The Employment of Digital Simulation in the Planning Departments in US Cities

How does it affect design and decision-making processes?

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The increased interactivity of digital simulation tools has offered a wide range of opportunities that may provoke a paradigmatic shift in urban design practice. Yet, research results did not provide any clear evidence that such shift seems to exist. Further studies are required to examine the methods and impact of their usage on decision-making and design outcome. To that goal, this research uses the single-case study design that has been pursued in three phases: literature review, online survey, and semi-structured interviews. The results have shown inadequacies, inconsistency, and ineffectiveness of usage of the tools that are most appropriate to the design activities of each phase and thus a limited impact on critical areas of the decision-making. The impact of the tools` usage is found to be correlated with not only the extent of their usage, but also with a variety of procedural and substantive factors such as the plan methodology, extent of tool's usage, choice of the appropriate tool, and planners' skills and capabilities in using those tools.

Keywords: *Urban Simulation , Urban Design Practice*

1. INTRODUCTION:

1.1. Research background

Literature suggests the emergence of a neo-planning paradigm where urban design and planning tasks are carried out through web 2.0 and combine data sources in new ways via real-time collection, new forms of interactivity, and new methods of data visualization (Hemmersam et al 2015). The ways and modes of participation and decision-making processes are changing and the emphasis tends to be on new tools and structures (Wallin et al 2012; Wiliamson and Parolin 2012).

The field of urban design encompasses very different design approaches, tools, and media (Billger et al 2016; Marsall, 2015). Modes of representations employed while designing frame designers' thinking and have a strong influence on the scheme's design (Angelova 2015; Carmona et al, 2010). They would influence how effectively designers design, communicate, evaluate and represent design proposals (Carmona et al, 2010; Neto, 2006). Hence, the tools' choice, integration, and pattern of usage through the design process are of critical importance in urban design practice.

The increased sophistication and interactivity of simulation and visualization tools offer a wide range of opportunities for designers and public to visualize and communicate the constituent plans, to conduct sensitivity analysis, to increase design collaborations and to enhance the quality of design and decision-making (Caliskan 2015; Derix et al, 2012).

There are a number of design theories, principles, and assumptions that are adopted intuitively and developed after encountering numerous examples of successful and unsuccessful urban design strategies. With the development of a reliable set of simulation and analysis tools, many of the urban design theories, principles, and assumptions could be evaluated for effectiveness with much greater certainty than is currently possible, bringing a higher level of rationale and rigor to the practice of urban design (Besserud & Hussey 2011).

1.2. Research Problem

Planning departments will employ a wider scope of simulation and decision-support tools that offer interactive applications with a wide range of opportunities for designers and public (Derix et al, 2012). Despite the potential promised by the usage of those tools to provoke a paradigmatic shift in urban design practice, research results did not provide any clear evidence that such shift seems to exist. Instead, they showed that same design steps were pursued conventionally but with the support of IT tools and that the interactive capabilities and dynamic simulation of the design decisions have not been effectively used. Thus, urban designers are expected to examine the role of simulation technologies at various phases of the design development process.

The gap in our understanding of how interactive simulation techniques could support the design activities and decision-making has expanded 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). Much of the knowledge about potential outcomes comes from studies that have narrowly focused on particular technologies within a single scale or context (Kunze et al 2012; Slotterback 2011). A few studies were focused on their impact on the design outcome, but a systematic outlook on the impact of their usage on decision-making and various design activities has to be empirically examined (Derix et al, 2012).

1.3. Research objectives

This research departs from the hypothesis that simulation 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; Besserud &Hussey 2011; Kunze et al, 2012; Derix et al 2012).

Urban Planning and Design departments that have used computational tools in their practice may help gathering evidence regarding this hypothesis. This research has used the mixed-method approach to examine the extents and methods with which those tools have been used in the Department of Planning in Portland, Oregon that has always been cited it for its exemplary urban design practice.

The objective of this study is twofold. First, it documents and assesses the extent to what urban designers and planners are using urban simulation tools in support of various phases. Second, it empirically investigates and assesses how various methods and extents of usage of simulation tools may influence the design and decision-making process in an attempt to establish a relation or a correlation between them.

2. RESEARCH METHODS AND DATA COLLECTION

This research has been pursued in three phases. In the first phase, a review of the related literature has been pursued to construct theoretical propositions to which the empirical results have been compared.

In the second phase, a questionnaire survey was forwarded to all urban designers and planners working at the Department of planning, City of Portland, Oregon, US.

The questionnaire consisted of four closed-ended questions and one open-ended question. Question one asked planners to identify the extent to what they used simulation and visualization tools and techniques (SV tools hereafter) during the design process. The question listed twenty-nine techniques collated from reviewing related literature and have been categorized into five main functions following the framework of Ryan (2007). Question two asked designers to identify the extent to what they used SV techniques at each phase of the urban design process. The questions listed four phases including their constituent design activities as described by Cooper and Boyco's model (Cooper and Boyco 2010; Boyco, Cooper, Davey, and Wootton, 2006). Question three asked designers to assess the impact of using SV tools on decision-making and quality of the design outcome. In question four, the participants were asked to assess the extent and the phase(s) at which they use each of the fourteen SV tools that are commonly used in urban planning departments (Slotterback and Hourdos, 2009; Al-Kodmany 2002, Simpson 2005; Al-Douri, 2010). The survey has meant to explore two key substantive factors: the staff's level of expertise in the SV usage, and the approach to its usage. In the third phase, the semi-structured interviews have helped gather rich qualitative data that have been used to triangulate the quantitative data collected from the survey.

A total of 25 invitations were sent to all potential participants listed in the Department's website. The response rate was 64% among whom 40% were self-identified as planners with the remainder consisting of people working in the related fields of research, GIS, and transportation planning. The distribution of responses for the staff 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 to the results of similar research to highlight any patterns and consistencies that could explain and justify the mechanism and improvements in the design decision-making and outcome. The comparison has helped drive conclusions about the usage of SV tools in planning departments and professional practice.

3. EMPIRICAL FINDINGS AND JUSTIFICATION

3.1. Extent and methods of usage of simulation tools:

The simulation techniques listed under each category were sorted in descending order according to their weighted average mean (table 1). The results showed that those categories were employed with a variety of extents at an average of [2.06] (figure 1). In the collaborative & participation visualization category, all techniques have been used above average level. The results show that simulation techniques are being used more extensively for design reviews, collaboration and data communication with design participants and stakeholders. 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 the long-term (Angelova et al 2015). Their usage, compared to the results of previous studies, was higher in extent and effectiveness of supporting core design activities (Al-Douri 2013).

In the thematic mapping & visualization category, 8/10 of its techniques have been used at an above-average level. The simulation tools have been used more extensively and effectively for analytical techniques at early design phases such as the thematic mapping, analysis, and overlay analysis of spatial data when their potential role in decision-making support is at the highest layers.In the data navigation & visualization category, 1/3 of its techniques has been extensively used to generate visualizations of the proposed design. These results are consistent with the theoretical propositions regarding the extensive usage of visualization techniques to represent design alternatives and visualize complexities of the spatial structure at a variety of scales. In the urban modeling category, 2/4 of its techniques have been used at an above-average level for the assessment of the environmental impact and visual impact of the design solution on the study area (table 1, rows 3.1-3.2).

Finally, only 1/7 technique of the simulation & visualization category is being used at an above-average level for modeling and testing the proposed zoning changes (table 1, row 4.1). Although the extent of their usage is markedly higher than the results of previous studies (Al-Douri, 2013), there is a very limited usage in real-time dynamic visualization and simulation of the design decisions and changes over time that could support the generation of design solutions (rows 4.1-4.7).

Subsequently, all techniques were sorted in descending order according to their weighted average mean (figure 1). There were 17 techniques that have been used above the average [2.2-3.8] and that may be clustered in three levels A, B and C. The first level (A) includes one technique that is related to generating static 2D visualizations. The second level (B) includes 10 techniques that are being used at a high-/very high level predominantly for design communication, collaboration, and analysis such as communicating design information and solutions with design participants and stakeholders, reviewing the project to get feedback from the public, and visual analysis and thematic mapping. The third (C) includes 6 techniques that have been used predominantly for analytical functions at an above-average level. The six least-extensively used techniques were related to pursuing planning scenarios, animations, simulations, and real-time dynamic visualization.

This pattern of usage is in line with the argument regarding the planners' preference to use conventional static 2D visualizations over their dynamic, real-time 3D simulations (Ryan 2007). They suggest that simulation techniques have been ineffectively used in the planning process and that their capabilities appeared to have not been employed through the design process. This is consistent with the literature premises concerning the low extent of usage of simulation techniques in US planning departments.

Table 1
Extent of usage of IT techniques and functions

No	Categories of Functions	Extent of Usage						
		Not Used	little	Sometimes	High	Very High	Not Applicable	Weighted Average Mean
	Category 1: Data Navigation-Visualization							
1.1	Generating 2D Visualizations (e.g. maps & perspectives)	0	0	0	3	13	0	3.8
1.2	Zoom-in and -out: visualizations at various scales	1	6	5	2	2	0	1.9
1.3	Building views analysis	4	2	6	2	2	0	1.8
1.4	Facilities distribution analysis	3	5	5	3	0	0	1.5
	Average							2.2
	Category 2: Thematic Mapping & Visualization							
2.1	Thematic mapping of various design aspects	0	0	6	3	7	0	3.1
2.2	Urban land-use analysis	0	0	3	9	4	0	3.1
2.3	Overlay analysis of spatial data layers	0	0	5	9	1	0	2.7
2.4	Visual analysis of the urban form	0	0	7	7	2	0	2.7
2.5	Layering and delayering: Combining and isolating complex entities	0	4	2	5	4	1	2.4
2.6	Demographic analysis	1	2	5	5	3	0	2.4
2.7	Analyzing eye-level and view corridors	1	2	7	3	3	0	2.3
2.8	Circulation analysis	3	0	3	9	1	0	2.3
2.9	Housing analysis: housing stock inventory	1	5	5	3	1	1	1.8
2.10	Flood plain analysis	3	7	3	3	0	0	1.4
	Average							2.4
	Category 3: Urban Modeling							
3.1	Environmental impact analysis: urban light/shadow analysis	1	1	7	5	2	0	2.4
3.2	Visual impact assessment of the design alternatives	0	4	5	4	2	0	2.3
3.3	Static 3D visualization of design area and proposal	1	2	8	4	1	0	2.1
3.4	Animations (fly-through and fly-over) of design area and proposal	4	9	3	0	0	0	0.9
	Average							1.9
	Category 4: Simulation & Visualization of Virtual Models							
4.1	Modeling and testing proposed zoning	3	1	5	4	3	0	2.2
4.2	Simulating vehicular traffic	4	3	6	2	0	1	1.3
4.3	What if scenarios: Planning scenarios	4	5	6	1	0	0	1.3
4.4	Dynamic Simulations of changes in zoning and density over time	5	5	3	3	0	0	1.3
4.5	Simulating pedestrian movement	4	4	6	1	0	1	1.2
4.6	Real-time dynamic visualization (Virtual Reality)	10	4	0	0	0	2	0.3
	Average							1.2
	Category 5: Collaborative & Participation Visualization							
5.1	Communicating data and concepts within the design participants	1	0	4	4	7	0	3.0
5.2	Major projects review within the design team and private developers	1	0	3	7	3	1	2.6
5.3	Using WebGIS to communicate zoning and parcel information	2	2	2	5	5	0	2.6
5.4	Major projects review with the public	1	2	3	7	3	0	2.6
5.5	Using the Internet to get public feedback on plans	1	2	5	5	3	0	2.4
	Average							2.6
	Overall Median							2.3
	Overalll Mean							2.1

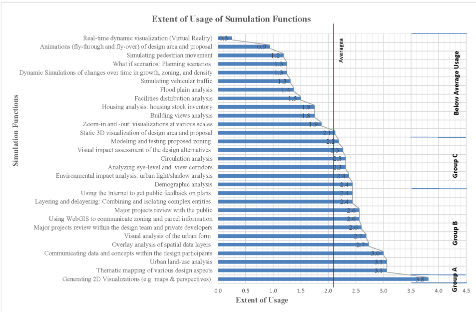

Figure 1
Extent of usage of IT techniques and functions

3.2. Extent of usage of IT Tools at various design phases

The results of question two were analyzed to highlight the patterns of simulation tools' usage at various design phases. The design phases and their constituent activities were sorted in descending order according to the weighted average of tools' usage (table 2).The overall extent of usage was above-average [2.67] at phase 1, increased in phases 2 [2.73] and phase 3 [2.72] but declined sharply in phase 4 [2.23]. The pattern of usage through phases 1-3 shows that the simulation tools have been used at "sometimes", "high", or "very high" extents at all design activities, but they have been used either with little, sometimes or high extents in phase 4 (Figure 2). This pattern is inconsistent with the results of a previous study which showed that IT tools usage was limited at the initial, analytical phase but increased at the conceptual and design production phases (Al-Douri, 2013). They are also inconsistent with the literature which suggests those tools are extensively used at the initial design phase when their influence is potentially the highest and then gradually declines in the following phases.

This pattern of usage is aligned with the results of question 1. Phases (1-3) which featured the highest overall usage involve require the usage of analytical and communication techniques which were the most extensively used techniques, and also require the usage of simulation and modeling techniques which were the least effectively used ones (table 1). Also, phase 4 with the lowest overall usage, requires selective usage of simulation, visualization and modeling techniques which were the least extensively used techniques. This pattern of usage is inconsistent 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 the visualization, communication, and analytical techniques are being used effectively in core design activities at the initial design phases when the impact of their usage on the quality of the design process and product is at its highest. Conversely, the simulation, dynamic visualization, and urban modeling have been ineffectively used. 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 community and stakeholders. Hence, all design activities were sorted in descending order according to their weighted average (figure 2). There were 7 design activities that involved an above-average usage of simulation and visualization techniques with a weighted mean average that ranged from [2.69-3.06] and there were 6 activities that involved below-average usage of those techniques with a weighted mean that ranged from [1.88-2.56]. Ironically, environmental impact assessment and testing design alternatives were among the activities that involved the lowest usage of those techniques.

These inadequacies may be due to a variety of procedural and substantive issues. First, the planners' limited capability and skill of usage of the simulation techniques that are most appropriate to each design phase. Second, the results have been influenced by the methodology of the development process. 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, 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 is utilized as a communication tool to enhance the original design argumentation either against the external stakeholders or within the design group itself.

Finally, the results may be interpreted in light of a 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). Hence, it is essential for urban designers to use a combination of both 2D and 3D resources during the design process.

Thus, it is critical to choose, align, and effectively use the techniques that are most appropriate to each design activity and phase. Similarly, the planners' skills of usage of advanced tools and techniques are critical to contemporary urban design and planning practice. Hence, the alignment of the nature of the design methodology with the available tools and techniques opens a wide range of possibilities to support designers in core design activities.

No.	Design Development Phase	Extent of Usage						
		Not Used	little	Sometimes	High	Very High	Not Applicable	Weighted Average Mean
1	**Phase 1: Creating teams, appraising the situation, and forming goals**							2.67
1.1	Data collection, survey and site appraisal	1	1	2	9	3	0	2.75
1.2	Identifying stakeholder requirements, communicating aims to all stakeholders	0	1	6	6	3	0	2.69
1.3	Data analysis and formulation of goals and objectives and vision	0	1	7	6	2	0	2.56
2	**Phase 2: Designing and developing alternative strategies**							2.73
2.1	Soliciting community input and stakeholders feedback on design alternatives	0	0	5	5	6	0	3.06
2.2	Generation of alternative concepts, refinement into design alternatives	0	1	4	7	4	0	2.88
2.3	Testing design alternatives	1	1	8	5	1	0	2.25
3	**Phase 3: Evaluating, selecting and creating the plan**							2.72
3.1	Consulting stakeholders about design decisions	0	0	6	7	3	0	2.81
3.2	Developing the final alternative into a workable plan, guidelines, and policies	0	0	5	9	2	0	2.81
3.3	Evaluating design alternative; selecting the final alternative	0	1	6	6	3	0	2.69
3.4	Environmental impact assessment of plans/alternatives	1	1	3	10	1	0	2.56
4	**Phase 4: Implementing, monitoring and follow-up**							2.23
4.1	Implementing the plan	0	2	5	5	3	1	2.44
4.2	Updating the plan	0	2	5	6	2	1	2.38
4.3	Reviewing performance, and monitoring progress	1	3	7	3	1	1	1.88
	Overall Median							2.69
	Overall Mean							2.60

Table 2
Extent of usage of IT techniques and functions at each phase of the design development process

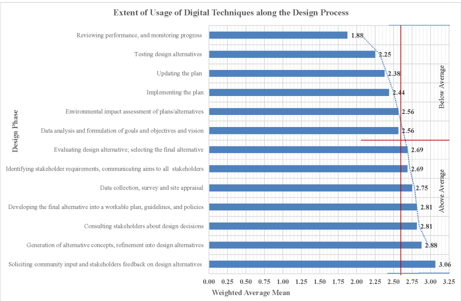

Figure 2
Extent of usage of IT techniques and functions at each phase of the design process

3.3. Overall Impact of usage on the design process and product

The results of question three were analyzed to assess the impact of SV tools usage on the design process and product. The areas of impact were sorted in descending order according to their weighted average of response (table 3). The results show three levels of impact: high, medium and low. The highest level includes areas 1 and 3 where the impact of all sub-areas but one is above-average. The medium level includes area 5 where the impact of 50% of the sub-areas is above-average. The low level includes areas 2 and 4 respectively (figure 3). These results are aligned with those of question 1 and 2 regarding the extensive usage of analytical and communication techniques in phases 2 and 3. They are consistent with the notion that the highest impact of visualization tools is its ability to represent contextual complex data (Al-Kodmany 2002).

The medium impact on the decision-making process (area 5) particularly activities 5.5 and 5.6 (table 3) is a discrepancy that is due, in part to two factors: first, the inappropriate choice of tools that are relevant to the design activity, and second, the planner's limited capability and skill of using the available range of dynamic techniques. Those factors would restrict the planner's analytical vision and the urban analysis that is predominantly pursued with conventional 2D maps rather than 3D dynamic tools (Ahmed and Sekar, 2015). These results are consistent with those of questions 1 and 2, which showed that the simulation, real-time dynamic visualization have been ineffectively used to support the relevant design activities (rows 2.4-2.5, table 1) and thus may not support effective communication and design decision-making. 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 not lead to the desired impact on the quality of the plan (Angelova, 2015; Kunze et al 2012; Billger et al, 2016).

Hence, all areas of impact were collapsed and sorted in descending order according to their

Table 3
Assessment of the impact of IT tools usage on the design outcome and decision making

No.	Impacts of IT tools usage	Assessment: Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable	Weighted Average Mean
1	**Communication and interactivity. The usage of IT tools has increased the following:**							**3.54**
1.1	Efficiency of communication with community and stakeholders	0	0	2	7	4	0	4.15
1.2	The amount and diversity of information used in plan development	0	0	2	9	2	0	4.00
1.3	Efficiency of communication with planning teams and consultants	0	0	1	11	1	0	4.00
1.4	Speed of conflict resolution among stakeholders and planners	0	2	8	3	0	0	3.08
2	**Cost. The usage of IT tools has:**							**3.04**
2.1	Reduced the time required for plan development	0	1	8	2	2	0	3.38
2.2	Increased the cost of plan development	0	2	7	4	0	0	3.15
3	**Ability to represent contextual complex data. The usage of IT tools has helped designers in:**							**3.63**
3.1	Effective visualization of the scale and compelxity of the urban form	0	0	0	12	1	0	4.08
3.2	Relating the plans of individual sub-systems (eg. open spaces) to the entire system (city)	0	0	2	9	2	0	4.00
3.3	Increased understanding of the complex relationship between various urban systems	0	0	3	9	1	0	3.85
3.4	Switching between various urban scales [Zoom-in and zoom-out]	0	0	1	10	1	1	3.69
4	**Comprehensiveness of work. The usage of IT tools has helped designers in:**							**3.15**
4.1	Analyzing the study area at multiple scales	0	0	2	9	1	1	3.62
4.2	Underpinning alternative solutions with analytical findings	0	1	4	7	1	0	3.62
4.3	Generating a larger number of alternative solutions	0	1	6	4	2	0	3.54
4.4	Relating the plan to other planning scales (project scale, metropolitan, or regional scales)	0	0	5	6	1	1	3.38
4.5	Allocating more time to analytical tasks	0	2	6	4	1	0	3.31
4.6	Management of more urban elements/subsystems	0	2	6	4	1	0	3.31
4.7	Management of each element/subsystem comprehensively	0	2	9	2	0	0	3.00
5	**Decision-making process. The usage of IT tools has led to:**							**3.46**
5.1	Increased the quality of the final plan	0	0	3	7	3	0	4.00
5.2	Helped planners relate plan strategies to the nature of the area problem	0	0	3	9	1	0	3.85
5.3	Allowed stakeholders to view a realistic model of the plan in its actual context	0	1	2	9	1	0	3.77
5.4	Improved the efficiency of decision-making	0	1	5	6	1	0	3.54
5.5	Improved the efficiency of the design and development process	0	1	5	6	1	0	3.54
5.6	Increased the time allocated to creative thinking	0	1	7	4	1	0	3.38
	Overall Median							3.62
	Overall Mean							3.62

weighted average, 10 of which were above the average with a weighted mean that ranged from [3.69-4.15], and 13 that were below the average [3.0-3.62] (figure 4). These areas of impact were clustered into three groups A, B, and C. In the high-impact group (A) (rows 1-10, table 3), almost all survey participants replied with either [strongly agree] or [agree] of the impact of the simulation tools on increasing the effectiveness of visualization, the efficiency of communication, and the understanding of the relation between the urban system and its constituent subsystems. In the average-impact group (B), (rows 11-18, table 3) nearly 50% of the survey participants replied with either [strongly agree] or [agree] of the impact of the simulation tools on increasing the efficiency of the design and decision-making process. In the low-impact group (C), (rows 19-23, table 3) only 25-30% of survey participants replied with either [strongly agree] or [agree] of the impact of the simulation tools on cost-effectiveness and management of the plan and the urban systems and subsystems.

These results provide evidence that simulation tools could support designers in various design activities, and they would allow them working at various scales, levels of abstraction, and hierarchical order of the urban subsystems that may result in increasing the equality of design decision-making and product. To do so, it is imperative to address the inadequacies that led to the ineffective usage of those tools and techniques along the design process.

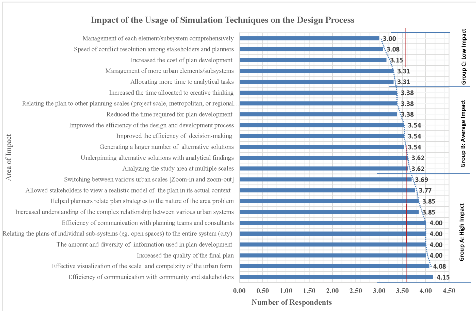

Figure 3
Assessment of the impact of IT tools usage on the design outcome and decision making: grouped in areas

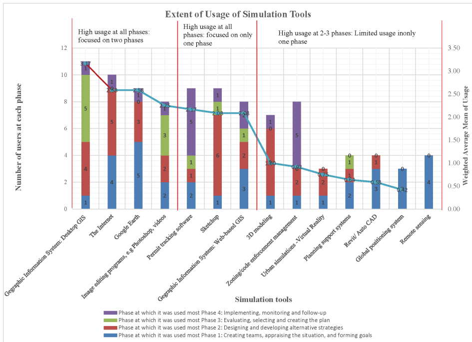

Figure 4
The impact of IT tools usage on the design outcome and decision making

3.4. The IT tools used across design phases

The simulation tools were ranked in descending order according to their weighted average mean of usage and were clustered into four groups, A through D; extensive, high, average and low respectively (table 4). In group C, Sketchup has been used at an above-average level [2.17], whereas real-time and dynamic simulation and 3D modeling have been used at a moderate or little/very little usage by 5/12 of the survey respondents. In group D, urban simulation/virtual reality [0.92] and Revit/AutoCAD [0.64] have been used at a little or very little extent or not used by 10/13 of the survey respondents.

The results of questions 4.1 and 4.2 were combined in one chart to relate the extent and consistency with which each tool was used along the design phases (figure 4). The results show that some tools such as Desktop GIS and the Internet were used with high extent but predominantly in two phases (2 and 3) (rows 1-4, table 5). Some tools were used at an above-average level at all phases but predominantly in only one phase, whereas other tools were used very ineffectively at one or two phases.

The results show three patterns. First, the most effective usage occurred in phase 2, but the least effective was in phase 3, which involves developing and selecting the plan. Second, the analytical and communication tools, such as the GIS, the Internet, and Google Earth have been used extensively and consistently at the appropriate phases. Third, SketchUp and urban modeling tools have been used at an above average level at all design phases but predominantly in phase 2 whereas the urban simulation and VR have been used at a below-average level only in the first two phases. They could have been used in other phases to support a variety of visualization and decision-making activities (Table 4 and 5).

These results show that the usage of 6/14 of the SV tools was ineffective and inconsistent. These results are aligned with those of question 1 regarding the high usage of analytical and communication techniques and the average usage of the decision making and visualization techniques (Table 1, Figure1). They are also aligned with the results of question 2 regarding the extent of support those tools provide for a variety of design tasks. They may explain the medium impact on the areas of decision-making and comprehensiveness of work (Table 2, Figure 2). These findings provided evidence that the impact of SV usage is not correlated only with the number of tools used in each design phases or the extent of their usage but also with the choice 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 the tools' usage to support the variety of design activities along the design process.

	Tools and Technologies	Not Used	Little-Very little	Moderate	High	Very High	Unavailable	Not sure what this tools is	Weighted Average	Level of Usage
1	Gegraphic Information System: Desktop GIS	0	0	3	3	6	0	0	3.25	
2	The Internet	0	0	4	2	6	0	0	3.17	A
3	Image editing programs, e.g Photoshop, videos	2	1	2	2	5	0	0	2.58	
4	Google Earth	1	1	3	4	3	0	0	2.58	B
5	Permit tracking software	1	2	4	3	2	0	0	2.25	
6	Sketchup	2	2	3	2	3	0	0	2.17	
7	Gegraphic Information System: Web-based GIS	2	3	2	2	3	0	0	2.08	
8	3D modeling	2	2	3	3	2	0	0	2.08	C
9	Zoning/code enforcement management	4	2	2	2	0	0	2	1.00	
10	Urban simulations -Virtual Reality	5	5	0	2	0	0	0	0.92	
11	Planning support systems	6	4	1	1	0	0	0	0.75	
12	Revit/ Auto CAD	7	2	1	1	0	0	0	0.64	
13	Global positioning system	6	5	1	0	0	0	0	0.58	
14	Remote sensing	8	3	1	0	0	0	0	0.42	D
	Sum	46	32	30	27	30	0	2		
	Percentage	25.6	17.8	16.7	15	16.7	0	1.1111		
	Overall Median								2.08	
	Overall Mean								1.75	

Table 4
The extent of usage of each IT tool and technology

No.	Tools and Media	Phase at which it was used most						
		Phase 1: Creating teams, appraising the situation, and forming goals	Phase 2: Designing and developing alternative strategies	Phase 3: Evaluating, selecting and creating the plan	Phase 4: Implementing, monitoring and follow-up	Count of Users	Weighted Average Mean of Usage	Level of Usage
1	Gegraphic Information System: Desktop GIS	1	4	5	1	11	3.25	A
2	The Internet	4	5	0	1	10	3.17	
3	Google Earth	5	3	0	1	9	2.58	B
4	Image editing programs, e.g Photoshop, videos	2	2	3	1	8	2.58	
5	Permit tracking software	2	1	1	5	9	2.25	C
6	Sketchup	1	6	1	1	9	2.17	
7	Gegraphic Information System: Web-based GIS	3	2	1	2	8	2.08	
8	3D modeling	1	5	0	1	7	2.08	
9	Zoning/code enforcement management	1	2	0	5	8	1.00	D
10	Urban simulations -Virtual Reality	1	2	0	0	3	0.92	
11	Planning support systems	2	1	1	0	4	0.75	
12	Revit/ Auto CAD	3	1	0	0	4	0.64	
13	Global positioning system	3	0	0	0	3	0.58	
14	Remote sensing	4	0	0	0	4	0.42	
	Sum at each phase	33	34	12	18			
	Median						2.08	
	Mean						1.75	

Table 5
Design phases at which each IT tool land technology was used the most

4. Conclusions

The research provided evidence that SV tools could support designers in pursuing core design activities that would ultimately affect decision making and the quality of the design product. The findings showed a wide variety of extents of usage across the five categories of techniques and across the four phases of the design process. The urban modeling and simulation & visualization that could support the generation and assessment of design alternatives were the least extensively used categories at a below-average level. In particular, there was a very limited usage of animation, real-time dynamic visualization, and simulation of the design decisions and changes over time. These results suggest that the capabilities of simulation techniques have been ineffectively used through the design process.

The pattern of the SV tools' usage has involved inadequacies and ineffectiveness in the extent of usage, inconsistency across design phases, and inappropriate choice of the tools that are most relevant to each design activity. Thus, the impact of their usage on design and decision-making process and comprehensiveness of work was at an average and below-average level respectively. In particular, they have a very limited impact on critical areas namely, the time used for generating alternative design strategies, the number of those strategies, and the assessment of the environmental and visual impact of those strategies on the urban system. Instead, they could have been employed to generate, test, and evaluate, for effectiveness and performance, a greater number of alternative strategies with certainty and rigor that could have ultimately improved the design outcome and decision-making process.

The considerations that are typically addressed in urban design practice are expanding to include issues such as environmental sustainability, health and well-being, security, and economic and social vitality that require an effective usage of the increasing amount and diversity of information using performance-based criteria for evaluation and assessment. Similarly, the shifting paradigms in contemporary urban design practice requires challenging or examining the applicability of the existing urban design principles, models, and approaches. Thus, the methodology of the plan development plays a pivotal role in the effective employment of simulation and visualization tools to support designers and planners in pursuing those activities and tasks. The methodological issues need to be addressed early in the development process and requires a comprehensive framework for simulation tools usage.

Therefore, it can be inferred that the impact of usage pf SV tools on the decision-making and outcome is correlated not only with the extent of their usage but also with a variety of procedural and substantive factors particularly the following:

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

Yet, among those factors, the design methodology is the most influential one that can affect the effectiveness of computational support in design decision-making. Thus, it is strongly recommended that urban planners and designers examine how the alignment of the appropriate simulation and visualization tools with the design activities and phases and with the nature of the design methodology could effectively support the decision-making process and ultimately help transform the group work from one way to multiple ways and affect the design outcome. On the other hand, the 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. Their role, methods of usage, and potential support to urban designers at various phases of the design process have yet to be examined.

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