1 and if they can be exported, imported or both.

2.1.3 Open API

Tekla Structures provides an opportunity to its users to enhance and extend Tekla features to adapt the needs: through creation of macros, custom components and properties, external applications and plugins (Table 2.1). Most of the features are available through the Tekla Open API which is developed on the Microsoft .NET Framework (14).

Table 2.1 Tekla Structures features enhancing options (15)

	1. Macro	2. Custom Component	3. Custom property	4. External application	5. Plug-in
Description	Tekla Structures feature to record and run scripts that call commands in the Tekla Structures user interface.	Tekla Structures feature to build components that automatically adjusts to changes in the model.	Programmed plug-ins that enables external calculation of template values fields.	Programmed external applications that communicate and interact with Tekla Structures.	Fast and intelligent piece of software that runs inside Tekla Structures process.
Use cases	Macros can be used save time on routines. Macros replace multiple user interface commands in menus, dialog boxes, or shortcuts.	Custom components are used to define your own connections, parts, seams and details.	Custom properties are used to calculate template values in reports and drawings.	External applications are used for multiple purposes, like extracting data from model, creating drawings, checking or modifying objects, etc.	Plug-ins are used to create connections between parts, details, custom parts, or any components.
Easiness	Beginner	Beginner	Intermediate	Intermediate	Advanced
Coding needed	No*	No	Yes	Yes	Yes
Tools and software needed	Tekla Structures (Notepad or Notepad++, Tekla Open API) *	Tekla Structures	Tekla Structures, Microsoft Visual Studio Community (free), Tekla Open API	Tekla Structures, Microsoft Visual Studio Community (free), Tekla Open API	Tekla Structures, Microsoft Visual Studio Community (free), Tekla Open API

In Table 2.1 the description of the options, use cases, required skills in Tekla Structures and coding, as well as tools and softwares needed are given.

In order to take advantage of the potential of the Tekla Open API, it is necessary to write program code outside Tekla Structures. At the same time another option is to download already created extensions.

File formats and industry standards supported by Tekla are presented in the table that is shown in Appendix 1 and if they can be exported, imported or both.

2.1.4 Reinforcement tool

In Tekla Structures, there are different methods to create reinforcement, and in most cases different combinations of them are required to achieve the desired result. Figures 2.2 and 4.20 show examples of using Tekla reinforcement tools.

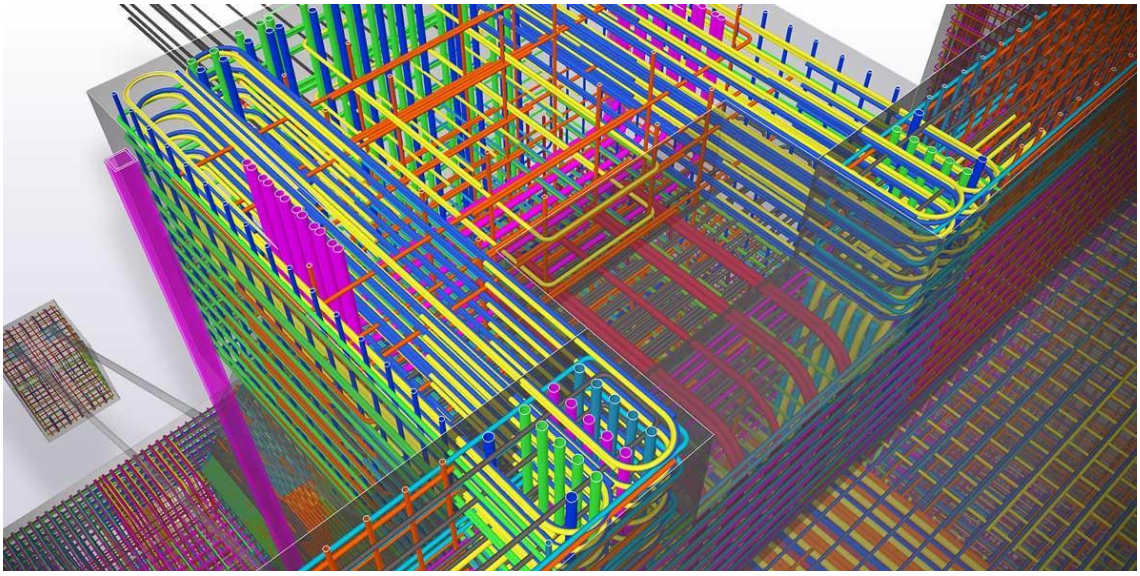

Figure 2.2 Reinforcement modelled in Tekla Structures (16)

Standard methods are (17):

- Single reinforcing bars;
- Reinforcing bar groups;
- Reinforcement meshes;
- Reinforcement components.

Reinforcement components tool is the most recommended due to adaptability, attachment to concrete parts and automatic updating when changing the dimensions of the reinforced part.

Reinforcement meshes are bars located perpendicular to each other. Tekla recognizes the mesh as one unit, but when editing, main and crossing bars are distinguished.

Reinforcing bar groups include several identical bars, all actions on the group are performed simultaneously and in the same way.

Single reinforcing bars tool is used in special cases when it is convenient to place the rebars one by one.

In addition, a special extension “Concrete Bridge Reinforcement” was developed for Tekla Structures to make reinforcement modelling more productive (18). Obviously, this extension can be used not only for bridge structures, but also for structures of complex geometry (for example, varying cross sections or curved shape).

Convenient workflow can be achieved by using a combination of "Concrete Bridge Reinforcement" with another extension “Beam Extruder”, which allows to create a curvilinear model by specifying coordinates of the structure path in the Excel file and selecting or drawing a section of the structure. This combination of extensions was applied in this thesis work that is described in chapter 4.3.

2.2 Autodesk Revit

Autodesk Revit (or Revit) is a software package for computer-aided design that implements the principle of BIM. It is used for modelling architecture, structure and engineering MEP systems and provides 3D modelling and producing 2D drawings (19). Revit database can contain project information at various stages of a building’s life cycle, from concept development to construction and maintenance/demolition (4D BIM).

2.2.1 Interface

The software interface is shown in Figure 2.3.

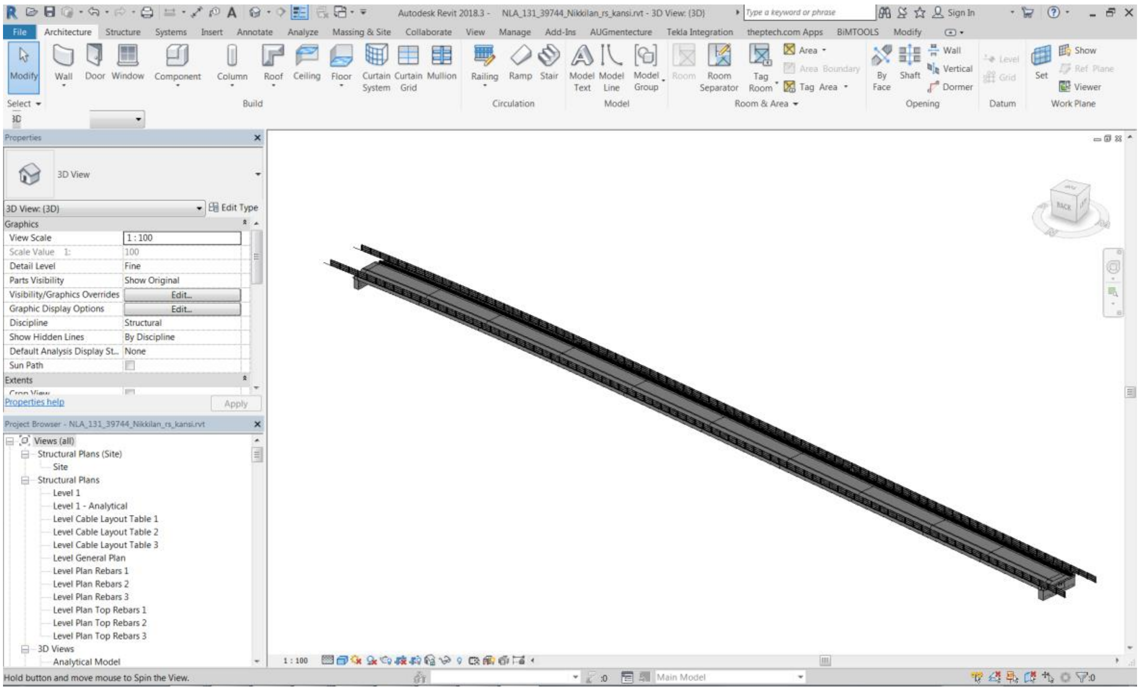

Figure 2.3 Autodesk Revit interface

The interface contains multiple tabs (20):

- The “File” tab provides access to frequently performed file operations, such as “Create”, “Open” and “Save”, as well as “Export” and “Print”;
- “Architecture”, “Structure”, “Systems” tabs are dedicated to work with the relevant disciplines respectively;
- In “Insert” tab management of substrates, external CAD applications, etc. are available;
- “Annotate” tab contains a control panel for dimensions, element details, text, etc.;
- “Analyze” tab includes commands necessary to perform engineering calculations (HVAC, electrical, energy, etc.);
- “Massing & Site” tab is for work with master plan and conceptual elements;
- “Collaborate” tab serves for management of joint work in one file;
- “View” tab deals with creating and configuring views;
- “Manage” tab gives the path to the project settings commands;
- “Add-Ins” tab represents available to customers software utilities for use with Revit software. Usually they must be downloaded independently;
- “Modify” tab is used for editing objects.

2.2.2 Supported file formats

Revit supports the following industry standards and file formats: Revit native formats (RVT, RFA, RTE, RFT), CAD formats (DGN, DWF, DWG, DXF, IFC, SAT, SKP), image formats (BMP, PNG, JPG, JPEG, TIF) and other formats (ODBC, HTML, TXT, gbXML) (21).

2.2.3 Open API

Autodesk Revit provides a .NET API that can be used to adapt and extend the functionality of Revit, develop vertical and enterprise solutions, and more (22).

Common areas where the API is used in Revit are (23):

- Creating add-ins and macros to automate repetitive tasks in the Autodesk Revit user interface;
- Enforcing project design standards by checking for errors automatically;
- Extracting project data for analysis and to generate reports;
- Importing external data to create new elements or parameter values;
- Integrating other applications, including analysis applications, into Autodesk Revit products;
- Creating Autodesk Revit project documentation automatically.

2.2.4 Reinforcement tool

Standard reinforcement tools can be used to place a single rebar or groups of rebars considering the maximum or minimum spacing, number of rebars or both along with area reinforcement, path reinforcement and fabric area (Figure 2.4).

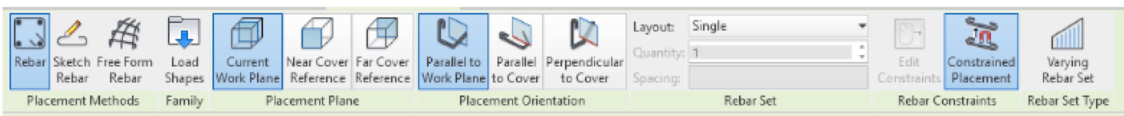

Figure 2.4 Revit standard reinforcement tool

Figure 2.4 shows the settings that can be set to model the reinforcement - this is the placement method, placement plane, placement orientation, as well as other settings in special browsers or dropdown lists, for instance, rebar shape.

In Figures 2.5 and 4.14 you can see the possibilities of reinforcement tools in Revit.

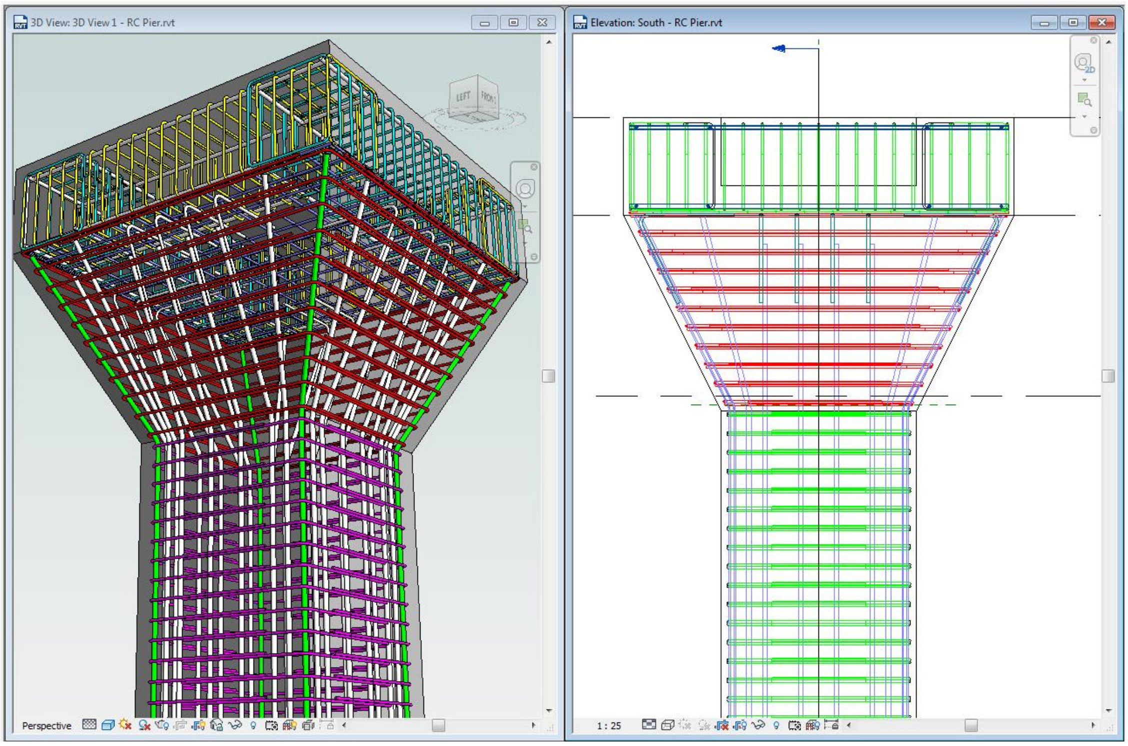

Figure 2.5 Reinforcement modelled in Autodesk Revit (24)

Working with standard tools is quite easy but can be time consuming depending on the complexity and quantity of the elements to be reinforced.

Due to the complex geometry of the bridge another method of reinforcement modelling was used in this work. It is described in Chapter 4.2.

3 REVIT & TEKLA INTEROPERABILITY

Despite the fact that both of the programs reviewed are related to BIM, interop-erability between them is limited.

Designers use IFC format as one of the output forms but in fact, recognition of objects, modeled in one program and exported in IFC format to another program, does not always happen successfully in this “another” program to continue working in it.

The following describes what options are available for transferring the model and the information it contains from one program to another.

3.1 Revit to Tekla transfer information workflow

To transfer information of a model from Revit side to Tekla is possible by exporting IFC format which is the most common option when sharing information between project stakeholders and their software. The task is easy, it is necessary only to define an appropriate setup (Figure 3.1, 3.2).

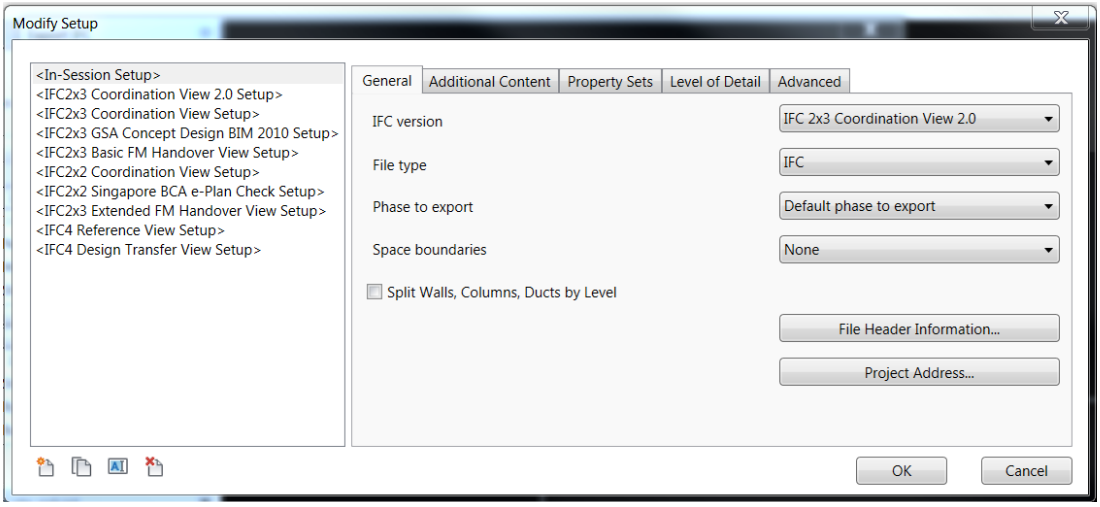

Figure 3.1 Revit "Modify Setup" – “General” settings when exporting IFC

In Figure 3.1 the tab of the settings “General” is shown. There are different types of settings that can make the model more or less full and are designed to solve various problems.

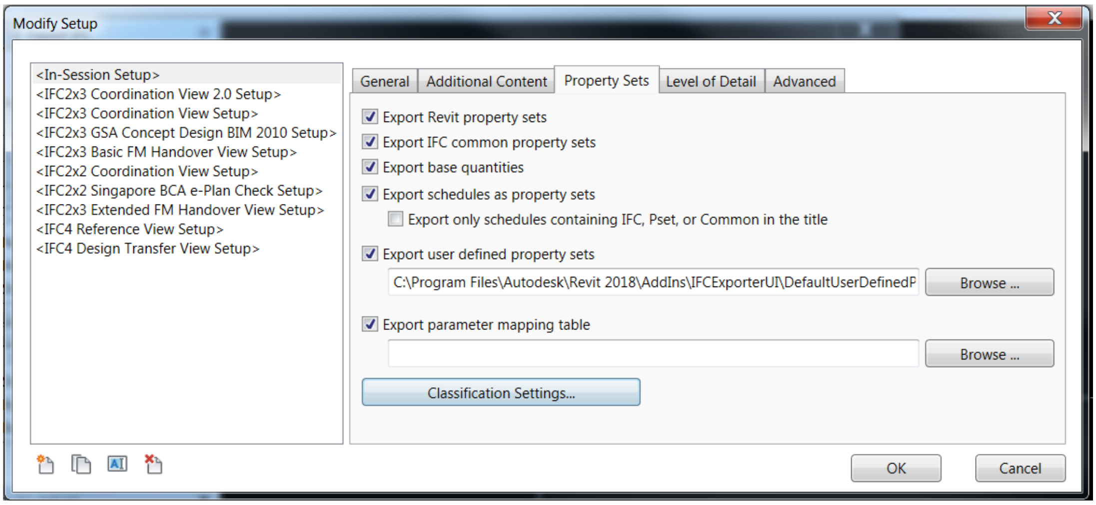

Figure 3.2 Revit "Modify Setup" – “Property Sets” settings when exporting IFC

“Property Sets” (Figure 3.2) is the most influencing completeness of the transmitted information tab. The rest of the settings can be left by default.

The next step is to import a file, open it in Tekla, select the model and “Convert IFC objects”. Here is the start of detecting all the issues. The thing is that not all the objects can be identified by Tekla appropriately. It depends on how objects were modeled.

There is usually no problem with objects created by using standard tools (for example standard family categories as Wall, Column, etc. instead of In-Place families) and with modifying by profile rather than using the Revit Opening tool (By Face, Shaft, Wall Opening tools etc.) or void family objects. These and other instructions developed by Tekla developers can be found on the software user assistance website (25).

3.2 Tekla to Revit transfer information workflow

There are two variants for transmitting model from Tekla to Revit. The first one is to export and use IFC and two ways are available to use IFC: open IFC through the “Open” tool in Revit or link IFC.

Linking a file is applied as an external reference – as one block, for visualization and getting property and attribute information. Updated files can be re-linked and re-uploaded to the Revit model. Linked IFC files may be dimensioned and used as a location to model own Revit content from scratch.

In its turn, opening IFC allows items of a model to be selected, identified as one of Revit family category, annotated, tagged and scheduled as usual Revit items and in some cases edited. However, not all information can be displayed as expected. First, family types and categories are not assigned correctly and convenient for using. Moreover, the generated analytical model will be incomplete and deficient. It is not crucial for the goal of the thesis but, when applying BIM, it is an essential fact.

Another option and at the same time "best solution" for interoperability between Tekla and Revit, when it comes to reusing a model, is the implementation of extensions to softwares: "Import from Tekla Structures" and "Export to Revit" (Figure 3.3). Both applications can be downloaded from Tekla Warehouse.

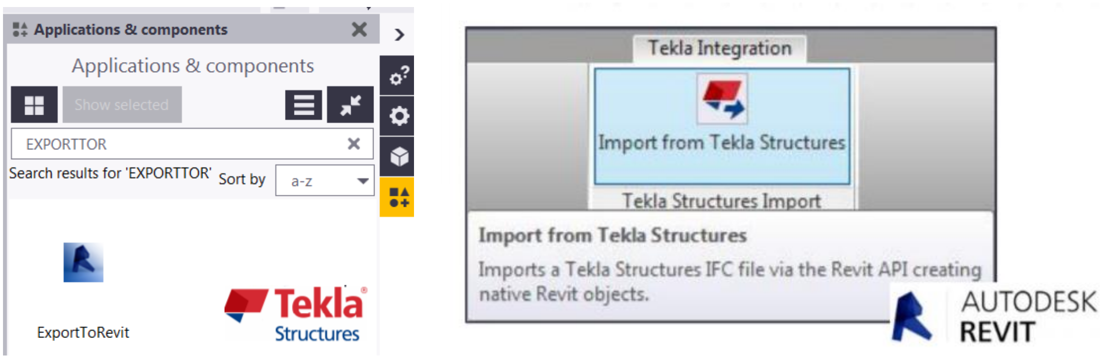

Figure 3.3 Extensions for exporting process from Tekla to Revit

In this way, TCZIP file is exported, Revit items are generated in accordance with the imported content and are collected into common family types with correctly defined categories. As well as fewer In-Place families are created what improves model performance. But still often the model is impossible to use for further work, for example, reinforcement of concrete parts.

3.3 Alternative ways

Another option to export information from Tekla to Revit / Revit to Tekla is to use such a format like 3D dwg as reference models for remodelling and taking out coordinate information.

The practical application of this format is described in Chapters 4.2, 4.3.

4 RE-ENGINEERING PROCESS

This chapter focuses on the practical aspects of re-engineering BIM. Two initial test models were obtained (Figure 4.1, 4.3) and two processes of re-engineering were carried out: from Tekla Structures to Revit and backwards, and two re-engineered models were accordingly created (Figure 4.2, 4.4). The level of detail of both initial models is a “Final design” level.

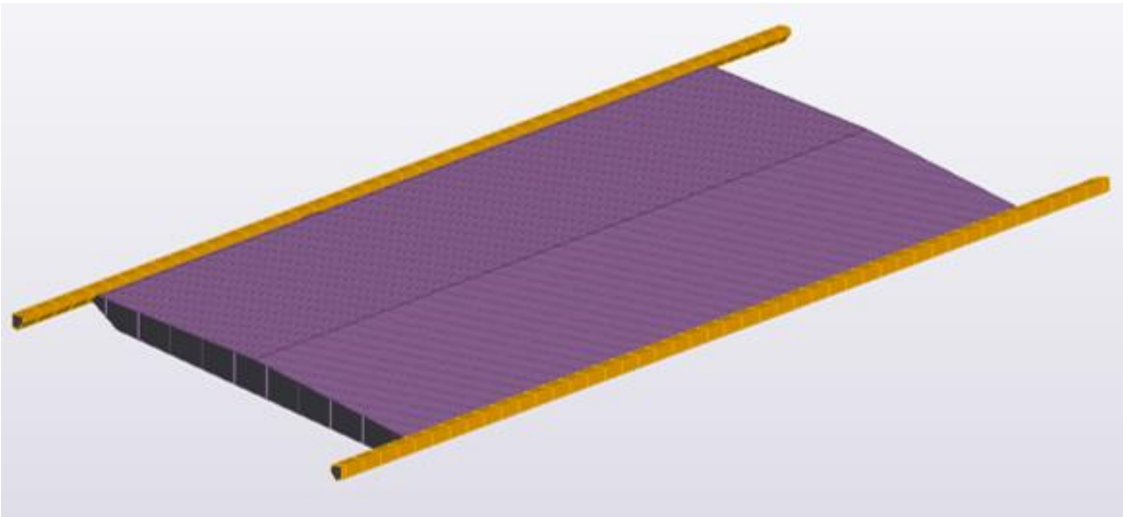

Figure 4.1 Initial model from Tekla

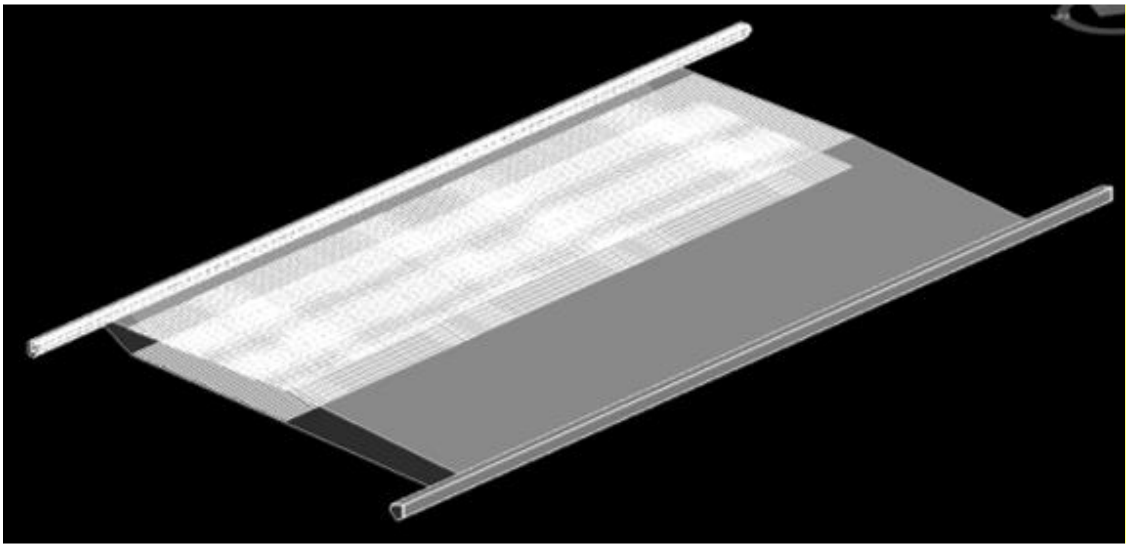

Figure 4.2 Re-engineered model in Revit

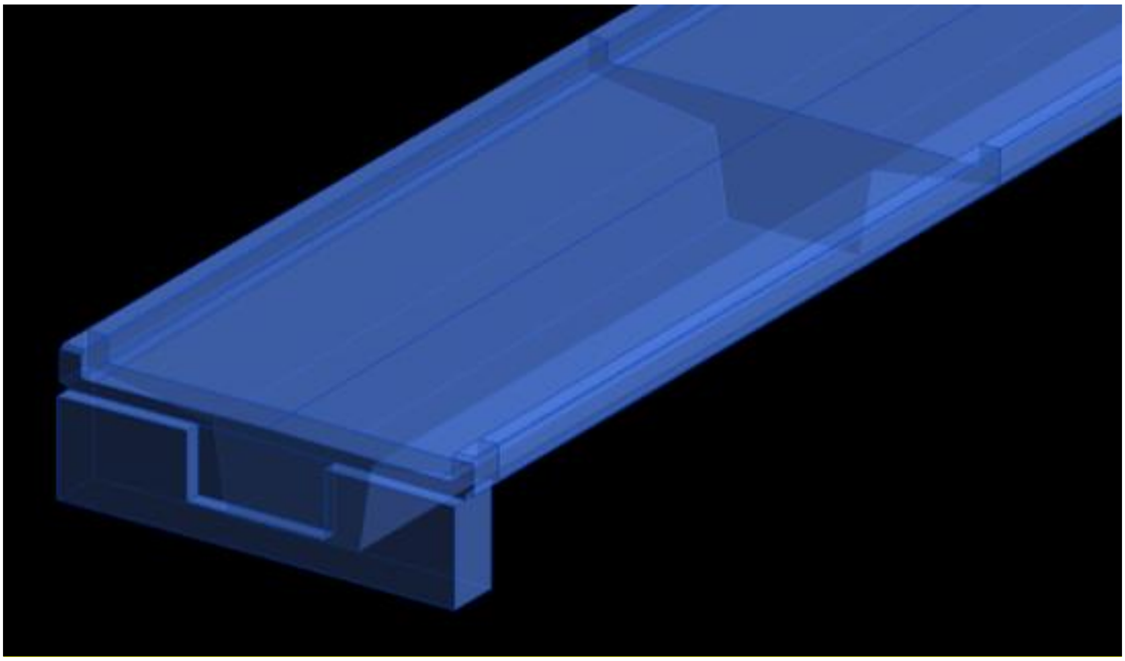

Figure 4.3 Initial model from Revit

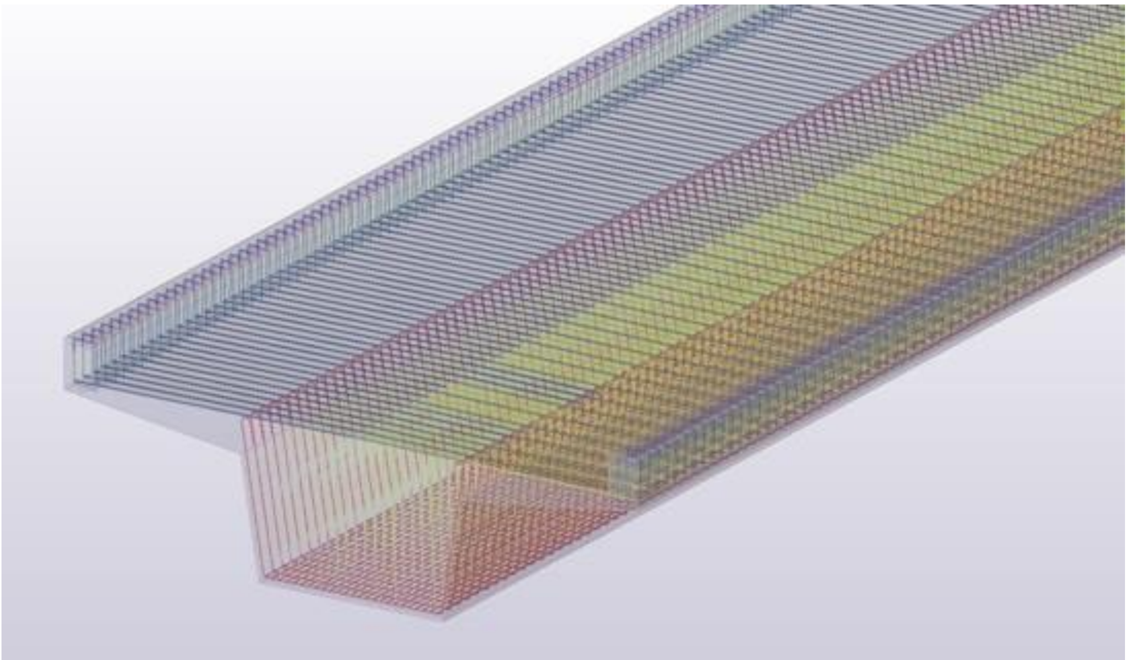

Figure 4.4 Re-engineered model in Tekla

The task was to reconstruct a model in the opposite program and to model reinforcement. Figures 4.1-4.4 display the models of deck and edge beams which were chosen as the working model.

4.1 Project description

Below are the data on the projects and photos of the bridges to which the tested models belong (Figure 4.5, 4.6).

1. Nikkilä Project

Object: Railroad Bridge.

Location: Sipoo, Finland.

Type: prestressed continuous concrete beam bridge.

Foundation type: supports have driven steel piles, filled with reinforced concrete, D=610 mm.

Thickness of load bearing structure: 2,04 m.

Spans: 28+34+37+34+28 (m).

Year of design: 2017.

Construction phase: under construction.

Figure 4.5 Nikkilä Project bridge during construction

In Figure 4.5 photos of the bridge formwork and reinforcement are given.

Models that correspond to this project are shown in Figures 4.3 and 4.4.

2. TaaLa S15 Project

Object: Highway bridge.

Location: crossing of VT6 and local road (Taavetti – Lappeenranta).

Type: continuous reinforced concrete slab bridge.

Foundation type: supports have foundation slabs based on ground.

Thickness of load bearing structure: 1,14 m.

Spans: 10,5+15,7+10,5 (m).

Year of design: 2015.

Construction phase: in use.

Figure 4.6 TaaLa S15 Project bridge during construction

Figure 4.6 shows the aerial view of the bridge on the Taavetti-Lappeenranta highway section.

The models that correspond to this project are shown in Figures 4.1 and 4.2.

4.2 Tekla to Revit re-engineering process

The process described can be represented as the following diagrams (Chart 4.1, 4.2).

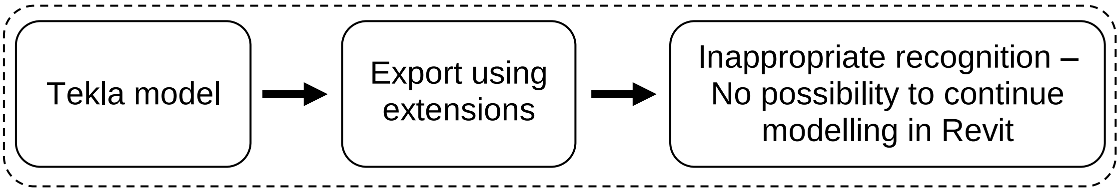

Chart 4.1 Export from Tekla to Revit using extensions

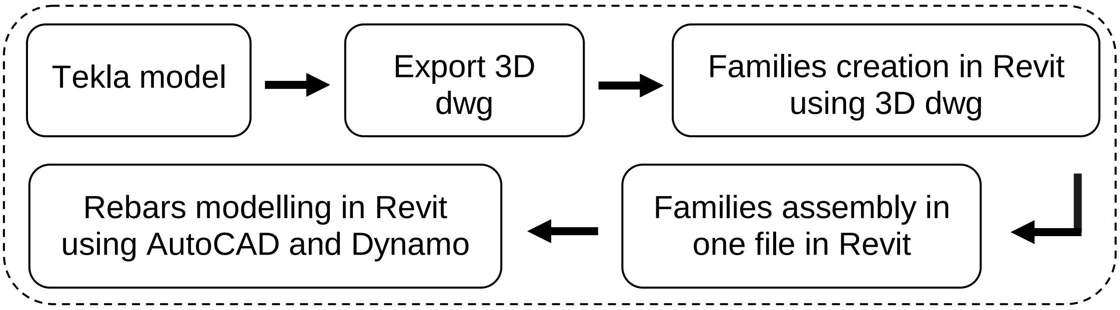

Chart 4.2 Re-engineering process from Tekla to Revit using 3D dwg data

The following is a description of Chart 4.1. At the beginning of the work there were Tekla model of the bridge (Figure 2.1) and related drawings. The objects necessary for export (Figure 4.1) were selected and transferred to Revit (Figure 4.7) using extensions described in Chapter 3.2.

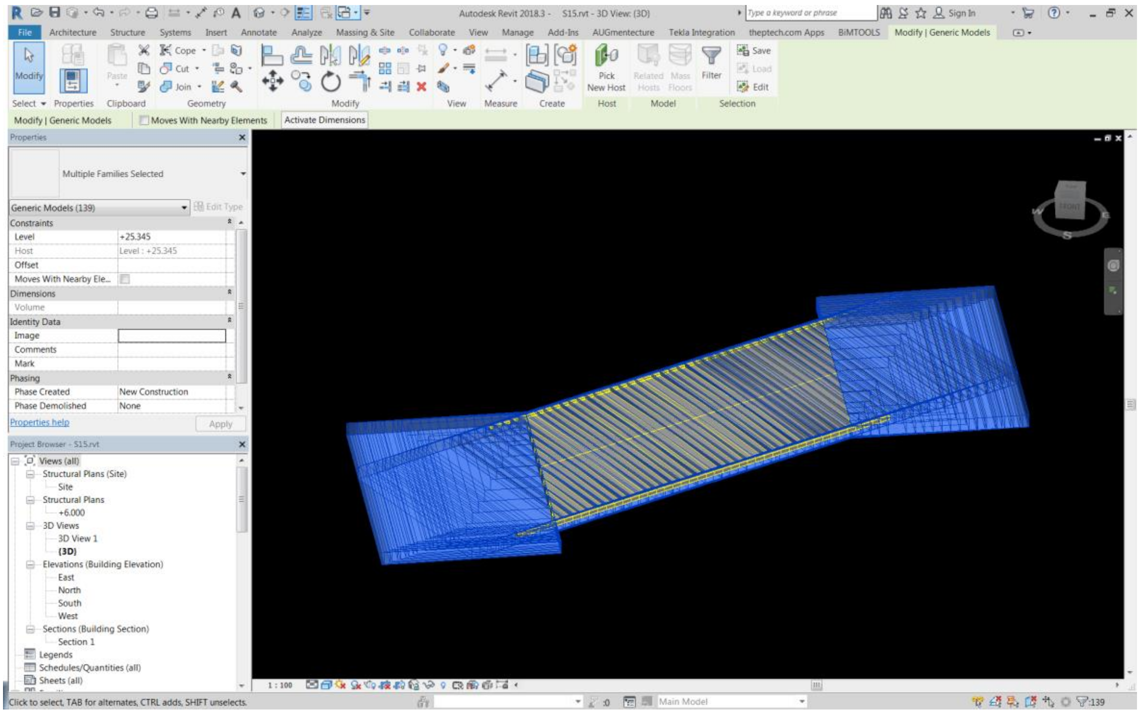

Figure 4.7 Imported to Revit using extensions Tekla model

It has been found that the deck is made up of many parts, because of what it would be impossible to use standard reinforcement. Then it was concluded that remodelling of the bridge is needed. For this purpose Tekla objects were exported to 3D dwg format (Figure 4.8) to form profiles of the deck and edge beams and transfer it to Revit. The schematic description of this process is given in Chart 4.2.

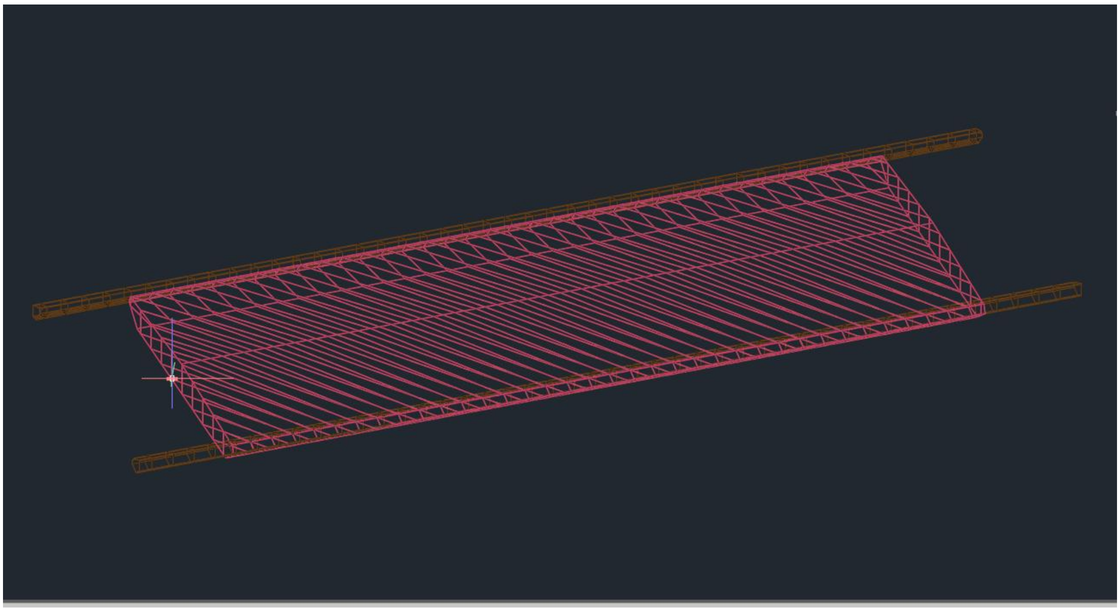

Figure 4.8 Imported Tekla model in 3D dwg format

In order to insert files into Revit properly, it is essential that the transmitted co-ordinates and units of measurement are taken into account. In this case, local coordinates were used in Tekla, and for importing to Revit global coordinates are necessary in order to transfer object location data, so some amendments must have been made in this regard.

The profiles were further created at some intervals of the model and inserted into RFA file for concrete parts modelling (Figure 4.9, 4.10) and into so-called “main” combined RVT file (Figure 4.11) for using it as a reference model.

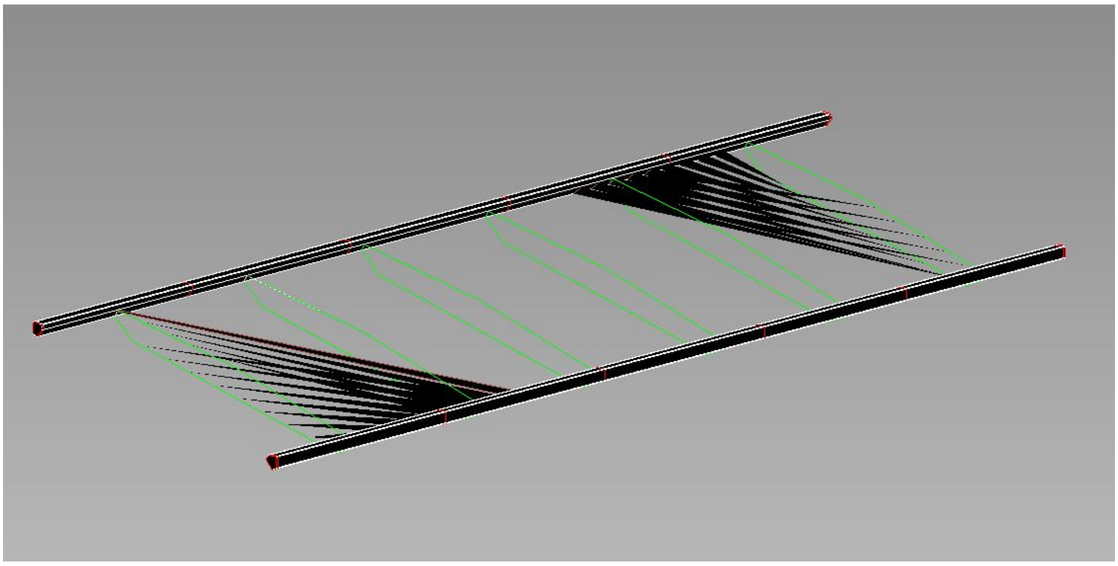

Figure 4.9 Revit family of edge beams (.RFA format) with reference profiles

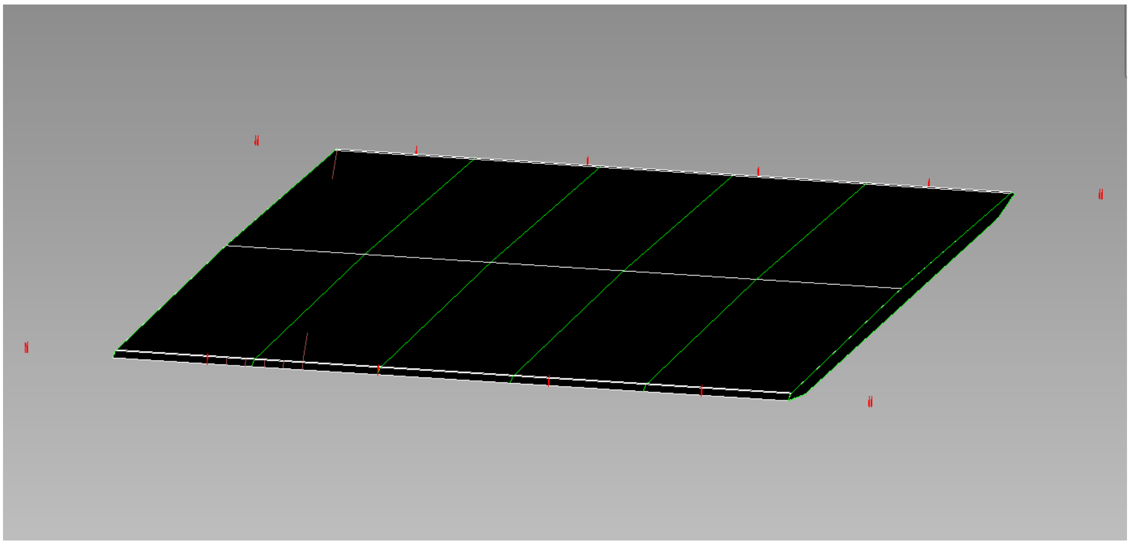

Figure 4.10 Revit family of the deck (.RFA format) with reference profiles

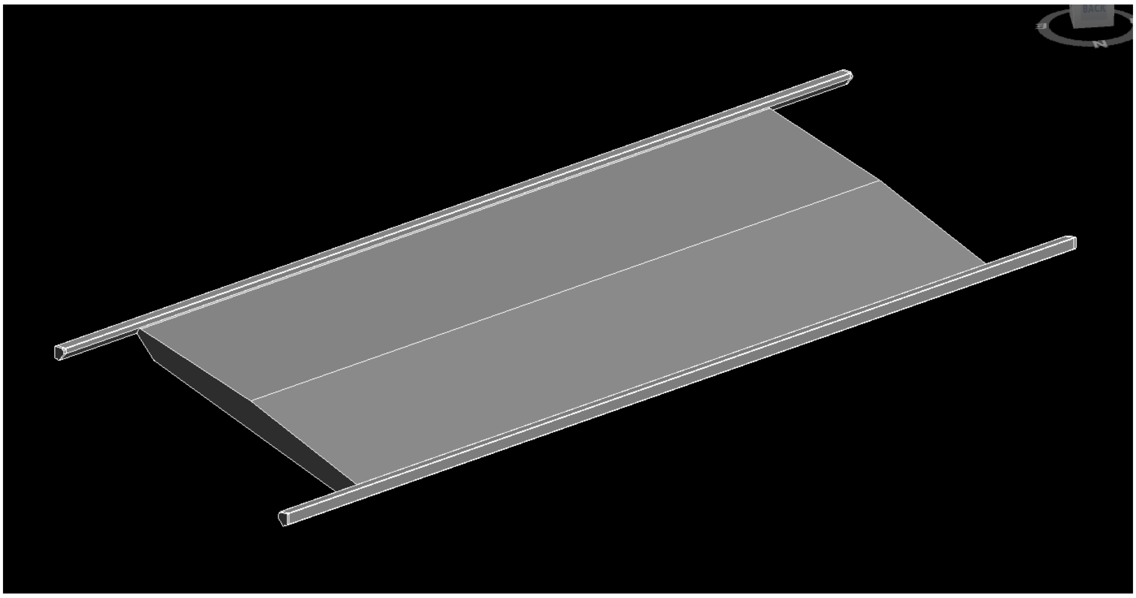

Figure 4.11 Combined Revit model of concrete parts (.RVT format)

For reinforcement modelling Dynamo was used through the creation of rebars in the form of lines in AutoCAD (Figure 4.12).

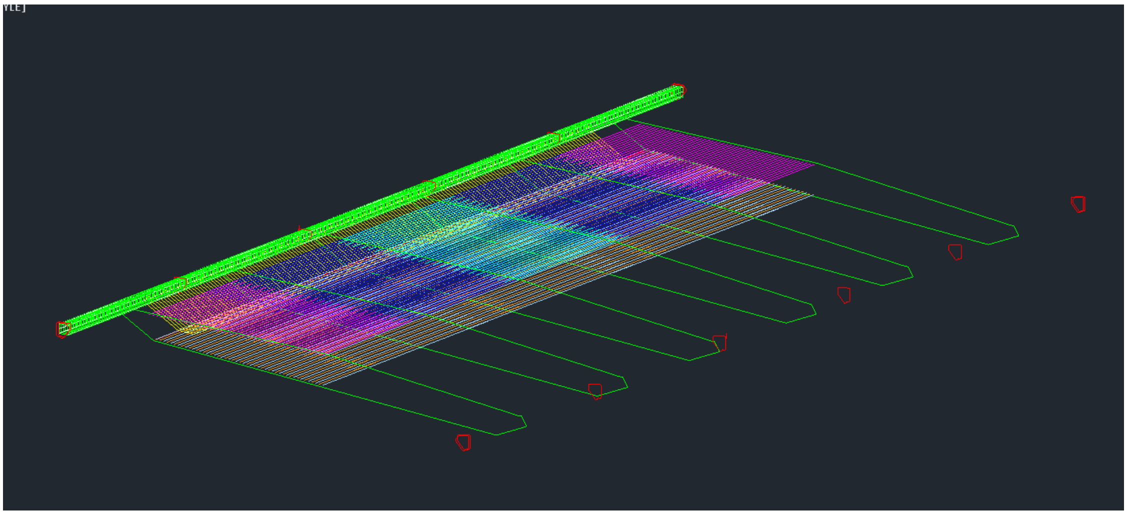

Figure 4.12 AutoCAD lines imitating reinforcement

Figure 4.12 shows the profiles of the deck and edge beams drawn in AutoCAD by the exported Tekla model. These lines were further applied in the Dynamo script (Figure 4.13) by the choice of a particular layer in AutoCAD characterizing a particular diameter of the reinforcement. The picture shows that the reinforcement is drawn in different colours, which corresponds to different diameters of the rebars.

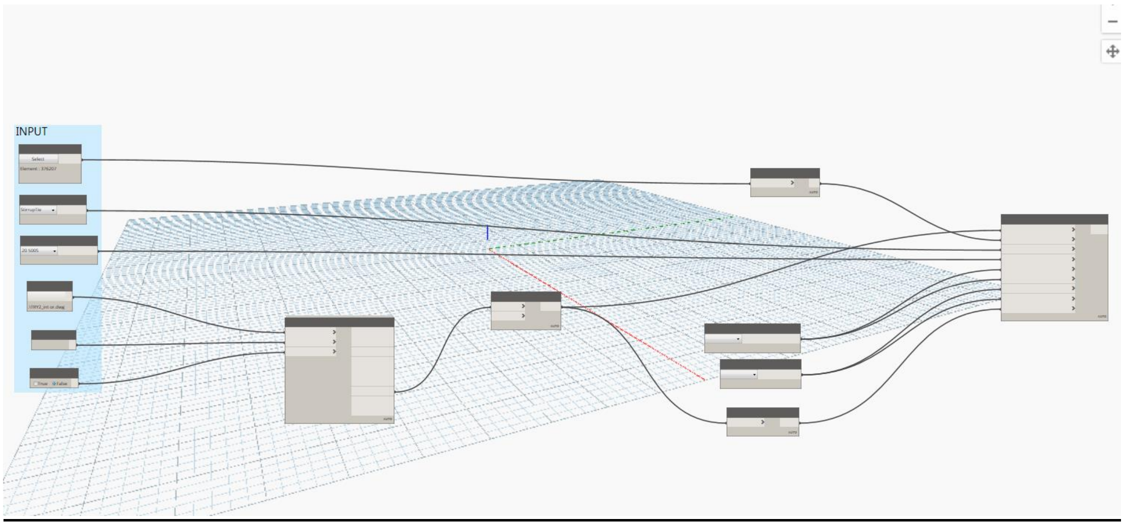

Figure 4.13 Dynamo script

The implementation of this script on Figure 4.13 is quite simple: you need to specify the path of the AutoCAD file, select the desired AutoCAD layer from the drop-down list, the required rebar diameter and hook type.

The result of rebars modelling and re-engineering process can be seen in Figure 4.14.

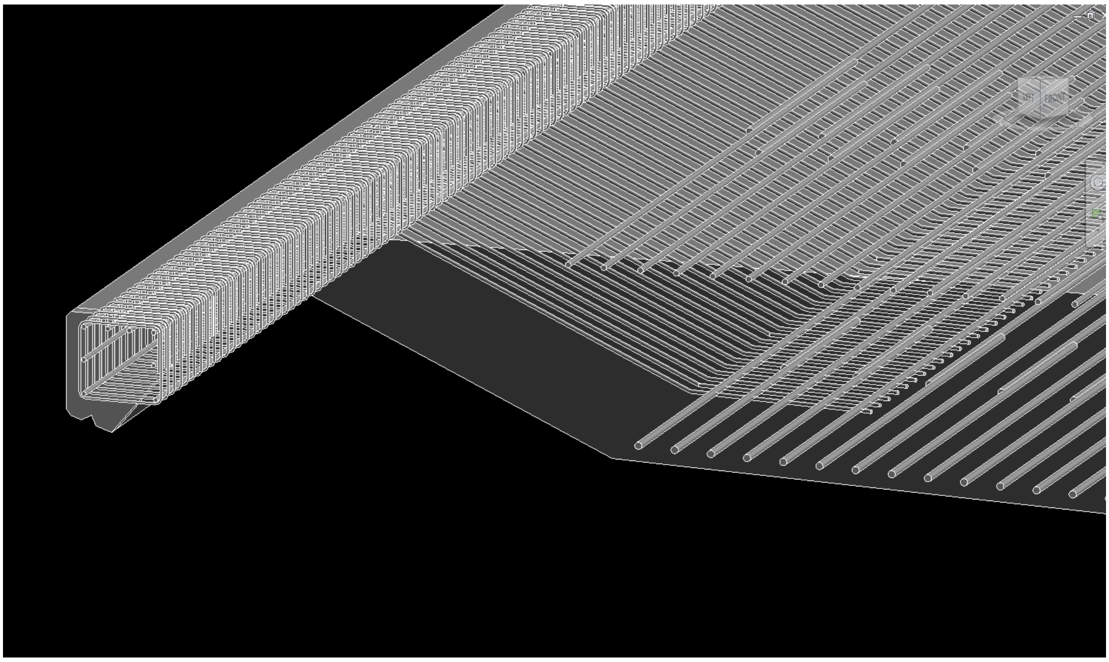

Figure 4.14 Re-engineered model in Revit

In Figure 4.14 you can see the only part of the required quantity of reinforcement.

4.3 Revit to Tekla re-engineering process

As inputs Revit model (Figure 2.3), 3D dwg of deck with its track line (Figure 4.15) and drawings were obtained. To start reengineering, the deck with edge beams were isolated (Figure 4.3).

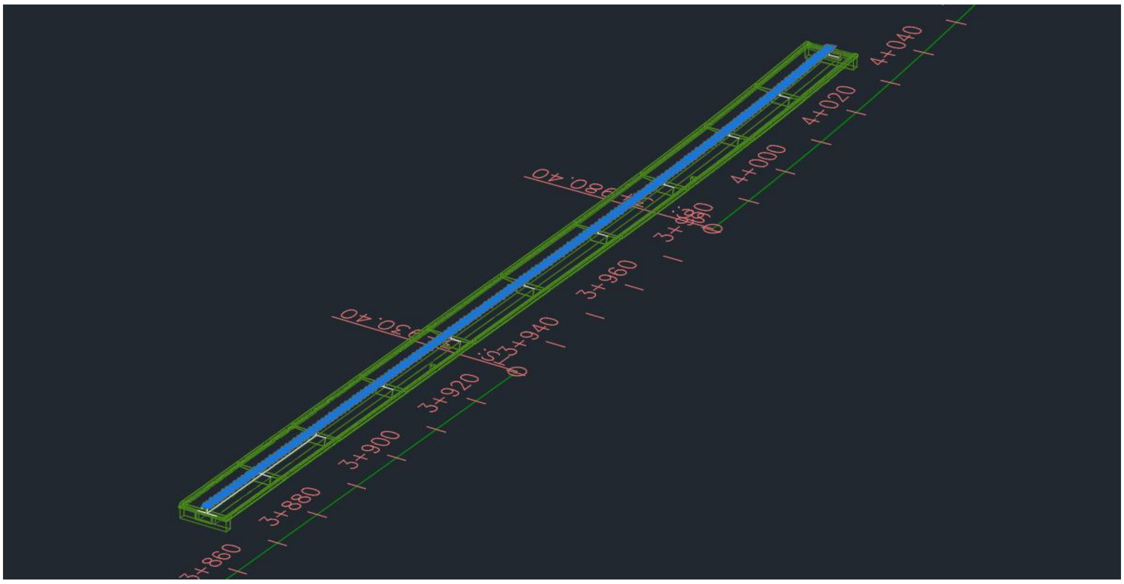

Figure 4.15 3D dwg of deck and edge beams with the track line

The implemented process is shown schematically in Charts 4.3 and 4.4.

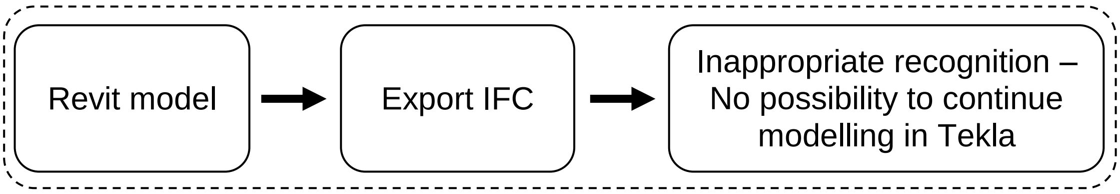

Chart 4.3 Export from Revit to Tekla using IFC

The following is a description of Chart 4.3. IFC file was generated through the process described in Chapter 3.1 and transferred to Tekla. After attempting to “Convert IFC objects”, it turned out that they were not converted in such a way as to be recognized by Tekla. The process diagram of the next steps is shown in Chart 4.4 and explained below.

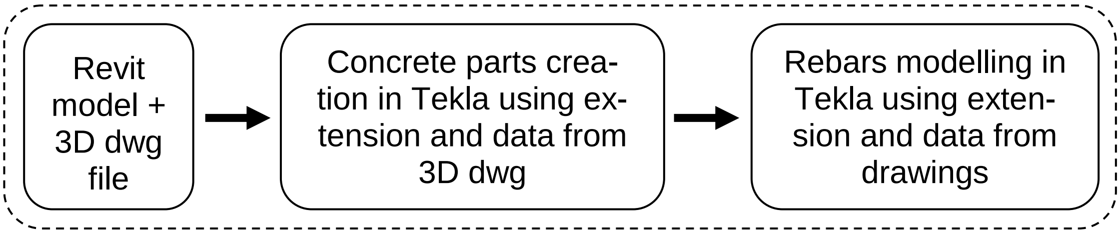

Chart 4.4 Re-engineering process from Revit to Tekla using 3D dwg data

It was necessary to remodel concrete parts in Tekla from zero what was done by means of Tekla Structures extension Beam Extruder (Figure 4.16). To apply that extension, an Excel file with the coordinates of some point of profile plane needed to be prepared (Figure 4.17).

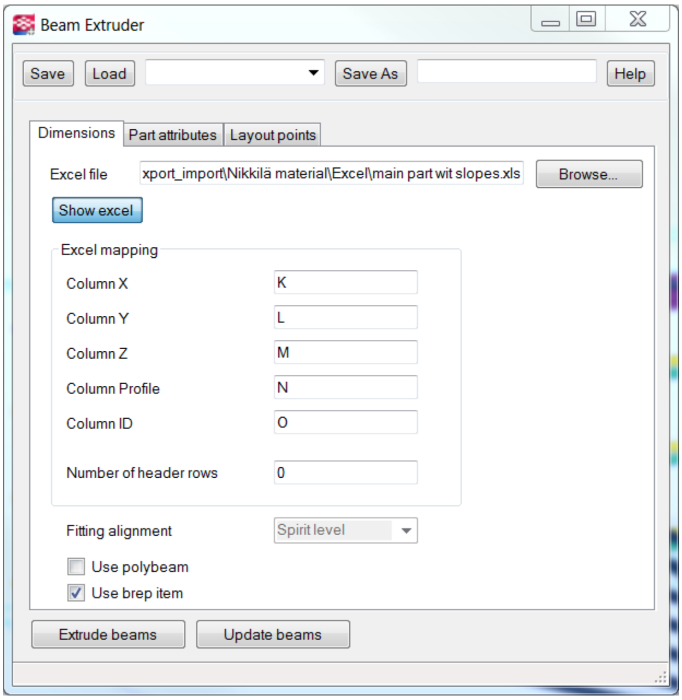

Figure 4.16 Beam Extruder extension window

Figure 4.16 shows one of the tabs of the extension used, on which it is needed to specify the path to the Excel file and columns with working data.

Position X	Position Y	Position Z	PROFILE	ID
152888	608716	15042	PROFILE 1	093635e9-c691-4e1b-bbd3-aab55fb59503
153849	608443	15042	PROFILE 1	b1ad40d7-e17b-4c38-a37e-0a5c668fb6f4
154811	608170	15043	PROFILE 1	2697a2dc-53ea-4f54-90c4-ad9d485762ea
155773	607896	15043	PROFILE 1	f0f6d658-ee73-46f4-bfd6-a4dd0d847b13
156735	607623	15044	PROFILE 1	c07fe5d4-705d-4ea7-84db-dcae1197b3da
157697	607350	15044	PROFILE 1	d76adc53-87bc-43a0-8465-daa83fb3cacd
158659	607076	15045	PROFILE 1	8fd7ae0f-1f09-4c3f-aae7-cfdcc9d8c440
159621	606803	15045	PROFILE 1	be8bdd5f-9cd9-47f5-b9c9-0661c2d8a04d
160583	606529	15046	PROFILE 1	b3b15490-d4e7-4bc3-bc9c-ef92b98aa110
161545	606256	15046	PROFILE 1	7d15b04c-b08a-41cb-ac77-a622af3ee6d2
162507	605983	15047	PROFILE 1	2f5030c5-228e-4163-8c80-5bb0c41ae311

Figure 4.17 Excel file with the coordinates

In Figure 4.17 Excel file fragment with x, y, z coordinates of one of the profile plane points is given. For this, it is necessary to select the bridge track line (Figure 4.18), the coordinates of the points of which will be used, array the points on it with a certain interval and export the coordinate data to Excel. In addition, the name of the structure profile created for modelling should be specified and ID points are automatically assigned by the program (Figure 4.17).

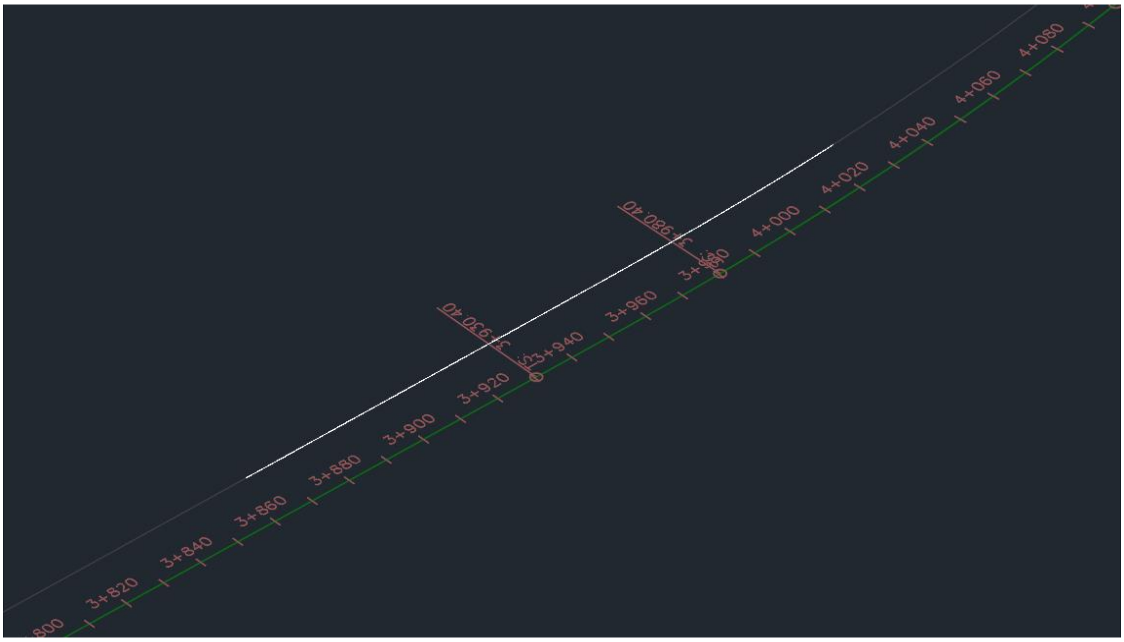

Figure 4.18 Bridge track line in AutoCAD

Such a solid structure was obtained after using Beam Extruder (Figure 4.19).

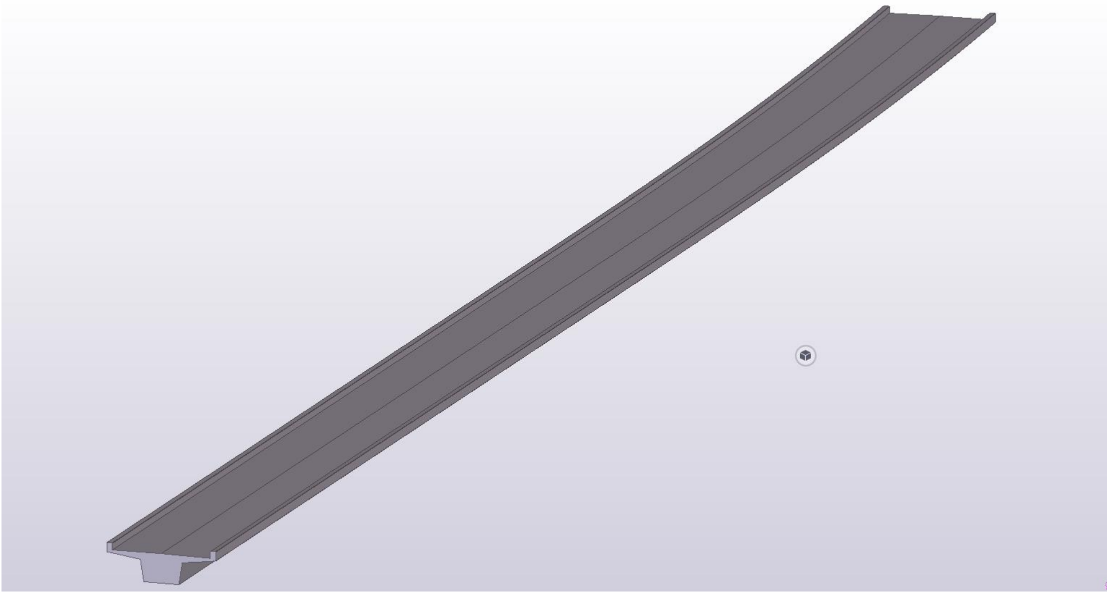

Figure 4.19 Concrete parts modelled in Tekla

To model reinforcement Concrete Bridge Reinforcement plugin was applied as it was told in Chapter 2.1.4. The only problem with this tool is that, when applying particular spacing between rebars as it is defined by the designer, it should be manually fitted to the needed quantity of rebars. Most likely this is required only for a curved shape.

The result of rebars modelling and re-engineering process can be seen in Figure 4.20.

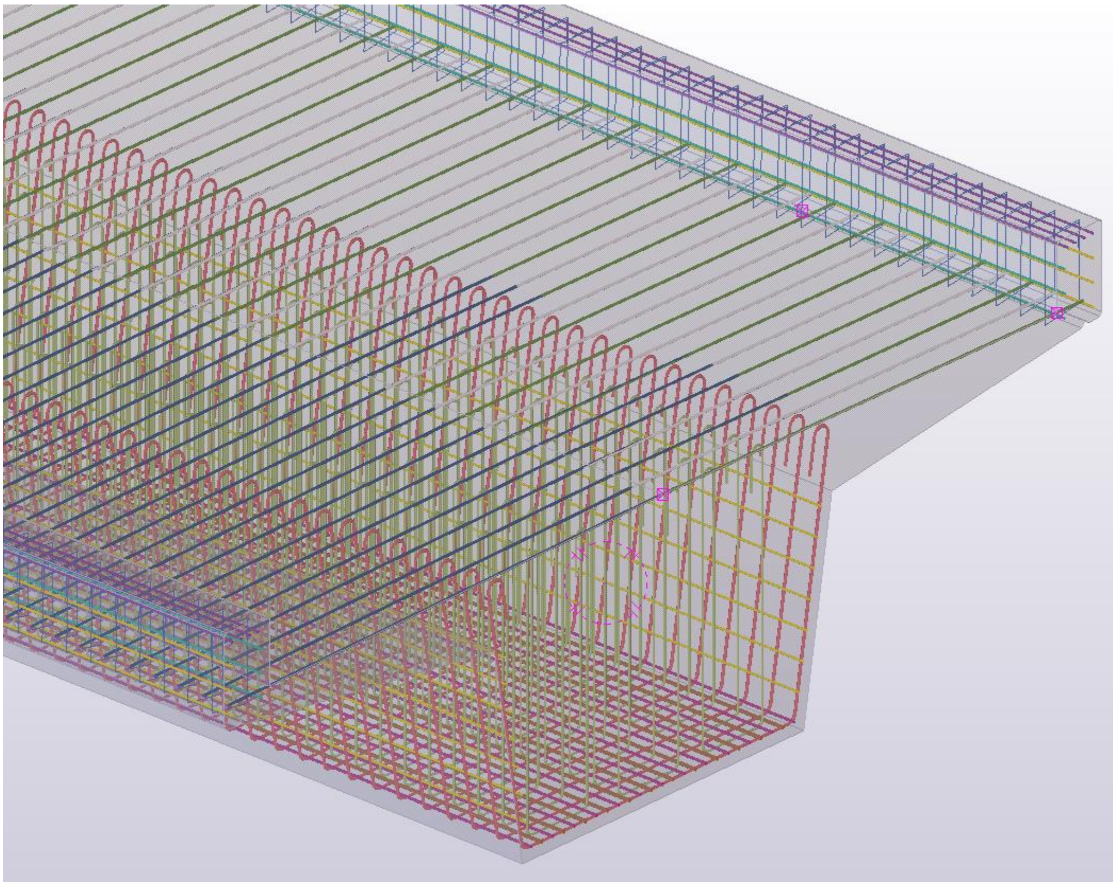

Figure 4.20 Re-engineered model in Tekla

Figure 4.20 displays the reinforcement of different shapes and different directions. Different typical sizes vary by colors for clarity.

5 CLOUD-BASED PLATFORMS

This chapter considers products provided by different market representatives for BIM and document coordination: Trimble Connect and Dalux (Figure 5.1).

Figure 5.1 Trimble Connect and Dalux logos

5.1 Trimble Connect

Trimble Connect is a cloud-based project collaboration platform designed for construction. Stakeholders of the project can share, comment and manage up-to-date project documents, photos, drawings and models during the different phases of workflows (Figure 5.2). This information can be easily accessed across desktop, web and mobile tools depending on the role or tasks of the person concerned (26).

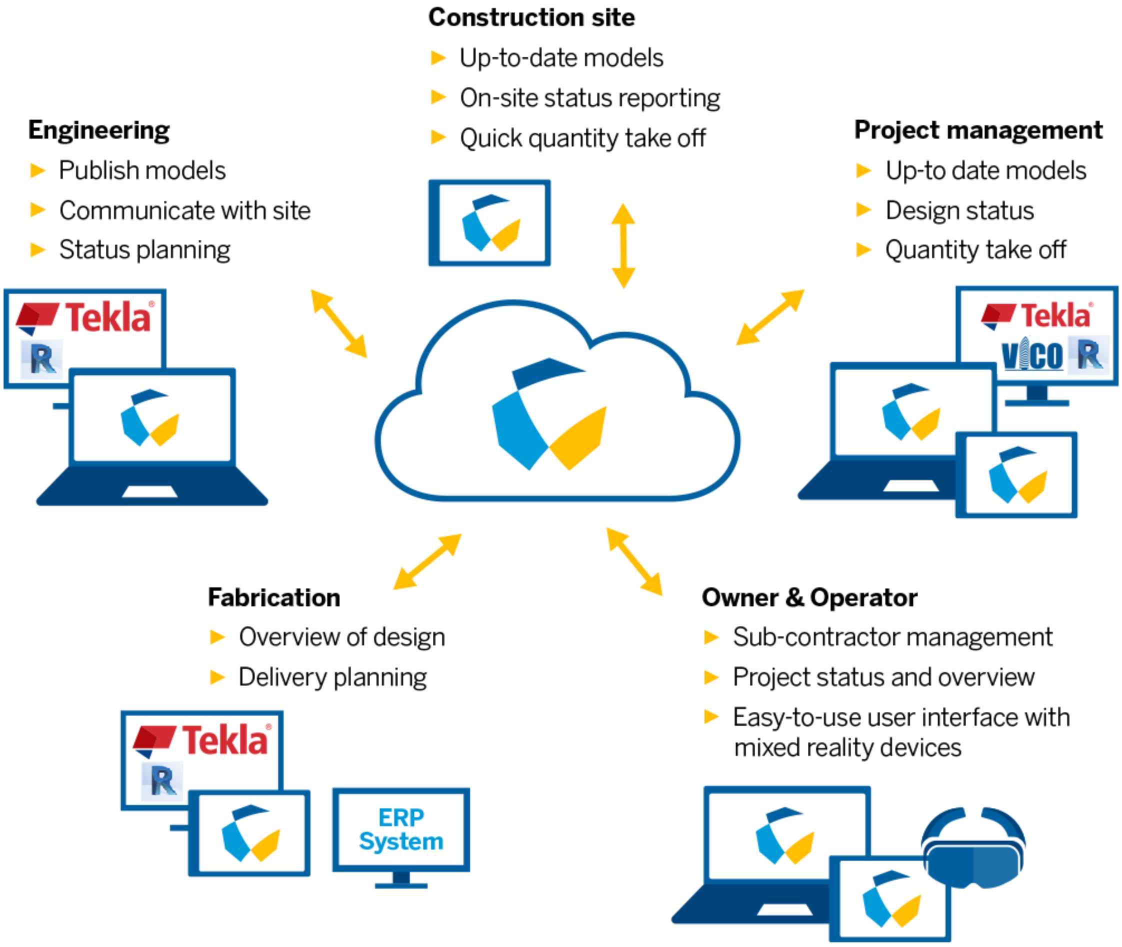

Figure 5.2 Trimble Connect opportunities in various fields of activity (26)

In Figure 5.2 the collaboration between different members of construction process is shown, as well as what customer needs this platform can provide.

Mobile app is intended for professionals working in remote access mode or on site (such as the construction job site manufacturing facilities, or in project meetings or presentations). Tasks that have been assigned in the office using Trimble Connect for web or desktop can be performed by one click access to concrete information needed for it. Project data and files can be used via mobile app offline when there is no internet access. In this way, new tasks, called To-Do's, can be created and edited offline, then synchronized after connecting to the internet.

Most importantly, large complex models created by various BIM softwares of numerous formats (Appendix 2) can be quickly loaded, superimposed and managed. Is it possible to share data from over 50 tools or add another source by means of API (27).

This is what the program interface looks like (Figure 5.3).

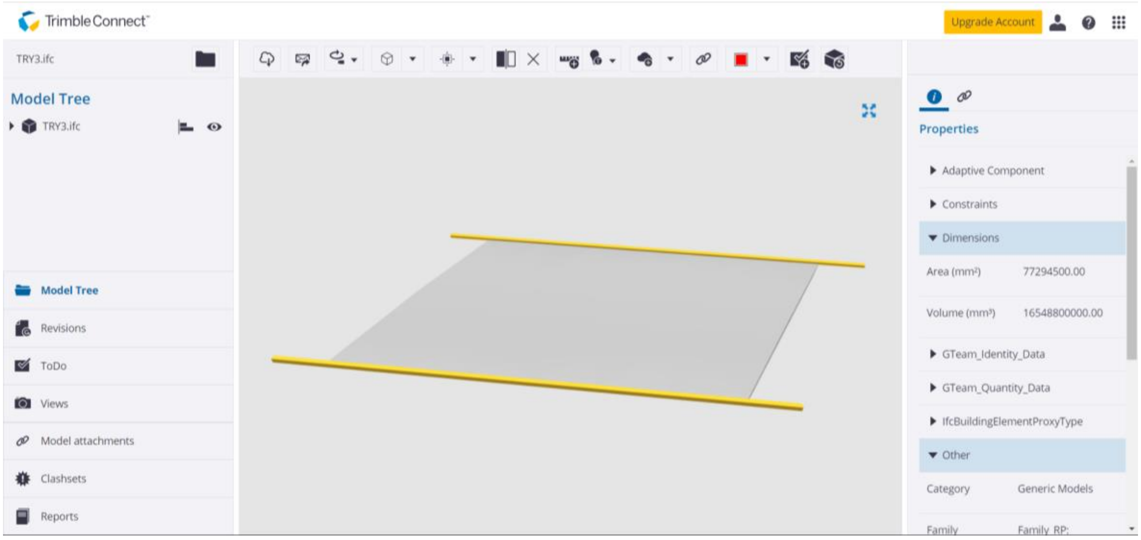

Figure 5.3 Trimble Connect desktop interface

Figure 5.3 demonstrates that the program window has several workspaces: the first one for organizing files, tasks and reports, the second for manipulating downloaded files, in particular with a model, and the third for working with object properties.

Mixed Reality (MR)

Trimble offers mixed reality technology for clients in Engineering, Construction, Architecture, Mining, Geospatial, Natural Resources and Facility Operations. One of the products is Trimble Connect for Hololens. The HoloLens (Microsoft HoloLens) is mixed reality smartglasses (Figure 5.4), developed by Microsoft, which allows interacting with the digital content and holograms. It gives possibility to work with advanced 3D design, coordination, collaboration and project management (28).

Figure 5.4 Microsoft HoloLens (29)

The device is a “computer without any wires” that is worn on the head. Inside, there is a central and graphics processor, a holographic chip capable of processing terabytes of information from detectors: an inertial measurement unit, including an accelerometer, a gyroscope and a magnetometer, sensors, a wide-angle depth camera, a photo-video camera, and a set of microphones and a light sensor.

5.2 Dalux

Dalux is a Denmark-based developer of BIM technology and digital tools for contractors, builders and advisors. The company has customers, besides Denmark, both in the Nordic countries and further abroad, especially the UK and Germany (30).

The product suite of Dalux contains a free BIM viewer (Figure 5.5, 5.6) for Apple iOS and Android devices, primarily providing cloud based access to 3D models and 2D drawings to clients. Other products, that can be purchased from Dalux, are a mobile quality control tool (Dalux Field), document management system (Dalux Box), as well as FM (Facility Management) system (DaluxFM).

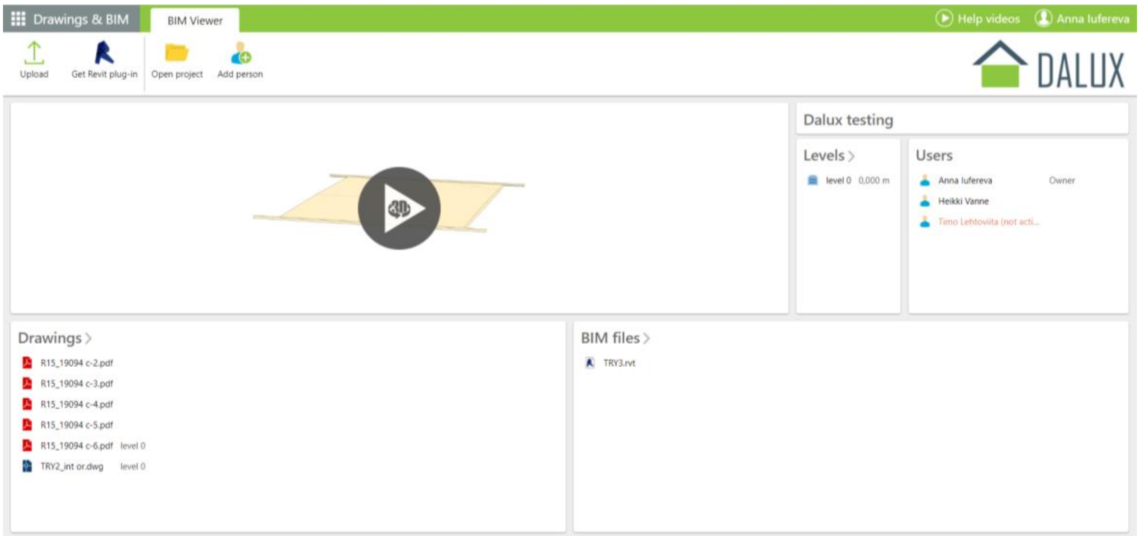

Figure 5.5 Dalux BIM Viewer interface

Figure 5.5 demostrates that the product allows to upload several models at the same time: IFC and Revit file both. There is a Revit plugin and extension for Revit to add files directly from the software. Other supported formats can be seen in Appendix 2.

A convenient option is the opportunity to add drawings and locate them at the appropriate level in the model. To do this, the model must have the necessary levels.

Dalux Field is a performance tracking tool for better supervision, quality assurance and safety inspection. It allows assigning an issue from the phone and sending it to a subcontractor by documenting with photos, lining, text and list values (31).

Dalux Box represents a cloud-based platform for collecting BIM-models from different disciplines and other files in one place and ensures staying participants updated via the web or through the app (32).

In its turn, everything from HelpDesk reports from tenants of managing properties, suppliers, work orders, space, energy, lease and asset management, documentation and models can be handled with the DaluxFM (33).

In addition, Dalux gives the option of API that enables it to interact with systems of a client and common data environments of other vendors (30).

Augmented Reality (AR)

Dalux has such AR technology like TwinBIM^{TM} which is compatible with Google ARCore and iOS ARKit toolkit to create an AR BIM tool on smartphones (Figure 5.6). It allows users to see elements of a 3D model superimposed on live video imagery created by the device's camera, and the application can then be used to create issue workflows where, for example, there might be discrepancies between the model and the constructed components (34).

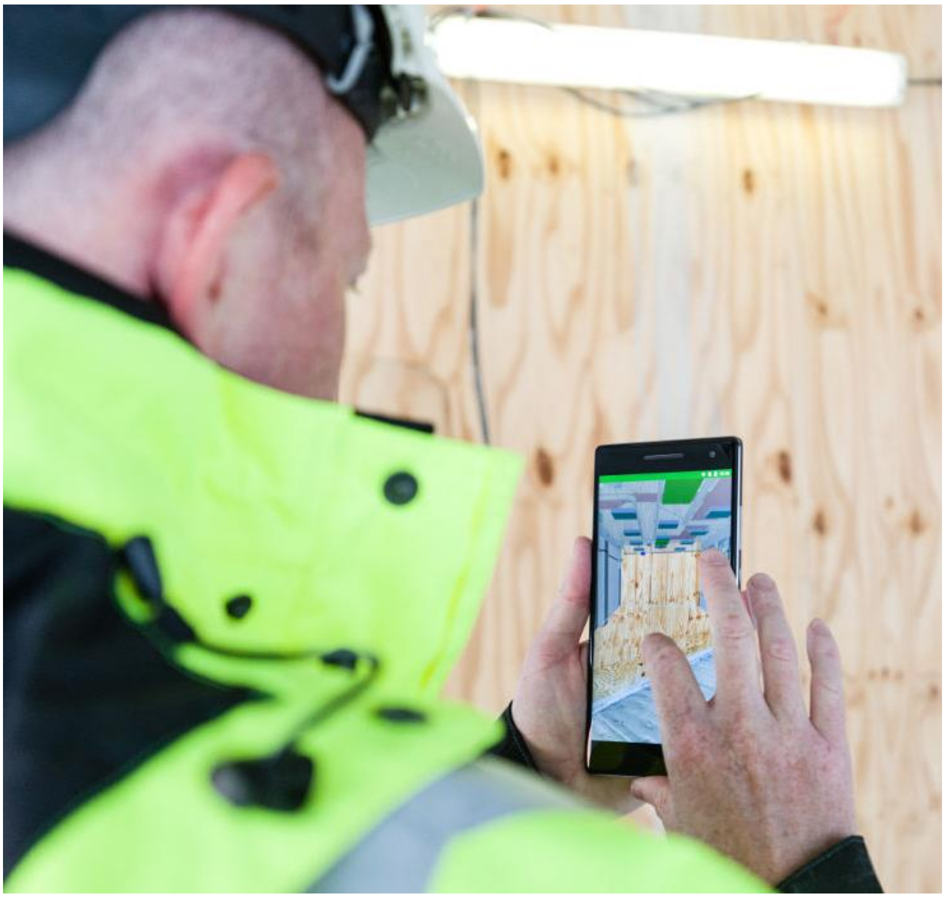

Figure 5.6 Augmented Reality by Dalux (34)

In Figure 5.6 the construction worker uses TwinBIM^{TM} by scanning surroundings and putting BIM model into created 3D map and aligning them.

In bridge design such digital tools as Trimble Connect and Dalux can help to collaborate more effectively across a multi-company, multi-disciplinary team members by sharing project information in one place accessible to all (cloud) and using and highlighting data needed for adjustments, when and where it is needed with multiple available devices. This is possible by adding visual and audio notes such as photos, videos and sound comments, which ensures the best perception of the incoming information for other stakeholders.

Moreover, virtual reality allows to compare the model of latest design with what was being built and thereby create issue workflows. This technology also provides adding geo content, making the picture more complete and clear.

6 SUMMARY

To carry out this thesis work, two powerful softwares were chosen to review and perform two re-engineering processes: Autodesk Revit and Tekla Structures.

First results indicated that interoperability, namely full data transferring between programs using IFC or through any extensions is not achieved. Analysing this result, it was concluded that this situation could occur due to the complexity of the modelled structures and used tools. Tekla developers have already issued the guidelines on how to create a reliable model for exporting, but they describe work with the standard tools. Some of the points were covered in the thesis, others can be found on the software user assistance website. Due to intermediate results, the work was continued using 3D dwg format and two re-engineered models were created.

In the process of work, the method of modeling reinforcement in Revit using Dynamo and AutoCAD was successfully tested. The method may be convenient for some models, but not so automated compared to “Concrete Bridge Reinforcement” extension for Tekla.

Research of BIM tools including cloud-based platforms (Trimble Connect and Dalux) showed that nowadays the programs can be modified to suit any particular task through using API and many of them seek to develop modern technologies: augmented and mixed reality is one of the current trends of development.

The experience of the tested and described re-engineering processes and the review of cloud-based programs can be useful in working life.

Future development of re-engineering requires better workflow between softwares which can be achieved by improved exporting/importing functions between formats or extensions and programs, by development of IFC data trasferring fullness or unified standard tools the means by which the models must be created in the way that models could be recognized by all other softwares.

FIGURES

CHARTS

TABLES

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APPENDICES

Appendix 1 File formats supported by Tekla

Format	Import	Export
aSa (.TEK)		X
Autodesk (.dwg, .dxf)	X	X
Bentley ISM	X	X
BIM Collaboration format (.bcf)	X	X
BVBS (.abs)		X
CIS/2 LPM5/LPM6 analytical / design (.stp , .p21 , .step)	X	X
CIS/2 LPM6 manufacturing (.stp , .p21 , .step)		X
CPIxml		X
DSTV (.nc , .stp , .mis)	X	X
EJE		X
Elematic ELiPLAN, ELiPOS (.eli)	X	X
EPC		X
Fabsuite (.xml)	X	X
FabTrol Kiss File (.kss)		X

FabTrol MIS Xml (.xml)	X	X
High Level Interface File (.hli)	X	X
HMS (.sot)		X
IBB Betsy (.fa , .f , .ev)		X
IFC2x2 (.ifc)	X	
IFC2x3 (.ifc)	X	X
IFC4 (.ifc)	X	
IFCXML 2X3 (.ifcXML)	X	X
IFCZIP 2x3 (.ifcZIP)	X	X
Initial Graphics Exchange Specification (IGES) (.iges , .igs)	X	X
LandXML (.xml)	X	
Microsoft Project (.xml)	X	X
Microstation (.dgn)	X	X
Oracle Primavera P6 (.xml)	X	X
Plant Design Management System (.pdms)		X
SAP, Oracle, ODBC, etc.	X	X

SketchUp (.skp)	X	X
Staad ASCII file (.std)	X	X
Steel Detailing Neutral Format (.sdf , .sdnf , .dat)	X	X
Steel12000		X
STEP AP203 (.stp , .step)	X	
STEP AP214 (.stp , .step)	X	X
StruM.I.S	X	X
Tekla BIMsight project file (.tbp)	X	X
Tekla Collaboration file (.tczip)	X	X
Tekla-FabTrol Report (.xsr)		X
Tekla Structural Designer neutral file (.cxl)	X	X
Tekla Structures shape (.tsc)	X	X
Trimble Field Link .tfl	X	X
Trimble LM80 (.txt , .cnx)	X	X
TubeNC (.xml)		X
Unitechnik (.uni , .cam)		X

Appendix 2 File formats supported by Trimble Connect and Dalux

Trimble Connect	Dalux
- integrates with Autodesk Revit, Tekla Structures, Sketch Up native formats; *Trimble Connect Web:* IFC (2x3), IFCZIP, SKP (2018 and below), DWG (AutoCAD 2013 and below), Revit (2018 and below), DGN, IFCXML, STEP (.stp, .step), TCZIP. *Trimble Connect Desktop:* IFC (.ifc), IFC XML (.ifcXML), IFC ZIP (.ifcZIP), TC ZIP (.tcZIP), DWG (.dwg), DGN (.dgn), SKP (2018 and below), STEP (.stp, .step), IGES (.igs, .iges), Revit, DXF, Potree (Point Cloud), LAS, LAZ. *Trimble Connect Mobile:* IFC (.ifc), IFC XML (.ifcXML), IFC ZIP (.ifcZIP), DGN (.dgn), SKP (2018 and below), DXF. - integrates with Vico Office for scheduling and estimating using 3D model uploaded to the cloud; integrates with Prolog for using RFI’s and making different changes	- integrates with Autodesk Revit, Autodesk DWG, Autodesk DWF, IFC, BCF, PDF, JPEG and PNG formats