Practical Trajectories of Parametric Tools in Small and Medium Architectural Firms

Adeline Stals[1], Elsen Catherine[2], Sylvie Jancart[1]

[1] *LNA - Faculté d'Architecture, Université de Liège, Belgium*
[2]*LUCID - Faculté des Sciences Appliquées, Université de Liège, Belgium*
Adeline.stals@ulg.ac.be

Abstract.

Initially used as an extension of hand-drawing tools, digital design tools and moreover parametric ones are nowadays deeply modifying the architectural design process. Big offices with star-architects were able to adopt these tools but most architects working in a small office are still trying to cope with these parametric design tools.

Several questions arise in this regard: what digital tools do architects usually use? Do they express interest for new technologies and software such as parametric ones? What is their understanding of the term "parametric architecture"? Why is this kind of tools still not largely adopted? Going through the results of an online survey, this paper first discusses the meaning of parametric design for architects. The contribution then analyzes the Belgian case regrouping mostly small and medium offices. It reflects particularly on the way architects do or do not implement these new digital tools in their workflows, and it sheds light on the fact that parametric tools also have the potential to free the creativity of SME's.

Keywords: Complexity of digital tools · Parametric tools · Small architectural firms

1 Introduction

First introduced as a substitute for hand-drawing tools, digital design tools and particularly parametric ones are today challenging the entire architectural design process. Conventional Computer Aided Design (CAD) tools and packages are nowadays deeply rooted in most day-to-day architects' work. It took time, however, for them to be implemented in such a global way. Parametric tools are facing an even slower adoption rate, their integration to the design processes being still a challenge for most small and medium architectural firms. One of the reasons is that beyond enabling the integration of multiple parameters, these design tools are also partly responsible for the growing complexity of the design process itself.

Originally, parametric modeling was developed for design in aerospace and automotive areas [1]. "Star-architects", thanks to their large teams of software

engineers and resources to train teams to a new workflow, were of course able to adopt, and adapt, these innovative tools. But when we consider the practice of most other architects, there is a very different reality – at least at the time being.

The paper first discusses the meaning of parametric design and analyzes theoretical contributions comparing different practices embedded in this concept. The contribution then describes and analyzes the situation of small and medium Belgian offices, reflecting particularly on the way architects implement and take advantage of digital and parametric tools when designing architecture.

2 A Theoretical Look Into Parametric Practice Through History of Architecture

On the theoretical side, we can define three different eras in architectural history from the viewpoint of design support tools' evolution. These three eras can be summarized as follows: 1. morphogenesis through experimentation; 2. first steps into the digital era and 3. digital architecture nowadays [2]. Parametric modeling is one of the digital modeling methods integrated in the current architectural design praxis.

The impacts traditional digital tools have on the main phases of design processes have been the subject of scientific attention since their adoption in the 80s. By now, many researchers have demonstrated the positive and negative influences of these tools and moreover report on the influence of parametric tools and their growing interest for architects given the new perspectives they open in terms of workflow and diversity of morphologies [3], [4]. Yet, these studies are generally performed within large offices whose parametric practices are recognized, this way setting aside the experimental applications of parametric tools inside Small and Medium Enterprises (SME's). Some of our previous research indeed sheds light on the fact that parametric tools are mainly used by large agencies while smaller offices still operate with more traditional CAD tools, more profitable to their day-to-day activities [5]. Therefore, we can confirm that the architects' community is split into two major groups such as described by Bourbonnais [6]: the ones easily adopting technologies and the so-called "technophobes", somehow reluctant to implement renewed ways of modeling on a day-to-day basis.

Within the communities of adopters, two main types of parametric tools are currently at use [1]. The first group of tools is more focused on *Building Information Modeling* (BIM), where parametric relationships encapsulate parametric descriptions of components of a building design, across multiple disciplines [7]. ArchiCAD© is an example of such a software. The second group of parametric design tools is based on *associative-geometry*, where parameterized mathematical descriptions and associations between points, curves, surfaces and solids are made possible. Parameters, in this context, can also characterize and control performance, structural, material, social, urban or environmental features. The tools belonging to this second group include Bentley Generative Components© and Rhino Grasshopper© for instance. Worth to underline is the fact that the evolutionary processes implemented through parametric tools totally contrast with the static behaviors of more traditional modeling methods,

used to create one instantiated model. Theoretically, this evolutionary process is more effective than traditional numerical modeling [8]. A survey, described in the next section, helps us understand how both communities of adopters and technophobes interact with these different ways of practicing.

3 A Look Into Practices of Small and Medium Architectural Firms

Digital tools and parametric ones in particular are presently recognized for their potential to develop new kind of complex, "non-standard" architecture. But how do small architectural offices deal with those tools? Do they achieve such breakthrough as easily? This section will report findings from a survey sent to all Belgian architects and architectural engineers, and more specifically about the challenges they face in dealing with digital and parametric tools during the various steps of their design processes. Belgium is, in this regard, an interesting case study because it is known to be dotted with quite small offices.

3.1 Research Gap

Following up existing literature, we understand that a gap of knowledge exists when it comes to current parametric architectural practices in small offices. A significant amount of work has been done about large architectural firms using parametric tools, such as Shelden [4] focusing on Gehry's architecture. The only study paving the way on how small agencies deal with such design tools was carried out in Austria and England but could not be concluded due to lack of architect's participation [9]. More specifically in Belgium, the last study about the use of digital tools by architects was conducted in 2008 [10]. The goal of this research, mainly addressed to the North part of the country, was to assess the impact of different types of design support tools (DSTs) through the decision making process. This research was thus not specifically focusing on the role of digital tools in architectural practices. It rather classified six types of design tools according to the role they played all along the design process: knowledge–based tools, communication tools, modeling tools, presentation tools, structuring tools and evaluation & analysis tools.

Considering this current state of knowledge, and regarding results previously published elsewhere [2], this paper will therefore address three main research questions:

[-] How do architects use digital tools in general? Do they express interest for new technologies and software such as parametric ones?

[-] What is their understanding of the term "parametric architecture"? What fears/hopes/beliefs are driven by this term?

[-] Why are parametric tools still not largely adopted, at least by the Belgian practitioners?

3.2 Methodology

Regarding the large amount of people to reach (about 13.000 architects or architectural engineers), we used an online-based survey strategy in order to explore the previous research questions. The following sections aim at developing the methodology used to rigorously build and analyze this survey.

The questionnaire was built around three main sections. The first part began with collecting the participants' demographic data in order to contextualize each profile. Ten questions were formulated (1 open-ended question, 7 semi-open questions and 2 closed-ended questions) and mainly related to the participants' gender, age, background, expertise, main day-to-day tasks and size of firm. The second and most important section questioned designers' digital culture, the digital tools they use, their feelings about those digital tools and the impact those digital tools have on the architectural design process, from their point of view. This section contained 26 questions with 6 open-ended questions, 10 semi-open questions and 10 closed-ended questions. The results about the use of digital tools in general, the feelings about those digital tools and their impact on the architectural design process, have been published elsewhere [2]. The concluding section investigated parametric design and tools. It was structured around 9 questions (1 open-ended question, 1 semi-open question and 7 closed-ended questions). This section asked, for example, to rank the difficulties encountered when using parametric tools, according to the architect's priorities; it also investigated whether designers felt concerned by the arrival of new design tools called "parametric" or also in what time period they plan to train themselves to parametric tools use. The whole survey is available on demand (please contact authors).

The questionnaire was tested with a first round of a few participants, which enabled us to specify the meaning of some statements, to adapt some fixed-alternatives answers and to test the time needed to complete the questionnaire rigorously.

After this test-survey, we concluded that if a completed survey fulfilled one of the following criteria, it was considered unusable and therefore was not included in the next steps of our research:

[-] The survey was completed far too quickly and therefore could not have been taken seriously. The test-survey round demonstrated that the 15 minutes boundary was the right limit;

[-] Only the first section of the survey was completed (the other two completely ignored), and therefore offered no data about neither digital nor parametric design/tools. This means that some surveys, where only a few questions had been dismissed, were still considered as valuable (in that case, a "no answer" – NA appears in regard to the few dismissed questions);

[-] Regarding the size of the firm, we put aside participants working in structures of more than 100 people. These people, the "background" and "main tasks" sections reveal, are mostly architects working as academics only or included in larger, contractor structures.

The analyze of the data mostly concentrates on quantitative results basically treated in order to delineate general trends, and supported by qualitative data to more closely look at some of these trends.

3.3 Sample Description

For this study, over 700 responses were collected and 572 answers were eventually selected for analysis after cleaning data. This amount represents 4.1% of the architects registered to the three different regional Architects Associations. The female-male observed ratio is close to the one collected through a survey conducted in 2014 by the Architects' Council of Europe (73% male architects at that time, [11]). In our case, 72.9% of the surveys have been answered by men and 26.8% by women (while 2 people did prefer not to answer), indicating that the current sample is sufficiently representative of the Belgian population. Our survey displays 49.3% of the participants under 40 years old, confirming the relative youth of the population as already observed by the 2014 survey. In regard of expertise, 32.9% of the respondents are practicing their main occupation for less than 10 years, 27.3% are practicing it for 10 to 20 years and 38.3% for more than 20 years. Regarding their professional situation, 52.6% of the respondents are isolated, independent architects (working on their behalf), 22% are independent architects working for some collaborator, 5.5% are employees, while 3.9% are architectural engineers and 2.6% are teachers (other participants distribute among other occupations). Throughout this paper we will refer to the participants as "designers".

The 2014 survey moreover showed that the amount of medium-sized offices is continuously decreasing, in favor of smaller structures: at the time being, already 74% of European offices counted only 1 person [11]. Table 1 demonstrates the relevance of our Belgian case, since 42.7% of the respondents are indeed working in a firm of only one or two people. Furthermore, almost 80% of the participants are working in a structure smaller than 10 people. This trends also supports why the paper intensively focuses on understanding the daily routines of small and medium architectural offices, not deeply studied by researchers and yet making up the larger part of the professional practice.

Size of firms (number of people)	1 to 2	3 to 5	6 to 10	10 to 20	20 to 50	50 to 100	NA
Percentage	42.7%	22.6%	12.4%	11.9%	5.2%	3.7%	1.6%

Table 1. Size distribution of firms in Belgium, according to our survey.

3.4 Use of Digital Tools in Belgian Offices

Our results first show that 76.9% of the participants indeed use digital tools during the design phase. Figure 1 moreover shows that designers using design tools just for 2D drawing mainly use AutoCAD© (56.2%), followed by Vectorworks© (19.6%) and ArchiCAD© (14.8%). ArchiCAD© is also used as a 3D support tool (22.8%) but Sketchup© remains the reference for 3D modeling in architectural design, at least for 52.3% of the users. Parametric software such as Grasshopper©, Generative

Component©, Vasari© or Digital Project© as Figure 1 demonstrates are either totally, or largely unknown by the Belgian sample.

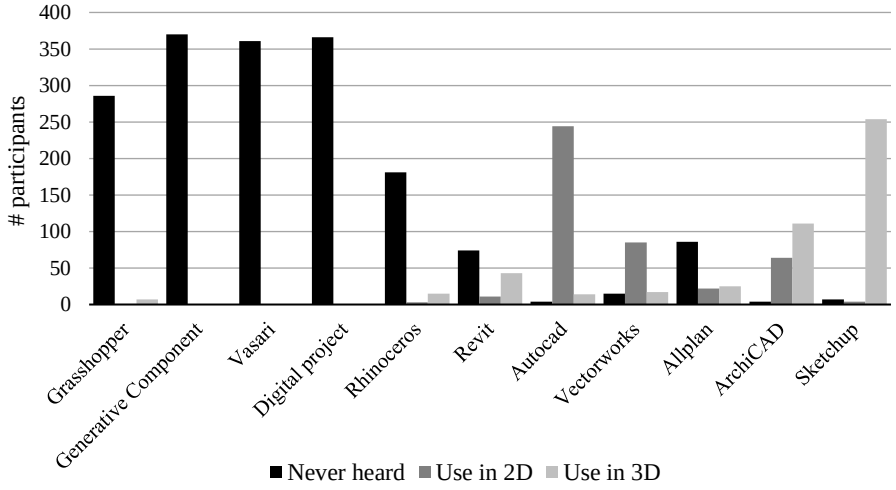

Fig. 1. Knowledge levels and use of digital tools in architecture.

The survey moreover asked the participants to evaluate how design tools impact several parameters of the architectural practice (Fig. 2). Most of them agree that digital tools have strongly increased the execution speed of projects, strongly facilitated exchanges with stakeholders and the implementation of projects, but they state digital tools have not promoted diversity of the shapes produced. Excerpts of free-field answers such as "*complex shapes are difficult to represent"* (e.g., curves) and "*non-standard element is complex"*, generating *"less creativity"* bring qualitative support to this result.

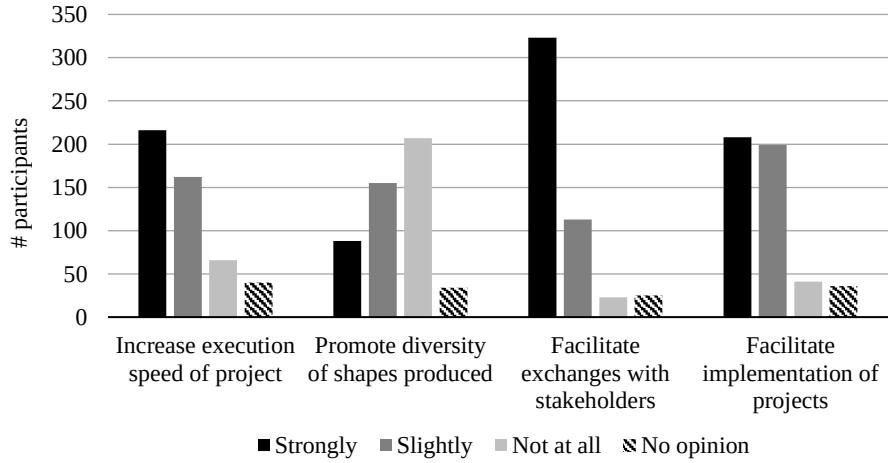

Fig. 2. Influence of digital tools on several parameters of architectural design.

A deeper analyze has been published by the authors [2] addressing the notion of complexity in the use of digital tools according to the designers' age or size of office for example. This previous paper also develops the factors and actors influencing the designed and produced shape, and eventually discusses the interdisciplinarity management inherent to such digital design task.

3.5 Use of Parametric Tools in Belgian Offices

In this section we will consider why parametric tools are still not largely adopted, at least by the Belgian practitioners; we will discuss the meaning of the "parametric" term and the perception and interest practitioners develop for this type of tools.

Interest and Understanding of Parametric Tools

First of all, our study shows that more than half of architects (51.5%) have never heard of the term "parametric modeling". X axis on Figure 3 shows the increasing size of offices, while the Y axis presents the percent of participants that respectively (from top to bottom) didn't answer that question, "never heard" about parametric modeling or "already heard" of the term. We can observe that there is a slight growing tendency to know about parametric modeling with the office growing in size.

Our results moreover underline that only 14.4% of the respondents state "being concerned" about the arrival of these parametric tools on the market, leaving 38.6% of non-concerned participants and 47% who do not have an opinion. Figure 4 additionally shows that the larger the size of the office, the higher the interest rate for parametric tools is. Small offices, at least at the time being, do not see any interest in those.

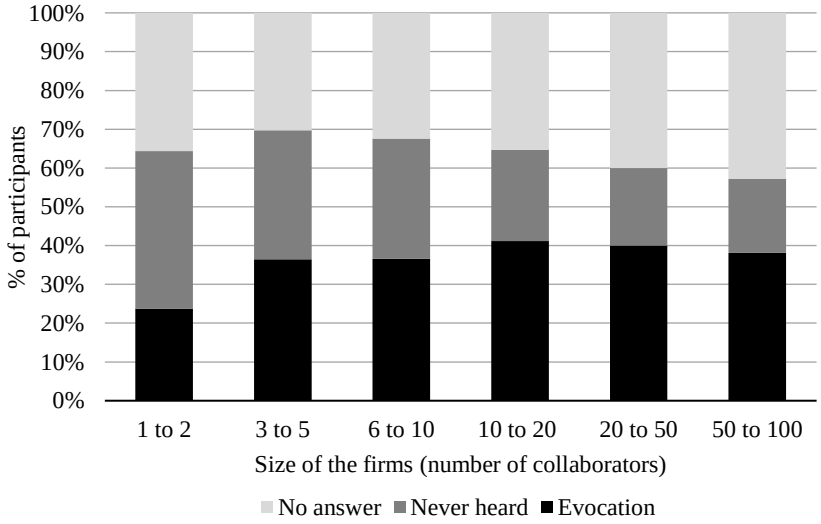

Fig. 3. Evocation of the term "parametric modeling" depending on the size of the offices.

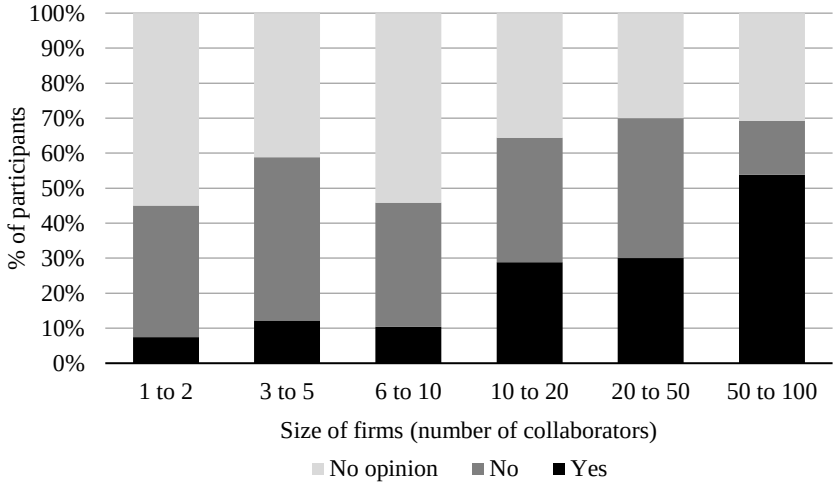

Fig. 4. Interest rate for parametric tools depending on the size of the offices.

Let's now focus on the perception of the term "parametric tool". Among the 87.5% of Belgian architects *not* using parametric tools, 34.5% refrain from giving a definition of parametric modeling, according to their point of view. 25.5% of these "non-users", on the other hand, try and give a definition. Out of this rough quarter, 18.8% associate it with BIM process and 53.6% incorrectly define it. Answers such as these ones are given by non-users: *"ability to output 3D, 2D and cuts generated by the model"*, *"complexity of shapes"*, *"whim of the 2000s"*. As for the remaining 27.6%, the definitions are not complete. Globally speaking, one can observe that designers are generally able to explain the methodology but do not grasp the added-value parametric tools could have for their own practice. Moreover, they associate to the term some strong mathematical notion generating an impression of complexity and fear of use (one of the respondent for instance quotes: *'A modeling of complex shapes using mathematical formulas.'*). Moreover, the parametric is obviously associated by some of the non-users with large projects: *'an advantage for large projects'*. The Belgian architects surveyed associate the term "parametric" to three well-known offices: Zaha Hadid, Frank Gehry and Foster and Partners. This misunderstanding of the term is also observed when looking at numbers: 82% of ArchiCAD© users indeed think that it is not a parametric software; yet this software can be consider like one of the BIM category with it library of parametric objects. Conversely 83% of those who have taken the plunge of the second type of parametric software (associative-geometry process) and who do use a plug-in such as Grasshopper© are aware of doing parametric design.

In that regard, 95% of the architects actively using parametric tools have given an explanation of what this term means to them. 3.3% of them provide what can be considered as a wrong answer with no regards to the real added value: *"image created on basis of points defined on the X and Y axis"*. 2.8% associate the parametric only to the BIM process and 93.9% of those who use parametric tools give a complete definition. We can refer to given definitions like this one:

'Design by using certain parameters (see i.e. grasshopper). The term is mostly associated with the flamboyant forms of architects like Zaha Hadid or Frank Gehry but the technique could also be used for less extravagant designs, i.e. to design a façade system, vegetation scheme in a landscape plan...'

This means that the more parametric tools one uses, the more coherent the definition is.

Usefulness of Parametric Tools

Coming back to the current use of these tools in Belgian practice, 12.5% of the participants state they use parametric tools on a regular basis. Those who do engineering calculations are the most frequent users of so-called parametric software (Fig. 5), followed by those who practice 3D modeling (18.6%) and those who do designs of public buildings (17.8%), i.e. larger projects. The design of residential projects come in last (11.9%), whereas this type of project represents 37% of the tasks globally undertaken by Belgian architects. These numbers validate the fact that designers carrying out residential projects (generally corresponding to small to medium-sized buildings) do not feel concerned by the arrival of the new generation of digital tools, leaving those tools to larger, more complex projects.

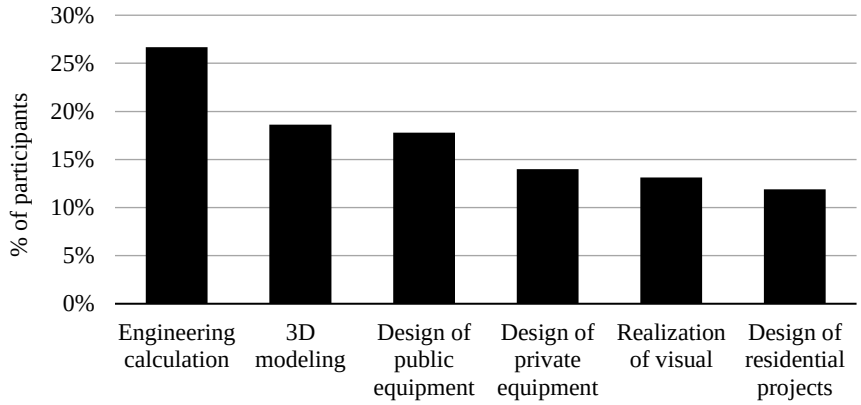

Fig. 5. Types of tasks and respective use (in % of respondents) of parametric tools.

Figure 6 lists several impacts parametric tools have on the design process, and presents how participants evaluate this impact (from "it facilitates" to "it complexifies" through "I do not know"). Looking at the proportion of "I do not know" answers, we can observe how underestimated the impacts of parametric tools can be. However, when respondents have an opinion, black sticks indicate they believe parametric tools make it much easier to generate shapes with complex geometry and generate a coherent numerical model that keeps and coordinates changes all along the process. More generally, participants recognize in a significant way that parametric tools facilitate

different aspects of the design process (taking into account more parameters, exchanges between stakeholders, consistency of form and structure).

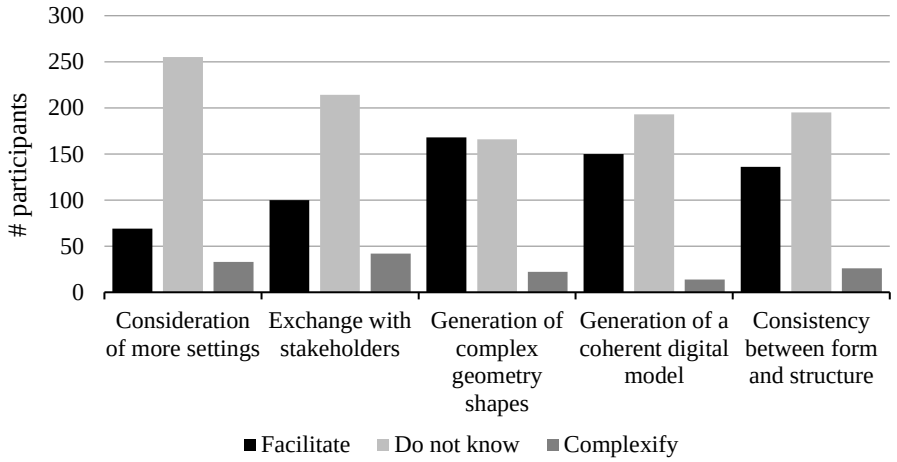

Fig. 6. Influence of parametric tools on several parameters of the design process.

When looking at how those results divide according to the frequency of use, other interesting observations arise. Those who do *not* yet use parametric tools think they can facilitate the generation of shapes with complex geometry (39.6%) and think that those tools could facilitate different aspects of the design process in general. 35.7% of them think parametric tools help to generate a coherent model that keeps and coordinates the modifications all along the design process. But more fundamentally, almost 60% of the non-users prefer not to pronounce in regard of the impact of these tools. Figures 5 and 6 again confirm how underestimated the advantages of parametric tools can be.

On the other hand, among those who state using parametric tools, a large majority consider that they facilitate the design process in general and particularly the generation of complex shapes (86.4%) and the generation of a coherent model (75%).

Comparing to Figure 2 that revealed that traditional digital tools are not considered as promoting the diversity of shapes produced, this new generation of parametric tools seems to remain a possible solution to rediscover a diversity of forms in the day-to-day design process, even for small and medium architectural firms.

This observation also correlates with another question asked to close the survey. Participants had to classify six main difficulties one can encounter (or expect, in the case of non-users) when using parametric tools. In first position (the most crucial problem from the point of view of 44.3% of the respondents), we find the slow and laborious learning of the software. This is indeed one of the problems encountered when using software in general. Second (for 34.3%) is the difficulty to stay up to level because the updates are frequent and the trainings expensive. Then two difficulties are highlighted (for respectively 18.6% and 30.5% of the respondents): the fear of losing control on the designed shape in favor of software, and the difficulty to reach easy interpretation of formal results at a technical and structural level. Additionally, the methodological workflow and the decreased speed of execution associated with the use

of parametric tools seem to be considered less crucial for designers (fifth and sixth position for 34.3% and 50.5% of the participants).

If we compare the difficulties encountered by those who already use this category of tools, and the difficulties anticipated by those who do not yet use them, they are quite similar. However, fear of losing control of the shape decrease sharply in importance (from position 3 for 18.7%, to position 5 for 15.4% of participants) when designers use these parametric tools. We can therefore draw from those observations that what actually repels most users is the slowness and the difficulty to learn and to remain at level. This highlights the need to promote training on new techniques and technologies by the representatives of the sector.

4 Discussion

Our first research topic is concerned with the current use and perception of digital tools in Belgium, where firms are mostly of small and medium size. Our results underline that Belgian architects still use a traditional combination of software, mostly one commercial package for 2D design and another one for 3D modeling. Architects mostly agree that digital tools have strongly facilitated different aspects of their architectural practice such as speed of execution of projects, exchanges with stakeholders and implementation of projects, but they state digital tools have not promoted any diversity in the shapes produced. Considering these statements, we formulate two additional questions: are parametric tools accessible to every architect and can they restore freedom of creativity?

Researchers generally report the influence of parametric tools and the growing interest architects have for them, given the new perspectives they open in terms of workflow and diversity of morphologies. But these studies are carried out in large and renowned architectural agencies. Our paper underlines that Belgian architects do not currently work a lot with complex 3D or parametric tools, and feel remote from these new design support tools considered as designed for – and more adapted to - larger offices working larger-scale projects. Our survey indeed shows that half of the designers even never heard of the term “parametric modeling”, while 87.5% of them state not using parametric tools and only one seventh feels concerned by the arrival of tools called "parametric", such as the plug-in Grasshopper©. However, a trend shows that the larger the size of the office architects belong to, the most they know about parametric design and the most they feel interested in these tools. This disinterest expressed by smaller structures’ architects obviously leads to misunderstandings of what is at the core of parametric process and what parametric design might offer. The non-users cannot give a complete definition of what and why parametric process is interesting, mostly associating it to a mathematical process dedicated to large agencies. On the contrary, 95% of users give a correct definition, shared and understood by the community of users.

While parametric tools are mostly used for engineering calculations, the design of residential projects is the least affected sector while it represents almost 40% of the daily architects’ work in Belgium. Additionally, the paper looks into how parametric

tools shape the way architects master the design process. All designers and even more users largely agree they ease the design process at different levels and, above all, 86% of the users agree parametric tools contribute to the diversity of shapes conceived.

Our results eventually shed light on the fact that parametric tools already freed the creativity of renowned offices and that, when adopted by SME's them, these new generation of tools have similar effects on their design processes. The transition to these tools is a bigger, more complex step for SME's to overcome but has the potentiality to ease freedom of expression for designers.

5 Conclusion and Future Work

This paper looked into the challenges architects working in small and medium firms face when dealing with digital tools, and more specifically parametric ones during their design processes. It underlines how their perception and understanding of these tools all along their day-to-day practices diverge from the current trends discussed in literature, especially in regard to the practice of larger architectural firms.

Future work will concentrate on two areas. Firstly, we will implement the same survey in other European countries in order to test and eventually validate and amplify the trends already identified in this paper. This may also lead to the emergence of digital culture trends. Secondly, we will deepen our understanding of current working strategies by interviewing and observing selected offices that answered positively to the possibility of further contact and on-field observation. This last phase will help us detect how to sensitize small and medium offices to new technologies, researching whether we should help Belgian designers adapting their processes or rather push for software adaptations and continuing training programs.

References

1. Dilys, F. and Burry, J. : Software Openness: Evaluating Parameters of Parametric Modeling Tools to Support Creativity and Multidisciplinary Design Integration, D. Taniar et al. (Eds.): ICCSA 2010
2. Stals, A., Jancart, S., Elsen, C. : How do small and medium architectural firms deal with architectural complexity? A look into digital practices, in eCAADe (2016)
3. De Boissieu, A. : Modélisation paramétrique en conception architecturale : Caractérisation des opérations cognitives de conception pour une pédagogie, Ph.D. thesis, University Paris Est (2013)
4. Shelden, D. : Digital Surface Representation and the Constructibility of Gehry's Architecture, Ph.D. Thesis, Masachusetts Institute of Technology (2002)
5. Woodbury, R.: Elements of parametric design. Ed. Routledge (2010)
6. Bourbonnais, S. : Sensibilités technologiques : expérimentations et explorations en architecture numérique 1987-2010. Ph.D. thesis, University Paris-Est (2015)
7. Drogemuller, R.M., Crawford, J., Egan, S.: Linking early design decisions across multiple disciplines. In: Proceedings of the Conference on Product and Process Modelling in the Building and Construction Industry (ECPPM 2004), Istanbul, Turkey (2004)

8. Gallas, M-A. and Delfosse V.: Sketch-based and parametric modeling - Association of two externalization processes for early daylight Optimization, in CAAD Futures 15 (2015)
9. Dokonal, W. and Knight M. W.: What is the state of digital architectural design? In Proceedings of Congreso SIGraDi, La Habana, Cuba (2008)
10. Weytjens, L., Verdonck, E., Verbeeck, G.: Classification and Use of Design Tools: The Roles of Tools in the Architectural Design Process. In Design Principles and Practices: an International Journal (2008)
11. Architects' Council of Europe. La profession d'architecte en Europe : une étude du secteur. Etude réalisée par Mirza & Nacey Research (2015), consulted on 10/08/2016 http://www.ace-cae.eu/