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Abstract: The growing complexity and fragmentation of the architectural design process, largely due to stricter regulations, new technologies and increasing specialization, has led to an important rise in the number of design support tools available to designers today. These tools, ranging from simple checklists to complex simulation software, are intended to facilitate different aspects of the design process. While there are numerous studies available that provide a possible classification, most studies focus on specific design aspects, for instance sustainability or user-centered design; there is no general outline of tools available. However, researchers and design tool developers need this general information about the way designers incorporate tools into their design process, and about the kind of support designers need in the different stages of the design process, in order to improve available tools or to develop new tools. In this paper a classification is composed, based on a representative number of design tools, derived from literature. The proposed classification defines six types of design tools according to the role they play in the design process: knowledge – based tools, communication tools, modeling tools, presentation tools, structuring tools and evaluation & analysis tools. A tool can belong to one or more categories. These categories provide the framework for a survey. Aim of the survey is to gain insight into the use of these types of tools by Flemish designers in architectural practices, as well as the phase in the design process in which they are used or most needed. The collected data show the kind of support designers need in the different stages of the design process. This may help researchers and tool developers to develop design support tools accordingly, to maximize their usability.

Keywords: Architecture, Design Methodology, Design Support, Design Tools, Survey

Introduction

THE GROWING COMPLEXITY and fragmentation of the architectural design process, largely due to stricter regulations, new technologies and increasing specialization, has led to an important rise in the number of design support tools (DSTs) available to designers today. The term 'Design Support Tools' includes a diversity of tools, ranging from simple checklists to complex simulation software. DSTs are intended to facilitate different aspects of the design process.

Numerous studies are available that provide a possible classification (e.g. Daru, 1996; De Wilde, 2004; Gowri, 2005; Lawrence, 1993), and most studies focus on specific design aspects, for instance sustainability or user-centered design. However, there is no general outline of tools available. Besides, very little is known about the spread and frequency of tool usage

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in practice (Lam et al., 1999; Mahdavi et al., 2003). As Mahdavi indicates, this is problematic because new tools and applications will be developed without knowledge of users' needs.

The present paper provides a classification into six categories of design support tools, based on literature review and on a large number of available tools. A survey was conducted, based on this classification by 319 architects in Flanders, Belgium. This paper discusses the results of this survey.

After a brief presentation of the literature review, this paper describes the suggested classification, followed by the methodology of the survey. The results of the survey are discussed and finally, some conclusions are drawn.

Classification of Design Tools

While several ways of categorizing design methods have been proposed, most of the categorizations are made with the purpose of helping designers to select appropriate methods (e.g. Goodman-Deane et al., 2008). Furthermore, most of the classifications found in literature focus on a specific design aspect and corresponding tools, for example user-centered tools (Goodman-Deane et al., 2008) or sustainable design tools (Gowri, 2005). There are classifications, based on the supported design task (Daru, 1996), the characteristics of the design tool (Lawrence, 1993), or the supported design behavior (Pedrini et al., 2005). In some cases no ground for the classification is explicitly stated (e.g. De Wilde, 2004).

This study proposes a general classification that allows for the insertion of all DSTs. This general overview should assist researchers and DST-developers. Therefore, knowledge is required about the roles tools play in the different phases of the architectural design process. Each design phase may require a different level of support, provided by each of the roles design tools can play. Based on literature, mentioned above, and on a comprehensive number of tools available to architects today, we defined six roles DSTs can play during the design process, notably as knowledge base, for evaluation and analysis, for modeling, for structuring, for presentation, and for communication.

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. The design process itself was decomposed into three major design phases and the construction phase, according to the RIBA plan of work (Lawson, 1983). This classification was chosen because it is easily comprehensible to architects and could therefore be used as such in the survey.

The design process is represented as a linear process, with feedback loops between the different design phases. In reality, however, the design process is generally characterized as a dynamical, cyclical process with continuous feedback loops (Van der Voordt et al., 2000). Starting out from the design program, the design process starts with the conceptual design phase, during which the designer tries to establish a basic framework for the design. During the next phase, the preliminary design phase, many concrete design options for the adopted framework are considered, and weighed against each other and a single design is decided on. The designer then moves on to complete the design in detail and to check if the design conforms to the rules and regulations and starts the process of getting building permission. During the building permission phase or detailed design phase, minor design changes may still occur. After a building permission is obtained, the design process is theoretically finished,

but the designer will often still have to concretize some remaining technical details of the design, an activity that often partly coincides with the construction phase.

During all design phases, the designer can use any of the six categories of design tools distinguished here.

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. These tools can be used during the entire design process and after, for example in case of post occupancy evaluation. The white horizontal arrow stands for the modeling tools used during the design process to visualize the design. Typically, a different DST is used during the conceptual design phase than during the preliminary to construction design phases. The switch is generally made during the preliminary design phase, at the point in which the designer begins to finalize the layout of the design. The vertical lines in the scheme represent the structuring tools, which help the designer to organize the design process. Presentation design tools are often used in close relation to the modeling tools and are used whenever the designer has to present his design to anyone who needs to be updated about the design. These tools are marked as crosses. Lastly, the communication tools are represented as a continuous but dotted horizontal line. They are also used throughout the design process, to support communication between team members or with third parties.

To check this theoretical model and to find out more about the use of DSTs by architects in Flanders, a questionnaire was developed, based on the classification of DSTs described above.

Legend:
CD: Conceptual Design   K-B: Knowledge-Based   C: Communication
PD: Preliminary Design   x: Presentation   E-A: Evaluation and Analysis
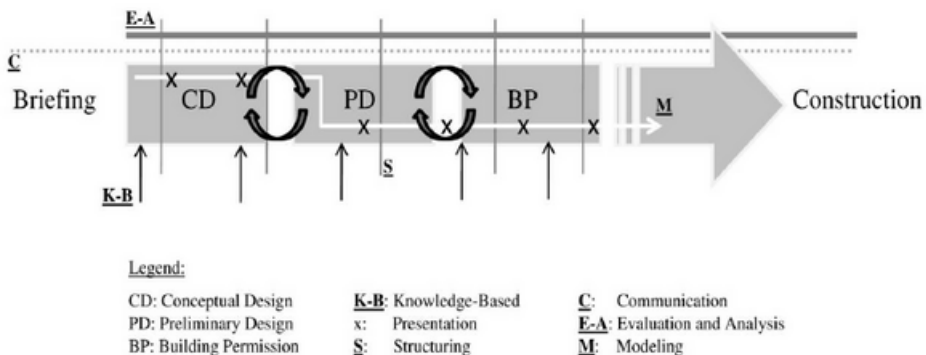BP: Building Permission   S: Structuring   M: Modeling

Figure 1: Overview of the Design Process and DSTs' Roles

Use of DSTs in Architectural Practices in Flanders

Methods

A self-administered questionnaire was distributed to 319 architects in Flanders, Belgium. The questionnaires were structured in such a manner that they would provide information regarding:

- types of DSTs used in daily architectural practice;
- role of these DSTs in the design process;
- phases of the design process that require more support;
- important characteristics of DSTs;
- influence of DSTs regarding design decisions; and
- general background information such as age, gender, and size of architectural firm

The survey was conducted in September 2008 and was distributed to 319 architects, attending the course "Energy Conscious Architect", organized by the Flemish government in collaboration with the NAV[1]. The course was open to all Flemish architects. 70, 21% of the questionnaires were completed and returned.
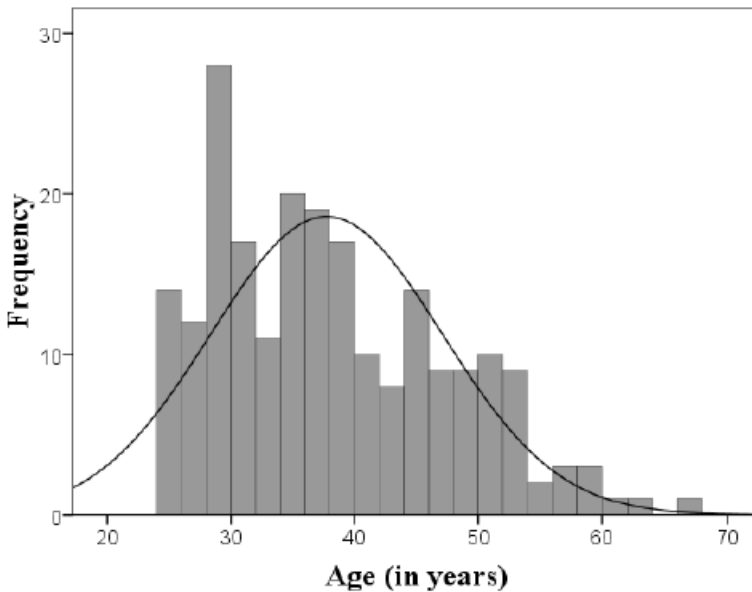
Figure 2: Respondents' Age

68% of the respondents was male, and the average age of the architects in our sample was 37, as shown in figure 2 above. A comparison to statistical data of all Flemish architects (6169 architects of which approximately 75% male architects)[2], indicates that the current sample is sufficiently representative for the Flemish population.

The used approach resulted in a very high response rate, contrary to the typically rather low response rate of mailed questionnaires (only 28% in the case of Lam et al. (1999) study).

The structure and content of the questionnaire was based on the classification of tools, presented in the first part of this paper. The questionnaire was fine-tuned after a pilot test, including 63 respondents. This pilot test was not incorporated in the final sample. The following 19 DSTs were included: technical documentation, standards and regulations, Neufert architects database, checklists, scale-models, books and journals, case-based reasoning,

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[1] Vlaamse architectenorganisatie – Flemish architects association
[2] Data provided by NAV

specialists, sketches, 2D CAD software, 3D CAD software, simulations, presentation techniques, evaluation and analysis software, photos, communication tools, and post occupancy evaluation. In addition to this, respondents had the possibility to include their own experience and to add other DSTs.

The questionnaire consisted of multiple response questions. Respondents could not only select more than one option, but also add their own.

Results

Current use of DSTs

Figure 3 shows the usage of various DSTs by the architects surveyed. The results display that technical documentation, 2D CAD software, standards and regulations, books and journals, and specialists are used by approximately 80% of the respondents. Other DSTs that are commonly used (over 70%) are sketches, 3D CAD Software, and photos. Presentation techniques and Neufert Architects Database are used by over 60% of the architects included in our survey. 47% indicated that experience is an important supportive factor in their design process. About 35% uses checklists and scale-models, while only 20% mentioned simulations or evaluation and analysis tools. Case-based reasoning and Post Occupancy Evaluation are used by less than 10% of respondents. Figure 4 shows a histogram of the number of tools used by the respondents. The average number of tools used is 9.
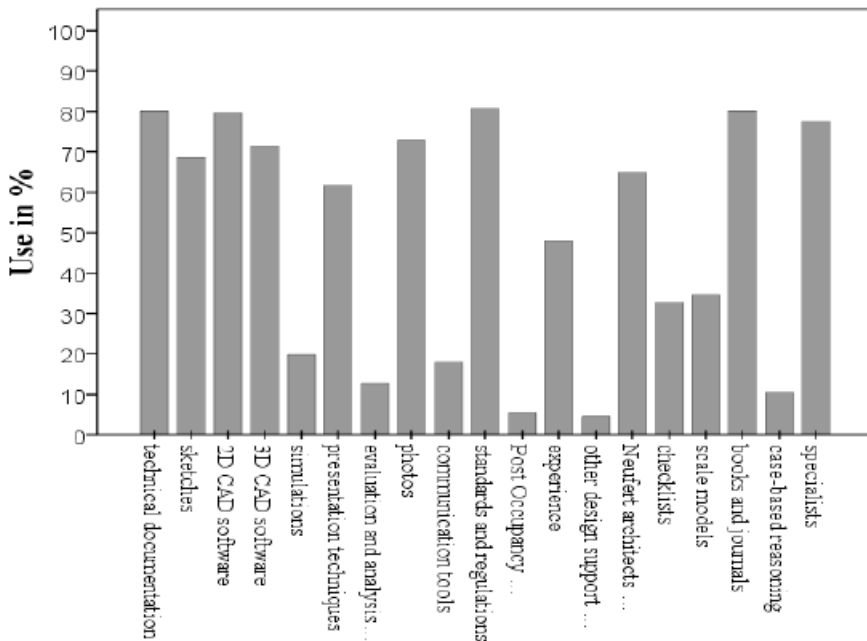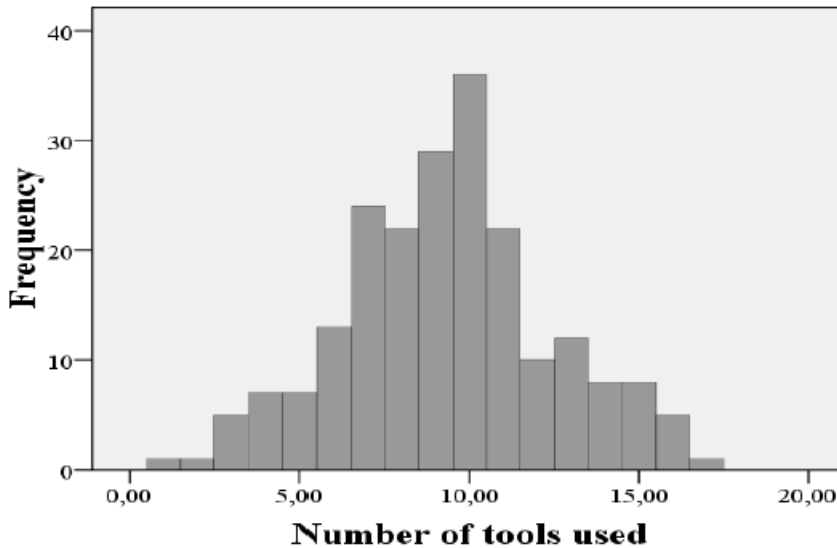

Figure 3: Use of DSTs

Figure 4: Number of Tools Used

The multi-criteria presentation in figure 5 displays, for each of the ten most frequently used DSTs, in which way the respondents use that DST, or in other words, which role(s) the specific DST has in the architectural design process. The data reveals that no DST is limited to only one of the six categories of DSTs presented in the first part of this study. Books and journals, Neufert Architects Database, and technical documentation come closest to single category use, all three being predominantly used as knowledge-based design tools. Standards and regulations are not only commonly used as a knowledge-based DST, but also as an evaluation and analysis DST. Photos are another knowledge-based DST, but they are also used for presentation purposes. 2D CAD Software, 3D CAD Software and presentation techniques are of almost equal importance for both modeling and presentation of the design. Sketches are generally used for modeling the design and for evaluation and analysis. Finally, specialists are primarily engaged as a DST for communication, evaluation and analysis, and for structuring the design process.

Books and Journals

2D CAD Software

Technical Documentation

Photos

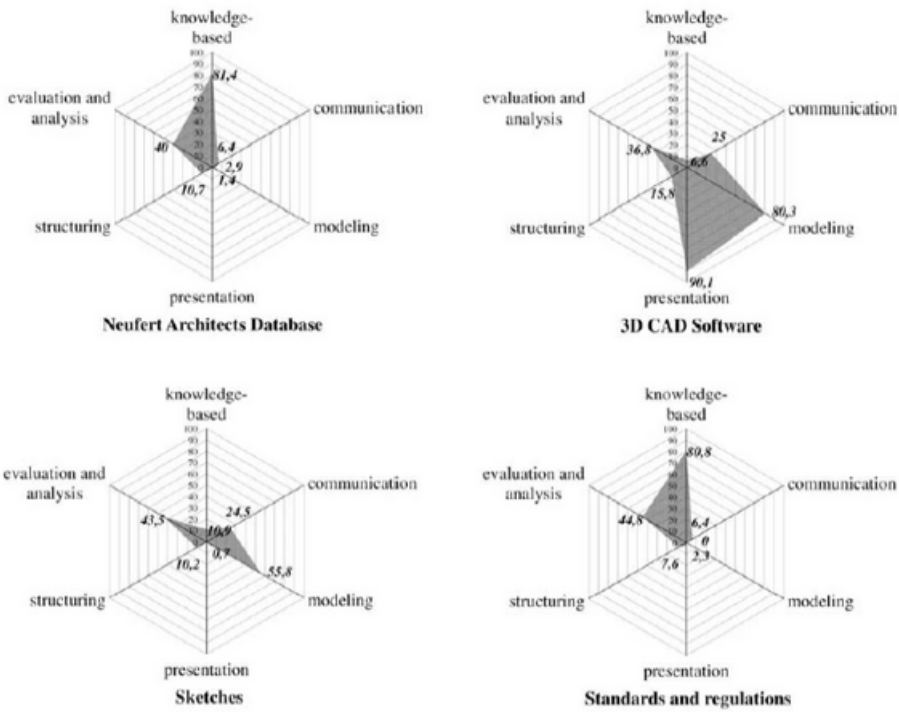**Specialists**

Presentation techniques
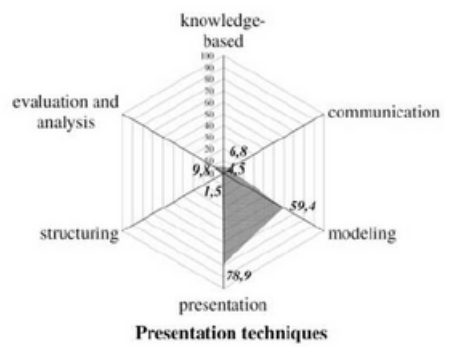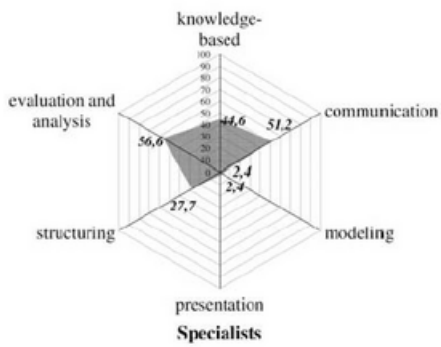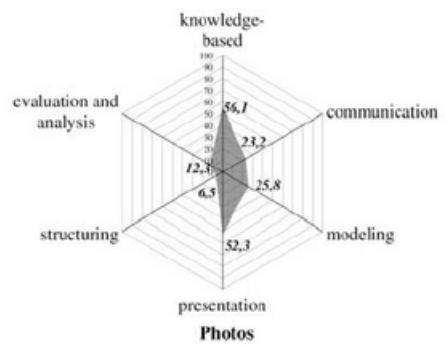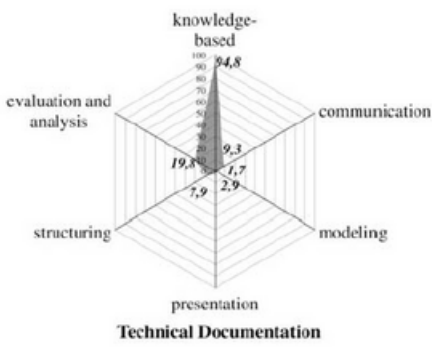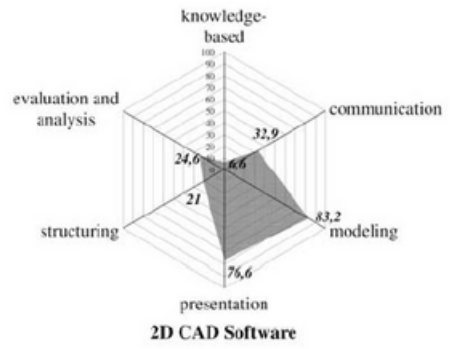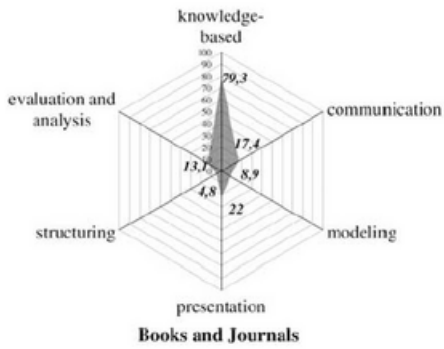
Figure 5: For the Ten Most Frequently Used DST's the % of Respondents is Presented that uses the DST for a Specific Role According to the Six Categories of Support Tools, as Presented above

Figure 6 below, summarizes the most often used categories of tools, based on the ten most frequently used DSTs, as shown in figure 5. This shows that presentation tools, modeling tools and knowledge-based tools are clearly the most commonly used categories of DSTs.
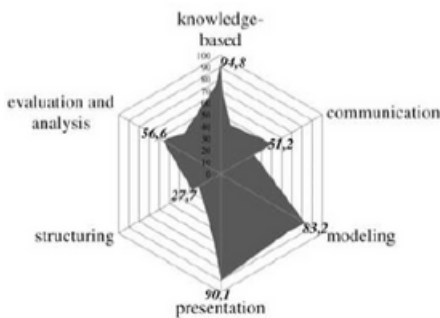

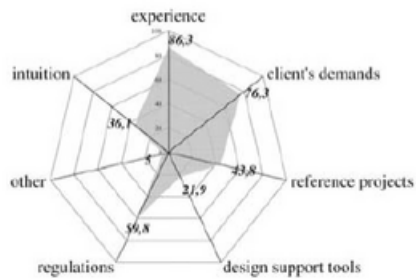Figure 6: Categories of most frequently used DSTs

Figure 7: Factors for Design Decisions

To assess the impact of DSTs in the decision making process, the survey also contained questions on the factors that determine design decisions made by the respondents. As figure

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7 shows, it appears that experience is the most important factor (86%), closely followed by the client's demands (76%). Almost 60% 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 21% use DSTs as a deciding factor.

Figure 8 gives an overview of the use of DSTs per age group. There is a clear tendency of decreasing use of DSTs with increasing age of the respondent. However, the respondents between 31 to 40 indicate they use slightly more tools than those under 30 years of age.
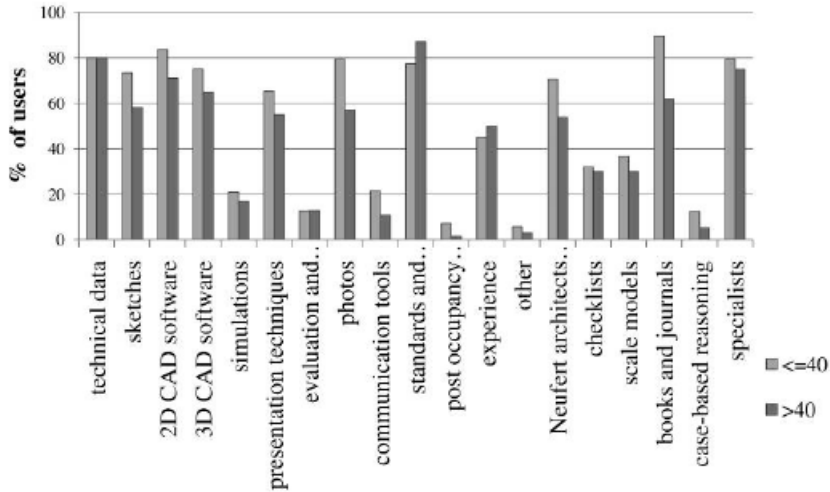

Figure 8: Use of DSTs per Age Group (in %)

DST Requirements for the Future

Figure 9 reveals for which types of DSTs respondents require additional support. For structuring, modeling and presentation, less than 10% of respondents

indicate they would like to have more DSTs available. Almost 30% of our sample would like to have more support from knowledge-based tools, whereas close to 40% requires additional tools for communication and evaluation and analysis purposes.
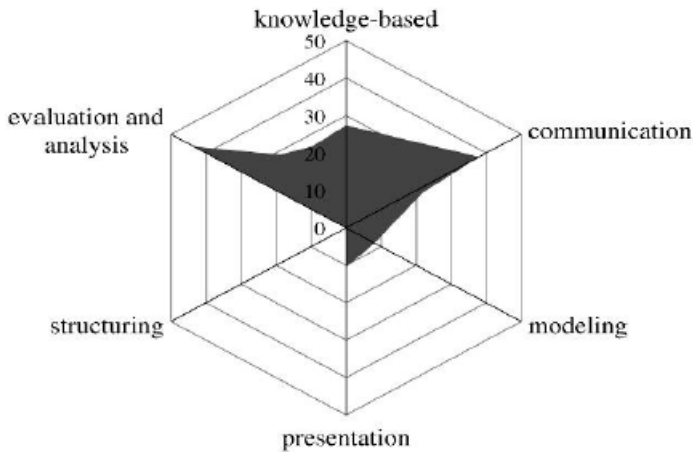
Figure 9: Categories of DSTs Requiring Additional Support

Figure 10 shows the type of DSTs, respondents indicated they needed more support for in each of the phases of the design process. This shows that there is little or no need for more DSTs for presentation and modeling in any of the design phases, but that respondents require more evaluation and analysis tools, predominantly in the preliminary design phase and in the construction phase of the design process. Respondents also expressed a particular need for more support for communication during the building permission phase. The need for more knowledge-based DSTs is evenly spread over all four design phases.
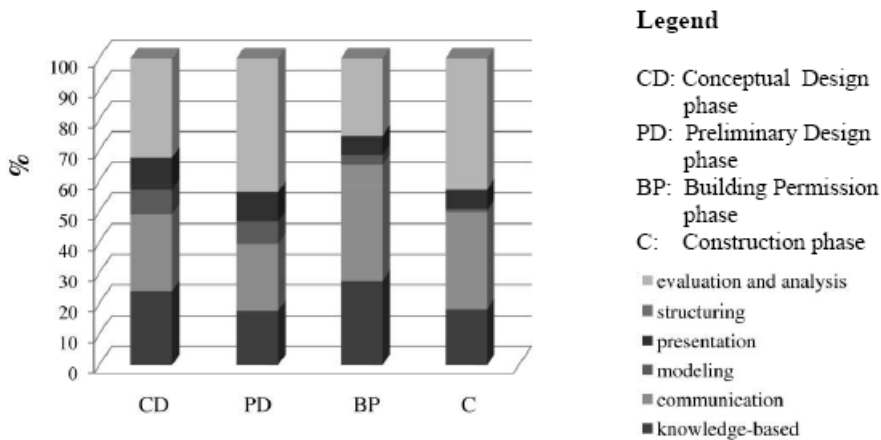

Figure 10: Design Phases that require more DSTs, According to the six categOries of Support Tools

When asked for which aspect of the design process they would like additional support, more than 50% expressed the need for support for the optimisation of the design, whereas over

45% indicated a need for more support to generate design alternatives and to choose between alternative design options. 40% would like more support to evaluate their designs.

Design Criteria for DSTs

Figure 11 shows the criteria that are important to respondents when selecting DSTs. Ease of use (85%) is the most important criterion, closely followed by cost (63%). Easy interpretation of results, compliance

with standards and regulations, compatibility with other software, ease of learning, and a clear and simple interface are all considered as important criteria by about 40% of respondents. Popularity (10%) seems to be of little importance.

Finally, figure 12 reveals that for 70% of respondents, a good DST should increase the design quality. For about 50%, it is important for DSTs to comply with standards and regulations and to allow for provisional evaluations of the design. Only 30% believes a DST should expand the knowledge of the designer.
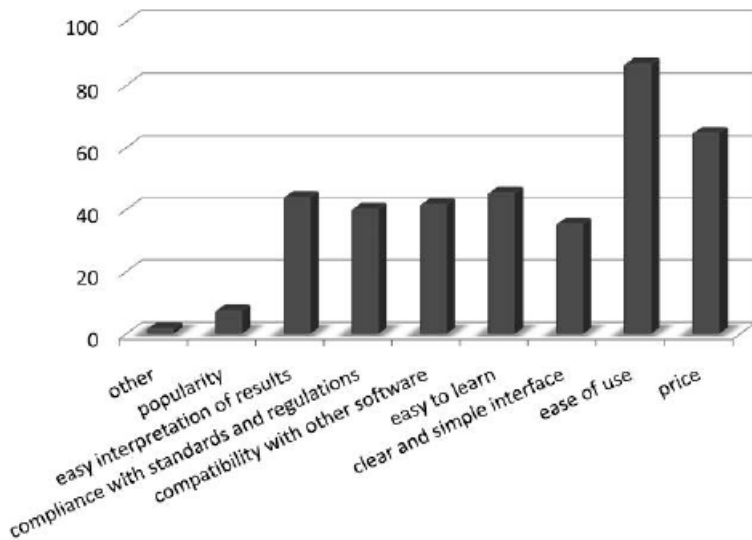

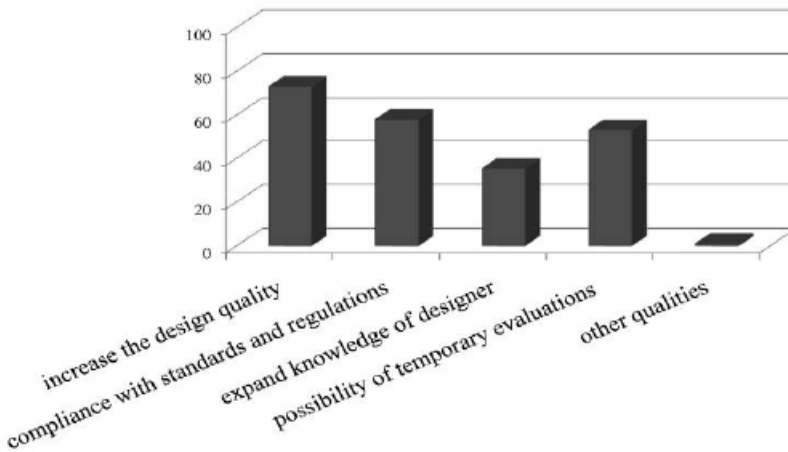Figure 11: Criteria for the Selection of DSTs

Figure 12: Qualities of DSTs

Discussion

The results of the survey reveal that DSTs are particularly important in the architectural design process, given that the ten most selected tools are all used by over 60% of the respondents. The importance of DSTs is further confirmed by the decreasing use of tools with increasing age. This seems to indicate a trend for increasing use of DSTs for the future. These results stress the importance of a clear understanding of users' needs and tool criteria to DST developers and researchers.

The results further imply that single tools often play multiple roles in the architectural design process. The major roles are presentation and modeling, closely followed by knowledge-based. The findings confirm the fact that CAD-software is widely taken up in architectural practice (Mahdavi et al., 2003), but also point out that CAD-software is merely used as a presentation and modeling tool, a problem also identified by Daru (1996). Evaluation and analysis is the next important role. Though presently used by only a small percentage of respondents, these percentages are likely to increase, since over 40% of respondents indicate they require additional support in this area. This suggests that there is an insufficient number of suitable evaluation tools available to architects today. Tools seem to be less used for communication and structuring. This may be due to the fact that 74% of respondents are employed in firms of 3 associates or less. However, given the growing complexity of the design process, firm sizes will probably increase. It is therefore likely that more communication and structuring DSTs will be needed in the future, which was further confirmed by the survey.

Concerning decision-making, only one in five respondents indicates they rely on DSTs. The major basis for design decisions are experience and the clients demands. 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. The importance of experience might also explain the more widely spread DST use among respondents under 40 years of age.

Prescriptive knowledge-based DSTs, such as technical documentation, are equally used by all respondents, whereas standards and regulations show higher use by older respondents. However, for non-prescriptive knowledge-based DSTs, such as books and journals, and photos, the usage percentage is significantly higher for respondents younger than 40.

For the future, additional support is mainly required for evaluation and analysis, for communication, and through knowledge-based DSTs. The current availability of presentation and modeling DSTs seems to meet the respondents' needs. In general, the need for more DSTs is evenly spread over all four design phases. The demand for evaluation and analysis tools is slightly more pronounced in the preliminary design phase, while communication tools are most needed during the building permission phase.

Finally, when considering design criteria for the development of DSTs, respondents are looking for DSTs that are easy to use and that will improve the quality of their designs, while non design related benefits are of less importance.

Conclusion

This study proposed a general framework for the classification of DSTs, according to their role in the architectural design process. A survey was conducted to gain insight into the use of DSTs and the needs for additional DSTs in architectural practice in Flanders.

Results indicate that DSTs are an important factor in the design process. However, currently available DSTs do not always provide architects with adequate support for every design role.

Finally, some criteria for the development for DSTs were identified, of which ease of use and design quality improvement are the most important.

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