Reversible BIM

Reuse Potential Tool

Date: **16/12/2022**
Tool owner: **4D Architects ,Elma Durmisevic**

RBIM MODELLING PROTOCOL

Reversible BIM has been developed by Dr Elma Durmisevic in 2019 as a follow-up to the EU Buildings as Material Banks project, where the concept of reversible building design and tools such as Reuse Potential Tool have been validated. In 2019, Reuse Potential Tool has been digitised by 4D Architects to enable digital assessment of Reuse Potential of building elements. As such, RBIM has become one of four digital tools that have been integrated into the Digital Deconstruction Platform and tested by GTB Lab.

Reversible BIM has two features:

1. ***Digital Parametric representation of Building*** containing information about geometry, location, function, relationships and connections between building elements. Reversible BIM translates 3D point cloud files from 3D scanning (with the help of additional technical building specifications) into standardised geometry and properties that enable digital reversibility analysis of the building and its materials. Such a reversibility assessment enables the specification of reuse and disassembly strategies for high value recovery of components and materials, which are explained as the second feature below.
2. ***Digital Reversibility Assessment (DRA)*** provides an assessment of reversibility/reuse potential using the model of (Durmisevic, 2019), which was developed to assess how easily building products and materials can be recovered without damaging the surrounding parts. It also links the assessment to multiple reuse options and the reversibility category of the building/product. The model measures the effort and time required to recover an element from the building, as well as the level of damage that occurs during the disassembly process (to the element itself and to surrounding elements). This reversibility assessment is performed at three levels of the technical composition of the building (i.e. building, system and component levels) (Durmisevic 2019).

Based on the Digital Reversibility Calculation, a score indicates the Reuse Potential of each element in a building. The Reuse Potential (RP) scoring system from Dr E. Durmisevic's methodology (ranging from 0.1 worst to 0.9 best) classifies all building elements into three categories: (i) irreversible buildings (are building elements/materials with low Reuse Potential, materials are in degrading loop towards recycling and down cycling), (ii) partially reversible buildings (partial Reuse Potential, materials can be remanufactured or reused after major repair and (iii) reversible buildings (buildings whose materials can be reused directly or after minor repair or reconfiguration). The Reversibility of buildings measured by Reuse Potential indicates the reuse options that products and materials have after recovery. As it measures effort and time, the model also takes into account the number of disassembly steps and operations required to recover an element. Ultimately, the model results provide a solid basis for environmental and economic assessment of disassembly and recovery operations (see Figure 4). This calculation system is based on the model E.Durmisevic updated in 2009 and tested and verified during the EU H2020 BAMB-Buildings as Material Banks project (Durmisevic, 2006), (Durmisevic, 2019).

In order to use RBIM for automated assessment of buildings Reversibility and Reuse Potential of its materials BIM modeler needs to follow modeling rules that enable reversibility assessment of digital building model.

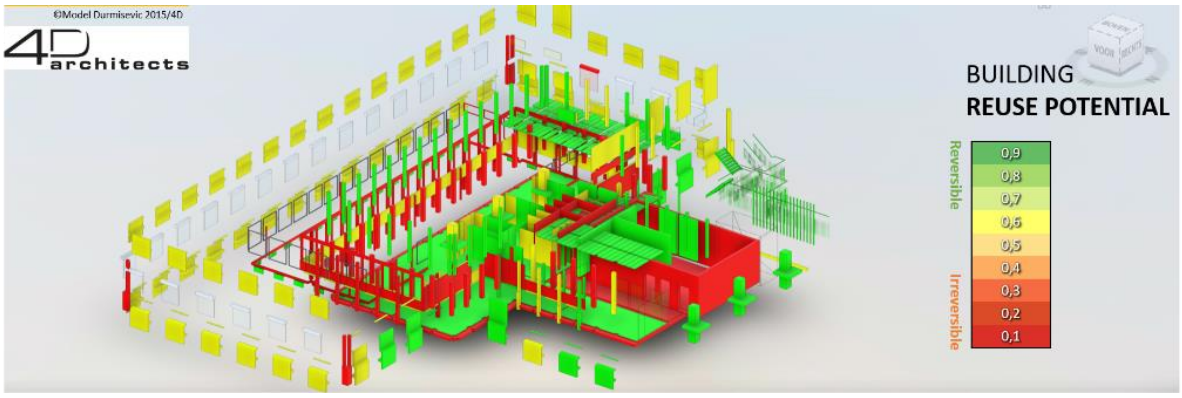


Figure. Color coded Reversible BIM module, (model E.Durmisevic)

This document specifies rules and recommendations for modelling in Revit for the purposes of creation of Reversible BIM which enables assessment of Reus Potential

RBIM Protocol

1. MODELLING SETUP

1.1. Modelling is done in Revit
Current RBIM add-in version only supports Revit version 2018 to 2022

1.2. Revit project is created using RBIM Template file (.rte), which contains all the parameters needed for RBIM analysis and calculations.

1.3. Parameters used for RBIM analysis are by definition shared and specified in the shared parameter file "RBIM.txt", is divided into four parameter groups:

GROUP 1 **RBIM Analysis Parameters:**
RBIM Assembly Sequence
RBIM Total Reversible-Reuse Potential

GROUP 2 **RBIM Functions:**
RBIM Vertical Communication
RBIM Multifunctional
RBIM Load-bearing
RBIM Intermediary
RBIM Servicing
RBIM Enclosure
RBIM Partitioning
RBIM Equipment

RBIM categories including main building functions and sub-functions

1. Load bearing	man structure inner wall
	main structure outside wall
	slab (main structure in-between floors)
	basement slab main structure
	roof slab main structure
	ethic slab main structure
	main structural columns
	main structural beams
	floor infill horizontal (secondary structure between loadbearing beams)
	roof infill (secondary structure between loadbearing beams)
	substructure
	structure protection material
	other

2. Enclosing	Non-loadbearing wall
	insulation (servicing)
	facade finishing
	external windows
	external doors
	roof insulation
	roof finishing
	horizontal facade bars (base)
	vertical façade bars (base)
	base for facade
	intermediary element
	facade ventilation elements
	other

3. partitioning	partitioning wall
	inner floor insulation (servicing)
	inner wall insulation (servicing)
	indoor door
	indoor window
	floor finishing
	ceiling finishing

	partitioning wall (finishing)
	prefab partitioning wall panels
	prefab sanitary panels
	support partitioning wall (base)
	intermediary element
	other
4. installation services	**main installation net**
	water
	electricity
	HAVAC
	ICT
	rain water
	base for main installation (base)
	connector
	distributing installation network
	water
	electricity
	HAVAC
	ICT
	rain water
	base for distribution installation (base)
	intermediary element
	outlets
	switches
	other installation units
	base for outlets (base)
	intermediary element
	installation equipment's
	boiler
	heat pumps
	PV panels
	batteries
	converter
	heat exchange units
	air handling units
	electricity meter
	water meter

5. intermediary	**intermediary between two building functions**
	intermediary between two building products
6. multifunctional	loadbearing /finishing
	insulation/ finishing
	loadbearing/Vertical communication
	other
7. vertical communication	lift
	escalator
	staircase
	ramp
	other
8. equipment	kitchen sink
	toilets
	heating elements
	other

GROUP 3 **RBIM Technical Lifecycle:**
RBIM Year Built
RBIM Last Renovation

GROUP 4 **RBIM Element Data:**
RBIM Element Condition

1.4. RBIM template contains 3D views set up for color-coded presentation of four views namely:

- RBIM functions (with a view template based on RBIM Function parameters)
- number of relations between elements
- assembly sequence
- total RP

1.5. LEVEL NAMES:
All levels should be named Plan xx (where xx = 00 for ground floor, -01, -02, etc. for underground levels, and 01, 02, etc. for levels above ground)

RBIM uses BIM material database for specification of materials. This database is based on ICE database and links on one hand sad material specification directly with embodied CO2 information and on the other material specification with technical life cycle of materials(which is based on Dutch technical life cycle database and heritage experts assessing durability of materials built in before 1940)

2. MODELLING APPROACH:

2.1. Geometry should be created in a way that would reflect the existence (touching) or non-existence (avoiding contact) of connections between elements.
A connection will be detected if the distance between elements is less or equal to 1 mm (this value can be modified in the add-in, but it cannot be zero).
2.2. Elements should be divided by levels
2.3. Hosted families, such as windows and doors should be created as self-standing. Any openings they would normally create in their usual hosts should be created in the host geometry by appropriate tools (profile edits, sketch edits etc.)
2.4. All families that will be analysed at system/component level must consist of nested families only. No voids should be used in the top-level family.
2.5. Use of complex geometry for the initial analysis should be avoided. Use low detail, rough representation of the overall geometry for the appropriate level analysis (e.g. a space frame at the building level should be a solid piece of geometry, and only developed in more detail for the system level analysis).
2.6. Elements that have standardized intermediary connections via specialized systems as ceiling of faced systems should model one simple zone that will be called intermediary zone and avoid further detailing.
2.7. Walls covered with plaster work do not need plaster layer instead a symbol can be created hosing information about the size/m2 of the wall. Material will be assigned to the system.
2.8. Elements that do not real connection as floor finnishing (tiles, screed etc) and surrounding walls, etc. need to be modelled with an offset from other elements larger than 1mm. This applies to floor finishing, ceiling systems etc.

3. NAMING STANDARD

Certain naming standards is applied within RBIM

3.1. Element Family/Type names should all be formatted as *FUNCTION – CATEGORY – OTHER DATA*
For the *FUNCTION*, only first three letters of the function name should be used.
CATEGORY will include standard building component categories (wall, floor, window, door…)
OTHER DATA includes all relevant information about an element that makes it different from other types of the same family (material, dimensions…)

Example of naming of a window: ENC window wood 1000x1200 mm

4. ASSEMBLY SEQUENCE

RBIM is analysing assembly and disassembly sequences. In order to do so information about assembly sequence needs to be added to the elements as listed bellow

4.1. The first modelled geometry must be assigned assembly sequence 1
4.2. All elements must be in an interrupted sequence

5. GENERAL RECOMMENDATIONS

5.1. During the work on a model, it is advisable to use the “Refresh Model” function (under Tools), if any of the analysed elements have been deleted
5.2. If any changes in geometry are made, the “Detect Connections” tool should be rerun, and all its set connection types should be revised.
5.3. The tool will detect all connections between elements, even when elements “touch” diagonally in a single point. Such cases should be recognized beforehand and avoided by careful modelling and making planned changes in geometry that would prevent them from touching (moving one element from the other by 1mm, or resizing the part that creates contact). Otherwise, this will cause a significant amount of unnecessary manual work to remove those false connections.
5.4. In certain cases of irregularly shaped geometry, the tool may detect connections that actually do not exist. All such elements and their detected connections should be carefully reviewed.
5.5. Zones consisting of a large number of identical elements (tiles, façade panels, etc.) can be modelled as single unified geometry, as long as the dimensions of the single component are recorded. In such cases, their connection with other elements that support them needs to be defined at the beginning, as “intermediary zones”.

6. MODELING STAPES

6.1 Preparation stapes

Prior to modelling four preparation staps need to be made in Revit as listed bellow:

STAP 1: Add RBIM Year Built parameter in Project Information
STAP 2: Add RBIM Last Renovation parameter in Project Information
STAP 3: Create specific 3D color-coded views
STAP 4: Check your project parameters and make sure that you have all RBIM parameters included

See examples for each of the stapes illustrated in the screen short tables bellow.

STAP 1:

Project Information

Family: System Family: Project Information — Load...

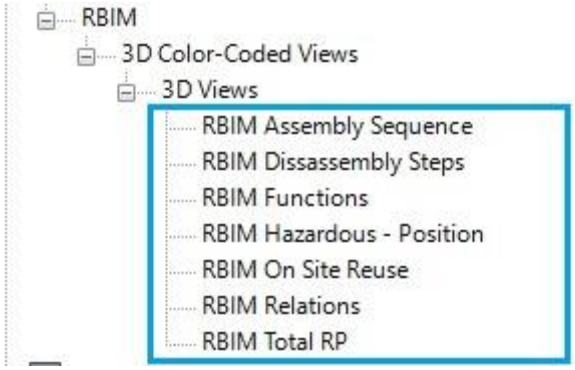
Type: — Edit Type...

Instance Parameters - Control selected or to-be-created instance

Parameter	Value
Identity Data	
Organization Name	
Organization Description	
Building Name	
Author	
Energy Analysis	
Energy Settings	Edit...
Route Analysis	
Route Analysis Settings	Edit...
Other	
Project Issue Date	Issue Date
Project Status	Project Status
Client Name	Owner
Project Address	## Street
Project Name	Project Name
Project Number	Project Number
Assembly Sequence	
RBIM Assembly Sequence	
RBIM Disassembly Steps	
RBIM Number of Connections	
RBIM Total Reversible-Reuse Potential	
RBIM Disassembly Typology	
RBIM Element Condition	
RBIM On Site Reuse	☑
RBIM Product	
RBIM Embodied CO2	
RBIM Last Renovation	2010
RBIM Year Built	1939

OK Cancel

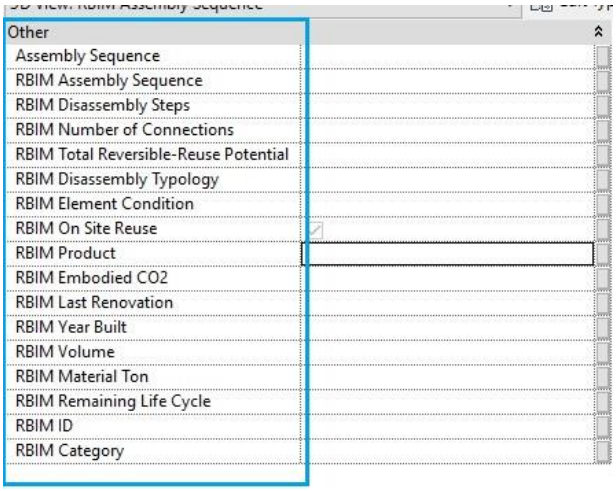
STAP 2



STAP 3

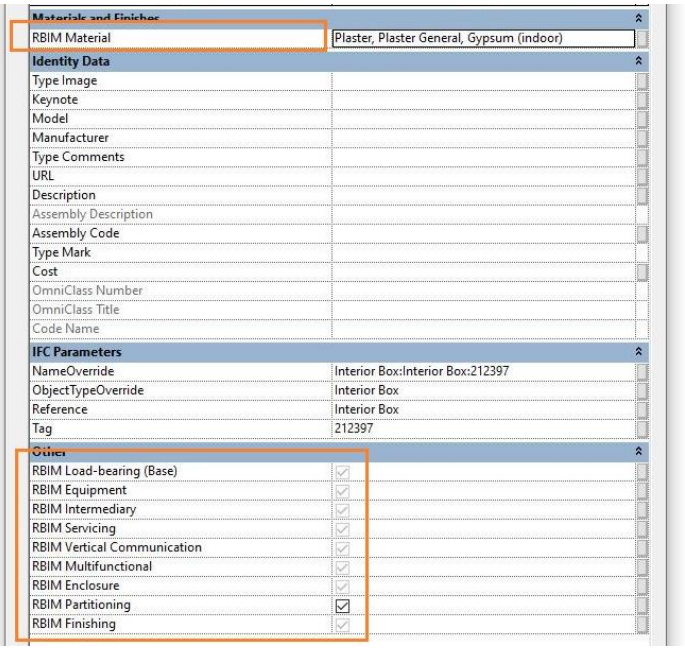
Shared parameters in Project parameter (Instance parameters and Type parameters)

Instance parameters:



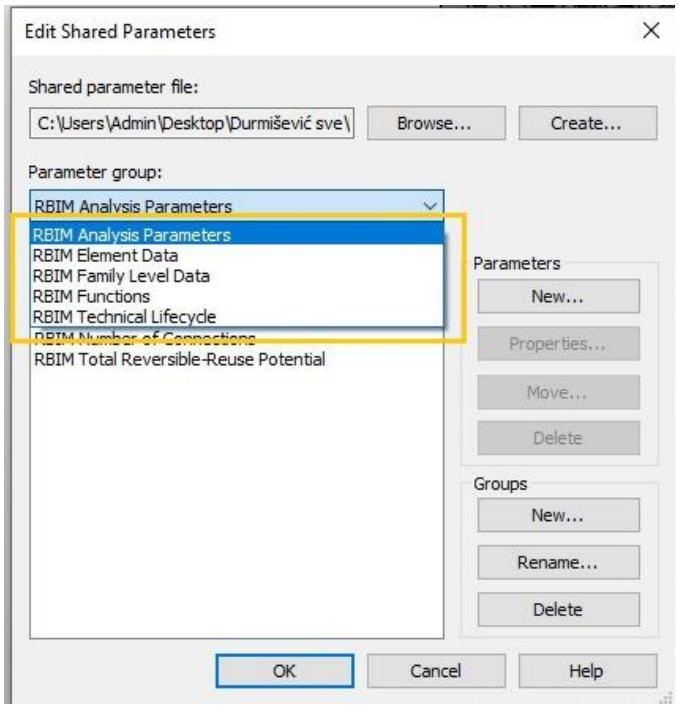
Assembly Sequence
RBIM Assembly Sequance
RBIM Disassembly Steps
RBIM Number of Connections
RBIM Total Reversible-Reuse Potential
RBIM Disassembly Typology (Sequential, Parallel)
RBIM Element Condition (Regular, Partly Damaged, Fully Damaged)
RBIM On site Reuse (yes/no checkmark)
RBIM Product (Element, Component)
RBIM Spaces (Space 1, Space 2, Space 3...)
RBIM Embodied CO2
RBIM Last Renovation
RBIM Year Built
RBIM Volume
RBIM Material Ton
RBIM Remaining Life Cycle
RBIM ID
RBIM Category (Generic Models)

Type parameters:



RBIM Material
RBIM Load-bearing (Base)
RBIM Equipment
RBIM Intermediary
RBIM Servicing
RBIM Vertical Communication
RBIM Multifunctional
RBIM Enclosure
RBIM Partitioning
RBIM Finishing

Shared parameters have FIVE PARAMETERS GROUPS with sub-parameters which are illustrated on print screen table in text below.



RBIM Analysis Parameters (instance param.

- Assembly Sequence (text)
- RBIM Assembly Sequence (text)
- RBIM Disassembly Steps (text)
- RBIM Number of Connections (integer)
- RBIM Total Reversible – Reuse Potential (number)

RBIM Element Data RBIM Disassembly Typology (text – instance)

- RBIM Element Condition (text - instance)
- RBIM Material (text – type param.)
- RBIM On Site Reuse (yes/no – instance)
- RBIM Spaces (text - instance)
- RBIM Product (text - instance)

RBIM Family Level Data (instance param.)

- RBIM Category (text)
- RBIM Embodied CO2 (number)
- RBM ID (text)
- RBIM Material Ton(age) (number)
- RBIM Remaining Life Cycle (number)
- RBIM Volume (number)

RBIM Functions (type param.)

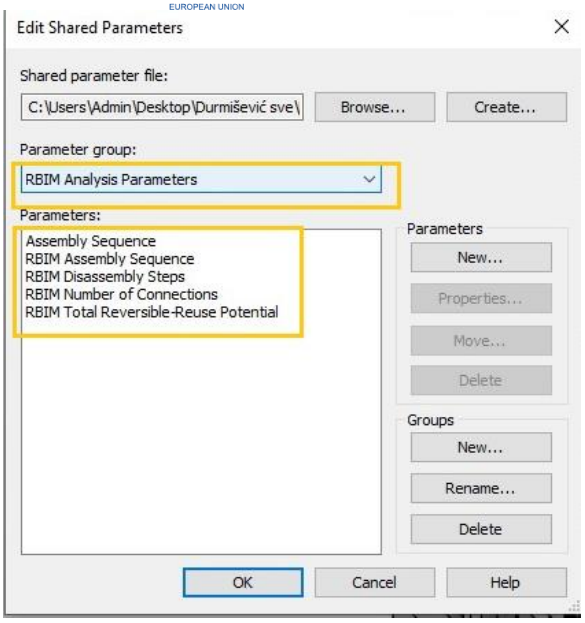
- RBIM Enclosure (yes/no checkmark)
- RBIM Equipment (yes/no checkmark)
- RBIM Finishing (yes/no checkmark)
- RBIM Intermediary (yes/no checkmark)
- RBIM Load-bearing (Base) (yes/no checkmark)
- RBIM Multifunctional (yes/no checkmark)
- RBIM Partitioning (yes/no checkmark)
- RBIM Servicing (yes/no checkmark)
- RBIM Vertical Communication (yes/no checkmark)

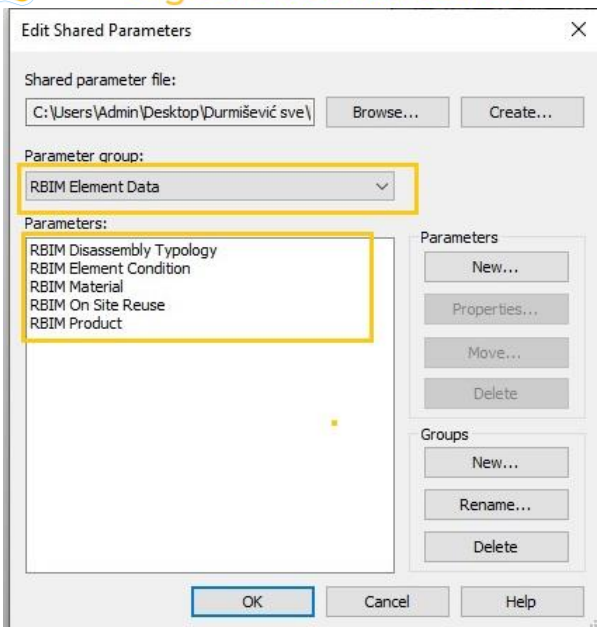
RBIM Technical Lifecycle (instance param.)

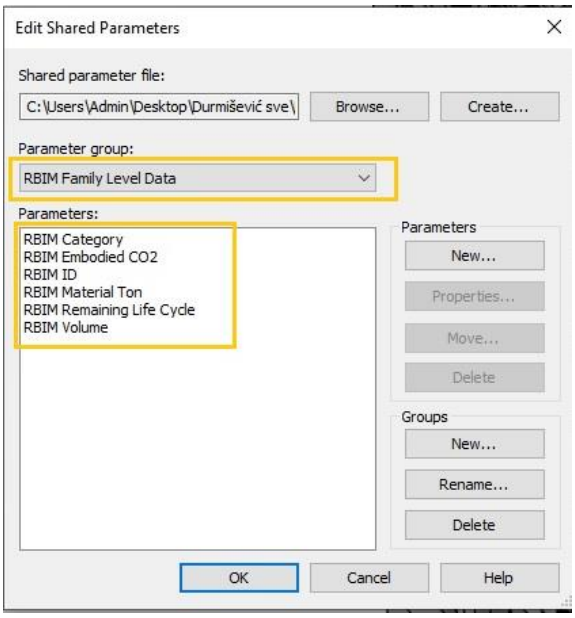
- RBIM Last Renovation (integer)
- RBIM Year Built (integer)

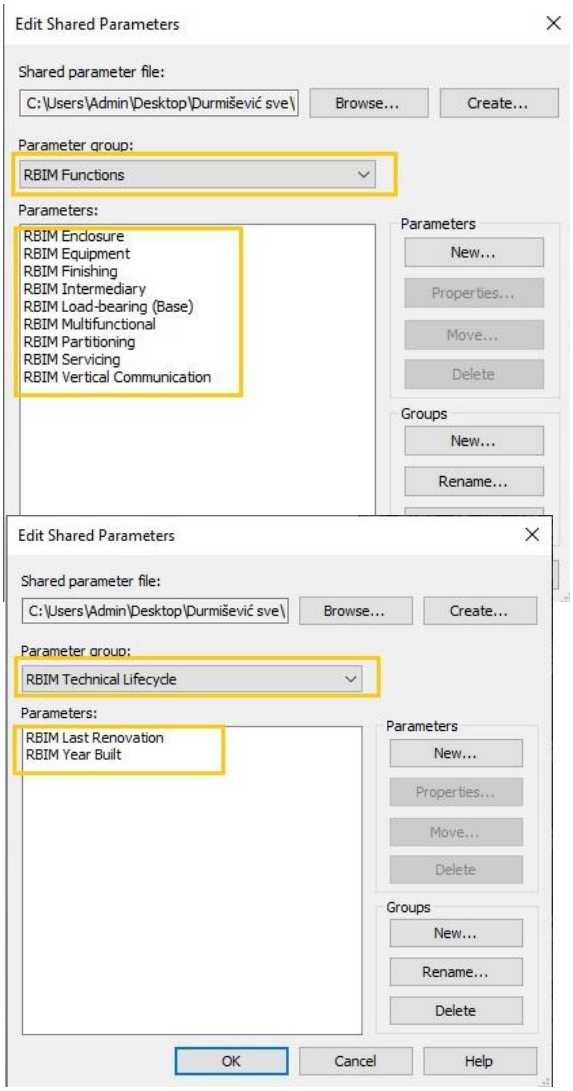
Reversible BIM

Reuse Potential Tool









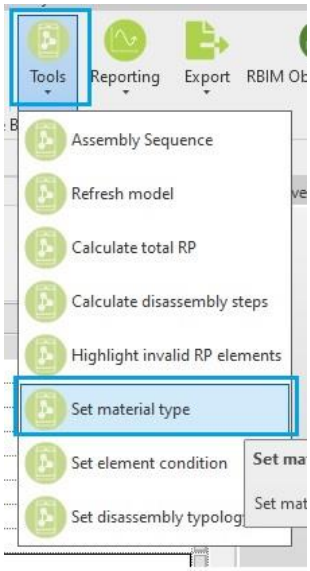
6.2 Adding RBIM information to the model

Once the basic geometry of the model has been created in a project template prepared with RBIM parameters and following the rules defined in Chapter 2, the ©RBIM plugin is used to add ©RBIM relevant information to the model. Six steps are identified to do this:

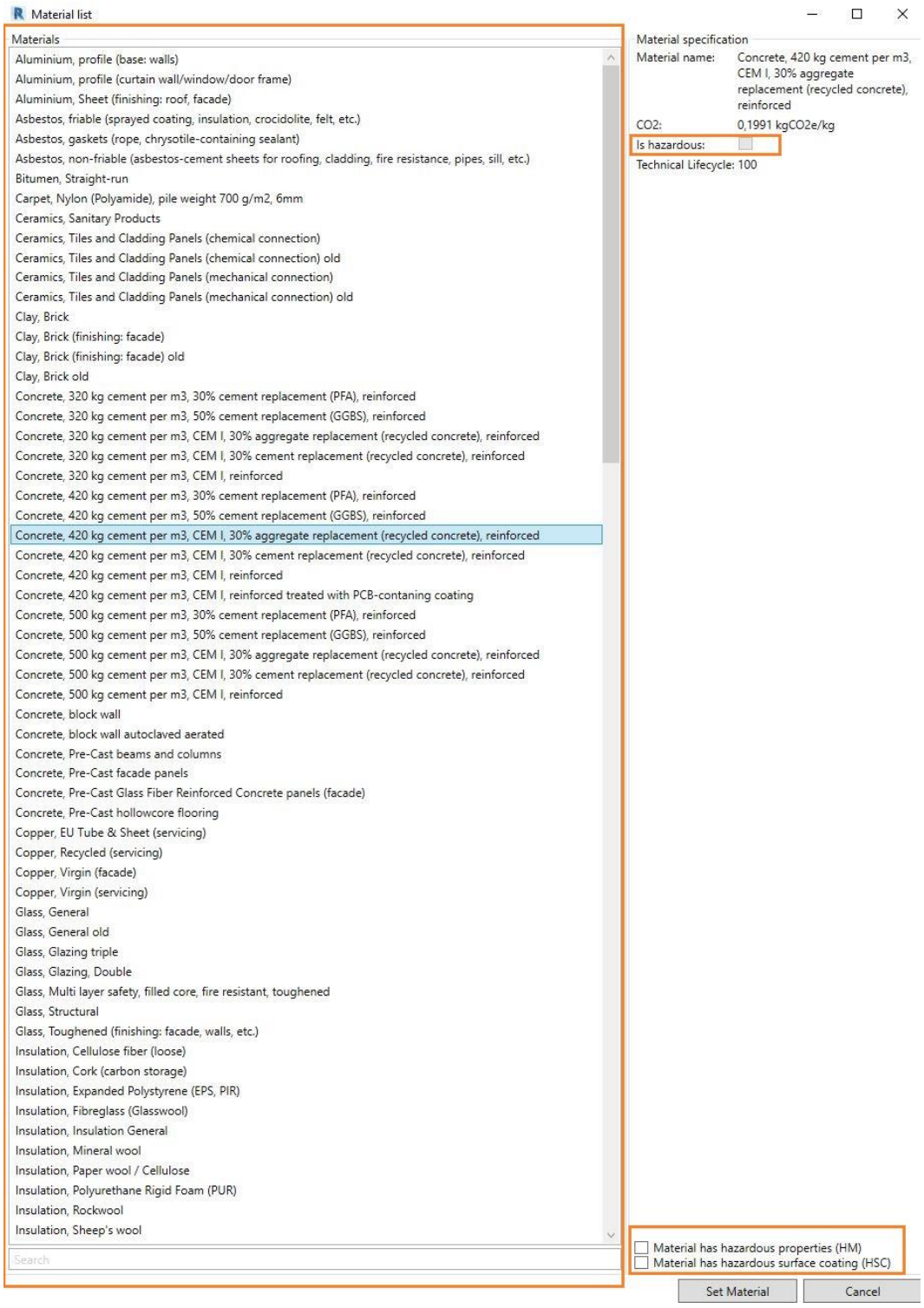
1. Assign RBIM materials to each element/material
2. Mark all categories/functions in Properties for each element/material
3. Detect all connections between individual element/material and surrounding element/material
4. Set connections types for each identified relation by RBIM
5. Apply connections on all similar elements with same connections
6. Check if all Assembly staps are assigned

Examples of each step in the process are shown below

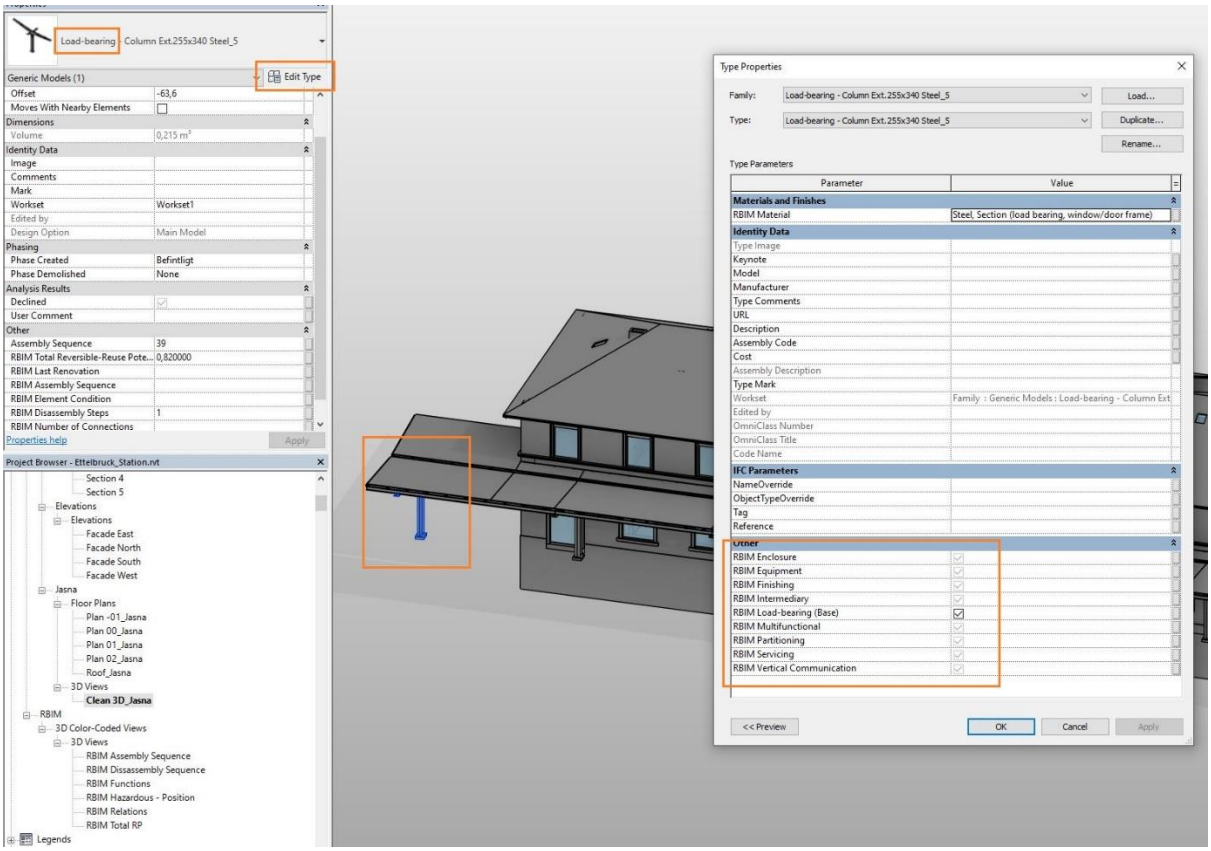
6.2.1 Assign RBIM materials to each element – select specific element, set material type, select material from Material list, check if the material has a hazardous surface coating (HSC) or if the material has hazardous properties (HM)



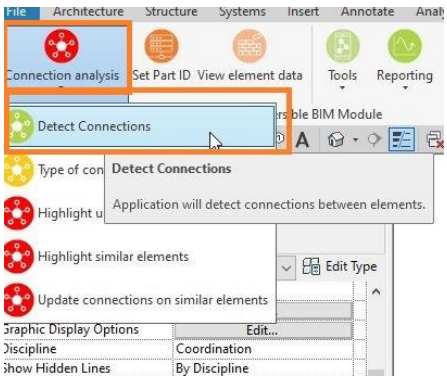
When selecting material within an existing building, it is possible to specify whether the material itself has hazardous properties or whether it may have a hazardous coating. When specifying the type of joint at a later stage, it is also possible to specify whether the joint itself contains a hazardous material.

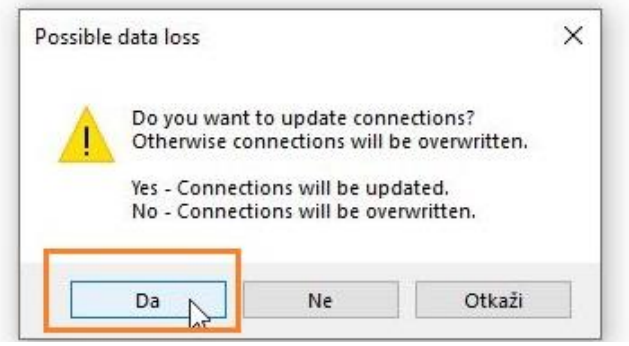


2. **Mark all categories/functions in Properties for each element/material**
   Checkmark all categories/functions in Properties for each element – select an element, edit type, checkmark the appropriate category

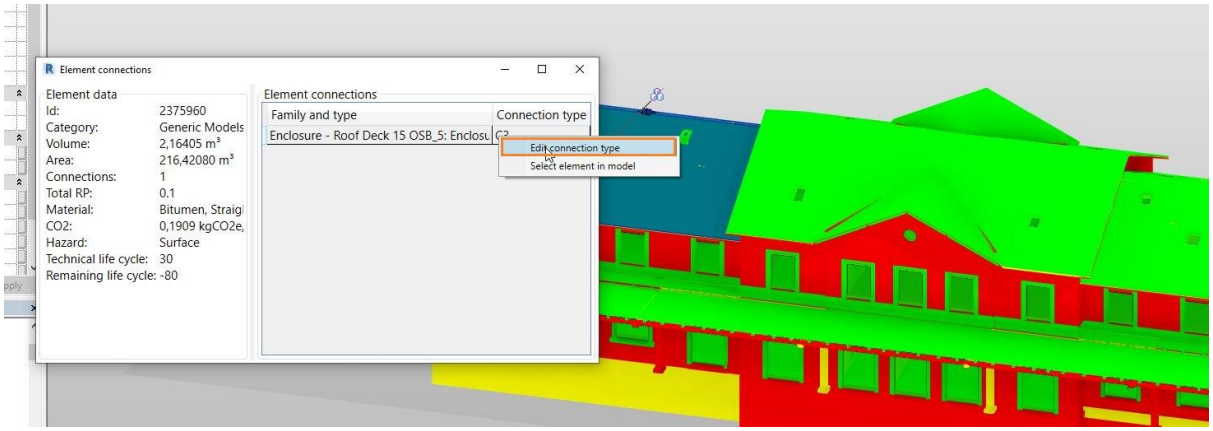


3. **Detect all connections between individual element/material and surrounding element/material**
   detect connections first and then set all for each element. During this process a update menu will pop up asking whether you wont to update connections or overwrite the connections

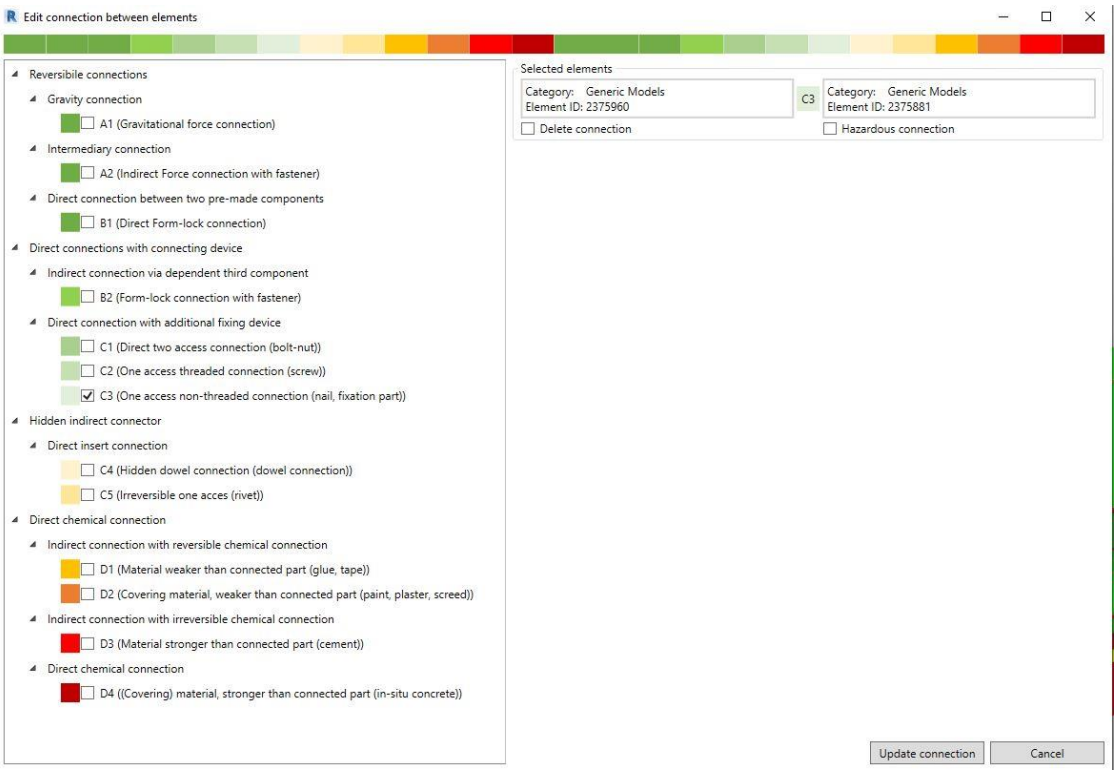




4. **Set connections types for each identified relation by RBIM**
   Select an element in a model, right-click Edit connection type



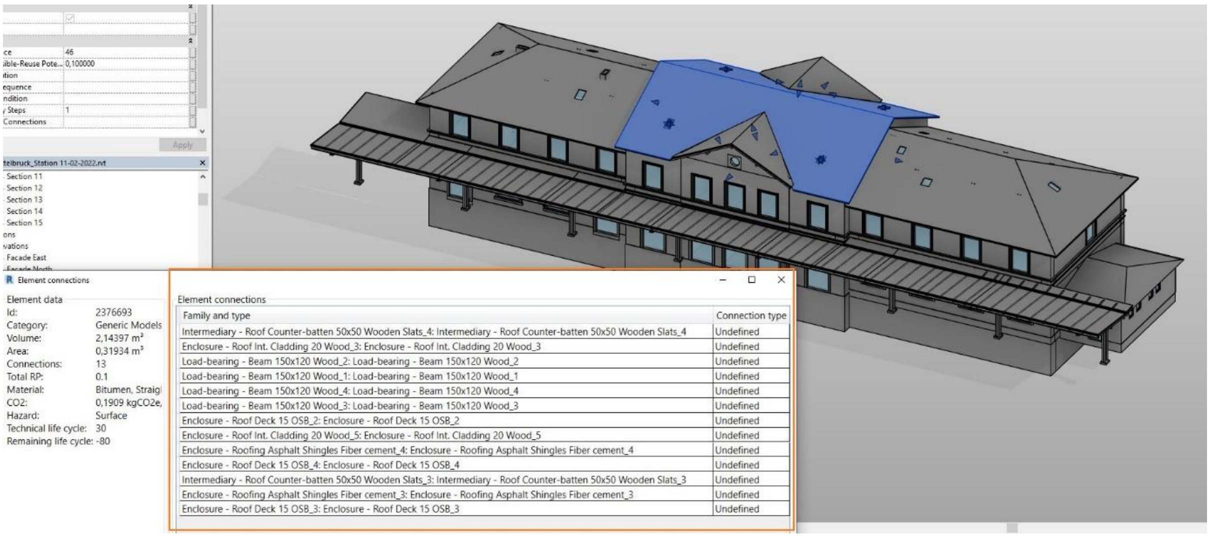
Checkmark the appropriate Connection type by choosing a connection type form the RBIM connections (see bellow).



After all connection types are assigned to individual connections that one element has with others all connections are listed in Element connections window and number of connections added to the Element Data list. An example is illustrated on print screen table.

Reversible BIM

Reuse Potential Tool



Element connections

Element data

Id:	2117654
Category:	Generic Models
Volume:	23,58480 m³
Area:	10,24444 m³
Connections:	44
Total RP:	0.57
Material:	Stone, Sandstone old
CO2:	0,06 kgCO2e/kg
Hazard:	None
Technical life cycle:	500
Remaining life cycle:	390

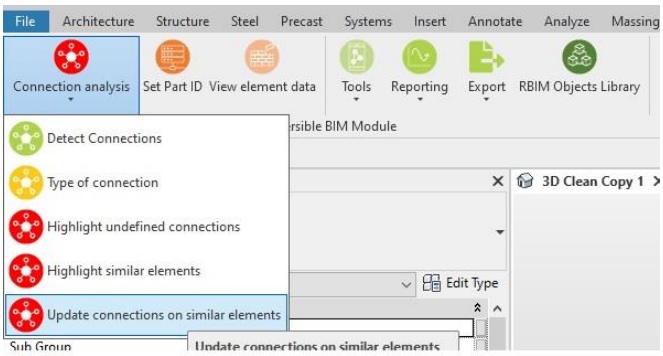
Element connections

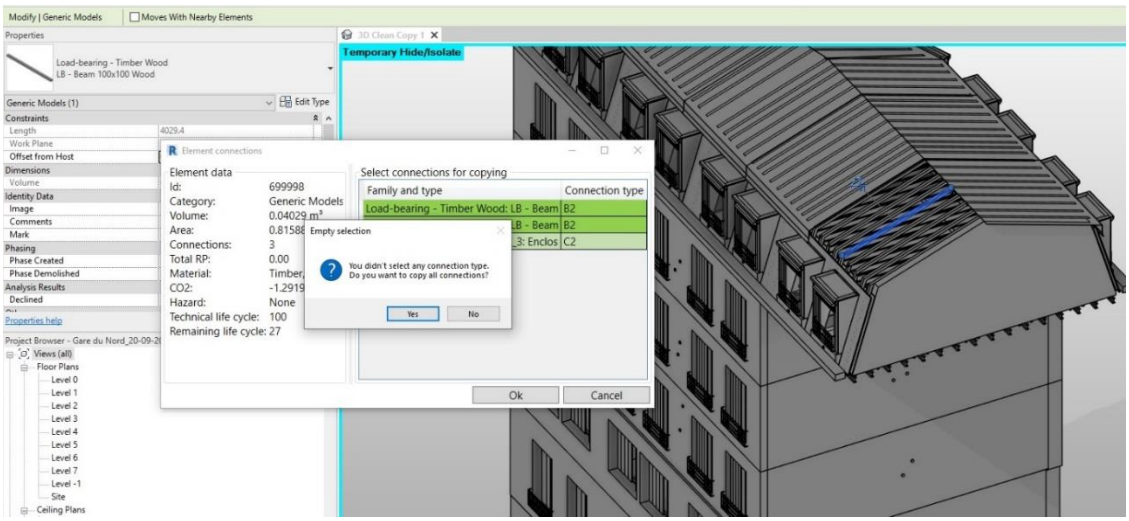
Family and type	Connection type
Load-bearing - Wall Ext. Masonry 480 Stone_7: Load-bearing - Wall Ext. Masonry 480 Stone_7	D2
Load-bearing - Wall Ext. Masonry 480 Stone_5: Load-bearing - Wall Ext. Masonry 480 Stone_5	D2
Load-bearing - Wall Ext. Masonry 480 Stone_3: Load-bearing - Wall Ext. Masonry 480 Stone_3	D2
Load-bearing - Wall Int. Masonry 400 Stone_13: Load-bearing - Wall Int. Masonry 400 Stone_13	D2
Load-bearing - Wall Ext. Masonry 480 Stone_8: Load-bearing - Wall Ext. Masonry 480 Stone_8	D2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Timber Wood: Load-bearing - Beam 100x80 Wood	A2
Load-bearing - Floor Slab 200 Reinforced Concrete_3: Load-bearing - Floor Slab 200 Reinforced Concrete_3	D2
Load-bearing - Beam Ext.C profile 80x180 Steel_2: Load-bearing - Beam Ext.C profile 80x180/3900 Steel	A2
Load-bearing - Beam Ext.C profile 80x180 Steel_2: Load-bearing - Beam Ext.C profile 80x180/3750 Steel	A2
Enclosure - Window Masonry 190x200 Stone_19: Enclosure - Window Masonry 190x200 Stone_19	D2
Enclosure - Double Window Glass: Enclosure - Double Window 1260x1910 Glass	B2
Enclosure - Window Masonry 190x200 Stone_22: Enclosure - Window Masonry 190x200 Stone_22	D2
Enclosure - Double Window Glass: Enclosure - Double Window 1260x1910 Glass	B2
Enclosure - Window Masonry 190x200 Stone_21: Enclosure - Window Masonry 190x200 Stone_21	D2
Enclosure - Double Window Glass: Enclosure - Double Window 1260x1910 Glass	B2
Enclosure - Window Masonry 190x200 Stone_20: Enclosure - Window Masonry 190x200 Stone_20	D2
Enclosure - Double Window Glass: Enclosure - Double Window 1260x1910 Glass	B2
Enclosure - Window Masonry 190x200 Stone_34: Enclosure - Window Masonry 190x200 Stone_34	D2
Enclosure - Double Window Glass: Enclosure - Double Window 1260x1910 Glass	B2
Finish - Wall Plaster Gypsum: Finish - Wall Plaster Gypsum	D2
Finish - Int. Wall Paint: Finish - Int. Wall Paint	D2
Enclosure - Facade Decorative Element Stone_19: Enclosure - Facade Decorative Element Stone_19	D2
Enclosure - Facade Decorative Element Stone_20: Enclosure - Facade Decorative Element Stone_20	D2
Enclosure - Facade Decorative Element Stone_21: Enclosure - Facade Decorative Element Stone_21	D2
Enclosure - Facade Decorative Element Stone_22: Enclosure - Facade Decorative Element Stone_22	D2
Enclosure - Facade Decorative Element Stone_9: Enclosure - Facade Decorative Element Stone_9	D2
Enclosure - Facade Decorative Element Stone_24: Enclosure - Facade Decorative Element Stone_24	D2

5. Apply connections on all similar elements with same connections

Update connections on similar elements

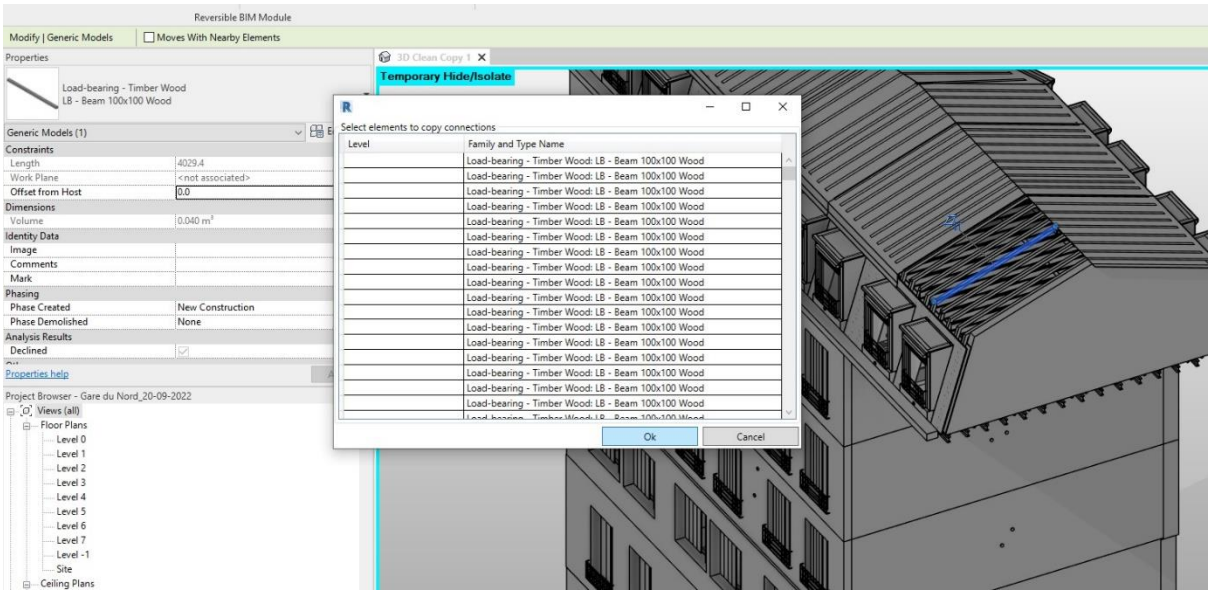
Select an element with all connections applied, then choose Update connections on similar elements, click OK. Then copy connections to all similar elements and click – OK.
Some examples are illustrated below.

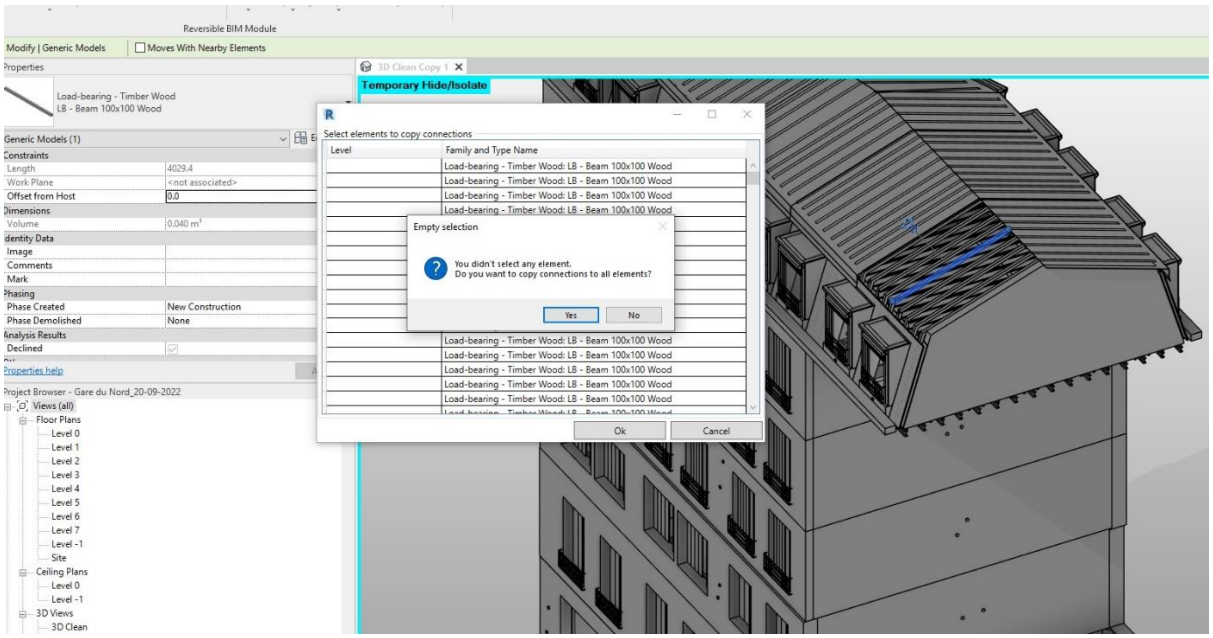




Reversible BIM

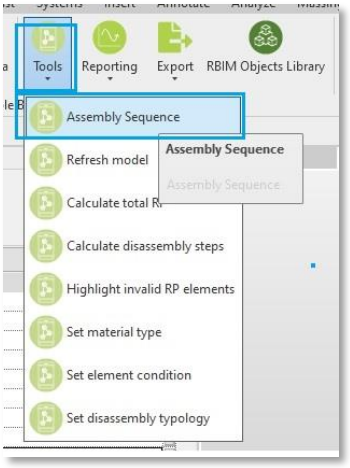
Reuse Potential Tool





6. Asign assembly sequences

First, we need to arrange all the elements according to an assembly sequence. This means, elements on the left side drag and drop to the right side and then click Update (Update is Save).

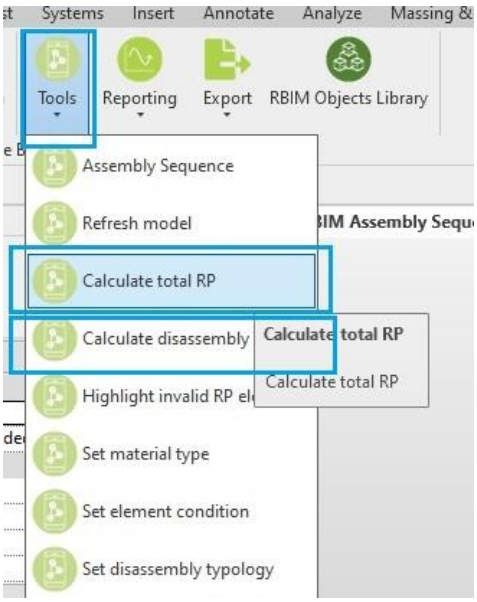


7. Check if all Assembly steps are assigned

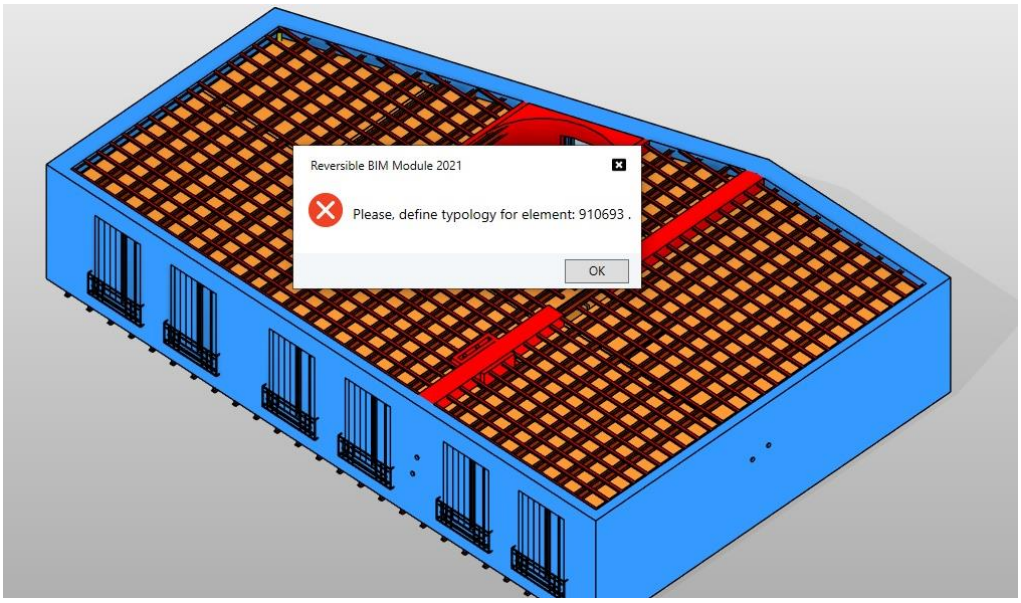
It is possible to check if everything is set up properly and done correctly if you use Calculate Disassembly steps or Calculate Total RP.

If some information is missing, messages will appear in a pop-up window such as:

- the assembly sequence should be done,
- the material should be applied,
- the element has no connections, or
- define typology for element.

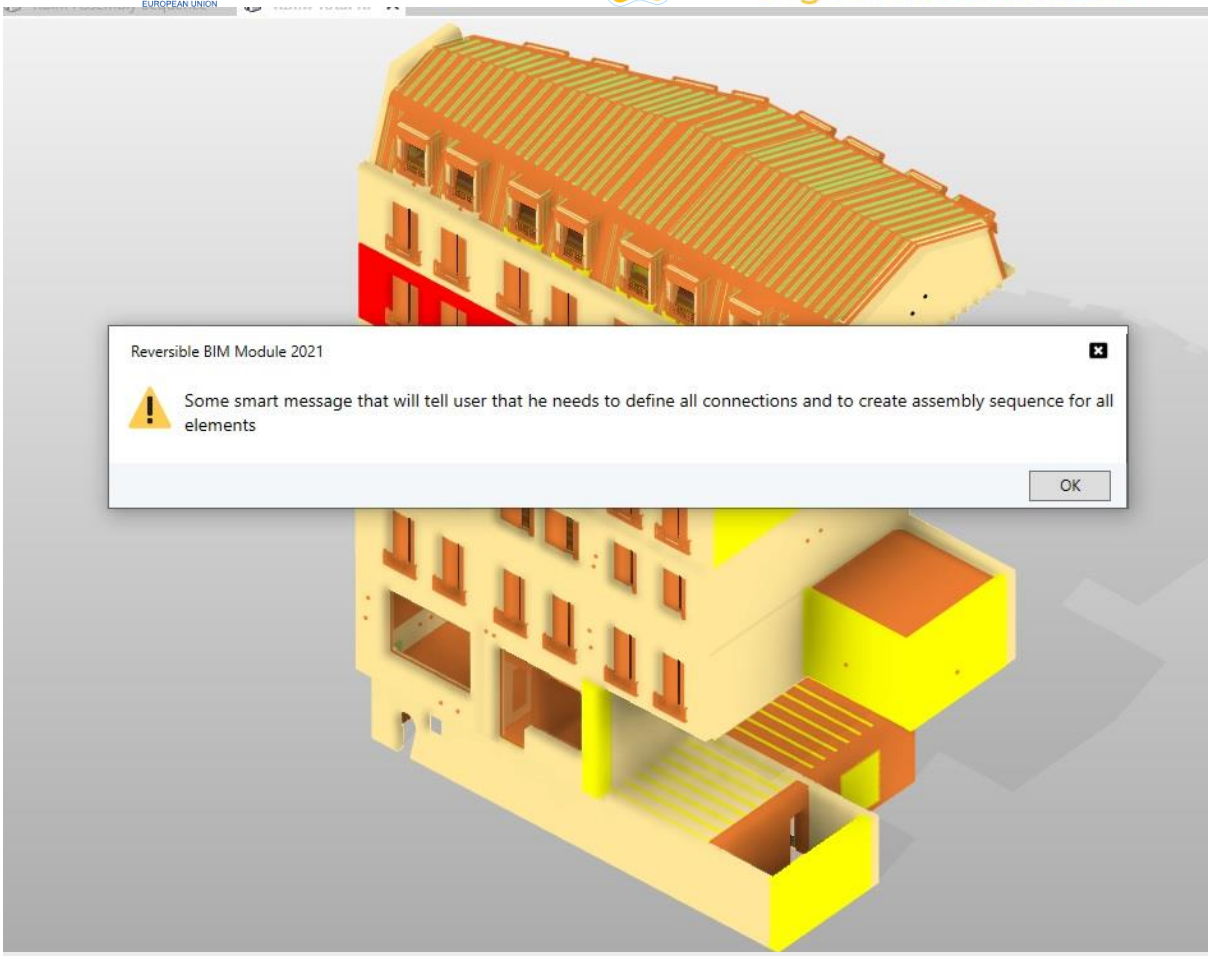


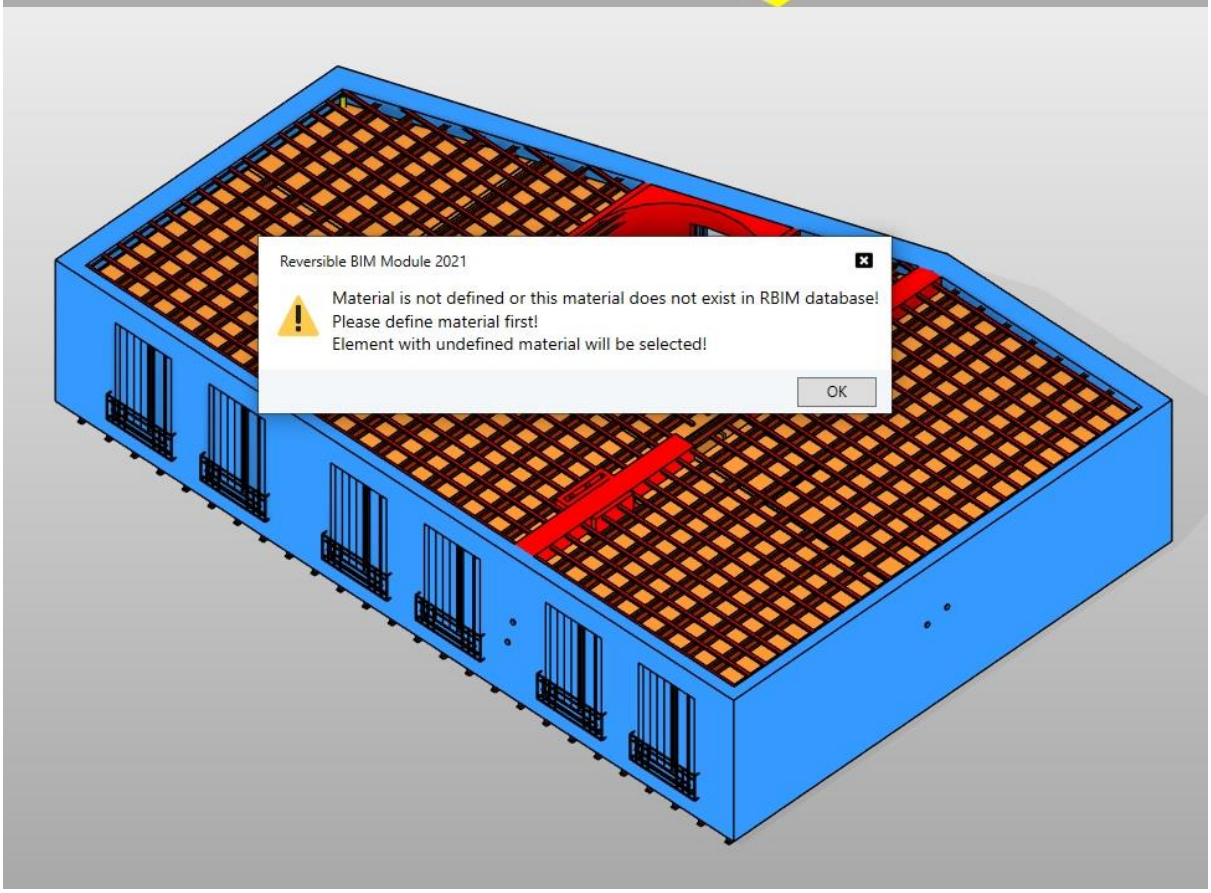
Examples of possible pop-up messages that require additional information are illustrated in the following print screen insulations.



Reversible BIM

Reuse Potential Tool





Reversible BIM

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