Computational and Modeling Tools

How effectively are Urban Designers and Planners using them Across the Design Development Process?

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Literature suggests that despite the increasing range and variety of computational tools and technologies, they have not really been employed for designing as extensively as it might be. This is due in part to the numerous challenges and impediments limiting their effective usage such as the methodological, procedural, and substantive factors and limitations, and skepticism about their impact of usage on the design process and outcome. The gap in our understanding of how advanced computational tools could support the design activities and design decision-making has expanded considerably to become a new area of inquiry with considerable room for the expansion of knowledge. This research is a single-case study that has been pursued in two phases: literature review and survey followed by analysis and discussion of the empirical results. The empirical observations were compared to the theoretical propositions and with results of similar research to highlight the areas and the extent to what the IT tools’ usage have influenced the outcome of the design process. The comparison has helped highlight, explain, and justify the mechanism and improvements in the design outcome. Please write your abstract here by clicking this paragraph.

Keywords: Computational urban design, Urban Design Practice

INTRODUCTION

Research background
The increased interest in a holistic, multi-disciplinary, and collaborative approach to urban design practice has multiple dimensions and challenges that require extensive and effective usage of analytical, communication, and dynamic visualization techniques (Batty, 2007). Literature suggests that despite the increasing range and variety of computational and modeling tools and technologies, they have not really been employed for designing as extensively as it might be (Al-Douri, 2013; Fraser and Bjornsson, 2004; Simpson, 2005). A recent study provided a critical evaluation of the vision, methods, and content of urban design plans in large North American cities. It showed that despite the considerable developments in computer-based technologies and analytical tools such as GIS, 3D modeling, and remote sensing, few of the plans that have been examined offer innovative ways for studying and interpreting the envi-
A lack of sophistication in tools development and usage of IT tools are highlighted in other studies such as Hammerlinck (2011), Hombeg (1994), and Klosterman (1997). This is due primarily to numerous challenges and impediments that affect the effectiveness and impact of their usage on the quality of the design process and outcome. In particular, the developments in computational and modeling technologies have not been supported by similar methodological developments outlining their usage through the design process (Batty, 2007). Different types of representation fit different design phases, and different kinds of tools are suited to different parts of the process (Billger et al. 2016; Marsall, 2015). Yet, one challenge concerns how different computer generated representations can be integrated into the process.

Modes of representations employed while designing frame our thinking and has a strong influence on the scheme’s design (Angelova 2015; Carmona et al., 2010). Also, it can influence decision-making when it empowers a wider engagement of all stakeholders in the design process (Caliskan 2015). Hence, choosing the appropriate mode of representation and using it extensively should be given a special consideration in urban design practice. It is strongly recommended that urban planners and designers examine how a combination of computational tools could effectively support the decision-making process and ultimately help transform the group work from one way to multiple ways. This would influence how effectively designers design, communicate, evaluate and represent design proposals (Carmona et al., 2010; Neto, 2006).

**Research Problem**

The entire range of advanced computational tools and interactive visualization technologies has not really been employed for designing across all design phases as extensively and effectively as it might be. The gap in our understanding of how they could support the design activities and decision-making has expanded considerably to become a new area of inquiry with considerable room for the expansion of knowledge (Kunze et al., 2012; Lewis et al, 2012). The empirical research literature on the usage and impact of those tools on the design decision-making in real urban design and planning processes is sparse and rare (Billger et al 2016). A few studies were focused on their impact on the design outcome, but a systematic outlook at their impact on decision-making and on various activities across all design phases has to be empirically examined. Therefore, further studies are required to examine the methods, pattern, viability, and impact of the consistent usage of computational tools for design, decision-making, presentation, and evaluation (Carmona et al., 2010; Derix et al., 2012).

**Research objectives and questions**

This research departs from the hypothesis that computational tools may support design activities and result in improving various aspects of the decision-making process including participation, 2D, 3D and 4D design representations, and decision quality (Appleton and Lovett 2005; McGrath, 2008; Carmona et al., 2010; Bosselmann, 2008; Al-Douri, 2006, 2010, 2013; Kunze et al., 2012; Derix et al. 2012).

Urban Planning and Design departments that have used computational tools in their practice may help to gather evidence regarding this hypothesis. This research has used the quantitative approach to examine the extents and methods with which those tools have been used in the Department of Planning and development in San Diego, CA. The objective of this research is twofold:

1. Investigating how urban designers and planners are using computational tools in support of various phases of the urban design process
2. Assessment of the impact of their usage of computational tools on the design and decision-making processes.
To attain these objectives, the study will address the following primary questions:

1. To what extent have urban designers and planners used the variety of computational tools and techniques and at what phases?
2. How has the usage of computational tools influenced the output of the design process?
3. What computational tools have designers used at each design phase?

RESEARCH METHODS AND DATA COLLECTION

This research has been pursued in two phases. In the first phase, a review of related literature such as Angelova (2014), Marsall (2015), Billger et al (2016), Batty (2007), and Al-Douri (2010, 2013) among others was pursued to construct theoretical propositions to which the empirical results have been compared. In the second phase, an online questionnaire survey was forwarded to all urban designers and planners working at the Department of Planning and Development, City of San Diego, California, US to document, quantify, and assess the methods and extent with which they used computational tools across all design phases and to assess how their usage has influenced the outcome of the design process. The questionnaire consisted of four sections of closed-ended questions and one section of open-ended questions.

For question four, the survey explored key design and technology issues by gathering the participants’ perspectives on fourteen technologies commonly used in urban design activities. The list of technologies were compiled from the review of related literature and participants’ feedback in a previous research which involved conducting series of interviews and focus groups (Slotterback and Hourdos, 2009; Al-Kodmany 2002, Simpson 2005, Al-Douri, 2010). The participants were asked to assess the extent and the phase(s) at which they use each of those technologies. The survey also explored two key issues identified in the literature as pertinent to computational quality of the design outcome. There were 23 questions grouped in five major areas of impact based on literature review. Responses were measured on a five-point scale ranging from Strongly Disagree (1) to Strongly Agree (5).
tools usage in urban design activities: the level of expertise in its usage, and the field of practice. Respondents have been asked to indicate their level of expertise within a range that varies from non-user to advanced user.

A total of 19 invitations were sent to all potential participants listed in the Department’s website. The response rate was 79% among whom 50% were self-identified as planners, 25% as urban designers, with the remainder consisting of people working in the related fields of architecture, GIS, environmental planning, and transportation planning. The distribution of response for these two questions (years of experience, and field of practice) is comparable to the characteristics of planners in the US planning departments (Slotterback 2011), thus suggesting a relatively representative sample.

The empirical observations were compared to the theoretical propositions and with results of similar research to highlight any patterns and consistencies that could highlight, explain, and justify the mechanism and improvements in the design outcome and output. The comparison has helped drive conclusions about the prospected future of IT tools usage in professional practice.

**EMPIRICAL FINDINGS AND JUSTIFICATIONS**

The results of questions 1-4 in the questionnaire were discussed in light of the theoretical propositions and were compared to those of a previous study that was conducted in 2006 in an attempt to highlight any patterns in the extent of usage of IT tools over the years.

**Extent and methods of usage of IT tools**

In question one, the IT techniques listed under each functionality were sorted in descending order according to the sum of responses with ‘very high’ ‘high’ and “sometimes” of each IT technique (Table 1). The results showed that the IT functionalities were employed with a variety of extents (Figure 1). They showed an extensive usage of the analytical and communication techniques, but only above-average usage of simulation & decision support and visualization techniques. These results are inconsistent with the literature premises concerning the low extent of IT tools usage in current urban design practice.

In the analytical functionality, the most extensively used techniques (rows 3.1-3.8, Table 1) appeared to have supported designers in a wide range of core design activities including analysis, synthesis, and alternatives generation. These results, compared to those of the 2006 study (46.2%), show a higher extent and more effective usage of the analytical techniques in core design and development activities, particularly at early design phases when their potential role in decision-making support is the highest.

In the communication functionality, the most extensively used techniques (rows 2.1-2.3, Table 1) were utilized as a communication platform to communicate 2D and 3D information within the design team and to represent and illustrate design products to the public. This is inconsistent with the theoretical proposition that most urban information systems fail to create conditions for communication and constructive dialog between professionals and decision makers and thus remain to serve only experts in long-term (Angelova et al 2015). Their usage, compared to the results of the 2006 study (71.7%), was higher in extent and effectiveness of supporting core design activities (Al-Douri 2013).
4.2, table 1) were used to support designers in creating a vision and physical development policies, designing the urban form, and modeling and testing proposed zoning. Although the extent of their usage is markedly higher than the results of the 2006 study (39.1%), their capabilities to support planners in dynamic simulation of the design decisions and changes over time have not been effectively used. This inadequacy is due, in part to three main reasons. First, the nature of urban codes that have limited the usage of simulation software to quantifiable design elements such as micro-climatic calculations (Derix 2012). The second reason is that simulation and decision-making tools only operate as a black box not as a collaborative design instrument which is essentially required for vision building. Finally, research has proven that in professional urban design workflows, continuous simulations that integrate many scales and temporal changes alienate designers and their heuristic tools (Derix et al 2012).

In the visualization functionality, most techniques were used with above-average level (rows 1.2-1.8, table 1). They involved dynamic visualization, animation and design alternatives assessment that could improve designers’ abilities to view and analyze elements of the urban environment. However, the results showed a very limited usage of the real-time dynamic visualization technique (see row 1.9, Table 1) that could support the process of design generation. These results are consistent with those of the 2006 study (61.4%) and with the theoretical propositions regarding the above-average usage of visualization tools to represent design alternatives and to visualize complexities of the spatial structure at a variety of scales.

**Extent of usage of IT tools at various design phases**

The results of question two were analyzed to highlight the patterns of IT tools usage at various phases of the design process. The design phases were sorted in descending order according to the combined number of respondents with “very high”, “high” and “sometimes” levels (Table 2).

The highest extent of IT tools usage was at phases 2 and 1 and was characterized by “high” and “very high” usage at all design activities comprising those phases (Figure 2). The extent of usage though gradually declines across phases 3 and 4 and is characterized by the respondents’ selective usage “sometimes” of IT tools to support certain design activities. This pattern is inconsistent with the results of the 2006 study which showed that IT tools usage was limited at the initial, analytical phase but has increased at the conceptual and design production phases (Al-Douri, 2013).
techniques (rows 3.1-3.8; and rows 2.1-2.3, Table 1) are central to the analytical and conceptual activities in phases 1 and 2. Conversely, the design activities that involved low extent of usage occurred at the advanced design phases that require selective usage of visualization and simulation & decision-support techniques. This pattern is in line with the argument regarding the planners’ preference to use conventional 2D techniques over their 3D counterparts (Ryan 2007). It can also be viewed in line with the theoretical proposition that too much detail and visual realism in visualizations at the initial stages of the design process are often not necessary and can even be misleading, as that information will not be decided on until a later date (Billger et al 2016).

These results show that IT functions were used most extensively in the initial design phases when the impact of their usage on the quality of the design process and product would be at its highest. Such pattern provides evidence that IT techniques were effectively used to support designers in core design activities and may have ultimately increased the overall quality of the design product. However, their declining usage in phase four which typically requires extensive and effective communication and outreach is inconsistent with the mission of the planning department that emphasizes outreach to the Downtown’s community and stakeholders.

The results may have been influenced by the design methodology. The conjecture-led cognitive nature implies that the analytical work in urban design practice does not represent the first and foremost phase in urban design thinking. Instead, it runs in parallel with the other consecutive steps: conjecturing, modeling, and testing in design (Çalışkan, 2012). In addition, the literature suggests that designing by alternative is not always applied in practice; alternative thinking in design is not taken as a cognitive tool to make design synthesis. Instead, it might be utilized as a communication tool to enhance the original design argumentation either against the external stakeholders or within the (design) group itself. Thus, the alignment of the extent of IT tools usage with the design phases and with the nature of the design methodology opens a wide range of possibilities to create new design techniques and activities.

**Overall Impact of usage on the design process and product**

The results of question three were analyzed to assess the impact of IT tools usage on the design process and product. The areas of impact were sorted in descending order according to the combined number of “strongly agree” and “agree” responses (Table 3).

<table>
<thead>
<tr>
<th>No.</th>
<th>Impacts of IT tools usage</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strength</td>
<td>Degree</td>
</tr>
<tr>
<td>1.1</td>
<td>Efficiency of communication with planning teams and consultants</td>
<td>0</td>
</tr>
<tr>
<td>1.2</td>
<td>The amount and diversity of information used in plan development</td>
<td>0</td>
</tr>
<tr>
<td>1.3</td>
<td>Efficiency of communication with community and stakeholders</td>
<td>0</td>
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<tr>
<td>1.4</td>
<td>Speed of conflict resolution among stakeholders and planners</td>
<td>0</td>
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<tr>
<td>1.5</td>
<td>Communication and interactivity</td>
<td>0</td>
</tr>
<tr>
<td>2.1</td>
<td>Communication and interactivity</td>
<td>0</td>
</tr>
<tr>
<td>3.1</td>
<td>The cost of plan development</td>
<td>0</td>
</tr>
<tr>
<td>3.2</td>
<td>Increased the time required for plan development</td>
<td>1</td>
</tr>
<tr>
<td>3.3</td>
<td>Cost</td>
<td>1</td>
</tr>
<tr>
<td>3.4</td>
<td>Ability to represent contextual complex data</td>
<td>4</td>
</tr>
<tr>
<td>3.5</td>
<td>Effective visualization of the scale and complexity of the urban form</td>
<td>0</td>
</tr>
<tr>
<td>3.6</td>
<td>Switching between various urban scales [zoom-in and zoom-out]</td>
<td>0</td>
</tr>
<tr>
<td>3.7</td>
<td>Increased understanding of the complex relationship between various urban systems</td>
<td>0</td>
</tr>
<tr>
<td>4.1</td>
<td>Relating plans to individual sub-systems (eg. open spaces) to the entire system</td>
<td>0</td>
</tr>
<tr>
<td>4.2</td>
<td>Ability to represent contextual complex data</td>
<td>0</td>
</tr>
<tr>
<td>4.3</td>
<td>Ability to represent contextual complex data</td>
<td>0</td>
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<tr>
<td>4.4</td>
<td>Management of more urban elements/subsystems</td>
<td>0</td>
</tr>
<tr>
<td>4.5</td>
<td>Relating the plan to other planning scales (project scale, metropolitan, or regional)</td>
<td>0</td>
</tr>
<tr>
<td>4.6</td>
<td>Management of each element/subsystem comprehensively</td>
<td>0</td>
</tr>
<tr>
<td>4.7</td>
<td>Analyzing the study area at multiple scales</td>
<td>0</td>
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<tr>
<td>4.8</td>
<td>Competing a larger number of alternative solutions</td>
<td>0</td>
</tr>
<tr>
<td>4.9</td>
<td>Understanding alternative solutions with analytical findings</td>
<td>0</td>
</tr>
<tr>
<td>5.1</td>
<td>Allowing more time to analytical tasks</td>
<td>0</td>
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<tr>
<td>5.2</td>
<td>Comprehensive of work</td>
<td>0</td>
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<td>5.3</td>
<td>Comprehensive of work</td>
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<tr>
<td>6.1</td>
<td>Decision-making process</td>
<td>1</td>
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<tr>
<td>6.2</td>
<td>Decision-making process</td>
<td>1</td>
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The results show three levels of impact: high (area 3), medium (area 1, 4, and 5), and low (area 2) (Figure 3). These results may be interpreted in light of the results of question 1 regarding the extensive usage of analytical techniques, and question 2 regarding the...
extensive usage of IT tools at phases 1 and 2. They are also consistent with the theoretical model proposed by Al-Kodmany (2002) which suggests that the highest impact of visualization tools is its ability to represent contextual complex data.

Yet, the medium impact on the “communication and interactivity” area is a discrepancy that may have resulted from three interrelated factors. First, the available IT tools lack the high degree of interactivity that is required to create opportunities for communication and higher participation (Billger et al 2016). Second, the ineffective usage of IT tools as a communication platform to represent and illustrate design products to the public (rows 2.4-2.5, table 1). Ineffective communication does not allow professionals and decision-makers to combine efforts and collaborate at all design phases, particularly the early phases, and hence will reduce the quality of the plans (Angelova, 2015; Kunze et al 2012). Finally, the overall impact on communication requires addressing the challenge of developing the actual dialogue and collaboration process (Billger et al).

The average impact on the comprehensiveness of work (area 4), particularly the activities in rows 3.4-3.7 (Table 3), may have resulted from restriction in the planner’s analytical vision and the urban analysis that is predominantly pursued with conventional 2D maps rather than 3D tools (Ahmed and Sekar, 2015). Also, the average impact on the decision-making process (area 5), particularly the activities in rows 5.5 and 5.6 (Table 3) may be interpreted in light of the study that was pursued to compare the benefits of the 3D methods of information interrogation over alternative 2D methods. The findings showed that the 2D resource allowed faster and more accurate decisions to be made, even though the 3D resource allowed a greater understanding of more specific information. The users believed that 3D resources allowed increased spatial awareness and subsequent understanding of information, and would, therefore, allow them to make quicker decisions (Ryan 2007). These results imply that it is essential for urban designers to use a combination of both 2D and 3D resources during the design process.

Finally, all areas of impact have involved activities that have been highly affected by the IT tools usage. Hence the results of this question were sorted in a descending order according to the sum of “agree” and “strongly disagree” (Figure 4). The six highest areas were related to increasing the spatial awareness, understanding the relation between the urban elements, and the efficiency of communication with the planning teams. This provides evidence that IT tools usage could support designers in pursuing core design activities and decision making that would ultimately affect the quality of the design product. Those tools would allow designers working at various scales and levels of abstraction and managing various urban subsystems in a hierarchical order at various phases of the design process.
The IT tools used across the design phases

The results of question 4.1 were listed in descending order according to the sum of the “very high”, “high” and “moderate” responses (Table 4). The results of question 4.2 were listed in descending order according to the phases where IT tools were most extensively used (Table 5).

The results show two patterns. First, the IT tools that are typically used for analytical and communication functionalities, such as the Geographic Information systems, the Internet, and software for plan implementation and management, are the most extensively used tools, and they were consistently used at the appropriate phases. Second, the IT tools that are used for visualization functionalities, particularly 3D modeling, such as VR/urban simulation, Sketchup, and 3D modeling are the most inefficiently used tools. They have been moderately used only in phases 2 and 3 where they could support a variety of visualization and decision-making activities (Table 4 and 5). Such ineffectiveness is due, in part to urban designers’ reluctance to integrate 3D tools into various design activities due to the complexity of data integration, cost, skepticism of the impacts, and lack of appropriate skills (Ahmed and Sekar, 2015).

These results reflect those of question 1 regarding the high usage of analytical and communication techniques and the average usage of the decision-making and visualization functions (Table 1, Figure 1). The results also may explain the medium impact on the areas of decision-making and comprehensiveness of work (Table 2, Figure 2). In addition, these results provide evidence that planners perceive greater capacity and a likelihood of use and understanding of those technologies that focus on providing information such as project website, as opposed to stimulating discussion and interaction such as photo editing and GIS-based scenario evaluation (Slotterback 2011).

It must be noted though that the extent of usage of IT tools in each design phase is not correlated only with the quantity of tools used in it but also with the usage of the tool (s) that is/are most appropriate for each design activity and phase. This highlights the importance of increasing the planners’ knowledge and skills of the capabilities, potential, and methods of IT tools usage to support the variety of design activities.

**CONCLUSIONS**

The findings showed that IT functionalities were used with a wide variety of extents of usage at various design phases. The overall extent of IT tools’ usage was between very high and above-average. These findings are inconsistent with the premise concerning the low extent of usage of IT tools in current urban design practice. The extent of IT tools usage varied along the design process. The highest extent was at phases 2 and 1 but it gradually declined across phases 3 and 4. This pattern is inconsistent with the theoretical propositions that IT tools usage is limited at the initial phases but increases at the design production phases.

The results have shown a variety of levels of impact of IT tools’ usage on the design outcome and
decision-making process. They provided evidence that IT tools usage could support designers in pursuing core design activities and decision making that would ultimately affect the quality of the design product.

The results provide evidence that the impact of IT tools usage on the urban design process and outcome is correlated with not only the extent of their usage, but also with a variety of procedural and substantive factors particularly the following:

- the planners’ level of expertise with the capabilities and methods of usage of the variety of IT tools including data handling and representation, the choice of the appropriate tool and level of realism and detailing that best fit a specific purpose.
- the planning and development methodology employed.
- The consistency and effectiveness with which IT tools are used across the design process.
- The capability of the available digital tools to visualize and represent different kinds of data.

The results have shown that the design methodology is the main factor that can affect the effectiveness of computational support in design decision-making. Thus, the alignment of the extent of IT tools usage with the design phases and with the nature of the design methodology opens a wide range of possibilities to create new design techniques and activities.

With the increased sophistication and usage of IT tools in urban design practice, particularly simulation and decision-support tools, the emphasis shifts from monolithic simulations to discrete simulations units for cross-scale distinct design aspects (Derix et al, 2012). Their increased interactivity offers a wide range of opportunities for designers and public to visualize and communicate the constituent plans and to increase design collaborations and enhance the quality of design and decision-making. On the other hand, emerging geospatial technologies such as GPS, remote sensing, BIM, cloud computing, wireless communications, and parametric modeling may be used to support a wide array of design activities (Drummond and French 2008; Marsall 2015). Their role, methods of usage, and potential support to urban designers at various phases of the design process have yet to be examined in future studies.

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