WPT3 - PILOT IMPLEMENTATION

Deliverable DT3.1.3

General protocol for the development of deconstruction and reuse strategies and undertaking deconstruction at pilots

(using DDC modules)

INDEX

ABBREVIATIONS

WP	Work Package
BIM	Building Information Modelling
CDW	Construction and Demolition Waste
DDC	DigitalDeConstruction
DRA	Digital Reversibility Assessment
MTA	Manual Testing Activities
DTA	Digital Testing Activities

DDC modules. *For homogeneity, DDC modules or DDC components are DDC modules.*
DDC platform. *In some case, you can find DDC system.*

1. INTRODUCTION

This deliverable is an output of the task DT3.1.3 *General protocol for the development of deconstruction and reuse strategies and undertaking deconstruction at pilots* of the DDC project. The task aimed to define a guidance document including a set of rules, advices to follow for the development of a deconstruction and reuse strategies using DDC tools.

It is addressed to the DDC partners (mainly pilot partners and their project teams) and the information will be used as inputs for guidance documents for external actors proposed at the end of the project.

A first word was carried out to define the reuse process inventorying all the phases/actions and their links. The resulted diagram, presented and shared on line with DDC partners, was used to then define rules and advices for each phase/action of the process. The diagram is presented in section 2.

Two entry points are proposed in this document to detail the support information. First, presented in section 3, is by DDC module. Respective developers (GTBLab, BIM-Y, BLM) detailed the interest of their modules in the process, aspects to take into account. The second, presented in section 4, is by phase/action of the reuse process. Information presented in the tables in this section were proposed by DDC partners collaboratively.

2. ROUTES FOR PREPARATION OF DECONSTRUCTION AND REUSE PROJECTS

Diagram of the reuse process was defined within the task and share with partner on line: https://miro.com/app/board/uXjVOdpBtHU=/

The diagram presents phases/actions of a reuse process using or not DDC tools. Thick arrows represent main routes, blue arrows routes using DDC tools (some are specific), double arrows interactive interactions.

The apparent complexity of the diagram reflects that there is not a unique route for a reuse approach but many different routes in function of specific context of each project.
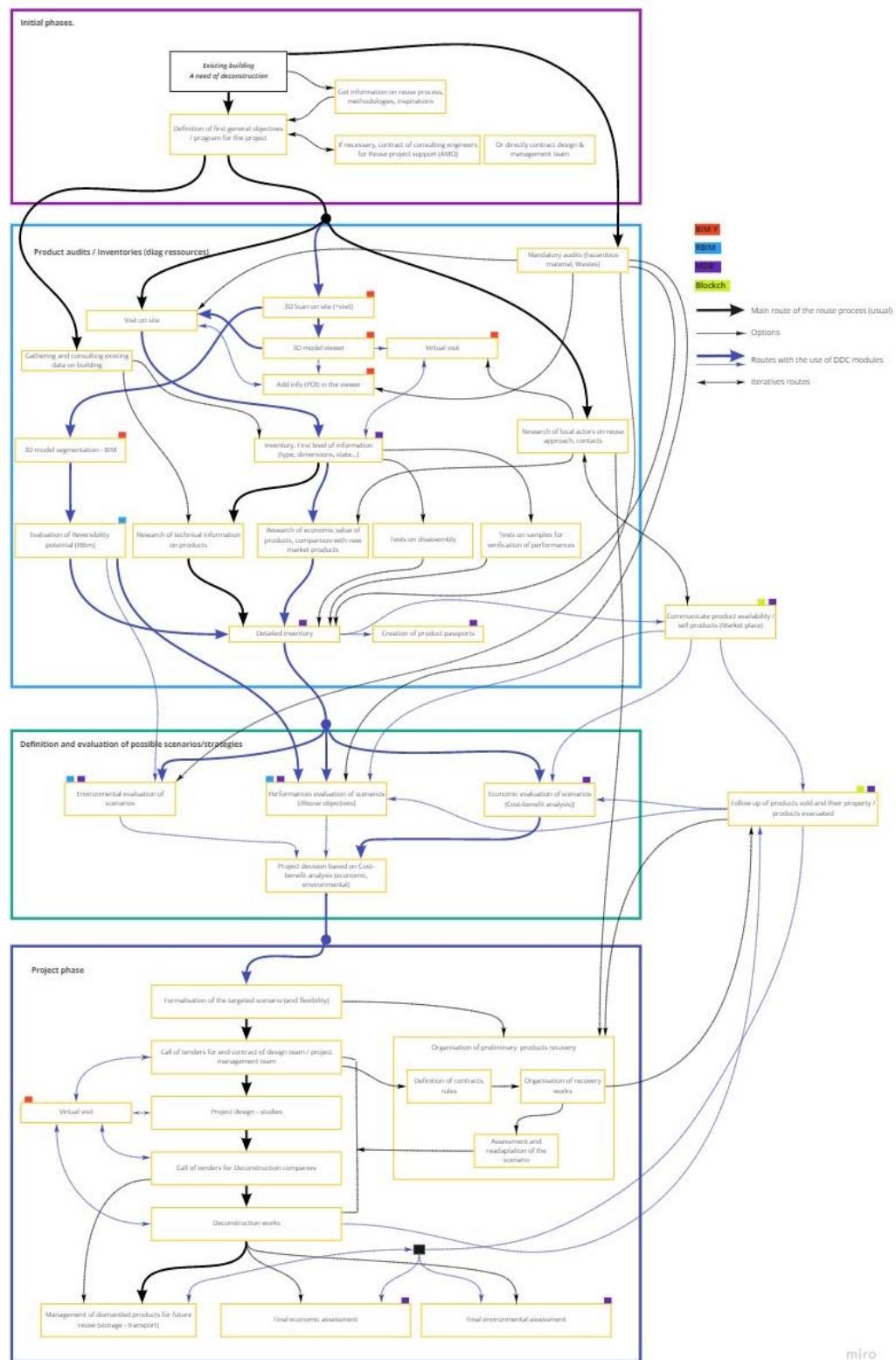
Figure 1 : diagram of potential routes of a reuse approach

3. MAIN RULES BY MODULE

3.1. 3D Scan and viewer

The 3D Scan is the first step to the creation of the digital twin of the building which will be deconstructed.

Laser scanning has been around since the 60's. But the first 3D scanner used by surveyors and engineers, appeared in late 90's.

One of the main rules using 3D scan for the DDC is to be fast and enough accurate to provide the best realistic view of an entire building.

For the DDC project, we use the mobile scanner VLX (manufactured by NavVis). Thus, we can scan (or map) around 10.000 sqm per day. And, at the same time, we take a lot of panoramic pictures of the building.

After the post-processing of the raw data, the building can be visited virtually through a web browser. The end-users can virtually visit the building and add manually some information to an asset and share them with the other stakeholders. They can make measurements or crop and download the point cloud or a part of it.

During the 3d scanning, we collect a lot of geometric data (point clouds and panoramic pictures) that we can use to automate the asset inventory processing of a building.

We use computer vision to automatically identify the assets (doors, windows, lights, sensors, …) and geolocate them inside the viewer.

The point cloud is used to create the Reversible BIM model and the list of assets provide accurate information to the Material Database.

3.2. Reversible BIM

Introduction

Reversible BIM module is a BIM software (owned by 4D architects) based on model (Durmisevic 2006 and 2015), that based on captured cloud of points (from 3D scanning) and with use of Revit plugin for digital reversibility assessment, enables the reconstruction of the digital model of existing building covering spatial dimensions, material relationships, quantities and reversibility and reuse properties of building and its components.

Reversible BIM has two integral features:
Digital Parametric representation of Building with information about geometry, position, function, relations and connections between building elements.

Digital Reversibility Assessment (DRA) provides assessment of reversibility/Reuse potential using model of, developed to assess how easy building products and materials can be recovered without damaging surrounding parts.

Therefore, reversible BIM module is a digital application for the assessment of reversibility and disassembly of buildings and building products resulting in calculation of reuse potential of building product and materials. At the same time RBIM stores and manages data about building materials, life cycle, functions, dimensions, volume, embodied carbon and reuse potential in a BIM environment

which enables micro and macro analyses of circular capacity of building and its material throughout building's life cycle. As such it generates information about number of deconstruction/ recovery steps of building materials, level of damage of material after recovery, reuse potential score reflecting the effort needed to recover as well as reapplication of materials indicating embodied environmental and economic value of recovered materials.

Reversibility assessment is carried out on three levels of building's technical composition (i.e., building, system and component level) (Durmisevic 2019, 2020).

Based on Digital Reversibility Calculation a score indicates Reuse Potential of each element in a building. Reuse Potential (RP) score (ranges between 0,1 worst and 0,9 best) sorts 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) partly reversible buildings (partial Reuse Potential, materials can be remanufactured or reused after major repair and (iii) reversible buildings (buildings whose materials can be directly reused or after minor repair or reconfiguration). Reversibility of buildings measured by Reuse Potential indicates reuse options that products and materials have after being recovered. As it measures the effort and time, the model also considers number of disassembly steps and operations needed to recover an element. Ultimately models result from a solid base for environmental and economic assessment of disassembly and recovery operations. The shorter the lifecycle feedback loop of a building product the lower environmental and economic impact and therefore the higher reuse potential score (See Figure below). This calculation system is based on Model Durmisevic published in 2006 updated in 2009 and tested and verified during EU H2020 BAMB-Buildings as Material Banks Project (Durmisevic, 2006), (Durmisevic, 2019).
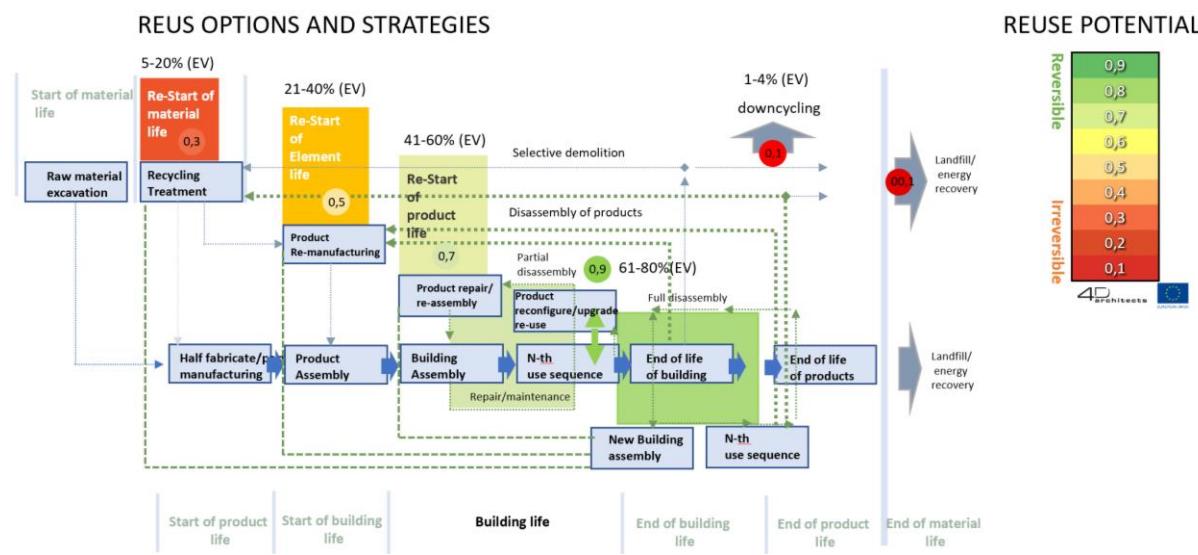
Relation between Reuse Potential score, reuse options of elements (Durmisevic, 2019)

How to create RBIM of a building?

Creating a RBIM for deconstruction projects stars with collection of point cloud files from 3D scanning, technical drawings and material list where available. Based on this data basic Reversible BIM representation of a building is created following protocol for modelling of RBIM. Once basic model has been created reversibility and disassembly of its parts is analysed with use of RBIM plugin which

enable automated creation of overview of number and type of relations that elements have between each other and hierarchical dependences that form obstacles for their smooth recovery.

RBIM Plug ins assess indicators which reflect reuse potential of individual elements such as:
- Number of relations
- Hierarchical dependency of individual element in assembly
- Type of connections and level of damage
- Assembly/Disassembly sequences
- Life cycle coordination

Final Reuse potential is calculated while taking into account different weighting factors of above-mentioned individual indicators with regards to reuse potential. Having that in mind indicators with higher impact on Reuse potential Score /weighting factor are type of connections, life cycle coordination

RP score = (I1*2+I2*3 +I3*1+I4*4+I5*4+I6*5)/19

Digital reversibility assessment within RBIM is illustrating RP score with use of color-coded 3D viewer providing an overview of circular capacity of building. (Figure below)
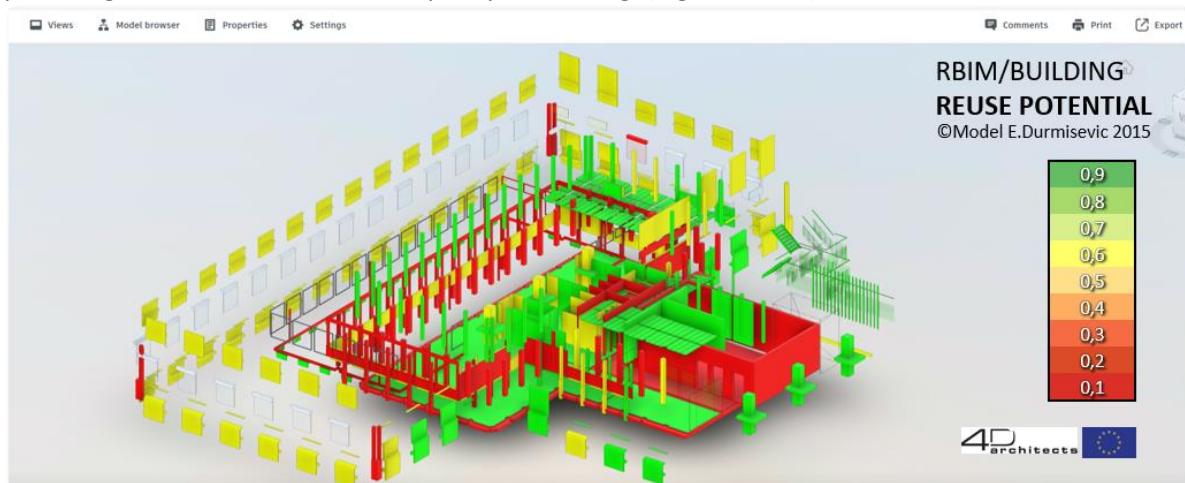
This methodology developed by E. Durmisevic has been a main pillar of EU BAMB H2020 project initiated by Durmisevic during which the Reuse Potential tool has been tested on pilot sites.

How to use and exploit the outputs?

RBIM outputs

RBIM outputs are multi-layered and can be used as decision support by different stakeholder groups.

Owners of the building

RBIM output provides information about the quantities, volume, weight, per material and product type, including their embodied CO_2 and Reuse Potential score which is reflected in the indication of avoided tonnages of CO_2, waste, and raw material as well as reuse options of materials. As such RBIM outputs is used to develop reuse strategies and define more detailed circularity ambition which is than integrated into a tender documentation and requirements for the constructor.

Use embodied value calculation assessed by RBIM 4D architects, reflects the effort needed to recover material as well as the repair effort needed for material reapplication. Embodied value reflects potential labour, equipment and new material needed for recovery and reapplication of harvested material. Therefore

RBIM outputs are also used for preliminary elaboration of the most desirable reuse options for a particular economic objective of the project.

Based on a library listing reusable materials owner of the building can start purchasing materials before deconstruction starts.

Deconstruction/construction company
RBIM output provides information about the position of elements to be recovered as well as disassembly steps and operations indicating easy of recovering of an elements. This is used to develop deconstruction and sorting strategies.

Architects
Reversible BIM creates a digital library with BIM objects of reusable elements enabling architects to start using reusable elements in their new designs before the building has been deconstructed.

Manufacturing industry
digital library with BIM objects of reusable elements is used by manufactures who are remanufacturing and refurbishing reusable elements. BIM objects are than used by manufactures as part of the sale catalogues.

Public authorities
Digital reversibility assessment with its scoring reflects building's capacity to enable circular material feedback loop through new applications. As such RBIM defines circularity profile of a building classifying all buildings into 5 circularity profiles from irreversible to fully reversible buildings products and materials. This is used by authorities to standardise the performance of circular buildings, define circular ambition through building code and manage the transition from linear to circular economy in construction smoothly.

3.3.   Material Data Base

Introduction

The Materials Database is an IT-application that stores information about materials in a building in materials passports. A building that is owned by one of the pilot partners for example. It makes information about all the materials transparent, so every owner knows what it actually owns. The Materials Database can be seen as a support system to make a cost-benefit analysis for reusing materials, since it is able to store all information about this analysis, or by providing statistical data coming forward from earlier inventories and analyses.

How to use and enter information in the materials database?

A Materials Database is able to provide materials an identity. In order to do so every material should have its own passport. In this passport information about the materials in a building is stored, which is acquired by making an inventory of every material by 3D-scans and manual activities. Normally inventory activities are performed by people with knowledge about buildings and materials going through building and "writing down" the materials they see on each floor and in each room. Activities that can be supported by the use of 3D-scans, BIM-models and drawings of a building. The Materials Database that is used in the DDC-project, Cirdax, has an inventory support application that makes it easier to enter information about the materials. Property owners, their staff or specialized consultant can learn this inventory process in about two days of training. Normally a training to learn how to use Cirdax begins with only one room, and only a few materials to be registered. A sample that can be prepared in Excell as well.

Doing so characteristics of the materials in terms of size, weight, colour, place in the building etc. get a place in the passport, just like the notification about the removability of the material out of a building. Information that is gathered from the Reversable BIM processes. The Reuse-score of a material is an integral part of its passport and tells us if a material can be used alternatively, including a correction for the costs of removal and processing it for alternative use.

How to use and exploit the outputs?

The Materials Database provides the owner of a building and the materials in that building with information about the materials in terms of quantity and quality, which can be combined in economic and financial terms. Especially it provides information about the economic, social and financial value of the materials, that is used on the benefit side in a cost-benefit analysis. By economic value we mean the sum of both financial and social/environment values of the materials.

Registering every material in a materials database is economically feasible for all materials that can be removed easily or with medium effort according to the information that comes forward from the combined 3D-scan and the Reuse-score. For those materials that take a lot of effort to remove a cost-benefit analysis of the total process of inventory, registering, storing and selling is necessary to conduct. The Materials Database provides information that can support this cost-benefit analysis, especially concerning the benefit side of this equation, since it not only provides a materials owner with detailed information on the materials in its building, it also provides a transparent view on the quality of the materials and the costs involved to make an inventory and to process the materials in such a way that the materials can be used alternatively.

Cost-Benefit-Analysis and the Materials Database

The Materials Database can be seen as a support system to make a cost-benefit analyses for reusing materials, since it must be able to store all information about these analyses, or by providing statistical data coming forward from earlier inventories and analysis. This last functionality can only be applied when there is enough data about such inventories. Until this goal has been reached, the materials database provides us with data about the materials in a building, that can be used as a half-product in the cost-benefit-analysis, and the other half-product is a clear methodology to make the calculations, coming forward from the following equations:

1. K = O + Sk + Dk − Mk

2. C = O + I + Sc + Dc + R − Mc

The letters stand for the following aspects of the demolition and/or dismantling process:

K = The costs and benefits of the classic method of demolition

C = The costs and benefits of the circular demolition method

O = the organizational costs of the demolition and/or dismantling process

Sk = the cost of the classic services of a demolition company

Dk = the cost of removing and depositing the materials after demolition

Mk = the yields of materials from a classic demolition process

I = the costs of inventory and recording of the materials in a building with a materials passport

Sc = the costs of the circular services of a demolition company

Dc = the cost of disposing, depositing materials that no longer have value, and storing for reuse the materials that still have value.

R = the cost of processing the materials released from a building into new materials to be used

Mc = the yields of materials from a circular demolition process

Final remarks

The aim of the analysis above with data form the Materials Database is to determine what exactly the above variables embody in a pilot situation. And which aspects can ensure that the additional efforts in a circular process also result in additional benefits, so that the K > C, i.e., until the situation in which the costs of the classic demolition process are higher than those of the circular demolition/ dismantling process.

Or described the other way around, when a circular demolition process is of added value, on which a pilot owner can determine its strategy as an organization and in terms of building, land and materials. Once the strategy is clear, it is also easier to initiate long-term investments in circular demolition and to use the associated tools, such as the Digital Materials Database. The methodological explanation is therefore a basic framework within which the use of the Digital Materials Database can be placed.

Links with other tools and instruments within the DDC-project

The Materials Database stores information about ownership of the materials, supported by the blockchain module and the (technical) ability to reuse materials in the building, supported by the Reversable BIM-module. The inventory process to enter information in the Materials Database makes use of information provided by digital or 3D-scanning saving inventory time compared to manual inventories. The Materials Database provides information that can be used for cost-benefit-analyses

3.4. BlockChain

Introduction

The Blockchain Module provides an instrument that strengthens the use of the Materials Database. It is only effective if it can be used in combination with a Materials Passport. Every Material has its own Material Passport, which gives this material its identity. The identity can be verified by registering the ownership of the passport in the blockchain, which gives us also the opportunity to see that registration as a property right at the time of registration. The blockchain registration serves as a property right that is also included in the materials passport by means of its hash i.e., the blockchain-identity of the materials passport.

How to get a blockchain registration?

Within the DDC-project a connection has been made between Cirdax, the Digital Materials Database, and the Euthereum-blockchain with the help of two api's, or connection parts between the database and the blockchain. These api's can be accessed by the use of Cirdax and is a separate chapter in Cirdax. It give the owner of the data in Cirdax the possibility to add a hash to its information. This hash or blockchain-ID fulfils the role of enabler between Cirdax and the blockchain is organised in an automated way. The manual for Cirdax and the Blockchain-modules shows how this is done. So with access to Cirdax everyone can also execute the blockchain registrations.

What can we do with the blockchain-registration?

With the blockchain-registration property rights on the materials are established. Property rights give us the opportunity to link them to other rights, like Co2-rights, or to sell these rights to other stakeholders. The combination of materials with an identity, the verified blockchain registration, and the characteristics of property rights, give us the possibility to link materials to marketplaces and future contracts, because the immutable character of information in the blockchain can also handle issues like liability and term contracts. We always know who is the owner of the materials.

What is the strategic aspect of the blockchain registration?

An important topic with regard to the strategic use of materials is the materials in a building itself without having to be removed immediately. After all, in a classical way of thinking about materials, these materials cannot be used alternatively and are not of value. However, by linking a property right to each material (blockchain registration), the property rights or options on the property rights can be given a different owner. This provides the strategic choice for the tripartite division of land, building, material, and can lead to new choices on how to deal with materials, because materials in buildings can then also get a different (specialized) owner separately from the building. In this way, the future reuse of materials can also be organized in advance in the form of contracts, including the issue of liability in case something goes wrong with the materials. In this way there is a strong incentive to prevent damage or waste to materials, including the social waste of the production of new materials in the form of CO2 emissions during production.

The above option fits in with the strategy of a pilot organization and other real estate owners regarding circularity and can already be organized with the help of the Digital Materials Database and the Blockchain module. Within DDC this could lead to different strategies, which will only become effective after DDC. The costs and benefits of these activities mainly belong to the costs of organization (O). The benefits of these activities will be visible in advance in the revenues from the sale of materials from buildings, or the method of circular construction of new buildings.

Links with other tools and instruments within the DDC-project

See the description under Materials Database.

4. MAIN RULES BY PHASE IN RELATION WITH DDC MODULES

This section has been redacted in collaboration with DDC partners who shared their experience to propose main rules, advices, aspects to take into account in the different phases and actions of the reuse process. This information, not exhaustive, can be use by DDC pilots to support their studies and facilitate their reuse approach.

Partners can also read the existing DDC HANDBOOK for which the redaction is continuous until the end of the project and has a direct connection with the DT3.1.3. The HandBook targets phases/actions of the process and for them gives information on Inputs, products and services, results, quality factors, process activities. Target phases are marked by a "*" in the tables below.

Initial phases

Phases / Actions	Main aspects
Get information on reuse process, methodologies…	GENERAL: • Identify and contact building owner and/or architect and/or design office, ideally in the territory of the project, who have experience in Reuse approaches. They will give you targeted contacts of actors, information sources, tips and experience. • Search and consult sources that gather information (ex in France: materiauxremploi.com, BAZED, Circolab, etc) • Search and consult admitted guidance papers (ex in France : REPAR, Guides FBE, Circolab, etc) • Receive a dedicated training session. Specialized actors are proposing training sessions based on experience and admitted methodologies for reuse approaches (ex in France: Bellastock, IDRE, Nobatek/Inef4, etc) • Make aware your collaborators for the project of context / vocabulary / needs of deconstruction and reuse approach. • Search for a storage place near the building that will be deconstructed • Exchange with local partners that already carried out circular projects. IN RELATION WITH DDC MODULES / PLATFORM: • Visit the DDC navigator, contact DDC module providers (if needed) to know more about the DDC tools, how they work, conditions, etc.
Definition of first general objectives / program for the project	GENERAL: • Remind vocabulary internally in order all actors understand each others, speak the same language and program be really understood. You can also propose a glossary all your collaborators can use. • To date, to can plan real deconstruction and reuse approach, foresee additional time for studies and works, additional budget (generally). • Internally or with a support office, identify the resources / products usually reused (for reason of ease of deconstruction, adapted market), recycled in order to orientate the program. • Be realistic, generally not think to deconstruct properly and to reuse all the components of your existing building but define general expectations, targets.

	- Define if you want / need to reuse products in situ (in the renovation or reconstruction). Define with the owner if a few elements have to be deconstructed for his own needs on other projects - Even it is early, if you can, identify the existence of local actors able to deconstruct, to support your project, to stock, to treat and reuse elements. It can influence the feasibility of your wishes. - Express clearly the wishes for deconstruction and reuse, and define it as crucial objective for the project. - If you have not the competences internally, search for an experienced office for the approach, and integrate it the earlier possible. Ideally, this support office needs to be local in order to know well the local context. - Identify an experienced control office in deconstruction and reuse approaches. Integrate him the earlier possible in the process. - Give access to the support office to the maximum of existing information on the building (drawings, conception documents) - With the support office or project management team, speak about these issues the earlier possible: - Does exist a site locally to stock the deconstructed elements before to be sold or reused ? - If reuse on the same site, Does the control office has a specific mission on reuse issues ? IN RELATION WITH DDC MODULES / PLATFORM: - Nothing specific (?) - The support office may be given access to the 3D scan viewer at this early stage, if available
Contract of consulting engineers for Reuse project support (AMO)	GENERAL: - In certain cases, if the building owner has the minimal knowledge internally and project management teams (architect + study offices) with expertise in Deconstruction and Reuse approach exist, so support office could not be necessary (even if it is preferable, if economically feasible) - Be precise on the terminology used in documents. You can add a glossary to the call of tenders. - Frame the mission / expectations for the support office. Is it just assessor and stimulator of the project management team, or it need to support the design team in design and implementing the approach? - Be clear on the deconstruction and reuse objectives of the project in the call of tenders. - Select support office and/or project management team experimented in reuse approaches. Add value to references and success in the call of tenders. - Use guidelines or existing specifications and templates to draft call of tenders (ex in France: document Circolab, etc) - Give access to the maximum of existing information on the building. IN RELATION WITH DDC MODULES / PLATFORM: - Precise that DDC tools are used and need to be used.

	• Propose information source and contact to be trained to the tools. • Give access to the DDC platform and linked information. • Identify the storage capacity (cloud) that has to be rented for the project

Product audits / Inventories

Phases / Actions	Main aspects
3D Scan on site	GENERAL: • Evaluate if 3D scan is relevant for the project. It can depend on the typology and size of the building, budgets, distance of building to the involved actors, support and management teams. Speak of the issue with support and project management teams. • Define your expectation for the 3D model: integrate 3D model in a BIM program, allow a virtual visit, allow to add POI, communicate, provide a technical tool for project management team • Select service provider (BIM-Y ideally), who has experience in reuse approaches, can provide point clouds + segmented 3D models, and ideally proposed 3D viewer easily accessible/usable. • Define the time at which the 3D scan can be taken: ideally it should be taken when the move have been made so that the building appears on the 3D scan as it will be at the deconstruction start IN RELATION WITH DDC MODULES / PLATFORM: • Contact BIM-Y to speak about the project, conditions. Send to him existing plans and information on the building to evaluate the mission. • Ideally, program the intervention on site during a period in which the building is empty of workers, or with the less affluence possible.
Visit on site	GENERAL: • Prepare the visit with plans (paper or tablet), maximum of information on building and existing products, targeting products to specially evaluate. • Prepare the logistic of visit with the building owner to optimize the intervention, to have access easily to the locals, to have light, to access to the elements, etc; • Be 2 persons with at least one construction/reuse expert. • In some cases, take advantage of the visit to scan. • Take and locate pictures of products. • Try to observe behind elements in order to see connections, hidden products. IN RELATION WITH DDC MODULES / PLATFORM: • Use the previous 3D scan done with BIM-Y and the viewer on the tablet to prepare the visit and add information on site targeting the relevant products. • Think to note all information (that can be noted on site) needed for Rbim and Material Data Base modules. *(See specific documents / guidelines)* • Use existing Revit model and technical drawings (if any) to prepare site visit with respect to the data collection needed for RBIM

3D Model viewer, Add info and POI	GENERAL: • Chose a relevant tool that you have tested before, that have experience on reuse approaches, ideally ask opinion of previous users. • Ideally chose a tool for which you can give free access to the stakeholders to your project IN RELATION WITH DDC MODULES / PLATFORM: • Detail all the POI you want/need taking into account (if used) the inputs expected in RBim and MdB modules, in DCC platform. Think also to the information expected by design team, by potential buyers.
Virtual visits	GENERAL: • Provide access to the stakeholders of your project, and simple guidelines to the use. • Organize a short presentation meeting on-line to present the tool, the building. • Communicate largely on the possibility to can visit the building virtually (by asking access to you) in order to link with potential buyers/users of your deconstructed products. • Ask contact information to all they want to visit and feedback on elements they are interested on. IN RELATION WITH DDC MODULES / PLATFORM: • Create an e-mail address where people who made the virtual visit can address their questions. This e-mail address should be on the start page of the viewer
Gathering and consulting existing data on building	GENERAL: • Before visit on site, it's necessary to take into account every information available about construction. This information allows a first assessment of the construction components and their compatibility with a reuse process Main information are: technical and regulatory audits, plans and drawings, technical documents on products, call of tenders, information on renovation projects, history of the building. • Ask to the building owner to gather all the available information he has internally and depending of the typology of the building, search historical information on public archives. If necessary, you can also contact the architect agency who be in charge of the construction. • Use existing tools to help searching information in many documents (ex MASSDOC). • Create a storage place (cloud) and a glossary for all the gathered documents. IN RELATION WITH DDC MODULES / PLATFORM: • In addition to above Following is of particular importance for RBIM assessment of Reuse potential: Construction date, Specification of renovated sessions and individual date of each renovation

Mandatory audits (hazardous material, Wastes, etc)	GENERAL: • Carry out mandatory audits in your territory (lead, asbestos, hazardous wastes, C&D wastes, etc). • Ideally to do before the inventory on site for Reuse strategy to avoid contact, to target recoverable products, and to can integrate all the data in support tools of the approach. • Contract specialized / authorized auditors. • Ask as possible as details on localisation of hazardous products, contact with other elements, photos. • Create a storage place (cloud) and a glossary for all the reports IN RELATION WITH DDC MODULES / PLATFORM: • Add the link to the information on the 3D viewer when it is possible. • This information can be added in Cirdax as well, but best is to use it for the assessment of the reversibility activities • Integrate information in the RBIM for the reversibility and reus potential assessment
Inventory. First level of information *	GENERAL: • The level of information has to be estimated depending the interest of the products for reuse. Do not lose time detailing products that are impossible do deconstruct properly or to be reused, and focus effort on all products with potential. • Information needed depend on products. Generaly: product (ex window), material(s), state, dimensions, brand and ref of the product, location in the building, photo, quantity. + if possible and useful: info on potential of disassembly, potential reuses • If digital tools are used for the rest of the process, use digital materials database for the registration of the various data arising from an inventory. IN RELATION WITH DDC MODULES / PLATFORM: • Add the information directly in the 3D viewer (POI) and/or the DDC platform • In a case that RBIM is done for the inventory of reversibility/disassembly and ruse potential above mentioned information about the number of products, their dimensions, disassembly potential is automatically generated from RBIM
Research of local actors on reuse approach, contacts	GENERAL : • Anticipate this action in order to have the sufficient time to contact, to generate known information. • Research various typologies of actors: potential building owners interested to reuse on their projects, specialized deconstruction companies, social companies proposing specific works (preliminary recovery of products, stock, treatment, commercialisation, reuse), associations, experimented design actors, industrials and construction companies who can integrate reused/recycled materials, physical and on-line market places, • Identify potential users / buyers of the products, physical and digital market places. Identification searching in internet (directly or through web site

	gathering info like http://materiauxreemploi.com/, FCRBE, etc), asking information to local actors.
	• Regarding potential users, a part of transiting by marketplace, you can also contact directly building owners, associations. Search information on local construction projects, contacting local municipalities, social housing owners, identified support offices and architects.
	• Communicate on the web, local event and press, largely to attract potential actors.
	• If possible, organise visits on site, and plan to have a person available to organise specific visits for interested actors.
	• Precise with some of them, what are their activities, how they take action on site, on the process (do they deconstruct? buy ? on which products ? etc)
	IN RELATION WITH DDC MODULES / PLATFORM:
	• Communicate largely and allow the virtual visit.
	• See Materials Database and the Blockchain Module previous sections. As long as the ownership of the materials is put into Cirdax we can connect it legally to all other partners.
	• Allow architects and industry access to digital library generated from RBIM (with BIM objects of reusable products)
3D model segmentation - BIM	GENERAL :
	• To be done by the service provider except if the expertise exists internally.
	• Define with the service provider, the level of detail needed, the use of the 3D model, tools then used.
	• Define intermediate stages in the process where the consulting offices (architects ; engineers) can get a view on the on-going segmentation to see if the defined goals are still realistic or need to be reviewed xxx
	IN RELATION WITH DDC MODULES / PLATFORM:
	• Communicate largely and allow the virtual visit.
Evaluation of Reuse potential (RBim)	GENERAL :
	IN RELATION WITH DDC MODULES / PLATFORM:
	• Contact 4D Architects to know the conditions of the RBIM assessment and access of RBD (reversible building design) platform with guidelines and protocol.
	• Gather all the information needed. See Section 4, previous deliverables on DDC project.
	• Ideally provide a segmented 3D model that can be used by 4D Architects.
	• Speak with 4D Architects to define the objectives of the assessment, the targeted products / parts of the building / desired ambition regarding CO_2 reduction, avoiding of raw material use/ desired ambition regarding material reuse and waste elimination

	• Use color coded 3D reversible model viewer to visualize potential reuse options of building products which corresponds to color code and their distribution through the building.
	• Use overview of materials with high reversibility/disassembly and reuse potential and information on the dimensions, quantity, embodied CO_2, product positions to investigate the market and industry conditions for their recovery
Research of technical information on products	GENERAL :
	• Gather the information from onsite inventory, from documents on the buildings, and from new researches regarding targeted products. Researches can be done on the web or contacting fabricants. This additional information can be on the assembly/disassembly protocols, on technical sheets visually damaged martials/products, (characteristics and performances, lifespan, store conditions, etc).
	• Search additional information only for targeted products.
	IN RELATION WITH DDC MODULES / PLATFORM:
	• Add the information directly in Cirdax with the specialised device for entering inventory data
	• Join technical documents to the products in DDC platform, in Cirdax.
Research of economic value of products, comparison with new market products	GENERAL :
	• Estimation of product prices. For reuse products, search on marketplaces (online and physical), contacting experimented actors, and for new products, search on common databases (used for all construction projects)
	• Consider prices relevant for your territory. Prices can be different for a urban territory (ex Paris) and for a regional place.
	• Contact interested actors to estimate if products can be sold (not just offered), and if yes, at which price? (depends on the market, conditions for reintegration, treatment needed, etc)
	• Define a price (penalty) in case when a buyer has reserved a product but resigns after that the product has been disassembled xxx
	IN RELATION WITH DDC MODULES / PLATFORM:
	• Organise liability issues in the delivery contracts based on the blockchain registration (tokens), when finishing the inventory data in the Materials Passport (Cirdax)
	• Use embodied value calculation assessed by RBIM 4D architects, based on the assessment of the effort needed to disassembly/recover material and repair/ remanufacturing effort needed for its reapplication. Embodied value reflects potential labour, equipment and new material needed for recovery and reapplication of harvested material.
Tests on disassembly	GENERAL :
	• Not obligatory but ideal in some cases.

	• Tests on disassembly allow to identify the best deconstruction method to conserve the integrity of product. If possible, try to observe physically the potential of disassembly during the visit, or posterior visit organized after targeting products. • Organise a specific visit with deconstruction company. They are can provide expert view and advices. • For real deconstruction previous tests, target products who not need heavy machine (except if these machines are on already on site). • Prepare a contract for the disassembly tests • Time for disassembly tests has to be foreseen in the project timetable (see "program for the project" IN RELATION WITH DDC MODULES / PLATFORM: • Use results of RBIM 4D architects (Model:Durmisevic 2015) specifying: (i) number of disassembly operation per product, (ii) no. of disassembly steps, (iii) number of physical relations per product/material (iv) type and number of direct and indirect connections created during assembly and after assembly of the products to develop disassembly strategy
Tests on samples for verification of performances	GENERAL : • If residual performances are not known and are critical (or demanded by users, control office), foresee the required verification tests. For this or consult existing guides (ex French FBE guides[1] on a series of products, detailing the verification protocols), consult product standards (national and/or European) that detail the tests needed for new products, speak with the control office on characteristics required and needing tests. • Reduce at the maximum the number of tests (= costs), and when it is possible consider the estimated performance. • Estimate the costs contacting local laboratories, fabricants, or actors with experience on targeted products. • Sometimes, tests in universities are accessible in terms of costs. • Do tests on representative samples. • In all cases, thinking to the insurability, validate with the design team, with the control office, with your insurance you have all the needed characteristics. IN RELATION WITH DDC MODULES / PLATFORM: • Add the results of the tests in the product description, in the DDC platform, in Cirdax. Attach test documents. • Organise blockchain registrations as a legal instrument for delivery and liability when delivery cannot take place
Detailed inventory *	GENERAL : • Complete the inventory with all the information found and from tests. • If digital tools are used for the process, use digital materials database for the registration of the various data arising from an inventory.

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[1] http://www.batiment-energie.org/index.php?p=70

	• The level of details can be different in function of targeted or not products and their potential. • The detailed inventory is a support information needed by many actors during the whole process. It needs to be accessible, updated. • Give access to the inventory to all actors of the project. Provide data base and/or tool usable, understandable. If needed, provide guidelines for the use of the database, tools. If a commercial tool is used, can give free access to the actors. • Provide synthesis of product quantities / typologies, etc to can collaborate with actors using general and understandable data. • Communicate the synthesis or detailed inventory to the targeted network in order to find potential buyers, users. • Follow, update the information with products and interest of actors, product sold, deconstructed, attached documents. IN RELATION WITH DDC MODULES / PLATFORM: • Use Cirdax as detailed material data base and to provide synthesis. • A special form of registration and metadata is the blockchain registration of the characteristics of materials in a digital materials database. This is aimed at recording the materials passport of a material in a building, and thereby also establishes the property rights to the materials. • Use RBIM output tables with overview of products and materials per building function, product type/ material containing information on ruse potential of individual products and materials quantities, dimensions and corresponded avoided CO_2, waste, and raw material • Communicate and share RBIM digital library of reusable element and thair BIM objects with architects, industries and sales platforms to ensure boost their potential reapplication. • Use RBIM outputs with overview of quantities of materials with no reuse potential and requiring special treatments
Creation of product passports	GENERAL : • Use home made tools to create and share detailed technical sheets, or use existing tools (ex CIRDAX). Material passport, need to be easy to group, consult, download, use. • Material passport need to be detailed (not generic information but info on a specific product). • Find information on the web regarding the concept of material passports (ex BAMB project[2]) • Use material passport for technical and commercial interactions with design team, with buyers. IN RELATION WITH DDC MODULES / PLATFORM: • Use Material Data base module (Cirdax), through or not DDC platform, to generate material passport. • Add token transactions based on blockchain registration of materials passports

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[2] https://www.bamb2020.eu/

	• Use where applicable (ex. during design) 3D BIM object module from RBIM with basic information about the product its dimensions, material, year of fabrication, wight, embodied CO2
Communicate product availability / sell products (Market place)	GENERAL : • To do before and after the definition of scenarios • Sell products directly on physical place and/or in on-line market place. Products presented on-line can also be sold in physical place. • Publish information on market places. To date, there are various well known existing e-marketplaces. They are different on each country and also between regions. Some e-market-places are "national" but 90% of the published elements are on a specific territory. Try to find a e-marketplace introduced in your territory. • Send information by email to your network (all actors identified previously), publish an information on your own web site • Ideally to have reservation of some products before deconstruction. It can influence the deconstruction and reuse scenarios • Have information on the destination of the product (be stored, implemented directly, sold…) recovered by the targeted actor. In function, some additional aspects need to be discussed and controlled. • Prepare typical contracts using existing template, copying documents used on previous projects with success, asking to the support office or project management team. • Consolidate contracts with buyers (conditions) in order they commit to buy, accept the product after deconstruction and on the defined timing. Validate also the delivery mode. • Conserve information on all transactions, and make reporting. Be clearly aware on sold products, to who, if products still available, if contracts are signed, etc; IN RELATION WITH DDC MODULES / PLATFORM: • Use Material Data base module (Cirdax) and virtual visit to communicate on products. • Use MdB to generate ads on marketplaces (with API) • Use blockchain to sell products and follow transactions.

Evaluation of scenarios

Phases / Actions	Main aspects
Environmental evaluation of scenarios	GENERAL: • Compare values with the objective of the project. • Environmental criterion can be: quantities of products from the existing building reused and/or recycled, reduction of wastes, new products avoided, reduction of transport, Kg of CO2 emissions avoided. • Use LCA existing tools (ex SimaPro), and/or tools proposed by marketplaces (ex Cycle-Up), and/or tools from DDC (RBim, Cirdax). NBK developed also a

methodology (for Bordeaux Metropole) to evaluate impacts reduction of reuse approaches.

IN RELATION WITH DDC MODULES / PLATFORM:
- Use Cirdax Data base to estimate embodied CO_2 of the products deconstructed, reused.
- Use RBim to evaluate potential of reversibility of elements, evaluate impacts of scenarios and wastes quantities.
- Use environmental embodied value calculation assessed by RBIM 4D architects, based on the assessment of the effort needed to recover material and repair efforts needed for its reapplication. Environmental Embodied value reflects potential avoiding of CO_2 emissions, waste, and energy as well as potential material reuse.

Performance evaluation of scenarios (/Reuse objectives)	GENERAL: • Calculation units for the objectives have to be defined (weight of re-used objects; embodied CO_2) IN RELATION WITH DDC MODULES / PLATFORM: • Use RBIM outputs to elaborate most desirable reuse options for a particular circularity performance objective of the project

Economic evaluation of scenarios
 	
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	GENERAL:
	• Make a balance between costs for reuse process and traditional process considering a some of aspects at different levels: studies, demolition works, logistics, products (deconstruction vs demolition, gains not landfilling or waste management, transport, storage, costs of tests, price of new product and his transport), new project (for which economies can be done integrating reused products)
	• Collect data internally (previous projects), use existing cost material data bases (ex BatiPrix), consult an economist for construction.
	• Push at the maximum completeness and reliability of all economic data and hypothesis.
	• In his section "Making a qualitative cost-benefit analysis", the DDC handbook lists variables to consider:
	    a. An overview of the available materials in a building
	    b. An overview of the alternative applicability of these materials
	    c. An overview of the economic value of materials that can be reused
	    d. An overview of the social benefits of reusing materials
	    e. An overview of other revenues associated with the demolition of a building
	    f. An overview of the costs of inventory, transparency and alternative use of materials in a building
	    g. An overview of the costs of removing materials from a building
	    h. An overview of the costs of making the quality of materials in a building or the removed materials transparent
	It proposes this list of activities to discuss:
	    a. Analyzing the costs associated with removing materials in a building.
	    b. Analyzing which (alternative) benefits are associated with the reuse of materials from a building.
	    c. Analyzing the costs associated with increasing the (alternative) yields of materials from a building.

> *d. Analyzing other returns associated with the demolition of a building.*
> *e. Analyzing those information aspects that increase the transparency of the quality of materials.*
> *f. Analyzing the combined legal, economic and technological aspects that ensure that the reuse of materials is secured over time.*
> *g. Analyzing, maintaining and improving methodologies for making cost-benefit analyzes with regard to the reuse of materials in a building.*

- For deconstruction costs, ask evaluation by deconstruction companies. Some of them use their own assessment tools. Ask for comparison between demolition and deconstruction scenarios in order to take the value into account in the general economic assessment.
- The DDC HandBook lists part of the information required for economic assessment of deconstruction works:

> *a. The data of the building in terms of size, construction, and all other aspects of a building that can be read from drawings of the building.*
> *b. The inventory of the materials in the building*
> *c. The removability of the materials in the building*
> *d. The types and extent of a demolition contractor's services with regard to the stripping, removal, dismantling and demolition of the various elements and materials in a building, as well as the preparation thereof.*
> *e. The logistics costs of removing the materials in terms of transportation and storage.*

IN RELATION WITH DDC MODULES / PLATFORM:
- Use economic assessment tool proposed by GreenFlex.(Excel form with cost and revenue variables)
- Use RBIM outputs for preliminary elaboration of the most desirable reuse options for a particular economic performance objective of the project.

Project phase

Phases / Actions	Main aspects
Formalisation of the targeted scenario	GENERAL: • The most appropriate way would be that the target is defined through consultation between the project owner and the architects + engineer offices (competitive tender) • Define a scenario to follow permitting flexibility. • Acknowledge with all stakeholders these aspects: timing, storage, costs, elements to deconstruct and by who and for what, destination of deconstructed elements. IN RELATION WITH DDC MODULES / PLATFORM: • Use DDC platform and tools to identify potential of the existing building and potential scenarios prior to formalising and targeted scenarios with regards to circularity ambition. • Use Digital assessment of circular capacity of a building to define design requirement for the design team and required circularity profile of the building as well as deconstruction and reuse requirements for the contractor.

Call of tenders for and contract of design team / project management team	GENERAL: • Information about the building shall be in the tender documents • Provide all the elements concerning the reuse approach in the call of tenders of design teams: technical inventories, reuse objectives. • Provide a catalogue/inventory of the potential elements to deconstruct with attention, organise visits on sites. • Be very clear on objectives, concerns. • Don't hesitate to ask to other experimented building owners to share approved documents for call of tenders, contracts. • Select experimented and strong references on reuse approach. • Don't select the chippiest but add value the technical note. • Ideally work with local teams. They know better the local network, building sites on going and to come, they will me more present during the project. • Ask they provide methodology, first ideas, etc = information specific to the project. IN RELATION WITH DDC MODULES / PLATFORM: •
Project design - studies	GENERAL: • During project design studies, scenarios are refined (scenarios needed flexibility) • If the same project team manage a reconstruction project with objectives of reintegration of products, the technical project management team (architect, engineers, etc) and support office team (AMO) make, detail and justify propositions for reuse or reutilisation (changing the use). • Push and challenge the project team continuously. IN RELATION WITH DDC MODULES / PLATFORM: • Assess and improve preliminary and final design solutions with respect to the circularity ambition. Where applicable use RBIM for the assessment.
Virtual visits	GENERAL: • Communicate the existence of the virtual building, give access to the viewer to all the actors of the project and provide tutorials. • Organise a virtual visit in common (ex sharing the screen). • Define use rules, secure writing right to protect the file of errors. • If products to deconstruct carefully are targeted, show and detail them explicitly in the model. IN RELATION WITH DDC MODULES / PLATFORM: •
Organisation of preliminary products recovery *(Deconstruction of specific targeted products before*	GENERAL: • Define temporality and the distribution (who?) of the possible deconstruction interventions (not necessary by 1 deconstruction

general deconstruction/demolition)	company giving specialized associations/companies can intervene previously to deconstruct specific elements) • Integrate these preliminary deconstruction activities in the follow up process and data. Take photos, keep traceability documents. • Previously: Target and contact associations, social and solidarity economy actors, physical market places with deconstruction service • Be sure of the security of the interventions (access, deconstruction) IN RELATION WITH DDC MODULES / PLATFORM: •
Call of tenders for Deconstruction companies	GENERAL: • Additionally to locate on drawings elements that would be reused, provide a catalogue of all the elements integrated to the reuse approach. • Organise visits • Require companies to provide proof of insurance for the implementation of reuse solutions. • Be very clear on objectives (deconstruction actions, requirements for the quality of products after deconstruction, % of damages, timing, responsibilities for storage and transports, etc) • Choose experimented companies with strong references in deconstruction and reuse approaches. • Maximize the weighting on quality of works/methodology rather than que price. • Ask to the companies, information on methods to deconstruct, store and transport the main products targeted. IN RELATION WITH DDC MODULES / PLATFORM: • Use RBIM outputs with regards to deconstruction staps, type and number of connections and their locations as a part of tender documentation. • Include 3D reversibility 3D viewer in the documentation.

Deconstruction works
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	GENERAL:
	• Linked to parallel actions (see below). The design and support teams have to strictly follow the deconstruction works, gather the documents, take photos, manage in live the recuperation of deconstructed elements by targeted actors, report elements deconstructed, sold, stored…
	• During the preparation of the demolition activities, the following process activities are discussed:
	    a. Defining the goals of the demolition between the client (owner of the building) and contractor (demolition company).
	    b. Making an operational demolition plan aimed at optimizing the value for the customer, given the preconditions as agreed in the assignment.
	    c. Setting up the work area, making risk analyzes and making available the necessary capacities, machines, aids and tools to carry out the demolition process.
	• Organise a specific meeting with the deconstruction company, ideally with the site team to remind objectives, explain concerns and strategic products, etc, to be sure that workers on site are aware of the expectations.

	IN RELATION WITH DDC MODULES / PLATFORM:
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Follow up of products sold and their property / products evacuated	GENERAL: • Use follow up templates (ex CIRCOLAB templates) and homogenize follow up documents. • In function of the specificities of the project and his actors, implement a method for the correct traceability of elements. Many actors defined templates (Circolab, Nobatek, Plaine Commune, etc) • Follow actions continuously (a to long frequency to make follow up and report generates losses of information) IN RELATION WITH DDC MODULES / PLATFORM: • The Blockchain registration gives the possibility to track and trace products by means of the way the blockchain is organised i.e. each new owner in a chain of activities or ownership means that an extra block or ledger is added. The follow up of products sold can be monitored in this way.
Management of dismantled products for future reuse (storage - transport) *	GENERAL: • Management of the dismantled products through the deconstruction company • Control of the dismantle works and of the storage through the architects or engineer offices • Use precise and serious traceability method, documents and tools. There applicability has to be clear in all the call of tenders. • When you have physical storage site, add digital method / tool to follow transactions. Define also delivery, entrance, security, exit rules. • Push to use / sell the products quickly. The longer the time between a match of supply and demand, the higher these costs will be, including loss through use, which can be visualized by the discount rate of loss of value of materials in depots. • For the transport, define sufficiently in advance the transport mode and packaging (not wait the d day). Ask to construction companies or specific providers how new products are packaged, search on web and on reuse reports/guides. IN RELATION WITH DDC MODULES / PLATFORM: • The stock registration system can be a specialization of the digital materials database, or be linked to this database via an API
Final economic assessment	GENERAL: • Use all the data gathered during the building site and follow up of reused element transactions. • Estimate possible reduction of transport costs. • Don't forget all the secondary costs of the reuse approach (specific support team, insurances, tests on products, storage, …)

	• If elements are reused by the same building owner (same site or not), consider economies VS new products. IN RELATION WITH DDC MODULES / PLATFORM: • Use cost benefits analyses on the DDC platform and economic assessment tool created by GF. • Every material has been given an identity by means of its passport. Attached to this passport is also the blockchain registration, which gives every materials property rights. In order to make a final economic assessment of the reuse of the materials all the costs and benefits attached to those property rights and the alternative use of those property rights (materials) give us the possibility to make exact calculations. And even draw an audit-proof balance sheet with all the value attached to the alternative use of the materials.
Final environmental assessment	GENERAL: • Assess all the indicators you defined at the beginning of the approach. Embodied CO2, waste reduction, number of elements reused, reduction of new products/resources for other projects… • Use common LCA tools, homemade tools, tools from marketplaces (ex Cycle-UP), DDC tools. IN RELATION WITH DDC MODULES / PLATFORM: • Use Cirdax to estimate final impacts, defining which products were reused, recycled • Since every material has its own property right, we can attach environmental rights, like to ones for Co2-savings, when materials are used in an alternative way, so new production has been avoided. This makes it also possible to make a balance sheet for every environmental value that can be attached to a material right. This will support the final environmental assessment. • Use RBIM tables to estimate final impacts, defining which products were reused, recycled

Common to all phases

Phases / Actions	Main aspects
All	GENERAL: • Anticipate • Keep a flexibility • Aline budgets with expectations, needs • Be clear on objectives, responsibilities, tools to use, methodologies to follow • Share the information • Give access to the digital collaborative tools, and provide description and tutorials/guidance documents for the tools if you want stakeholders use them.

	IN RELATION WITH DDC MODULES / PLATFORM: •