Design Support Tools in Practice. The Architects’ Perspective

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Abstract. In recent years, a large number of design support tools (DSTs) has been developed to address the ever increasing complexity of the architectural design process. This study investigates the use of DSTs in Flemish architectural practice through a large-scale survey including 629 architects. The survey was based on a practice-oriented conceptual framework. Six categories of tools were defined, according to the roles they play in the design process, namely knowledge-based, presentation, evaluation/analysis, structuring, modeling, and communication. The mapping of these roles on the design process resulted in the final framework, which was then used as a base for the questionnaire. The survey reveals that there are distinctly different needs for each of the roles defined, as well as a specific frequency of use within each design phase. Furthermore, the results indicate possible influences of tools on the collaborative design process. Finally, the data collected show researchers and tool developers what kind of support designers need in the different stages of the design process, and may help them to develop DSTs accordingly, to maximize their usability and eventually contribute to decrease the gap between tools and practice.

1. Introduction

Although numerous design support tools [DSTs] are available to architects today [1, 2], literature reveals that there is still a mismatch between existing tools and the design practice, as Dorst states: "the tools we are developing are not widely
E. VERDONCK, L. WEYTJENS, G. VERBEECK and H. FROYEN

used in design practice" [3, p.7]. He claims this cannot be explained, but other authors suggest that current tools often do not fit the design process [1, 4, 5, 6].

Further examination of this discrepancy might reveal possible strategies for the improvement of tools. Therefore, this study investigates the Flemish architectural practice directly through a large-scale survey including 629 architects (nearly 10% of the population). The survey was based on a practice-oriented conceptual framework, which was developed as a theoretical background for this study. First the nature of the design process was explored through extensive literature review. In addition to this, a study of tools and possible classifications was carried out. Although numerous studies are available that provide a possible classification, most focus on specific design aspects, for instance sustainability or user-centered design. However, there is no general outline of tools available that would be adequate for the purpose of this research. Besides, very little is known about the spread and frequency of tool usage in practice [7, 8]. As Mahdavi [8] indicates, this is problematic because new tools and applications will be developed without knowledge of users’ needs. The DSTs included in this study range from sketches and checklists to 3D CAD and simulation software, in other words any instrument intended to support one or more aspects of the design process. The findings from both literature studies were synthesized in the conceptual framework.

2. Conceptual framework

Understanding the structure of the architectural design process (DP) is a first and necessary step to study tool usage in practice. For many decades, this has been an important research topic. Extensive literature review was conducted to provide a theoretical framework as a base for the development of the survey.

The importance of understanding the DP was first addressed in the 1960s when its effectiveness became an issue in the technological competition following WW II. Jones, Thornley and Alexander were among the first to develop a scientific view on the DP. Several models of the DP emerged and aimed at optimizing the DP to improve its efficiency and innovativeness. Due to criticism, this systematic approach was gradually replaced by new models, emphasizing the ill-defined [9], wicked [10] nature of design problems. These descriptive models focused on the simultaneous development of problem and solution, replacing the logical succession of problem definition and solution development found in the first generation of models. These new insights defined the DP as a "satisficing" [Simon, cited in 11] process rather than the search for an optimal solution. One of the most influential contributions was Darke’s definition of the primary generator [cited in 5], which asserts that early in the DP the designer outlines some basic ideas as a guide towards an adequate design outcome. At the same time the participative nature of the DP was explored, acknowledging the importance of the
different stakeholders. From the 80s on, design research evolved in different directions. Important new fields included the integration of computers in design and the collaborative DP. The current study focuses specifically on the use of tools to facilitate this aspect in architectural design practice.

The developed framework was based on the literature review and decomposes the DP into the conceptual, preliminary and building permission design phases and the construction phase, according to the RIBA plan of work [5]. The DP is represented as a linear process, with feedback loops between the different design phases. This classification was used to reflect the practice-oriented nature of the current study. Additionally it is easily comprehensible for architects and could therefore be used as such in the survey. In reality, however, the DP is generally characterized as a dynamical, cyclical process with continuous feedback loops.

Subsequently, the different DSTs had to be mapped onto this framework. Based on literature and a comprehensive number of tools available to architects today, six roles DSTs can play during the DP were defined, notably as knowledge base, for evaluation and analysis, for modeling, for structuring, for presentation, and for communication. Each design phase may require a different level of support provided by each of the roles. The proposed classification is shown in Figure 1. The diagram represents the design process, the different roles of tools and the way in which each of these roles influences the design process. A detailed description of the background and the framework can be found in Weytjens et al. [12].

Fig. 1. Conceptual framework of DSTs and the DP.

The vertical arrows in the scheme represent knowledge-based design tools. This type of DST provides the designer with information that can be incorporated into the design at any moment. The horizontal line at the top represents the evaluation and analysis design tools, which allow the designer to check the design for certain aspects of its expected performance. The white horizontal arrow stands for the modeling tools used during the DP to visualize the design. The vertical
lines in the scheme represent the structuring tools, which help the designer to organize the DP. Presentation design tools, marked as crosses, are often used in close relation to the modeling tools and are used whenever the designer has to present the design to anyone who needs to be updated about the design. Lastly, the communication tools are represented as a continuous but dotted horizontal line. They are also used throughout the DP, to support communication between team members or with third parties. The last three roles in particular can contribute to a collaborative DP and will therefore be the main focus for the analysis in this paper.

Next, a questionnaire was developed, based on the classification of DSTs described above.

### 3. Methodology of the survey

A self-administered questionnaire was distributed among 984 architects in Flanders, Belgium. The survey consisted mainly of multiple choice questions, for which the respondents could not only select more than one possible answer, but also add their own.

In June 2008, a pilot test was conducted with a response rate of 70%. The results of this pilot test were used to fine-tune the questionnaire, but were not included in this analysis. The final questionnaire was distributed to all architects attending the course "Energiebewust Architect" [Energy Conscious Architect], which was organized between September 2008 and February 2009 by the Flemish government and the two major Flemish architects associations. The course was free of charge and open to all architects. By attending three evenings of lectures the participants received the label of energy conscious architect. The data were gathered in two separate series of the course. The results of the first series, with a response of 223 completed questionnaires were analyzed and published in [12]. Subsequently, the questionnaire was slightly changed and completed by 406 respondents during the second series of the course. In total, 629 questionnaires were completed and returned, representing a response rate of 64%. 70% of the respondents was male and the median age was 36. A comparison to statistical data of all Flemish architects (6985 architects, of which 71.5% male)\(^1\) indicates that the current sample is sufficiently representative for the Flemish architects’ population.

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\(^1\) Data provided by the Order of Architects (Belgium)
DESIGN SUPPORT TOOLS IN PRACTICE. THE ARCHITECT’S PERSPECTIVE

The results of the two series of the survey have been analyzed both separately and together. This revealed no major discrepancies between the two series. Therefore, most results described in this paper cover the entire sample (629). However, some minor differences will be indicated. A more detailed comparative analysis is documented in an extensive report [13].

4. Results

4.1. Current use

Figure 2 shows the usage of various design support tools by the architects surveyed. Besides the overall results (all 629 respondents), the figure distinguishes between the results of the first and second series of the survey. Both series show similar tendencies, although the percentages of the second series are generally slightly higher. These differences are not statistically significant. Therefore, the overall results will be discussed. The data show that standards and regulations (88%), technical documentation (85%), and 2D CAD software (85%) are used by the overwhelming majority of architects. The former two support architects in achieving compliance to legal requirements. The widespread use of computers has resulted in the general adoption of CAD software in architectural practice. Other DSTs that are commonly used (over 70%) are specialists, books and journals, 3D CAD software, sketches, Neufert architects’ database and photos. Presentation techniques are also more often used than experience. 48% of the respondents indicated that experience is an important supportive factor in their DP. About 40% of the respondents use checklists and scale models. Less than 30% of the respondents mentioned simulations, communication tools, evaluation and analysis tools, case-based reasoning and post occupancy evaluation. Only 3% use other tools.

The average number of tools used by the respondents is 10. Furthermore, there is a significant difference in the amount of tools used by small and large architectural offices. On average, small firms (1 to 2 associates) use 9 DSTs, whereas large firms (more than 10 associates) use 12 DSTs in the DP.
E. VERDONCK, L. WEYTJENS, G. VERBEECK and H. FROYEN

Figure 3 displays the way the respondents use a DST, or the role(s) a specific DST has in the architectural DP. The survey results show that all tools are used for more than one role in the DP, though knowledge-based tools come closest to single-role use. Standards and regulations, for instance, while predominantly a knowledge-based tool, show a clear secondary role as an evaluation tool. Checklists serve as both knowledge-based and evaluation tools by approximately equal numbers of respondents. In addition to this, checklists have a minor role as a structuring DST. Photos support designers mainly as knowledge-based and presentation tools, but they are also used as modeling and communication tools. 2D/3D CAD software and sketches are roughly of equal importance for both modeling and presentation of the design, and have a secondary role as communication DSTs. Sketches have an additional role in evaluating the design. This shows that presentation and modeling roles are closely linked. Evaluation and analysis tools and specialists are mainly used for evaluation purposes. Specialists also fulfill knowledge-based and communication roles. Finally, communication tools are primarily communication oriented, but also have significant knowledge-based and structuring purposes.

Fig. 2. Use of DSTs.
4.2. Future requirements

Figure 4 presents the type of DSTs required for each of the design phases. The respondents indicated they needed more support for all design phases. Moreover, the figure uncovers that the distribution of the distinctive roles is analogous for all design phases, except for the building permission phase. In this phase, communication is the dominant role in need of more support, followed by knowledge-based and evaluation. The latter is clearly the main role requiring more support in all other phases. The need for more communication is more pronounced in later design phases, while the need for knowledge-based is evenly distributed between the four design phases. The results further show that there is little or no need for more DSTs for presentation and modeling in any of the design phases.
Concerning the criteria that are important to respondents when selecting DSTs, ease of use (84%) appeared to be the most important criterion, closely followed by cost (65%). Easy interpretation of results, compliance with standards and regulations, compatibility with other software, and ease of learning are all considered as important criteria by about 45% of respondents. Popularity (7%) seemed to be of little importance.

Figure 5 reveals that for 74% of respondents, a good DST should increase the design quality. For about 50%, it is important for DSTs to comply with standards and regulations, to allow for intermediary evaluations of the design, and to accelerate the design process. Only 30% believes a DST should expand the knowledge of the designer.

Fig. 5. Qualities of DSTs.

4.3. Tools in relation to the collaborative design process

Examining the use of tools in relation to the collaborative DP, three main stakeholders have been identified: clients, specialists, and the design team. From the survey, the nature of collaboration between the stakeholders can principally be assessed by the impact the client has on design decisions, the role of specialists during each phase of the DP, and the importance of communication in the design team. The latter was examined through the respondents’ use of communication tools and the relative need for the communication role during each phase of the design process. Although the collaborative DP is characterized by many different factors, communication (in relation to the design phase) is a major component, and it will be used as such in the analysis below.
First, to assess the impact of the client in the DP the survey also contained questions on the factors that determine design decisions made by the respondents. As Figure 6 demonstrates, it appears that the client’s demands have a large impact (75%), along with the designer’s experience (85%). Almost 65% of respondents make design decisions based on regulations. Intuition and reference projects are taken into account by over 35% of the respondents when making design decisions, whereas only 22% use DSTs as a deciding factor. This is in accordance with the limited use of evaluation and analysis DSTs, since these DSTs have the most relevant contribution to the decision-making process. Consequently, the major basis for design decisions currently are the clients demands and experience.

![Graph showing factors for design decisions](image1)

Figure 6. Factors for design decisions (left).

*Fig. 7. Collaboration with specialists in the different design phases (right)*

(CDP = conceptual design phase, PDP = preliminary design phase, BPP = building permission phase, CP = construction phase).

Figure 7 presents an overview of the collaboration with specialists during the different design phases (e.g. structural engineers, energy consultants, HVAC engineers, access consultants, etc.). The results indicate that specialists are mainly consulted (over 80%) during the construction phase, after a building permission is obtained. For the conceptual design phase, on the contrary, less than 15% of the respondents collaborate with specialists. Limited budgets may be one of the reasons for this late collaboration. Further, around 60% of the respondents state that specialists are consulted during the preliminary design phase. Less than 40% of the respondents collaborate with specialists during the building permission phase.

Looking specifically at the use of tools within the design team, Figure 8 displays the overall use of tools and the specific use of tools for communication purposes. Apart from communication tools themselves, the communication role is most pronounced for 2D/3D CAD software, sketches, photos and books and journals. At least one in five users of each of these tools perceives them to be supporting the communication aspect of the DP. Furthermore, over 40% of
respondents who indicated they consult specialists, believe this also benefits communication.

Fig. 8. Use of tools for communication versus general use.

Concerning communication tools in particular, respondents had the possibility to specify which ones they use. Only about 15% of the respondents using communication tools, supplied tools that are architecture-specific, while other tools included email and general media.
Considering the communication within the design team itself, the size of the team and the type of projects could be significant factors for the importance of communication during the DP. First, an analysis was carried out to identify a possible correlation between both factors. As shown in Figure 9, a strong relation exists between the size of the architectural firm and the type of design projects. Almost half of the small firms (one or two associates) only execute residential projects exclusively, while over 90% of the large firms (6 or more associates) also take on larger projects. This difference appeared to be statistically significant, as indicated by the Pearson chi-square test (value lower than 0.05). Hence, subsequent analyses explicitly focus on the size of firm.

Figure 10 illustrates the use of DSTs for communication purposes according to the size of the architectural firm. For clarity, only the six tools for which the difference was statistically significant are displayed. The results demonstrate that tools are more often used for communication purposes by larger firms. This tendency also applies to those tools for which the difference was not statistically significant. Only books and journals and specialists are more frequently used by smaller firms. Although no significant difference could be observed considering the need for communication DSTs in relation to the size of architectural firm, large firms indicate a slightly more pronounced need for these DSTs in all design phases.
5. Discussion

To study the use of tools in Flemish architectural practice, a large-scale survey was conducted using a theoretical framework as a background. Literature review showed the DP is complex and varied. Nevertheless, a simplified scheme was developed to represent the impact of tools on the DP in practice rather than a detailed description of the DP itself. The four phase linear model was easily comprehensible to the architects responding to the survey and adequate for the subsequent analysis, as it focused on the roles of the tools in the architectural DP in general, rather than on the intricacies of the DP itself.

The results reveal that DSTs play an important role in the DP, as the ten most popular tools are used by at least 70% of the respondents, while the five most popular tools are used by 80% or more. Further, the average number of tools used is 10. Besides specific design related information tools, other more traditional tools like sketches and photos are prominent among the most popular tools. These last tools are still commonly used for modeling and presentation, alongside the now widely adopted 2D and 3D CAD software. Apart from specialists, communication and evaluation and analysis tools are rarely used in current architectural practice.
Most commonly used tools have multiple roles throughout the DP, with the exception of books and journals, and technical documentation. The results further show that despite the limited uptake of communication and evaluation and analysis tools, these roles are adopted as a secondary use by some of the more traditional tools, like sketches and 2D CAD software. Additionally, future requirements indicate that there is a predominant need for more evaluation tools in (early) design phases, and for communication tools in later design phases. This shows a clear demand for specific communication and evaluation tools.

According to the results, however, future tools should incorporate multiple roles, as all of the currently popular tools seem to suggest. Respondents further mention user-friendliness and compatibility with standards and regulations as important features when selecting new tools. These qualities are clearly present in the tools that are currently most commonly used. For instance, user-friendliness is a prominent quality for 2D and 3D CAD software, while compatibility with standards and regulations is apparent in both the actual use of these documents as a design tool along with technical documentation. The latter however, could benefit from additional ease-of-use. Above all, new tools should increase the quality of the design.

The results further revealed that clients are a very important factor in the design decision-making process. Therefore, good communication between the client and the design team could potentially contribute to the quality of the design. To achieve this, the client should be able to contribute more actively to the DP, and DSTs should support this communication aspect.

The considerable influence of the client’s demands in design decisions, corroborated by the frequent consultation of specialists by 80% of respondents, shows that the collaboration between different stakeholders in the DP is becoming increasingly important. However, from the current use of DSTs a strong prevalence of the traditional DP can be derived. The data show that designers still develop the design before submitting it to specialists for evaluation. The greater demand for communication in the later design phases, after the initial design has already been completed, further confirms this trend. The important need for evaluation and analysis tools in early design on the other hand, supports the designers’ request for increased design quality.

However, the significantly higher application of DSTs for communication purposes by larger architectural firms, as opposed to the smaller firms, indicates that for larger projects at least, there is a trend toward more intense collaboration. Here, the survey results may reflect the specific Flemish context, characterized by small-scale projects for private clients executed by small firms with only one or two associates. In addition, larger firms are consulting less external specialists, which may be interpreted as a sign that members with highly specialized
knowledge are already present within the design team. Overall, this shows that more tools are devoted to support communication.

Fig. 11. Framework with future needs and needs for the collaborative DP.

In conclusion, Figure 11 incorporates the results in the conceptual framework and summarizes the needs for more tools in the DP. The two roles that need the most additional support are evaluation and analysis in the early design phases and the construction phase, and communication in the later phases. Architects indicated they also need more knowledge-based tools in later design phases. This need is currently often filled by involving specialists in the later stages of the design process. However, to help facilitate the collaborative DP, communication with not only specialists, but also with the clients, as they are an important factor in the decision-making process, should be supported throughout the early stages of the DP as well. This emphasizes the importance of easy-to-use communication tools in early design phases. If different stakeholders are expected to work more closely together to increase design quality, future DSTs could facilitate an evolution away from the traditional "design and discuss" approach and towards truly designing together.

6. Conclusion

This study discussed the results of a large-scale survey into the use of design support tools among a large group of Flemish architects. DSTs are an important factor in the DP, but currently do not provide adequate support for every role. Future tools should match designers’ needs and facilitate the collaborative DP.

References

E. VERDONCK, L. WEYTJENS, G. VERBEECK and H. FROYEN


