The Impact of 3D Digital Modeling on the 3D Design Aspects in Urban Design Plans

A case study of Pittsburgh downtown development plan

Firas A. Al-Douri[1], Mark J. Clayton[2], Robin F. Abrams[3]

[1]Doctoral Candidate, Department of Architecture, Texas A&M University,

[2]Associate Professor, College of Architecture, Texas A&M University,

[3]Associate Professor, Department of Architecture, Texas A&M University,

Abstract. *Some experts suggest that urban design plans in US cities may lack adequate coverage of the three-dimensional design aspects of the built environment. 3D digital models may help designers visualize and interact with design alternatives, large urban data sets, and 3D information more effectively, thus correcting this problem. Case studies of recent urban design plans that have used 3D digital models may indicate whether these technologies can increase the quality of the plan. This research discusses the role 3D urban models can play in supporting designers in addressing the 3D design aspects. A literature review focused on reviewing secondary sources to construct or adopt theoretical propositions against which the empirical data can be compared and contrasted. A case study involved investigating the methods with which 3D models have been used in developing a selected urban design plan. The content analysis of the case study refuted the premise that the plan would inadequately address 3D aspects and utilize 3D information, and indicated an effective usage of 3D modeling to analyze and represent most of the 3D and 2D information elements and issues. The results are consistent with a hypothesis that the effective usage of 3D modeling would result in the effective coverage of 3D information and issues. The effective usage of the model's functionalities has improved the quality of the decision-making process through improving designers' cognitive capabilities and providing a platform for communicating design ideas among and across design teams.*

Keywords. *3D modeling: urban design plans; digital models; 3D design aspects.*

Problem statement

Some experts suggest that urban design practice is flawed by reliance upon assumptions and conventions that are a consequence of using 2D media to communicate spatial information and design spatial structures. Most design and planning applications have been considered within the framework of two-dimensional land-use and rigid zoning codes (Gosling and Gosling 2003, Punter and Carmona 1999, Lang, 1994, Bourdakis 2001). Designers, as such, have rarely been able to utilize the growing volume of information, particularly 3D information, to generate sound and well-spaced design concepts and strategies. Accordingly, 3D information and the analytical content and results are not likely to underpin effectively the resulting urban design strategies. Without a diverse range of alternatives, it is impossible to choose a solution that can be demonstrated to be superior. More importantly, the plans that are developed may lack the coverage of the three-dimensional aspects of the built environment that would normally be considered to be central to the role of urban design plans in controlling design.

Urban design processes that have incorporated 3D digital modeling may result in plans that may better incorporate 3D considerations. This research uses a case study to gather evidence regarding this hypothesis. Although the evidence presented is insufficient to be conclusive, it constitutes a data point that supports the hypothesis.

Research background and methods

Information technology, such as 3D urban models, Web-based information systems, and Internet communications, are being employed by urban planners and designers under the assumption that they can improve the process and product of urban design. However, there remain many doubts regarding whether IT is useful and consequently hesitation about the appropriate and effective applications. There is also little consensus on the methods by which these models should be used in core design tasks. These suggest a need for research into how the usage of 3D digital models and information systems can affect the extent with which urban design plans cover 3D design aspects of the built environment. 3D digital models may help designers visualize and interact with design alternatives, large urban data sets, and 3D information effectively. They are likely to encourage experiments with new forms of communication, visualization, and information retrieval to produce more imaginative design solutions that are a better fit to designers' needs and requirements. They may also facilitate rapid exploration of alternative concepts that would help stakeholders to comprehend, accept, and participate in the design process. Failure to use these capabilities effectively in actual practice may result primarily from a limited understanding of the proper role these tools should play or the impact they may have.

This research discusses the role 3D digital models can play in supporting designers in addressing the 3D design aspects. It also describes the modeling methods used in Pittsburgh Downtown Development Plan: a Blueprint for the 21st Century (PDDP) which was produced by a process that incorporated 3D modeling. The research objective is to understand how the usage of 3D digital models affected the coverage of 3D design aspects. The research uses the single-case study approach and involved two phases. The first phase, literature review, focused on reviewing secondary sources to construct theoretical propositions against which empirical observations can be compared. The second phase involved investigating the case study along two dimensions: first, how 3D models were used in the planning and design process; second, qualities of the resulting plan that may be consequences of 3D models usage. Using qualitative content analysis technique, the data collected have been categorized and analyzed to establish a cohesive framework of models functionalities and their likely impact on the 3D design aspects in PDDP. The analysis results are compared with the theoretical propositions, followed by conclusions.

Using 3D modeling in urban design practice

Although 3D digital models have been used to support urban design for many years, they have not become ubiquitous. Many researchers and practitioners remain skeptical of the benefit of these tools. In this section we review the techniques and the commentary that has attempted to explain the impact, or lack of impact, of 3D modeling in urban design.

Common tools and techniques

The main common tools and techniques for modeling urban environments include DBMS, CAD, VRML, and GIS. This section describes these tools and the problems associated with their usage. Koshak (2002) defined these tools as follows:

1- DBMS: Traditional relational Database Management Systems (DBMS), in contrast with CAD and GIS, capture only nongeometric information about certain objects within an urban area. An example of this tool would be a database of buildings that include a table of all the buildings in an urban area with associated data such as name, use, owner, year built, and condition.

2- CAD: A Computer Aided Design (CAD) model captures the 2D and the 3D geometry of various entities in an urban environment. CAD is mainly used for visualization purposes. The level of detail in the 2D CAD maps and the 3D CAD models is determined by their use. CAD models can be used to model a whole city or a single building with detailed elevations. Some examples of CAD urban models are the city of Glasgow model project, the 3D block model of the city of Adelaide, and the city of Bath model. In contrast with GIS, CAD captures geometric details.

3- GIS: Geographical Information Systems tool (GIS) mainly supports the representation of places of a larger scale, like countries, regions, or urban areas. A major difference between CAD and GIS is that the geometries in GIS are geographically referenced. Another important feature of GIS is that it offers the possibility of linking non-geometric attributes with geometries. It provides powerful spatial analytical and visualization tools. Recently, 3D visualization capabilities have been added to GIS, allowing for the generation of 3D representations from 2D digital maps, yet GIS provides less 3D modeling capabilities than CAD.

4- VR: Virtual reality (VR) takes 3D visualization a step further. VR is generally defined as a 3D computer generated synthetic environment or structure that gives the user a sense of being immersed in a real world. VR tools can be used to communicate the experiential nature of urban settings. They allow users to navigate and explore the virtual world and thus enable designers to increase their imaginations by visualizing their hidden intentions and thoughts, and to facilitate comprehending design concepts and alternatives. Hence, they are increasingly being used in the public participation portion of urban design (Poerbo 2001, pp. 113-114; Al-Kodmany 2002, pp. 197-199). [Please refer to Al-Kodmany, 2002; Koshak, 2002; and Simpson 2001 for an exhaustive list of tools and their potential applications in urban design and planning].

Roles and functions of 3D models in urban design practice

Despite some limited approaches underlying its role in urban design practice, 3D modeling may have a more profound role when it becomes a means to rethink the process of 3D creativity. To put that into effect, a methodological framework underlying its usage in urban design practice is required. Pietsch (2000), for instance, suggests that such usage requires a framework balancing abstraction, accuracy, and realism (Pietsch 2000, p. 525), yet this framework did not consider the relationship of modeling methods and applications with models types. Therefore, we will approach 3D modeling with respect to two aspects: first, the purposes and functions for which models were designed, and second, the key techniques used to implement and deliver various visualization styles.

Batty et al (2004) defined four distinct purposes of 3D models: exploration, explanation, engagement, and education. A model and its visualization may stress these four purposes in different ways, with one purpose dominating. The first purpose, exploration, is more geared to investigate how models' structures translate inputs and outputs. The second, explanation involves using visualization to confirm or falsify some theory which is embodied in the model and the usual processes of comparing pattern in the input and output data is central to this. Third, engagement is geared towards forecasting for policy making and testing design impacts, management, and control. In the fourth, education, models enable an understanding which would not be possible without pictorial help (Batty et al, 2004, pp. 9-10). The models' function(s) and the intention with which reality is approached determine, to a large extent, the choice of the model's type (Klassen 2002, p.186). Klassen (2002) classified models into three types according to their relation to reality: concrete, conceptual, and formal (Klassen 2002, p.183). Hence, 3D models make explicit certain entities in a transparent way and explain how the explicitness is achieved. Their main advantage is to describe, with various methods and techniques, the properties of and the structural and spatial relations between elements of the built environment. The following section explains some of those methods and techniques.

Methods and techniques of visualizing 3D design information and issues

Multiple levels of representation: Multiple levels of representation build on the natural abstraction of architectural representations evident in the conventional sequence of drawings at different scales (Koutamanis 2002, p.237). That may help enhance the depth of points of view and range of designers' visions and concepts of the 3D aspects and attributes of the physical environment. Those visions may be further improved with techniques such as zooming and layering and delayering. The first technique must be considered relative to the scale of the area under study. Zooming into that area at successive orders of scales reveals discrete elements and structures in a clear succession of steps. At each scale, graphic reduction in the form of isolations of visual information helps reveal relevant structural and spatial relationships and reduces confusion. The second, delayering, is a process that sets up an isolation and various recombination of factors and elements which synthesizes sets of spatial relationships within the urban environment. This technique, if combined with topographic or sectional views, may facilitate understanding complex spatial structures and interrelationships (Gosling and Gosling 2003, pp.249-250).

Multiple levels of details: To enable quick model viewing in various zoom scales, models are often created with multiple levels of details. The model of Bath, UK, for instance, involved modeling the buildings in four levels of detail, each of which is relevant to one level of design control (Koshak 2002, p. 243; Poerbo 2001, p.128). Some models allow for variable levels of detail by flexible and interactive switch between those levels. This means adding increasing levels of detail to a view as the user approaches (Fraser and Bjornsson 2004, p.190), which allow designers to focus on urban elements and configurations relevant to the scale of design intervention.

Real-time Interactive Simulations: Virtual Reality (VR) provides real interactive simulations of the visual features of the urban environments which may support design participants in various ways. It enables them to analyze and navigate through the urban elements and spaces interactively, to input into a simultaneous discussion of a proposal from the earliest stages onwards, and helps explain design proposals to a far wider audience than has been possible hitherto (Fraser and Bjornsson 2004, p.191). The ideal computer model is one that can be continuously updated to include real change as it occurs as part of the design process (Gosling and Gosling 2003, p.251), therefore, this technology may support designers significantly if it is coupled with an interactive database that is directly linked to any change made in the 3D attributes of and relationship between urban elements.

This provides designers with precise instant feedback as they make initial design decisions at the start of the project

Urban simulation, which integrates CAD and GIS with real-time visual simulation, is another powerful decision-making support tool. It facilitates the modeling, displaying, assessing visual impact of design proposals, evaluating alternative proposals, and visualizing urban areas as they currently exist or as they are proposed (Koshak 2002, p.23). These capabilities allow urban designers to assess visual impact of alternative proposals and view the city and reconfigurations of its components in accelerated time from a fixed point of view which altogether improve their understanding of the spatial behavior (Gosling and Gosling 2003, p.249).

Limitations and emerging capabilities

Some authors suggest that functions, types, and techniques of 3D modeling do not support effectively the design of 3D design aspects. They argue that most 3D models have not been developed from the perspectives of spatial databases technologies and associated analytical functionalities (Batty et al 2000, p.24), and thus lack capabilities to deliver multiple representations and dynamic visualizations and to perform the multiple functions for which 3D modeling is required. However, failure to use models effectively in actual practice results primarily from a limited understanding of the proper role these tools should play, and little consensus on the methods by which they should be used.

Literature suggests that design analysis is moving towards a new paradigm based on simulation rather than abstractions derived from legal or professional rules and norms (Koutamanis 2002, p.245). Therefore, addressing the 3D design information and issues requires integrating and managing a rich hybrid of geometric, geographic, and annotative information and datasets, which requires advanced computational tools to be developed. These tools are currently provided within the recent developments in scientific and dynamic visualization. Koutamanis (2002) explained the role of scientific visualization suggesting that the close correlation of photorealistic and analytical representations clarifies and demystifies designers' insights and intuitions. Dynamic visualization adds depth and time to the subject in the framework of a specific event or state which results in dynamic descriptions that are superior to other representations for visual exploration, analysis, and communication (Koutamanis 2002, p.246).

Although an integrated urban design support system is still considered an utopia (Poerbo 2001, p. 141), scientific and dynamic visualizations may lead to the emergence of a wide variety of visualization styles that help visualize and interact with the 3D design aspects in two ways: first, by visualizing complicated systems to make things simple and /or explicable; second, by exploring unanticipated outcomes and by refinement of processes that interact in unanticipated ways.

Pittsburgh downtown development plan: a case study of 3D modeling

Pittsburgh Downtown Development Plan (PDDP) is an example of an urban design plan that has been developed using digital tools and specifically 3D digital models. A careful review of the plan as documented in reports and Web sites reveals artifacts of the methods that can be used to assess the extent of the use of digital technology. The PDDP, completed in 1998, is readily available on the Web and has been the subject of several publications (Gosling and Gosling 2003; Stern 1998; Schmertz 1997). This section examines PDDP in two tasks. The first is documenting and comparing the 3D modeling methods and techniques used in PDDP with their counterparts in theory. The second is assessing the extent with which PDDP has efficiently covered the essential 2D and 3D urban design issues, and hence to assess its design content. The two tasks will be discussed in the follow-

No.	Categories of functionalities	Extent of usage					
		N/A	Not Used	Very little	Average	Very much	A lot
1	*Category 1: Navigation-Visualization- functionalities*				■		
	Viewing the visual configuration and the impact of design proposals; providing spatial data through GIS; generating 2D and 3D visualizations; and representations at different geometrical and geographical scales						
2	*Category 2: Communication (decision-support) functionalities*					■	
	Communicating project-specific design data; information, and scenarios within the design team and with city authorities; assessment of design alternatives; and selecting the best design alternative-scenario.						
3	*Category 3: Analytical functionalities*						■
	Modeling and testing spatial/structural relationships between urban elements and subsystems; analyzing the visual/3D characteristics; graphic reduction; layering and delayering; overlay analysis; thematic mapping, and structured query of data to generate						
4	*Category 4: Manipulation functionalities*			■			
	Scenario analysis; impact analysis; modeling and testing proposed guidelines						

Table 1: The extent of usage of modeling functionalities of 3D models in the PDDP

ing two sections respectively.

In both tasks, the study used the qualitative content analysis technique. This technique relied on the axial coding approach, as defined by Strauss and Corbin (1999), in clustering and reconfiguring categories identified or developed by others. It relied on the recording instructions of published content analysis research with similar aims and from available literature and theories of design content and 3D modeling. This approach has many advantages, namely increasing the reliability of data. It helps avoid simplistic formulations and taps into established conceptualizations.

3D Modeling methods and techniques: theory versus practice

The content analysis at this task involved two issues: first, documenting the extent of usage of 3D modeling functionalities in PDDP; second, investigating the extent with which using 3D modeling to analyze and represent 3D information and issues in PDDP departs from theory. In the first issue, we modified and adopted Batty's classification (Batty et al 1998) to document the array of modeling functionalities and techniques under a coherent, well-defined framework of four main categories: navigation, communication, analytical, and manipulation functionalities (Table 1). The second issue involved setting the computational analysis techniques of Hong's (1997) conceptual model against their counterparts in PDDP (table 2). Hong (1997) adopted Shirvani's approach (1985) to classify urban design information elements and issues into 2D and 3D categories, and used that classification to develop a conceptual model for the computational analysis and representation of those elements and issues. From using these tools for analyzing PDDP's content, it appears that 3D computer modeling was used extensively and appropriately in support of the plan development.

Assessment of PDDP design content: coverage of 2D and 3D elements and issues

Experts have different approaches to classifying urban design information and issues. Barnett (1982), for instance, focused on establishing a list of urban design policies which constitute a development strategy in the wider context. Conversely, Hedman and Jaszewsk (1984) discussed the fundamentals of urban design from an architectural point of view. Shirvani (1985) defined and grouped the elements of urban physical form into categories that ensemble natural environment and social aspects to reflect his broader viewpoint. Other studies such as that of the Royal Town Planning Institute (RTPI) also attempted to build on a broader range of fundamental design concerns that should be reflected in a core design strategy (Carmona, Punter, and Chapman, 2002). RTPI's study includes: townscape, urban form, public realm, mixed-use and tenure, connections and movements, and sustainable urban design.

Computational analysis and representation in Hong's model											Computational analysis an representation used in PDD							
Charts	Tables	Diagrams	Figure ground	Thematic maps	2Dimensional maps	Photographs	Perspective drawings	Computer 3D models		Urban Design information and issues	Computer 3D models	Perspective drawings	Photographs	2Dimensional maps	Thematic maps	Figure ground	Diagrams	Tables
									2D	**Land-use**								
	■			■						Zoning	■		■		■			
									3D	**Building form and Massing**								
				■				■		Building height	■	■	■		■			
						■		■		Building characteristics	■	■	■					
								■		Shadow pattern	■							
								■		Building silhouette	■	■						
									2D	**Circulation and parking**								
	■	■								Circulation network	■		■	■	■		■	
	■									Number /Type Parking								■
		■								Pedestrian ways	■			■	■			
									2D / 3D	**Open Space**								
			■							Physical form	■		■	■		■		
	■			■						Building ground floor uses	■		■					■
									2D	**Population**								
■	■									Number of people, age distribution								■
									2D	**Natural Environment**								
■	■									Local climate (temp, sun, wind, etc.)								■
									2D	**Building regulations**								
	■				■					Building height control	■	■		■				
	■			■						Building bulk control (FAR, coverage)	■			■	■			

Table 2: Comparison between the computational analysis and representation of urban design information elements and issues of a conceptual model against their counterparts in PDDP

In the content analysis at this task, we modified and adopted RTPI's agenda as a framework of the essential 2D and 3D design issues and elements of urban design plans (table 3) and compared them with their counterparts in PDDP to assess the extent with which PDDP has efficiently covered the essential 2D and 3D design issues, and hence to assess the plan's design content. With that respect, we considered that there are three hierarchical levels of urban design intervention: city/conurbation level, city/district level, and the level of individual spaces or groups of spaces. Each level is concerned with a certain scope of intervention and design issues (Frey 1999, p.20). We used that agenda also to document the computational and conventional techniques of representing the constituent urban design policies of PDDP (table 4).

Findings

Content analysis of PDDP found that the most used functionalities are the analytical functionalities followed in descending order by communication, navigation, and manipulation functionalities (Table 1). This may be due, in part, to the model's type that, in consequence, determined the styles and techniques of analyzing and representing 2D and 3D information elements and issues. The modeling techniques most effectively used were: layering and delayering, graphic reduction, and conceptual modeling. Layering and delayering technique was applied to almost every level of modeling to build a set of analytical switching capability. The layering structure was initially arrayed into three groups: the environmental-geographic, movement fabric, and architectural components. The movement fabric layer allowed isolating and viewing intersections and isolating major and minor streets by orientation. Graphic reduction of masses allowed to visualize the existing and proposed facilities of each focus area with respect to the downtown's urban pattern. Derivative conceptual models were created to explore the view structure in and around the downtown area. The GIS functionality allowed to create multiple linkages between 3D entities to produce a genuine 3D GIS (Gosling and Gosling

Types	Scale	Number	Urban design elements and issues	Extent of coverage: No coverage	Extent of coverage: Minor	Extent of coverage: Significant
3D	Urban	1	**Townscape (Visual composition of space)**			■
			District character and identity; views and vistas; skyline; and continuity of spaces, streetscape, and streetscene			
		2	**Urban Form (Three-dimensional built volume)**			■
			Density; scale; open space system; shadow patterns; and urban pattern.			
	Local	3	**Architectural Character**		■	
			Architectural form: bulk, character, height, massing, scale; elevations: design vocabulary, style, and details.			
		4	**Conservation areas and/or areas of special character**		■	
			Urban form and townscape; architectural form and scale; and elevations: design vocabulary, style, and details.			
2D	Urban	5	**Connection and Movement Network**			■
			Accessibility to open spaces; street and pedestrian networks; and parking			
		6	**Land -use (Mixed-use and diversity)**			■
			Zoning, diversity, and mixed land-use			
	Local	7	**Public Realm (The social experience)**		■	
			community			
		8	**Landscape Architecture**		■	
			Soft landscape design and hard landscape design			

Table 3: The extent of coverage of basic urban design elements and issues in PDDP

2003, p. 251). The ratio of used to applicable modeling functionalities (22 out of 28, i.e. almost 3/4) indicates an efficient usage of the functionalities in the design process.

Content analysis also found that 3D modeling in PDDP departs significantly from Hong's conceptual model in two main aspects: the extent of usage and modes of representation (Table 2). In contrast to Hong's conceptual model which involved using 3D model in 3D design issues only, the PDDP involved using the 3D computer model in all 3D design issues and most (8/12) of 2D design issues of qualitative nature such as circulation and parking, open spaces, and building regulations. In addition, PDDP involved integrating multiple, 2D and 3D, and conventional and digital modes of representation which may help improve the capabilities of comprehending design concepts for designers and public alike. In light of these findings, it may be argued that the model's functionalities have effectively supported designers and thus, affected the quality of the design product. To verify this assumption, the second task involved an assessment of PDDP.

Content analysis of PDDP found a significant coverage of 3D design issues related to townscape and urban form, both of which are concerned with the characteristics of and structural and visual relations between urban elements at the city/ district level. Conversely, findings indicate a minor coverage of 3D design issues related to the architectural

Type	Scale	No.	Basic urban design issues of PDDP	Computer models-existing	3D Computer models-Manipulated	3Dimensional maps	Physical Models	Perspective drawings	Photographs	2Dimensional maps	Thematic maps	Schematic maps	Surface maps	Figure ground	Diagrams	Tables	Charts
3D	Urban	1	Townscape	■	■			■	■	■	■			■			
		2	Urban form	■	■			■	■	■	■			■			
	Local	3	Architectural character	■	■			■	■	■					■		
		4	Conservation areas	■	■				■	■	■				■		
2D	Urban	5	Connections and movement	■	■			■	■	■	■				■		
		6	Land-use (Mixed use and diversity)	■	■				■	■						■	■
	Local	7	Public realm	■	■				■	■	■						
		8	Landscape Architecture	■	■				■	■							

Table 4: The presentation modes of the basic urban design elements and issues in PDDP

character and urban form of conservation areas that are concerned with individual elements or groups of elements at the local level. The coverage of 2D design issues varies similarly. Content analysis found that the plan involves a significant coverage of land-use and connection and movement issues, both of which operate at a city/district level, and a minor coverage of public realm and landscape architecture issues both of which operate within city/district level and local level respectively (Table 3). Hence, it may be argued that the variety of levels with which PDDP covered the 2D and 3D design aspects in its wider and local contexts is due, in part, to three factors: the model's function(s) and types, the plan's scope, goals and objectives, and methodological approach, and the extent of model's usage.

First, the model's iconic type has confined its functions to explanation and education of public whereas other functions were less effectively used.

Due to model's lack of interactive capabilities, the plan involved multiple levels of representation but they were not coupled with representations at multiple levels of details, and as such, did not analyze and represent the attributes of and relationships between urban elements at the local level. Second, the plan's explicit and foremost goal was integrating ongoing public and private development proposals into a "comprehensive 10-year vision" (Stern 1998, p.25; PDDP, 1998, p.3). The plan, as such, was concerned with three hierarchical levels of design control: development proposals, downtown, and regional context. The methodological approach was underpinned by the awareness of design as a process which was recognized in the development proposals of some districts. These proposals were diagrammatic and abstract in accordance with "urban design as a second order" approach which creates a sound environment for subsequent detailed architectural design decisions. Therefore, the plan's emphasis on integrating projects with the downtown and emphasizing the downtown's regional role was reflected in focusing on analyzing and representing the environment at an abstract wider level rather than local detailed level. Third, compared to theory, the number of design issues that involved 3D model's usage reflects the designers' tendency to address and consider the impact of all planning decisions on the visual and spatial qualities of the built environment.

Conclusions

The content analysis of the PDDP demonstrates both an effective and intelligent use of 3D digital modeling in the planning process and a greater than normal attention to spatial and visual qualities in the resulting plan. The findings falsified to a greater extent the early premises concerning the lack of coverage of 3D aspects and ineffective utilization of 3D information in developing urban design plans in US cities. The findings revealed that PDDP involved an effective usage of 3D modeling functionalities to analyze and represent all 3D- and most of the 2D-information elements and issues. The findings also revealed a significant coverage of 3D and 2D design issues at the urban scale and minor coverage of other 2D and 3D design issues at the local scale. These findings are consistent with the hypothesis that the effective usage of 3D modeling would result in the effective coverage of 3D information and issues. However, the causal relationship between the model's usage and the coverage of 3D design issues cannot be proven within the scope of this pilot case study. Although a single case cannot support general conclusions, this research also provides a method for additional case studies to increase the confidence in the conclusions. The effective usage of most of the model's functionalities may have improved the quality of the decision-making through providing certain improvements and support to designers' capabilities in performing core design tasks, notably the following:

1-Improving designers' cognitive capabilities to visualize and interact with the characteristics of and the visual and structural relationship between the urban elements. As Koutamanis (2002) suggests, it helped registering input and output to cognitive processes whereby internal mental representations are refreshed and reinforced by creating external versions and subsequently internalizing them again through perception (Koutamanis 2002, p. 231).

2-Providing a platform for communicating design ideas among and across design teams. This would help overcome one of the hurdles that often hamper the systematic flow of the design process due to the various backgrounds, and hence, perspectives and visions of design team members.

By using modeling techniques effectively, the team appears to have enhanced the management of urban design information and issues. Arguably, this management could have been further improved to cover the other design information and issues efficiently if the model had provided real-time visualization and interactive capabilities. Such tools could allow the planning committees to improve the modes with which they communicate alternative design strategies and scenarios.

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