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Parametric design and BIM, systemic tools for circular architecture

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Abstract. The current change in societal model, from linear to circular, coupled with the digital transition, is changing certain architectural practices. The emergence of BIM (Building Information Model, Modeling, Management) generates an evolution of the work process and collaborative tools. However, the BIM tools hardly integrate digital information of the elements found during the material inventory. Moreover, these tools are not really adapted to the modeling of formally complex elements. The designers are thus led to appropriate new tools such as those of parametric design. Although for a long time reserved for "star-architects" projects, we will rely on a Belgian research showing that these tools are gradually appearing in architectural agencies. Our study has shown that the use of parametric design can be a lever of creativity in architectural practice as well as a springboard for the integration of reuse materials. We therefore ask several questions in this regard: What are the challenges of a circular architectural approach? How can digital tools be used in this process? Does parametric have a place in a reuse perspective? This contribution analyses how to include a form of circularity in architecture and mainly around the implementation of reuse elements. We propose a workflow between BIM and parametric tools as a means of valuing reuse in architecture. We will approach these questions with concrete examples illustrating the relevance of the link between parametric and reuse.

Keywords: BIM, Reuse, Parametric Modeling, Circularity

1. Introduction

Slowly aware of its consumption model's environmental impact, the society is trying to switch to a more responsible and sustainable model. The societal model slowly tries to leave its current linear model (extract, produce, use, discard) for a circular model. Digital technology can undoubtedly support this transformation. Although integrated in most architectural design processes, digital design tools generate sometimes complexities including communication and shape control.

The loss of time, sometimes due to digital practice, has led to rethink communication between project stakeholders. The emergence of BIM took place in this context. At the same time, digital practice does not always facilitate the shape management by architects and moreover with the emergence of BIM collaborative process. In this sense, tools developed in other sectors under the name of parametric modeling tools, have been integrated and adapted to the architectural design process.

Nowadays these two modeling processes, BIM and parametric software have gained recognition while sometimes induce certain forms of confusion (figure 1). Indeed, these two modeling logics share the same goal of integrating various data[1] into the architectural project. While in the BIM process (c), data integration involves adding an additional layer of information to a geometric model, the case of parametric modeling (b), based on associative-geometry, directly integrates the data in a process of morphogenesis, and can therefore be referred to as *computational design*.

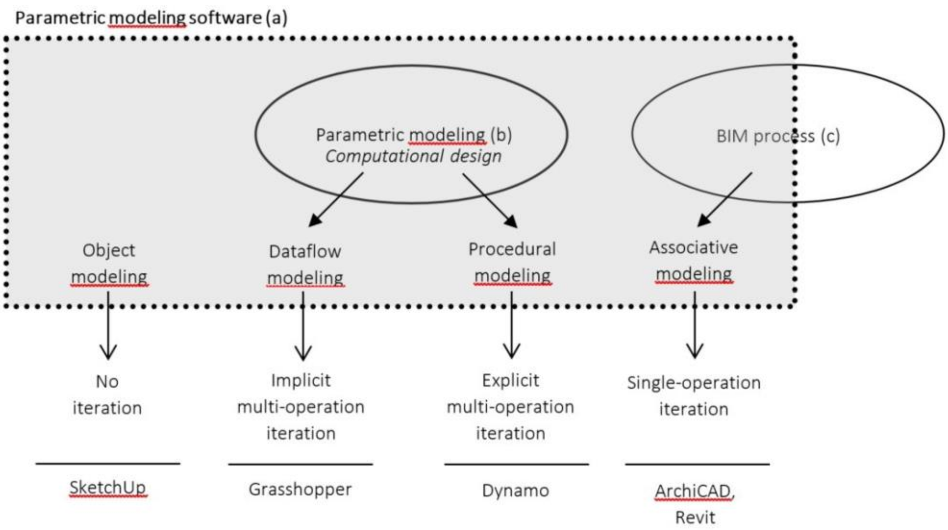

Figure 1. Relation between parametric modeling and BIM process on basis of Janssen and his colleagues' work (source [5])

This paper first goes through a brief review of three current topics: circular architectural approach, BIM process and parametric modeling tools. These theoretical notions contextualize its purpose and highlights our research gap. We go further with case studies and suggest how parametric can be useful to design in light of current challenges.

2. State-of-the-art

2.1. Sustainable development in the architectural practice

The general awareness of natural resources' limits following the oil crisis of 1979 has given rise to a common desire for the sustainable development of our society. This notion of sustainable development

[1] The term "data" is used in the BIM process and parametric processes. Yet its definition is different in both cases. The information ("I") in BIM process includes all non-graphical computing, intrinsic to the elements, components and model. For example, we can find the fire resistance, the thermal conductivity, the bearing structure. These 'data' have no impact on the morphology of the project.

In parametric tools, data are parameters influencing the morphology of the project such as the color, the position or the shape of the components, the brightness. The border is then between these two definitions. This is why we will talk about parametric data and non-graphical information in the BIM.

therefore appeared in 1987 in the Brundtland report (yellow cell, bottom of figure 2), with the aim of developing society without compromising the development and needs of future generations.

In this context, the Life Cycle Analysis (LCA - first orange drop, bottom of figure 2) method is developed in the construction sector. The element's life cycle is apprehended upstream with the question of resources and downstream with the destination at the end of exploitation. The LCA is one of the first methods to take into consideration the environmental impact of a product or system at all stages of life.

Since the 90's, LCA method has influenced many labels such as LEED in the United States, BREEAM in England and HQE in France evaluating the environmental impact of elements. In Belgium, sustainable architecture has however long been synonymous of energy saving and building's energy performance (PEB - first red drop, bottom of figure 2), resulting from the 2002 EC Directive. Beyond these labels, our ecological footprint is becoming stronger. The construction sector is responsible of nearly 50% of the consumption of natural resources and close to 40% of waste production throughout Europe [1]. The issue of sustainable architecture is today the life cycle of construction and its components.

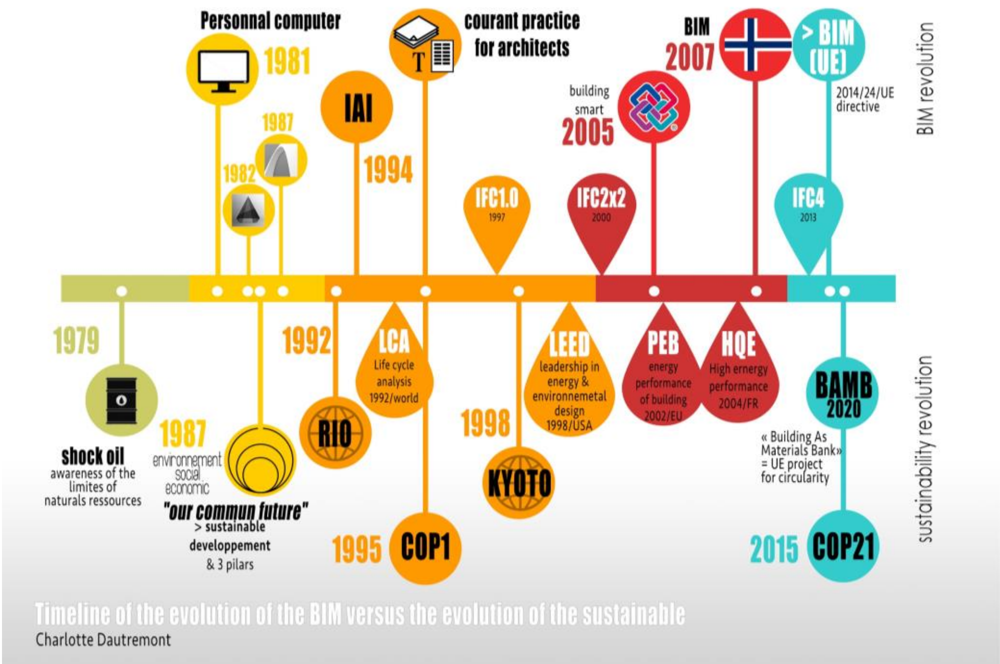

Figure 2. Timeline of the evolution of the BIM (top) versus the evolution of the sustainable (bottom)

Considering all these theoretical notions, we can state that sustainable development is developing and becoming more precise, leaving its current linear model (produce, consume, discard). The aim of this new circular societal model is to maintain the initial value of the elements to avoid giving them a waste status as fast as possible.

E. Gobbo [2] conducted a research on reusing building materials. She identified two key factors in ensuring the success of a circular architecture strategy: on the one hand a communication with a clear data exchange and ordered, and on the other hand anticipation upstream of the project by the architect.

The following two sections are an overview of the evolution of digital tools currently on the rise: BIM and parametric modeling tools. We discuss the potentials of these digitals tools and how they are actually integrated in the circular approach.

2.2. BIM evolution in the architectural practice

In regard of the sustainability evolution, we focus on the key moments of the BIM development (top of the timeline in figure 2). During thirty years, the architectural design process has been metamorphosed. Replacing drawing, computers have upset the traditional workflow, both in design, and communication with other stakeholders in the construction industry. This metamorphosis has continued to evolve and intensify to reach its climax with the birth of BIM, Building Information Modeling, Model, Management.

The exponential excitement around BIM in recent years reflects the aspirations of the construction sector. Indeed, this sector was seeking a systemic response to their profession taking shape through collaborative work around an informed digital avatar [3], BIM process tries to optimize data exchanges thanks to interoperability and different exchange formats such as CoBie and BCF. Although at the beginning of the use of the informed and collaborative digital model (BIM3D), the process aims at new dimensions including management (BIM4D) and the cost of the project (BIM5D). This new translation of the BIM brings the notions of time and life cycle as part of sustainable development.

2.3. Parametric modeling tools in the architectural practice

To better understand the parametric approach, we start by resuming what we mean by parametric modeling in this paper and rely on the words of Turrin and his colleagues [4]:

“Parametric modelling allows representing geometric entities having editable attributes, and relationships by means of associations. Attributes can be expressed by independent values, which act as input to the model; their eventual variations generate different solutions of the model”.

If we look at the actual practice of these tools, we can state that big offices, thanks to their human and financial resources, have faced the difficulties when introducing new tools in the workflow and pushed the limits of their architectural projects. Going through the results of a large-scale online survey in Belgium, a study [5] reports the challenges small and medium offices face in dealing with digital tools during their design processes. Considering that more than half of all the respondents to the survey (51.5%) have never heard of the term "parametric modeling", one can observe that some designers are able to explain the methodology but do not grasp the added-value parametric tools might have for their own practice. However, the other ones validate the potential impacts of parametric tools outlined in the literature and demonstrate by case studies in the following chapters. Firstly, parametric modeling tools allow to take into consideration more settings such as reuse criteria (technical, mechanical, normative or aesthetic for instance). As a modular component-based system, it could be infinitely varied with minimal cost (time and effort) [6] and provides a coherent model throughout the design process [7] [8]. In addition to that, these tools are recognized to manage the generation of complex geometry shapes and rise the freedom to design exploration [9].

These three crucial criteria; input settings, modifications and complex geometry shapes, are studied around the question of reuse and circularity in architecture.

3. Challenges of integrating parametric modeling into BIM6D

In a recent study (2018), Dautremont and colleagues [10] found a correlation between reemployment barriers [11] and limits of BIM use [12] grouped into five main families. In the same article, they hypothesize that integrating reuse into a BIM process is part of the response to one of the families corresponding to emotional, institutional and cultural barriers.

Indeed, by activating the creative part of the designers upstream of the project, they remove two major obstacles: on the one hand, the aesthetic barrier of reuse and on the other hand, the significant initial investment of BIM for a return to the final phase only.

If we consider BIM as a reuse integration tool in architecture, it is particularly suitable for 'future reusing''. This concept is nevertheless nuanced for 'past reusing'. Figure 3 shows few examples of brakes on the reuse of past elements as the availability off-site or the modeling of non-standard elements. All these brakes hinder today the insertion of the reuse of past elements in architecture.

Although a promising sector, we actually find that reuse integration tools in the architectural design process are missing. This lack of tools dedicated to circular architecture supports the marginal and/or pilot status of reusing projects.

This lack of digital control drives us to discuss the emergence of parametric modeling tools in architecture. Three main questions are formulated in this paper and are addressed through case studies developed in the next section: What are the challenges of a circular architectural approach? How can digital tools be used in this process? Does parametric have a place in a reuse perspective?

We believe that the algorithmic and parametric design tools, combined with the BIM process, allow the stated brakes to be leveraged. This new dimension of the BIM is under the acronym BIM6D oriented circular. The next chapters discuss parametric issues and challenges in the BIM6D process.

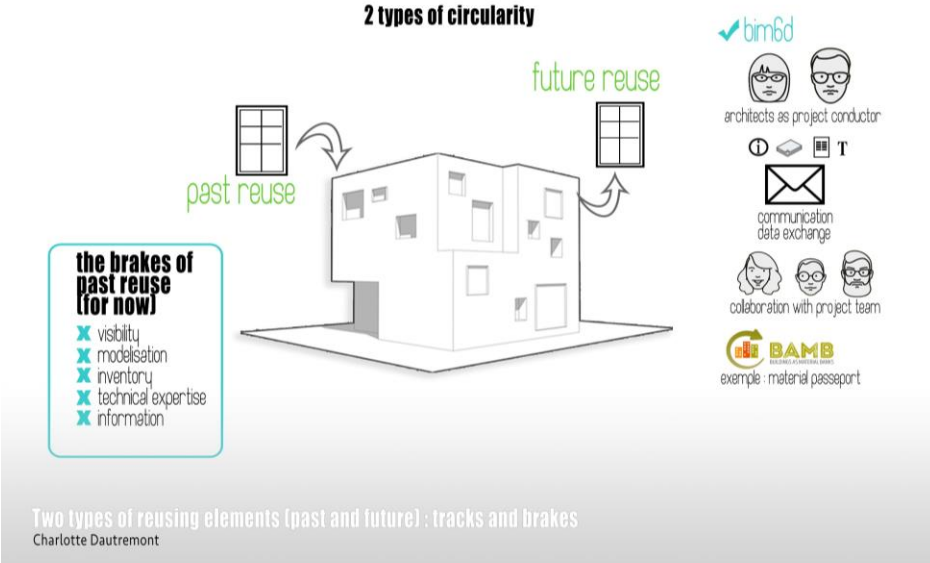

Figure 3. Two types of reusing elements (past and future): tracks and brakes

4. How can parametric serve circular architecture?

In this paper, we introduce parametric tools as tools of creation and leverages to the brakes of reuse where reusing is means to design and not an end. The examples presented in this section illustrate some opportunities of parametric in circular architecture. Through them, we show that parametric tools allow to play on the design by including reuse. Through this use of parametric tools, we also want to avoid the notion of waste to the elements and move from downcycling to upcycling.

The following example (figure 4) illustrates this dual management with the generation of a parametric model. The project was designed to use different steel profiles (three "U" profiles). The difficulty identified for this project lies in the formal search for the desired cladding (rhythm of the layout) according to the constraints of the project (volume, interior spaces, etc.) and also in the flexibility of subsequent modifications.

Unlike the BIM architectural design tools commonly used in agencies, parametric tools can overcome these two difficulties. Indeed, the flexibility of the parametric process will promote the integration of re-use elements into formal design and research and subsequent modifications. The reuse elements serve as inputs and are modulated until the desired aesthetic result is achieved.

Initially conceived as a "new" project, we diverted it into a circular project where the initial metal profiles become reuse gutters. When used as cladding, waste status and downcycling are avoided thanks to the parametric design simply by changing an input parameter: initially three U profiles become a gutter profile. Finally, thanks to the parametric we can easily include different gutter profiles (moulded, drooping) according to the available reuse stocks.

Indeed, if it is true that in a traditional design process the elements implemented result from the intentions of the project, it is not so obvious with reusable elements. Indeed, reuse can be integrated into the project like any other resource. In this case, reuse is a means of the project and not an end in itself. It is with this vision that we advance on the second case study.

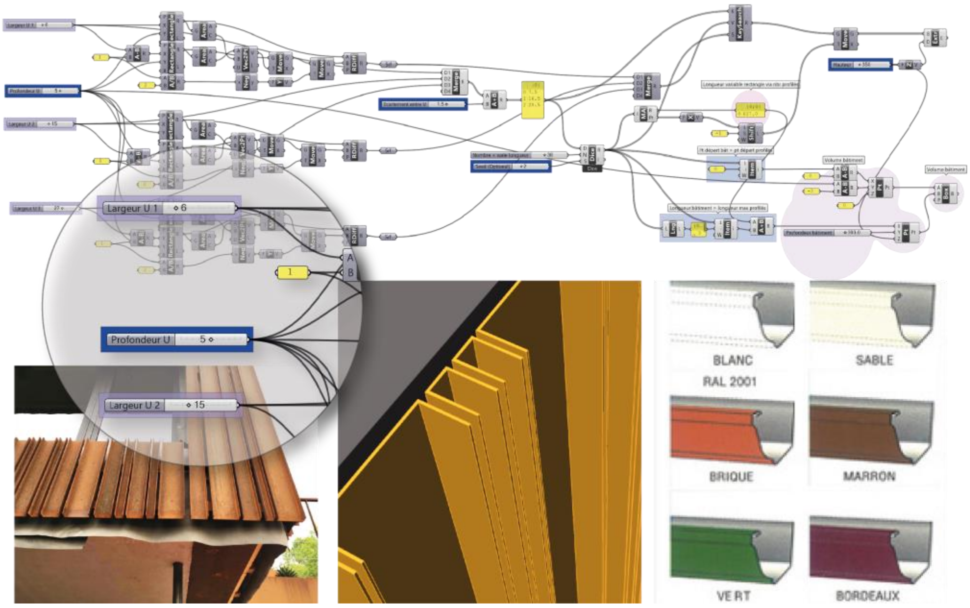

Figure 4. Parametric definition of a facade (Grondal Architect) where the modelled elements can easily be changed from U-beams to gutters with only one parameter.

The example illustrated in figure 5 shows the difficulty of including reuse elements from different sites in a design process. It highlights the advantages of parametric before and after design: upstream, inputs are easily modified (shape, size, colours, etc.) and downstream, the result can be applied to different supports (on a gable, a tower, a cut façade, etc.). This means that the designer, by the parametric performance, is no longer undergoing the design of a circular architecture but rather to define and control it.

We can see that the BIM architectural design tools commonly used in agencies do not detail each element of a facade (considering them as similar). In the example shown in figure 5, modeling reuse slates one by one would be a tedious task. That is why these tools consider the wall element as a single volume. However, the reality of reuse (availability, original stocks, etc.) does not correspond well to these BIM tools. Thus, by integrating parametric tools with BIM tools and processes, we can easily detail the design phase.

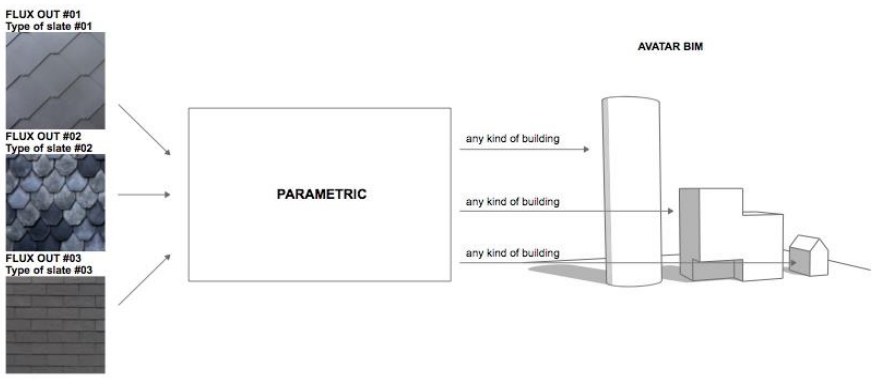

Figure 5. Flow IN & OUT of reusing slate in conception parametric process.

Figure 6 applies this principle by modifying the cladding elements on any type of building. By using filters (size, color, etc.), parametric tools would help designers to find an (re)organization of different elements corresponding to their wishes and constraints. Once the design is done with the help of parametric, the BIM increases the productivity by bringing, among other things, the quantity in schedules. In a BIM workflow, the parametric share continues to evolve during the process and remains flexible: changes made in parametric tools have an impact in BIM tools and vice versa.

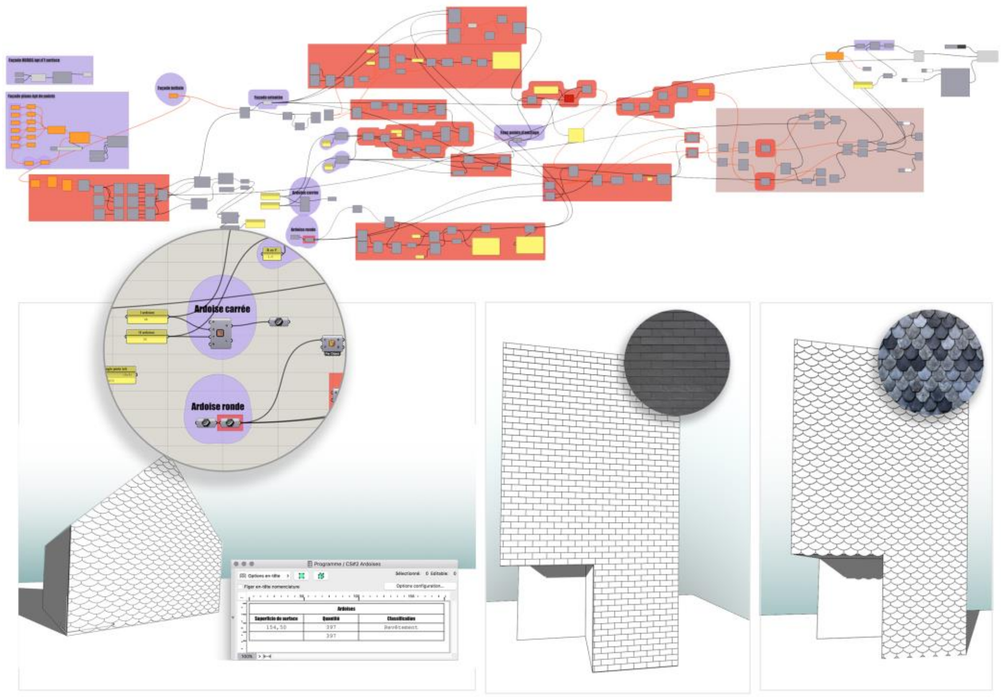

Figure 6. Parametric definition showing the flexibility of changing the incoming (two types of slates) and outgoing (three different facades) parameters.

As we have already mentioned, reuse can also be an initial constraint to the project, like budget or urban constraints. It is then an end in itself. We choose to illustrate this concept by mentioning, among many others, the case of the project “la passerelle” by Niclas Dünnebacke in Saint-Denis (Paris).
Through this case, we wanted to highlight only the implementation dimension and not the social dimension of the project. We also welcome this dimension of emergency architecture for a precarious public. In this case, window frames are reused to build a curtain wall. This repetition of reuse elements could have been supported by a parametric design such as explain for figure 5.

This closes the section with the interest of parametric for a non-strandard architecture or non-standard elements. The integration of reused elements into a design process increasingly involves modeling an element. However, BIM programs are currently more commonly used with an element library based on the manufacturer's standard elements. In such a reuse process including elements information, geometric data is really important but BIM programs as they stand are not really suited for modeling non-standard elements. This modeling could be facilitated by the use of parametric tools. Once the elements have been found or modeled, these tools make it possible to define different criteria that will guide the organization of the elements.

5. Discussion and conclusion

Through this article, we hypothesize that the parametric allows the integration of reuse through the parametric in BIM processes at different levels.

First, we tried to answer the question "What are the challenges of a circular architectural approach?». One of the challenges of reuse is to facilitate its integration into the daily practice of design. We took advantage of the emergence of BIM to introduce reuse and leverage creativity. Another major challenge of re-employment is to go beyond its connotations of "DIY", "marginal" or "exceptional" to integrate it into a professional practice, particularly recognized as being at the forefront of the construction sector. This part completes the first question but also answers the second one "How to use digital tools in this process? ». Taking advantage of EU support for the use of digital technologies in public procurement (Directive 2014/24 / EU), BIM offers many opportunities to achieve this transition to a circular architecture. This document offers a solution in that regard. We also found that there are different ways to integrate the concept of circularity into a BIM process. Currently, most procedures are intended for future reuse (Material Passports or ToTEM). Thus, referring to the five main families of BIM brakes and reuse identified in a study [10], this article is part of an approach to optimize "emotional, institutional and cultural" brakes where the parametric in a BIM process is a bridge to reuse. Through case studies, we have identified some parametric possibilities that provide flexibility to the BIM process. First of all, parametrics brings upcycling notions by integrating elements diverted from their initial functions. This example provided a more in-depth explanation of the advantages of parametric before and after the design process.

Indeed, parametric design allows designers to explore different solutions based on element modeling and design parameters. The parametric allows the shape of the elements to be easily modified and easily applied to another building shape.

Finally, we questioned the interest of using parametric modeling tools to model non-standard elements as they are generally found in a reuse process. Given the level of complexity that can be easily managed by parametric modeling tools, we suggest that reusable elements can be routinely encoded and managed with these tools.

6. References

[1] Guide pratique du réemploi réutilisation des matériaux de construction (2013), dans le cadre de l’Alliance Emploi – Environnement. Online on ULG website, Unité CIFFUL.

[2] Gobbo E 2015 Déchets de construction, matières à conception, Analyse des stocks et flux de matières dans le cadre des opérations de rénovation énergétique en Région de Bruxelles-Capitale, *PhD Thesis*, LOCI, Louvain-la- Neuve, Belgique.

[3] Lebègue E and Cuba Segura J-A 2015 Conduire un projet de construction à l’aide du BIM, Ed CSTB.

[4] Turrin M Sariyildiz S and Paul J 2015 Interdisciplinary parametric design : the XXL experience. Iass - *Proceedings of the International Association for Shell and Spatial Structures*, Amsterdam, Holland. Page 5

[5] Stals A Jancart S and Elsen C 2018 Influence of parametric tools on the complexity of architectural design in everyday work of SMES’s. *IJAR*, (Paper accepted).

[6] Aish R and Woodbury R 2005 Multi-level Interaction in Parametric Design. *Computer Science*.

[7] Peters B and Whitehead H 2008 Geometry, Form and Complexity. *London: RIBA Publishing*.

[8] Patrick J and Wee C K 2011 Visual Dataflow Modelling: A Comparison of Three Systems. *Proceedings of the 14th International CAAD Futures*, 801–816.

[9] Aish R and Bredella N 2017 The evolution of architectural computing: From building modelling to Design computation, *Architectural Research Quarterly* 21 1 pp 65–73.

[10] Dautremont C Dagnelie C and Jancart S 2018 BIM6D: un levier pour une architecture circulaire?, *Proceedings of the 18th* SCAN.

[11] Delmée H 2017 Un vade-mecum pour la conception à partir de matériaux de réemploi, Master thesis LOCI, Bruxelles, Belgique

[12] Marin P and Segura J A C 2014 Outils, méthodes et acteurs : analyse des limites à l’utilisation de la maquette numérique, *ENSA* Lyon, MAP-ARIA UMR CNRS-MCC, France