EVOLUTION OR REVOLUTION: IS DIGITAL CONCEPTUAL DESIGN THE WAY FORWARD FOR ARCHITECTS?

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Abstract. This research investigates architectural conceptual design and discusses its recent historical, philosophical and theoretical development within the overall architectural design process and attempts to establish an objective definition more tuned to current thinking and advancement in technology. It also evaluates the various traditional and information technology (IT) tools available to the designer and establishes their relationship to the conceptual design process in order to identify if any of these tools, in particular the IT tools, have a role to play in the practice and the enhancement of the conceptual design process.

A survey of Scottish practicing architects (small to medium size practices) was undertaken to validate the results of the investigation. The results seem to suggest that IT tools are not essential to the conceptual design process but that they are very well capable of enhancing the creativity and speed of some aspects of it. They also suggest the existence of an inherent resistance amongst Architects / designers to utilising these tools in conceptual design.

It is, furthermore, identified that if practitioners were to encompass new working practices and acquire new skills, IT tools could also provide powerful new modes of communication with the client. A correlation between the size of the practice and the degree of exposure and experience of IT tools was also established.

To test some of the above findings, a design studio experiment was undertaken where half of the students adopted digital tools, utilising SketchUp software and digital sketchpads, whilst the others adopted traditional tools for the conceptual design part of their projects. No attempt was made to gauge the quality of the actual designs produced.

The results indicate that the SketchUp group rated their conceptual design experience higher in terms of efficiency, flexibility and communication. The control group, who had dominantly adopted traditional freehand sketching, were impressed by the outcome from

the SketchUp group. All student who answered the questionnaire, both SketchUp and control groups, said they would consider adopting some form of 3D sketching in the future.

1. Introduction

The use of information technology (IT) as a design tool is one of the most contentious issues in Architecture today; questions such as "How is the use of the computer going to influence our creativity or problem solving capability?" (BERTOL, 1997) and "Are architects embracing the full potential of IT design tools?" need to be addressed. When architects began automating their offices in the 1980's they substituted word processors for typewriters, and computer aided drawing for drafting pens (LAISERIN, 20001). The use of IT in the project production design stage is now well established in that as long ago as 1996 an estimated 90% of architectural design offices had some sort of computer aided drawing (CAD) system in use (O'HALLORHAN et al. 1996). CAD is now all-pervasive in this field, the associated benefits of efficiency and cost reduction now being reaped by all.

IT has generally been adopted in architectural offices for repetitive high volume tasks that contained no creative design element (DAY, 1997). However IT offers a greater range of tools to the architect than just CAD (UDDIN, 1999). Tools such as image editing suites, digital sketching and composition, 3D modelling and rendering, animations and much more are readily available for use off the shelf. This paper sets out to evaluate if these tools are of any relevance to architects in terms of conceptual design

2. What is Design?

Even the word design itself is open to interpretation in architectural circles (LAWSON, 1997) in that it can be interpreted as meaning the design process itself as well as the finished product of the design process. For the purposes of this paper the definition "design process" is being adopted.

Some architects are of the opinion that "design" is a creative art, similar to sculpture, painting and music, in that they are creating something new for people to experience. LAWSON (1997) seems to confirm this as he states that "design is not some mystical ability, but a skill which must be learned and practised" whilst BIJL (1989) is of a similar opinion in that he states "design is an activity which lies between calculated reason and magic".

Other architects believe that design is not only the result of a specified routine but that good design comes from inspiration. This seems to infer that

good design is arrived at as a result of chance. COHEN (1993) disagrees as he adopts a Thomas Edison quotation that good design, like genius," is one percent inspiration and ninety-nine percent perspiration". He goes on to identify that most designers will take a small idea and work with it until it is manageable. This he says describes the design process.

BEAKLEY et al (1973) warn against confusing style with good design. A design might contain no amount of good style but if it does not satisfy the essential functions of the brief then it cannot be considered a good deign. Indeed they introduce the concept that style is just the modern equivalent of marketing.

LAWSON (1997) believes that "there is no infallibly correct design process" and there are many and diverse opinions as to what constitute the design. However most architects would agree with SANDERS (1996) that the design process is an iterative one where schemes are identified, explored, measured, revised and enhanced until a solution is identified. This is confirmed by TAYLOR (1992) who describes design as the reverse of analysis by expounding that design begins with no specification only a brief from which proposals must be created and a specification derived. It is this cyclic process, which he believes, leads to the description of design being synthesis. Design can therefore be described in general terms as being a cyclic creative process.

3. Nature of Architectural Design

Design of buildings is only one of a number of design processes, which lead to the making of some artefact. Architectural design has been acknowledged for thousands of years, Vitruvius treatise is a clear proof, because of the complexity of Architecture and its symbolic values- higher content, its impact on peoples lives and the physical environment as a whole.
It can be safely said that architectural design, meaning the design process as defined above, has been undergoing extensive appraisals and redefinitions at least since the late 19th century. The contributions of architects such as Le Corbusier as illustrated in "Towards a New Architecture", Frank Lloyd Wright and architectural groupings such as the International Congress of Modern Architecture are well established. It is the intention in this section to briefly examine the thinking that has recently emerged on what is architectural design.

BRAWNE (1992) draws an analogy between Karl Popper's model of theory construction and design: P1 TS EE P2. P1 stands for problem, TS (TS1…. TSn) stands for tentative solutions, EE error elimination and P2 for newly formulated problem. In this model, architectural design develops through a series of criticism where a particular set of answers is seen to be failing in some way- formally, socially, technically. Then those aspects seen

as the dominant failings are identified and alternative suggestions are first made then tentative answers provided, usually by going through the process of a model shift; and these in turn are elaborated and criticised. Arguably this summarises what happens at the conceptual stage of design and surely the dominant method of teaching in architectural schools- repeated criticism and problem solving. The attitudes of the architect, cultural, psychological… and how they are assessed is an issue that arises given its influence on the design.

BROADBENT (1988) on the other hand splits the design process into 2 components: the quantifiable and the non-quantifiable. The former may use a range of techniques that have become available to the architect from ergonomics, operational research, system analysis, computer applications that offer powerful tools for decision-making. The latter, however, relates to more subjective matters of imagery, values, identity and sense of place, which are not fully understood by human sciences and therefore architectural design cannot be fully automated i.e. subjected to any objective model. Add also the historical and cultural elements without which the continuity of architecture and peoples' associations with it would be seriously fractured. Clearly the view here is that the non-quantifiable, often referred to as form, remains within the realm of artistic creativity.

BRAWNE (1992) argues that form and technical matters are so closely intertwined together in design that it would be hard to approach them separately. The emphasis on form stems from the belief that it is more obvious, more easily understood and more visible and therefore more easily related to every day experience.

SANDERS (1996) view is that the design process is an iterative one where schemes are identified, explored, measured, revised and enhanced until a solution is identified is one that agrees most with the model derived from Popper's. Considering the TS and EE in the sequence, computer tools offer a tremendous potential not only of stimulating the design in the widest sense but also to assist the design process in the widest range of problem solving and error elimination during the design and development stage.

Traditional design tools available to the architect take the form of drawings (sketches, orthographics, pictorial views and rendered scenes) and 3D physical models (exploratory or communicational). Sketch drawings and sketch models are utilised to explore ideas and arrive at the concept which forms the basis of the design- they may be considered as very useful for generating ideas but poor communication tools especially to the non trained eye. Orthographic views and pictorial views are used to communicate the design and form an integral part of the language of architecture. They are an effective means of ensuring design intentions are understood.

Historically these tools have not changed much and ensured an established means of communication between architects and to a lesser extent their clients. One may claim that traditional tools are strong for the development of ideas but weak for the presentation of these ideas. IT tools potentially

offer a wide range of alternative solutions to the architect for the generation and communication of ideas provided the gap of understanding and adopting, or even accepting new languages can be bridged.

4. Evaluation of IT Tools to Support the Conceptual Design Process

It is generally accepted that the starting point of conceptual design is the evaluation of the client's brief and thereafter the exploration of ideas to satisfy those requirements via the application of intelligence, experience and creativity. Tools adopted for these tasks must allow the designer to record and develop ideas. Information technology provides a number of tools that may be suitable for adoption; these include digital sketching, formal drawing via computer aided drawing (CAD) software, parametric CAD, 3D modelling, drawing rendering, image photorealism and virtual reality. Some of these tools are capable of complimenting the traditional design process whilst others provide entirely new tools and thereby new techniques. CROSER (2001) identifies that the adoption of new IT tools could be detrimental to the generation of new ideas as they will necessitate learning new skills and that if the designer does not fully understand his/her tools then the design will inevitably suffer.

It is important at the conceptual design stage to be able to create quick sketch drawings to aid the process of design development. BERTOL (1997) believes that computer aided design is a misnomer because of its infrequent employment in the conceptual design process, whilst SNYDER (1998) comments that CAD tools are geared more towards accurate construction drawing than rough sketching. CAD therefore does not seem to be able to support the requirement for a digital sketch tool and most design practices refute the idea that IT could replace hand sketching with many believing that CAD should be redefined as computer aided drafting. There is however a number of IT tools available that can be employed to create quick sketch drawings, these are painting and image processing software, digital palettes and sketch based CAD tools.

A hand drawn sketch cannot be easily scaled up edited or converted into a formal drawing, however a digital sketch can be comparatively easily manipulated and converted. Most CAD software enables the importing, re-scaling and tracing of digital sketches. Indeed many designers commonly convert their hand drawn sketches into digital sketches by scanning then into image processing software application where the benefits of easy manipulation can be obtained. Adobe PhotoShop is the most commonly used painting/image manipulation software tool employed by designers.
GOIRDIAN (2001) comments that PhotoShop, in its current version, has vector drawing capabilities that may more easily enable the incorporation of digital sketches into CAD drawings. Sullivan (1999) identifies that hand held computers are becoming more popular and that these tools are capable

of supporting hand drawn sketching via the use of a stylus directly onto the computer screen and thereby more closely mimic the traditional hand sketching process.

Another requirement of the conceptual design stage is the need to produce formal orthographic and pictorial views of the "design" for communication and information transfer purposes. In many design offices the task of producing these formal drawings is seen as being a "technical skill" and is commonly performed by technicians working from the hand drawn sketches provided by the designer. Consequently it could be argued that since this is not a tool employed directly by the designer that it is therefore technically not a design tool. Few would however argue that formal drawings, 2D and 3D, did not form part of the conceptual design process. The conceptual design of some but not all projects may also make use of three-dimensional modelling. Traditionally physical three dimensional scale models are made of the whole or parts of the conceptual design so that the designer can gain a real feeling for the scale and propositions, space and light relationships of the design (MORGAN et al, 1995). These physical models, usually made of wood or foam, are expensive and very time consuming to create can be easily damaged and are not easily portable. The use of three-dimensional digital models is not dissimilar in concept. Three-dimensional 3D modelling can take many forms e.g. solid, wire frame or surface modelling. These various techniques have evolved and developed as IT and CAD have themselves developed and are closely related to the functionality and power of the computer systems upon which they were made to operate. As IT has become more powerful and affordable the more powerful and affordable the modelling techniques have become to the architectural designer. Digital solid modelling is a boon as it allows rapid movement of virtual solid objects on a computer screen (MORGAN et al, 1995). Once a model is created, pictorial views can be generated in a much simpler way than traditional methods. Instead of creating tools which will aid the design process, the design process is changed to suit the IT tools available (CROSER, 2002). Further 3D modelling has the advantage of allowing the model to be viewed more realistically from more natural viewpoints than a physical model allows as these are often unnatural and are not how the final building will be seen. Three-dimensional 3D modelling can be taken a step further by rendering the model. Various techniques can be employed that can be described as rendering (UDDIN, 1999). All attempt to make the line model appear more realistic. This is normally performed at the conceptual design stage to communicate design intentions in a photo realistic fashion. Adding detail to computer models is an effective way of increasing photorealism (Fleming, 1998). By combining the visualisations produced from 3D modelling with real life photographic images photo-montages can be created placing photorealistic images of a conceptual design into their real world environment (SANDER, 1996) and helps to visualise the design as it will appear when the building is completed. Alternatively photo-

rendered three-dimensional images can be created from the model and then "painted" adopting image painting/editing software to create sketch quality images that may fit in better with the design portfolio (UDDIN, 1999). All of the foregoing IT tools compliment the traditional design process. However IT is also capable of providing access to new tools and techniques that may be useful to leverage the conceptual design. These include parametric CAD systems, three dimensional model animation and virtual reality.

The concept of parametric CAD is that a single model is made of the building from which all drawings and visualisations can be generated. The first feature of a true parametric CAD program is object orientation, which enables the designer to work not with mere lines, but with virtual objects (O'HALLORHAN & SPOHRER, 1996). Using objects rather than lines gives a far greater degree of control than a standard CAD program (Morgan et al., 1995). Parametric CAD enables three-dimensional models to be easily and quickly created from a library of parametric objects. Using object orientation is a good way to describe the architectural world as it is made up of real-life components which can be represented as model objects in the view of WEI (1998), EARNSHAW, JONES & VINCE (1997) AND SANDERS (1996). The single model concept has advantages over the traditional CAD drafting approach, for as the model is being created so are the basis of the orthographic drawings and also the rendered visualisations thereby saving time and effort. Another tool, which is not available with the adoption of traditional techniques, is architectural animation. The reason for animating a design is to add even more realism than is possible with photorealistic still images and to further enhance the visualisation of the design concept. Motion will give the illusion of life to a design (SANDERS, 1996).

Animations vary in complexity, from a simple moving viewpoint to a scene with moving people and objects and can include walkthroughs, sun-studies and fly-arounds. These are normally generated from the same digital models as the static visualisations. An animated viewpoint leads the viewer to believe that there is nothing to hide, rather than seeing the design from a viewpoint chosen by the designer. This can be a very impressive thing for a client to see, and can "sell" the concept to him in a way no static representation could (KERLOW, 2000). SPILLER (2001) has an alternative view considering animation unnecessary and detracting from the communication of the design philosophy whilst FEAR (2001) considers architectural animation a gimmick which has the ability to impress with style, but not with substance.

Virtual Reality (Desktop VR) is another new tool provided by IT. This is closely allied to architectural animation but can be used to create real-time animation of an architectural scene. The intention is to create a viewing experience as if it were a real world scene (WOOLEY, 1993). ROWE (2001) envisages that desktop VR could be used at the design stage in the same way as a traditional sketch model. Immersive VR has however been criticised as

being a poor communication tool and Rowe points out that immersion prevents collaborative interaction of simple communication such as pointing out and discussing aspects of a design.

5. How Could IT Tools Enhance Conceptual Design?

The preceding literature review suggests that IT tools are available to support and possibly enhance the traditional conceptual design techniques of sketching, formal drawing and modelling and that it provides new tools and techniques in the form of parametric CAD, architectural animation and DESKTOP VR. It was further identified that the IT tools were not seen as being essential in the development of the conceptual design but were likely to lead to efficiency gains especially in terms of speed. It also identified that whereas the traditional tools were strong in developing ideas IT tools were strong in communication of the concepts developed and also in terms of the quality of the presentation materials.

To validate and test these findings a survey was carried out of practitioners. A total of 291 questionnaires were sent and 45 (out of a total of 69 returns) valid responses were considered. To guarantee reliability, architectural firms with only one staff member were deliberately omitted. Of the 45 firms surveyed, 15 were very small (up to 3 staff), 15 small (4 to 7 staff), 7 medium (8 to 12 staff) and 8 large (more than 12 staff). A distinct correlation between the size of the firm and the type of work undertaken was evident in the response. The small and very small firms worked predominantly upon housing projects and secondly commercial projects. Medium sized firms had a more or less equal spread of workload over housing, commercial and industrial commissions. The very large firms were predominantly occupied with commercial projects and secondly with housing commissions.

It was anticipated that practitioners' views would be influenced by their exposure to and experience of IT tools and the survey reviewed what experience respondents had of the various tools. All but one of the respondents had experience of at least one of the IT tools identified. In many instance a range of tools had been experienced although in the case of the very small firms the experience had in many instances been limited to 2D CAD drawings replacement. It was noticeable that as the size of the firm increased the exposure to CAD decreased. Modelling with laser CNC cutting tools was the least utilised tool of all with only one respondent claiming to have used them. In the case of the very small firms' digital pictures, 3D modelling and rendered images were the most adopted tools after CAD. A similar picture of use was evident in the small firms excepting that they also made use of animation. Large and medium sized firm returned very similar results excepting that CAD was much less predominant and that digital pictures was the tool with most exposure. Interestingly none of the large

firms had any experience of laser and CNC modelling as may have been expected.

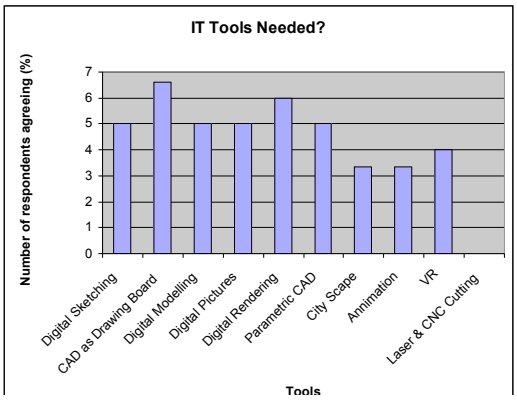

Figure 1. IT tools needed

The tool CAD as drawing board replacement being needed in conceptual design was a view held strongest amongst the small and very small firms as was the need for 3D modelling. The one respondent who had experience of Laser and CNC modelling did not think it necessary as a conceptual design tool. The priority of IT tools for conceptual design are, in terms of the feedback from respondents, CAD and then rendered images, then the following which were all seen to be equally important, Digital sketching, 3D modelling Digital pictures and parametric CAD.

5.1 TOOLS VIZ. CREATIVITY

The literature review had identified hand sketching as being the ultimate tool associated with creativity. All firms irrespective of size clearly favoured this tool as their creative tool of choice. Very small, small and medium sized firms identified pictorial views as a very poor second tool of choice. Large firms on the other hand identified physical modelling as their second tool of choice and there was evidence here of a broader range of tools being employed. Very small firms least preferred hand rendering; small and medium sized firms orthographic projections and large firms identified digital photographs as the least creative tool. Hand sketching is unquestionably the creative tool of choice with small variations in the use of other tools being identified and correlated to the size of the firm. The results of the literature review were validated and confirmed.

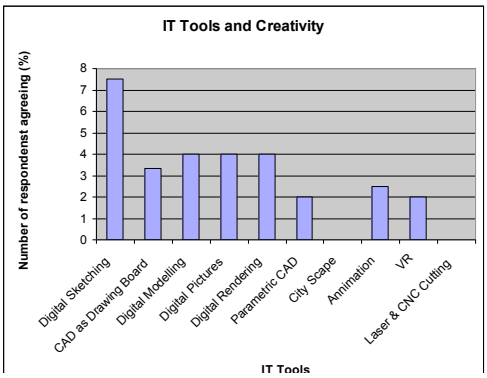

Figure 2. IT Tools and Creativity

There was some agreement amongst respondents that IT tools were not creative. However, some very small firms identified CAD as the most creative tool, small firms digital sketching and medium sized firms 3D modelling. Large firms did not identify that any of the tools were particularly creative. The mixed responses may be due in the case of large firms to the fact that apart from the initial conceptual ideas, design is delegated to others. In smaller firms, architects do most of the production work themselves. The literature review also identified that IT tools are perceived as not creative.

5.2 TOOLS VIZ. COMMUNICATION

The literature review identified that formal drawings are primarily a presentation tool for showing design evolution progress or a completed design concept in a universally understood format and that they are sometimes used to convey scale and proportions of a design idea. The literature review also identified that hand rendering was necessary at the conceptual design stage for exploring ideas of colour and also to communicate these to the client. The survey established that very small firms favoured hand sketching whilst all of the others chose physical modelling as their tool of choice. Large firms equally favoured physical modelling and hand sketching. The literature review had identified that physical modelling was a helpful tool for communication of the design but that it was not essential and that constructing models was expensive and time consuming. Very small firms second tool of choice was pictorial views whilst that of small and medium sized firms was hand sketching. Least favoured by all without exception was orthographic projections. A greater variance of opinion was evident here with hand sketching being less dominant and once again a correlation to size of firm and range of tools used was evident. The survey largely contradicted the findings of the literature review and further

established that hand sketching was a commonly adopted communication tool.

None of the respondents identified any of the IT tools as being particularly good in respect of communication; this contradicted the findings of the literature review which had identified this as strength of the IT tools. Very small firms thought CAD the strongest tool; small firms also favoured CAD as well as DESKTOP VR and medium sized firms' favoured animation and 3D modelling. Large firms did not identify that any of the tools were particularly good at communication.

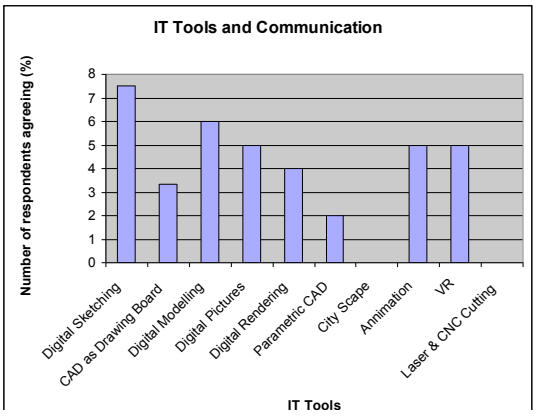

Figure 3. IT Tools and Communication

5.3 TOOLS VIZ. EFFICIENCY

The literature review identified that hand sketching was a highly efficient tool followed by orthographic views. The survey revealed a wide and disparate range of views although all clearly favoured hand sketching in terms of efficiency. Very small firms tool of second choice was orthographic projections as it was for large firms. It should be noted however that as many respondents from large firms identified orthographic projections as their least favoured tool as did their tool of second choice. Orthographic projection was also the least favoured tool of choice identified by small firms. Very small firms identified physical models and photography as their least favoured tools in respect of efficiency. Photography was also identified by large firms as being their least favoured tool. Medium sized firms gave a conflicting range of views other than clearly identifying hand sketching as their tool of choice. Hand sketching was clearly the tool of choice for all which substantiated the findings of the literature review.

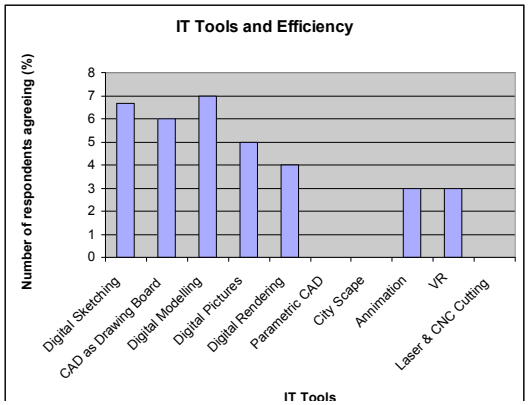

Figure 4. IT Tools and Efficiency

CAD and 3D modelling were identified by very small and small firms as being the most efficient of the IT tools. Small firms also identified digital pictures as being efficient. Medium and large sized firms both identified 3D modelling as being the most efficient of the IT tools. These results suggest that there is consensus amongst most respondents on the efficiency of IT tools, a fact also identified by the literature review.

5.4 TOOLS VIZ. FLEXIBILITY

The survey identified that hand sketching was the very clearly the tool of choice of all in this respect yet the literature review had identified this technique as being inflexible. Very small firms identified orthographic projections and pictorial views as their tools of second choice. Orthographic projections were also identified by small firms as their tool of second choice whist hand rendering was the tool of second choice of large firms. Conversely orthographic projections were identified by small and large firms as their least favoured tool. Whilst very small firms identified physical modelling as their least favoured tool. Medium sized firms, other than identifying hand sketching as their tool of choice, returned a disparate and contradictory set of results. The survey contradicted the findings of the literature review by identifying hand sketching as being the most flexible traditional tool instead of orthographic projections.

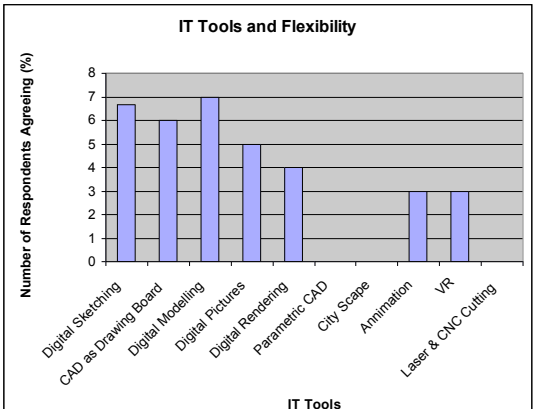

Figure 5. IT Tools and Flexibility

None of the respondents considered the IT tools to be particularly flexible, this was an unexpected result given that the literature review identified that this was one of the IT tools strengths. Very small and small firms identified CAD as the most flexible. Small firms also identified digital sketching as being flexible. Medium and large sized firms identified 3D modelling as being the most flexible.

5.5 TOOLS VIZ. ACCURACY

The literature review had not identified accuracy as being a characteristic associated with conceptual design. This measure produced the widest range of views in the survey of all the questions asked in relation to the traditional tools. Hand sketching was the tool of choice of very small and small firms but less dominantly so for the other measures assessed. Medium sized firms favoured physical modelling and large firms' orthographic projections. Least favoured by very small and small firms was hand rendering and medium sized firms identified pictorial view as being the least accurate tool. Large firms least preferred photography. None of the respondents commented that accuracy was not a characteristic of conceptual design which contradicted the literature review.

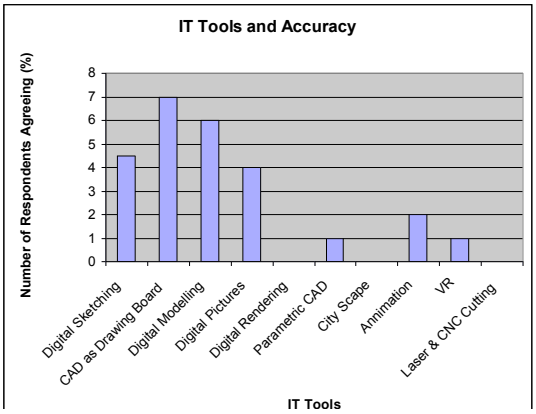

Figure 6. IT Tools and Accuracy

None of the respondents considered the IT tools to be strong in terms of accuracy. All, with the exception of medium sized firms, favoured CAD in this respect. Medium sized firms identified 3D modelling as being the most accurate as did large firms after CAD.

7. Studio Experiment

To pilot test some of the findings of this investigation, namely attitudes and working practices of designers, a design studio experiment was undertaken. Half of the students adopted SketchUp (a sketching application not CAD based and very easy to master) and digital sketchpads whilst the others adopted traditional techniques. The experiment was set to measure the following within a teaching environment of years 2 and 3:

- validity of digital sketching as a design tool
- speed: do digital sketching tools speed up the conceptual design process
- communication: do digital sketching tools enhance the communication of design ideas both to the designer and client
- could digital sketch pads be a substitute for or a compliment to pen and paper.

Students were instructed to keep a log of the number and duration of digital sketching iterations carried out. They were all subsequently surveyed to see what benefits or disadvantages had resulted from the experiment.

8. Studio Experiment Findings

Given the pilot nature of this experiment and not testing practising architects / designers, the findings can only be viewed as indicative. The results were that the SketchUp group rated the software higher in terms of efficiency, flexibility and communication. The control group, who had adopted traditional freehand sketching, was obviously impressed by what they saw from the SketchUp group too - everyone who answered the questionnaire, both SketchUp and control groups, said they would consider adopting SketchUp in the future. About half of the control group felt they had been disadvantaged by not using SketchUp.

Unfortunately only one of the SketchUp group had used the digital sketchpad. The others cited access problems, we only had five pads, and difficulty in mastering a technique which they felt was unnatural compared to freehand sketching. The one user however thought it useful and had employed it with both SketchUp and Photoshop.

6. Conclusions

Although conceptual design is capable of being defined by practitioners in many different ways all agree that it is an iterative creative process that involves the identification and evaluation of different design solutions to satisfy the Clients brief. The essential requirements of the process are flexibility, visualisation, communication and speed.

Free hand sketching is without doubt the traditional tool of choice of the conceptual designer as unanimously confirmed by all respondents. A slight variation in choice of tools was then evident according to the size of firm and also with the type of work undertaken.

Small and very small firms rated hand rendering and photography as their second most preferred tools of choice. Medium sized firms favoured pictorial views, hand rendering, physical modelling and digital photography as their second tool of choice, as did large firms although they equally also chose orthographic projections as a second tool of choice. The data seems to suggest that the size of firm has an influence upon the traditional tools utilised by practitioners upon conceptual design as does the type of commission undertaken, although all use hand sketching extensively.

Exposure to and experience of IT tools is a key factor to their adoption in the workplace. There was evidence that the larger the firm and the greater the diversity of the workload away from housing the greater the experience of IT tools became. The latter finding confirms a similar study of architectural practices in the US (KALISPERIS 1994). The data also revealed that the more complex the IT tool, e.g. DESKTOP VR, CNC, and Parametric CAD, the less exposure there was to them. There was general

agreement upon the lack of flexibility of the IT tools; this was surprising as this had been identified as one of their strengths. Conversely there was agreement as to the efficiency of the IT tools. All but one of the respondents had experience of some of the IT tools identified and many had experience of more than one which suggests that practitioners are now experimenting with these tools.

The data also revealed that most had experience of 2D CAD drawings replacement where CAD was not being utilised to its full potential and further that no attempt had been made to change work practices in the adoption of this new tool. Rendered images and 2D CAD drawings replacement were the IT tools most utilised in conceptual design. It was surprising, however, given the superiority of hand sketching that digital sketching did not prove more popular. Users of digital sketching rated it highly in terms of creativity, communication, efficiency and flexibility.

IT tools are clearly not essential to the conceptual design process but are, when utilised appropriately, capable of supporting and enhancing existing working practices. For this to happen, attitudes and working practices amongst conceptual designers may need to change and adapt to these new tools to take advantage of the potential benefits. This may necessitate supplementary material and training resources. KALISPERIS (1994) states in this respect:

Continuing education should be offered for practicing architects so that they could become familiar with possibilities presented by incorporating computers into the design process and not simply utilising them as drafting tools.

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