# 05 - MEASURING DEMOUNTABILITY

# Measuring Demountability


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## Abstract


The gradually changing Dutch Peat Polders are one by one converted from grasslands into wetlands as a plan for making them futureproof. This change will take many years and leave these polders unused in the meantime. This landscape can therefore be used for temporary housing requiring demountable structures for the buildings to be movable from site to site.

Using a literature review a calculation methodology is explored later to design the building and check if it meets the requirements stated in this report. The document is used to create an ambition document that is later compared to the outcome of the final design. This design is documented in the final chapters, to register the used resources stored in the building for later reuse, and to enable the building to be assembled and disassembled quickly and easily.



**Keywords**

Demountability, Disassembly, Circularity, Reuse

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# Introduction

The Dutch Peat Polders are prone to change over time, the now well-known grasslands will gradually change to wetlands, also changing the way of agriculture in the process. Because this transition will take many years the polders are, in their current state, still inhabitable until the water comes. Housing is possible in the form of demountable and temporary structures that can be moved from site to site, making the most out of the now unused polder landscapes.

The objective of this research is to explore a way of measuring the demountability of a building, that enables the designer to compare various solutions to come up with the best possible solution for a temporary housing proposal. Before the design, there should also be an ambition document, that states the principles the demountable structure should meet. Furthermore, it is important to register the resources that are stored in the building and to make a detailed description of the assembly and disassembly of the structure. The question for this research paper is as follows: *How is impermanence measured and registered?*

In the first chapter the scope of demountability, consisting of the different levels of demountability and the conditions of the site is written down. Following up is a description of the steps one can take to create a demountable ambition according to the CB'23 platforms guidelines. These steps will then be used to formulate the ambitions per building detail, which will help the designer make the right decisions. Thereafter, a general description is given of the measurement methodology described in a document of the Dutch Green Building Council. Finally, the document continues to describe how the final design is documented and calculated.

# The scope of demountability

Demountability has many facets and can be interpreted in many ways. It is therefore important to define the understanding and scope of the way demountability is seen from the perspective of the project that will be realized. For the palliative care facility in the polder of Midden-Delfland, the scales of the building that will be measured and the site conditions of the current site and future sites will influence the decision-making later on in the document. In the first part of this chapter, the 5 levels of the building are defined, inspired by the CB'23 platform, thereafter the site conditions will be formulated.

## Five levels of demountability

According to the CB'23 platform demountability can play a role on multiple levels. This platform focuses on the building products and building elements, and not on the other three levels mentioned. Whole buildings are considered movable anyway, so the demountability of these buildings should be evaluated on the lower levels of elements and products. Materials and raw materials, because these are not detailed since these elements are first converted into products or elements before they are assembled[1]. To give a complete picture, and to show the interrelation between the five levels all levels are mentioned and briefly explained. The definitions are formulated by the Dutch Green Building Council in the whitepaper *Circulariteit in de praktijk losmaakbaarheid*[2].

### Raw materials

A base material that is being used during the process of building goods, energy, (building) products, or semi-manufactured products.

### Materials

A material is defined as a combination of raw materials, which specifically aims to be used as a building product. A material can be a natural or manufactured resource.

### Building products

An item built or converted for use in buildings. One building product is made out of one or more materials.



### Elements

A part of a building with a certain combination of (building)products. A building element is made out of one or more (building)products.

### Buildings

A building exists out of the construction of elements, building products, and materials.

## Site Conditions

To complete the scope of demountability for the design project the conditions and constraints of the site have to be taken into account. In the Dutch peat polders, the water and soil conditions are the dominant factors and will have a big influence on the way the structure will be built. Additionally, the target group that will be building affects the way of detailing and building as well.

### Soil

The soil on the plot is made up of many layers and also varies in lithology as discovered during the site analysis. Close to the Zweth a mixture of peat and clay soil is found, whilst on the tidal inversion ridge sand is the most predominant soil type. These different classes of lithology require different forms of foundation, which indicates that this part of the building should be flexible and adaptable to the conditions found below it.

Furthermore, the strength of the soil needs to be taken into account when transporting the building, heavy trucks and mobile cranes will have a hard time reaching the site. Besides, they run a great risk of getting stuck in the soft soil that is not strong enough to support the weight of heavy machinery.

### Water

The main reason that the building has to be demountable is to move it, once the site is completely flooded and unsuited for dwelling. In the process the land will become flooded during heavy rainfall, requiring careful detailing

### Target Group

To cut costs for the institution of the hospice the building will largely be assembled and disassembled by amateurs, who do not have construction as their daily practice. They will be supported by one or two professional carpenters, but still require understandable and simple detailing, with the need of a minimum amount of tools.

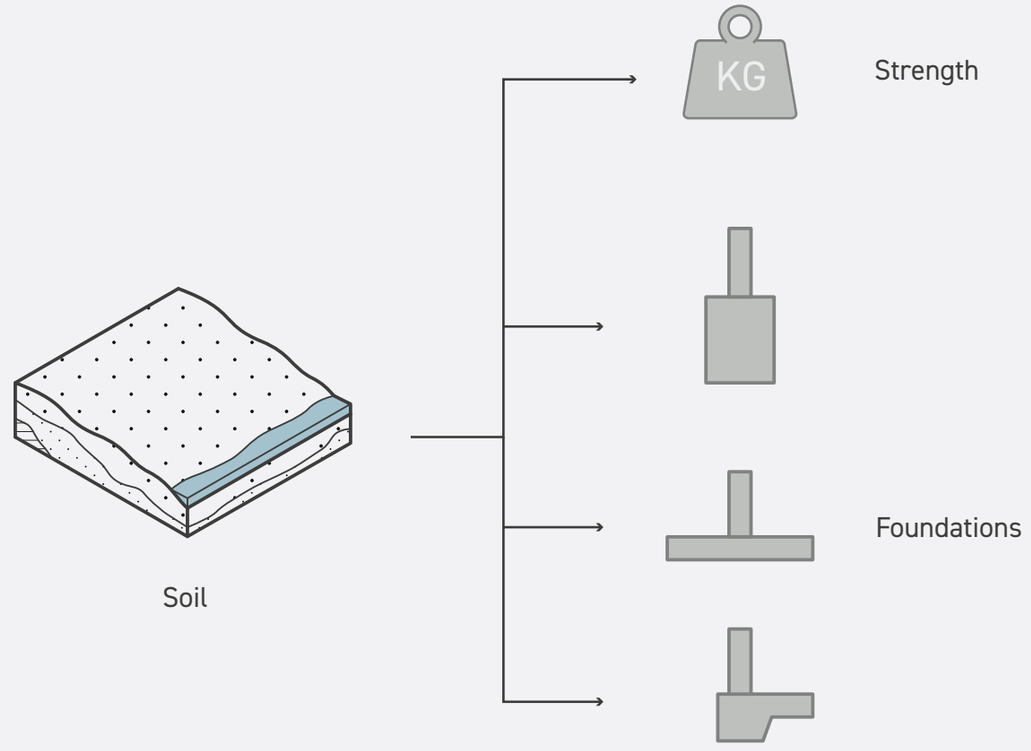


*figure 01 - Site conditions*

## Steps towards a demountable ambition

When a demountable detail needs to be designed, many factors will influence the decision-making to achieve this goal. The platform CB'23 has developed a guide[3] with 10 steps to take into account when designing or setting the ambition for designing demountable. In the guide, every step is explained clearly and will be useful to keep in mind once experimenting with the design of details and prototypes.

**Step 1: Determine the ambition of the project**

**Step 2: Determine the circular strategy**

**Step 3: Determine the goal of the demountable detail**

**Step 4: Check if the goal is realistic**

**Step 5: Determine the layers of Brand**

**Step 6: Determine the requirements for the moment of disassembly**

**Step 7: Determine the requirements for the phase of use**

**Step 8: Determine additional requirements for the detail**

**Step 9: Design a detail that meets the requirements**

**Step 10: Secure the demountability**

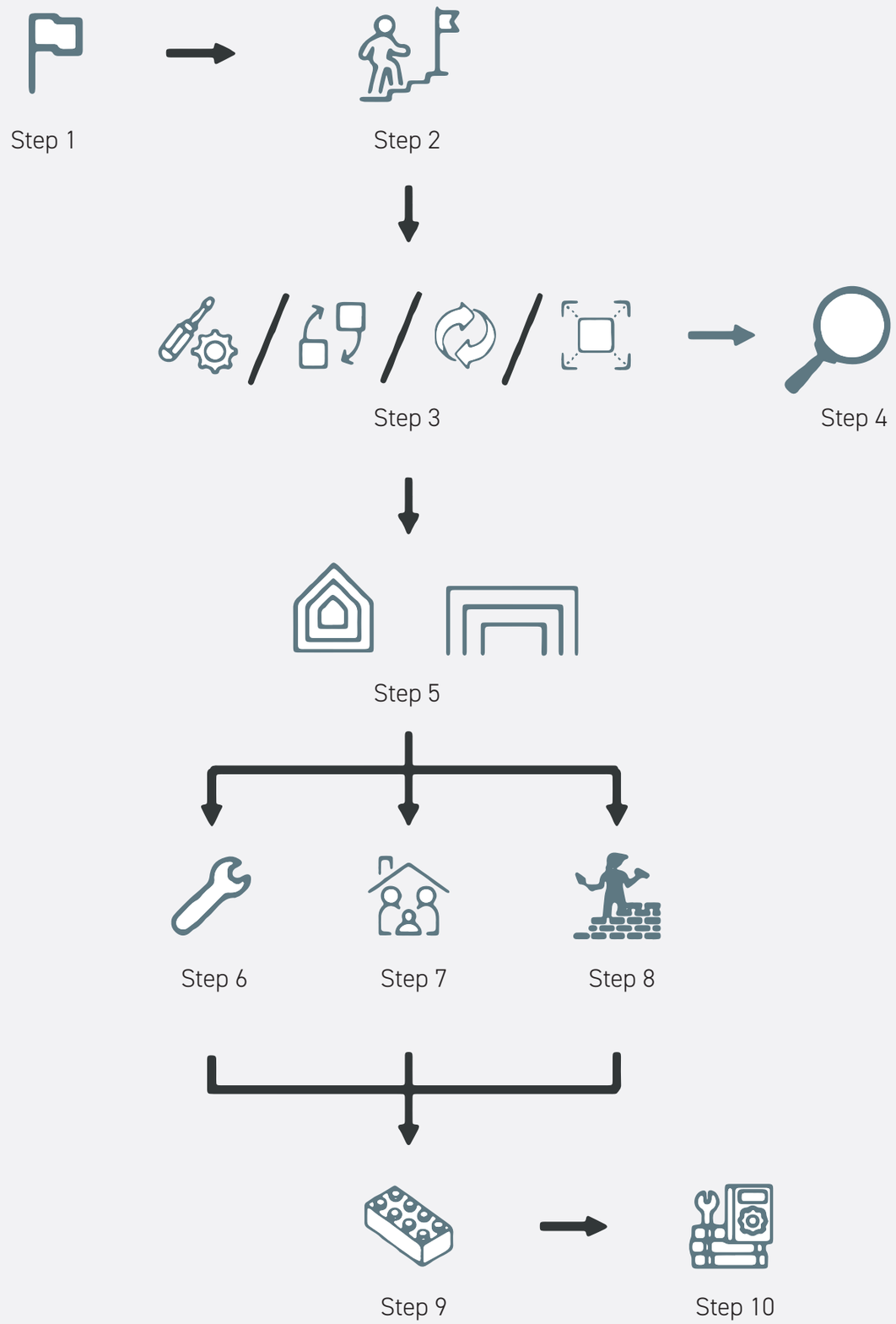


*figure 02 - Steps towards a demountable ambition*

# Demountable Ambition

To avoid too many repetitions a general ambition will be formulated that would be applicable during the design of building details following the steps of the previous chapter. These ambitions are a general guideline and will have to be constantly evaluated during the design process by testing and calculating the demountability index.

**1. Project ambition**

As previously discussed in the introduction of this report the overarching ambition for the project is to create a fully demountable and movable structure. The structure has to be able to be disassembled when the site conditions make inhabitation of the polder area unsuitable for the target group. It has then to be transported in a flatpack way since heavy transportation is not possible in peat polders. Once arrived at a new location the building will be assembled in a suitable configuration for the site conditions found. The future condition of the building and the ambition are thus intrinsically linked, the movable building has to be demountable for the concept to work.

**2. Circular Strategy**

The ambition of the project clearly illustrates the aim to build a disassemblable structure that could be assemblable in another location, this leads to a circular strategy of R3 reuse. Because the building could be placed in many locations over its lifespan without actually being destroyed and newly built over and over again this might also have components of circular strategy R2 Reduce and maybe even R1 Reconsider.

As an addition to the demountable ambition the building also has to be light to be transported over the soft grounds of the polders, only needing light electric tools and cranes. Material wise it is aimed to reduce the amount of concrete as much as possible and use as much biobased and natural materials as possible, without sacrificing indoor comfort.

**3. Target of details**

On both elements and products, the main target for the details is to enable them to be demountable to be reused in the same building in another location. Replacement or repair needs to be considered if parts of the building are damaged by accident.



**4. Goal realism**

The first element that needs to be considered is the moment of disassembly, in most cases the elements will be disassembled when the complete building is being taken apart to be moved to another location. This ensures there is no disturbance for inhabitants since the building will be temporarily unused waiting for the new location. Secondly, the materials that come out of the building will need to be considered, the second-hand market is not completely considered since almost all elements will be reused in the same building in another location. Beyond this elements in standard sizes or convenient sizes will be considered in the design. The interior elements and the structure will most probably be in good shape, exterior cladding may need some refurbishment. Especially weight and sizes of the elements are especially important since the soil cannot carry heavy trucks, the elements will therefore be as light as possible and also not too long enabling the elements to be transported on smaller lorries or trailers. Lifting still needs to be done by a small electric crane, of which will influence the weight and size of the elements. Finally, the cost aspect, normally the project would probably not be feasible, but because a lot of volunteers are involved this enables the building to be constructed in the way described above.

**5. Layers of Brand**

The layers of Brand depend on where the detail is taken and which elements or products are contained within this detail. Therefore the layers of Brand need to be determined per detail.

**6. Requirements for disassembly**

When the building needs to be disassembled the reversed order of construction is used. This means that for every step the connection needs to be accessible, of course, one element can cover another but after the removal of that element the connection needs to be accessible. The crossing of elements through other products or elements should be avoided, if one element crosses another, this needs to be disassembled first, without damaging both elements. It is preferable to be able to remove the structure with common tools, that the volunteers can use without too much carpentry experience.

**7. Requirement for use**

The elements need to meet the requirements stated by the government in the building code, beyond these requirements, the thermal insulation meets the requirements stated in the programmatic document. Furthermore, since the building will be a hospice the materials need to be hygienic or easy to clean to some extent, it does not have to meet hospital requirements.

**8. Other requirements**

Again it is to be stressed that the building is assembled and disassembled primarily by volunteers that have limited experience in carpentry. The tools needed for the job, and the actual materials and elements that are used need to be tailored to these target groups. Wet trades, such as masonry, concrete work, and plaster are to be avoided. Details need to be simple and understandable, preferably designed in an IKEA way.

**9 Detail design**

The design of the details will be documented in the building design booklet, please refer to this booklet to see the design process.

**10 Securement of demount ability**

To secure the disassembly of the materials it is aimed to create a manual that can be used for the construction of the building, it should be designed in an IKEA way that enables everyone involved in the construction process to understand the steps that need to be taken. Materials are also stored in a material passport for the building, which comes in useful at the time the building becomes obsolete. And materials are usable for other purposes.

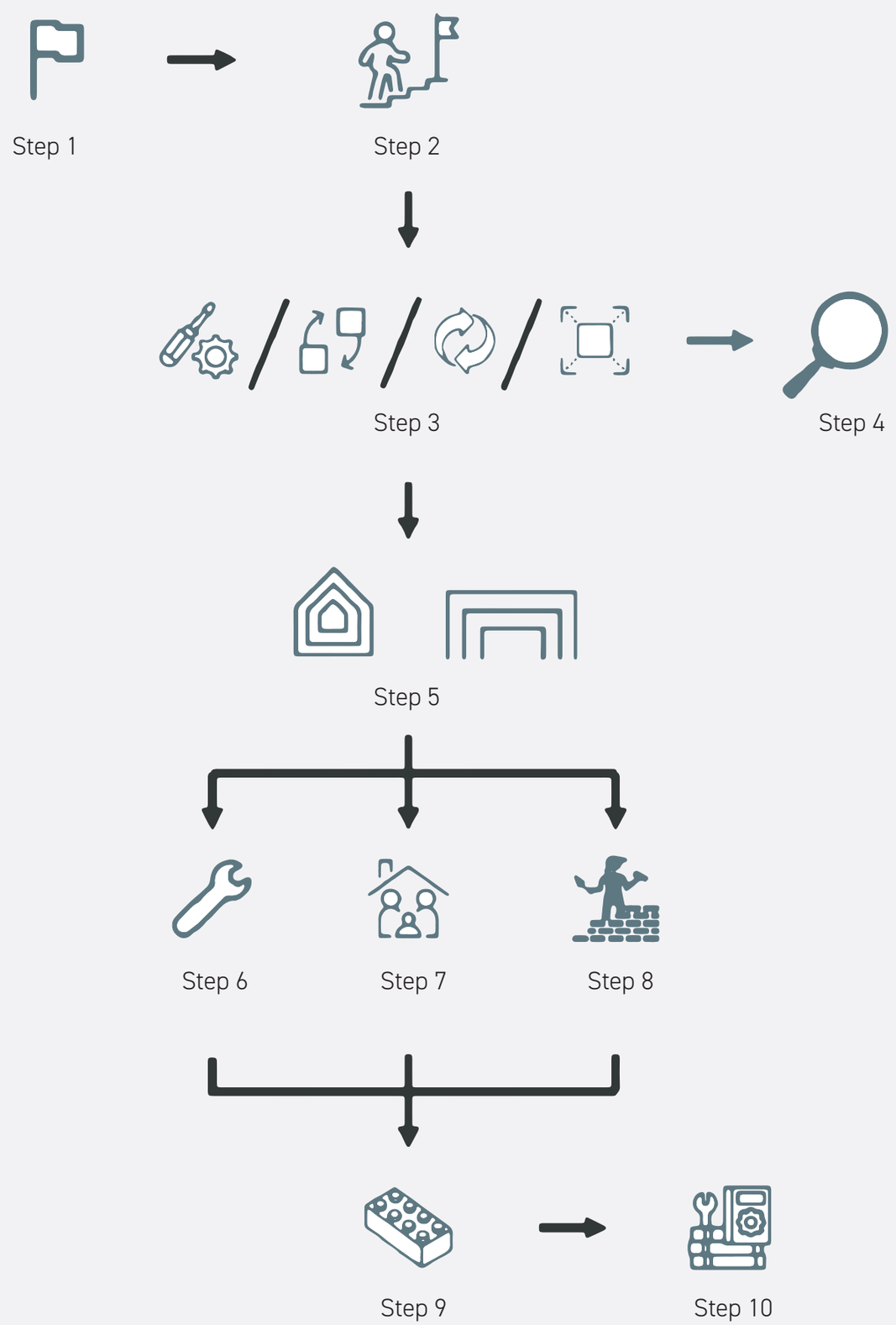


*figure 03 - Steps towards a demountable ambition*

# Calculation methodology

The calculation methodology is described in a document published by the Dutch Green Building Council and was designed and made by Alba Concepts. The document describes the calculation method in great detail, to avoid repetition the general outlines are described here. Source: Vliet, Grinsven, and Teunizen, "Circular Buildings: Disassembly Potential Measurement Method 2.0," 11–12[4].

## Aspects of Demountability

The report starts with a differentiation of three aspects of demountability, naming technical aspects, process-related aspects, and financial aspects. The technical aspects can be defined as the design determining if products and/or elements are physically demountable. Process-related aspects are steering during the design and building phase to guarantee demountability at the end-of-life phase of a building. Financial aspects are all about the financial feasibility of the project. The value of a product or element must be greater than the disassembly costs.

This Financial aspect is also clearly mentioned by Arend van de Beek during an interview on the demountable courthouse in Amsterdam, "Demountability is all about how detached you can make something, but a demolisher can demount everything. Demountability is thus determined by the preparation of the joints, if we have to demolish something it is not demountable anymore. But it also has to do with the speed something can be demounted... if something is demounted, transported, and reassembled and it costs more than what a new product costs, we call this product not demountable.[5]"

The focus of the report is to determine the technical disassembly potential of products and elements, and how these products and elements can be disassembled. This is also the main focus of the research, but it is to be noted that the other aspects should also be borne in mind.

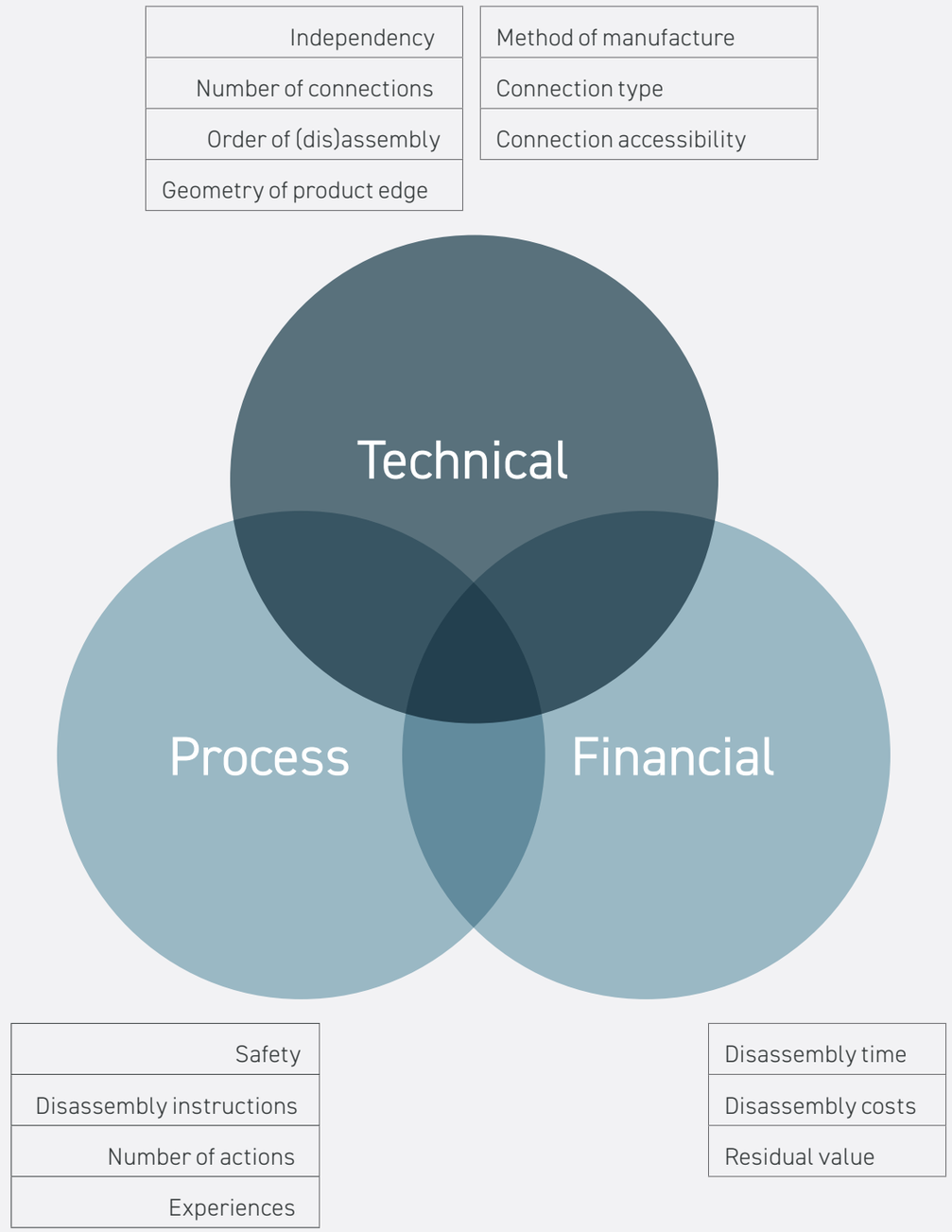


*figure 04 - Aspetcts of Demountability*

## Technical Aspects

All elements within the mentioned scope of demountability can receive an disassembly potential (DP.) This potential is made up of the disassembly potential of the connection (DPc) and the disassembly potential of the composition (DPcp.) The DP is a total score that represents to what extent a product or element in a building can be disassembled. The DPc and DPcp are further spliced up into two categories each, as shown in the figure on this spread.

### Disassembly potential of the connection (DPc)

This potential represents the ability to disassemble a product or element at the end of the life phase of a building, this disassembly often follows the reversed order of construction. The DPc is made up of two factors the connection type (CT) and the accessibility of the connection (CA).

### Disassembly potential of the composition (DPcp)

This potential represents how easily the product or element can be disassembled during the time the building still is in use. This could be the case during renovations, or with repair works. The two are thus to be considered in a situation where the other elements or products are preserved. The two factors for the composition are independency (ID) and Geometry of product edge (GPE).

### Layers of Brand

An optional, but useful step is determining the disassembly potential per the layer of brand. It is often the case that different types of products are being categorized by easier or harder disassembly. This is also affected by the ambition one might have for certain types of layers. The shell might be more adaptable, whilst the structure is more permanent. The differentiation in layers might give the user more insight into the demountability of a building.

Eventually, the goal is to determine the demountability index of the whole building, which is done by combining the layers of Brand to form the final disassembly potential of the building (LI)



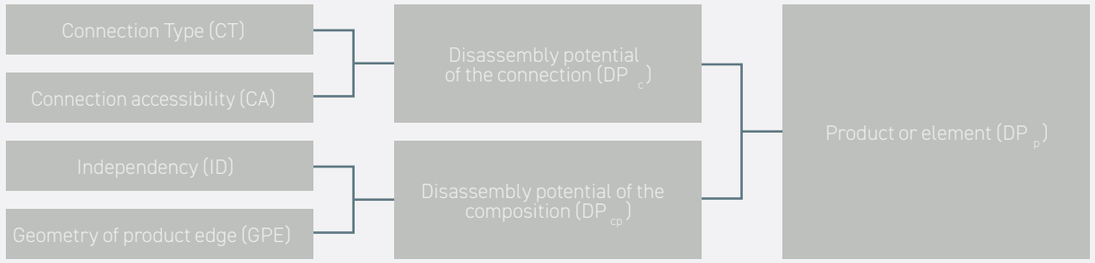


*figure 05 - Structure of disassembly potential*

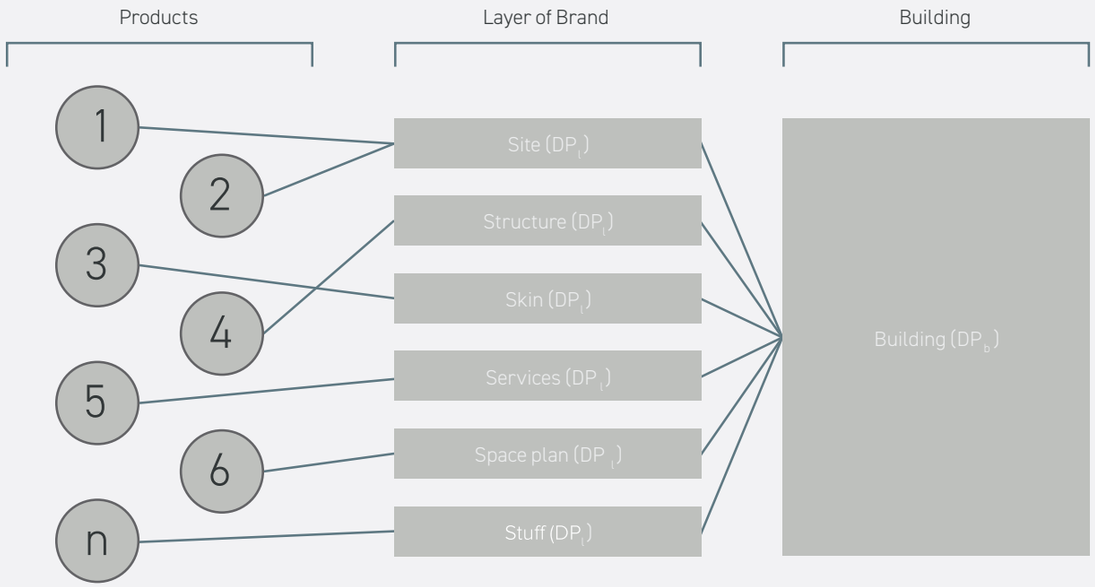


*figure 06 - Structure of building potential*

## The Formula

With the technical aspects presented in the previous paragraph, now the formula that is used to calculate the demount ability of the project will be briefly explained. Each of the four aspects has a table of values that the designer can choose from when reflecting on the design details. These numbers are in a range of 0.10 to 1.00 and reflect the effectiveness or amount of potential that is in certain aspects of the product or element.

### Potential of the product or element

At first, the disassembly potential of the connection (DPc) and the potential of the composition (DPcp) are calculated by taking the average score of the two factors it has been based on, as prescribed in the previous chapter. This score already reflects the potential of the product or element and can serve as a moment of reflection.

### Potential per layer of Brand

Once the potentials of the products and elements are calculated the next step is to calculate the potential disassembly per layer of Brand (DPln), it is therefore essential that one knows which element belongs to which shearing layer. This is done by taking the average of all elements and products whilst also incorporating the Environmental Cost Indicator of these products and elements into account. This way the most unsustainable materials are having the biggest impact on the calculation. Again this could be a moment of reflection on the technical design.

### The potential of the building

Finally, the potential of the building is calculated by taking the average of the shearing layers, whilst again keeping the Environmental Cost Indicator incorporated in the calculation. This is the final calculation and reflects the total disassembly potential of the building. After this number is known one can reflect on the goals they have set beforehand and find ways to improve if needed.



| Connection accessibility (CA) | Score |
|---|---|
| Freely accessible without additional actions | 1.00 |
| Accessible with additional actions that do not cause damage | 0.80 |
| Accessible with additional actions with fully repairable damage | 0.60 |
| Accessible with additional actions with partially repairable damage | 0.40 |
| Not accessible - irreparable damage to the product or surrounding products | 0.10 |

| Independency (ID) | Score |
|---|---|
| No independency - modular zoning of products or elements from different layers. | 1.00 |
| Occasional independency of products or elements from different layers. | 0.40 |
| Full integration of products or elements from different layers. | 0.10 |

| Geometry of product edge (GPE) | Score |
|---|---|
| Open, no obstacle to the (interim) removal of products or elements. | 1.00 |
| Overlapping, partial obstruction to the (interim) removal of products or elements. | 0.40 |
| Closed, complete obstruction to the (interim) removal of products or elements. | 0.10 |

| Connection type (CT) | | Score |
|---|---|---|
| Dry connection | Loose (no fastening material) | 1,00 |
| | Click connection | |
| | Velcro connection | |
| | Magnetic connection | 1.00 |
| Connection with added elements* | Bolt and nut connection | 0,80 |
| | Spring connection | |
| | Corner connections | |
| | Screw connection | |
| | Connections with added connection elements** | |
| Direct integral connection | Pin connections*** | 0,60*** |
| | Nail connection | |
| Soft chemical connection | Caulking connection | 0,20 |
| | Foam connection (PUR) | |
| Hard chemical connection | Adhesive connection | 0,10 |
| | Dump connection | |
| | Weld connection | |
| | Cementitious connection | |
| | Chemical anchors | |
| | Hard chemical connection | |

**Disassembly potential of composition**

$$DPcp_n = \frac{2}{\frac{1}{ID_n} + \frac{1}{GPE_n}}$$

Where:
$DPcp_n$ = disassembly potential of the composition of element n:
$ID_n$ = independency of product or element n;
$GPE_n$ = product edge geometry of product or element n

**Disassembly potential of connection**

$$DPc_n = \frac{2}{\frac{1}{CT_n} + \frac{1}{CA_n}}$$

Where:
$DPc_n$ = disassembly potential of the connection of n product or element n:
$CT_n$ = type of connection of product or element n;
$CA_n$ = accessibility connection of product or element n.

**Disassembly potential of product or element**

$$DPp_n = \frac{2}{\frac{1}{DPc_n} + \frac{1}{DPcp_n}}$$

Where:
$DPp_n$ = disassembly potential of product or element n.
$DPc_n$ = disassembly potential of the connection of product or element n.
$DPcp_n$ = disassembly potential of the composition of product or element n.

**Disassembly potential per layer of Brand**

$$DPl_n = \frac{1}{\sum_{i=1}^{l} ECI_n} \cdot \sum_{i=1}^{l} ECI_n \cdot DPp_n$$

Where:
$DPl_n$ = disassembly potential of a Layer of Brand n;
$DPp_n$ = disassembly potential of product or element n;
$ECI_n$ = Environmental Cost Indicator of product or element n.

**Disassembly potential of building**

$$DPb_n = \frac{1}{\sum_{i=1}^{l} ECI_n} \cdot \sum_{i=1}^{n} ECI_n \cdot DPp_n$$

Where:
$DPb_n$ = disassembly potential of building n;
$DPp_n$ = disassembly potential of product or element n;
$ECI_n$ = Environmental Cost Indicator of product or element n.

*figure 07 - Schedule of the formula*

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# List of Figures

# 05 - Measuring Demountability

Hospitable Movement

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Advanced Housing Design